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Sustainable integrated farming system model for small farm holders of Uttar Pradesh

L R MEENA[1]*, S A KOCHEWAD[2], A K PRUSTY[1], CHANDRA BHANU[1], SANJEEV KUMAR[3], A L MEENA[1], LALIT KRISHAN MEENA[4], K J RAGHAVENDRA[1], DEVENDRA KUMAR[1], N SUBASH[1] and S P SINGH[1]

ICAR-Indian Institute of Farming Systems Research, Modipuram, Uttar Pradesh 250 110, India

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ABSTRACT

The developed IFS model is having different coich comprise of arable crops (1.04 ha), horticulture crops (0.22 ha), fishery (0.10 ha), mushroom (0.02 ha), poultry (10 birds), vermicompost (0.02 ha) and kitchen garden (20 m^2). The overall productivity of model was 174.04 tonnes/ha/year in terms of sugarcane equivalent yield (SEY) during the representative years (2013–18). The farmyard manure (FYM) together with vermicompost and other farm-based by-products saved the nutrients by 338.71 kg N, 124.60 kg P, 306.22 kg K and 769.56 kg NPK (kg/year). The entire annual man-days generated were 441, 465, 473, 467 and 470 in various components during 2013–14, 2014–15, 2015–16, 2016–17 and 2017–18, respectively. However, maximum man-days were generated by crop component (209/year) followed by dairy component (152/year) of the IFS model. The gross return/year/ha obtained was ₹6.12×10^3/ha and net returns of (₹3.74×10^3/ha) with per day income of ₹1025 from 1.5 ha of the IFS model under irrigated agro-ecosystem. Inclusion of horticulture components and boundary plantations in the IFS model also tend to reduce GHG emissions.

Keywords: Carbon footprint, Complementary interaction, Food security, Resource recycling

Integrated farming systems (IFS) approach is one of the most powerful tools for enhancing productivity, profitability, nutritional security, livelihood improvement and sustainability of the farm household, particularly for small and marginal farming communities. These small and marginal farming communities presently constitute around 87% of the total farm households in the country (Panwar *et al.* 2018). In Indian situation, crop + dairy is the prime farming system and it is the means of livelihood for 120 million farm holders. With unabated shrinkage of landholding size, income from crop activity alone is becoming insufficient to sustain farm families' requirements (Behera and France 2016). Therefore, farmers' income and their food security need to be augmented by the adoption of complementary/supplementary enterprises. The IFS approach not only ensures higher productivity of the system but also enhances profitability and ascertains household food supply and fodder demands along with nutritional security by the means of producing enough and customary production of various commodities for the farm family and round the year fodders for the dairy component (Manjunatha *et al.* 2014). Moreover, IFS approach develops the models which are socially acceptable, environmentally hygienic and economically viable as reported by (Gupta *et al.* 2018). Precise recycling of farm wastes in the system to reduce the cost of production are the primary factors of the research plan. This approach due to its diversified nature acts as a safeguard to farmers against changing climate to bring down the yield gaps through efficient resource utilization and can increase yield by 30–40% in general in western Uttar Pradesh (Panwar *et al.* 2016). Therefore, there is a need to improve the agro-ecology of the region where sugarcane-ratoon-wheat system is dominant to be examined. Keeping in view all the above facts, the present study was conducted to develop a profitable and sustainable model for the small and marginal landholders of the western plains of Uttar Pradesh.

MATERIALS AND METHODS

The present study was carried out at ICAR-Indian Institute of Farming Systems Research, Modipuram, Uttar Pradesh during 2013–18 to expand a sustainable IFS model for North Western Plain Zone (NWPZ, 26'4° and 30'21°N latitude, 77' 3° and 80'4°E longitude and 237 m amsl). The IFS model was developed on 1.5 ha of land under irrigated

[1]ICAR-Institute of Farming Systems Research, Modipuram, Uttar Pradesh; [2]ICAR-National Institute of Abiotic Stress Management, Baramati, Maharashtra [3]ICAR-National Dairy Research Institute, Karnal, Haryana; [4]ICAR-Directorate Of Rapeseed Mustard Research, Bharatpur, Rajasthan. *Corresponding author email: laxman.meena@icar.gov.in

conditions. The average annual rainfall is 650 mm which is highly irregular, uncertain and unevenly distributed. About 80% of the total precipitation is received between June–September. Long dry spells are usually experienced during winter (*rabi*) seasons. However, small amounts of precipitation were received during dry spells of winters which boost growth of *rabi* crops. The experimental site soil was clay loam in texture with *p*H 7.8 and low in organic carbon content (0.40%) and the EC was 0.8 dS/m. The available nitrogen was medium (320 kg/ha), high in available phosphorus (46 kg/ha) and medium in available potash (125 kg/ha) in the soil. Six combinations of cropping sequences were utilized in this model to supply different commodities to farm families and livestock throughout the year. The different components of the model are dependent upon complementary and supplementary interactions with each other. The dairy animals were reared on available green and dry fodders and locally prepared concentration ration from the farm. Crop-based residues and animal-based by-products, viz. cow dung and urine were used for the creation of vermi-compost in which the indigenous earthworm species strain (*Jai Gopal*) was used. Under horticulture component (0.22 ha) multipurpose fruit plants were planted. In the fish pond, both Indian and exotic species (Rohu, Catla, Mrigal, Common carp, Silver carp, and Grass carp) fishes were reared. The fish species were fed with rice bran and mustard cake, sometimes tree leaves and green fodder (Berseem and Cowpea) were also offered. The pond water *p*H was maintained neutral to acidic. The fish feeds were given @2% of their body weight and were harvested twice a year. Mushroom cultivation was done using three different ferns (oyster mushroom, milky white, and button mushroom) according to their temperature adaptability under low-cost prepared hut. Boundary plantation was done across all field boundaries and a small kitchen garden of size 20 m^2 was developed. All the yield values of different components were converted into sugarcane equivalent yield and economics were calculated based on prevailing market prices of the inputs and outputs (Table 1).

RESULTS AND DISCUSSION

Crop component productivity in the IFS model: The IFS embodies multiple crops like cereals, pulses, oilseed, vegetables and sugarcane in the different cropping sequences under irrigated agro-ecosystem in the western plain zone of Uttar Pradesh. On the other side only predominant crops and cropping sequences were chosen in the model owing to uphold productivity, profitability, and sustainability of crop component. For this purpose, in predominant cropping sequences, diversification was the main aim to grow versatile crops for achieving household and market demands from the planned model. The sugarcane equivalent yield of different crops varied due to variation in the yield potential of individual crops and allocation of variable landholding size under each cropping sequence given the requirement of diverse commodities. However, the sugarcane-based cropping sequence (sugarcane-ratoon-wheat) had higher sugarcane equivalent yield (26.83 tonnes in 3500 m^2 area) followed by rice-wheat-sesbania system (20.89 tonnes in 1800 m^2 area). The collective productivity of all cropping

Table 1 Details of various components of IFS model (1.5 ha)

Component	Area (ha)/no.	Treatment details
Cropping sequence	1.04	CS1: Sugarcane-Ratoon-Wheat (0.35 ha) CS2: Rice-Wheat-Sesbania (0.18 ha) CS3: Pigeon pea + Maize (1:2)-Chickpea-Okra (0.18 ha) CS4: Maize-Berseem-Black gram (0.18 ha) CS5: Sorghum-Mustard-Moong bean (0.11 ha) CS6: Napier + Cowpea/Berseem + subabool (0.04 ha)
Dairy	2 Buffaloes and 1 Cow	Murrah breed of buffalo (*Bubalus bubalis*) Gir breed of Cow (*Bos taurus*)
Horticulture	0.22	Mango (*Mangifera indica*), Guava (*Psidium guajava*), Pear (*Pyrus communis*), Peach (*Prunus persica*) and Karoda (*Carissa carandas*)
Fish pond	0.10	Rohu fish (*Labeo rohita*), Catla fish (*Labeo catla*), Mrigal fish (*Cirrhinus cirrhosus*), Common carp (*Cyprinus carpia*), Grass carp (*Ctenopharygodon idella*) and Silver carp (*Hypophthalmichthys molitrix*)
Mushroom	0.02	Button mushroom (*Agaricus bisporus*), Milky mushroom (*Calocybe indica*), Oyster mushroom (*Pleurotus* spp.)
Poultry	10 birds	Poultry variety, Gramapriya
Kitchen garden	0.002	Green vegetables, leafy vegetables
Vermicompost	0.02	Indigenous earthworm species strain (*Jai Gopal*)
Boundary plantation	200 m running length	Jackfruit (*Artocarpus heterophyllus*), Bael (*Aegle marmelos* L.), Aonla (*Emblica officinalis*), Jammun (*Syzygium cumini* L.), Lemon (*Citrus limon* L)
Total	1.5	

systems surged up to 93.93 tonnes from 10400 m^2 area of IFS model which contributed 36.07% of the total model productivity. The highest gross and net returns were fetched with sugarcane-ratoon-wheat cropping sequence (₹123×10^3/year and ₹72×10^3/year) with B:C ratio of 3.24 from 3500 m^2 area) followed by pigeon pea + maize (1:2)-chickpea-okra (₹100×10^3/year and ₹66×10^3/year from 1800 m^2 area) cropping sequence along with B:C ratio 2.93 based on 5 years pooled data (Table 2). Similar results were also reported by Mahapatra and Behera (2011) from Odisha that mono-crop of rice is less profitable than diversified cropping system because multiple crops in the system had a synergistic effect on each other and compensate for nutrients requirement and reduce environmental risks when these are grown at the same piece of land.

Productivity of the IFS model: The results of studies exhibited that component-wise overall average farm production was varied after a range of values were brought together and converted into sugarcane equivalent yield (SEY tonnes/year). However, crop component alone had contributed the highest production (SEY 99.93 tonnes/year) followed by dairy unit (SEY 61.80 tonnes/year), horticulture (SEY 56.44 tonnes/year), fishery (SEY 20.43 tonnes/year), poultry (SEY 5.24 tonnes/year), mushroom (SEY 6.92 tonnes/year), kitchen garden (SEY 2.54 tonnes/year), boundary plantation (SEY 4.44 tonnes/year) and vermi-compost (SEY 8.66 tonnes/year). The total productivity of entire farming system model was 174.04 SEY tonnes/ha/year (Supplementary Table 1).

Employment generation: Diversified agriculture including multifarious activities of different enterprises were included in the IFS model which provide a lot of opportunities for employment generation and keeps farmers and their family members engaged throughout the year and as such it helps in resolving joblessness problem of the farmers in the western part of the UP mainly for rural educated youths. The total annual man-days were generated out of various components varied from 21 (kitchen garden) to 209 (crop component). Maximum man-days were generated by crop component (209/year from (1.04 ha land) followed by dairy component (152/year), horticulture (111/year), fisheries (64/year), poultry (46/year), mushroom (38/year), respectively (Supplementary Table 1). The man-days required for the production of crops alone was 209/year under IFS. This might be due to IFS is based on crop and it requires more man-days as compared to other components of the model. The whole IFS model has generated 695 man-days from 1.5 ha and on the hectare basis, it was 463 man-days/annually on average data of 5 years (Ansari *et al.* 2014, Kabuei and Kllevis 2014).

Profitability of the IFS Model: The different complementary and supplementary enterprises significantly contributed to total productivity and an increase in the net profit of the system was observed. These results are in conformity with the findings of Kumar *et al.* (2018). The data after 5th year indicated that adoption of integrated farming with given components has reduced the inputs purchase and increased overall average gross return (₹612×10^3/1.5 ha) and net returns (₹374×10^3/1.5 ha) (Fig 1). Among the different integrated components of IFS model, crop component had registered highest gross income (₹380×10^3/1.04 ha) and net return (₹244×10^3/1.04 ha) under assured irrigation situation followed by dairy and horticulture components. The model also yielded average the B:C ratio of 2.52, indicating very

Table 2 Comparative productivity and profitability of different cropping sequences in IFS Model (1.04 ha)

Cropping sequence	Land allocation under different cropping sequences in (m^2) and per cent area	SEY* (tonnes/year)						Gross return (₹×10^3/year)	Net return (₹×10^3/year)	B:C ratio
		2013–14	2014–15	2015–16	2017–18	2017–18	Mean	Mean over 5 years		
Sugarcane-Ratoon-Wheat	3500 (33.65%)	24.75	26.83	27.59	28.26	26.82	26.83	123	72	3.24
Rice-Wheat- Sesbania (GM)	1800 (17.31%)	16.94	20.61	23.68	20.86	22.39	20.89	58	43	2.72
Pigeon pea + Maize (1:2) – Chickpea-Okra	1800 (17.31%)	12.46	15.16	19.13	17.46	19.06	16.65	100	66	2.93
Maize-Berseem-Black gram	1800 (17.31%)	10.45	11.65	15.55	13.75	15.64	13.41	50	32	2.02
Sorghum (F)- Mustard-Moong bean	1100 (10.58%)	9.63	10.54	12.64	10.07	13.45	11.27	32	21	2.13
Napier + Cowpea/ Napier + Berseem + Subabul)	400 (4.0%)	3.42	4.43	5.41	5.10	5.44	4.76	17	10	2.06
LSD (P=0.05)		3.52	3.84	4.08	3.43	2.86	3.57			
Total	10400 (100%)	77.65	89.82	104.00	95.40	102.80	93.93	380	244	3.02

*SEY, Sugarcane equivalent yield (tonnes/year).

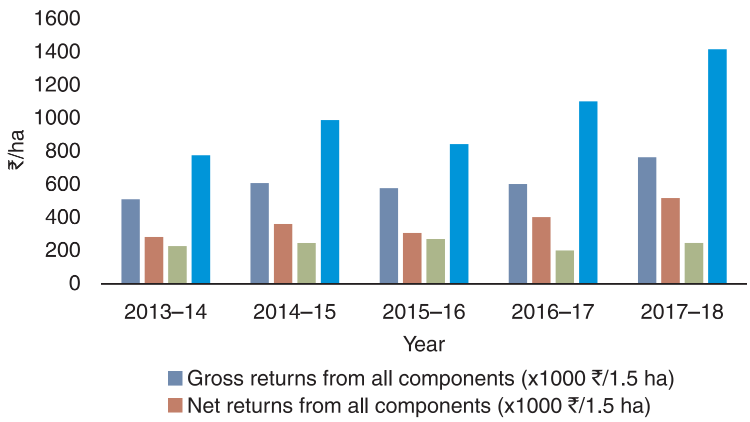

Fig 1 Economic analysis of the integrated farming system in the western plain zone of Uttar Pradesh.

profitable returns from investment. Through this intensive land utilization the model has earned per day income of ₹1025 from the 1.5 ha IFS.

Food security and Livelihood improvement: Overall monitoring and livelihood analyses of the IFS model (Table 3) revealed that by removing constraints which were responsible for yield gaps and optimum integration of farm and eco-friendly enterprises in the existing on-farm farming system, farmers' income can be doubled compared to growing crop component alone. With regard to livelihood security, the IFS approach adopted in the model meet almost all the domestic family needs of cereals, pulses, oil, vegetables, fruits, meat and eggs from the different components of the IFS model. The daily requirements of all components in IFS meet out from the model itself and even all farm commodities were produced surplus after fulfilling the needs of the farm family. Through the sale of vermi-compost, fish, milk, eggs and fruit in the market, a sizable amount of money was saved.These savings were exclusive of all the fixed and running costs of the IFS model. This surplus production of diversified crops suffices the nutritional requirements of the family. Hence, farming under the IFS approach improves farmers social and economical livelihood (Panwar *et al.* 2016).

Farm waste management in IFS: Recycling of farm wastes and crop residues promotes organic farming and supply healthy food to the farm family and it is also a tool of congenial environment. The farming system approach can

Table 3 Livelihood assessment of integrated farming system model

Farm commodities	Production year-wise (kg/litre/no.)					Average value over 5 years (kg/litre/no.)	Per person (kg/litre/no./ year)	Per family 5 members (kg/litre/no.)	Surplus for sale in the market (kg/litre/no.)
	2013–14	2014–15	2015–16	2016–17	2017–18				
Crop (1.04 ha)									
Cereals	3100	3010	3270	3324	3220	3184.8	157	785	2400(+)
Oilseeds	246	290	350	250	257	278.6	8 (20)	40(100)	179(+)
Pulses	460	450	410	456	430	401.2	15	75	326(+)
Sugarcane	29450	30600	32000	26500	25900	28890	12 (120)	60(600)	28290(+)
Green Fodder	27700	29650	28500	32800	34200	30570	-	-	30570(+)
Horticulture (0.22 ha)									
Fruit	1300	1560	1650	1850	1750	1622	12	60	1562(+)
Vegetable	370	427	472	540	340	429.8	18.25	91.25	339(+)
Dairy animals (2 buffaloes + 1 cow)									
Milk	3200	3390	3750	3140	3220	3340	275	1375	1965(+)
Fish production (0.10 ha)									
Fish meat	350	450	520	430	440	438	12	60	378(+)
Poultry (10 birds)									
Eggs	1830	1760	1780	1680	1785	1767	182	910	857(+)
Mushroom (12 four-tier racks) (0.02 ha)									
Mushroom production	236	250	240	248	257	246.2	-	-	246(+)
Kitchen garden (0.02 ha)									
Vegetables	155	165	180	155	160	163	18.25	60	163(+)
Boundary plantation (200 running meter)									
Fruit production	810	826	853	890	920	859.8	12	60	860(+)
Vermi-compost	12000	13560	12000	11460	12340	12272	-	-	12272(+)

*As per needs of farm family, (-) deficit in and (+) surplus production from components of the IFS model.

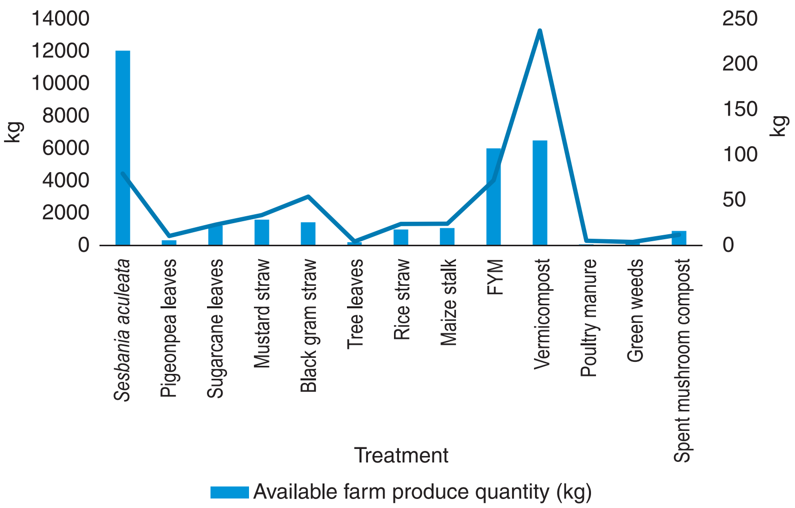

Fig 2 Source of nutrients and per cent nutrient content (N:P:K) on dry wt. basis.

be made holistic when crop and animal wastes are used as input for other components to increase nutrient efficiency at the farm through nutrient recycling (Fig 2). As a result of the developed IFS model, the total nutrients fulfilled about 55.6% of the total nutritional (NPK) requirement to the system. The total N, P and K requirements of the system in the IFS model were 285.3, 116.3 and 109.9 kg/ha, respectively. In this way, diverse farm and animal-based by-products recycled, viz. crop residues, cow dung, urine, tree leaves, mushroom spent, vermi-compost and green manure crop like Sesbania. The fish pond water and silt not only saved the expenditure which was incurred on the cost of chemical inputs but also kept the surroundings clean and environmentally safe. Nutrient budgeting of the available farm wastes and crop residues showed that by adopting proper management practices for recycling of these farm resources a farmer can save at least 10% N, 30% P and 100% K (36% of NPK), which otherwise are applied through chemical fertilizers. The addition of organic residues into the system in the form of recycled from plant and animal wastes could also help in improving the soil health and thereby improve productivity over a long period with lesser environmental hazards. Further, recycling of farm wastes and residues etc promotes organic farming and help in improving the environment as well (Kumar *et al.* 2012).

Carbon footprint from the IFS Model: The huge use of agricultural chemicals in crop production resulted in immense GHG emissions from crop fields and other linked enterprises. In the present study, results revealed that under different cropping systems rice-wheat systems had produced higher GHGs than other cropping systems i.e. (1304 kg CO_2^{-e} from 1800 m^2 area) followed by the sugarcane-ratoon-wheat system (641 kg CO_2^{-e} from 3500 m^2 area). The total sources from the 1.5 ha model were 6638 whereas the total sink was 44028 from the same piece of land. Thus, GHG from the IFS model was negative (-37390 kg CO_2^{-e}) from 1.5 ha of the model (Supplementary Fig 1). The higher carbon sink in the IFS model was due to fruit trees and boundary plantation due to which the GHG emission is negative, so more intensification of crops or enterprises can be done. Therefore, an integrated farming system approach may be one of the possible ways to mitigate the effect of climate change as reported by Yadav *et al.* (2019).

IFS model of 1.5 ha area comprising of crop, dairy, horticulture, fishery, mushroom, kitchen garden, boundary plantation, and vermi-compost is the most suitable and efficient farming system model giving the highest system productivity (SEY 174.04 tonnes from 1.5/ha) for the irrigated agro-ecosystem of the western plain zone of Uttar Pradesh. This model has considerable potential for livelihood security, nutritional benefits, employment generation and providing additional regular income to resource-poor farmers of India.

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