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Research Paper

Land productivity enhancement and soil health improvement in rainfed rice (*Oryza sativa*) farms of Odisha through integrated farming system

H.K. SAHOO[1], B. BEHERA[2], U.K. BEHERA[3] AND TIRJYAK KUMAR DAS[4]

Orissa University of Agriculture and Technology, Bhubaneswar, Odisha 751 003

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ABSTRACT

Field investigation was carried out at 5 clusters located in 5 different blocks viz. Khajuripada of Kandhamal district, Dhenkanal Sadar and Odapada of Dhenkanal district, Golamunda and Narla of Kalahandi District of Odisha, under rain-fed medium land situations across 2010–2013. The experiment aimed at comparing performance of pond based integrated farming system (IFS) model comprising rice (*Oryza sativa* L.)–onion (*Allium cepa* L.) cropping system, pisciculture + on dyke plantation, poultry and mushroom with conventional cropping system of rice–greengram (*Vigna radiata* L.) for system productivity and impact on soil health. The IFS model gave total system productivity of 31.92 tonnes rice equivalent yield (REY) as compared to 3.78 tonnes and net returns of ₹1,61,148 as compared to ₹11,631 under rainfed rice–greengram cropping system. There was decrease in bulk density, increase in soil pH, organic carbon, soil N, P and K status and increase in the population of heterotrophic bacteria, actinomycetes and *Azotobacter* compared to initial values.

Key words **:** Conventional cropping system, Integrated farming system, System productivity, Soil health

Marginal farm holdings account for 72.2% of the total in Odisha with average farm size of 0.57 ha (DAFP, 2014). Base line survey on marginal farm families of 5 clusters located in 5 different blocks, viz. Khajuripada of Kandhamal district, Dhenkanal Sadar and Odapada of Dhenkanal district, Golamunda and Narla of Kalahandi district of Odisha indicated an average land holding of 0.87 ha. The rice is the predominant crop grown by such farmers in all the clusters during *kharif* with the minimum productivity of 940 kg/ha in Khajuripada cluster to the maximum of 1670 kg/ha in Golamunda cluster. The onion was grown in Golamunda and Narla clusters during winter with productivity of 15.8–16.9 t/ha. Next to cropping, the other off-farm/subsidiary enterprises for livelihood included poultry, goatery, fishery and mushroom. Average farm income per household in the three rain fed disadvantaged districts from rice amounted to ₹ 2552 during normal year and the average income per farm on other crops amounted to ₹622. The average total income/household during normal year was 15098/-, which was reduced by 29% during the drought year in the selected clusters under study. In Khajuripada cluster of villages, the marginal farmers raised crops predominantly under rainfed condition. In other cluster of villages, the marginal farmers had very low percentage of land under irrigation. The cropping intensity was the minimum in Khajuripada cluster of villages and major productive lands were kept fallow during *rabi* season and monocropping was the reality. In other clusters, the *rabi* crops were grown either under residual soil moisture condition or under limited irrigation.

Construction of on-farm water harvesting structures like farm ponds and integration of allied enterprises with cropping is likely to enhance land productivity and improve livelihood of marginal farmers in the current scenario. Some of the by-products of these enterprises serve as valuable manure for the crop component within the system. Waste materials are effectively utilized by exploiting complementarity among components and utilizing the byproducts as organic manures. Walia and Kaur (2013) reported that IFS plays an important role in improving the soil health by increasing the nutrient value of soil. To identify the exact outcome as improvement in productivity and soil health of the possible complementarities of four different enterprises (cropping, pisciculture, mushroom and poultry) meant for integration, a study involving rice based cropping as base activity was undertaken.

[1]**Corresponding author Email:** bdbehera1@rediffmail.com
[1,2&4] Department of Agronomy, OUAT, Bhubaneswar 751 003;
[3] Principal Scientist, Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012

MATERIALS AND METHODS

The present investigation was carried out for three consecutive years from 1 April 2010 to 31 March 2013 under 0.8 ha marginal land holding size with two sources of water i.e. no pond/rainfed and pond/irrigated and five replications (clusters) located in five different blocks viz. Khajuripada of Kandhamal district (North Eastern Ghat Zone), Dhenkanal Sadar and Odapada of Dhenkanal District (Mid Central Table Land Zone), Golamunda and Narla of Kalahandi District (Western Undulating Zone) of Odisha under rain-fed medium land situations. Khajuripada, Dhenkanal Sadar, Odapada, Golamunda and Narla cluster had 374, 416, 509, 563 and 530 farm families, out of which 284 (76%), 270 (65%), 346 (68%), 394 (70%) and 387 (73%), respectively, were marginal. In each cluster, one pond based model and one rainfed farm was taken for study. The objectives of the experiment aimed at comparing performance of pond based farming system comprising rice–onion cropping sequence, pisciculture, broiler farming and mushroom cultivation with rainfed rice–greengram conventional cropping system for productivity and its impact on soil health. In 8,000 m^2 IFS model, cropping, pond, poultry and mushroom units were allocated area of 7,110, 800, 45 and 45 m^2, respectively.

The soils of Khajuripada were well-drained, light textured with sandy clay loam texture and mostly acidic in reaction. In Dhenkanal Sadar and Odapada, soils were clay loam in texture with slightly acidic soil reaction. The soils of Golamunda and Narla were heavy textured with textural class of clay and slightly acidic in reaction.

The farming system components were selected based on the popularity of the components in the study area. Pond was excavated in an area of 0.08 ha to provide assured irrigation to rice crop in *kharif* season during dry spell, grow a profitable crop of onion during *rabi* season and adopt multilayer pisciculture comprising surface feeder (*catla*), column feeder (*rohu*) and bottom feeder (*mrigal*). Pond dykes were used for planting of papaya, banana and drumstick. Poultry and mushroom cultivation was taken as allied enterprises using the available by-products/wastes from cropping.

Cropping: In all the IFS models, high yielding rice cv. 'Lalat' was taken during *kharif* season and onion cv 'N 53' during *rabi* in all the years i.e. 2010–11, 2011–12 and 2012–13. During the first year, FYM and chemical fertilizers were applied to the rice crop and onion. During the second and the third year, organic compost prepared from paddy straw, dried onion leaves, pond silt, poultry excreta and spent mushroom substrate were used along with chemical fertilizer to rice and onion crop in the IFS model, whereas only chemical fertilizer was applied to the rice and greengram crop raised under rainfed situation. Under rainfed condition, conventional cropping system of rice–greengram or rice only was adopted in the whole farm of 0.8 ha. In 0.8 ha IFS model, cropping area was restricted to 7110 m^2 in diversified model and the rest area was diverted to various land and non land based enterprises viz. pisciculture, mushroom and broiler farming.

Pisciculture and on-dyke plantation: Fingerlings of *catla* (*Catla catla* L.), *rohu* (*Labeo rohita* L.), and *mrigal* (*Cirrhinus mrigala* L.) in the ratio of 3:4:3 @ 5000/ha were released to the ponds every year in the month of August. For pond size of 0.08 ha; 120, 160 and 120 fingerlings of *catla, rohu* and *mrigal,* respectively, were used. The poultry droppings @ 40 kg/ha or 3.2 kg /800 m^2 pond was applied to the fish pond daily morning as feeding material for the growth of fingerlings in the pond (Kumar and Ayyapan, 1998). Seedlings of papaya (cv. 'Red Lady'), banana (cv. 'Bantal') and drumstick (cv. 'PKM 1') numbering 60, 56 and 48, respectively, were planted on the pond dyke with plant to plant distance of 2.0, 2.1 and 2.5 m. Papaya and banana were planted in the inner side of dykes and drumstick was planted in the outer side of pond dykes.

Poultry: Poultry units of size 4.5 m × 3.0 m (15' × 10') were constructed for rearing 100 broiler birds per batch/shed. One-day old chicks numbering to 100 of improved breed 'Vencobb' were reared with recommended feeding, health care and management. In total five batches were reared in a year. The birds were marketed at 6-week stage.

Mushroom: Mushroom cultivation was taken as a supplementary enterprise in the IFS models to utilize paddy straw efficiently. Mushroom sheds each with size of 7.5 m × 3.6 m (25' × 12') with three-tier arrangement was constructed for raising mushroom. A total of 120 beds of paddy straw mushroom (*Volvariella volvacea*) / month for 8 months during March to October and 225 bags of oyster mushroom (*Pleurotus sajar-caju)*/two months twice during November to February were raised. After harvest of fruiting bodies, the spent mushroom substrate was used for composting.

The productivity of different enterprises were expressed as rice equivalent yield (REY) to assess system performance. Soil samples were collected from the experimental sites in the beginning of experimentation. The samples were collected upto a depth of 15 cm at random from several locations. After thorough mixing, the composite soil samples were taken to characterize their physico-chemical and biological properties. Soil samples were collected after conducting experiment for three years and analysed for physico-chemical and biological properties as per the standard procedure. The data collected were analyzed following procedure for randomized block design(Gomez and Gomez, 1984)

RESULTS AND DISCUSSION

Productivity of cropping enterprise

During three years of study, the year 2012–13 gave the maximum rice grain yield of 3.13 t and straw yield of 3.42 t in IFS model (Table 1). Other two years recorded significantly less grain and straw yield. Under conventional cropping system, rice grain and straw yields were the highest during 2010–11. Other two years recorded less grain and straw yields. In rainfed rice farm, growth and yield of rice was affected due to irregularities of weather. Being a shallow rooted crop, rice was highly susceptible to drought and supplemental irrigation through pond favoured growth and development and gave higher yield. Among the clusters, Narla proved to be the best for grain and straw yields of rice in IFS model which was due to presence of moisture retentive vertisol with higher clay content and all other clusters recorded significantly less grain and straw yields. Khajuripada cluster recorded the minimum grain and straw yield of rice. This was due to prevalence of eroded soil with low nutrient status, clay content and water holding capacity. Islam and Mandal (1992) found supplemental irrigation from on-farm water harvesting farm pond to be highly profitable for *kharif* rice production and one time supplemental irrigation of about 6.0 cm at critical stage could increase the rice yield up to 59% relative to the rainfed condition. A pond size of about 5% of the total cultivable land area was required to store enough water for one supplemental irrigation.

For onion, bulb yield during 2012–13 and 2011–12 were statistically at par and 2010–11 recorded significantly less bulb yield. Narla cluster gave the maximum onion bulb yield of 16.44 t and it was at par with Golamunda. This was due to existence of vertisol with high moisture retention capacity and nutrient status. Onion, being a shallow rooted crop, the bulb and root were restricted to 3 cm of top soil. In heavy soil, the retention of moisture following irrigation was prolonged. Bulb development, during 60–70 days stage of the crop required presence of sufficient soil moisture. In light textured soil, leaching and percolation was rapid following irrigation and bulb development was affected due to insufficient soil moisture. Khajuripada recorded the minimum yield of onion which was significantly less due to prevalence of low moisture retentive sandy clay loam soil.

The greengram crop was taken up in four clusters, viz. Dhenkanal Sadar, Odapada, Golamunda and Narla under residual moisture condition. The crop could not be taken in Khajuripada cluster due to low water holding capacity of the soil and cattle menace. The farmers took traditional '*Suni*' or '*Jhain*' greengram depending on moisture status of the soil at the time of harvest of rice. '*Suni*' greengram was raised if rain ceased early in rainy season and '*Jhain*' was taken if rainy season prolonged and the crop was sown late after soil conditions become congenial for tillage operations. Dhenkanal Sadar ranked the first with respect to greengram productivity. This was due to presence of loamy soil with higher moisture retention and good aeration. The yield declined by 6.7, 8.9 and 20.0 per cent in Odapada, Narla and Golamunda clusters, respectively.

Table 1. Productivity of crops (t) in 0.8 ha IFS models and rainfed farms in different clusters during different years

Particulars	Integrated farming system (IFS)			Conventional cropping system (CCS)		
	Grain yield of rice	Straw yield of rice	Onion bulb yield	Grain yield of rice	Straw yield of rice	Grain yield of green gram
Year						
2010–11	2.88	3.12	14.68	2.49	2.81	0.43
2011–12	3.03	3.30	15.49	2.36	2.66	0.40
2012–13	3.13	3.42	15.63	2.45	2.77	0.41
Mean	3.01	3.28	15.27	2.44	2.75	0.41
SEm±	0.01	0.01	0.07	0.02	0.02	0.01
CD (P=0.05)	0.02	0.05	0.22	0.06	0.07	0.02
Cluster						
Khajuripada	2.72	3.03	13.94	2.27	2.56	0
D. Sadar	3.16	3.42	15.02	2.40	2.70	0.45
Odapada	3.01	3.26	14.72	2.32	2.61	0.42
Golamunda	2.86	3.10	16.22	2.50	2.82	0.36
Narla	3.32	3.60	16.44	2.70	3.04	0.41
SEm±	0.01	0.02	0.09	0.03	0.03	0.01
CD (P=0.05)	0.03	0.06	0.28	0.08	0.09	0.02

Productivity of non crop enterprises

Total fish yield in all the cluster was the maximum during 2010–11 followed by 2012–13 and 2011–12 (Table 2). Golamunda cluster recorded the minimum fish yield in all the years due to early capture of fish in March due to early drying of pond. In Golamunda cluster, the water level declined faster due to low rainfall and early withdrawal of monsoon than that in Narla cluster. The maximum fish yield in Dhenkanal Sadar cluster was due to retention of water for a longer period due to high rainfall and more delayed withdrawal of monsoon. The low fish yield in Khajuripada cluster was due to early drying of pond and extremely low atmospheric temperature during November to February in the cluster located at high altitude of 476 m above mean sea level. Yashouv (1963) reported low growth rate of *catla, rohu* and *mrigal* during November to March due to the low water temperature during these months. April to October, when the water temperature ranged from 28.01 °C to 34.81°C at noon time, usually was the best period for fish growth.

Papaya, banana and drumstick were planted on the dykes. Banana was taken in the lower part of inner slope, papaya in the upper part of inner slope and drumstick in the outer side of the pond embankment. Das *et al*. (2013) successfully demonstrated fruits like banana and papaya in the pond dykes/banks in farmers' field in Meghalaya. The productivity of papaya was comparatively higher in 2nd year of planting and the productivity declined thereafter. Among different clusters, Dhenkanal Sadar gave the maximum fruit yield of 1806 kg from IFS model. Odapada cluster ranked the 2nd in papaya productivity. Golamunda cluster gave the lowest fruit yield in IFS model. The higher yield in Dhenkanal Sadar than Golamunda cluster was due to congenial atmospheric condition with moderate temperature throughout the year. In all the years, papaya productivity was less in Kalahandi district as compared to Dhenkanal district due to prevalence of high temperature and desiccating wind during summer months. Irrespective of location, the banana (*bantala*) productivity was the maximum during 1st year and it declined from year to year due to occurrence of diseases in subsequent years of planting. Among all the clusters, Khajuripada recorded the lowest fruit yield due to occurrence of diseases in subsequent years of planting. The maximum drumstick yield was recorded in Dhenkanal Sadar cluster closely followed by Odapada and Narla clusters due to better atmospheric condition for flowering and fruiting. The minimum drumstick yield was recorded in Khajuripada cluster.

The maximum productivity of poultry meat in Khajuripada cluster was due to congenial atmospheric conditions. The minimum productivity in Odapada was due to high temperature condition prevailing in the cluster. Cool temperature and moderate humidity favoured the growth of birds. Growth, food intake and physiological response were influenced by environmental temperature. Poultry birds, being homeotherm animals, could live comfortably only in a relatively narrow zone of thermo neutrality. Both low and high temperatures were stressful and had negative effect on economy of production and animal health (Yunianto *et al.,* 1997).

Paddy straw mushroom was taken up in all the clusters for a period of 8 months starting from April to March. The

Table 2. Productivity of non-crop enterprises in 0.8 ha IFS models

Particular	Yield from pond unit				Meat yield of poultry (kg/year)	Mushroom yield (kg/year)	
	Fish (kg)	Fruit of papaya (kg)	Fruit of banana (kg)	Fruit of drumstick (kg)		Paddy straw	Oyster
Year							
2010–11	221.96	1481	876	423	839.7	906.1	715.7
2011–12	203.41	2007	841	551	853.8	852.7	698.3
2012–13	214.29	1222	812	600	877.0	944.9	729.3
Mean	213.22	1570	843	525	856.8	901.2	714.4
SEm±	0.91	24.20	4.72	7.82	1.04	6.86	3.28
CD (P=0.05)	2.98	79.06	15.43	25.55	3.41	22.41	10.72
Cluster							
Khajuripada	209.08	1457	728	487	887.4	885.4	672.7
D.Sadar	220.47	1806	952	573	852.6	1024.5	765.6
Odapada	219.59	1648	900	548	811.5	966.8	757.2
Golamunda	203.16	1358	759	469	862.5	824.9	692.5
Narla	213.80	1581	876	546	870.1	804.5	684.2
SEm±	1.18	31.25	6.10	10.10	1.35	8.86	4.24
CD (P=0.05)	3.85	102.07	19.92	32.98	4.40	28.93	13.85

temperature condition for paddy straw mushroom was not congenial from November to February. Among three years, the maximum of 944.9 kg paddy straw mushroom per annum was recorded during 2012–13 due to the maximum degree of perfection in managing the enterprise by women members of the farm family, while the minimum of 852.7 kg per annum was recorded during the 2nd year of experimentation. The moderate production of 906.1 kg/ annum was recorded during 1st year of experimentation. Among clusters, Dhenkanal Sadar recorded the maximum mushroom production of 1024.5 kg/annum closely followed by Odapada cluster due to congenial temperature and relative humidity. The optimum temperature of 30–35°C is ideal for cultivation of paddy straw mushroom. Akinyele and Adetuyi (2005) found appreciable mycelia growth of *Volvariella volvacea* between 25 and 40 °C with the highest mycelia dry weight (80. 0 mg) obtained at 30°C and the least mycelia weight (0.5 mg) was obtained at 10°C. The 2 clusters of Kalahandi District, viz. Narla and Golamunda recorded low fruiting body production of 804.5 and 824.9 kg/annum, respectively, due to uncongenial weather conditions as compared to other clusters. Khajuripada cluster in Kandhamal district recorded medium level mushroom productivity.

Oyster mushroom was taken up twice, once during November–December and again in January–February. Averaged over years, Dhenkanal Sadar cluster recorded the maximum oyster mushroom production of 765.6 kg per annum closely followed by Odapada with 757.2 kg per annum. Khajuripada cluster recorded the minimum mushroom production of 672.7 kg per annum. The minimum fruiting body in Khajuripada cluster was due to chilling temperature hindering growth of fruiting bodies. Uddin *et al.* (2011) found the temperature regime 14–27°C with relative humidity of 70–80% to be favorable for cultivation of *Pleurotus spp*. Thakur and Singh (2014) reported temperature range of 20–28°C to be ideal for growth of oyster mushroom. Golamunda and Narla clusters of Kalahandi District recorded the moderate mushroom production of 692.5 and 684.2 kg/annum. Among three seasons, the maximum of 729.3 kg/annum was obtained during 2012–13 and the minimum of 698.3 kg/annum during 2011–12.

System productivity and profitability

Dhenkanal Sadar cluster gave the maximum annual system productivity as REY of 33.37 t from IFS model (Table 3). Narla was the 2nd best with REY of 33.23 t. This was due to better soil resources for land based enterprise i.e. cropping and more congenial climate for pisciculture, poultry and mushroom. Khajuripada gave the minimum REY of 28.6 t.

Narla cluster recorded the maximum REY of 4.34 t closely followed by Dhenkanal Sadar from rice-greengram conventional cropping system under rainfed situation (Table 3). The IFS model in Narla cluster recorded the maximum REY of 12.96 t from cropping. Diversification of rainfed rice farm to IFS model resulted in decrease in area under cropping. But the REY for cropping activity was many times of that in rainfed farms due to growing of remunerative crop of onion after rice in place of green gram. Among the clusters, Khajuripada cluster recorded the minimum REY from cropping. Dhenkanal Sadar ranked the first for REY from pisciculture. Golamunda and Khajuripada clusters gave the lowest REY of 4.06 t from pisciculture. Narla cluster proved the best for REY from poultry in IFS model followed by Golamunda with REY of 5.31 t. Odapada cluster recorded the minimum REY of 5.0 t. Among the clusters, Dhenkanal Sadar cluster recorded the maximum REY of 11.19 t from mushroom. Khajuripada cluster recorded the minimum REY from mushroom. Among the clusters, average productivity of 0.8 ha farm was the maximum of 18.79 t in Narla cluster and the minimum of 15.55 t in Khajuripada cluster.

The 0.8 ha IFS model gave 7.44 times higher rice equivalent yield than respective conventional cropping

Table 3. Productivity of CCS, IFS, cluster average productivity (rice equivalent yield in t/year) and net returns (₹) of 0.8 ha farm in various clusters

Name of cluster	CCS (8,000m^2)	Enterprises of IFS models					Cluster average productivity	Net returns (₹)
		Cropping (7,110 m^2)	Pisciculture (800 m^2)	Poultry (45 m^2)	Mushroom (45 m^2)	System productivity		
Khajuripada	2.50	10.89	4.06	5.06	8.59	28.60	15.55	65073
Dhenkanal Sadar	4.15	11.97	4.96	5.25	11.19	33.37	18.76	95423
Odapada	3.96	11.66	4.77	5.00	10.69	32.12	18.04	87063
Golamunda	3.95	12.32	4.06	5.31	10.59	32.29	18.12	88460
Narla	4.34	12.96	4.54	5.36	10.36	33.23	18.79	95929
Mean	3.78	11.96	4.48	5.20	10.28	31.92	17.85	86390

CCS, conventional cropping system; IFS, Integrated farming system

(Table 4). This was due to inclusion of appropriate enterprises and efficient recycling of resources from one system to another. The system profitability was the minimum in Khajuripada cluster. The maximum profitability was recorded in Narla cluster with ₹95,929 closely followed by Dhenkanal Sadar with ₹95,423 and Golamunda with ₹88,460. Net returns from conventional cropping system of rice–greengram was ₹11,631. The net return increased significantly to ₹1,61,148 in pond based IFS model (12.9 times hike). Different years differed significantly for system net return. The net return was the minimum of ₹61,878 during the 1st year. The values increased by 33.2 and 85.6%, respectively, during 2011–12 and 2012–13 over the 1st year. Pond based model during 2012–13 gave the maximum net returns of ₹2,14,281. All other combinations of sources of water and year recorded significantly less net return.

Impact on soil health

Physical properties: IFS models were established in medium land situations in Kandhamal, Dhenkanal and Kalahandi districts. The soil was sandy loam, clay loam and clay in texture. The bulk density of the soil before start of the experiment varied from 1.39 to 1.46 mg/m^3 in different clusters (Table 5)**.** After three years of experimentation, the soil texture remained constant as observed before the start of the experiment. There was slightly decrease in bulk density and it varied from 1.36 to 1.42 mg/m^3 (Table 5). This was due to decrease in use of chemical fertilizers and application of tank silt and organic manure prepared from poultry droppings, mushroom spent, rice straw and onion leaves. Jeyamangalam *et al.* (2012) reported decrease in bulk density due to increase in the doses of organic manure like tank silt. Decrease in bulk density was an indicator for improvement in soil physical properties and congenial environment for crop growth.

Chemical properties: In general, soil pH showed marginal increase over years as compared to initial status. In Khajuripada cluster, initial soil pH was very low and the increase was significant (Table 6). The increase of pH was due to addition of organics which enhanced the buffering capacity of the soil. The values of EC increased marginally compared to the initial values in all clusters. In all clusters, organic carbon status increased appreciably. The models having low initial carbon content exhibited medium organic content and models having medium carbon content showed medium carbon status with higher values at the end of the experiment. Sharanappa and Shivaraj (1995) reported that the organic carbon content of the soil increased due to addition of organic matter in the soil. Except K content in IFS model in Khajuripada cluster, the content of N, P and K increased substantially due to conversion of rice farm to IFS model. The increase in available N, P and K was due to addition of organic matter in form of compost which released nutrients after decomposition and helped in dissolution of unavailable form of the nutrients in soil. Walia and Kaur (2013) reported that the benefits of the use of livestock manure in crop production as improvement in soil physical properties and the supply of N, P, K and other mineral nutrients. Continuous incorporation of poultry manure increased the activity of phosphatase enzyme involved in hydrolytic cleavage of inorganic P that became available to the plants. The application of livestock manure increased soil organic matter con-

Table 4. Interaction effects of source of water (S) and year (Y) on productivity and economics

Particular	No pond	Pond	Mean
Year			
	Rice equivalent yield (t)		
2010-11	3.86	29.52	16.69
2011-12	3.65	32.21	17.93
2012-13	3.83	34.04	18.94
Mean	3.78	31.92	17.85
SEm± for S = 0.25	SEm ± for Y = 0.31	SEm ± for S × Y = 0.43	
CD (P=0.05) for S = 0.52	CD (P=0.05) for Y = 0.64	CD (P=0.05) for S × Y = 0.90	
	Net returns (₹)		
2010–11	10,656	113,101	61,878
2011–12	8,773	156,061	82,417
2012–13	15,464	214,281	114,873
Mean	11,631	161,148	86,389

SEm± for S =2641 SEm ± for Y = 3235 SEm± for S × Y = 4575
CD (P=0.05) for S = 5,510 CD (P=0.05) for Y = 6748 CD(P=0.05) for S × Y =9543

tent and this led to improved water infiltration and water holding capacity and an increased cation exchange capacity. Due to the effective recycling of organic residues and animal wastes from different IFS components, the soil fertility improved, with higher values of organic C, soil N, P and K nutrients of the fields with different IFS components compared with the crop cultivation alone (Solaiappan *et al.,* 2007).

Biological properties: The population of heterotropic bacteria, actinomycetes and azotobacter varied from 33 to 65, 34 to 72 and 24 to 41 CFU × 10^4 g soil, respectively (Table 7). The fungi population ranged from 33 to 58 CFU × 10^3 g soil in different locations.

The population of heterotrophic bacteria, actinomycetes and *Azotobacter* increased compared to initial values (Table 7). The increase in population over years was due to addition of organic matter to the soil which favoured multiplication and growth of these bacteria. Fungi population declined compared to initial values which was due to increase in soil pH which inhibited the growth of fungi. Rousk *et al.* (2009) reported negative correlation between fungal growth and bacterial growth in pH range from 4.5–8.3. Neutral or slightly alkaline conditions favoured bacterial growth and acid *p*H favoured fungal growth. The concentration of organic carbon and population of microbes namely bacteria and actinomycetes in IFS showed an increasing trend. All these parameters were indicators of good soil health (Walia and Kaur, 2013).

In a marginal farm of 0.8 ha, integration of 4 enterprises with rice–onion cropping 7,100 m^2, pisciculture 800 m^2, broiler farming 45 m^2 and mushroom 45 m^2 provided the maximum productivity of 31.92 t REY/year compared to conventional cropping system of rice-greengram with REY of 3.78 t under rainfed condition of Odisha. The IFS model also provided net return of ₹1,61,148 as compared to ₹11,631 under rainfed rice-greengram cropping system. The physical, chemical and biological health of soil improved due to application of organic compost from waste materials, poultry manure and tank silt from various IFS components.

Table 5. Physical properties of soil as influenced by IFS model

Name ofcluster	Sand (%)	Silt (%)	Clay (%)	Textural class	Bulk Density (mg/m^3)
		Initial			
Khajuripada	59.2	16.6	24.2	Sandy clay loam	1.46
Dhenkanal Sadar	36.2	33.8	30.0	Clay loam	1.42
Odapada	36.6	33.9	29.5	Clay loam	1.40
Golamunda	24.0	30.3	45.7	Clay	1.39
Narla	23.1	30.3	46.6	Clay	1.39
		After end of experiment			
Khajuripada	58.3	17.1	24.6	Sandy clay loam	1.42
Dhenkanal Sadar	35.7	34.6	29.7	Clay loam	1.40
Odapada	35.8	34.3	29.9	Clay loam	1.37
Golamunda	23.3	30.8	45.9	Clay	1.36
Narla	22.2	30.9	46.9	Clay	1.36

Table 6. Chemical properties of soil as influenced by IFS model

Name of cluster	pH	EC (dS/m)	Organic carbon (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
			Initial			
Khajuripada	5.5	0.12	0.34	165.0	19.7	178.0
Dhenkanal Sadar	6.4	0.40	0.43	161.2	31.8	103.5
Odapada	6.2	0.22	0.84	239.6	15.2	320.8
Golamunda	6.3	0.21	0.42	182.4	12.2	195.3
Narla	6.6	0.24	0.52	224.0	11.8	218.2
			After end of experiment			
Khajuripada	6.3	0.21	0.68	218.3	24.2	161.2
Dhenkanal Sadar	6.6	0.48	0.60	191.4	33.2	115.4
Odapada	6.8	0.36	0.94	249.6	17.8	338.4
Golamunda	6.6	0.39	0.61	204.0	15.0	209.1
Narla	6.8	0.35	0.69	232.6	14.2	232.7

Table 7. Population of heterotrophic bacteria, actinomycetes and free living N fixer *Azotobacter* (CFU × 10^4 g soil) and fungi (CFU ×10^3 g soil) in soil as influenced by IFS model

Particulars	Heterotrophic bacteria	Actinomycetes	*Azotobacter*	Fungi
		Initial		
Khajuripada	33	34	24	58
Dhenkanal Sadar	42	34	33	39
Odapada	65	66	31	38
Golamunda	63	71	41	33
Narla	63	72	29	38
		After end of experiment		
Khajuripada	53	42	36	29
Dhenkanal Sadar	72	56	49	32
Odapada	103	112	55	23
Golamunda	86	103	49	28
Narla	79	78	46	34

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