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Integrated farming systems for Eastern India

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ABSTRACT

Integration of different agriculturally related enterprises with crop activity as base, provide ways to recycle the products and by-products of one component as input to another linked component and reduce the cost of production. Seven farming system models with different combinations of crop, animal, fish and bird were developed and evaluated at the main experimental farm of ICAR Research Complex for Eastern Region, Patna during 2007-10 for sustained productivity, profitability, employment generation and nutrient recycling for lowland situations. Crop+ fish + duck + goat emerged as the best integrated farming system (IFS) in terms of productivity, net returns (₹159,485/yr), employment generation (752 man- days/year) and income sustainability index for net returns (80 %). It also added appreciable quantity of N, P and K into the system in the form of recycled animal and plant wastes. The waste material/byproducts of crop/animals were used as input for the other components of IFS to increase the nutrient efficiency at farm level through nutrient recycling. Crop + fish + cattle model added higher quantity of N, P and K over all other models. Growing crops under IFS with different recycled wastes produced 39.1% higher yield than growing crops in conventional rice-wheat cropping system.

Key words : Economics, Integrated farming system (IFS), Productivity, Nutrient recycling, Sustainability

In eastern India about 70 percent farmer community comes under the marginal and small farmers category (GOI, 2009). Farmers under these categories are economically poor and work in diverse, risk prone environments. The income from seasonal field crops on small and marginal farms is hardly sufficient to sustain their family. During last five decades agricultural research has focused on the development of higher productivity animal breeds and crop varieties, better farm implements and machinery, increased fertilizer use and other production and plant technologies which enabled the farmers to grow more food but at the same time it over exploited the resources and resulted in decreasing factor productivity, resource use efficieucy, less farm productivity and profitability. To tackle such problems, integrated farming system (IFS) has been advocated as one of the tool for harmonious use of inputs and their compounded response to make the agriculture in the region profitable and sustainable. IFS aim at an appropriate combination of farm enterprises like field crops, dairy, piggery, poultry, apiculture, goatry, mushroom cultivation etc.for a productive, profitable and sustainable agriculture. IFS interact appropriately with the environment without dislocating the ecological and socio-economic balance on the one hand and attempt to meet the farmers needs on the other. Thus, IFS is a reliable way of obtaining high productivity with substantial nutrient economy in combination with maximum compatibility and replenishment of organic matter by way of effective recycling of organic residues/wastes etc. obtained through integration of various land- based enterprises (Gill *et al.*, 2010; Solaiappan *et al.*, 2007). The present investigation was envisaged to identify the most productive, profitable, employment generating and sustainable IFS for the eastern region of India.

MATERIALS AND METHODS

Field studies on integrated farming systems (IFS) were carried out at the main farm of ICAR Research Complex for Eastern Region, Patna during 2007-10. It involved field crops, poultry, cattle, goat, mushroom farming, fishery and duckery in different combinations, to recycle the residues and by-products of one component to the others. The experimental site is located at about 25°35'N and 85°5'E at 67 m above mean sea level. The soil of the experimental block was clay loam in texture, having pH 6.6, electrical conductivity 0.44 dsm^{-1}, organic carbon 0.59 (kg/m^3), available N 186.0 kg/ha, available P 6.1 kg/ha and exchangeable K 175.1 kg/ha. The size of the experimental block was 4.0 acre.

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Seven farming systems (FS) were taken for evaluation and each FS was allocated an area of 0.8 ha (2 acre). The FS studies were: (i) field crops alone (ii) field crop + fish + poultry (iii) field crop + fish + duck (iv) field crop + fish + goat (v) field crop + fish + duck + goat (vi) field crop + fish + cattle (vii) field crop + fish + mushroom. In IFS the area allocation was as follows: 0.1 ha for growing fodder crops to feed cattle (3 cows + 3 calves) and goat (20 goat + 1 buck), 0.02 ha for goat shed, 0.02 ha for cattle shed, 0.02 ha for mushroom shed, 0.02 ha for making FYM and vermipits and 0.12 ha to 2 fish pond. The cropping area of each system varied depending upon the area occupied by different components/enterprises of that IFS (Table 1). In IFS by-products of one component act as input for other linked component(s) and thereby reduce input cost. Number of units or allocation of area under different enterprises follows this relationship. It gives an idea about the output of one component, which can fulfill the input requirement of other related component so that an effective integration can be made among different enterprises. One unit of goat (20 goats +1 buck) or one unit of cattle (3 cows) has been selected for integration in a 2 acre model. Three cows provide sufficient amount of FYM to fertilize the soil in combination with inorganic fertilizer. Vegetable and fruit crops are grown to fulfill the family requirements and for getting regular income. The animal waste from cow @ 16 kg/day/animal, goat @ 400 g/day/animal, poultry litter along with the unutilized feed and crop residues/ byproducts were collected and used for preparing vermicompost, which was recycled to the field of the respective IFS model. This model has been developed depending upon the requirement of a family having seven members (Table 1).

Hundred poultry birds, 35 ducks sheltered over 2 fish ponds and cattle unit maintained in cattle shed were linked to supplement the feed requirement of polycultured fingerlings (300 numbers) reared in each pond to assess the feasibility of rearing fish by using different manure as feed. Vermi-pits and FYM pits were also linked with cattle and crops. Under goatry component, 20 female goats + 1 buck (Black Bengal breed) were reared for meat purpose and goat droppings were used as goat manure to the crops. In one year, 60 kids were reared and sold @ ₹ 100/kg live weight (kids were sold at the age of 9-10 months).

Under poultry component, one-day-old broiler chicks of Ross breed were reared in batches. One hundred broiler chicks/batch (total 9 batches/year) were maintained for meat purpose. Each batch was maintained for 40 days. The broilers attained an average weight of 1.5 kg over a period of 40 days and were sold @ Rs. 60/kg live weight. Twenty five percent of poultry droppings/litters were used in pond as feed for fish and 75 percent of droppings were used in the field crops as manure. Under fishery component, composite fish farming was practiced. Fresh water fish, rohu (*Labeo rohita*) as column feeder (30 percent), catla (*Catla catla*) and silver carp (*Hypophthalmicthys molitrix*) as surface feeder (30 percent), mrigal (*Cirrhinus mrigala*) and common carp (*Cyprinus carpio var. communis*) as bottom feeder (40 percent) were raised in both the ponds. At the end of first year, the grown up fish were harvested thrice at 20 days interval. Water in the pond was drained and dried and settled silt (5 tonnes) was removed and applied as organic source to the first crop in the sequence.

In duckery (*Khakhi Campbell*), 30 female and 5 male ducks were integrated with the pond. Three months old 35 ducklings were purchased and reared, which after five months started laying eggs. Droppings of ducks were fed to fish; no extra feed was provided. Number of eggs laid /annum were recorded.

Year round mushroom production was also included in the system in an area of 0.02 ha by making a small hu

Table 1. Allocation of area under different components of farming systems

Treatment/ farming system	Area (ha)								
	Crop	Fish	Poultry	Duck	Goat	Cattle	Fodder area	Mushroom	FYM & VC pit
Field crop (FC)	0.8	-	-	-	-	-	-	-	-
FC + fish + poultry	0.66	0.12	Sheltered over fish pond	-	-	-	-	-	0.02
FC + fish + Duck	0.66	0.12	-	Sheltered over fish pond	-	-	-	-	0.02
FC + Fish + goat	0.54	0.12	-	-	0.02	-	0.1	-	0.02
FC + fish + duck + goat	0.54	0.12	-	Sheltered over fish pond	0.02	-	0.1	-	0.02
FC + fish + cattle	0.54	0.12	-	-	-	-	0.1	-	0.02
FC + fish +mushroom	0.54	0.12	-	-	-	-	-	0.02	0.02

with available local materials. From March to September, 50 beds of Paddy straw mushroom (*Volvariella spp.*) and 50 bags of Milky mushroom (*Calocybe indica*), whereas from October to February, 100 bags of Oyster mushroom (*Pleurotus spp.*) were raised by making bamboo racks in the shed through out the year. Proper humidity (75- 80 per cent) was maintained in the hut during the crop season by sprinkling water over the walls of hut and over the bags. Healthy and hygienic conditions was maintained for animals and birds.

In another 2 acre (0.8 ha) area, conventional cropping system as practiced by farmers was taken up for comparison. In conventional cropping systems i) Rice (*Oryza sativa L.*) – wheat (*T. aestivum*) and ii) Rice (*Oryza sativa L.*) - maize (*Zea mays L.*), each in 0.4 ha as practiced by farmers were followed, while under IFS, i) Rice (*Oryza sativa L.*) – wheat (*T. aestivum*) - moong (*Vigna radiata*) and ii) Rice (*Oryza sativa L.*) - maize (*Zea mays L.*)- moong (*Vigna radiata)* were taken. 100 kg N + 60 kg P_2O_5 + 40 kg K_2O was applied for rice, wheat and maize, while moong received 20 kg N and 60 kg P_2O_5/ha. In other farming systems inorganic as well as organic manure (obtained through that particular system) were applied to the crops. The yield of rice- wheat- moong and rice- maize- moong obtained from different organic and inorganic fertilizers as discussed were taken as yield of treatment 'crop alone' as well as crop component under different farming systems. To sustain the productivity of soil, inorganic fertilizers combined with organic wastes obtained from various components of IFS, *viz.* recycled pond silt, poultry manure, duck manure, goat manure and cow dung as FYM, composted residues (cereal residues) and vermicompost each @ 10 t/ha were applied to the crops grown under different IFS; these were applied once in a year before raising rice crop. Water was applied as per requirement of different enterprises. All crops were irrigated on the basis of optimum IW:CPE ratio and 5 cm water was applied for each irrigation. Summer maize (*Zea mays* L.)- napier grass (*Pennisetum purpureum* Schum.)- berseem (*Trifolium alexandrinum*) fodder system were grown as fodder in 0.1 ha of land.

Concentrate feed for animals and poultry were purchased from market and expenditures on these items were included in the cost of production. Observations were made on productivity in terms of rice–grain equivalent, economics and employment for different farming systems as well as conventional cropping system. Economics was calculated using prevailing market price of different commodities *viz.* Rice grain @ ₹12/kg; poultry @ ₹60/kg; duck egg @ ₹3/egg (or say ₹30/kg); goat meat @ ₹150/kg; milk @ ₹ 20/l and fish @ ₹70/kg.

IFS models were evaluated based on sustainability index (S.I.) as described by Vittal *et al* (2002). The S. any IFS model can be computed as:

S.I.= (NR- SD) / (MNR)

Where, NR stands for net returns obtained unde model,

SD stands for standard deviation of net returns models and

MNR stands for maximum net returns attained any model.

A suitable and viable IFS model can be identifi the basis of net return, sustainability index, employ generation and improvement in soil fertility attained a period of time.

RESULTS AND DISCUSSION

Productivity

The productivity of different components (viz. fish/duck/poultry/goat/cattle/ mushroom) integrat each system was expressed in terms of rice grain equivalent (RGYE) (Table 2, 3). The contribution of crops towards the system productivity ranged from 5 81.1%, while it ranged from 8.5 to11.8% for fish; 2 28.7% for goat; 24.2% for poultry; 7.4 to 10.1% for 34.4% for cattle and 7.2% for mushroom (Table 4). gration of field crop + fish + duck + goat resulted in est system productivity in terms of RGYE. Field c fish + duck + goat and crop + fish + cattle model rec 130% more productivity over field crop systems a Similarly, field crop +fish + goat model gave 113% h productivity than growing crops alone. Besides inor fertilizer application of recycled pond silt, poultry ma duck manure, goat manure and cow dung as F composted residues (cereal residues) and vermicon under different IFS provide congenial situation to inc the yield. Productivity of conventional cropping sy was lesser than the productivity of cropping systems included moong practiced in integrated farming sy models (Table 2&3). Korikanthimath and Manju (2009) working in Goa also opined that integrated far systems are much better over existing cropping syst

Among different cropping sequences, rice – ma moong recorded higher mean yields than rice – wh moong cropping sequence (Table 2). Further, rice – n – moong registered higher average productivity wit cycled pond silt + poultry manure (50 + 50 per cent)

Nearly 35 tonnes of grasses and legume mixture (n – napier – berseem) was obtained from 0.1 ha, and utilized as feed for animals. Field crop + fish + du goat and field crop + fish + cattle integration reco nearly equal RGYE (Table 4), but in terms of econo field crop + fish + duck + goat supersedes it. The hig yield from different cropping sequences was obtained

poultry recycled droppings pond silt and was followed by vermicompost in combination with 50 per cent inorganic fertilizers. Similar results of higher productivity obtained by integrating crop + fish + goat in lowland farming in Tamilnadu were reported by Jayanthi *et al* (2003).

While, considering the individual animal components, the highest RGYE of 5.63 t was obtained with goat unit. The goat unit also produced 2,300 kg of goat manure, which was used in field crops within the system. While, assessing the feasibility of rearing fish by using poultry and duck droppings as feed, the fish fed with poultry droppings resulted in higher average fish yield of 170 kg/0.06 ha over duck droppings fed fish (140kg/0.06 ha) during the experimental period (Table 5). Singh *et al.* (2004) also reported a higher level of fish productivity through recycling of poultry manure by owing to better plankton development as well as direct feed to fishes. An average productivity of 4370 litres of milk was obtained through one unit of cattle. Poultry was reared for meat purpose whereas ducks were reared for egg purpose. On an average ducks produced 6225 eggs/year.

Economics

Individual component wise net income, production cost and benefit:cost ratio during the three year study period is presented in Table 5, while the pooled economic analysis of the system for one hectare area is given in Table 6. Field crops integrated with fish, goat and duck was highly economical with the highest net return as well as net return per day. Field crop integrated with fish and goat was next best in terms of net returns.

While considering the individual animal component, higher average net return of ₹42,746/year was obtained with one goat unit. Poultry (broilers) rearing is economical only when proper care is taken, otherwise, it is a risky enterprise due to frequent occurrence and breakout of severe pest and diseases leading to 50-100 per cent mortality of the birds. So, proper hygienic conditions should be maintained and birds should be properly vaccinated (Solaiappan *et al*., 2007). A higher B:C ratio was obtained with application of different droppings/recycled manures used in the crops in combination with inorganic fertilizers in integrated farming system as well as pure field crop system over crops raised on chemical fertilizers only (Table 3). The field crop + fish + duck + goat and crop + fish + cattle IFS produced higher and nearly equal RGYE over all other IFS, but in terms of net returns and income sustainability index field crop + fish + duck + goat model was on the best where as crop + fish + cattle model acquired fourth position. The reason behind it is that average expenditures incurred in crop+ fish + cattle model was more due to cost of cattle rearing. This higher expenditure on rearing cattle was due to purchase of concentrate mixtures from the market. If concentrates are prepared at farmer's level with produced materials by the system, expenditure can be lessened by 50 per cent and crop + fish

Table 2. Productivity [rice grain yield equivalent (RGYE) in t/ha] of different cropping sequences under integrated farming system as affected by different manures/by-products (2007-10)

Source of nutrients	Rice-wheat-moong (R-W-MO)				Rice-maize-moong (R-M-MO)				Average of R-W-M and R-M-M cropping system			
	2007-08	2008-09	2009-10	Pooled data	2007-08	2008-09	2009-10	Pooled data	2007-08	2008-09	2009-10	Pooled data
Recycled pond silt (poultry) + poultry manure	11.36	11.59	11.10	11.35	13.24	13.38	13.14	13.25	12.30	12.49	12.12	12.30
Recycled pond silt (duck)	11.15	11.27	10.96	11.13	12.85	12.96	12.77	12.86	12.01	12.12	11.87	12.00
Goat manure	11.33	11.42	11.12	11.29	13.10	13.16	13.06	13.11	12.21	12.29	12.09	12.20
Cattle manure	11.36	11.21	11.14	11.24	12.93	13.15	12.75	12.94	12.15	12.18	11.95	12.09
Vermicompost	11.42	11.78	11.21	11.47	13.05	13.37	12.80	13.07	12.23	12.57	12.00	12.27
Mean	11.38	11.51	11.17	11.36	13.03	13.20	12.90	13.05	12.21	12.36	12.04	12.20
S.D.	0.21	0.35	0.20	0.25	0.15	0.18	0.18	0.15	0.14	0.25	0.12	0.17

Table 3. Rice grain yield equivalent (RGYE) and economics of the conventional cropping systems (2007-10)

Cropping Systems	RGYE (t/ha)				Gross returns ($\times 10^3$ ₹/ha)	Production cost ($\times 10^3$ ₹/ha)	Net return ($\times 10^3$ ₹/ha)	B : C ratio
	2007-08	2008-09	2009-10	Av.				
Rice- wheat	8.38	8.09	8.58	8.35	83.5	51.6	31.9	1.6
Rice- maize	9.16	9.07	9.37	9.20	92.0	50.5	41.,5	1.8
Mean	8.77	8.58	8.97	8.77	87.8	51.0	36.7	1.7
S.D.	0.55	0.69	0.56	0.60	6.01	0.8	6.8	0.15

+ cattle system can be made more profitable. Behera and Mahapatra (1998) also reported increase in net income through integrated farming system due to use of recycled products within the system. Field crop + fish + duck + goat model emerged as highest profitable enterprise for irrigated lowlands with an average net return of ₹ 437/day during the period of experimentation. This was due to the fact that system as a whole provided opportunity to make use of byproduct or waste materials of one component as input for the other.

Income Sustainability Index

The different IFS were evaluated on the basis of income sustainability index (Vittal *et al.*, 2002). Field crop systems alone had the lowest income sustainability index value of 19.3 percent only. Integrating field crops with poultry, duck, goat, cattle etc. increased income sustainability index. The highest average income sustainability index for net returns (80 %) was obtained from field crop + fish + duck + goat IFS, which was followed by field crop + fish + goat (75.1%) (Table 6). Income sustainability index of other IFS varied from 51.5 – 67.4%. However, income sustainability index of integration of different components were much higher over cropping alone. Higher the Income Sustainability Index, higher will be the net return (Vittal *et al.*, 2002) and more profitable will be the IFS. A suitable IFS model can be identified for adoption based on net returns, income sustainability index, employment generation and improvement in soil fertility attained over a period of time (Solaiappan *et al.*, 2007).

Table 4. Productivity in terms of rice grain yield equivalent (t/ha) of different models of integrated farming systems models (mean value of 3 years)

Farming Systems	Component Productivity (RGYE)							System RGYE (t/ha)
	Crop	Poultry	Fish	Duck	Goat	Cattle	Mushroom	
Field crops (FC)	9.23 (100)	–	–	–	–	–	–	9.23
FC + Fish + poultry	12.30 (66.1)	4.50 (24.2)	1.81 (9.7)	–	–	–	–	18.61
FC + Fish + Duck	12.00 (78.1)	–	1.81 (11.8)	1.56 (10.1)	–	–	–	15.37
FC + Fish + Goat	12.20 (62.1)	–	1.81 (9.2)	–	5.63 (28.7)	–	–	19.64
FC + Fish + Duck + Goat	12.20 (57.5)	–	1.81 (8.5)	1.56 (7.4)	5.63 (26.6)	–	–	21.20
FC + Fish + Cattle	12.09 (57.1)	–	1.81 (8.5)	–	–	7.28 (34.4)	–	21.18
FC + Fish + Mushroom	12.42 (81.1)	–	1.81 (11.8)	–	–		1.10(7.2)	15.33

Note: Figures in parenthesis indicate percent contribution to the total system productivity

Table 5. Productivity (t) and economics (Rs.) of individual components under developed farming systems (2 acre)

Components	RGYE (t)			Av RGYE (t) (2007-10)	Production cost (×10³ ₹/ha)	Net return (×10³ ₹/ha)	B: C ratio
	2007-08	2008-09	2009-10				
Field crops (FC)	7.28	7.51	7.36	7.38	48.0	40.6	1.8
FC + poultry manure	9.84	9.99	9.70	9.84	52.1	65.5	2.3
FC + Duck manure	9.60	9.70	9.50	9.60	52.0	63.2	2.2
FC + goat manure	9.77	9.83	9.67	9.76	51.9	65.2	2.3
FC + FYM	9.72	9.74	9.56	9.67	51.6	64.5	2.2
FC + vermicompost	9.78	10.06	9.59	9.81	52.1	67.2	2.3
Poultry (100 no./batch)	4.50 (900 broilers)	4.50 (900 broilers)	4.50 (900 broilers)	4.50 (900 broilers)	24.6	29.4	2.2
Duckery (30 + 5)	1.56 (6228 eggs)	1.56 (6225 eggs)	1.55 (6223 eggs)	1.56 (6225eggs)	11.0	7.7	1.7
Goat (20 +1)	5.56 (445)	5.60 (448)	5.73 (459)	5.63 (450)	24.8	42.75	2.7
Cattle (3+3)	7.33 (4398 lit)	7.25 (4350lit)	7.27 (4362 lit)	7.28 (4370 lit)	66.8	20.5	1.3
Mushroom	1.1	1.2	1.00	1.10(160 kg)	5.6	7.6	2.3
Fish fed with poultry dropping (0.06 ha)	1.02 (176 kg)	0.98 (168 kg)	0.98	0.99 (170kg)	4.8	7.1	2.5
Fish fed with duck dropping (0.06 ha)	0.82 (140 kg)	0.83 (142 kg)	0.82 (140 kg)	0.82 (140 kg)	4.8	5.0	2.0

Note: Figures in parenthesis denotes actual yield, RGYE: Rice grain yield equivalent

Nutrient recycling

Nutrients play key role in increasing agricultural production. Efficient utilization of this costly input is the need of the time. Integration of different system components and recycling of by-products and farm wastes has been practiced in this study. Samples of raw manures/dung of animal and bird, recycled products like FYM, goat manure, vermicompost and silted silt in the ponds were collected and analyzed for their N,P,K contents. The quant of nutrients received through poultry, duck, goatry, cat as droppings and plant wastes in form of vermicompost provided in Table 7.The nutrient content of manure i creased manifolds after recycling into compost an vermicompost. Residue recycling revealed that integratio of field crop with fish and poultry resulted in higher fis productivity over duck dropping fed fish; resulting i

Table 6. Productivity (RGYE) t/ha and economics of different farming systems (mean value of 3 years)

Farming System	RGYE (t/ha)	Production cost (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Net returns/ day (₹)	Income Sustainability Index
Field crops (FC)	9.23	48.0	62.8	172	19.3
FC + fish + poultry	18.61	83.9	139.5	382	67.4
FC + fish + Duck	15.36	70.2	114.1	313	51.5
FC + Fish + goat	19.63	83.9	151.6	415	75.1
FC + fish + duck + goat	21.20	94.9	159.5	437	80.0
FC + fish + cattle	21.18	125.6	128.5	352	60.6
FC + fish + mushroom	16.56	70.8	127.9	350	60.2
Mean	17.40	82.5	126.3	346	59.2
SD	4.22	24.1	31.9	87	
CV (%)	24.2	29.2	25.3	25.1	

Table 7. Nutrient recycling within integrated farming systems, (mean value of 3 years)

Nutrient	Raw poultry dropping		Poultry manure (75%)		Pond manure (25%)		Additional nutrient gained by recycling
	%	kg/2880 kg	%	kg/2160 kg	%	kg/5000 kg	kg
N	2.80	80.6	3.72	80.3	1.92	96.0	95.7
P_2O_5	1.82	52.4	2.68	57.9	50.5	50.5	56.0
K_2O	0.86	24.7	1.23	26.6	36.5	36.5	38.4
	Raw duck droppings				**Pond manure**		**Additional nutrient gained by recycling**
	%		kg/1500 kg		%	kg/5000 kg	kg
N	1.80		27.0		0.92	46.0	19.0
P_2O_5	0.65		9.7		0.36	18.0	8.2
K_2O	1.02		15.3		0.62	33.5	18.2
	Raw goat droppings				**Goat manure**		**Additional nutrient gained by recycling**
	%	kg/2300 kg	%		kg/1840 kg		kg
N	1.48	34.0	2.62		48.2		14.2
P_2O_5	0.93	21.4	1.60		29.4		8.0
K_2O	0.66	15.2	1.08		19.9		4.2
	Raw Cow dung				**Farm Yard Manure**		**Additional nutrient gained by recycling**
	%	kg/14,000 kg	%		kg/11,200kg		kg
N	1.18	165.2	1.96		219.5		54.3
P_2O_5	0.72	100.8	1.62		181.4		80.6
K_2O	1.12	156.8	1.88		210.5		53.7
	Plant waste				**Vermicompost**		**Additional nutrient gained by recycling**
	%	kg/1060 kg	%		kg/742 kg		kg
N	1.13	9.0	2.5		16.2		4.8
P_2O_5	0.82	6.6	2.12		11.3		3.1
K_2O	1.1	8.8	2.24		14.7		3.6

higher net return of ₹ 7,070/yr from 0.06 ha of pond. Poultry unit produced 2,880 kg of raw droppings, out of which 25% was fed to fish and 75% was used for preparation of poultry manure and finally applied to the field crops (Table 7). Duck unit produced 1,500 kg raw droppings per year and these were fed to fishes. Recycling of droppings (25% poultry droppings and100% duck droppings) through fish ponds, enhanced the nutrient content by 2–3 folds. Apart from this, poultry unit also provided poultry manure (2,160 kg/year) for crop cultivation. Due to recycling of different droppings viz. poultry, duck, goat, cattle and plant waste (vermicompost) an additional quantity of N : 188 kg, P : 70.68 kg (162.1 kg P_2O_5) and K : 98.02 kg (118.1 kg K_2O) were generated over raw droppings which were used within the system as input. Acharya and Mondal (2010) also reported similar benefits due to recycling of different animals' droppings and plant wastes from their findings. By analyzing all waste materials obtained from animals and plants, it can be concluded that cattle recycled droppings generated highest P and K while poultry generated highest N into the system. The additional nutrients gained by recycling of waste/byproducts over raw wastes were also confirmed by Rangasamy and Jayanthi (1994) and Baishya *et al.* (2004) in lowland situation. Recycling of wastes obtained in the IFS having field crop + fish + cattle generated 235.7 kg N, 192.7 kg P and 225.2 kg K, whereas crop + fish + poultry IFS added 192.5 kg N, 119.7 kg P and 77.8 kg K which was followed by field crop + fish + duck + goat model (110.4 kg N, 58.7 kg P, 68.1 kg K). Recycling of organic manures like FYM, goat manure, vermicompost, duckery recycled manures obtained from different components added 506.2 kg N, 348.5 kg P_2O_5 and 341.7 kg K_2O into the system as a whole, which can minimize the dependency upon chemical fertilizer up to some extent and provide good soil health on long term basis.

Integration of different components with crop depending upon suitability in the system and preferences provided encouraging results and to enhance the productivity, economic returns, generating employment and maintaining soil health of farm and farm families, field crop + fish + duck + goat combination can be adopted iu eastern part of India, instead of cultivating crop alone on same piece of land under irrigated condition. A flow chart based upon the interaction among different components is presented as Fig.1. Mahapatra and Behera (2011) also presented similar interaction for integrated farming system model.

Employment generation

Integration of different components in an IFS results in an increase in employment generation (Fig. 2). The average employment generation increased to 752 man–days/

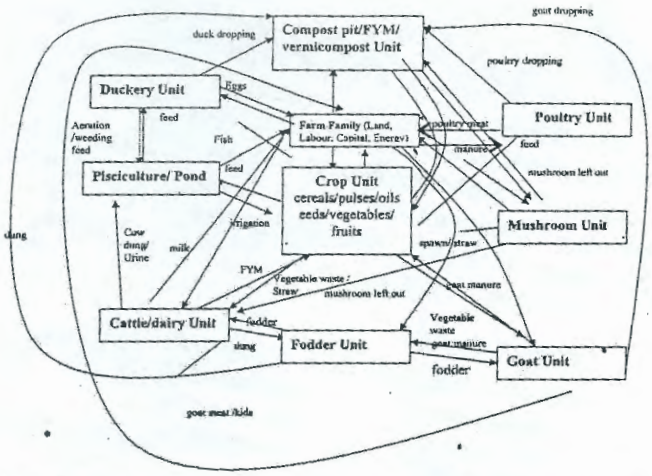

Fig. 1. Input-Output flow diagram existing under the developed IFS module

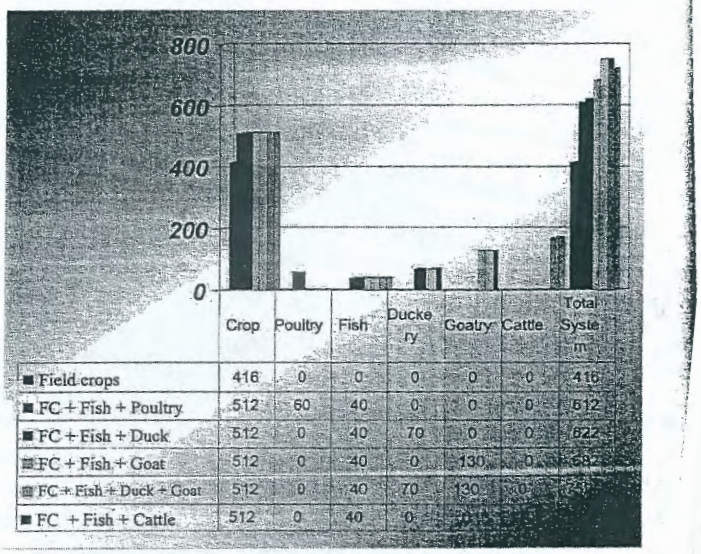

Fig 2. Employment generated by different components in various Integrated Farming Systems

ha/yr by integrating field crop + fish + duck + goat over all other farming systems and was followed by field crop + fish + cattle (722 man–days/ha/yr). An extra average employment of 96 man-days per year was generated from crop components due to inclusion of one more crop (moong) into the system over the traditional cropping system (rice-wheat). Keeping in view, the other enterprises like fish, duck and goatry an additional employment of 40, 70 and 130 man-days, respectively had been generated (Fig. 2). A similar increase in employment was reported by Ravishankar *et al.* (2007) and Singh *et al.* (1999) with integration of field crop + horticulture + goat + poultry int the system.

Thus IFS not only ensures economic returns but als provides employment to farm families and others. Bas

ata reported in the paper on IFS, field crops + ıck + goat is recommended for lowland condi- eastern India. Addition of organic residues in animal and plant wastes could also help in im- the soil-health and productivity over a longer of time with lesser environmental hazards. Live- of small and marginal farmers could be upgraded oting IFS technologies on a larger scale.

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