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Enhancing farm productivity, profitability, sustainability and livelihood of small farm holders through integrated farming system

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ABSTRACT

The present study was carried out from 2018 to 2024 at ICAR-Research Complex for Eastern Region, Patna, Bihar to evaluate eight farming system models [Field crops (FC) alone; FC + Fish + Duck; FC + Fish + Poultry; FC + Fish + Cattle; FC + Fish + Horticulture; FC + Fish + Horticulture + Duck; FC + Fish + Horticulture + Poultry; and FC + Fish + Horticulture + Cattle] with an objective to enhance productivity, improve profitability, optimize resource use through recycling, generate employment, and reduce production costs. The findings revealed that diversified integrated farming systems significantly outperformed over conventional rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) systems in terms of economic returns and nutrient recycling efficiency. Integrating field crops with fish, horticulture, and cattle increased system productivity by 186% compared to traditional rice-wheat system. Among the models studied, the field crops + fish + horticulture + poultry integration fetched the highest net returns and B:C ratio (₹3,04,900/ha; 2.36) and was followed by FC + Fish + Horticulture + Cattle (₹2,81,600; 1.99) but on the basis of B:C ratio FC + Fish + Horticulture (₹2,45,000; 2.31) and FC + Fish + Poultry (₹2,13,300; 2.26), respectively supersedes FC + Fish + Horticulture + Cattle combinations due to more production cost involved in raising of cattle. Contribution from pond dyke cultivation (vegetables + fruits) was found remarkable which added 3.9 tonnes rice equivalent yield (REY) with a net return of ₹52,950 from an area of 0.1 ha and made the system more profitable. An ample quantity of man-days (230–455) has been also generated in comparison with rice-wheat (128) system. Apart from these economic benefits the integrations of different components with crop also added 97.5 kg N; 114.5 kg P_2O_5 and 75.5 kg K_2O.

Keywords: Employment generation, Integrated farming system, Nutrient recycling, Profitability, Sustainability

Eastern India predominantly comprises small and marginal farm households, which constitute nearly 70% of the region's agricultural community (Gill *et al*. 2010) and the farmers often face significant economic and environmental challenges due to poverty, limited resources, and high-risk prone farming conditions (Khandwal 2015). With limited landholdings and resources, their reliance on seasonal field crops frequently falls short of meeting even basic subsistence needs. Moreover, the region's agroclimatic conditions, characterized by unpredictable rainfall, soil degradation, and fluctuating temperatures, further worsen the vulnerabilities of these farming systems. Over the past five decades, agricultural advancements have revolutionized food production through the adoption of high-yielding crop varieties, increased mechanization, and extensive use of chemical fertilizers and pesticides (Mahapatra and Behera 2011). While these innovations have improved productivity, they have also led to unintended consequences, including the depletion of natural resources, declining soil fertility, reduced farm profitability, and adverse environmental impacts. Addressing these challenges requires a shift toward more holistic and sustainable farming practices.

Integrated Farming Systems (IFS) offer a transformative approach by combining various agricultural activities, such as crop cultivation, livestock farming, aquaculture, poultry, beekeeping, and horticulture. This integration enhances the efficient use of farm resources while maintaining ecological balance (Kumar *et al*. 2012). The approach emphasizes synergy between components, where the by-products of one enterprise serve as inputs for another, fostering nutrient recycling, minimizing waste, and reducing dependence on external inputs. The IFS promote crop diversification, enhance soil quality, support agroecological balance, and improve pest and disease management (Manjunath *et al*. 2018, Paramesh *et al*. 2020). Additionally, IFS strengthen farm resilience, diversify income sources, and mitigate economic vulnerability, particularly for smallholder farmers. With minimal investment, IFS offer a system that

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is economically advantageous, environmentally sustainable, and socially acceptable (Biswas *et al*. 2013). However, a significant challenge lies in selecting the optimal combination of crops, livestock, and fish to maximize economic returns and ecosystem services (Dumont *et al*. 2013).

The semi-humid climate of eastern India presents unique agricultural challenges. Farmers in this region face recurring issues such as soil degradation, low productivity, and vulnerability to climate variability. Traditional monoculture practices, coupled with resource inefficiencies, have limited the potential of smallholder farms to achieve sustainable growth. IFS aim to mitigate these issues by leveraging a diversified and synergistic farming model that maximizes resource utilization, supports ecological health, and strengthens farm income. This study evaluates the potential of IFS to address the agricultural challenges in the Eastern India, particularly in regions like Bihar. Despite the region's fertile land and water resources, productivity remains low, and many farms focus on subsistence agriculture. IFS offers a pathway to improve resource use efficiency, soil health, and farm profitability, while diversifying income sources. The objective of this research is to identify the most productive, profitable, and sustainable IFS models for irrigated ecology of the region. The findings aim to provide insights into how IFS can enhance agricultural resilience, increase employment opportunities, and contribute to long-term ecological sustainability.

MATERIALS AND METHODS

The present study was carried out 2018 to 2024 at ICAR-Research Complex for Eastern Region (25°35'N and 85°5'E, 67 m amsl), Patna, Bihar. The soil was predominantly clay loam with a *p*H of 6.6, electrical conductivity of 0.44 dS/m, organic carbon content of 0.59%, available nitrogen of 186.0 kg/ha, available phosphorus of 6.1 kg/ha, and exchangeable potassium of 175.1 kg/ha.

The study explored different combinations of field crops, fish, poultry, duck, cattle and horticultural components with the aim of recycling residues and by-products from one component to others. Eight diversified Integrated Farming System (IFS) models were, Field crops (FC) alone; FC + Fish + Duck; FC + Fish + Poultry; FC + Fish + Cattle; FC + Fish + Horticulture; FC + Fish + Hort + Duck; FC + Fish + Horticulture + Poultry; and FC + Fish + Horticulture + Cattle. Within each 2-acre (0.8 ha) farm, the allocation of areas within the IFS was as, 0.12 ha for fish ponds, 0.1 ha for horticultural components (fruits and vegetables), 0.1 ha for fodder crops to feed cattle (2 cows and 2 calves), 0.02 ha for poultry unit, 0.02 ha for cattle sheds, 0.02 ha for FYM and vermicomposting pits and remaining area for growing field crops. The duck unit was sheltered over the fish pond itself (Table 1).

Each system was carefully managed to optimize synergies among its components so that the by-products of one component serve as inputs for other components, reducing input costs. For instance, poultry and duck droppings were utilized as manure for crops and as feed for fish, while crop residues and livestock dung were processed into vermicompost and farmyard manure (FYM). The number of units allocated to each enterprise followed a specific relationship to meet the input needs of each component. For example, a unit of cattle (2 cows) provides sufficient farmyard manure (FYM) to fertilize the soil in combination with inorganic fertilizers. Horticultural crops (fruits and vegetables) were grown on pond dykes for family consumption and regular income as well as utilizing otherwise underutilized spaces to enhance productivity. Animal waste, including cow dung (16 kg/day), droppings (400 g/day/animal), poultry litter, and unused feed and crop residues, were collected and used to prepare vermicompost, which was recycled into the respective fields of each IFS model.

The system included 100 poultry birds, 35 ducks, and a fish pond stocked with 1000 poly-cultured fingerlings.

Table 1 Area allotted to different integration under developed farming system models

System	Crop (ha)	Fish (ha)	Duck (ha)	Cattle (ha)	Horticulture (ha)	Poultry (ha)	Fodder (ha)	FYM/ Vermi-pit (ha)
Field rop	0.80	-	-	-	-	-	-	-
FC + Fish + Duck	0.66	0.12	Sheltered over fish pond	-	-	-	-	0.02
FC + Fish + Poultry	0.64	0.12	-	-	-	0.02	-	0.02
FC + Fish + Cattle	0.54	0.12	-	0.02	-	-	0.10	0.02
FC + Fish + Horticulture	0.54	0.12	-	-	0.10			0.02
FC + Fish + Horticulture + Duck	0.54	0.12	Sheltered over fish pond	-	0.10	-	-	0.02
FC + Fish + Horticulture + Poultry	0.54	0.12	-	-	0.10	0.2	-	0.02
FC + Fish + Horticulture + Cattle	0.44	0.12	-	-	0.10	-	0.10	0.02

FC, Field crop.

In the poultry component, Ross-308 broiler chicken were raised in batches of 100 birds, with 8 batches per year. Each batch was raised for 40 days, reaching an average weight of 1.2–1.5 kg. Composite fish farming was practiced with a mix of rohu, catla, silver carp, mrigal, and common carp. Fish were harvested thrice a year, and the pond water was drained, with the settled silt (5 tonnes) applied as an organic fertilizer to the crops. For duckery, 30 females and 5 male Khakhi Campbell ducks were integrated with the fish pond. After 5 months, the ducks started egg laying, and duck droppings were used to feed the fish. Vermicompost pits and FYM pits were also linked with cattle and crop components.

Fertilization for crops in IFS systems included both inorganic and organic inputs from the system, such as pond silt, poultry manure, duck manure, cow dung as FYM (10 t/ha) composted plant residues and vermicompost (5 t/ha). Water was applied to crops according to the IW: CPE ratio, with 5 cm of water applied per irrigation. Concentrate feed for animals and poultry was purchased from the market, and related costs were included in the production cost.

Data collection focused on three key aspects, firstly the productivity which was measured as Rice Equivalent Yield (REY); secondly the economic returns, which included gross and net returns, production costs, and Benefit-Cost (B:C) ratios; and thirdly the resource recycling for analyzing the nutrient content in recycled products such as vermicompost, FYM, and pond manure. The data were collected annually for six years and subjected to statistical analysis. Comparative analysis was conducted to identify the most efficient and sustainable models over conventional cropping systems (rice-wheat). Economics were calculated using prevailing market prices: rice at ₹20/kg, poultry at ₹120/kg, duck eggs at ₹6/pc., milk at ₹45/litre, fish at ₹150/kg, horticulture (fruits and vegetables) at ₹15/kg, fodder at ₹2/kg and vermicompost at ₹6/kg. Resource recycling efficiencies were quantified by analyzing the contribution of organic inputs to soil health and crop productivity. Samples of plant residues and animal by-products, along with recycled products like FYM, manure, vermicompost, and fishpond silt, were analyzed for their nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) content before and after recycling to highlight the additional nutrients gained. The experimental design of the study ensured that each model's performance was assessed under similar environmental conditions to provide reliable comparative analysis. Here, the year was taken as the replication.

RESULTS AND DISCUSSION

System productivity: The productivity of individual components (such as fish, duck, poultry, horticulture, and cattle) under developed farming systems of 2 acres (0.8 ha), expressed in Rice Equivalent Yield (REY) (Table 2). Field crops (FC) form the baseline with a yield of 7.9 t, which increases with addition of organic inputs like duck manure (9.55 t), poultry manure (9.77 t), FYM (9.13 t), and vermicompost (9.27 t). Ducks were raised for eggs, poultry for meat, and cattle for milk and FYM. On average, ducks produced 6,307 eggs/year, contributing a REY of 1.89 t. In assessing the feasibility of using duck droppings as fish feed, fish fed with duck droppings yielded an average of 285 kg from 0.12 ha, corresponding to an REY of 2.13 t. Poultry production generates 4.76 t REY from 800 broilers. The cattle unit produced an average of 3,411 litre of milk, contributing 7.65 t REY. Horticultural activities contribute 8.9 t REY in the form of fruits and vegetables. These figures demonstrate the enhanced productivity achieved through integrating diverse components and recycling resources in the farming systems. Organic inputs like poultry manure, diversified outputs from livestock and horticulture, and efficient resource recycling in fish production using duck droppings served as the keys to enhance productivity. Recycling duck manure resulted in higher fish productivity due to enhanced plankton development and direct feed for the fish (Majumdar *et al.* 2018).

The contribution of crops to overall system productivity

Table 2 Productivity and economics of individual components under developed farming systems (area=0.8 ha) (mean 2018–24)

Component	Avg. REY (t)	Production cost (×10³ ₹)	Net return (×10³ ₹)	B:C Ratio
FC	7.90	81.2	76.8	1.9
FC + Duck manure	9.55	85.5	105.6	2.2
FC + Poultry manure	9.77	86.2	109.2	2.3
FC + FYM	9.13	84.3	98.3	2.2
FC + Vermicompost	9.27	86.2	99.2	2.2
Duckery (30+5 ducks)	1.89 (6307 eggs)	21.2	16.6	1.8
Poultry (100 birds/batch)	4.76 (800 broilers)	36.7	58.5	2.6
Cattle (2 cows + 2 calves)	7.65 (3411 litre)	97.2	55.8	1.6
Horticulture	8.90 (11867 kg)	55.2	122.8	3.2
Fish fed with duck droppings	2.13 (285 kg)	24.3	18.3	1.8

FC, Field crop; REY, Rice equivalent yield. Selling price of the produce, Rice at ₹20/kg; Poultry at ₹120/kg; Duck eggs at ₹6/pc.; Milk at ₹45/litre; Fish at ₹150/kg; AND Horticulture (fruits and vegetables) at ₹15/kg.

Table 3 System productivity under different IFS models in terms of REY (mean of 2018–24)

Farming system models	Component productivity (t/ha)						System productivity (t/ha)
	Crop (t/ha)	Fish (t/ha)	Duck (t/ha)	Poultry (t/ha)	Cattle (t/ha)	Horticulture (t/ha)	
FC	9.88 (100)	-	-	-	-	-	9.88
FC + Fish + Duck	11.94 (74.8)	2.13 (13.3)	1.89 (11.8)	-	-	-	15.96
FC + Fish + Poultry	12.21 (63.9)	2.13 (11.2)	-	4.76 (24.9)	-	-	19.10
FC + Fish + Cattle	10.41 (51.6)	2.13 (10.5)	-	-	7.65 (37.9)	-	20.19
FC + Fish + Hort	10.58 (49.0)	2.13 (9.9)				8.90 (41.2)	21.61
FC + Fish + Hort + Duck	10.47 (44.8)	2.13 (9.1)	1.89 (8.1)			8.90 (38.1)	23.39
FC + Fish + Hort + Poultry	10.65 (40.3)	2.13 (8.1)		4.76 (18.0)		8.90 (33.7)	26.44
FC + Fish + Hort + Cattle	9.62 (34.0)	2.13 (7.5)			7.65 (27.0)	8.90 (31.5)	28.30

FC, Field crop; REY, Rice equivalent yield. Figures in parenthesis indicate percent contribution in total system productivity

ranged from approximately 34–74.8%, while individual contributions were as follows: fish contributed 7.5–13.3%; duck 8.1–11.8%; poultry 18–24.9%; cattle 27–37.9%; and horticulture 31.5–41.2% (Table 3). Integrating multiple components significantly enhanced overall system productivity compared to the conventional monoculture system. The integration of field crops with fish, horticulture and cattle (FC + Fish + Horticulture + Cattle model) resulted in the highest system productivity (REY: 28.30 t/ha). This model leveraged the complementary roles of horticulture, livestock, and aquaculture to optimize resource use and recorded 186% more productivity compared to traditional field crop systems. Similarly, the FC + Fish + Horticulture + Poultry model showed a 168% higher productivity than growing crops alone.

Extended monocropping is less profitable than diversifying with high-value vegetables, fruits, and livestock. In case of crop failure, livestock like dairy and poultry serve as a financial buffer. The IFS improves farm efficiency by promoting the simultaneous production of crops and livestock, reducing resource waste, and maximizing overall yields through synergistic interactions among its components (Kashyap *et al.* 2022). The use of recycled pond silt, poultry manure, cow dung as FYM and plant residues as vermicompost in various IFS model created a favourable environment for yield enhancement (Kumar *et al.* 2022). Additionally, models incorporating horticultural components, demonstrated notable improvements in system productivity due to quick turnover and efficient utilization of pond dyke for horticultural crop cultivation. The efficient use of land, water, and nutrient recycling within the system likely contributes to improved resource use efficiency, which may be a key factor driving productivity gains in IFS, particularly in lowland areas (Biswas *et al.* 2013, Kumar *et al.* 2023).

Economics: The economic analysis for each individual component over the six-year study period for 0.8 ha area, revealed horticulture as the most profitable component of the developed farming system, with an average rice equivalent yield (8.90 t), the highest net return (₹1,22,800), and the highest B:C ratio (3.2) (Table 2). This is attributed to the low cultivation costs, quick turnover, and the higher market prices fetched by fruits and vegetables (Nayak *et al.* 2023). Poultry farming, involving 800 birds/year, emerged as the most economically efficient animal-based component, with a REY of 4.76 t, a net return of ₹58,500, and a superior B:C ratio (2.6) among livestock. Fish farming, using duck droppings as feed, produced 2.13 t REY (285 kg of fish) with a net return of ₹18,300 and a moderate B:C ratio of 1.8. Duckery with 30+5 ducks, contributed a net return of ₹16,600 with a B:C ratio of 1.8. Cattle farming, yielded 7.65 t REY with a net return of ₹55,800, however it had the lowest B:C ratio (1.6) attributed to its relatively higher production costs. The results align with Nayak *et al*. (2023), who similarly found that the dairy component had the lowest economic efficiency compared to other IFS components. Overall, the system demonstrated the synergistic benefits of integrating horticulture, poultry, and organic inputs, showcasing their potential to maximize productivity and profitability while efficiently utilizing limited land resources.

The economic performance of developed IFS models, calculated on the basis of six-year average data for a 1 ha area, revealed that integrating multiple components into farming systems significantly enhances both productivity and profitability, which was attributed to the system's ability to make use of byproducts and waste materials from one component as inputs for others (Supplementary Table 1). Among the models studied, the 'FC + Fish + Horticulture + Poultry' model stands out as the top performer, delivering the highest net return (₹3,04,900/ha) and the most efficient B:C ratio (2.36), making it the most profitable and cost-effective system overall. The 'FC + Fish + Horticulture + Cattle' model provided a comparable net return (₹2,81,600), however with a poor B:C ratio (1.99) due to higher cost of production incurred in cattle rearing. In terms of profitability, the 'FC + Fish + Horticulture model ranked second, with a B:C ratio (2.31) and net return (₹2,45,000/ha), followed by the 'FC + Fish + Poultry' model (2.26 and ₹2,13,300/ha) respectively. On the other hand, the FC + Fish + Cattle model performed the least efficiently, with a lower net return (₹1,76,900/ha) and the lowest B:C ratio (1.78). The baseline field crop system, despite having the lowest production cost (₹1,01,500/ha), lags behind in both profitability and efficiency compared to the integrated systems.

This detailed analysis underscores the potential of diversified integrated farming systems to optimize resource utilization, enhance economic viability, and support sustainable agricultural development. Systems integrated with horticulture and poultry provided high returns due to less production cost and rapid turnover along with effective recycling of plant waste and poultry droppings as manure (Kumar *et al.* 2017). The integration of these units has enhanced the income of the system and provided nutritional security to the farm family (Ehsanul 2016, Kumar *et al.* 2012). Enhancement of income by Crop + Fish + Poultry integration under IFS as compared to Rice-wwheat + Sole fish system was also reported by Babu *et al*. (2019). Mahapatra and Behera (2011) also reported an increase in net income through integrated farming systems that utilized recycled products within the system. This increased profitability in IFS is due to the efficient use of land and time in producing short-duration vegetables, fruits, and livestock (Kashyap *et al.* 2022), as well as the efficient recycling of resources within the system, which enhances resource use efficiency and overall productivity (Biswas *et al.* 2013).

Production on pond dyke: Horticultural crops grown on pond dykes not only optimized land use but also provided substantial economic benefits. The cultivation of perennial crops such as mango, guava, lemon, and banana ensured consistent returns, thereby enhancing the financial stability of the system (Supplementary Table 2). Among these, lemon was the most profitable with a B:C ratio of 4.10, followed by guava (3.95), mango (3.76), and banana (3.68). Seasonal vegetables cultivated on pond dykes also contributed to income diversification. Among them, tomato and okra were identified as the most profitable, with B:C ratios of 2.65 and 2.41, respectively. The overall contribution from pond dyke cultivation (vegetables and fruits) was found remarkable, contributing a total of 3.9 t REY with a net return of ₹52,950 and a B:C ratio of 3.03 from an area of 0.1 ha, thereby significantly enhancing the system's profitability. The strategic use of pond dykes for horticulture demonstrated the potential for optimizing limited land resources. Year-round production of vegetables and fruits on pond dykes enhanced the total income under fish-based IFS (Babu *et al.* 2019 and Shukla *et al.* 2020). This additional income from vegetable and fruit production on pond dykes could have a transformative impact on the livelihoods of resource-poor farmers.

Resource recycling: Efficient recycling of resources is a key component of IFS. Recycling locally available resources and combining them with minimal external inputs can significantly enhance the sustainability of farming practices. IFS serve as an effective resource management strategy, which reduces reliance on market-supplied inputs and improves soil health (Hu *et al.* 2016). Resource recycling among different components within the developed IFS models is illustrated in Fig. 1. Nutrient removal occurs primarily through uptake by trees and crops, which either

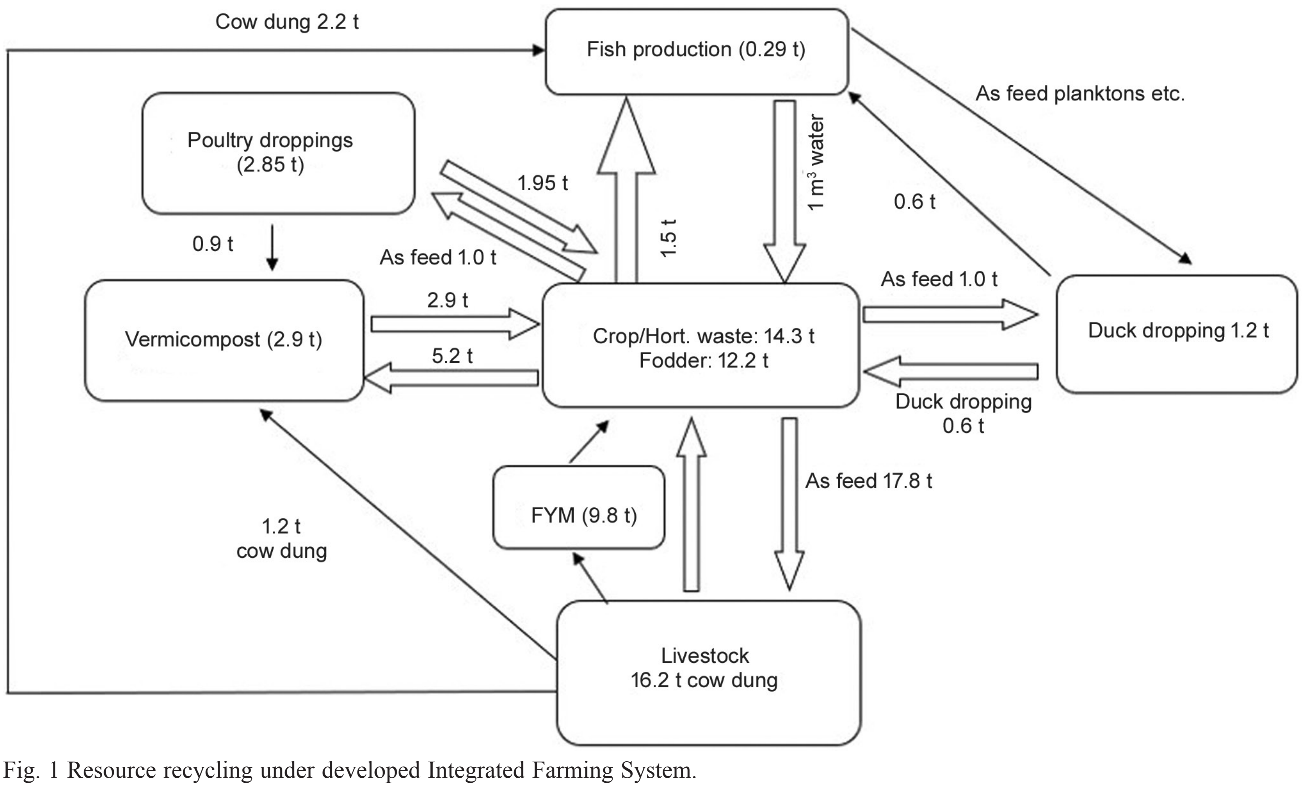

Fig. 1 Resource recycling under developed Integrated Farming System.

retain nutrients in their vegetative parts or export them via harvested produce. Nutrient loss is offset by inputs from manures, fertilizers, recycled crop residues, and tree nutrient cycling. Deep tree roots help intercept and recycle nutrients, preventing loss to leaching. A dynamic soil equilibrium is maintained through continuous additions of leaf litter, plant residues, and animal waste, balanced by nutrient removal via decomposition (Paramesh *et al.* 2019).

Data on nutrient contributions from recycling farm waste and animal by-products into products like vermicompost, FYM, and manure over six years, revealed that integrating various components with crop cultivation added 97.5 kg of N, 114.5 kg of P_2O_5 and 75.5 kg K_2O to the system (Supplementary Table 3). Cattle by-products provided the highest nutrient to the system, benefiting both field crops and horticulture. Recycling 12.8 t of cow dung into 9.8 t of FYM contributed 41.0 kg of N, 66.6 kg of P_2O_5 and 40.9 kg of K_2O. Vermicomposting 5.2 t of plant waste into 2.9 t of organic manure added 13.7 kg of N, 18.8 kg of P_2O_5, and 7.8 kg of K_2O. The poultry unit produced 2.85 t of droppings annually, converted into 2.64 t of manure, contributing 18.4 kg of N, 18.9 kg of P_2O_5, and 8.0 kg of K_2O. The duck unit generated 1.2 t of droppings, partly fed to the fishes and rest amount enriched pond manure. Although diluted, 5.0 t of pond manure added 24.4 kg of N, 10.2 kg of P_2O_5, and 18.8 kg of K_2O. Recycling droppings through ponds increased nutrient levels by 2–3 times. Integrating animals into cropping systems improved resource recycling by converting organic waste into valuable products, enhancing nutrient availability, and boosting manure quality. This approach reduced waste, produced manure essential for crop growth, minimized dependence on chemical fertilizers, and promoted long-term agricultural sustainability (Paramesh *et al.* 2022). The additional nutrients gained through recycling over raw animal droppings and plant waste were confirmed by Acharya and Mondal (2010). Sujatha and Bhat (2015) and Ramesh *et al.* (2021) also showed that integrating livestock and fisheries with crops improved nutrient use efficiency and enhanced nutrient recycling. Kumar *et al.* (2018) reported addition of ample quantity of NPK in soils due to resource recycling within different IFS.

Employment: Integrating different components in IFS significantly increases employment generation (Fig. 2) due to a higher demand for man-hours. The data showed substantial employment gains in IFS, ranging from 78–255%, depending on the specific integration compared to traditional farming systems. The 'FC + Fish + Horticulture + Cattle' model generated the highest employment, with 455 man-days/ha/year, followed by systems involving 'FC + Fish + Horticulture + Poultry/ Duck', which generated almost equal employment (348–356 man-days/ha/year) and the lowest employment was generated by the 'FC + Fish + Duck' model (230 man-days/ha/year), compared to sole field crops (128 man-days/ha/year). Monocropping is a costly practice with high risks of crop failure and often results in lower market prices (Manjunath *et al.* 2017), leading many small and marginal farmers to migrate to cities for better job opportunities (Paramesh *et al.* 2019). IFS offer a solution by reducing economic risks and boosting employment. Combining crop cultivation with enterprises like fish, poultry, ducks, cattle, and horticulture increases labour demand, ensuring year-round employment and minimizing downtime. This continuous labour need keeps farm families engaged in productive activities, which significantly improves their income and livelihoods (Das *et al.* 2013). Surve *et al.* (2014) also reported that IFS provided higher returns and better employment prospects than the traditional soybean-wheat system.

On the basis of above findings, it is imperative to say that IFS provides a pathway to sustainable agricultural practices by enhancing productivity, economic returns, resource use efficiency, and employment generation. Diversification through IFS reduces risks, increases resilience, and ensures better utilization of on-farm resources. The findings of this study emphasize the importance of promoting IFS models tailored to local conditions and the specific needs of farmers.

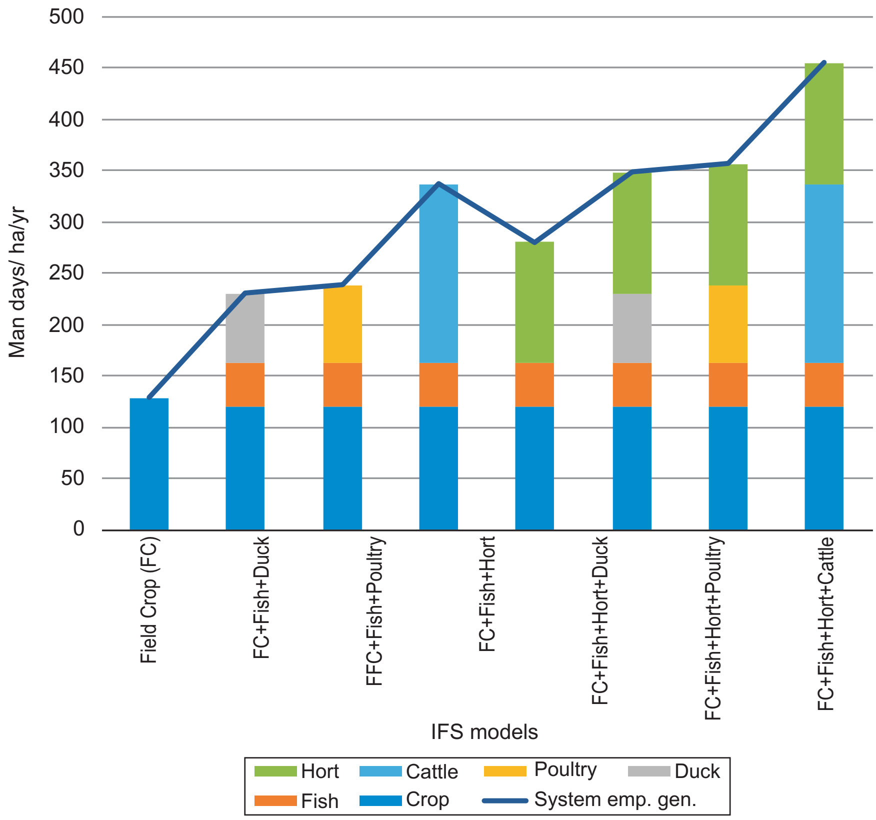

Fig. 2 Man-days generated under developed integrated farming system.

In particular, combining field crops with fish, horticulture and poultry presents a viable option for lowland areas in eastern India, offering a more sustainable alternative to traditional single-crop farming under irrigated conditions. Scaling up the adoption of IFS technologies can significantly improve the livelihoods of small and marginal farmers in Bihar. Policymakers may focus on raising awareness, providing technical support, and offering incentives for IFS adoption to ensure long-term sustainability and food security.

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