



Integrated farming system for economic resilience, food security and employment generation for smallholders in western Uttar Pradesh

KAMLESH KUMAR¹, R P MISHRA^{1*}, P C GHASAL¹, JAIRAM CHOUDHARY¹, A L MEENA¹, PEYUSH PUNIA¹, SURESH MALIK¹, CHANDRA BHANU¹, NIRMAL¹, RAGHUVEER SINGH¹, RAGHAVENDRA K J¹, MOHD ARIF¹, PUSHPENDRA PRATAP SINGH¹ and SUNIL KUMAR¹

ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh 250 110, India

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ABSTRACT

The sugarcane (*Saccharum officinarum* L.)-wheat (*Triticum aestivum* L.) cropping system has caused significant challenges, including groundwater depletion and soil degradation, necessitating the adoption of Integrated Farming Systems (IFS) for diversification and sustainability. The study was carried out during 2021–2024 at ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh to evaluate an IFS model designed for small and marginal farmers. Spanning 1.38 ha, the model integrates crops, dairy, horticulture, aquaculture, mushroom cultivation, and boundary plantations, emphasizing resource recycling and economic viability. The model demonstrated a high sugarcane equivalent yield (264.1 t/year), with contributions from crops (43%), dairy (29%), horticulture (15%), and fisheries (7%), achieving net annual returns of ₹5,50,090 and a benefit-cost ratio of 3.42. The model also generated 34% higher man-days (774) of annual employment, reducing seasonal unemployment. Components like fisheries, mushroom cultivation, and boundary plantations contributed significantly to income and ecological sustainability. The IFS approach enhanced food and nutritional security by fulfilling household needs and producing marketable surpluses of cereals, fruits, milk, fish, and mushrooms with a marketable surpluses of cereals (92.8%), fruits (94.6%), and milk (93.7%). This comprehensive system offers a sustainable solution to monocropping issues, boosting income and resilience for farm households.

Keywords: Employment generation, Integrated farming systems (IFS), Livelihood sustainability, Nutritional security, Resource recycling

The sugarcane (*Saccharum officinarum* L.)-wheat (*Triticum aestivum* L.) cropping system has led to a decline in the water table and deterioration of soil structure (Singh *et al.* 2003), highlighting the urgent need for diversification in this area. Adopting Integrated Farming Systems (IFS) provides an opportunity to diversify crops and incorporate other enterprises while adhering to the principle of circular economy (Rathore *et al.* 2022). IFS models aim to minimize external inputs and maximize resource recycling, thereby reducing adverse environmental impacts. IFS serve as a robust strategy to enhance productivity, profitability, nutritional security, livelihood improvement, and sustainability for farm households, particularly among small and marginal farmers (<1 ha), who comprise about 87% of the total farming community in India (Meena *et al.* 2022). In western Uttar Pradesh, the crop-dairy

combination stands as the predominant farming system. As landholding sizes continue to shrink, income from crop cultivation alone is no longer sufficient to support farm families (Meena *et al.* 2022). To address this challenge, integrating complementary and supplementary enterprises into farming systems is crucial for enhancing farmers' income and ensuring food security. The IFS approach not only boosts overall productivity but also improves profitability while meeting year-round household food and fodder requirements. Additionally, it ensures nutritional security by diversifying production for the farm family and providing adequate fodder for the dairy component (Manjunatha *et al.* 2014). Furthermore, IFS models are designed to be socially acceptable, environmentally sustainable, and economically viable (Gupta *et al.* 2018). Effective recycling of farm waste within the system reduces production costs, while the diversified nature of IFS safeguards farmers against climate variability, bridging yield gaps through efficient resource utilization. Studies have shown that this approach can increase yields by 30–40% in western Uttar Pradesh. Given these benefits,

¹ICAR-Indian Institute of Farming System Research, Modipuram, Meerut, Uttar Pradesh. *Corresponding author email: rp_min@yahoo.co.in

there is a pressing need to enhance the agro-ecology of regions dominated by the sugarcane-ratoon-wheat system, which covers an area of 1.56 million hectares (Singh 2017). Therefore, the present study aims to analyse an IFS model tailored to the needs of small and marginal farmers in the western plains of Uttar Pradesh.

MATERIALS AND METHODS

The study was carried out during 2021–2024 at ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh. The existing IFS model, initially developed between 2015–2020 (Meena *et al.* 2022), is tailored for the North-Western Plain Zone (NWPZ), located at 26°4′–30°21′ N latitude, 77°3′–80°4′ E longitude, and 237 m amsl. The site experiences an average annual rainfall of 660 mm, characterized by irregular and uneven distribution, with approximately 80% occurring during the monsoon season (June–September). Winter (*rabi*) seasons typically have long dry spells, occasionally interrupted by small amounts of precipitation beneficial for crop growth. The IFS model spans 1.38 ha of irrigated land. The soil is clay loam in texture, with a pH of 7.8, electrical conductivity (EC) of 0.8 dS/m, and low organic carbon content (0.42%). The soil is medium in available nitrogen (330 kg/ha), high in available phosphorus (48 kg/ha), and medium in available potash (135 kg/ha).

The model integrated six cropping sequence combinations to provide a year-round supply of diverse commodities to farm families and livestock (Table 1). Key components of the model included complementary

and supplementary interactions among crops, livestock, horticulture, aquaculture, mushroom cultivation, and boundary plantations. Dairy animals were maintained on green and dry fodders, supplemented with a locally formulated concentrate ration. Crop residues and animal by-products, including cow dung and urine, were processed into farmyard manure (FYM) and vermicompost utilizing the earthworm species *Eisenia fetida*. A horticultural component (0.2 ha) incorporated multipurpose fruit plants intercropped with vegetables and fodder crops. The aquaculture component involved rearing Indian and exotic fish species (*Labeo rohita*, *Catla catla*, *Cirrhinus mrigala*, *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*), fed with rice bran, mustard cake, tree leaves, and green fodders (berseem and cowpea). Fish were fed at 2% of their body weight, and harvests occurred twice annually. The pond water pH was maintained towards neutrality.

Mushroom cultivation included three varieties (oyster, milky white, and button mushrooms) grown in iron racks under a roof covered area using low cost local material suitable for their respective temperature requirements. Boundary plantations comprised jackfruit, bael, aonla, jamun, and lemon, on all field boundaries. To fulfill the family needs, a small kitchen garden of size 20 m² was developed. *Leucaena leucocephala* (subabul) was cultivated as a living fence and boundary hedge, serving as a protective barrier while contributing to the farm's ecological and economic sustainability. Yield values from all components were standardized to Sugarcane Equivalent Yield (SEY),

Table 1 Components of IFS model

Component	Area (ha)/no.	Treatment details
Cropping sequence	1.04 ha	Sugarcane (<i>Saccharum officinarum</i>)–Ratoon-Wheat (<i>Triticum aestivum</i>) (0.35 ha) Rice (<i>Oryza sativa</i>)–Wheat (<i>Triticum aestivum</i>)–Dhaincha (<i>Sesbania aculeata</i>) (0.18 ha) Pearlmillet (<i>Pennisetum glaucum</i>)–Chickpea (<i>Cicer arietinum</i>)–Okra (<i>Abelmoschus esculentus</i>) (0.18 ha) Maize (<i>Zea mays</i>)–Berseem (<i>Trifolium alexandrinum</i>)–Black gram (<i>Vigna mungo</i>) (0.18 ha) Sorghum (<i>Sorghum bicolor</i>) (F)–Mustard (<i>Brassica juncea</i>)–Moong bean (<i>Vigna radiata</i>) (0.11 ha) Bajra Napier Hybrid + Cowpea (<i>Vigna unguiculata</i>)/Berseem (<i>Trifolium alexandrinum</i>) (0.04 ha)
Dairy + Family unit	0.02 ha	Breeds: Buffalo (<i>Bubalus bubalis</i>): Murrah Cow (<i>Bos taurus</i>): Gir
Fruit components	0.20 ha	Guava (<i>Psidium guajava</i>), Mango (<i>Mangifera indica</i>), Pear (<i>Pyrus communis</i>), Peach (<i>Prunus persica</i>) and Karonda (<i>Carissa carandas</i>)
Fishery	0.10 ha	Catla fish (<i>Labeo catla</i>), Rohu fish (<i>Labeo rohita</i>), Mrigal fish (<i>Cirrhinus cirrhosus</i>), Common carp (<i>Cyprinus carpio</i>), Silver carp (<i>Hypophthalmichthys molitrix</i>) and Grass carp (<i>Ctenopharyngodon idella</i>)
Mushroom	25 m ²	Button mushroom (<i>Agaricus bisporus</i>), Milky mushroom (<i>Calocybe indica</i>), Oyster mushroom (<i>Pleurotus</i> spp.)
Kitchen garden	20 m ²	Green and leafy vegetables
Vermicompost	0.02	Earthworm species <i>Eisenia fetida</i>
Boundary plantation	200 m running length	Bael (<i>Aegle marmelos</i> L.), Jackfruit (<i>Artocarpus heterophyllus</i>), Aonla (<i>Emblia officinalis</i>), Lemon (<i>Citrus limon</i> L.), Subabul (<i>Leucaena leucocephala</i>)
Total	1.38	

and the economics of the system were calculated based on prevailing market prices for inputs and outputs (Table 2). SEY was calculated using formula:

$$SEY = Y_x \times (P_x / P_s)$$

where Y_x , Yield of the non-sugarcane crop; P_x , Price of the non-sugarcane crop and P_s , Price of sugarcane.

RESULTS AND DISCUSSION

Area allocation of different components in the IFS model: The results of study showed that land allocation (%) under each component was divergent due to household demands and varied market worth of farm produces. A major chunk of area (75.1 %) was devoted to the crop component. Within the component, sugarcane-ratoon-wheat cropping sequence had a higher proportion of land (33.6%) than other cropping sequences like rice-wheat-dhaincha (green manure) (17.3%), pearl millet-chickpea-okra (17.3%), maize-berseem-blackgram (17.3%), Sorghum (Fodder)-mustard-greengram (17.3%) and napier + cowpea/napier + berseem (10.6%), respectively. Besides this, the fish pond and orchard accounted for 7.4% and 14.8% of the total area, respectively, within the IFS model. The mushroom unit and kitchen garden were established over an area of 25 m², and 20 m², respectively. Additionally, the boundary plantation extended along a running length of 230 m. Thus, a total of 1.04 ha (75.11%) area of IFS model was kept under crop module throughout the year and the smaller area was put under the fodder crops component (3.79%) (Table 1 and Fig. 1).

The productivity of cropping sequences in the IFS model: The yield potential of different cropping sequences in IFS model was analyzed. The results of different cropping sequences showed that SEY was varied considerably among different crops. The yield disparity among the different cropping sequences were varied which might be due to disproportionate allocation of land, predominant prices in the market for the different crops and also varied production

from each crop in the system. Similar results were also testified by Meena *et al.* (2022) and Rymbai *et al.* (2021). Among the components, the crop module demonstrated the highest SEY, (113.50 t/1.04 ha/year) and was followed by dairy component (82.50 t/year), horticulture (38.50 t/year) and fishery (9.25 t/ha/year). Collectively, the IFS model achieved an impressive sugarcane equivalent yield of 264.14 t/1.38 ha/year and 195.16 t/ha/year (Table 2).

Apart from crop component in IFS model, other vibrant complementary and supplementary enterprises had also significantly contributed to total productivity. The relative net returns from crops, dairy, horticulture, and fishery were 43%, 29%, 15%, and 7%, respectively, cumulatively accounting for approximately 94% of total returns. The remaining 4% was contributed by smaller components like mushroom cultivation, kitchen gardens, and boundary plantations. These results align with the findings of Meena *et al.* (2022b) and Kumar *et al.* (2012), further validating the integrated approach.

Among all components, the highest gross and net returns were achieved from the crop (₹3,97,250 and ₹2,36,250/year, respectively) followed by dairy (₹2,88,750 and ₹1,61,750/year, respectively) horticulture (₹1,34,750 and ₹83,750/year, respectively) and fishery (₹49,900 and ₹36,400/year, respectively). These contributions underscore the pivotal role of these components in enhancing farm income. Collectively, the net profit of the IFS model was ₹5,50,090/year, highlighting its superiority in generating higher and more stable income compared to sole cropping systems. The findings reinforce the conclusion by Khobragade *et al.* (2021) that the adoption of IFS components ensures economic stability and resilience for farming households.

The cost of production of different components of IFS model had a wide range from crop module (₹1,61,000) to kitchen garden module (₹850). However, highest cost was incurred in the case of crop production (₹1,61,000/year) followed by dairy component (₹1,27,000). The variation in costs can be attributed to the higher input requirements of certain components, particularly crops and dairy. The benefit-cost (B:C) ratio also varied across components, with the highest ratio observed in the kitchen garden (6.51), followed by fishery (3.70) and boundary plantation (3.27). These results indicated that while the crop and dairy components were the primary contributors to gross and net returns, smaller components like kitchen gardens and fishery offered the highest returns relative to their investment. Similar findings have been reported by Reddy *et al.* (2018), further affirming the economic viability of diverse enterprises within the IFS model.

Employment generation: The IFS model created employment in the tune of 774 man-days/year, equivalent to 573 man-days/ha (Table 2). This employment generation was distributed across various components, highlighting the labour-intensive nature of the diversified system. Activities such as crop cultivation, livestock management, fish feeding, vermicomposting, and mushroom harvesting ensured year-round engagement for family members and additional

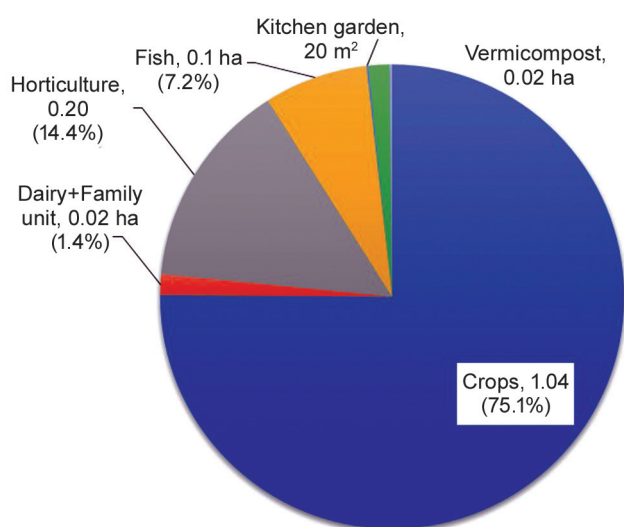


Fig. 1 Area allocation of different components in the IFS model.

Table 2 SEY, economics and employment generation of different components of IFS model (mean data of 3 years)

Components	SEY (t/ha)	Gross return (₹/year)	Cost of cultivation (₹/year)	Net return (₹/year)	B:C ratio	Employment generation (man days)	Per cent man days generated
Field crops (1.04 ha)	113.5	3,97,250	1,61,000	2,36,250	2.47	256	33.0
Livestock production cum Dairy (1 cow + 2 buffaloes) + Vermicomposting	82.5	2,88,750	1,27,000	1,61,750	2.27	212	27.4
Orchard (0.20 ha)	38.50	1,34,750	51,000	83,750	2.64	148	19.1
Fish production (0.10 ha)	9.25	32,375	13,400	18,975	2.42	75	9.7
Mushroom (25 m ²)	15.4	49,900	13,500	36,400	3.70	45	5.8
Kitchen garden (20 m ²)	1.58	5,530	850	4,680	6.51	20	2.6
Boundary plantation (220 m running length)	3.41	11,935	3,650	8,285	3.27	18	2.3
Total IFS (1.35 ha)	264.1	9,20,490	3,70,400	5,50,090	2.49	774	100
Per hectare	195.7	6,81,844	2,74,370	4,07,474	1.84	573.3	

SEY, Sugarcane equivalent yield.

labourers. The crop component emerged as the largest contributor, accounting for 256 man-days, emphasizing its pivotal role in farm operations like land preparation, sowing, weeding, and harvesting. Livestock production, integrated with dairy and vermicomposting, was the second-highest contributor, generating 212 man-days, reflecting the ongoing care and management required for animals and compost production. The orchard component added 148 man-days, demonstrating its importance in seasonal labour activities such as pruning, fertilization, and harvesting. Fish production accounted for 75 man-days, underscoring its moderate labour requirement for feeding, pond management, and harvesting. Smaller components like mushroom cultivation (45 man-days), kitchen gardens (20 man-days), and boundary plantations (18 man-days), collectively contributed 83 man-days, showcasing the additional employment generated by value-added and supplementary enterprises. So the IFS model has provided employment opportunities throughout

the year due to involvement of more manpower than used in one module of the system.

The per cent man-days (generated) distribution within the IFS model highlights the diverse contributions of its components to total labour requirements. Field crops were the largest employer, accounting for 33.1% of total man-days, followed by livestock production, including dairy and vermicomposting, which contributed 27.4%. The orchard component generated 19.12% of employment, while fish production added 9.69%. Smaller enterprises like mushroom cultivation (5.8%), kitchen gardens (2.6%), and boundary plantations (2.3%) collectively contributed 10.7%. This varied distribution showcases the balanced and inclusive employment potential of the IFS model, engaging labour across multiple activities throughout the year.

Diversification of farming including multifarious activities of different enterprises included in the IFS model paved to set of employment opportunities and

Table 3 System productivity, family requirements and marketable surplus of commodities in the integrated farming system (mean data of 3 years) (family size: 5).

Commodities	Production (kg/L/ no.) (Average of 3 years)	Per person daily requirement (g/day) (according to ICMR)	Per family daily requirement (g/day)	Family requirement per year (kg)	Marketable surplus (kg/no.)
Crop (1.04 ha)					
Cereals	3,478	250	1,250	456.30	3,021
Oilseeds	284.7	27	135	49.30	235
Pulses	710	85	425	155.10	555
Green fodder	32,788				32,788
Horticulture (0.22 ha)					
Fruit	1,854	100	500	182.5	1,671
Vegetable	780	400	2,000	730	50
Dairy animals (2 buffaloes + 1 cow)	4,750	300	1,500	547.5	4,202
Fish production (0.10 ha)	522				522
Mushroom (25 m ²)	252				252
Boundary plantation (200 running metre) fruit production	450				450

intact households with farming and their family members were always engaged throughout the year in this business. Rathore *et al.* (2019) also reported that integrated farming systems under arid and semi regions increased employment opportunities than adopted single farming system. So, the diversified nature of the IFS model ensures year-round labour engagement, addressing the seasonal unemployment often associated with monocropping systems. This continuous engagement enhances rural livelihoods and minimizes migration for work. These findings align with previous studies (Meena *et al.* 2022) indicating that IFS adoption can significantly boost on-farm employment compared to conventional single-component farming systems.

Food and nutritional security

System productivity: The IFS model effectively demonstrated its potential for diverse and sustainable agricultural production. The cropping component, covering 1.04 ha, showed high yields across cereals, oilseeds, and pulses, producing 3,478 kg, 284.7 kg, and 710 kg annually, respectively. These outputs not only fulfilled the family's dietary needs but also provided substantial marketable surpluses, with 86.8% for cereals, 82.7% for oilseeds, and 78.1% for pulses (Table 3). Such surpluses underline the efficiency of the model in generating income while ensuring food security. Green fodder production (32,788 kg annually) completely met the nutritional needs of the integrated dairy component, ensuring a sustainable supply of feed for the livestock. This underscores the effective interdependence of the crop and dairy components within the IFS model. The horticultural component (0.20 ha) further enhanced the system's productivity by diversifying the output. Fruits and vegetables were produced in significant quantities, with annual yields of 1,854 kg and 680 kg, respectively. The marketable surplus of fruits was particularly high at 90.2%, reflecting the potential for additional income from this component. Although the marketable surplus for vegetables was comparatively lower (41.2%), it still contributed significantly to the dietary diversity and economic gains for the household. The livestock component, comprising two buffaloes and one cow, contributed 4,750 litre of milk annually, with 88.5% of the milk being surplus after meeting family requirements. This demonstrates the role of livestock in providing nutritional security and additional income. The study findings are in agreement with those of Panwar *et al.* (2016).

Fisheries and mushroom production: Fish production (522 kg from 0.10 ha) and mushroom cultivation (252 kg from four-tier racks) achieved 100% marketable surplus. These components efficiently utilized limited space while generating high-value outputs. The fish were sustained using feed from the farm, including rice bran and mustard cake, supplemented with green fodder and tree leaves. Similarly, mushroom cultivation utilized low-cost local materials, making these components economically viable and environmentally sustainable. The fish produced in the pond served a dual purpose, providing a nutritious dietary

option for the farm households while generating additional income. Approximately 86.7% of the fish were sold in the local market, contributing to the household income, while the remaining 13.3% was retained for family consumption. This dual utilization emphasized the role of fisheries in improving both the nutritional and economic well-being of farm families. Mushroom cultivation within the IFS model demonstrated significant auxiliary potential by recycling mustard and paddy straws as substrates. These by-products, rich in proteins, were repurposed for mushroom production, enhancing resource use efficiency. The harvested mushrooms were entirely marketed (252 kg/year), yielding substantial profits due to their high market demand. The leftover substrate, a valuable source of nutrients, was further utilized by mushroom growers. This efficient recycling process underscores the economic and ecological benefits of integrating mushroom cultivation into the IFS model.

Boundary plantation: The boundary plantation, spanning 200 running metres, yielded 450 kg of fruits annually, all of which were surplus. This component not only enhanced the aesthetic and ecological value of the farm but also contributed to household income without competing for arable land. The inclusion of multipurpose fruit trees like jackfruit, bael, and jamun ensured a diverse and sustainable output.

Economic and nutritional contributions: The IFS model successfully fulfilled the family's year-round food and nutritional requirements across multiple commodities. For instance, cereals, fruits, vegetables, milk, and fish met and exceeded daily family requirements, ensuring dietary diversity and food security. The marketable surpluses provided a significant source of income, demonstrating the economic viability of the integrated approach. The farm-generated organic fertilizers, such as FYM and vermicompost (prepared using *Eisenia fetida*), reduced the dependency on external inputs and lowered production costs. This integrated recycling approach promoted environmental sustainability and contributed to maintaining soil health.

Resilience to climate variability: The diversified nature of the IFS model provided a safeguard against climatic uncertainties. With a wide range of components, including crops, dairy, fisheries, horticulture, and mushrooms, the system reduced the risk of total production failure. For example, even if one component was affected by adverse conditions, other components could sustain the system's productivity and economic returns. Without data this statement is not valid.

The IFS model developed on 1.38 ha area, integrating crops, dairy farming, horticulture, fishery, mushroom production, kitchen gardening, boundary plantation, and vermicomposting, is a highly efficient and sustainable approach for the irrigated agro-ecosystem of the western plain zone of Uttar Pradesh. Achieving the highest system productivity with a SEY of 264.14 t/1.38 ha, this model provides significant livelihood security, nutritional benefits, and employment opportunities for resource-poor farmers. By diversifying farm activities, the IFS model ensures

year-round income generation, reduces rural unemployment, and stabilizes farm households' economic conditions. Its emphasis on resource recycling and optimal utilization of inputs which further enhances sustainability while contributing to regular income through the sale of surplus produce. This makes the IFS model a practical and scalable solution for improving rural livelihoods and fostering agricultural resilience.

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