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Development of a successful IFS model for livelihood sustenance of small households of Uttar Pradesh

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ABSTRACT

An experiment was conducted at research farm of ICAR-Indian Institute of Farming Systems Research, Modipuram, Uttar Pradesh during 2016–17 to 2018–19 to develop integrated farming systems (IFS) model which has diverse commodities/components, viz. crops (1.04 ha), dairy (2 Murrah buffaloes and 1 Gir cow), horticulture (0.22 ha), fishery (0.1 ha), mushroom (0.02 ha), poultry (10 birds), vermicompost unit (0.02 ha), kitchen garden (0.002 ha) and boundary plantation with fruit trees (200 m in running length). The total productivity of all cropping sequences surged up to 124.96 tonnes/1.04 ha/year when yields of the whole system were transformed into sugarcane equivalent yield (SEY). Gross and net returns from crop components of IFS model were obtained in the extent of ₹282×10^3/1.04 ha/year and ₹199×10^3/1.04 ha/year and B:C ratio 3.37. The overall farm product of all components in the form of SEY was 246.95 tonnes/1.5 ha/year and 164.63 tonnes/ha/year. Similarly, gross return from involving all components of IFS model was erected at ₹777×10^3/1.5 ha/year and ₹518×10^3/ha/year and net return ₹491×10^3/1.5 ha/year and ₹328 $\times 10^3$/ha/year with B:C ratio of 3.37 for the entire IFS model. Given total availability of farm-based waste (19950 kg/year) was recycled within the system in the form of compost, vermicompost (VC), crops residues, litter falls, weeds and green manure (GM). As regards to livelihood security, the IFS approach had adapted to meet the homegrown family needs of cereals, pulses, oils, fruits, milk, meat, eggs and vegetables.

Keywords: Integrated farming system, Livelihood development, Nutritional security, Resource recycling

The integrated farming system (IFS) approach is one of the most powerful method for enhancing productivity, profitability, nutritional security and sustainability of the farm, particularly in small and marginal households of India, which comprise 87% of the total farmers. Crop and livestock cannot be separated for small agriculture holdings in Indian conditions to support livelihood for 120 million marginal and small farm holdings which revolve around this system (Meena 2019). The integrated farming system (IFS) approach along with yield increase, augments nutritional security by the way of producing adequate and customary production of commodities like cereals, pulses, vegetables, oilseeds, fruits, mushroom, eggs and fish meat for human beings round the year green and dry fodders for the animal component. This approach also leads to improving the energy use efficiency at the farm level and helps in maximization of exploitation of synergies. The developed approach has diversified in nature and safeguards to counter climatic risks and slash the production cost by applying farm-originated by-products thereby reducing market inputs by 30–40%. The developed IFS model should be socially acceptable, eco-friendly and economically viable as reported by Gill *et al*. (2009). Therefore, a location-specific integrated farming system was developed to cater to the needs of food, fodder, feed, nutritional security, sustainable profitability, ecological security along with employment generation opportunities. There is a need to develop an agro ecology-based integrated farming system that would augment soil health, ecological balance, employment generation, and fertilizer cost reduction through recycling farm by-products. Keeping all the above facts in view, the present study was carried out on developing a profitable and sustainable model for the small landholders of western plains region of Uttar Pradesh, India.

MATERIALS AND METHODS

An integrated farming system (IFS) model was conducted at ICAR-Indian Institute of Farming Systems

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Research, Modipuram, Uttar Pradesh, for three consecutive years 2016–17, 2017–18 and 2018–19 to augment the productivity, profitability, enhance soil health, food security, nutritional security, livestock nutrition, neutralize GHG emission from the different IFS modules, employment generation, resource recycling and nutrients budgeting for the Western Plain Zone of Uttar Pradesh on 1.5 ha of land under irrigated agro-ecosystem. The crop component of IFS model was comprised of 6 different cropping sequences, viz. Sugarcane (*Saccharum officinarum*)-ratoon-wheat (*Triticum aestivum*); Rice (*Oryza sativa*)-wheat (*Triticum aestivum*)–dhaincha (*Sesbania sesban*); Pigeonpea (*Cajanus cajan*) + maize (*Zea mays*) in 1:2 ratio–chickpea (*Cicer arietinum*)–okra (*Abelmoschus esculentus*); Maize (*Zea mays*)-berseem (*Trifolium alexandrinum*)-blackgram (*Vigna mungo*); Sorghum (*Sorghum bicolor*)-mustard (*Brassica juncea*)-green gram (*Vigna radiate*); Napier+ cowpea/Napier + berseem + subabool on 1.04 ha of land, milch animals, viz. 2 Murrah buffaloes and 1 Gir cow, horticulture module consisted with a mix of mango, guava, peach and pear fruit plants on 0.22 ha in which vegetables and fodder crops were grown as intercrops. The freshwater fish pond was made on 0.1 ha, mushroom unit (12 iron racks of size 22″×15″) and also a small covered roof area with 6 racks prepared from local materials, vermicompost unit (0.001 ha), 10 poultry birds (Gramapriya) was reared in 5'×4' size of hut, boundary plantation (BP) by fruit trees was got done at two sides of the experimental plots and a small area for kitchen garden (20 m^2) was kept to grow seasonal vegetables. The study area is located between 26' 4° and 30' 21°N latitudes, and 77' 3° and 80' 4°E longitudes and 237 m amsl. The average rainfall (650 mm) is highly irregular, uncertain, and unevenly distributed throughout the year. Out of which about 80% of total rainfall was received from June to September. Long dry spells were usually experienced during the winter seasons. However, small amounts of precipitation was received during dry spells of winter months to provide a boost to winter (*rabi)* season crops. The soil under different cropping sequences was found as clay loam with medium available N (320 kg/ha), high available P (46 kg /ha) and medium available K (126 kg/ha). The soil had *p*H of 7.8 with micronutrients, viz. Mn (7.0 mg/kg DTPA), Zn (1.5 mg/kg DTPA), Fe (15.0 mg/kg DTPA), Cu (2.5 mg/kg DTPA) and microbial biomass carbon (380 mg/g soil), respectively. The organic carbon (OC) content was 0.45% in the soil surface depth of 0–30 cm at the initial time of experimentation. Six cropping sequences were followed because of supply of different commodities to farm families and dairy animals round the year for fulfilling the demand of cereals, pulses, legumes, oilseed, vegetables, fodder and cash crop etc. The dairy animals were reared on green and dry fodders and local made concentrate ration available at the farm. The freshwater fish pond consisted of a mix of Indian as well as exotic fish species, viz. Rohu (*Labeo rohita*), Catla (*Labeo catla*), Mrigal carp (*Cirrhinus cirrhosus*), Common carp *(Cyprinus carpio)*, Silver carp (*Hypophthalmichthys molitrix*) and Grass carp (*Ctenopharyngodon idella*). The fish species were fed with rice barn, mustard cake, tree leaves, and sometimes green fodder (berseem and cowpea). The pond water *p*H was maintained as neutral to acidic. The feeds to fishes were given @2% of their body weight. The fishes were harvested twice a year. Mushroom cultivation was done through using three different ferns, viz. Oyster mushroom (*Pleurotus ostreatus*), Milky white (*Calocybe indica*) and Baton mushroom (*Agaricus bisporus*) grown according to their temperatures requirement under low-cost hut. The animal by-products as such farm yard manure (FYM) and crop-based wastes were used for the preparation of vermicomposting. For the preparation of vermicompost, the "*Jai Gopal"* species of earthworm was used to convert the raw materials into vermicompost. The economic yields of all components were converted into sugarcane equivalent yield (SEY) and further these outputs were analyzed statistically based on prevailing market prices.

RESULTS AND DISCUSSION

The productivity of cropping sequences in the IFS model: The results of study showed that land allocation (%) under each cropping sequence was divergent due to household demands and varied market worth of farm produces. However, sugarcane-ratoon-wheat cropping sequence had a higher proportion of land (3500 m^2) than other cropping sequences like rice-wheat-dhaincha (1800 m^2), pigeonpea + maize (1:2)-chickpea–okra (1800 m^2), maize-berseem-blackgram (1800 m^2), Sorghum (F)-mustard-green gram (1100 m^2) and Napier + cowpea/Napier + berseem + subabool in 400 m^2 area, respectively. Thus, a total of 1.04 ha (69.33%) area of IFS model was kept under crop module throughout the year and the smaller area was put under the fodder crops component (3.85%).

The yield potential of different cropping sequences in integrated farming system (IFS) model was analyzed. The results of different cropping sequences showed that sugarcane equivalent yield (SEY) was increased utmost with the sugarcane-ratoon-wheat cropping sequence (36.63 tonnes from the area of 0.35 ha) on pooled data basis (2016–19). The next best cropping sequence was rice-wheat-dhaincha in terms of SEY (25.85 tonnes from 0.18 ha of area) and minimum SEY was noticed under fodder based cropping system (Napier + cowpea/Napier + berseem + subabool) i.e. 4.13 tonnes from 0.04 ha. The yield disparity among the different cropping sequences were varied which might be due to disproportionate allocation of land, predominant prices in the market for the different crops and production from each crop in the system. Similar, results were also testified by Rimbai *et al*. (2021). A similar trend was also pragmatic in the case of economics as gross return (₹114×10^3/1.04 ha) and net return (₹82×10^3/1.04 ha), when sugarcane-ratoon-wheat cropping sequence was undertaken. The highest system B:C ratio (3.56) was verified with the same sequence. In the present study, crop component alone contributed highest sugarcane equivalent yield (110.95 tonnes/1.04 ha/year) and was followed by dairy component (70.61 tonnes/ha/year), horticulture (42.87 tonnes/ha/year) and fishery (11.15 tonnes/

ha/year) (Table 1). While the productivity of complete IFS model by way of sugarcane equivalent yield was recorded at tune of 246.95 tonnes/1.5 ha/year and 164.16 tonnes/ha/year. Apart from crop component in IFS model, other vibrant complementary and supplementary enterprises had also significantly contributed to total productivity. Different IFS components were appraised to assess the relative share of 45, 29, 17 and 5% from crops, dairy, horticulture and fishery. In the IFS model, 96% returns comes from the first four components like crop, dairy, horticulture and fishery and remaining 4% of return was contributed by other remaining enterprises such as mushroom, poultry, kitchen garden and boundary plantation. Our results are in confirmation with the findings of Kumar *et al.* (2012). Among the components, highest gross and net returns were achieved from the crop (₹356×10^3/year and ₹238×10^3 /year) followed by dairy (₹238×10^3/year and ₹133×10^3/year), horticulture (₹117×10^3/year and ₹68×10^3/year), fishery (₹28×10^3/year) and poultry (₹17×10^3/year), respectively. Thus, involving all components of IFS, the net profit increase of entire integrated farming system was of ₹491×10^3/year. Adoption of various components of IFS model leads to stability in farm income (Khobragade *et al.* 2021). The inclusion of crop, dairy, horticulture and fishery enterprises together resulted in increase in mean gross returns by 45.82, 30.63, 15.06 and 3.60%, respectively. Similarly, net profits from the integrated farming system were also boosted from crop, dairy, horticulture and fishery components in the tune of 48.47, 27.08, 13.85 and 3.46%, respectively. The cost of production of different components of integrated farming system model had a wide range from crop module (₹118×10^3/year) to boundary plantation module (₹4×10^3). However, highest cost was incurred in the case of crop production (₹118×10^3 /year) followed by dairy component (₹107×10^3/year). Such increase in cost of production of cropping sequences might be due to high need of inputs. Similarly, B: C ratio under different IFS components was dissimilar and the highest benefit: cost ratio was fetched from the poultry module (5.5) then followed by mushroom module (3.66) and crop (3.01). The average highest net income per day was from crop component (₹652) followed by dairy component (₹364), horticulture (₹186) and fishery (₹47), respectively. Thus, sum of daily net income from this developed integrated farming was of ₹1345/1.5 ha and ₹899/ha. These results are in accordance with the findings of Reddy *et al.* (2018).

Nutrient Budgeting: The farming system approach had made the system holistic that meets all around 56.74% of the total nutrients (NPK) requirement from the different by-products, weeds, crop residue and mushroom spent of integrated farming system components. The average quantity of nutrients recycled from farm-based wastes of various components (2016–19) accented for 19950 kg/year of worth ₹15052 (Table 2). The total by-products produced of 19950 kg/year which turns into 282.55 kg N, 126.31 kg P and 229.43 kg K. This saved total 56.74% of NPK requirements by recycling of farm waste in the form of vermicompost, farmyard manure (FYM), mushroom spent, dry tree leaves, weeds, crop residues etc within the system, hence it was found very profitable through declined cost on chemical fertilizers and improves the soil quality by promoting microbial activities. Similarly, fish pond water and silt have saved the expenditures incurred on the purchasing of synthetic chemical inputs. The dhaincha

Table 1 System productivity, economics and employment generation of different components of IFS model developed on 1.5 ha land at IIFSR, Modipuram (mean data of 3 years)

Component of IFS Model	Total farm production (SEY tonnes/year)	Gross return (×10^3 ₹/year)	Net return (×10^3₹/year)	Cost of production (×10^3 ₹/year)	B:C ratio	Income generated per day from IFS model (₹/1.5 ha)	Component-wise man-days generated/year
Crops (1.04 ha) cereals, pulses, oilseed, sugarcane, vegetables and green fodder	110.95	356	238	118	3.01	652	251
Dairy (2 buffaloes + 1cow) + VC (0.02ha)	70.61	238	133	107	2.22	364	204
Horticulture (fruit trees) (0.22 ha)	42.87	117	68	48	2.43	186	153
Fish pond (0.1 ha)	11.15	28	17	12	2.33	47	85
Poultry (10 birds)	3.11	11	8	2	5.5	22	27
Mushroom (0.02 ha)	3.03	11	8	3	3.66	22	26
Kitchen garden (20 m^2)	2.22	8	4	4	2.00	11	22
Boundary plantation (200 m running length)	3.22	9	7	4	2.25	19	20
Total IFS area (1.5 ha)	246.95	777	491	298	2.60	1345	787
Per hectare basis values	164.63	518	328	199	2.60	899	525

crop was grown between rice and wheat crops that contain nutrients in 3.50:0.60:1.20 of NPK on a dry weight basis. Thus, the nutrient balance sheet reflected that animals and crop components-based waste in IFS model supplied approximately 54.33% N, 47.66% P and 67.47% K and the overall 56.74% of NPK nutrients can be saved within the system (Table 2). Recycling of crop residues has enormous potential in improving of soil health as reported by Kumar *et al*. (2012). The total economic value of farm waste is of ₹15052/year, when all by-products (19950 kg/year) of different components were added into the soil resulting in saving of chemical fertilizers for crop and horticultural plants. The economic value of nutrients was obtained maximum of ₹6738/year through addition of vermicompost which is highly consistent with plant nutrients (2.1:1.5:1.4% of NPK/100 kg) on a dry weight basis as compared to other farm wastes. The most notable advantage of utilizing by-products at the farm level for recycling is that it will certainly reduce the production cost and ultimately improve the farm income considerably (Desai *et al.* 2013).

Food and nutritional security: Overall monitoring and livelihood analyses of IFS model revealed that by eliminating constraints which were accountable for the yield gaps and optimum integration of farm eco-friendly enterprises consequences saved 77.31% cereals, 48.71% oilseed, 75.57% pulses, and 97.90% sugar, respectively. Similarly, dairy component of IFS model produced 58.89% milk as surplus for selling in the market (Fig 1 a, b). Vermicompost prepared from animals excreta and crop residues was entirely used in the crops and fruit production. The third furthermost component of IFS model is horticulture, in which fruit and vegetables were twisted more than household obligation (92.69 and 92.62%). Therefore, household supplies of these commodities have been met out through other enterprises of the model. Fishes produced in pond can be used in diet of farm households and at the same time, these can also be sold in nearby market in order to earn some money for the purchasing of other essential commodities which are obligatory for the households. Hence, 86.66% fishes were sold in the market and rest were used in farm family food. Mushroom enterprise of IFS model has an axillary potential because mustard and paddy straws were recycled for mushroom production. They were traded in market at higher rates and remains were used by mushroom growers because they were a good source of proteins. However, 100% (172 kg/year) of extra mushroom was sold in market

Table 2 Nutrient budgeting through recycling of farm based by-products in IFS Model

By-products and NPK nutrient content (%)	Available quantity of farm by-products (kg)	Approx. N released (kg)	Approx. P released (kg)	Approx. K released (kg)	Total NPK released (kg)	Economic value of saved nutrients (₹)
Sugarcane dry leaves (0.4:0.19:1.29)	730	4.48	2.15	12.85	19.48	530
Mustard straw (0.42:0.08:0.88)	630	3.05	1.25	6.15	10.45	272
Chickpea straw (1.19:0.06:1.25)	2740	32.41	1.45	35.41	69.27	1539
Green gram straw (1.12:0.27:1.00)	590	6.17	1.06	6.26	13.49	306
Blackgram straw (0.85:0.18:0.53)	590	5.89	0.45	2.34	8.68	159
Pigeonpea dry leaves (1.28:0.37:1.62)	755	10.01	3.06	13.12	26.19	637
Dhaincha (3.50:0.60:1.20)	1260	38.02	6.41	14.58	59.01	1139
Paddy straw (0.36:0.08:0.71)	1480	4.59	0.87	6.74	12.2	295
Dry tree leaves (1.20: 0.58: 0.42	160	1.9	1.8	0.80	4.5	112
Farm yard manure (0.6:0.4:0.5)	4450	36.50	18.20	22.45	77.15	1789
Vermicompost (2.1:1.5:1.4)	5500	115.0	82.0	77.61	274.61	6738
Poultry manure (1.1:0.8:0.5)	265	3.04	2.181	1.35	6.571	157
Fish pond (0.1ha), nutrient supply through water and silt	-	4.4	2.04	5.4	11.84	294
	-	9.09	0.58	22.34	32.01	823
Mushroom spent compost (0.8:0.3:0.3)	800	8.0	2.81	2.09	12.9	262
Nutrients recycle	19950	282.55	126.31	229.49	638.35	15052
Nutrients requirement for crops and fruit plants in IFS Model		520	265	340	1125	22102
Nutrient balance sheet		-237.45	-138.69	-110.51	-486.65	-7050

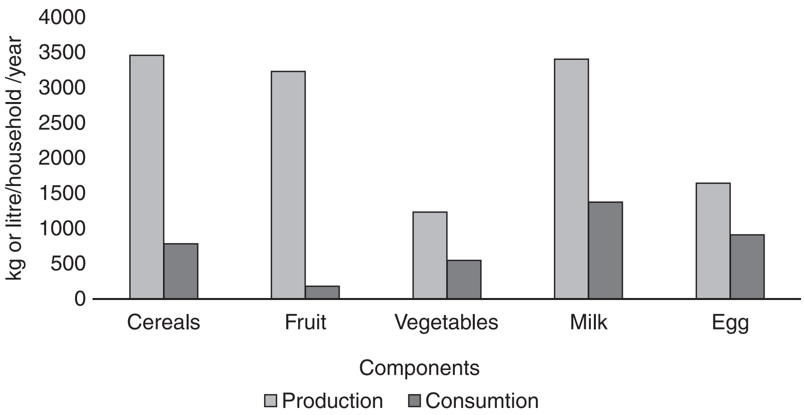

Fig 1 (a) Production and consumption of farm commodities under IFS model.

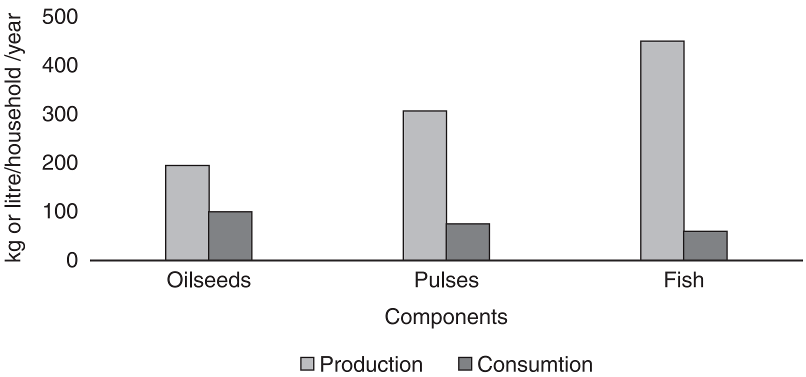

Fig 1 (b) Production and consumption of farm commodities under IFS model.

to gain profit. Poultry eggs are good source of proteins, especially for the poor families. Thus, extra 55.25% of eggs were sold in the market and remains 44.75% of eggs were used by households. Kitchen garden vegetables (100%) were purely organic and in lesser quantity. Thus, farm produces were in spare quantity for the selling in local market after leftover from the household intake. Besides, some enterprises are supplementary in nature because they are enormously depended upon other enterprises for their inputs supply (70–80%) as otherwise these inputs will go waste on farm itself. Crop-based foodstuffs were ample for consumption by farm family. The IFS model was found potential to improve the farmers livelihood by producing a variety of produce, on-farm resource recycling and enhancing the farmers' income (Bussa and Behera 2020). Thus, huge capital could be saved which was spent on paying for inputs purchased from the outside of model. In nutshell dairy, fishery, mushroom, poultry, kitchen garden, vermicompost and boundary plantation had been produced plenty in quantity for deployment. Kumar *et al.* (2012) emphasized that livelihood of small farm households can be achieved through adoption of developed IFS model in Bihar. Dasgupta *et al.* (2015) highlighted that integrated farming system also enhances farmers' socio-ecological capacities to sustain livelihoods.

Employment generation: The IFS has created more working hours in the system owing to more enterprises than the cropping system alone. The model had generated 787 man-days/1.5 ha/year and 525 man-days/ha/year. The IFS model has provided employment opportunities throughout the year due to involvement of more manpower than used in one module of the system. Diversification of farming including multifarious activities of different enterprises included in the IFS model paved to set of employment opportunities and intact households with farming and their family members were always engaged throughout the year in this business. Rathore *et al.* (2019) also reported that integrated farming systems under arid and semi regions increased employment opportunities than adopted single farming system. Thus, IFS model helped in solving the problem of unemployment of farm families. The total man-days required for the crop component was 251 man-days /ha/ year followed by dairy (155 man-days/year) and horticulture (153 man-days/year) on the mean data of three years (2016–19).

The developed IFS model shall promote sustainable agriculture, meagre environmentally feasible and more profitability than existing farming systems. It will also be helpful in employment generation through additional manpower engaged in the various activities of components. Production of cereals, pulses, oil, fruits, vegetables, milk, eggs and mushroom shall be regulated throughout year supply to households and augments nutritional security and trails regular income from different enterprises and synergistic interaction between components of the IFS model through use of by-products. Thus, we can reduce the competition for available limited resources in higher production and finally enhance resource use efficiency through recycling. Integration of components is often employed as a livelihood strategy for the small landholders in the western plain zone of Uttar Pradesh.

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