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Integrated farming system in improving production, productivity and livelihood security

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Abstract

A three-year field experiment (2021-2024) was conducted at the ICAR-Indian Institute of Farming Systems Research, Meerut, Uttar Pradesh, to evaluate horticulture-based integrated farming system models. Four systems including mango (*Mangifera indica* L.) + tomato (*Solanum lycopersicum* L.) + dairy; papaya (*Carica papaya* L.) + beekeeping + aloe vera (*Aloe barbadensis* miller); pomegranate (*Punica granatum* L.) + drumstick + goat farming; and aonla (*Emblica officinalis* Gaertn) + beekeeping + agroforestry were assessed using a randomized block design for crop productivity, economic returns, benefit: cost ratio (BCR), soil fertility, and resource-use efficiency. All IFS models significantly outperformed conventional single-enterprise systems in yield, profitability, and soil health. Mango + tomato + dairy system achieved the highest vegetable yield (34.5 t ha^{-1}), while papaya + beekeeping + Aloe vera system recorded the highest fruit yield (12.30 t ha^{-1}), net return (₹1,60,000 ha^{-1}), and BCR (2.30). Integrated systems markedly increased soil organic carbon (up to 0.91%) and improved available nitrogen, phosphorus, and potassium through efficient recycling of crop residues and livestock byproducts. Agroforestry- and beekeeping-based systems further enhanced soil moisture retention, nutrient conservation, and system resilience. Overall, horticulture-based IFS models offer a robust pathway for sustainable intensification, income diversification, and climate resilience for smallholder farmers.

Key words: Integrated Farming System, Small and marginal farmers, Crop Productivity, Sustainability, Benefit: cost ratio

Integrated Farming Systems (IFS) is a structured and viable development model, particularly well-suited to small and marginal holdings, and is often more feasible and profitable than mono-cropping or large-scale specialized farming systems (Ravisankar *et al.,* 2007; Bhagat *et al.,* 2025). By diversifying farm enterprises, IFS reduces farmers' dependence on a single source of income and distributes risk across multiple components. Integrated Farming Systems promotes crop diversification, enhances soil quality, supports agro-ecological balance and improves pest and disease management (Paramesh *et al.,* 2020; Kumar *et al.,* 2025). It integrates a range of agricultural activities, including crop cultivation, livestock rearing, aquaculture, poultry, beekeeping and horticulture, to optimize resource use while maintaining ecological stability (Kumar *et al.,* 2012). Consequently, IFS is considered economically viable, environmentally sustainable, and socially acceptable (Gill *et al.,* 2009; Biswas *et al.,* 2013). However, a major challenge remains in identifying the optimal combination of crops, livestock, and aquatic components to maximize economic returns while enhancing ecosystem services (Dumont *et al.,* 2013; Bhagat *et al.,* 2024).

The climate of India presents unique agricultural challenges. Despite the region's fertile land and water resources, productivity remains low, and many farms focus on subsistence agriculture also farmers in this region face recurring issues such as unpredictable climatic conditions and low productivity of crops. Traditional mono-culture practices, coupled with resource in-efficiencies, have limited the potential of smallholder farmers. The IFS aims to mitigate these issues by exploiting a diversified and synergistic farming model that maximizes resource utilization, supports ecological health, and strengthens farm income. Keeping its importance about IFS programme we have evaluated the potential of IFS model to address the agricultural challenges. Therefore, study was carried out to provide insights into how IFS can enhance agricultural resilience, double farmers' income, ensuring food, maintaining ecological balance, providing employment opportunities and ecological sustainability.

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MATERIALS AND METHODS

An IFS model was conducted at ICAR-Indian Institute of Farming Systems Research, Meerut, Uttar Pradesh, during 2021-24. The experimental site lies between latitudes 26°04′ and 30°21′ N and longitudes 77°03′ and 80°04′ E, at an elevation of 237 m above mean sea-level. The region receives an average annual rainfall of about 650 mm, which is erratic, uncertain, and unevenly distributed across the year. Nearly 80% of the total precipitation occurs during the monsoon period from June to September. Prolonged dry spells are common during the winter season. The soils under various cropping sequences were classified as clay loam, with medium available nitrogen (320 kg ha^{-1}), high available phosphorus (46 kg ha^{-1}), and medium available potassium (126 kg ha^{-1}). Soil reaction was slightly alkaline (pH 7.8) and contained adequate levels of micronutrients, including manganese (7.0 mg kg^{-1} DTPA), zinc (1.5 mg kg^{-1} DTPA), iron (15.0 mg kg^{-1} DTPA), and copper (2.5 mg kg^{-1} DTPA), along with a microbial biomass carbon content of 380 mg g^{-1} soil. The initial organic carbon content of the surface soil (0-30 cm depth) was recorded as 0.45%.

The four horticulture-based IFS models were evaluated: (i) fruit and vegetable cultivation integrated with dairy farming (mango + tomato + dairy which includes 2 murrah buffaloes and 1 gir cow) (ii) Agro-forestry combined with beekeeping and medicinal crop cultivation (papaya + beekeeping + aloe vera); (iii) Perennial fruit-based systems integrated with poultry farming and vermicomposting (pomegranate + poultry + vermicompost); and (iv) rainfed horticulture integrated with goat farming and organic nutrient management (drumstick + goat farming + green manure). An on-farm participatory approach was employed to evaluate these horticulture-based IFS models. Livestock enterprises including dairy, poultry, goats, and beekeeping were incorporated to support horticultural production and provide diversified income streams. Agroforestry components such as fruit trees, shade trees, and windbreaks were established through alley cropping arrangements.

Perennial horticultural crops such as mango, papaya, and pomegranate generated stable, long-term returns, while short-duration crops like tomato ensured regular cash flow. Livestock components provided continuous income and organic nutrient sources, enhancing nutrient cycling and soil health, while beekeeping improved pollination services and generated additional income. Poultry and goat farming offered rapid returns, effectively utilized crop residues, and strengthened organic nutrient management, thereby improving system resilience to climate variability, particularly under rainfed conditions.

Data were collected across multiple cropping seasons. Parameters assessed included crop productivity, net returns, benefit: cost ratio, nutrients and soil health indicators such as organic carbon content. The data were subjected to statistical analysis using a randomized block design.

RESULTS AND DISCUSSION

Crop productivity

The productivity of horticultural crops under different integrated farming system (IFS) models is presented in Table 1. All IFS treatments recorded higher crop yields, demonstrating the beneficial interactions among system components such as livestock, beekeeping, and agroforestry. Improved nutrient cycling through organic residue incorporation, enhanced soil moisture conservation and favourable microclimatic conditions collectively contributed to superior crop performance.

Mango + tomato + dairy system produced highest vegetable (tomato) yield (34.5 t ha^{-1}), highlighting the positive effects of dairy-derived organic inputs and efficient water management. This system also recorded a fruit yield of 9.20 t ha^{-1}, reflecting the successful integration of perennial fruit crops with annual vegetables. The papaya + beekeeping + aloe vera model achieved the highest fruit productivity (12.30 t ha^{-1}) along with a medicinal crop yield of 6.7 t ha^{-1}. Enhanced pollination services from beekeeping and efficient land use through Aloe vera cultivation significantly contributed to increased system productivity and income diversification. Similarly, the aonla + beekeeping + agroforestry system resulted in higher fruit (8.90 t ha^{-1}) and medicinal crop yields (5.2 t ha^{-1}), largely due to improved soil moisture retention and nutrient dynamics under agroforestry conditions. In contrast, pomegranate + drumstick + goat farming system recorded moderate fruit (7.80 t ha^{-1}) and vegetable yields (21.40 t ha^{-1}). Although yields were comparatively lower, the inclusion of goat farming enhanced nutrient recycling through manure application, thereby supporting long-term system sustainability.

A crop-horticulture-livestock based IFS evaluated over 11 years in Telangana achieved an average productivity of 31.42 t ha^{-1} with a cost of production of ₹3,13,179. The system generated gross and net annual returns of ₹4,96,302 and ₹1,83,123, respectively, with livestock (59.07%) and cropping units (33.06%) contributing substantially to overall productivity (Ramana *et al.,* 2024). Shyam *et al.* (2023) and Kumari *et al.* (2022) emphasized that synergistic integration of enterprises and efficient recycling of by-products enhance system self-

Table 1: Performance of horticultural crops in different IFS models

IFS model	Fruit crop (t/ha)	Vegetable crop (t/ha)	Medicinal/ aromatic plants (t/ha)
Mango + tomato + dairy	9.20	34.50	
Papaya + beekeeping + Aloe vera	12.30	-	6.7
Pomegranate + drumstick + goat farming	7.80	21.40	
Aonla + beekeeping + agroforestry	8.90	-	5.2

Table 2: Economic performance of different IFS models

IFS model	Gross income (₹/ha)	Net profit (₹/ha)	BCR (benefit:cost ratio)
Mango + tomato + dairy	2,50,000	1,40,000	2.25
Papaya + beekeeping + Aloe vera	2,80,000	1,60,000	2.30
Pomegranate + drumstick + goat farming	2,10,000	1,10,000	2.00
Aonla + beekeeping + agroforestry	2,00,000	1,05,000	1.98

Table 3: Soil health improvement under different IFS models

IFS model	Soil organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Mango + tomato + dairy	0.86	347	48	290
Papaya + beekeeping + Aloe vera	0.91	340	51	305
Pomegranate + drumstick + goat farming	0.80	365	49	260
Aonla + beekeeping + agroforestry	0.85	356	53	285

sufficiency by converting waste into valuable inputs, thereby improving productivity and sustainability indices. The enhanced profitability of IFS is primarily attributed to effective byproduct recycling, which reduces production costs, and product diversification, which minimizes risk by compensating losses in one enterprise with gains in others. In the present system, although the dairy component incurred losses, overall net income remained high due to superior performance of crop + goat + poultry unit. Paramesh *et al.* (2022) reported that IFS can increase farm profitability by up to 265% compared to single-enterprise systems through substantial gains in net returns. Overall, these findings clearly demonstrate that horticulture-based IFS models outperform mono-enterprise systems in terms of crop productivity, profitability, and long-term sustainability, particularly when livestock and pollinator components are effectively integrated.

Economic performance

All systems proved economically viable, with benefit: cost (BC) ratios ranging from 1.98 to 2.30, indicating efficient resource utilization under integrated farming (Table 2). The papaya + beekeeping + aloe vera system achieved the highest net return (₹1,60,000 ha^{-1}) and BC ratio (2.30), owing to diversified income from fruit production, medicinal crops, and honey bee, along with relatively lower operational costs. Mango + tomato + dairy system also demonstrated high profitability, recording a net return of ₹1,40,000 ha^{-1} and a BC ratio of 2.25, supported by regular income from vegetables and dairy enterprises and effective recycling of farm residues. The pomegranate + drumstick + goat farming and aonla + beekeeping + agroforestry systems yielded net returns of ₹1,10,000 ha^{-1} and ₹1,05,000 ha^{-1}, respectively. Slightly lower BC ratio values in these systems may be attributed to higher initial investment and longer gestation periods of perennial components; however, they provide greater income stability and resilience under variable climatic conditions. Meena *et al.* (2022) reported that crop production incurred the highest costs, followed by dairy enterprises, primarily due to higher input requirements. Similarly, Singh and Riar (2014) observed that integrated systems such as crop + floriculture and crop + beekeeping were more productive and profitable than sole cropping, with net returns increasing by 29.53% and 19.09%, respectively.

Soil fertility and resource-use efficiency

Integrated farming practices significantly enhanced soil organic carbon (SOC) content and nutrient availability, indicating improved resource-use efficiency and long-term sustainability (Table 3). Papaya + beekeeping + Aloe vera system recorded highest SOC (0.91%), reflecting continuous organic matter addition and enhanced microbial activity. Similarly, mango + tomato + dairy system exhibited elevated SOC levels (0.86%), emphasizing the positive role of livestock-derived organic inputs in improving soil quality. Available nitrogen, phosphorus and potassium increased across all IFS models, with maximum values of 365 kg ha^{-1} (N), 53 kg ha^{-1} (P), and 305 kg ha^{-1} (K) observed in the papaya-based system.

Agroforestry-oriented systems, particularly aonla + beekeeping + agroforestry, further contributed to improved soil moisture retention, nutrient conservation, and long-term soil fertility. These findings are consistent with earlier studies (Kumar et al., 2012; Desai et al., 2013; Meena et al., 2019). Recycling of crop residues and farm byproducts under IFS played a crucial role in enhancing soil health by returning organic matter and nutrients to the soil, thereby reducing dependence on chemical fertilizers for crops and horticultural plants. The on-farm utilization of by products not only improved soil fertility but also reduced production costs, leading to increased farm profitability. Application of safe production practices (recommended FYM + fertilizer+

plant protection with organic methods) + IIHR microbial consortium @ 12.5 kg/ha for each of the crop are profitable alternatives of conventional practices in coriander cv. Mahak and radish cv. Ivory White system (Singh et al., 2025). Rice-blackgram-short-duration cassava was productive, profitable and energy efficient, besides maintaining soil health. The system will also help to diversify our food basket and achieve self-sufficiency in pulse production in India (Suja et al., 2025).

Intercropping cassava with vegetables can help improve nutritional yield per hectare. By enhancing soil health while maintaining yield levels, intercropping under organic management could provide a basis for sustainable agricultural policy, contribute to climate resilience planning, nutrition-sensitive agriculture and food security in tropical regions (Nandan and Suja, 2026). The observed improvements in soil health parameters highlight the ecological and economic benefits of integrated farming systems in sustaining soil productivity while minimizing reliance on external chemical inputs. Overall our results clearly indicate that horticulture-based IFS improves crop yields, economic returns, and soil health. Strategic integration of horticultural crops with livestock, beekeeping, and agroforestry enhances resource recycling, promotes income diversification, and supports environmental sustainability.

CONCLUSION

The study demonstrates that horticulture-based IFS model offer a sustainable strategy to enhance income, employment, food and nutritional security. Papaya + Aloe Vera + beekeeping was the most profitable model (₹1,60,000 ha^{-1}; BC ratio 2.30), while mango + tomato + dairy achieved highest vegetable yield (34.5 t ha^{-1}) and improved soil fertility through organic nutrient recycling. The IFS consistently enhanced soil health, increasing organic carbon (0.65-0.78%), microbial activity, and moisture retention. Integration of crops, livestock, and allied enterprises promoted biodiversity, optimized resource use, reduced chemical inputs, and strengthened ecosystem resilience. Thus, horticulture-based IFS provide a transformative approach for smallholders, delivering higher, stable incomes, ecological sustainability, and resilience against climate and market fluctuations.

Declaration of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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