sustainability

MDPI

Article

Achieving Food and Livelihood Security and Enhancing Profitability through an Integrated Farming System Approach: A Case Study from Western Plains of Uttar Pradesh, India

Poonam Kashyap [1], Ashisa K. Prusty [2,*], Azad S. Panwar [3], Venkatesh Paramesh [4], Ravisankar Natesan [5], M. Shamim [6], Nisha Verma [7], Phool Chand Jat [5] and Mahendra Pal Singh [8]

[1] Fruit Science, Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (ICAR-IIFSR), Modipuram, Meerut 250110, UP, India; pakhihorti@gmail.com
[2] Aquaculture, Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (ICAR-IIFSR), Modipuram, Meerut 250110, UP, India
[3] Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (ICAR-IIFSR), Modipuram, Meerut 250110, UP, India; director.iifsr@icar.gov.in
[4] Agronomy, Indian Council of Agricultural Research-Central Coastal Agricultural Research Institute (ICAR-CCARI), Goa Velha 403402, Goa, India; parameshagron@gmail.com
[5] Agronomy, Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (ICAR-IIFSR), Modipuram, Meerut 250110, UP, India; ifsofr@gmail.com (R.N.); jat4pc@gmail.com (P.C.J.)
[6] Agrometeorology, Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (ICAR-IIFSR), Modipuram, Meerut 250110, UP, India; shamimagrimet@gmail.com
[7] Farm Resource Management, Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (ICAR-IIFSR), Modipuram, Meerut 250110, UP, India; verma.nisha61@gmail.com
[8] Agricultural Extension, Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (ICAR-IIFSR), Modipuram, Meerut 250110, UT, India; mpspdfsr@gmail.com
* Correspondence: aasiana143@gmail.com

Abstract: The integrated farming system (IFS) is a comprehensive farm practice to improve small and marginal farmers' livelihoods. The IFS enhances nutrient recycling and food security and promotes greater efficiency of fertilizers and natural resources. To improve livelihood, profits, and employment generation holistically through an IFS method, a study was conducted over four years, from 2016 to 2019, to define the farming condition in 1036 households in the Muzzafarnagar district of Western Uttar Pradesh. Crop + dairy was the most frequent farming method (68%) followed by crop + dairy + horticulture + goatary. Compared to older cultivars, improved rice, maize, wheat, and barley cultivars enhanced crop yield by 17 to 42%. Transplanting sugarcane and intercropping of mustard increased system yield from 58.89% to 86.17% compared to the sole sugarcane crop. Nutritional kitchen gardening resulted in an average saving of \$20 to \$25 during the *Kharif* season and \$20 to \$27 during *Rabi* season. Exotic vegetables such as broccoli, Chinese cabbage, cherry tomato, kale, parsley, and lettuce were introduced, which increased regular income. With the adoption of a multi-tier-based system, the net returns from the system improved from 0.6 lakh to 2.20 lakhs per ha. Enhancing the fodder availability resulted in a 27.5% milk yield improvement. The study's outcomes demonstrated that a five-member family's annual protein (110–125 kg) and carbohydrate (550 to 575 kg) requirements can be easily met using the IFS technique. According to the study, IFS approaches combined with better technical interventions can ensure the long-term viability of farming systems and improve livelihoods.

Keywords: crop–livestock integration; food security; livelihood security; sustainability; Uttar Pradesh

check for updates

Citation: Kashyap, P.; Prusty, A.K.; Panwar, A.S.; Paramesh, V.; Natesan, R.; Shamim, M.; Verma, N.; Jat, P.C.; Singh, M.P. Achieving Food and Livelihood Security and Enhancing Profitability through an Integrated Farming System Approach: A Case Study from Western Plains of Uttar Pradesh, India. *Sustainability* **2022**, *14*, 6653. https://doi.org/10.3390/su14116653

Academic Editors: Anup Das, Subhash Babu, Jayanta Layek, Raghavendra Singh and Ramkrushna Gandhiji Idapuganti

Received: 22 April 2022
Accepted: 23 May 2022
Published: 29 May 2022

1. Introduction

Modern agricultural production systems are simplified due to specialization, and they are intensified with high rates of external inputs to maintain favorable and consistent production conditions. These methods can be efficient and productive, but they frequently result in environmental issues, soil nutrient depletion, soil biota disruption, and more significant production costs [1]. Intensive livestock farms, such as large dairy, poultry, piggery, and animal feed preparations, are also reliant on external inputs (e.g., feed), resulting in pollution both externalized (for the manufacture of inputs) and locally generated (due to improper handling, storage, and disposal) [2,3]. Because they relied on fewer agricultural commodities, these modern specialized and intense farming practices influence flora and fauna diversity and increase resource-poor farmers' vulnerability to climate and market change [4,5]. At the farm level in India, intensive agriculture systems cannot provide stable income and employment, food, environmental, and energy security. Farmers that rely on a single farm enterprise, such as a traditional monocropping system, cannot make a living. To overcome the challenges faced by specialized, input-driven agriculture, integrating crops, livestock, and fishery components that preserve food and nutritional security while delivering regular and periodic income to farmers is vital [6]. Integrated farming systems (IFSs) that integrate animal and crop enterprises receive renewed interest in marginal, small, and medium farmers [7] who cultivate less than one hectare. The IFS technique encourages ecological intensification by reducing anthropogenic inputs while improving ecosystem functions such as nutrient recycling, soil formation, soil fertility, and environmental performance. Well-managed IFSs are thought to be safer because they benefit from business synergy, crop diversification, and ecological stability [8].

The vast majority (~65%) of the population in Uttar Pradesh, India, relies on agriculture for livelihood. Sugarcane, rice, and wheat are the most common crops farmed in Uttar Pradesh's Western Plain Zone. The farmers of this region suffice the requirement of cereals through these crops but cannot fulfill their nutritional needs. The farmer's diet is not rich in fruits, vegetables, milk, and animal proteins, leading to a healthy diet deficiency. Therefore, in this regard, the IFS approach is considered the most essential for improving family nutrition and livelihood security. The research approach based on crop and cropping systems must give way to agricultural-system-based research, especially for small farmers [9]. Residue recycling and improved land-use efficiency are the two critical features of the IFS. The components/enterprises in the IFS vary by region, based on agro-climatic factors such as land type, water availability, farmer socioeconomic status, and market demand. Good linkages and complementarities between components are required to construct effective holistic farming systems [10]. Integrating land-based enterprises such as aquaculture, poultry, duckeries, apiaries, and field and horticultural crops into farmers' biophysical and socio-economic environments is crucial in the IFS to make farming more profitable and dependable [11–13]. The proper management of crop wastes and an appropriate allocation of scarce resources lead to sustainable production for resource-poor farmers. A combination of one or more operations with crops offers better returns than a single enterprise when carefully chosen, planned, and implemented, especially for small and marginal farmers. Dairy, poultry, pisciculture, sericulture, biogas generation, mushroom cultivation, agro-forestry, and agri-horticulture, among other activities, play a significant role in bolstering farm income.

Review of Literature

In comparison to the typical rice–wheat system ($1258), the IFSs involving various land-based enterprises generated net returns of $5050 [14]. Jayanthi et al. [15] found that crop integration with fish and poultry increased economic returns by 25% in lowland Tamil Nadu. Das et al. [16] found that the crop–fish–pig (pig-based IFSs) and crop–fish–duck systems produced much more employment, income, and livelihood for farmers than crop alone. Surve et al. [17] demonstrated IFS adoption as a promising and profitable alternative to an existing soybean–wheat cropping system, with improved returns, water productivity, job creation, and energy output. The IFS is the most effective resource management technique for reducing input reliance and improving soil health [2,18]. When cattle and fisheries, among other things, were integrated with crops, Shekinah et al. [19] and Sujatha and Bhat [20] showed increased nutrient usage efficiency, nutrient recycling, and soil microbial activity. In Kerala, India's homestead farming integrated with a livestock component supplies a farm family of four individuals with vegetables, milk, and eggs throughout the year on an area of 0.2 hectare [21]. According to Devendra and Thomas [1], the IFS is critical for poor small and marginal farmers to meet their protein needs through eggs, milk, and meat from animals. Through an improved use of available resources, introduction of legumes, vegetables, oilseed crops, or agroforestry systems, the IFS could help attain food and nutritional security [22,23]. The critical factors affecting the adaption of innovative technology in the IFS are education, farming experience, family size, cropping area, and access to weather forecast information [24,25]. Furthermore, Elahi et al. [26] opined that effective use of agricultural loans and agroadvisory services are very much essential for efficient adaption of the IFS by small and marginal holders.

Despite the complexities of how future food and nutritional demand will develop, India's regional IFS will be critical in meeting that demand. Another challenge is that the production strategy to meet food demand would have to be implemented in the face of climate change and unpredictability. Given the relevance of the IFS to the farm family's food and nutritional security, economics, and employment generation, a study was conducted in three villages in Western Uttar Pradesh to promote the IFS with technical interventions to achieve food and nutritional security. The current study's major goal was to evaluate how the implementation of the IFS methodology with a suitable package of practices improves farmers' food and nutritional security.

2. Materials and Methods

2.1. Study Area

The zone is characterized by semi-arid and sub-humid conditions with hot to warm summers and cool winters. Three selected villages belong to Khatauli block (29.2885217 N Latitude and 77.8479168 E Longitude) in Muzaffarnagar district (Figure 1). The average maximum temperature is 41 °C, with an average lowest temperature of 7 °C. Average annual rainfall ranges between 750 and 1500 mm. The majority of the soil is sandy loam. A large part of the geographical area is cultivated and is well irrigated. Canals, tube wells, and wells mainly provide irrigation. Over 70% of the area is sown, and nearly 65% of this is irrigated. The major cropping systems are sugarcane–ratoon–wheat and rice–wheat systems. Crop–livestock interaction has been a unique feature of the region. Approximately 89.21% of farmer families fall into the small and marginal farmer category. The western portion of Uttar Pradesh is the state's most agriculturally advanced region. The study region includes the farming systems of Uttar Pradesh's Western Plain zone in the Khatauli block of Muzaffarnagar district. The research locations for the farming system were chosen with care, taking into account agro-climatic and socioeconomic conditions, landholding patterns, and farming techniques. Based on this, a cluster of three villages comprising 238 households of Bhangela village, 400 households of Sonta village, and 398 households of Satheri village were selected. Farmhouses in all three adopted communities were divided into distinct types of farmers based on the size of their landholdings. The total sample comprised 1036 households for which a detailed benchmark survey was carried out during 2016 through a baseline survey, which could form a basis for identifying the constraints and subsequent planning of module-wise IFS interventions.

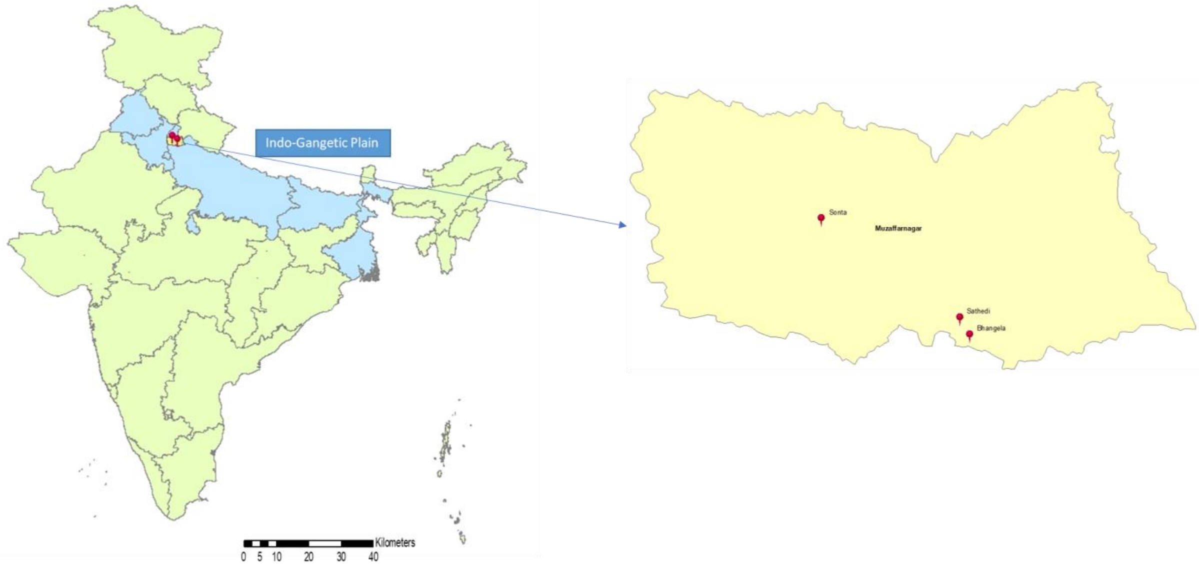

Figure 1. Depicting the study area.

2.2. Technological Interventions

During the reporting period of 2016–2019, module-wise technological interventions were planned and implemented in the field based on constraint analysis and requirement needs of different categories of farmers. The farming system approach for holistic development of farm households was used, keeping in mind the food, fodder, and other requirements of households for ensuring food and nutritional security besides enhancing farm income. For sustainable development of farm households, the on-farm trial of an improved package of practices with the introduction of improved varieties along with capacity development was carried out. Sugarcane nutrient and pest management were implemented to solve low yield due to unbalanced fertilizer use and inadequate plant protection measures. Critical inputs such as fertilizers, plant protection chemicals, Trichoderma card, etc., were used in the technological intervention. Component-wise detailed interventions are listed in Table 1.

Table 1. Module-wise technological interventions.

Modules of IFS	Technological Interventions
Crop and cropping systems	Intensification and diversity of cropping. HYV, intercropping, INM, IPM, and IWM are all examples of enhanced production technology. Oilseeds and pulses are emphasized.
Livestock	Management of fertility and nutrition in dairy cows. Vaccination, deworming, and calcium supplements for livestock. Introduction of improved poultry, goat, and pig breeds. Diversification of agricultural systems for feed and fodder management.
Horticulture	Demonstration of the enhanced vegetable crop production package of practices. Growing exotic vegetables for a bigger profit. Vegetable multi-tier cropping and promotion of a nutritional kitchen garden. Low-cost nursery/low-cost poly house for off-season vegetable production.
Capacity building for secondary agriculture	Value addition of farm products (pickle/jam/jaggery manufacturing) and SHG formation for marketing. Composting and vermicomposting. Improved small farm equipment to reduce farm women's drudgery. Skill development (composting/vermicomposting, nursery raising, on-farm processing, mushroom production/pruning, appropriate agricultural practices). Visits to agri fairs, Krishna Unnati Melas, awareness activities, and Kisan Gosthi. Literature dissemination in local languages and risk management agro-advisory services.

2.3. Sampling Procedure and Data Collection

Multistage surveys were conducted using a standardized questionnaire to determine agricultural output, food, and nutritional security, animal production, fodder availability, and milk production in 2016–2017 (baseline survey during pre-IFS intervention phase) and 2019 (post-IFS intervention phase). Households in each hamlet were separated into groups based on the size of their land allotment (marginal 1 hectare, small 1–2 hectares, semi-medium 2–4 hectares, medium 4–10 hectares, large 10 hectares, and landless).

2.4. Impact Analysis

The impact of IFS interventions on crop productivity, milk production, availability of forage resources, and household nutrition was calculated using the following equation.

$$\text{Impact} = \frac{\text{Difference in yield or milk or forage production between 2016 to 2019}}{\text{Baseline value in 2016}} \times 100$$

3. Results

3.1. Socioeconomic Characteristics

3.1.1. Farmers' Holding Size

Farm households in each of the three adopted villages were classified according to the size of their landholdings. The results reveal a significant presence of landless farmers (36.29%) while marginal, small, and landless farmers together constitute about 87.45% of the farming community (Table 2). Satheri village had the most significant percentage of landless farmers (49%), followed by Sonta (33.4%) and Bhangela (33.4%) (19.7%). Bhangela village had the highest concentration of marginal farmers. The adopted villages had a very low percentage of medium farmers (2.1%), whereas large farmers were absent, implying that landholdings were fragmented.

Table 2. Households under different categories of farmers.

Category	Farmers (Nos.)	Sonta	Satheri	Bhangela	Total (%)	Cumulative (%)
Landless	376	33.4	49	19.7	36.29	36.29
Marginal (<1 ha)	346	30.91	28.3	46	33.40	69.69
Small (1–2 ha)	184	23.61	12.2	17.2	17.76	87.45
Semi-Medium (2–4 ha)	108	10.32	7.3	16.2	10.42	97.87
Medium (4–10 ha)	22	1.76	3.2	0.9	2.12	100
Total	1036	100 (398)	100 (400)	100 (238)	100	

3.1.2. Socioeconomic Characteristics

The socio-personal characteristics of questioned farmers were explored in terms of age, education, occupation, home size, family type, monthly income, and participation in social activities. According to the findings, the majority of farmers in the cluster under study were in the middle age group (36 to 55 years), followed by the elderly (>55 years) and the younger age group (35 years), with a tiny percentage of the young farmer population migrating to metropolitan regions in pursuit of work. Most farmers were uneducated or just had primary education, and farming was their principal vocation. The average household had more than four individuals and a monthly income of less than $13.

3.1.3. Pre-Dominant Cropping/Farming System

Crop + dairy farming was the most common farming style in all three villages studied. Sugarcane, wheat, rice, maize, and sorghum were the most common crops under cultivation, although potatoes and vegetables were cultivated in isolated places where irrigation water was available. Buffalo and cows dominate the dairy industry, but goats, chickens, and pigs dominate meat production.

The study found that crop + dairy farming is the most common agricultural system among households in the study cluster (578 homes), accounting for around 56% of the total sample, with the most houses in Sonta (266), Satheri (162), and Bhangela (150) (Figure 2). The next dominant farming system was found to be only dairy (380), which was found at 30% of the existing farming system, the maximum being in Satheri (158), followed by Sonta (111) and Bhangela (39). The predominantly prevalent system was only crop (54) which accounted for 5% of the existing farming system, the maximum being in Satheri (30) followed by Bhangela (24) and nil in Sonta. Goatary/poultry/piggery was also found to be reared by 45 (4%) farm households, the maximum being in Sonta (16), followed by Bhangela (15) and Satheri (14). However, around 5% of farm households were engaged in other professions, *viz.* government/private service, earning income through providing their land on lease, shopkeeping, etc.

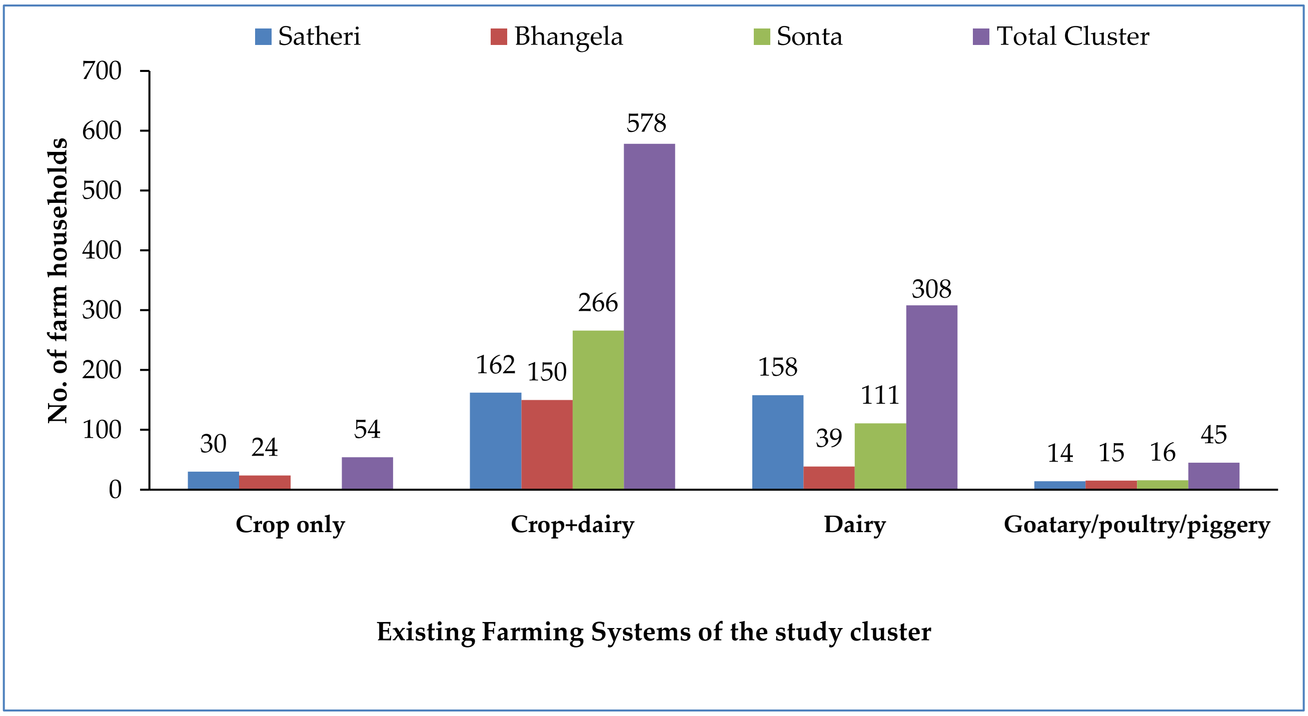

Figure 2. Predominant farming systems in the selected villages.

3.2. Critical Intervention under Different Crop Enterprise

3.2.1. Trench Planting of Sugarcane in Autumn with Intercropping of Mustard

The sugarcane–ratoon–wheat cropping system is predominantly practiced in western Uttar Pradesh. The farmers usually in this intensive cropping system used to cultivate the most popular sugarcane variety Co 0238 from the last ten years, which is generally planted in May after harvesting late-sown wheat crop leaving only one month for tillering and canopy formation in the first plant of sugarcane resulting in the heavy downfall of cane as well as green top yield. Moreover, the most popular variety (Co 0238) is under heavy pressure from pathotypes and biotypes owing to being alone in the vast fray of its cultivation. Therefore, a strategic intervention by introducing a new variety of sugarcane CoPk 05191 along with mustard (RH 749) as an intercrop in autumn planting with the paired-row trench method was demonstrated in the six farmer's fields, two each in Satheri, Bhangela, and Sonta. This approach resulted in a considerable increase in cane yield ranging from 34.69 to 52.55%, as well as system yield due to mustard intercropping (Table 3). Results reveal a significant increase in cane yield as well as system yield due to the intercropping of mustard. The increase in system yield ranged between 58.89% and 86.17% compared to the sole crop of sugarcane farmer practice in summer crop (Table 3).

Table 3. Performance of sugarcane with intercropping of mustard.

	S. Cane CoPk-05191 (Main) Autumn Planting with Mustard (RH-749) as Intercrop			F.P. (Co-238 Summer Planting)	Increase in Cane Yield (%)	Increase in System Yield (%)
	Cane Yield (t/ha)	Seed Yield (t/ha)	System Yield (SEY) t/ha	Cane Yield (t/ha)		
Sonta	91.18	1.76	111.27	59.77	52.55	86.17
Sonta	88.96	1.74	111.07	62.55	42.22	77.57
Satheri	97.30	1.78	111.46	66.72	45.83	67.06
Satheri	96.18	1.87	112.55	66.44	44.76	69.40
Bhangela	91.74	1.74	111.07	68.11	34.69	63.08
Bhangela	94.52	1.68	110.43	69.50	36.00	58.89

3.2.2. Promotion of Improved Cultivars of Wheat for Higher Productivity and Profitability

Technical interventions such as introducing three improved cultivars of wheat (PBW 550, PBW 658, and DBW 90) and farmers' practices (PBW-226) as control were taken for field demonstration and evaluation. Plant height, grain yields, and other attributes such as effective tillers per plant, length of ear, grains per ear, and test weight were also evaluated. Uniform management practices such as integrated nutrient management and irrigations were applied during each crop season. Results indicate a significantly higher yield (Table 4) in the introduced cultivar (PBW-658) than in farmer's practice (PBW-226). Therefore, for this region, adopting a new variety (PBW-658) is more beneficial in increasing crop yield and income and forms a more practical consideration.

Table 4. Plant height, grain yield, and yield attributes of wheat during *rabi* 2018–2019.

Treatments	Plant Height (cm)	Effective Tillers/Plant	Ear Length (cm)	Grains/Ear	Test Weight (g/100 Seeds)	Grain Yield (kg/ha)
PBW-226	89.9	4.4	5.7	56.6	2.9	4373
PBW-550	80.4	6.9	7.7	61.7	3.0	4654
PBW-658	97.4	7.3	8.6	66.4	3.0	5326
DBW-90	85.2	6.6	9.2	55.8	4.5	4489
C.D.	1.7	1.1	1.3	6.0	0.3	239
SE(m)	0.6	0.4	0.5	2.0	0.1	81
SE(d)	0.8	0.5	0.6	2.9	0.2	115
C.V.	2.0	17.6	17.4	10.1	10.0	518

3.2.3. Balanced Fertilization and Disease/Pest Management in Sugarcane through IPM

A total of 659 trials were conducted to improve sugarcane yield and quality by managing nutrients (N 175, P 80, K 120, Sulfur 40, Zinc 25, and Boron 5 kg per hectare) and plant protection measures (Trico card was used three times during the rainy season for controlling shoot borer and mealybug, and Carbendazim @ 0.2% was sprayed on the crop for controlling shoot borer and mealybug). Compared to farmers' practice, sugarcane output increased to 15.01, 14.66, and 10.22% in Sonta, Satheri, and Bhangela, respectively (Table 5).

3.2.4. Nutritional Kitchen Gardening

The importance of fruits, vegetables, and kitchen gardening was brought to the farmers' attention. Planting of improved cultivars of fruit trees such as mango, guava, and lemon and training on scientific management of various fruits and vegetables were carried out for this purpose. Farmers were given a little kit of seasonal vegetable seeds to promote nutritional kitchen gardening on bare ground near their homes/water sources, etc. These tiny kits cost between 0.45 and 0.5 USD each. Seasonal vegetable availability for family consumption was secured from this intervention, which may save farmers 5–7 USD per month on vegetable purchases. Through kitchen gardening, we were able to save 20–25 USD during Kharif (monsoon) and Rabi (winter). Many of the study area's poor farmers were surprised by such measures.

Table 5. Comparative performance of sugarcane between farmer practice and on-farm trials.

Name of the Village	Farmer Practice				On-Farm Trials				Percent Increase in Yield
	Length of Cane (cm)	Weight of Cane (Kg)	No. per Running Meter (No.)	Total Production (Q/ha)	Length of Cane (cm)	Weight of Cane (Kg)	No. per Running Meter (No.)	Total Production (Q/ha)	
Sonta	209.67 ± 4.96	1.61 ± 0.06	5.90 ± 0.11	678.35 ± 6.91	242.07 ± 5.65	2.00 ± 0.06	6.50 ± 0.10	780.17 ± 9.97	15.01
Satheri	288.10 ± 4.54	1.82 ± 0.04	13.95 ± 0.30	637.6 ± 8.64	323.6 ± 4.48	2.10 ± 0.03	15.25 ± 0.19	731.1 ± 7.95	14.66
Bhangela	290.6 ± 4.45	1.73 ± 0.05	12.75 ± 0.16	654.00 ± 8.33	316.60 ± 5.43	1.95 ± 0.05	13.4 ± 0.15	720.85 ± 5.99	10.22
Overall Mean	238.64 ± 4.95	1.67 ± 0.04	8.61 ± 0.35	666.51 ± 5.13	270.44 ± 5.24	2.01 ± 0.04	9.34 ± 0.37	760.46 ± 7.02	14.09

3.2.5. Pulse Intercropping

Intercropping of pulses (blackgram/greengram/chickpea) was performed in juvenile orchards of guava and litchi for intensification and additional income through intercrops and protein sources for household nutrition. Intercropping of bananas in poplar plantations was demonstrated in the silvi–horti system, which provided added income from intercrops with diversification and intensification and provided a better microclimate suited for banana crops as intercrop (Table 6).

Table 6. Advantage of pulse intercropping under IFS.

Improved IFS	
	Orchard module
0.4 ha (50%)	Guava (intercropping of pulses)
0.4 ha (50%)	Litchi (intercropping of pulses)
	Animal module: 3 cows
	Manure, vermicompost
Net Return: 1.73 lakhs, B:C ratio 2.12	

3.2.6. Exotic Vegetable Cultivation for Higher Productivity and Profitability

Farmers were given a better package of practice in the vegetable module for the successful cultivation of exotic vegetables such as broccoli, Chinese cabbage, kale, and lettuce for increased profitability, as well as boundary planation of papaya to reduce the risk of heavy reliance on a single crop while also generating year-round income. Since adopting a diverse exotic-vegetable-based cropping scheme, net returns from 0.4 ha improved to 119%. With only a 9.5% rise in cultivation costs, overall net returns increased from 1234 to 2708 USD. In the modified agricultural system, the animal module's contribution to net revenue increased by 26%. The crop module's contribution to net income increased by 219% simply due to the addition of exotic vegetables to the current sugarcane-based system. The benefit-to-cost ratio in the modified system increased from 2.11 in the previous farming systems to 3.23. Thus the potential of horticultural crops in enhancing farmers' income proved worthy in farmer's fields. A multi-tier fruit crop-based system comprising strawberry, sponge gourd, and capsicum was field-demonstrated in the cluster considering the urban region's market accessibility, which garnered a lot of interest from the farmers in the locality. With the adoption of a multi-tier-based system, the net return improved to about 2.20 lakhs from 0.60 ha land, which was only Rs 40,000 with the sugarcane–ratoon–wheat system, while the B:C ratio increased from 2.24 to 3.20.

3.3. Technological Intervention in Livestock

3.3.1. Animal Health Management

Artificial insemination with high-quality sperm was used to address the problem of infertility. Milch animals were given a mineral mixture and balanced nutrition to increase milk output. Under the livestock module, technological interventions such as infertility and nutrition management in dairy animals, mineral mixtures, calcium and vitamin supplements, promotion and enhancement of indigenous cattle breeds, deworming, and disease control were carried out. The addition of a mineral mixture and balanced nutrition was used to boost milk production in mulching animals, as well as an increase in the provision of high-quality green fodder, increasing milk yield (Table 7).

3.3.2. Improved Fodder Production

For a steady supply of green fodder, berseem and oats were evaluated with improved management practices and proper seed rate which resulted in an about 27.5% yield enhancement (Table 8).

Table 7. Impact of animal health management on milk yield.

Particulars	Village	Number of Demonstrations	Increase in Milk Yield (ltr)	Increase in Yield (%)
Mineral mixture supplement Deworming Fodder availability Calcium supplement	Sonta	345	1.12	17.44
	Satheri		1.83	23.95
	Bhangela		1.52	16.49
	Mean		1.49	19.3%

Table 8. Performance evaluation of fodder crops under improved management practices.

	Village	No. of Demonstrations	Yield (q/ha) Improved Practice	Yield (q/ha) Farmer Practice	Increase in Yield (q/ha) (%)
Berseem (1kg seeds 400 m^{-2})	Sonta	35	792.86	613.9	178.9 (29.3%)
	Satheri		789	613	176 (28.8%)
	Bhangela		795.9	608.6	187.27 (30.9%)
	Mean		792.6	611.9	180.7 (29.5%)
Oats (Kent)	Sonta	22	474	370	104 (28.17%)
	Satheri		476.43	367.14	109 (30.21%)
	Bhangela		466.25	373.75	92.5 (24.97%)
	Mean		472.2	370.3	101.8 (27.5%)

3.3.3. Nutritional and Animal Health Care Management

The dietary intervention was used to help cattle and buffaloes grow faster and produce more milk. Farmers were taught to make low-cost balanced meals using feed components acquired locally. Mineral mixtures, reinforced calcium, and vitamin mixtures were added to the milking animals' diets to balance their rations (Vimeral). To eliminate calcium insufficiency in animals, farm households were given an enriched calcium supplement. Aside from vitamin combinations, farm households were also given food. Endo- and ectoparasites were also effectively controlled using medications. These activities significantly impacted the animal's overall well-being. The effects of dietary management on milk production are shown in Table 7. The provision of balanced nutrition led to an overall increase in milk yield of 1.03 L/day in various communities (Table 9), which is a 12.95% improvement over farmers' practice. Milk output is estimated to increase by 225–250 L each lactation. The animals' milk production improved, but they also improved their reproductive cycles and fecundity by becoming pregnant on time.

Table 9. Improvement in per-day milk production in buffaloes by nutritional management.

Name of the Village	Average per-Day Milk Production before Treatment (L)	Average per-Day Milk Production after Treatment (L)	Average per-Day Increase in Milk Production (L)	% Increase in per-Day Milk Production
Satedi	7.995 ± 0.31	9.027 ± 0.29	1.032 ± 0.04	12.91
Bhangela	7.815 ± 0.25	8.842 ± 0.26	1.027 ± 0.06	13.15
Sonta	8.040 ± 0.21	9.070 ± 0.19	1.030 ± 0.08	12.81
Overall	7.950 ± 0.15	8.980 ± 0.14	1.030 ± 0.03	12.95

3.4. Animal Husbandry

Animal-husbandry-based IFSs incorporating piggery, goatary, and poultry were carried out and evaluated to ensure the livelihood security of marginal, landless farmers. Results are presented in the following tables.

3.4.1. Promotion of Piggery among Landless Farmers

Landless farmers were provided with a large white Yorkshire breed of piglets for enhancing their livelihood through pig rearing. Each farmer was provided with one male and one female piglet. Results indicate a 40% increase (Table 10) in their income from pig rearing.

Table 10. Income enhancement through pig rearing.

	Village	No. of Households	Increase in Annual Income (USD)	Increase in Annual Income (%)
Large white Yorkshire	Sonta	15	12.5	48.81
	Satheri		152	30.48
	Bhangela		165	41.96
	Mean		147	40.42

3.4.2. Promotion of Backyard Poultry

Landless farmers were provided with backyard poultry for enhancing their livelihood through backyard poultry. Each farmer was equipped with 12 birds of CARI Nirbheek. Results indicate a 29% increase in their income from poultry rearing (Table 11).

Table 11. Income enhancement through backyard poultry.

	Village	No. of Households	Increase in Annual Income (USD)	Increase in Annual Income (%)
Nirbheek (12 birds to each farmer)	Sonta	24	173	31.18
	Satheri		167	30.23
	Bhangela		144	27.27
	Mean		161	29.56

3.4.3. Promotion of Goatery

Marginal and landless farmers were provided with Jamnapari goat (local breed) for enhancing their livelihood through goat rearing. Each farmer was provided with two goats. In each village, one male was maintained, the rest being females. Additional income to 32% was realized from the adoption of goatery (Table 12).

Table 12. Income enhancement through goat rearing.

Particulars	Village	No. of Households	Increase in Annual Income (USD)	Increase in Annual Income (%)
Jamnapari (2 goats to each farmer)	Satheri	9	163	32.79
	Bhangela		148	32.50
	Mean		155	32.65

3.5. Capacity Development Module

3.5.1. Drudgery Reduction of Farm Women

Uses of improved small farm tools/implements with efficient ergonomic efficiency were promoted among farm women for different agricultural and horticultural activities for drudgery reduction. Better gender-friendly tools for drudgery reduction were created into a demonstration kit. To increase their productivity and comfort during harvesting and weeding, farmers were given ergonomically designed instruments such as improved sickles for harvesting field crops, fodder crops, and improved khurpi. Eight hundred farmers endorsed an upgraded sickle for harvesting field crops and fodder crops, as well as an improved khurpi since they believe the improved equipment saves time and energy. An around 18.7% reduction in terms of time and a 10.89% reduction in terms of energy were noticed while working with an improved sickle compared to a traditional sickle. In contrast, an around 80.4% reduction in time and a 12.3% reduction in energy were noticed while working with a direct seed dibbler. By analyzing it through wheat harvesting, the upgraded sickle had a working capacity of 405.89 h/ha, which is considerably greater ($p \leq 0.05$) than the traditional sickle (499.31 h/ha). Farmers discovered that when using an upgraded sickle, the mean value of the strain index was 18.96; however, when using a standard sickle, it was 35.53, a substantial difference ($p \leq 0.05$). Further, a demonstration of seedling transplanter and direct seed dibbler was conducted through the participation of farm women in the study cluster to reduce drudgery (Table 13).

Table 13. Evaluation of improved versus traditional sickle in wheat harvesting (n = 40).

Parameter	Traditional Sickle (Mean)	Improved Sickle (Mean)	*t*-Value	*p*-Value
Working capacity (h/ha)	499.31	405.89	3.25 *	0.0024
Strain index	35.53	18.96	4.42 *	0.00009

* = significant, *t*-value = calculated value of *t*, *p* = probability value for differences of two sample means assuming equal variances at a 5% level of significance.

3.5.2. Skill Development of Farm Women for Value Addition and Women SHG Formation

A women's self-help organization (Devanjali Mahila Samuh) was established in Bhangela village to increase women's abilities in secondary agriculture activities as a source of income. The women's group received numerous pieces of training on value addition and processing of various items.The group gained expertise in the development of different products, *viz.* blended squash (guava + orange) and mixed jam (guava + apple + aonla + orange + persimmon) (guava + pineapple + pomegranate + apple), ginger paste, etc. The mixed jam and ginger products were packed into glass bottles, and blended squash was packed into PET bottles. The group gained expertise in the processing of spices, cereals, millets, fruits, vegetables, and sugarcane into different value-added products, viz. turmeric, coriander, powder, chilly powder, ginger paste, gram flour, rice flakes, maize flour, wheat porridge, mixed flour, pearl millet flour and biscuits, vermicelli, mango, lemon, chilly, aonla pickles, guava-based mixed jam, blended squash, water chestnut flour, nutritionally enriched jaggery production, etc. Aside from that, they were taught how to package various products using various packaging materials. By selling the created items at various exhibitions, farmer fairs, door-to-door marketing, order on phone calls, and other venues, the organization obtained experience in branding, labeling, marketing, and preserving sales records. The group developed 819 kgs of processed products by selling various value-added products and earned $760/per year in net revenue (Table 14). In addition, the organization gained experience in marketing and keeping track of sales for developed items. The profit margin (30%) on the sold products was split equally among the women. In addition, the business gained experience in sugarcane value addition by creating ready-to-serve (RTS) and jaggery (cane sugar).

3.5.3. Technology Dissemination through Training, Kisan Gosthi, Exposure Visits

Capacity-building efforts and public awareness campaigns on the improved package of practices for various rabi crops were carried out during the reporting year. Farmers were also introduced to cutting-edge technology via visits to Krishi melas and exhibitions. Awareness programs on Swachhata hi Seva, soil health day, etc., were observed in study clusters for cleanliness drive and soil health management.

3.6. Integrated Farming Systems (IFSs) for Different Categories of Farmers

Based on individual component modules, IFSs suitable for different categories of farmers with different component technologies were integrated and studied for their impact on economic performance, resulting in increased income ranging from 21% to 139%, presented in Figure 3.

Table 14. Economic performance of secondary agriculture module undertaken in the study cluster.

Secondary Agriculture Module	Quantity Produced (kg)	Cost of Production (USD)	Net Income (USD)
Processing of spices (Turmeric, coriander, powder, chilly powder, ginger paste, etc.)	201	376	215
Processing of wheat/rice/millets (Gram flour, rice flakes, maize flour, wheat porridge, mixed flour, pearl millet flour, biscuits, vermicelli, etc.)	238	183.64	179
Processing of fruits and vegetables (Mango, lemon, chilly, aonla pickles, guava-based mixed jam, blended squash, water chestnut flour, etc.)	380	564	366
Grand Total	819	1124	760

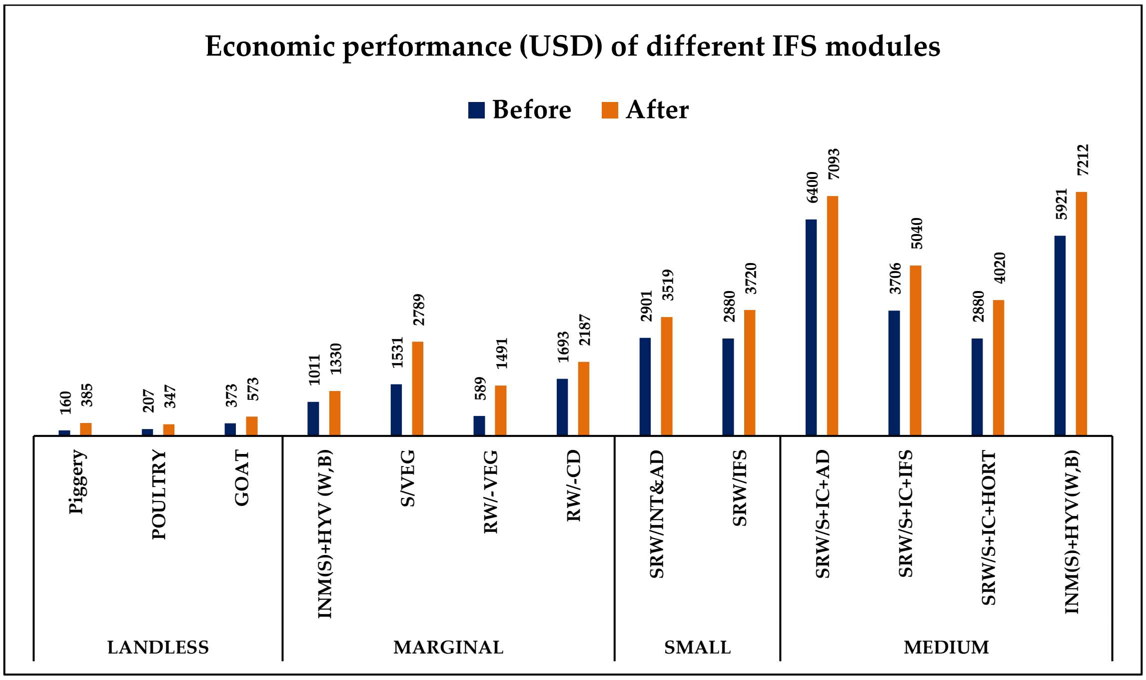

Figure 3. The economic impact of the farming system approach.

3.7. Changes in Food Consumption Patterns after the Farming System Interventions

A study on food consumption patterns was conducted in a cluster of three villages to know the accessibility of food to farm households as per recommended dietary allowance (RDA). It was found that the farm households (Table 15) were marginally lacking in cereal and millet consumption, pulse consumption, fats, and oils. In contrast, the farm households were severely lacking in consumption of vegetables, especially green leafy vegetables and other vegetables. Moreover, the mean consumption of meat products was deficient due to a significantly smaller non-vegetarian population in the adopted cluster. However, the mean consumption in terms of milk, sugar, and jaggery was found to be higher than RDA in the adopted cluster (Table 15). This is due to the sugarcane- and dairy-based farming systems prevailing in the villages of the adopted clusters. To expedite the adopted cluster's knowledge and capacity in terms of improvement in their food consumption pattern, the following farming system interventions were implemented: crop intensification through the introduction of high-yielding varieties along with IPM and INM practices in field crops, crop diversification through the integration of pulses and oilseed crops, fertility and nutrition management in milch animals, year-round nutrition kitchen gardening through seasonal and exotic vegetables, the inclusion of secondary agriculture, viz. vermicomposting, value addition, and food processing, drudgery reduction through improved tools, etc., along with nutrition awareness programs through Krishi melas, Mahila Kisan goshthis, etc. The food consumption pattern was re-evaluated after implementing farming system interventions, and it was discovered that the mean food consumption pattern in terms of cereals and millets, green leafy vegetables, other vegetables, roots and tubers, fruits, fats and oils, and meat products had improved. However, the mean consumption of pulse remained the same despite the integration of pulse crops. The mean consumption pattern for milk increased to 165.38% as of RDA, but the higher milk consumption is necessary to compensate protein requirements of the household as the mean pulse consumption is still low. Interestingly, the mean sugar and jaggery consumption pattern reduced, almost equivalent to RDA.

Table 15. Food consumption pattern (g/capita/day) before and after a farming system intervention.

Particulars	RDA (ICMR 2010)	Mean Consumption (Before Intervention)	Mean Consumption (After Intervention)
Cereals and millets	400	357.8	423.7
Pulses	80	32.1	31.49
Green leafy vegetables	50	8.64	23.48
Other vegetables	150	65.46	136.07
Roots and tubers	100	82.64	99.42
Fruits	100	10.23	57.78
Fats and oils	30	22.72	32.16
Milk	300	392.8	496.15
Meat products	60	0.32	4.82
Sugar and jaggery	40	74.46	47.7

4. General Discussion

Monoculture and conventional management practices cannot meet growing and changing food demand while simultaneously improving the livelihoods of smallholder farmers [27]. Crop diversification toward high-value crops and resource efficiency approaches such as the IFS are increasingly frequently supported as essential means of increasing farmers' income and improving farm productivity on a long-term basis [28]. Multi-enterprise farming contributes to the sustainability of the farming system by providing different cropping, biodiversity, and ecosystem services. Bell et al. [10] studied Australia's integrated crop–livestock system, and they concluded that planting dual-purpose cereals and canola for fodder decreases farm risk, diversifies crops, reduces demand on other feed resources, and increases livestock and crop output by 25–75%. Franzluebbers [29] investigated the IFS in the Coastal Plain and Piedmont regions of the United States. They found that by integrating crops and livestock more closely, the quantity and quality of production, as well as the economic return, can be increased and soil and water resources are also conserved. As a result, the IFS could be a viable choice in resource-constrained small and marginal landholdings to boost system output while still meeting the farm family's food and nutritional needs. Bringing crop diversification, including cereals (energy), pulses (proteins), oilseeds, fruits and vegetables, and animal diversification into a small piece of land at the same time is imperative for achieving family needs.

Long-duration mono-cropping is substantially less profitable than incorporating high-value vegetables and spice crops throughout the farm. In crop failure, the livestock component, such as dairy, goatary, poultry, and piggery, will operate as farm insurance. Jayanthi et al. [15] found that crop integration with fish and poultry increased economic returns by 25% in lowland Tamil Nadu. According to Rautaray et al. [12], the rice–fish system with vegetables, fruits, and agroforestry components in the dyke area can provide 2.8 times more income than rice alone in Assam's lowland ecologies. From 1.04 acres, the coconut-based IFS at ICAR-CPCRI, Kasaragod farmers can get an annual gross and net return of $2762 and $889 [30]. As a result, the IFS may be promoted as a vital source of income for the country's small and marginal farmers, allowing them to achieve economic and long-term production to meet the various needs of farm households in small and marginal landholdings. The IFS can be viewed as a feasible technique for rural bio-entrepreneurship and a crucial tool for doubling India's farmer income [7].

The IFS allows for the efficient use of land and time in the production of short-duration vegetable crops, pulses, and livestock fodder. These systems are crucial for ensuring future food and nutrition for India's rapidly growing population. In Kerala, India's homestead farming integrated with a livestock component supplies a farm family of four individuals with vegetables, milk, and eggs throughout the year on an area of 0.2 hectares [21]. Table 15 shows how the IFS might help small and marginal farmers diversify their food baskets by using a small land area. Table 15 clearly emphasizes the relevance of the IFS in fodder production for livestock and fuelwood for domestic use. Devendra and Thomas [1] highlighted the importance of the IFS for poor small and marginal farmers in meeting their protein needs through eggs, milk, and meat from livestock. Through better use of available resources, the introduction of legumes, vegetables, oilseed crops, or agroforestry systems, the IFS could help attain food and nutritional security [23,31,32]. Furthermore, understanding the complementary role of different components of the IFS on small and marginal farms is critical to meeting the farm family's food and nutritional needs [2,33,34].

5. Conclusions

The integrated farming system is a potent tool that holds the key to long-term income, employment, livelihood, and nutritional security for small and marginal farmers. Crop + dairy was the most common farming system (68%), followed by crop + dairy + horticulture + goatary. In all of the villages studied, the adoption of improved rice, maize, wheat, and barley cultivars increased yield by 17 to 42% above conventional cultivars. Transplanting of sugarcane (CoPk05191) through the trench paired-row method and sowing of mustard as an intercrop revealed a significant increase in cane yield ranging from 34.69% to 52.55%, as well as system yield due to intercropping of mustard. Technical interventions in three enhanced wheat varieties (PBW 550, PBW 658, and DBW 90) provided farmers with increased returns in terms of grain production and other yield-related characteristics. Nutritional kitchen gardening helped in achieving nutritional security. Successful growing of exotic crops such as broccoli, Chinese cabbage, cherry tomato, kale, parsley, and lettuce resulted in a higher benefit–cost ratio of 3.23 in the enhanced system, up from 2.11 in the existing agricultural method. With the adoption of a multi-tier-based system, the net return improved to about 2.20 lakhs from 0.60 ha while the B:C ratio increased from 2.24 to 3.20. Supplementing the fodder requirement through green fodders such as berseem and oats with improved management practices and proper seed rate resulted in a 27.5% milk yield enhancement. Balanced feeding resulted in an overall per-day boost in milk yield in different communities (1.03 L/day) compared to farmers' practices. According to the findings, farmers' revenue increased by 29% as a result of poultry farming. The study's findings revealed that an IFS method could readily meet a five-member family's annual protein (110–125 kg) and carbohydrate (550 to 575 kg) requirements. Diversification of existing farming systems with changes in crop(s), cropping systems, addition and improvement of livestock components, the horticulture, kitchen garden, primary and secondary processing, and boundary plantations is necessary to improve smallholders' on-farm income in India.

The research on farming systems mostly focused on significant production results for farmers, such as increased yield and revenue. As a result, future studies should look into the links between landholding size and farmer and laborer livelihoods. The IFS produces higher yields but lower absolute amounts of marketable produce, raising concerns about their livelihoods' long-term viability. To attain a sustainable life, small and marginal farm families should investigate both agricultural and non-agricultural sources of income (via value addition). There was just a small investigation on the different types of production and their environmental impacts. The IFS could be used to better identify scale-specific correlations between farm size and environmental impacts by assessing various farm sizes, types of operations, and recycling processes. Future research should further investigate the well-being of laborers, farmers, consumers, and their interaction with farm size and with other social and environmental outcomes.

Author Contributions: Conceptualisation, implementation of the project, and data collection—P.K., A.K.P., A.S.P., R.N., M.S., N.V., P.C.J. and M.P.S. Analysis, writing, and editing—P.K., V.P., A.K.P., A.S.P., R.N., M.S. and N.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Indian Council of Agricultural Research (Farmers' FIRST programme under KVK Scheme), New Delhi, India.

Institutional Review Board Statement: The technical programme of the study was performed in accordance with their relevant guidelines and regulations and was approved by the Zonal Project Management Committee (ZPMC) of Farmers' FIRST headed by Chairman and funding agency. The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of ICAR-Indian Institute of Farming Systems Research, Modipuram and ICAR-Agricultural Technological Application Research Institute (ATARI), Kanpur, UP.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study for participation in survey.

Data Availability Statement: Data will be provided on request.

Acknowledgments: The authors would like to thank the ICAR-Indian Council of Agricultural Research (Farmers' FIRST programme under KVK Scheme), New Delhi, ICAR-Indian Institute of Farming System Research, Modipuram, UP, India and ICAR-Agricultural Technology Application Research Institute, Kanpur, for providing the necessary funding required for conducting the study. The authors are also thankful to, project staff (Scientists, Research Scholars, Field Assistants involved in the study) and participating farmers for their support and valuable inputs during the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Devendra, C.; Thomas, D. Smallholder farming systems in Asia. *Agric. Syst.* **2002**, *71*, 17–25. [CrossRef]
2. Paramesh, V.; Chakurkar, E.B.; Bhagat, T.; Sreekanth, G.B.; Kumar, H.B.C.; Rajkumar, S.; Gokuldas, P.P.; Mahajan, G.R.; Manohara, K.K.; Ravisankar, N. Impact of integrated farming system on residue recycling, nutrient budgeting and soil health. *Indian J. Agric. Sci.* **2021**, *91*, 44–48.
3. Parajuli, R.; Dalgaard, T.; Birkved, M. Can farmers mitigate environmental impacts through combined production of food, fuel and feed? A consequential life cycle assessment of integrated mixed crop-livestock system with a green biorefinery. *Sci. Total Environ.* **2018**, *619–620*, 127–143. [CrossRef] [PubMed]
4. Manjunath, B.L.; Paramesh, V.; Mahajan, G.R.; Das, B.; Reddy, K.V.; Chakurkar, E.B.; Singh, N.P. Sustainability through resource recycling, soil fertility and carbon sequestration from integrated farming systems in west coast India. *Bioscan* **2017**, *12*, 1875–1880.
5. Paramesh, V.; Arunachalam, V.; Nikkhah, A.; Das, B.; Ghnimi, S. Optimization of energy consumption and environmental impacts of arecanut production through coupled data envelopment analysis and life cycle assessment. *J. Clean. Prod.* **2018**, *203*, 674–684. [CrossRef]
6. Gill, M.S.; Singh, J.P.; Gangwar, K.S. Integrated farming system and agriculture sustainability. *Indian J. Agron.* **2009**, *54*, 128–139.
7. Behera, U.K.; France, J. Integrated farming systems and the livelihood security of small and marginal farmers in India and other developing countries. In *Advances in Agronomy*; Elsevier: Amsterdam, The Netherlands, 2016; Volume 138, pp. 235–282, ISBN 0065-2113.
8. Behera, U.K.; Kaechele, H.; France, J. Integrated animal and cropping systems in single and multi-objective frameworks for enhancing the livelihood security of farmers and agricultural sustainability in Northern India. *Anim. Prod. Sci.* **2015**, *55*, 1338–1346. [CrossRef]
9. Jha, S.; Bacon, C.M.; Philpott, S.M.; Rice, R.A.; Méndez, V.E.; Läderach, P. A review of ecosystem services, farmer livelihoods, and value chains in shade coffee agroecosystems. In *Integrating Agriculture, Conservation and Ecotourism: Examples from the Field*; Springer: Dordrecht, The Netherlands, 2011; pp. 141–208.
10. Bell, L.W.; Moore, A.D.; Kirkegaard, J.A. Evolution in crop–livestock integration systems that improve farm productivity and environmental performance in Australia. *Eur. J. Agron.* **2014**, *57*, 10–20. [CrossRef]
11. Behera, U.K.; Jha, K.P.; Mahapatra, I.C. Integrated management of available resources of the small and marginal farmers for generation of income and employment in eastern India. *Crop Res.* **2004**, *27*, 83–89.
12. Rautaray, S.K.; Das, P.C.; Sinhababu, D.P.; Sinhababu, D.P.; Singh, B.N. Increasing farm income through rice-fish based integrated farming system in rainfed lowlands of Assam. *Indian J. Agric. Sci.* **2005**, *75*, 79–82.

13. Kashyap, P.; Kansal, A.; Prusty, A.K.; Singh, J.P. Evaluation of horticulture based IFS models for providing nutritional security to small and marginal farmers of western plain zone of Uttar Pradesh, India. *Int. J. Econ. Plants* **2015**, *2*, 15–17.
14. Bhargavi, B.; Behera, U.K. Securing the livelihood of small and marginal farmers by diversifying farming systems. *Curr. Sci.* **2020**, *119*, 854–860. [CrossRef]
15. Jayanthi, C.; Balusamy, M.; Chinnusamy, C.; Mythili, S. Integrated nutrient supply system of linked components in lowland integrated farming system. *Indian J. Agron.* **2003**, *48*, 41–46.
16. Das, A.; Choudhury, B.U.; Ramkrushna, G.I.; Tripathi, A.K.; Singh, R.K.; Ngachan, S.V.; Patel, D.P.; Layek, J.; Munda, G.C. Multiple use of pond water for enhancing water productivity and livelihood of small and marginal farmers. *Indian J. Hill Farming* **2013**, *26*, 29–36.
17. Surve, U.S.; Patil, E.N.; Shinde, J.B.; Bodake, P.S.; Kadlag, A.D. Evaluation of different integrated farming systems under irrigated situations of Maharashtra. *Indian J. Agron.* **2014**, *59*, 518–526.
18. Hu, L.; Zhang, J.; Ren, W.; Guo, L.; Cheng, Y.; Li, J.; Li, K.; Zhu, Z.; Zhang, J.; Luo, S.; et al. Can the co-cultivation of rice and fish help sustain rice production? *Sci. Rep.* **2016**, *6*, 28728. [CrossRef]
19. Shekinah, D.E.; Sankaran, N. Productivity, profitability and employment generation in integrated farming systems for rainfed vertisols of western zone of Tamil Nadu. *Indian J. Agron.* **2007**, *52*, 275–278.
20. Sujatha, S.; Bhat, R. Resource use and benefits of mixed farming approach in arecanut ecosystem in India. *Agric. Syst.* **2015**, *141*, 126–137.
21. John, J. Homestead farming in Kerala: A multi-faceted land-use system. *Rev. Agrar. Stud.* **2014**, *4*, 80–94.
22. Altieri, M.A. 1980 Fall Armyworm Symposium: Diversification of Corn Agroecosystems as a Means of Regulating Fall Armyworm Populations. *Florida Entomol.* **1980**, *63*, 450–456. [CrossRef]
23. Wezel, A.; Casagrande, M.; Celette, F.; Vian, J.-F.; Ferrer, A.; Peigné, J. Agroecological practices for sustainable agriculture. A review. *Agron. Sustain. Dev.* **2014**, *34*, 1–20. [CrossRef]
24. Elahi, E.; Zhang, H.; Lirong, X.; Khalid, Z.; Xu, H. Understanding cognitive and socio-psychological factors determining farmers' intentions to use improved grassland: Implications of land use policy for sustainable pasture production. *Land Use Policy* **2021**, *102*, 105250. [CrossRef]
25. Elahi, E.; Khalid, Z.; Tauni, M.Z.; Zhang, H.; Lirong, X. Extreme weather events risk to crop-production and the adaptation of innovative management strategies to mitigate the risk: A retrospective survey of rural Punjab, Pakistan. *Technovation* **2021**, 102255. [CrossRef]
26. Elahi, E.; Abid, M.; Zhang, L.; Ul Haq, S.; Sahito, J.G.M. Agricultural advisory and financial services; farm level access, outreach and impact in a mixed cropping district of Punjab, Pakistan. *Land Use Policy* **2018**, *71*, 249–260. [CrossRef]
27. Behera, U.K.; Amjath, B.; Kaechele, H.; France, J. Energy self-sufficient sustainable integrated farming systems for livelihood security under a changing climate scenario in an Indian context: A case-study approach. *CAB Rev.* **2015**, *10*, 1–11. [CrossRef]
28. Chand, R. *Doubling Farmers' Income Rationale, Srategy, Prospects and Action Plan*; Niti Ayog National Institution for Transforming India: New Delhi, India, 2017.
29. Franzluebbers, A.J. Integrated crop–livestock systems in the southeastern USA. *Agron. J.* **2007**, *99*, 361–372. [CrossRef]
30. Reddy, D.V.S.; Biddappa, C.C. Coconut based cropping/farming systems in India. *J. Plant. Crop.* **2000**, *28*, 1–18.
31. Altieri, M.A.; Funes-Monzote, F.R.; Petersen, P. Agroecologically efficient agricultural systems for smallholder farmers: Contributions to food sovereignty. *Agron. Sustain. Dev.* **2012**, *32*, 1–13. [CrossRef]
32. Paramesh, V.; Parajuli, R.; Chakurkar, E.B.; Sreekanth, G.B.; Kumar, H.B.C.; Gokuldas, P.P.; Mahajan, G.R.; Manohara, K.K.; Viswanatha, R.K.; Ravisankar, N. Sustainability, energy budgeting, and life cycle assessment of crop-dairy-fish-poultry mixed farming system for coastal lowlands under humid tropic condition of India. *Energy* **2019**, *188*, 116101. [CrossRef]
33. Ramanathan, K.; Sangeeviraman, V.; Chandrahasan, P.; Chaudhary, B.N.; Ramachandra, S.S. Integration of fish culture and poultry rearing in transplanted rice for nutritional security in smallholder farms. *Sci. Rep.* **2020**, *10*, 10566. [CrossRef]
34. Tittonell, P. Livelihood strategies, resilience and transformability in African agroecosystems. *Agric. Syst.* **2014**, *126*, 3–14. [CrossRef]