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Integrated Farming System: Key for Sustainable Agriculture

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ABSTRACT: In rainfed agriculture, farmers concentrate mainly on crop production, which intensified by climate change, degradation of natural resources, build up pests and diseases, market fluctuations and policy changes, which is turn in distress on Indian farmers. In India, around 85 percent of the operational holdings are small and marginal, *i.e.* holdings of less than 2 ha. The operational farm holding in India is declining and over 85 million out of 105 million are below the size of 1 ha. Due to ever increasing population and decline in per capita availability of land in the country, practically there is no scope for horizontal expansion of land for agriculture. Only vertical expansion is possible by integrating cropping and allied enterprises requiring less space and time and ensuring reasonable returns to farm families. In this context, integration of various agricultural enterprises, *viz.*, cropping, animal husbandry, fishery, forestry, backyard poultry etc. have great potentialities in the agricultural economy and it is also suitable strategy for augmenting the income of a farm. These enterprises not only supplement the income of the farmers, help in increasing the family labor employment throughout the year but also sustain soil health by effective residue recycling due to additional components brought into integration within the farm. For that reason, developed location specific Integrated Farming System (IFS) model that considers various factors such as socio-economic conditions, farm resources availability, and the nutritional requirements of families and integrating these elements can indeed lead to a more sustainable agricultural system, benefiting both individual families and the nation.

Keywords: Enterprises, Integrated farming system, Small holder, Sustainability, Climate resilience.

INTRODUCTION

In the post-independence era, transformation in Indian agriculture happens. During this period, several agriculture revolutions had occurred *viz.*, green revolution in crop, white revolution in milk, yellow revolution in oilseed and blue revolution in fish which enabled us to reach the level of self-sufficiency in various food commodities. However, most of such advancements could benefit well-endowed rich farmers. (Gangwar and Singh 2016). Small farmers could not afford farm investment from their own saving to transform traditional agriculture into modern scientific farming. In fact, the component and commodity–based research project for developing animal breed, farm implement and crop variety, mostly conducted in isolation and institution level (Behera *et al.,* 2008) found inadequate in addressing the multifarious problem of small farmer (Jha, 2003). Due to such approaches, several ill have appeared in Indian farming, such as addressing factor productivity, resource-use efficiency and declining farm profitability and productivity (Chopra, 1993; Sharma and Behera 2004). It further coupled with national problems like environmental degradation, ground water contamination and entry of toxic substances into the food chain. The farming system plays an important role in alleviating such problems and achieving sustainable intensification.

FARMING SYSTEM RESEARCH (FSR) CONCEPT

Sustainable use of resources holds the key for enhancing farm productivity, reducing environmental degradation, and to improve the standards of living of people who till the land. Conventional farming provides enhanced yield from the farm but leave the soil and other resources in a degraded state that makes it impossible for future generations to cultivate the land profitably. Hence, there is a need for location specific or ecosystem specific research plans for the farmers to adopt and to ensure environment friendly farm practices without compromising production from the farm as well. (Jayanthi and Ilamurugu 2018). Therefore, to achieve these sustainable goals farming system research approaches will be a better option.

Farming systems research is considered a powerful tool for natural and human resource management in developing countries like India. This multidisciplinary whole-farm approach is very effective in solving the problems of small and marginal farmers (Behera *et al.,* 2010; Mahapatra and Behera 2011). A farming system is the result of complex interactions among a number of inter-dependent components, involving land, labor, capital and management (Behera and France 2016). The farm family functions within the limitations of its capability and resources, socio-cultural setting and interaction of these components with physical, biological and economic factors. The term FSR in its broadest sense is any research that views the farm in a holistic manner and considers interactions (between components and of components with environment) in the system. This type of research is most appropriately carried out by interdisciplinary teams of scientists, who, continuously interact with farmers in the identification of problems and in advising ways of solving them. It aims at generating and transferring technologies to increase the resource productivity for an identified group of farmers.

The FSR advocated following points: (i) Development of relevant and viable technology for small farmers having the full knowledge of the existing farming system.

(ii) Technology should be evaluated not solely in terms of its technical performance but in terms of its conformity to the goals, need and socio- economic circumstances of the targeted small farm system with special reference to profitability and employment generation.

THE STATE OF SMALL HOLDER FARMER

Land Fragmentation is the core issue in agriculture, or it said to be characteristic of Indian agriculture. Due to ever increasing population and decline in per capita availability of land in country resulted into structure in fragmentation in Indian agriculture. The farming practices or farm structure are more oriented toward small holders. In India, around 85 percent of the operational holdings are small and marginal, i.e. holdings of less than 2 hectares but own just 47.3% of the arable land, in comparison, that semi-medium and medium land holding farmers own between 2 hectares and 10 hectares of land, account for 13.2 per cent of all farmers, but own 42.9 per cent of crop area. (GOI, 2015–2016). The average size of the landholding declined to 1.32 ha in 2000-01 from 2.30 ha in 1970-71, and absolute number of operational holdings increased from about 70 million to 121 million. If this trend continues, the average size of holding in India would be mere 0.68 ha in 2020 and would be further reduced to a low of 0.32 ha in 2030. (ICAR, Vision, 2011).

Table 1: Farm Size and Distribution of Operational Holdings and the Area Operated in India (%).

Sr. No.	Size class	1990-91	2000-01	2010-11	2015-16
1.	**Marginal**	59.4 (15)	62.9 (18.7)	67 (22.1)	68.5 (24.2)
2.	**Small**	18.8 (17.4)	18.9 (20.2)	17.9 (22.2)	17.6 (22.9)
3.	**Semi-marginal**	13.1 (23.2)	11.7 (24)	10 (23.6)	9.6 (23.8)
4.	**Medium**	7.1 (27)	5.5 (24)	4.3 (21.2)	3.8 (20.2)
5.	**Large**	1.6 (17.3)	1 (13.2)	0.8 (11.8)	0.5 (9.1)
Total		100	100	100	100
% contribution of small holders		78.2 (32.4)	81.8 (38.9)	84.9 (44.3)	86.1 (47.1)

Note: Figures in parentheses represent operated area

Source: Agricultural Census 2015-16, Agricultural Census Division Ministry of Agriculture and Farmers' Welfare, GOI, 2019

As shown in Table 1 small holder accounted for around 86.1 % of operational holdings in 2015-16 as compared to 78.2 % in 1990-91. Similarly, the area operated by small and marginal farmers has increased from about 32.4 % to 42.9 during the same period.

FARM SIZE, PRODUCTIVITY, AND INCOME GENERATION

Small farmer cultivates around 44 per cent of the area and produce around 60 per cent of the total food grain (49 per cent of rice, 40 per cent of wheat, 29 per cent of coarse cereals and 27 per cent of pulses) and over half of the country's fruits and vegetables production (GOI, 2015-16) in spite of the fact that their income from crop cultivation is not sufficient to meet their monthly expenditure of the household. Havnevik and Skarstein (1997) argue that smaller farms enjoy higher land productivity in the short term, but over the long-term land productivity tends to drop. They argue that this long-term drop-in land productivity results from over intensive cultivation of the land in order to maintain labour productivity, when more and more people need to survive on the same small area of farmland, and as the smaller farms are resource poor to invest in preserving soil fertility, soil productivity eventually becomes exhausted and land productivity drops. Chand *et al.* (2011) observed that small farms in India are superior in terms of production performance but weak in terms of generating adequate income and sustaining livelihoods. Because of smallholders earn an awfully low amount of income from agriculture on a per capita basis primarily due to very adverse land man ratio. Therefore, Farming system approach, is a valuable approach to address the problems of sustainable economic growth in farming communities in India.

INTEGRATED FARMING SYSTEM

Integrated farming is defined as biologically integrated system which, in a regulated mechanism, integrates natural resources into farming activities to achieve maximum replacement of off-farm inputs and sustain farm income (Titi *et al.,* 1993). The IFS approach encourages ecological intensification and aims to reduce use of anthropogenic inputs with enhanced ecosystem functioning like nutrient recycling, soil formation, soil fertility enhancement and improving environmental performance. Efficiently managed IFS are expected to be less risky, as they benefit from enterprise synergies, product diversity, and ecological reliability (Behera and France 2016). There are two main features of IFS first is residue recycling (wastes or by-products of one component become an input to another component) improved land-use efficiency. Second one is the components/enterprises in the IFS differ from region to region, depending on agro-climatic situations *viz*., the land type, water availability, socioeconomic condition of the farmers and market demand. There is a need to establish effective linkage and complementarities between components to develop effective holistic farming systems (Paramesh *et al.*, 2021).

A. Advantages of Integrated Farming Systems

1. Security against complete failure of a system
2. Minimization of dependence for external inputs
3. Optimum utilization of farm resource
4. Efficient use of natural resources, such as sunlight, water, land, etc.
5. Pooling and sharing of resources and inputs
6. Efficient use of family labor
7. Preservation and utilization of farm biomass including nonconventional feed and fodder resources
8. Income and employment generation for many people; and increased economic resources.

Table 2: On station farming systems developed in various regions of India, their productivity and profitability.

Sr. No.	Location of center	Farming system	Area	Mean production (Equivalent yield of base crop of region (t)	Mean net return (₹)
1. Western Himalaya					
1	Kangra (Himachal Pradesh)	Cropping Systems (0.70 ha)+ Horticulture (0.15 ha) + dairy (2 Cross bred cows + 1 Buffalo) + vermicomposting+ apiary + mushroom (0.05 ha)	0.90	26.42	1,77,896
2.	Uddham Singh Nagar (Uttarakhand)	Cropping Systems (0.68 ha) + horticulture (0.15 ha), dairy (3 Cross bred cows) + Vermicompost + fishery (0.1 ha)	1.00	27.3	2,29,500.
2. Eastern Himalaya					
1	Jorhat (Assam)	Cropping system (0.71 ha)+ horticulture (0.10 ha)+ dairy (2 Cross bred cow), fishery (0.1 ha) vermicomposting	1.1	20.87	1,60,262
2	Ri-Bhoi (Meghalaya)	Cropping system (0.70 ha), horticulture (0.20 ha), dairy (1 Cross bred cow + 1 buffalo), piggery (1 no.), poultry (100 birds, 6 batches) + vermicomposting	1.00	16.81	1,88,277
3. Lower Gangetic Plain					
1.	Nadia (West Bengal)	Cropping systems (0.44 ha) + Horticulture with vegetables (0.10 ha) + dairy (2 Cross bred cow + 2calves), fishery (0.05 ha) + vermicomposting	0.66	17.23	1,17,465.
4. Middle Gangetic Plains					
1.	Supaul (Bihar)	Cropping systems (0.60 ha) + Horticulture 5 (0.15 ha) + dairy (2 Cross bred cow), fishery (0.08 ha), Goatary (10+1) + vermicomposting	0.884	12.5	1,85,000.
2.	Patna (Bihar)	cropping systems (0.64 ha)+ fodder (0.09 ha)+ horticulture with vegetables (0.10 ha) + dairy (2 Cross bred cow), fishery (0.1 ha) with ducks (30+5) + poultry (700 no.) + goatary (20+1)+ vermicomposting, mushroom	0.82	46.28	2,34,953.
5. Upper Gangetic Plains					
1.	Meerut (Uttar Pradesh)	cropping systems (0.90 ha) + horticulture (0.20 ha) + dairy (1 Cross bred cow + 2 buffalo), fishery (0.1 ha) + vermicomposting	1.2	158	1,51,000
2.	Kanpur (Uttar Pradesh)	cropping systems (0.72 ha) + horticulture (0.19 ha)+ dairy (1 Cross bred cow + 1 buffalo) + apiary	1.00	15.60	97,405
6. Trans Gangetic Plains					
1.	Ludhiana (Punjab)	cropping systems (0.75 ha) + horticulture with vegetables (0.10 ha)+ dairy (2 Cross bred cow) + fishery (0.08 ha), backyard poultry (15 birds) + vegetable nursery+ apiary (5 boxes)	1.00	49.14	4,35,894
2.	Hisar (Haryana)	cropping systems (0.85 ha) + horticulture with vegetables (0.10 ha) + dairy (2 buffaloes) + vermicomposting+ apiary	1.00	19.99	1,67,000

7. Eastern Plateau and Hills					
1.	Ranchi (Jharkhand)	cropping systems (0.80 ha), horticulture with vegetables (0.15 ha), dairy (2 cross bred cow + 2 heifer), fishery (0.1 ha) +vermicomposting + apiary + mushroom	1.00	27.71	87,360
2.	Dhanbad (Jharkhand)	comprising cropping systems (0.80 ha) + vegetables (0.10 ha) + dairy (2 cross breed cow) + fishery (0.08 ha)+ vermicomposting	1.00	36	1,95,072
8. Western Plateau and Hills					
1.	Parbhani (Maharashtra)	cropping systems (0.70 ha) + horticulture with vegetables (0.20 ha)+ dairy (1 Cross bred cow + 1 buffalo) + poultry (150 birds) + vermicomposting	1.00	16.49	2,33,020.
2.	Akola (Maharashtra)	cropping systems (0.70 ha) + horticulture (0.25 ha) + backyard poultry (20 birds), goatary (10+2) + compost.	1.00	4.04	95,580.
9. Central Plateau and Hills					
1.	Jaipur (Rajasthan)	cropping systems (0.84 ha) + horticulture with vegetables (0.24 ha) + dairy (2 Cross bred cow + 1 buffalo) + poultry (150 birds) + goatary (10+1) + compost	1.42	18.6	3,52,888
10. Southern Plateau and Hills					
1.	Davanagere (Karnataka)	cropping system (0.75 ha) + horticulture with vegetables (0.15 ha) + fodder (0.10 ha) + dairy (2 Cross bred cow + 1 buffalo) + Sheep (5 nos.) + compost	1.00	23.39	1,95,577
2.	Coimbatore (Tamil Nadu)	cropping systems (1.02 ha) + horticulture with fruit trees (0.16 ha) + dairy (2 Cross bred cow+ 1 calf) + goatary (10+1) + vermicompost	1.20	40.43	2,55,956
11. East Coast Plains and Hills					
1	Thanjavur (Tamil Nadu)	cropping systems (0.44 ha) + horticulture (0.10 ha) + dairy (1 Cross bred cow + 1 calf) + fishery (0.08 ha) with azolla culture (0.01 ha) + poultry (150 birds) + goatary (4+1) + vermicompost	0.80	21.7	1,20,414.
12. West Coast Plains and Ghats					
1	Raigad (Maharashtra)	cropping systems (1.15 ha) + horticulture (0.10 ha) + dairy (1 cross bred cow + 1 buffalo), backyard poultry (8 birds) + goatary (2+1) + vermicompost	1.40	38.5	1,55,573.
2.	North Goa and South Goa	comprising cropping systems (0.40 ha) + horticulture (0.45 ha) + dairy (1 Cross bred cow + 1 calf + 1 Heifer), backyard poultry (25 birds) + piggery (15 nos.) vermicomposting + mushroom	0.95	42.87	1,17,991
13. Gujarat Plains and Hills					
1.	Sabarakantha (Gujarat)	cropping systems (0.70 ha), horticulture with vegetables (0.15 ha) + dairy (1 Cross bred cow + 2 buffalos) + fishery (0.07 ha) + backyard poultry (15 birds) + goat rearing (4+1) + compost	0.88	14.95	2,22,071

(Source: IIFSR Bulletin No. 2016)

B. Productivity Enhancement, Economics and employment generation by Integrated Farming Systems

The integration of various crops and animals enables synergistic interactions, which have a greater total contribution than the sum of their individual effects (Edwards *et al.*, 1988; Shyam *et al.* 2023). Reported that among the different module, the system productivity increased from 21–247 per cent of different cropping systems, over the predominant rice–wheat system (RWS). The integration of different components, *viz*., vegetable production (VP)+ Protected Vegetable Cultivation (PVC)+ Cropping System (CS) + Agri–Horti System (AHS) + Mushroom Production (MP) + Bee Keeping (BK) + Vermicompost (VC) in resulted in achieving the maximum net return (9446 USD ha^{-1}), employment opportunities (792 man-days), sustainable livelihood index (70.2%). Similar result report by Manjunath and Itnal (2003) the highest system productivity (21,487 kg ha^{-1} $year^{-1}$) of rice-grain-equivalent yield was recorded with rice-brinjal (*Solanum melongena* L.) system integrated with mushroom and poultry, followed by rice-cowpea (18, 027 kg ha^{-1} $year^{-1}$) and rice-groundnut system (16,922 kg ha^{-1} $year^{-1}$). The contribution of crops towards the system productivity ranged from 33 to 52%, while the share of poultry and mushroom production was 28 to 39% and 20 to 28% respectively. Kharche *et al.* (2022) demonstrated that integrated farming system model generated system productivity in sugarcane equivalent yield of 375 t ha^{-1}. The gross monetary returns from combination of crop + horticulture + dairy + goat + poultry + vermicompost unit were ₹ 10,55,758 and net monetary returns was ₹ 4, 58, 943 with B:C ratio of 1.77 and employment generated was 422 Man-days $year^{-1}$. The holistic Integration of animals with crops in 1 ha area resulted in a total productivity of 36.4 t REY ha^{-1} and net income of ₹ 2,97,770 ha^{-1} with the total operational expenditure of ₹ 3,48,796 ha^{-1} compared to that of an average farmer's net income of ₹ 52,000 in Southern Telangana in addition to generation of 602 man-days of employment in the system (Goverdhan *et al.,* 2020). Thavaprakaash and Premavathi (2019) revealed that, all IFS models were better than the farmers' practice in terms of coconut equivalent yield (CEY) and economic parameters. Among IFS models, Coconut + Cow + Desi chicken + Azolla + Vermicompost had produced the highest CEY of 46184 kg ha^{-1}, gross return (₹ 1016048 ha^{-1}), net return (₹ 742048 ha^{-1} and also B:C ratio (3.71) besides adding more nutrients to the soil. According to Kumara *et al* 2017 observed that total production from cropping system was (16.04 t ha^{-1} $year^{-1}$ of rice equivalent yield), horticulture components (11.80 t ha^{-1} $year^{-1}$ of rice equivalent yield), dairy (1.75 t ha^{-1} $year^{-1}$ of rice equivalent yield), sheep unit (0.10 t ha^{-1} $year^{-1}$ of rice equivalent yield) and vermicompost unit (1.88 t ha^{-1} $year^{-1}$ of rice equivalent yield). Similarly, the net returns from various components *viz*., crops (₹ 80, 795), horticulture (₹ 38, 526), dairy (₹ 4, 7278) and sheep unit (₹ 17, 876). The total annual man-days generated out of various components varied from 515 to 932 man-days. (Meena *et al.* 2022) recorded the overall productivity of model was 174.04 t ha^{-1} $year^{-1}$ in terms of sugarcane equivalent yield (SEY) during the representative years. The gross return obtained was ₹ 6.12×10^3 ha and net returns of ₹ 3.74×10^3 ha with per day income of ₹ 1025 from 1.5 ha of the IFS model under irrigated agro-ecosystem. Integrated farming system involving crop production (cotton + pigeonpea intercropping) and livestock rearing (2 bullocks, 1 desi cow and 40 goats) performed better with a net return of ₹ 89,937 $year^{-1}$ compared to other farming systems. (Gopinath *et al.* 2014). Pandey *et al*. (2012) experimental results indicated that integrated farming system including pisiculture was found more productive and remunerative than conventional cropping system giving highest net return of ₹ 108,875 $ha^{-1}yr^{-1}$, with B:C ratio 3.91 against conventional system (₹ 84,250 $ha^{-1}yr^{-1}$ and 2.59) and 400 kg fishes were recorded in a period of six to seven months and generate the average employment 540 man-days $ha^{-1}yr^{-1}$. Sharma *et al*. (2017). Suggested that the integrated farming system model of 1.5 acre under irrigated conditions was more remunerative in average net returns (₹ 452096) and employment generation (1032 man-days) than 3.5 acre of rainfed condition thus proving to be profitable for the small and marginal farmers of Gariyaband region of Chhattisgarh. Murugan and Kathiresan (2005) revealed that integration of low-land transplanted rice with either of fish culture or rabbit rearing or poultry rearing had the same positive effect of integration - highest net returns of Rs.1,55,920 ha^{-1} and Rs. 2, 28,090 ha^{-1} during the first and second season, respectively, highest grain yield of rice (5.67 tons ha^{-1} and 5.25 tons ha^{-1} during first and second season, respectively. Esther *et al*. (2005) suggested that farming system with enterprise combination of cropping, pigeon (10 pairs), goat (5+1), buffaloes (two milking buffaloes + one calf), agroforestry and farm pond could be recommended for the dry land tracts of Western Zone of Tamil Nadu. Pattanaik *et al*. (2022) evaluate six integrated farming system in the coastal region of Odisha, India. For these study combinations of Crop + Livestock, Crop + Poultry, Crop + Livestock + Poultry, Crop + Livestock + Resource Generating, Crop + Livestock + Fishery, and Crop + Livestock + Fishery + Mushroom + Resource Generating systems where FS IV generated high returns and FS-II was least profitable among 6 enterprises.

C. Effect of integrated rainfed farming system on resource, nutrient recycling and Soil Health

Nutrient recycling in an IFS is a practice of efficiently re using and redistributing nutrients within the system as it involves the utilization of organic waste, residues, or by- products from one component of the farming system as inputs for another (Kumar, *et al.* 2012) and efficient nutrient (resource) recycling within the farming system is a fundamental part of IFS (Kumar *et al.*, 2018). The farming system comprises a complex interconnection link between soil, plants, animals, labor, agricultural inputs, and environmental factors (Shekinah *et al.,* 2005). Integrated Farming Systems (IFS) therefore assumes greater importance in sustainable agriculture as in this system nothing is wasted, the by-product of one system becomes the input for other. “There is no waste”, and “waste is only a misplaced resource which can become a valuable material for another product” in IFS. (FAO, 1977). Monocultures are eroding biodiversity among both plants and animals. Synthetic chemical pesticides and fertilizers are polluting soil, water, and air; these are harming both the environment and human health. (Parama, *et al.* 2009)

(Layek *et al.,* 2023) Observed that efficient recycling of available farm resources by small and marginal farmers in the Integrated Organic Farming System model through vermicomposting/composting with animal excreta, weed biomass, tree leaves, kitchen wastes, etc., fulfilled most of the nutritional requirement (76.0 to 95.1% of N, 68.6 to 82% of P, and 85.5 to 96.0% of K) and sustained the overall productivity of the farm. Shyam *et al.* (2023) resulted that the maximum amount of nutrient cycling *viz*., 138.12, 67.9, and 381.6 kg ha^{-1} of nitrogen, phosphorus, and potassium, respectively was found in vegetable production-based module Vegetable production + Poly house vegetable cultivation + crop components + Agri Horti System. Meena *et al.* (2022) demonstrated that the farmyard manure (FYM) together with vermicompost and other farm-based by-products saved the nutrients by 338.71 kg N, 124.60 kg P, 306.22 kg K and 769.56 kg NPK (kg $year^{-1}$). Kumara *et al* (2017). Observed that effective recycling of farm waste in terms of vermicompost/compost can save ₹ 12634 by addition of 1256 kg of nutrients in-terms of N, P & Venkatesh *et al.* (2021) reported that about 4.8 t of dry biomass add through rice-based cropping systems were recycled through composting, mulching and as dry fodder to feed the dairy animals. About 55 kg of N, 17 kg P and 76 kg of K were recycled, which reduced the use of synthetic fertilizers and thereby the cost of fertilization. IFS models, Coconut + Cow + Desi chicken + Azolla + Vermicompost produced an increased quantity of manure, vermicompost (31675 kg ha^{-1}), and nutrient addition (386.2 kg nitrogen, 159.8 kg phosphorus and 247.3 kg potassium) compared to all other models and farming practice. (Thavaprakaash and Premavathi 2019). Ray *et al.* (2020) reported that introduction of vermicompost technology in IFS made it possible to recycle about 3.17 t of biomass to produce about 1.24 t mature compost annually. Radhamani (2001) observed application of 50 per cent nitrogen through fertilizer and 50 per cent through goat manure enhanced the soil fertility status and provided better opportunity for recycling of manure to the crops was under Vertisols of Western Zone of Tamil Nadu.

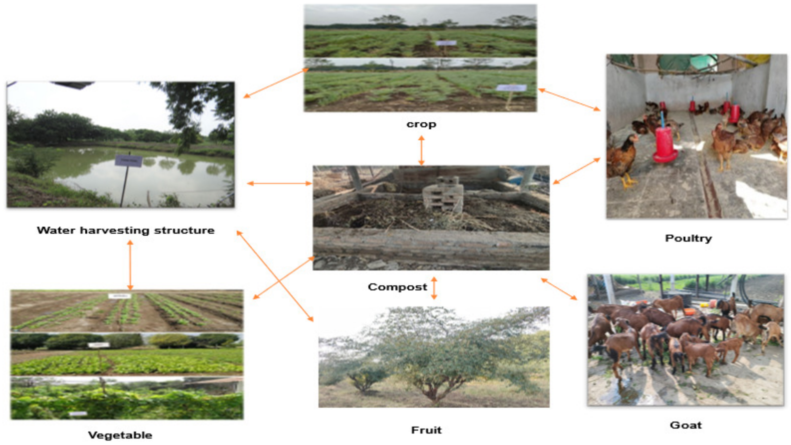

Fig. 1. Resurce flow in between different enterprises for western vidharbha region for rainfed condition.

D. Effect of integrated farming system on climate resilience

Developing climate-smart agriculture through integrated approach is also an ideal solution to ensure the food security of the ever-increasing global population at a time when there are twin problems of land degradation and carbon emissions (Bhat 2016). The farming system, as a concept, takes into account the components of climate, soil, water, crops, farm wastes livestock, land, labour, capital, energy and other resources with the farm family at the center managing agriculture and related activities (Shekinah *et al.*, 2005). Due to failure of monsoon, the farmers are forced to judicious mix up of agricultural enterprises like dairy, poultry, pigeon, fishery, sericulture, apiculture etc., suited to their agro-climatic and socio-economic condition and largely dependent on the farm size. (Kumar *et at.,* 2012). Through diversified crops and other enterprises, IFS provides a stable and sustainable production system, this helps in risk minimization and resilience to climate change (Ayyappan and Arunachalam 2014; Behera and France 2016). Diversified agricultural systems including livestock and crops (annual or perennial) is an ideal approach to build resilience in agricultural systems (Sahoo *et al.,* 2019). Recycling produces a variety of organic products that store carbon for a longer period of time and slow the calculation of organic carbon into CO_2. This study shows that a variety of integrated crop farming activities can be an alternative solution to climate change mitigation (Gupta *et al.*, 2012). Salton *et al.* (2014) observed net GHG emissions as positive in conventional system and negative in IFS, and this trend was mainly due to higher soil carbon sequestration in IFS system that counterbalanced N_2O emissions. Chen *et al.* (2011) reported 30% lesser CH_4 absorption in IFS under temperate plains. The negative impact of IFS on CH_4 absorption may have been due to increased nutrient recycling in the system through organic farming practices and may have further improved the abundance and activity of methanotrophs and possibly decreased air diffusion that could have impaired CH_4 diffusion.

Under Island conditions with incursion of sea water due to cyclone, excess moisture during post floods, moisture stress in winter season, losses due to pests and diseases, the IFS has been identified as resilient technology (Venkateswarlu *et al.,* 2012). The IFS provides not only the means of production, such as fuel, fertilizer/manure, and feed, but also a healthy environment for ecological balance (Gill *et al*., 2010).

Table 3: GHG emission from different IFS models tested under AICRP- IFS.

Location	**Components**	**GHG emission (kg CO_2 eq. ha^{-1})**
Palampur	Crops + Dairy + Horticulture + Fodder + vermi-compost + Boundary Plantations + Kitchen Gardening	-1787
Jorhat	Crops + Dairy + Horticulture + Fishery +poultry + Duckery + Goatery+ Apiary+ vermi- compost + Biogas + Liquid manure + FYM production	-3175
Kalyani	Crops + Dairy + Horticulture + Vermi- compost + Biogas + fishery	-4517
Raipur	Crops + Dairy + Horticulture + Fishery +poultry + Duckery + Goat+ Mushroom + Vermi- compost + boundary plantation + Kitchen gardening	-7713
Telangana	Crops + livestock + hortipasture IFS model	-27036

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

E. Energy Balance

Energy balancing/budgeting is crucial for designing an environmentally efficient production system. The energy input and energy output were influenced by the integration of different enterprises in integrated farming system models.

Shyam *et al.* (2023) reported that the highest energy input of 55.2×10^3 MJ ha^{-1} and higher energy productivity (1.50 kg MJ^{-1}) was incurred in the vegetable production (VP)+ Protected Vegetable Cultivation (PVC)+ Cropping System (CS) + Agri–Horti System (AHS) + Mushroom Production(MP) + Bee Keeping (BK) + Vermicompost (VC) module due to the integration of a maximum number of diverse enterprises. Paramesh *et al.* (2019) computed energy efficiency of crop-livestock-aquaculture integration in west coast of India and found that total energy input in the MFS model was 63284 MJ, with a total energy output of 166595 MJ and energy efficiency, net energy gain, and energy profitability of 2.63, 103311 MJ and 1.63 MJ, respectively.

Surve *et al.* (2014) studied three farming system models *viz.*, research farm IFS model, on-farm IFS model, research farm cropping sequence model, each model was taken under 2.0 ha area. The average energy balance in research farm IFS model was 411949 MJ while, in on-farm IFS model was 325528 MJ and in research farm cropping sequence model 153379 MJ. (Rahman and Barmon 2012) evaluate energy productivity and efficiency of the 'gher' (prawn-fish-rice) farming system in Bilpabla (Bangladesh) and reported that energy efficiency of 1.72 with a net energy balance of 18,510 MJ ha. (Kumar *et al.* 2019) concluded that total energy input in the experimental one-acre integrated farming model was calculated to be 45.08 GJ and total energy output obtained as 102.54 GJ and resulted in energy use efficiency ratio as 2.27.

F. Constrained in IFS adoption

The analysis of various IFS revealed that widespread adoption of IFS is hindered by several constraints. The major challenge in adopting an IFS for farmers is to find a suitable market to sell small production from different components and farmers has not will work in clustered form**.** The availability of im-proved livestock breeds, timely access to fish seed and feed, low- cost energy-efficient pumping machines, information on government schemes, and credit support from financial institutions. Moreover, establishing an IFS model is capital- intensive (requires high start-up costs) and invariably there is a lack of adequate funds for initial investment especially among the resource-poor groups constraining farmers from switching to IFS and from exploiting the benefits of resource integration.

CONCLUSIONS

The literature reviewed revealed that IFS is beneficial for the better management of available resources at the farm level for higher system productivity, profitability, and employment generation. IFS is needed to sustain the Green Revolution while protecting the environment and ensuring farmers' food, nutrition, and livelihood security as these farms also exhibit ecological and non-tangible benefits. The systematic adoption of an IFS model on farms ensures a substantial generation of income and diversified food products to sustain farmers' food, nutrition, and livelihood.

FUTURE SCOPE

Development of integrated farming system module at local level by diversification of cropping system and different enterprise has been found successful bring improvement in livelihood security, nutritional improvement, environmental safety and economic condition of small families. It is helpful to farmer in era of decreasing per capita land availability and climate change.

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