



RESEARCH ARTICLE

Economic performance and profitability of integrated farming system models under irrigated conditions in the Eastern Dry Zone of Karnataka: Resource recycling, economic returns and sustainability in integrated farming systems

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Abstract

Over the years, fragmented landholdings coupled with changing climatic conditions have put Indian farming under severe pressure. Hence, the only possible way to sustain a farming community is through the adoption of an integrated farming system (IFS). However, the benefits of IFS still need a quantifiable validation, particularly to a small and marginal farmer of Indian semi-arid regions. To address this, a field experiment was conducted for two consecutive years (2023–24 and 2024–25) under irrigated conditions to evaluate the regional suitability and economic performance of different IFS models. The study comprised five IFS models, integrating cropping systems, horticulture, livestock, agroforestry and vermicomposting. Results indicated significant difference in economic returns among the different components and models. Among the different cropping systems, baby corn-palak recorded the highest profitability with mean net returns of ₹25660 and a benefit : cost (B : C) ratio of 3.59. In horticultural systems, ornamental sunflower-beetroot exhibited superior performance with high net returns and benefit-cost ratios. Among the allied enterprises, the agroforestry component (Agase) showed the highest economic efficiency (B : C ratio 5.52), while dairy contributed the highest net returns (₹179800), ensuring stable income. Vermicomposting provided consistent additional returns and improved nutrient recycling within the system. Among the IFS models, the cropping + horticulture + livestock + agroforestry + vermicompost model recorded the highest mean gross returns (₹11.11 lakh), net returns (₹7.00 lakh) and system economic efficiency (₹1917.83 day⁻¹). Thus, the results of the present study clearly demonstrated that the integration of multiple enterprises significantly improved farm income, resource recycling and system sustainability. Hence, for attaining economic stability under changing climatic conditions, adoption of diversified IFS models is recommended for farmers of Eastern Dry Zone of Karnataka under assured irrigation supply.

Keywords: benefit : cost ratio; economic returns; employment generation; integrated farming system; system economic efficiency

Introduction

Climate change has intensified in recent decades, leading to increased frequency and severity of extreme events. Under changing climatic conditions, farming has become highly unpredictable with respect to yield and economic returns. Specifically, monocropping systems being practiced over the years fail to yield a stable economic output. Further, Indian agriculture is predominantly characterised by small and marginal landholdings, accounting for more than 85 % of total farm holdings, which poses serious challenges to farm productivity and income sustainability (1). Continuous fragmentation of land, rising input costs and a declining natural resource base have further reduced the economic

viability of conventional monocropping systems (2). In the current scenario, improving farmers' income and ensuring livelihood security have become key national priorities, necessitating the adoption of diversified and sustainable farming approaches (3). Integrated farming system (IFS) has emerged as a viable strategy to address these challenges by integrating crops, livestock, horticulture and allied enterprises to enhance overall farm productivity and profitability (4).

The IFS operate on the principle of resource recycling, where the output of one enterprise serves as the input for another, enhancing nutrient cycling, soil fertility, resource-use efficiency and overall productivity, profitability and sustainability while reducing

waste and dependence on external inputs under changing climatic conditions (5–7). For instance, rice-based integrated systems involving fish and poultry have shown higher system productivity and economic returns compared to monocropping systems (8, 9). Similarly, diversified IFS models integrating crops, horticulture and livestock have been reported to increase net returns and employment generation, particularly for smallholder farmers (10).

In recent years, IFS has gained importance as a climate-resilient farming approach, capable of reducing risks associated with weather variability and market fluctuations through diversification of enterprises (11). Integration of livestock and horticultural components ensures continuous income flow and acts as a buffer during crop failure, thereby stabilising farm income (12). Under irrigated conditions, the potential of IFS is further enhanced due to the availability of assured water resources, which reduce the risks associated with erratic rainfall and enable year-round cultivation of diverse crops and allied enterprises. Irrigated semi-arid regions are particularly suitable for diversified farming systems because irrigation facilitates crop intensification, inclusion of high-value crops, vegetables, fodder production, agroforestry and organic recycling units such as vermicomposting. It also ensures a regular supply of fodder and water for livestock, promotes efficient resource recycling, (2). Under irrigated conditions, the potential of IFS is further enhanced due to the availability of assured water resources, which reduce the risks associated with erratic rainfall and year around cultivation of diverse crop and allied enterprises. Integrated semi-arid region are particularly suitable for diversified farming system because irrigation facilitated crop intensification, the inclusion of of high-value crops, vegetables, fodder production, agroforestry and organic recycling units such as vermicomposting. It also ensures a regular supply of fodder and water for livestock, promotes efficient resource recycling, improves resource-use efficiency and provides stable farm income through multiple complementary enterprises (2). Thus, various research studies demonstrated that IFS can be a viable solution to changing climate and land fragmentation issues. However, the adoption of IFS models remains limited due to concerns regarding their suitability across diverse agro-ecological regions. The successful IFS models are region-specific, as their components vary based on the local climatic conditions and the available resources base. Hence, the present investigation was undertaken to evaluate the suitability of different IFS components under semi-arid conditions of the Indian peninsular region with assured irrigation. Also, to systematically evaluate the economic performance of these different IFS components and models to aid in their promotion as a suitable alternative to the traditional farming systems. The findings are expected to provide insights to developing sustainable and economically viable IFS models for the region.

Materials and Methods

Experimental site

The present investigation was conducted at the IFS demonstration unit, L-Block, Zonal Agricultural Research Station (ZARS), Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences, Bangalore, this site is located at the GPS coordinates 13°08'40" N latitude and 77°57'56" E in Karnataka, the study was carried out from August 2023 to September 2025. The experimental site falls under Region III of Agro-climatic Zone V (Eastern Dry Zone) of Karnataka.

Climatic and soil

Meteorological data for the study period were obtained from the agro-meteorological observatory located at ZARS, GKVK, Bengaluru. The region receives an average annual rainfall of 941.5 mm, most of which occurs between May and November. The mean maximum temperature ranges from 26.3 to 33.6 °C, while the mean minimum temperature varies from 14.1 to 20.5 °C. Relative humidity ranges between 77 and 89 %, with an average of 7.1 hr of bright sunshine per day and wind speed varying from 5.3 to 11.7 km hr⁻¹. During the experimental period, the total rainfall received was 829.2 mm in 2023–24, which was 11.92 % lower than the normal rainfall, whereas 1436 mm was recorded in 2024–25, which was 52.52 % higher than normal. The soil was red sandy loam with slightly acidic in nature (pH 6.18) and normal in electrical conductivity (EC) (0.22 dS m⁻¹). The organic carbon content was low (0.46 %), while available nitrogen (292 kg ha⁻¹), phosphorus (52.7 kg ha⁻¹) and potassium (188.5 kg ha⁻¹) were in the medium range. The soil exhibited a field capacity of 24.32 %, a permanent wilting point of 6.58 % and bulk density of 1.42 g cm⁻³.

Experimental details

The IFS was established on an area of 1.0 ha, with systematic allocation of different components, including cropping systems, horticulture, livestock, agroforestry and vermicomposting, to ensure efficient resource utilisation and recycling as shown in Fig. 1. The experiment was conducted as a whole farm IFS evaluation under irrigated conditions. A total experimental area of 1.0 ha was utilised and the entire 1.0 ha IFS unit served as the experimental unit. Five integrated farming system models (FS₁–FS₅) were developed through the sequential integration of different farm enterprises, namely cropping system, horticulture, animal husbandry (dairy, sheep and backyard poultry), agroforestry and vermicomposting. The models comprised FS₁ (cropping system), FS₂ (cropping system + horticulture), FS₃ (cropping system + horticulture + animal husbandry), FS₄ (cropping system + horticulture + animal husbandry + agroforestry) and FS₅ (cropping system + horticulture + animal husbandry + agroforestry + vermicompost). Within the 1.0 ha experimental unit, different enterprises were allocated according to the prescribed system design. The cropping component consisted of four cropping sequences, namely aerobic rice-cowpea, soybean-green gram, baby corn-palak and fodder maize-finger millet, each occupying an area of 0.10 ha. Similarly, the horticultural component comprised marigold-radish, ornamental sunflower-beetroot, tomato-carrot and lady's finger-French bean, each allocated an area of 0.10 ha. The livestock component included a dairy unit with two Holstein Friesian cows, a sheep unit comprising ten Bandur cross ewes and one ram and a backyard poultry unit consisting of 15 Giriraja birds. Agroforestry was established along the field bunds using *Melia dubia* Cav. and drumstick (*Moringa oleifera* Lam.) as boundary plantations, while *Sesbania grandiflora* (L.) Poir. (Agase) and curry leaf (*Murraya koenigii* (L.) Spreng.) were grown as alley crops. Vermicomposting was carried out in a 10 m³ unit using the earthworm species *Eisenia fetida*.

A major proportion of the cultivated area was allocated to crops and cropping systems and horticultural crops (40 %), highlighting their dominant role in the farming system. The remaining area was shared among animal husbandry, agroforestry, vermicomposting and farm infrastructure, which serve as complementary enterprises that support resource recycling, income diversification and ecological sustainability.

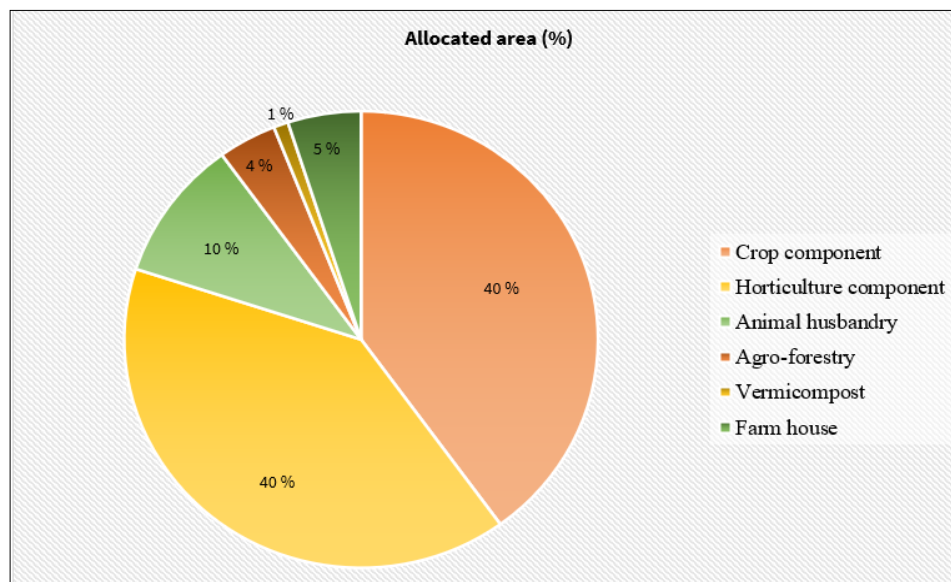


Fig. 1. Percentage distribution of area allocation among different components of the integrated farming system.

Crop husbandry and livestock management practices

Crop and horticultural components were managed according to the recommended package of practices of the University of Agricultural Sciences, Bangalore. Land preparation, sowing/transplanting and nutrient management were carried out using standard agronomic practices, with integrated use of organic manures (farmyard manure, vermicompost, poultry manure and sheep manure) and inorganic fertilisers. Livestock components were maintained under a semi-intensive system, where dairy animals, sheep and backyard poultry were provided with appropriate feeding and health care. Livestock wastes were recycled through vermicomposting, promoting nutrient recycling and improving the sustainability of the integrated farming system.

Integrated farming system models performance indices

Estimation of finger millet equivalent yield

Since different crop components in the IFS produce varied outputs, crop yields were converted into a common comparable unit by using finger millet as the base crop. Finger millet equivalent yield (FMEY) was calculated to express the productivity of diverse crops under a single metric. Productivity in terms of grain yield was recorded and expressed as kg of FMEY, which was calculated as follows (13).

$$\text{FMEY (kg ha}^{-1}\text{)} = \frac{\text{Yield of crop (kg ha}^{-1}\text{)} \times \text{price of crop (₹ kg}^{-1}\text{)}}{\text{Price of finger millet (₹ kg}^{-1}\text{)}} \quad \text{Eq. (1)}$$

For multiple crops, the FMEY values were summed across different components to obtain the total system productivity. This approach enabled comparison between IFS models based on an equivalent yield index.

Employment generation

Employment generation across IFS components was quantified by converting labour inputs into man-days. Labour utilised for land preparation, sowing, inter cultivation, harvesting, milking, feeding, cleaning, composting and marketing was carefully recorded.

$$\text{Employment (man - days ha}^{-1}\text{ yr}^{-1}\text{)} = \frac{\text{Total labour hour}}{8} \quad \text{Eq. (2)}$$

Labour contributions were analysed component-wise (crop, horticulture, dairy, sheep, poultry and vermicompost) to assess which units generated the highest employment opportunities.

Economic analysis

Economic analysis was carried out by estimating the cost of cultivation, gross returns, net returns and benefit : cost (B : C) ratio using the prevailing market prices of inputs and outputs during the study period. Labour costs were calculated based on the minimum wage rates prescribed by the Government of India.

$$\text{Gross returns (₹ ha}^{-1}\text{)} = \text{Yield} \times \text{Market price}$$

$$\text{Net returns (₹ ha}^{-1}\text{)} = \text{Gross returns} - \text{Cost of cultivation}$$

$$\text{Benefit-cost ratio} = \text{Gross returns} / \text{Cost of cultivation}$$

Incremental cost-benefit ratio (ICBR)

$$\text{ICBR} = \frac{\text{Added returns}}{\text{Added cost}} \quad \text{Eq. (3)}$$

For integrated systems involving diversified enterprises, yields were converted into equivalent yield to facilitate comparison, as suggested in earlier studies.

System economic efficiency

System economic efficiency (SEE) was computed to assess the net returns generated per day from the integrated farming system. It was calculated by dividing the annual net returns obtained from each IFS model by 365 days, following the standard procedure as suggested by (5).

$$\text{SEE} = \frac{\text{Net returns (₹)}}{\text{Total duration (365 days)}} \quad \text{Eq. (4)}$$

Higher SEE values indicated more economically efficient farming systems.

Livestock economics

Interest on working capital

Calculated at 14 % per annum of simple interest.

Depreciation on animals

For animals aged 1–3 years, appreciation was computed in ratio of 10 : 1

For 3–5 years, no depreciation.

For animals over 5 years, depreciation was calculated as:

$$\text{Depreciation} = \frac{\text{Present value} - \text{skin value (₹100)}}{\text{Remaining life}} \quad \text{Eq. (5)}$$

Variable costs

Included the cost of dry and green fodder, concentrates, labour, veterinary expenses and miscellaneous expenditures during the lactation and dry periods.

Statistical analysis

The data pertaining to inputs supplied and outputs harvested from each component of the IFS were converted into monetary values to facilitate comparison of the economic performance among the different IFS models. The total cost of inputs, calculated at the time of their use and the returns obtained from outputs, valued at the prevailing market prices at the time of sale, were aggregated for each IFS model. For statistical analysis, IFS models were allocated under randomised complete block design and for further comparison among the mean values of the IFS models, the standard error mean (SEM±) was calculated using the equation 6. This was further used to compute critical difference (CD) and employ Duncan multiple range test for significant comparison among the IFS models (treatments).

$$\text{SEM} \pm = \frac{\text{Standard deviation (SD)}}{\sqrt{\text{Number of treatments}}} \quad \text{Eq. (6)}$$

Statistical analyses were performed using R software (Version 4.4.1). Treatment means were compared using the least significant difference (LSD) at the 5% level of significance.

Results and Discussion

Productivity, profitability and employment generation

The mean values of system productivity, profitability and employment generation clearly demonstrate a progressive advantage with the integration of multiple enterprises in the farming system (Table 1). The FS₅ (cropping system + horticulture + animal husbandry + agro-forestry + vermicompost) recorded the highest system productivity (301.45 q ha⁻¹), which was about 3.84 times (284 % higher) than FS₁ (78.50 q ha⁻¹). Similarly, profitability in FS₅ (₹1225413 ha⁻¹) was approximately 3.85 times (285 % higher) compared to FS₁ (₹318280 ha⁻¹). Employment generation also showed a substantial rise, with FS₅ (804 man-days year⁻¹) being nearly 11.01 times (1001 % higher) than FS₁ (73 man-days year⁻¹), where gradual inclusion of enterprises resulted in consistent increases in all parameter. These findings indicate that each additional component contributed significantly to enhancing overall system performance.

The results emphasise that diversification through the inclusion of livestock, agro-forestry and vermicomposting markedly improved resource-use efficiency, resulting in higher system productivity, profitability and employment generation. The progressive increase in these measured parameters from FS₁ to FS₅ indicates the beneficial contribution of integrating multiple farm enterprises. The addition of livestock and vermicomposting facilitated the recycling of organic residues, animal excreta, crop by-products and leaf litter within the farming system, while agro-forestry contributed additional biomass. Such resource recycling is likely to improve the availability of organic matter and conserve soil moisture, thereby supporting sustained crop production and enhancing the overall performance of the integrated farming

Table 1. System productivity, profitability and employment generation of different integrated farming systems under irrigated condition during 2023–24 and 2024–25

IFS models	Finger millet equivalent yield (q unit area ⁻¹)							System productivity (FMEY q ha ⁻¹)	Pt (₹ ha ⁻¹)	EG (Mean days year ⁻¹)
	(C)	(H)	Animal husbandry			AF	VC			
			Dairy	Sheep	Poultry					
2023–24										
FS ₁	79.58	-	-	-	-	-	-	79.58 ^d	305587 ^d	70 ^d
FS ₂	32.25	102.23	-	-	-	-	-	134.48 ^c	516403 ^c	200 ^c
FS ₃	32.25	102.23	82.31	30.33	1.63	-	-	248.75 ^b	955200 ^b	747 ^b
FS ₄	32.25	102.23	82.31	30.33	1.63	19.35	-	268.10 ^b	1029504 ^b	779 ^{ab}
FS ₅	32.25	102.23	82.31	30.33	1.63	19.35	33.36	301.46 ^a	1157606 ^a	797 ^a
SEm+/-								9.71	28186.17	14.67
CD								29.93	86850.25	45.21
CV								9.41	7.11	5.66
2024–25										
FS ₁	77.15	-	-	-	-	-	-	77.15 ^d	330974 ^d	75 ^d
FS ₂	30.78	98.55	-	-	-	-	-	129.33 ^c	554826 ^c	210 ^c
FS ₃	30.78	98.55	91.95	28.93	1.96	-	-	252.17 ^b	1081809 ^b	757 ^b
FS ₄	30.78	98.55	91.95	28.93	1.96	19.64	-	271.81 ^b	1166065 ^b	790 ^{ab}
FS ₅	30.78	98.55	91.95	28.93	1.96	19.64	29.64	301.45 ^a	1293221 ^a	810 ^a
SEm+/-								9.22	30303.72	12.01
CD								28.40	93375.06	37.01
CV								8.93	6.85	4.55
Mean										
FS ₁	78.5	-	-	-	-	-	-	78.50 ^d	318280 ^e	73 ^d
FS ₂	31.52	100.39	-	-	-	-	-	131.91 ^c	535614 ^d	205 ^c
FS ₃	31.52	100.39	87.13	29.63	1.79	-	-	250.46 ^b	1018505 ^c	752 ^b
FS ₄	31.52	100.39	87.13	29.63	1.79	19.49	-	269.95 ^b	1097784 ^b	785 ^{ab}
FS ₅	31.52	100.39	87.13	29.63	1.79	19.49	31.5	301.45 ^a	1225413 ^a	804 ^a
SEm+/-								9.16	24839.32	14.14
CD								28.23	76537.57	43.58
CV								8.86	5.92	5.40

IFS: integrated farming system; FS: farming system; C: crops; H: horticulture crops; D: dairy; S: sheep; P: poultry; AF: agroforestry; VC: vermicompost; FMEY: finger millet equivalent yield; SP: system productivity; Pt: profitability; EG: employment generation; FS₁: cropping system; FS₂: cropping system + horticulture crops; FS₃: FS₂ + animal husbandry; FS₄: FS₃ + agroforestry; FS₅: FS₄ + vermicompost; NR: net returns.

system. These organic reserves in the soil serves not only as a good source of nutrients but also serve a water holding substrate in the soil. Further, the sharp increase in employment generation linked to the management of recycling enterprises such as livestock rearing, compost preparation, residue handling and agro-forestry management. Overall, the transition from FS₁ to FS₅ demonstrates a substantial and measurable improvement in productivity, profitability and employment, demonstrating the potential advantages of integrated farming systems over conventional Kulagar system of South Goa (4). These results also support the comprehensive advantages of IFS over conventional farming systems studied by previous researchers (9, 14).

Economics of cropping system components

The different cropping systems evaluated, CS₃ (baby corn-palak) emerged as the most profitable on a mean basis. Baby corn recorded mean net returns of ₹9479 with a B : C ratio of 2.34, while palak showed a markedly superior performance with mean net returns of ₹25660 and a B : C ratio of 3.59. The overall results clearly highlight the economic advantage of this system, with palak contributing significantly higher returns. The next best system was CS₄ (fodder maize-finger millet), where fodder maize recorded mean net returns of ₹9058 and finger millet performed better with ₹12374, supported by relatively the higher B : C ratios.

In comparison, CS₂ (soybean-green gram) recorded moderate economic performance, with mean net returns of ₹6740 from soybean and ₹4919 from green gram. The stable returns may be attributed to the complementary role of both legumes in biological nitrogen fixation and cycling of legume residues enrich soil fertility and reduce the requirement for external input. On the other hand, CS₁ (aerobic rice-cowpea) was found to be the least profitable system, with aerobic rice and cowpea recording mean net returns of ₹8466 and ₹3300, along with lower B : C ratios of 2.39 and 1.73. The results clearly indicated that vegetable-based and fodder-based cropping systems were more profitable than cereal-pulse systems under irrigated conditions. The superior performance of vegetable-based cropping systems might be attributed to higher yield potential, short duration and better market price compared to cereals and pulses (3, 4). Integration of fodder crops in CS₄ enhanced system efficiency by supporting livestock components and improving overall farm income (15). Legume-based systems showed moderate profitability due to lower input costs and biological nitrogen fixation (6), whereas cereal-based systems recorded lower returns due to higher the cost of cultivation and relatively lower market price (7, 8).

Economics of horticulture cropping systems under irrigated integrated farming system

Within the different horticultural cropping systems evaluated, CS₂ (ornamental sunflower-beetroot) recorded the highest economic returns during both years as well as on a mean basis (Table 2). Ornamental sunflower registered gross returns of ₹45000 and ₹47500 with net returns of ₹38911 and ₹40827 and exceptionally high B : C ratios of 7.39 and 7.12 during 2023–24 and 2024–25, respectively, while beetroot recorded gross returns of ₹56850 and ₹57000 with net returns of ₹42556 and ₹42478 and B : C ratios of 3.98 and 3.92 during the respective year. Pooled mean indicates superior economic performance of CS₂, with ornamental sunflower recording the highest net returns (₹39869) and B : C ratio (7.25), followed by beetroot with net returns of ₹42517 and B : C ratio of 3.95. This was followed by CS₄ (lady's finger-french bean), where lady's finger recorded net returns of ₹43900 and ₹51679 with B : C ratios of 4.21 and 4.59, while french bean recorded net returns of ₹40062 and ₹40251 with B : C ratios of 3.86 and 3.75 during 2023–24 and 2024–25, respectively, with mean net returns of ₹47790 and ₹40157 respectively. The consistently higher returns from these systems indicate their economic reliability under irrigated conditions (Table 3).

The CS₁ (marigold-radish) also exhibited high profitability, where marigold recorded net returns of ₹27731 and ₹22389 with B : C ratios of 5.19 and 4.13, while radish recorded ₹36001 and ₹35171 with B : C ratios of 4.81 and 4.32 during 2023–24 and 2024–25, respectively, with mean net returns of ₹25060 and ₹35586. In contrast, CS₃ (tomato-carrot) recorded comparatively lower B : C ratios despite higher gross and net returns, where tomato registered net returns of ₹31442 and ₹36056 with B : C ratios of 2.86 and 3.01, while carrot recorded ₹43357 and ₹43381 with B : C ratios of 3.75 and 3.69 during the respective years, with mean net returns of ₹33749 and ₹43369. The overall results clearly indicated that floriculture- and vegetable-based cropping systems were highly profitable under irrigated integrated farming conditions (Table 3), particularly those involving high-value and short-duration crops. The superior economic performance of CS₂ (ornamental sunflower-beetroot) could be attributed to the higher market price of floriculture crops along with relatively lower input costs, which resulted in enhanced benefit-cost ratios (2, 16). The better profitability observed in CS₄ and CS₁ was mainly due to short crop duration, multiple harvests and consistent market demand for vegetable and flower crops, leading to increased gross and net returns (17). The complementary nature of these crops within the

Table 2. Economics of horticulture crops and cropping systems in integrated farming system under irrigated conditions during 2023–24 and 2024–25

Crop component	Season	2023-24				2024-25				Mean				
		CoP	GR	NR	B:C	CoP	GR	NR	B : C	CoP	GR	NR	B : C	
		(₹0.1 ha ⁻¹)	(₹0.1 ha ⁻¹)	(₹0.1 ha ⁻¹)	ratio	(₹0.1 ha ⁻¹)	(₹0.1 ha ⁻¹)	(₹0.1 ha ⁻¹)	ratio	(₹0.1 ha ⁻¹)	(₹0.1 ha ⁻¹)	(₹0.1 ha ⁻¹)	ratio	
CS ₁	Marigold	Kharif	6622	34353	27731	5.19	7161	29550	22389	4.13	6891	31951	25060	4.66
	Radish	Summer	9449	45450	36001	4.81	10579	45750	35171	4.32	10014	45600	35586	4.57
CS ₂	Ornamental sunflower	Kharif	6089	45000	38911	7.39	6673	47500	40827	7.12	6381	46250	39869	7.25
	Beet root	Summer	14294	56850	42556	3.98	14522	57000	42478	3.92	14408	56925	42517	3.95
CS ₃	Tomato	Kharif	16888	48330	31442	2.86	17944	54000	36056	3.01	17416	51165	33749	2.94
	Carrot	Summer	15786	59143	43357	3.75	16154	59535	43381	3.69	15970	59339	43369	3.72
CS ₄	Lady's finger	Kharif	13675	57575	43900	4.21	14381	66060	51679	4.59	14028	61818	47790	4.4
	French bean	Summer	14010	54072	40062	3.86	14649	54900	40251	3.75	14329	54486	40157	3.8

CS₁ to CS₄: cropping systems; FMEY: finger millet equivalent yield; CoP: cost of production; GR: gross returns; NR: net returns; B : C: benefit : cost ratio.

Table 3. Economics of cropping systems components in integrated farming system under irrigated conditions during 2023–24 and 2024–25

Crop component	Season	2023-24				2024-25				Mean				
		CoP (₹0.1 ha ⁻¹)	GR (₹0.1 ha ⁻¹)	NR (₹0.1 ha ⁻¹)	B:C Ratio	CoP (₹0.1 ha ⁻¹)	GR (₹0.1 ha ⁻¹)	NR (₹0.1 ha ⁻¹)	B : C ratio	CoP (₹0.1 ha ⁻¹)	GR (₹0.1 ha ⁻¹)	NR (₹0.1 ha ⁻¹)	B : C ratio	
CS ₁	Aerobic rice	Kharif	5894	14094	8199	2.39	6332	15065	8733	2.38	6113	14579	8466	2.39
	Cow pea	Summer	4254	7700	3446	1.81	4802	7956	3154	1.66	4528	7828	3300	1.73
CS ₂	Soybean	Kharif	4733	11252	6518	2.38	5381	12342	6961	2.29	5057	11797	6740	2.34
	Green gram	Summer	4274	8415	4141	1.97	4822	10518	5696	2.18	4548	9467	4919	2.08
CS ₃	Baby corn	Kharif	6754	16300	9546	2.41	7409	16821	9412	2.27	7082	16561	9479	2.34
	Palak	Summer	9800	34261	24461	3.5	9980	36840	26860	3.69	9890	35550	25660	3.59
CS ₄	Fodder maize	Kharif	5038	14490	9452	2.88	5686	14350	8664	2.52	5362	14420	9058	2.7
	Finger millet	Summer	5995	17338	11343	2.89	6544	19949	13405	3.05	6269	18643	12374	2.97

CS₁ to CS₄: cropping systems; FMEY: finger millet equivalent yield; CoP: cost of production; GR: gross returns; NR: net returns; B : C: benefit : cost ratio.

cropping sequence enabled efficient utilisation of resources such as water, nutrients, labour and land thereby maximising overall system productivity. In contrast, although CS₃ generated higher gross income, the comparatively higher cost of cultivation which reduced its overall B : C ratio (18). Similar trends indicating higher profitability of floriculture- and vegetable-based cropping systems under irrigated conditions have been reported in earlier studies (19, 20).

Economic performance of animal husbandry, agro-forestry and vermicompost under irrigated integrated farming system

Across the different components evaluated, the agro-forestry component Agase (green fodder), recorded the highest economic performance during both years (Table 4). Agase registered gross returns of ₹41300 and ₹42000 with net returns of ₹33760 and ₹34460 and B : C ratios of 5.48 and 5.57 during 2023–24 and 2024–25, respectively, with a mean net return of ₹34110 and B : C ratio of 5.52. This was followed by poultry, which showed higher cost efficiency with net returns of ₹4740 and ₹6800 and B : C ratios of 4.16 and 5.25 during the respective years, with a mean net return of ₹5770 and a B : C ratio of 4.71. Among livestock components, dairy (2 HF cows) recorded the highest absolute net returns of ₹141773

and ₹217827 with B : C ratios of 2.01 and 2.53 during 2023–24 and 2024–25, respectively, resulting in a mean net return of ₹179800 and a B : C ratio of 2.27, indicating its major contribution to farm income despite moderate cost efficiency.

The vermicompost unit also recorded stable economic performance with net returns of ₹43240 and ₹41790 and B : C ratios of 2.09 and 2.02 during 2023–24 and 2024–25, respectively, with a mean net return of ₹42515 and B : C ratio of 2.05 (Table 4). Curry leaf under agro-forestry recorded net returns of ₹20049 and ₹29289 with B : C ratios of 2.55 and 3.26, resulting in a mean net return of ₹24669. Sheep rearing recorded comparatively lower profitability, with net returns of ₹18750 and ₹24850 and B : C ratios of 1.30 and 1.40 during the respective years, with a mean net return of ₹21800 and B : C ratio of 1.35. Overall, agro-forestry and poultry components exhibited higher economic efficiency, while dairy contributed maximum net income and vermicompost ensured stable returns through effective recycling of farm residues under irrigated integrated farming systems. The superior performance of Agase agro-forestry is attributed not only to its perennial nature, low maintenance cost and continuous biomass production but also to its role in enhancing system sustainability through the generation of

Table 4. Economics of animal husbandry, agro-forestry and vermicompost under irrigated conditions during 2023–24 and 2024–25

Crop component		Area (ha)	FMEY (q unit area ⁻¹)	CoP (₹ unit area ⁻¹)	GR (₹ unit area ⁻¹)	NR (₹ unit area ⁻¹)	B : C ratio
2023-24							
Animal husbandry	Dairy (2 H F cows)	0.05	82.31	140310	282083	141773	2.01
	Sheep (10 ewe + 1 ram)	0.05	30.33	62600	81350	18750	1.30
	Poultry (15 Giriraja birds)	-	1.63	1500	6240	4740	4.16
Agro-forestry	Agase (Green fodder)	Boundary plantation	10.76	7540	41300	33760	5.48
	Curry leaf	Boundary plantation	8.59	12951	33000	20049	2.55
Vermicompost	<i>Eisenia fetida</i>	10m ³	33.36	39760	83000	43240	2.09
2024-25							
Animal husbandry	Dairy (2 H F cows)	0.05	91.95	142500	360327	217827	2.53
	Sheep (10 ewe + 1 ram)	0.05	28.93	62600	87450	24850	1.40
	Poultry (15 Giriraja birds)	-	1.96	1600	8400	6800	5.25
Agro-forestry	Agase (Green fodder)	Boundary plantation	9.79	7540	42000	34460	5.57
	Curry leaf	Boundary plantation	9.85	12951	42240	29289	3.26
Vermicompost		10m ³	29.64	40960	82750	41790	2.02
Mean							
Animal husbandry	Dairy (2 H F cows)	0.05	87.13	141405	321205	179800	2.27
	Sheep (10 ewe + 1 ram)	0.05	29.63	62600	84400	21800	1.35
	Poultry (15 Giriraja birds)	-	1.80	1550	7320	5770	4.71
Agro-forestry	Agase (Green fodder)	Boundary plantation	10.27	7540	41650	34110	5.52
	Curry leaf	Boundary plantation	9.22	12951	37620	24669	2.90
Vermicompost	<i>Eisenia fetida</i>	10m ³	31.5	40360	82875	42515	2.05

CS₁ to CS₄: cropping systems; FMEY: finger millet equivalent yield; CoP: cost of production; GR: gross returns; NR: net returns; B : C: benefit : cost ratio; HF: Holstein Friesian.

leaf litter and organic biomass, which contributed to nutrient cycling and soil fertility improvement (14, 20). These benefits reduced external input dependence and improved overall resource-use efficiency within the farming system. Further, poultry recorded a higher B : C ratio due to minimal input cost and quick turnover (18), while dairy contributed maximum net income owing to regular milk production and assured market demand (21). Vermicomposting ensured stable returns through value addition of farm residues and improved nutrient recycling within the system (22). The relatively lower profitability of sheep rearing might be due to higher maintenance costs and lower market returns (2). These findings agree with earlier studies reporting higher economic efficiency of agro-forestry, poultry and dairy components in integrated farming systems under irrigated conditions.

Economics of components in irrigated integrated farming system

During both years of study, the economic performance of various IFS components under irrigated conditions demonstrated clear variances in cost of production, net returns and B : C ratio (Fig. 2). Gross returns were ₹123849 and ₹133841, while net returns were ₹79491 and ₹84903 respectively, during both years, with the cost of production ranging between ₹58938 and ₹60500. The cropping system assured a good profitability with a mean net return of ₹82197 and a B : C ratio of 2.14. The horticulture component achieved higher gross returns (₹400773 and ₹414295) and net returns (₹303960 and ₹312232) even with higher production cost (₹101980–102063). A higher B : C ratio (3.91–4.05) achieved under the horticulture component underlines the economic significance and suitability of horticultural crops under irrigated situations. The dairy component showed improved performance during the second year with higher net returns (₹217827) and gross returns (₹360327). Thus, dairy assured a steady source of income with a mean net return of ₹179800 and a B : C ratio of 2.27. With a mean net return of ₹21800 and a B : C ratio of 1.35, the sheep rearing component demonstrated lower economic performance, which can be considered as a supplementary enterprise under irrigated

conditions. The poultry component recorded a higher B : C ratio due to lower production costs and quick turnover, contributing to effective short-term cash flow in the system. The agro-forestry component recorded a mean net return of ₹58779 and a B : C ratio of 3.87 indicating its stable performance, thereby supporting long-term sustainability. The vermicompost unit encouraged the recycling of farm residues and raised the income with a mean net return of ₹42515 and a B : C ratio of 2.05. Collectively, the main sources of income were horticulture and dairy, whereas agro-forestry guaranteed long-term sustainability and vermicompost and poultry increased economic efficiency. Dairy produced a steady income through continuous output, whereas horticulture produced higher returns due to intense cultivation and greater market prices. Previous studies have revealed similar results on the economic advantages of integrated farming systems (11, 14, 23, 24).

Economics of different integrated farming system models under irrigated conditions

Among the integrated farming system models evaluated under irrigated situations, FS₅ (cropping system + horticulture + animal husbandry + agro-forestry + vermicompost) achieved the highest economic returns during both years and on a mean basis (Fig. 3). Higher mean gross returns (₹11.11 lakh), net returns (₹7.00 lakh) and a B : C ratio of 2.70 were observed under this farming system model despite recording a higher mean cost of production (₹4.11 lakh). This highlights the economic benefit of integrating multiple enterprises along with the vermicompost unit. Inclusion of agro-forestry in FS₄ (cropping system + horticulture crops + animal husbandry + agro-forestry), enhanced income stability with a mean net return of ₹6.57 lakh and relatively higher mean B : C ratio of 2.77, without significantly increasing production costs. FS₃ (cropping system + horticulture crops + animal husbandry) also showed notable improvement over crop-based systems. Mean gross returns (₹9.49 lakh), net returns (₹5.99 lakh) and B : C ratio (2.71) was observed under FS₃, which implies the benefit of integrating livestock for steady income and effective residue management. The FS₂ (cropping system + horticulture crops) performed moderately

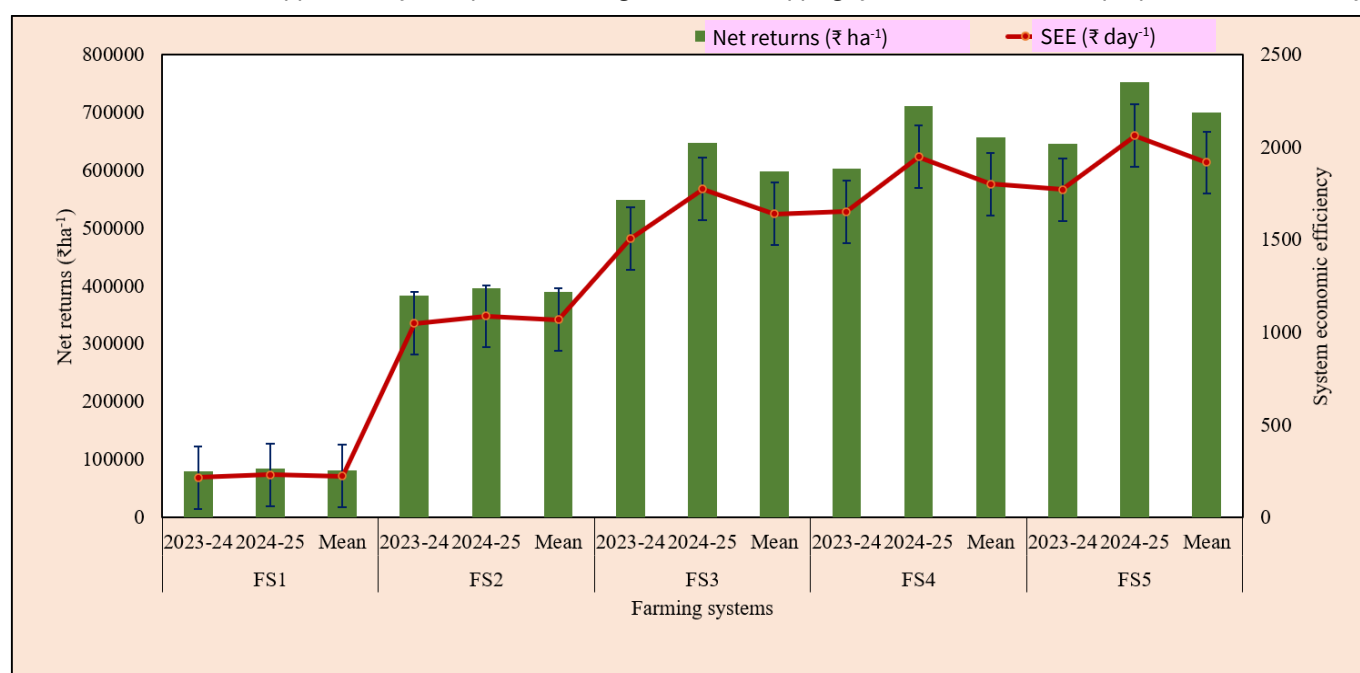


Fig. 2. Net returns and System economic efficiency of different integrated farming system models during 2023–24 and 2024–25.

FS₁: cropping system; FS₂: cropping system + horticulture crops; FS₃: FS₂ + animal husbandry; FS₄: FS₃ + agroforestry; FS₅: FS₄ + vermicompost; NR: net returns; SEE: system economic efficiency.

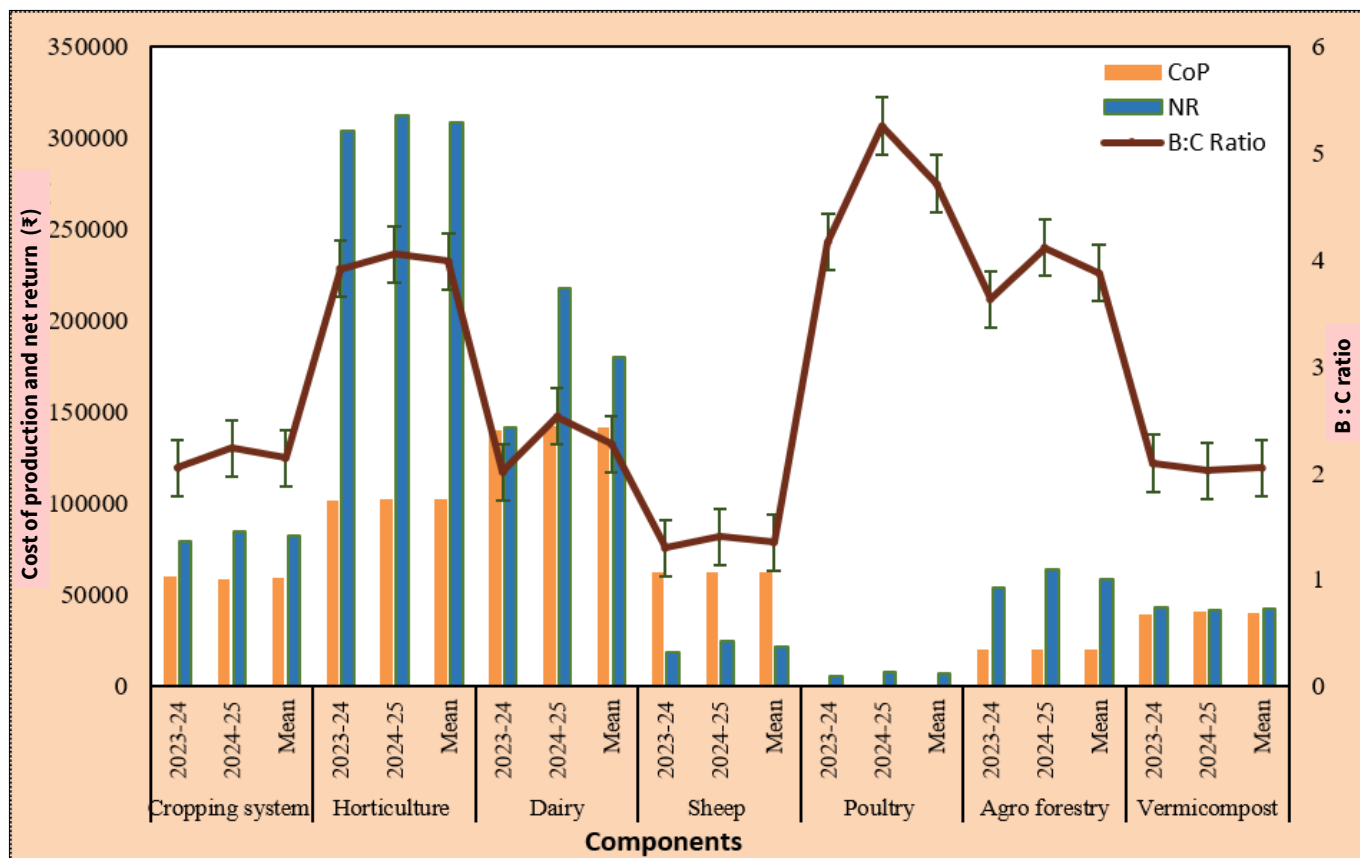


Fig. 3. Economics of different components in integrated farming system under irrigated conditions during 2023-24 and 2024-25.

with a mean net return of ₹3.90 lakh. The highest mean B : C ratio (2.96) was observed under this system, which signifies the profitability of horticulture-based systems under irrigated situations. The FS₁ (cropping system) recorded the lowest economic returns among all the farming system models. A mean net returns of ₹0.82 lakh and a B : C ratio of 2.16 was observed under the system, indicating reduced profitability with cropping system as a sole enterprise. Overall, system profitability and economic efficiency were significantly improved by the gradual integration of horticulture, livestock, agro-forestry and vermicomposting. This could be attributed to income diversification, efficient recycling of farm residues and reduced production risks. Agro-forestry and vermicomposting enhanced long-term revenue and lowered input costs; livestock guaranteed consistent income and resource usage; and horticulture enhanced returns through higher market value. Overall, under irrigated conditions, these factors increased resource-use efficiency and produced more steady and profitable results (6, 14, 25). A similar pattern of improved economic performance with diverse integrated farming systems under irrigated environments was reported by earlier researchers (17, 26, 27).

System economic efficiency of integrated farming system models

Between the different integrated farming system models evaluated, FS₅ recorded the highest SEE during both years as well as on a mean basis (Fig. 2). The FS₅ registered net returns of ₹646763 and ₹753252 with corresponding SEE values of ₹1771.95 and ₹2063.70 day⁻¹ during 2023-24 and 2024-25, respectively, with a mean SEE of ₹1917.83 day⁻¹. This was followed by FS₄ (cropping system + horticulture + animal husbandry + agro-forestry), which recorded net returns of ₹603523 and ₹711462 with SEE values of ₹1653.49 and ₹1949.21 day⁻¹ during the respective years, with a mean SEE of ₹1801.35 day⁻¹. The FS₃ (cropping system + horticulture

+ animal husbandry) ranked next, recording net returns of ₹549714 and ₹647712 with SEE values of ₹1506.07 and ₹1774.55 day⁻¹ during 2023-24 and 2024-25, respectively, with a mean SEE of ₹1640.31 day⁻¹.

The FS₂ recorded moderate system economic efficiency with net returns of ₹383451 and ₹397135 and SEE values of ₹1050.55 and ₹1088.04 day⁻¹ during 2023-24 and 2024-25, respectively, with a mean SEE of ₹1069.30 day⁻¹. In contrast, FS₁ (cropping system alone) recorded the lowest performance, with net returns of ₹79491 and ₹84903 and SEE values of ₹217.78 and ₹232.61 day⁻¹ during the respective years, with a mean SEE of ₹225.20 day⁻¹. The progressive increase in system economic efficiency from FS₁ to FS₅ clearly indicated that integration of additional enterprises such as horticulture, livestock, agro-forestry and vermicomposting substantially enhanced daily income and overall system profitability under irrigated conditions (Fig. 2). The higher SEE values during 2024-25 across all systems were mainly due to increased returns from different components under favourable conditions.

The superior performance of FS₅ could be attributed to efficient resource recycling, inclusion of vermicomposting and synergistic interactions among multiple enterprises, which enhanced nutrient availability and reduced input costs (3, 18). The higher system economic efficiency observed in FS₄ and FS₃ highlights the importance of integrating livestock and agro-forestry components for continuous income generation and risk minimisation (11, 15). Moderate performance of FS₂ indicates the role of horticulture in improving profitability, while the lowest SEE in FS₁ emphasises the limitations of sole cropping systems under irrigated conditions (9). Similar findings of increased economic efficiency with the diversification and integration of enterprises in IFS have been reported by several researchers (3, 6, 7).

Economic returns, incremental benefit : cost ratio and component contribution in integrated farming system models under irrigated conditions

The economic returns and ICBR are represented in Table 5, while the contribution of individual components is shown in Fig. 3 and the total monetary returns from each integrated farming model are presented in Fig. 4. Across the different integrated farming system models evaluated, FS₅ recorded the highest economic returns during both the years (Table 5, Fig. 3 and 4). The FS₅ registered gross monetary returns of ₹1051594 and ₹1171303 with corresponding cost of cultivation of ₹404830 and ₹418051 during 2023–24 and 2024–25, respectively, indicating superior system profitability. The ICBR of vermicompost addition was 2.09 and 2.02 during the respective years, while its contribution to gross and net monetary returns was 10.89 and 8.57 % in 2023–24 and 10.86 and 7.60 % in 2024–25, respectively. This was closely followed by FS₄ (cropping system + horticulture + animal husbandry + agro-forestry), which recorded gross returns of ₹968594 and ₹1088553 with ICBR values of 3.63 and 4.11 during 2023–24 and 2024–25, respectively. The contribution of the agro-forestry component to gross returns was 5.95 and 5.75 %, highlighting its role in enhancing system stability with relatively low additional cost.

The next best model was FS₃, (cropping system + horticulture + animal husbandry) which recorded gross returns of ₹894294 and ₹1004313 with ICBR values of 2.26 and 2.60 during 2023–24 and 2024–25, respectively, compared with FS₂, (cropping system + horticulture), the inclusion of animal husbandry increased the gross monetary returns by 90.20 and 97.02 % while the net monetary returns increased by 70.46 and 83.22 % during 2023–24 and 2024–25. Likewise, FS₂ (cropping system + horticulture) recorded gross returns of ₹524621 and ₹548136 ha⁻¹ with higher

ICBR values of 3.32 and 3.39 during both years, respectively, the integration of horticultural crops in FS₂ increased the gross monetary returns by 199.45 and 207.10 % and the net monetary returns by 323.60 and 309.54 %, respectively, over the cropping system alone (FS₁). In contrast, FS₁ (cropping system alone) recorded the lowest economic returns, with gross returns of ₹123849 and ₹133841 during 2023–24 and 2024–25, respectively. The results clearly indicate that progressive integration of components significantly enhanced system profitability, with maximum returns obtained under fully diversified IFS models (Fig. 2). The superior performance of FS₅ (cropping system + horticulture + animal husbandry + agro-forestry + vermicompost) might be attributed to enhanced nutrient recycling efficiency and additional income generated through vermicomposting, which minimised external input requirements and improved overall system productivity (14, 18). The higher economic returns observed in FS₄ and FS₃ could be linked to the integration of agro-forestry and livestock components, which ensured continuous income flow and improved resource-use efficiency within the system (25, 28). The substantial contribution of horticulture in FS₂ reflects the economic potential of high-value crops under irrigated conditions, owing to their higher market demand and better price realisation (2, 28). In contrast, indicate the relatively lower returns in FS₁ emphasise the economic limitations of sole cropping systems, highlighting the need for enterprise diversification to achieve sustainable farm income (22).

Fig. 5 illustrates the IFS model, showcasing the complex material and monetary flows among its major components, including crop production, horticulture, animal husbandry, agro-forestry and vermicompost production. The central "Farm House" component indicates a substantial net return of ₹700007, suggesting a successful and profitable system. The material flows highlight

Table 5. Economic returns, incremental benefit cost ratio and per cent contribution of different components in integrated farming systems models under irrigated conditions during 2023–24 and 2024–25

IFS components	CoC	GMR	Added cost	Added returns	ICBR	GMR	NMR
	(₹ ha ⁻¹)		(₹ ha ⁻¹)			(%)	(%)
2023–24							
FS ₁ : Cropping system	60500 ^e	123849 ^d					
FS ₂ : Cropping system + Horticulture crops	181170 ^d	524621 ^c	120670	400773	3.32	199.45	323.60
FS ₃ : FS ₂ + Animal husbandry	344580 ^c	894294 ^b	163410	369673	2.26	90.20	70.46
FS ₄ : FS ₃ + Agro-forestry	365070 ^b	968594 ^{ab}	20491	74300	3.63	5.95	8.31
FS ₅ : FS ₄ + Vermicompost	404830 ^a	1051594 ^a	39760	83000	2.09	10.89	8.57
SEm+/-	6208.45	26977.06					
CD	19130.15	83124.60					
CV	4.58	7.57					
2024–25							
FS ₁ : Cropping system	58938 ^d	133841 ^d					
FS ₂ : Cropping system + Horticulture crops	181001 ^c	548136 ^c	122063	414295	3.39	207.10	309.54
FS ₃ : FS ₂ + Animal husbandry	356601 ^b	1004313 ^b	175600	456177	2.60	97.02	83.22
FS ₄ : FS ₃ + Agro-forestry	377091 ^b	1088553 ^{ab}	20491	84240	4.11	5.75	8.39
FS ₅ : FS ₄ + Vermicompost	418051 ^a	1171303 ^a	40960	82750	2.02	10.86	7.60
SEm+/-	8673.85	33277.42					
CD	26726.80	102537.93					
CV	6.23	8.43					
Mean							
FS ₁ : Cropping system	59719 ^d	128845 ^d					
FS ₂ : Cropping system + Horticulture crops	181085 ^c	536379 ^c	121366	407534	3.36	203.28	316.57
FS ₃ : FS ₂ + Animal husbandry	350590 ^b	949303 ^b	169505	412925	2.43	93.61	76.84
FS ₄ : FS ₃ + Agro-forestry	371081 ^b	1028573 ^b	20491	79270	3.87	5.85	8.35
FS ₅ : FS ₄ + Vermicompost	411441 ^a	1111448 ^a	40360	82875	2.05	10.88	8.09
SEm+/-	7556.54	26882.26					
CD	23284.01	82832.47					
CV	5.50	7.16					

FS₁ to FS₅: farming systems of different components; CoC: cost of cultivation; GMR: gross monetary returns; NMR: net monetary returns; B : C: benefit : cost ratio. GMR (%) and NMR (%) indicate the percentage increase in gross and net monetary returns over the immediately preceding farming system and not the percentage contribution of each component to the total system returns.

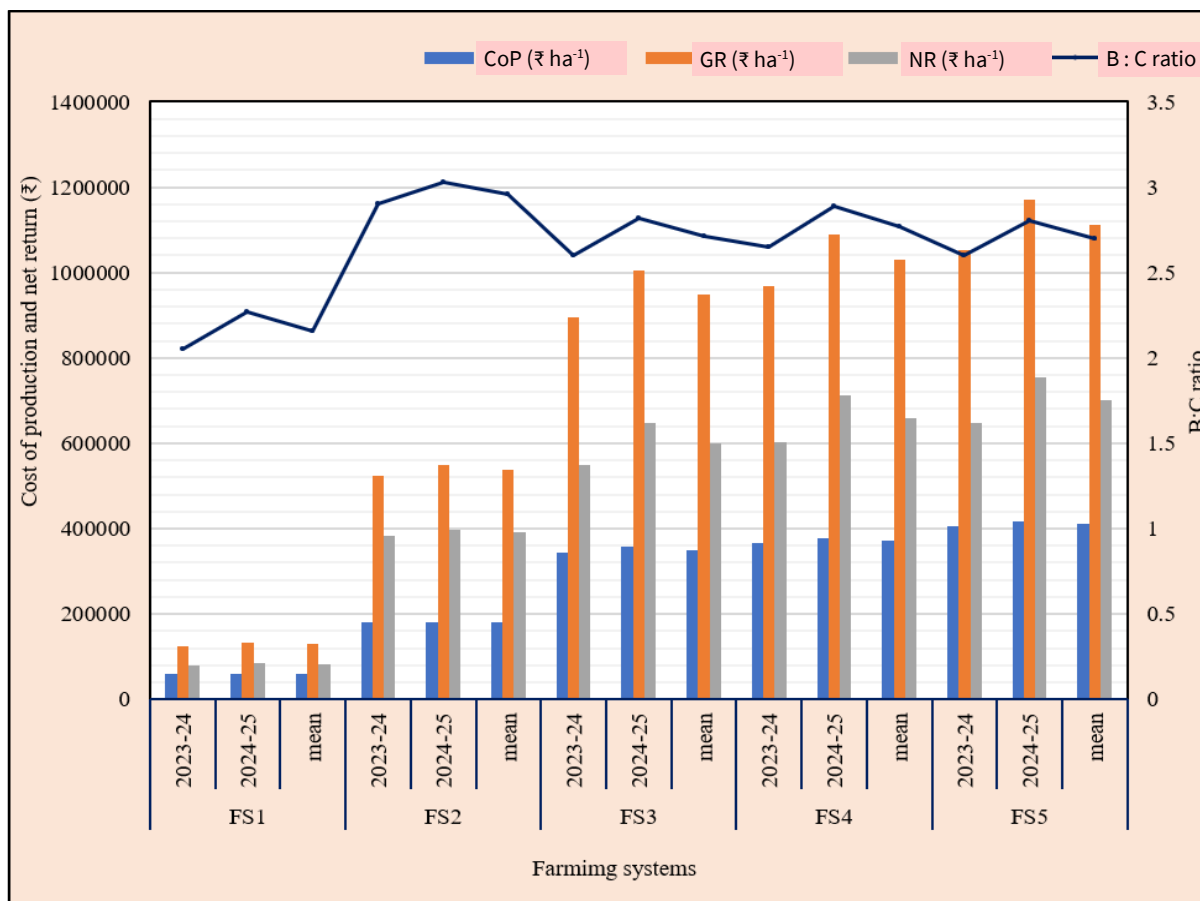


Fig. 4. Economics of different integrated farming system models under irrigated conditions during 2023–24 and 2024–25.

FS₁: cropping system; FS₂: cropping system + horticulture crops; FS₃: FS₂ + animal husbandry; FS₄: FS₃ + agroforestry; FS₅: FS₄ + vermicompost; FMEY: finger millet equivalent yield; CoP: cost of production; GR: gross returns; NR: net returns; B : C: benefit : cost ratio.

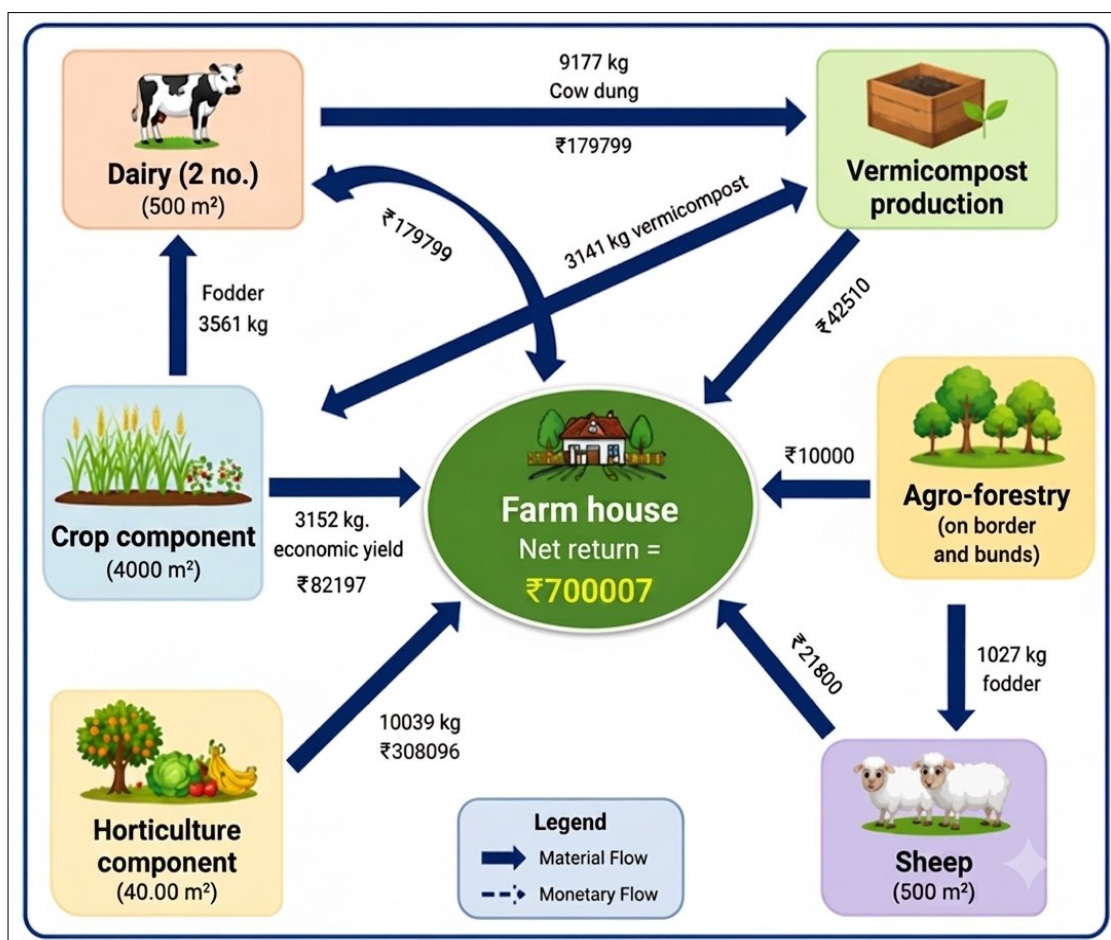


Fig. 5. Resource recycling between different components within the integrated farming system model (FS₅).

resource recycling, such as 9177 kg of cow dung from the dairy going to vermicompost production and 3141 kg of vermicompost being produced, demonstrating a circular agriculture approach where waste from one component becomes an input for another. Other flows include fodder from the crop component to the dairy and sheep sections and economic yields from agro-forestry and horticulture contributing to the overall farm income.

Conclusion

The present study demonstrated that integration of multiple enterprises in an irrigated farming system significantly enhanced productivity, profitability and sustainability compared with sole cropping. Among the integrated farming models evaluated, FS₅ (cropping + horticulture + livestock + agro-forestry + vermicompost) was the most economically viable, recording the highest net returns and system economic efficiency. The inclusion of horticultural crops and livestock diversified the income sources and substantially increased the farm profitability. While agro-forestry and vermicomposting contributed to long-term sustainability through resource recycling and reduced input costs. Vegetable-based cropping systems and high-value horticultural crops were more profitable than conventional cereal-based systems, highlighting their potential for income enhancement under irrigated conditions. Livestock enterprises, particularly dairy, ensured stable and continuous income, thereby reducing economic risks associated with seasonal crop production. Poultry and vermicompost further improved economic efficiency by generating higher returns with relatively lower investment and by facilitating effective utilisation of farm waste and by-products. The synergistic interactions among crops, livestock, agro-forestry and vermicomposting components promoted efficient resource use, enhanced nutrient cycling and improved overall system resilience. Therefore, diversified integrated farming systems can serve as a sustainable strategy for improving farm income, enhancing resource-use efficiency and ensuring livelihood security of small and marginal farmers under irrigated agroecosystems.

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Authors' contributions

D and KM conceptualised the study, while D, KM and DCH planned, supervised and conducted the field experiment. D analysed the data and drafted and edited the manuscript. KM, DCH, AS and BMR reviewed the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Government of India. Agriculture Census 2020–21. Ministry of Agriculture & Farmers Welfare.
2. Rymbai H, Sharma RR, Jha AK. Integrated farming system for sustainable agriculture. *Indian J Agric Sci.* 2012;82(5):435–40.
3. Karthik R, Venkata Ramana M, Pragathi Kumari C. Designing a productive and profitable integrated farming system model with low water footprints. *Sci Rep.* 2024;14:17066. <https://doi.org/10.1038/s41598-024-66696-5>
4. Behera UK, Paramesha V, Kumar A. Comparative economics of integrated farming systems under coastal agro-ecosystem of Goa. *Indian J Agric Sci.* 2020;90(8):1555–62. <https://doi.org/10.56093/ijas.v90i8.105962>
5. Kumar R, Patra MK, Thirugnanavel A, Deka BC, Chatterjee D, Borah TR, et al. Comparative evaluation of integrated farming system models for small and marginal farmers under Eastern Himalayas. *Indian J Agric Sci.* 2018;88(11):1722–9. <https://doi.org/10.56093/ijas.v88i11.84913>
6. Goverdhan M, Pragathi Kumari C, Reddy GK, Reddy PV, Srinivas A. Evaluation of integrated farming system for resource recycling and livelihood security. *Curr J Appl Sci Technol.* 2020;39(34):17–26. <https://doi.org/10.9734/cjast/2020/v39i3431033>
7. Vinodakumar SN, Desai BK, Channabasavanna AS. Integrated farming system for livelihood security. *Int Res J Agric Econ Stat.* 2017;8(2):216–21. <https://doi.org/10.15740/HAS/IRJAES/8.2/216-221>
8. Channabasavanna AS, Biradar DP. Relative performance of rice-fish-poultry integrated farming systems. *Karnataka J Agric Sci.* 2007;20(4):706–9.
9. Manjunath BL, Prabhu Desai HR, Ramesh R, Faleiro JR, Singh NP. Rice based cropping/farming systems for higher productivity and profitability. Technical Bulletin No. 22. Old Goa: ICAR Research Complex for Goa; 2010.
10. Thakur S. Development of integrated farming system model for marginal and small farmers of Mandi district of Himachal Pradesh-an innovative extension tool. *J Hill Agric.* 2012;3(1):46–52.
11. FAO. Climate-smart agriculture sourcebook. Rome: Food and Agriculture Organization; 2017.
12. Behera UK, Mahapatra IC. Farming system approach for livelihood improvement. *Indian Farming.* 1999.
13. FAO. Climate-smart agriculture sourcebook. Rome: Food and Agriculture Organization; 2020.
14. Jayanthi C, Balusamy M, Chinnusamy C. Integrated farming systems for sustainable agriculture. *Indian J Agron.* 2003;48(4):223–6.
15. Singh H, Jangid MK, Meena GL, Sharma SK. Enhancement of productivity through integrated farming systems. *J Anim Res.* 2019;9(3):473–81. <https://doi.org/10.30954/2277-940X.03.2019.13>
16. Mahapatra IC. Cropping system diversification and profitability. *Indian J Agron.* 2010;55(3):159–66.
17. Desai BK, Wali SY, Koppalkar BG. Integrated farming systems for enhancing productivity and profitability. *Karnataka J Agric Sci.* 2013;26(2):199–204.
18. Paramesha V, Behera UK, Reddy KS. Integrated farming systems for livelihood security. *Indian J Agric Sci.* 2019;89(6):989–96.
19. Ponnusamy K, Devi MK. Impact of integrated farming system on farm economy. *Agric Econ Res Rev.* 2017;30:123–30. <https://doi.org/10.5958/0974-0279.2017.00037.4>
20. Dasgupta P, Saha S, Chakraborty D. Economics of integrated farming systems. *Agric Econ Res Rev.* 2015;28(2):233–40.
21. Mahapatra IC, Behera UK. Farming system approach for resource management. *Indian Farming.* 2004;54(2):15–19.

22. Singh K, Bohra JS, Singh Y. Integrated farming systems for enhancing productivity. *Indian J Agron*. 2018;63(4):381–9.
23. Dasgupta P, Ganguly S, Goswami R. Integrated farming system and resource recycling. *Agric Syst*. 2015;135:1–10.
24. Paramesh V, Behera UK, Chakraborty D. Integrated farming system: A sustainable approach. *Indian J Agron*. 2019;64(4):396–402.
25. Dasgupta P, Ghosh PK, Bandyopadhyay KK. Role of livestock in integrated farming systems. *Agric Syst*. 2015;132:1–10.
26. Sharma RL, Abraham S, Bhagat R, Prakash O. Comparative performance of integrated farming system models under rainfed and irrigated conditions. *Indian J Agric Res*. 2017;51(1):64–8. <https://doi.org/10.18805/ijare.v51i1.7064>
27. Patel KM, Patel LJ, Desai KN, Patel SA, Chaudhary SL. Integrated farming systems for livelihood security of small and marginal farmers. *Multilogic Sci*. 2020;10(33):600–3.
28. Mahapatra IC, Behera UK. Farming systems for income and employment generation. *Indian Farming*. 2001;51(10):19–23.

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