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Integrated farming system for resource recycling and livelihood security for marginal farmers in three disadvantaged districts of Odisha

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ABSTRACT

Un-sustainability in rice cultivation necessitates diversification of farming in Eastern India. A study was undertaken under Eastern Indian conditions to develop pond based IFS models for marginal farm holdings (0.8 ha) and compare performance of the model comprising rice-onion cropping system, pisciculture, poultry and mushroom with conventional cropping system of rice-green gram. Field experiments were conducted at five cluster of villages *viz.,* Khajuripada of Kandhamal district, Dhenkanal Sadar and Odapada of Dhenkanal district, Golamunda and Narla of Kalahandi district of Odisha under rainfed medium land situations during 2010-11 to 2012-13. The IFS model gave rice equivalent yield (REY) of 31.92 t, net return of ₹ 1,61,148, B:C of 1.82 and employment generation potential of 588 man-days yr^{-1} as compared to REY of 3.78 t, net return of ₹ 11,631, B:C of 1.37 and man-days yr^{-1} of 193 in conventional rice-green gram cropping system. The 0.8 ha IFS model provided 3.0 t grain of rice, 15.3 t of onion, 213 kg fish, 1570 kg papaya, 843 kg banana, 525 kg drumstick, 857 kg poultry meat, 901 kg paddy straw mushroom and 714 kg oyster mushroom to the farm family and recyclable by-products of 3.3 t paddy straw, 3000 kg pond silt, 2129 kg poultry excreta and 13 t mushroom spent for recycling in the system and use as inputs by other units. The 0.8 ha rainfed farm with conventional cropping provided 2.4 t grain of rice and 0.4 t of green gram for consumption by the farm family. The sustainable yield index (SYI) and sustainable value index (SVI) values were 0.84 and 0.47, respectively, in pond based IFS model as compared to 0.10 and 0.03 in conventional cropping system of rice-green gram sequence cropping under rainfed conditions.

1. INTRODUCTION

The monocropping of rice is prevalent in the rainfed belt of Odisha. Land is kept fallow after rice or occasionally short duration pulses are grown as a sequence crops on residual moisture. Construction of on-farm water harvesting ponds on the medium and low land will be helpful in storing surplus precipitation. These ponds will facilitate diversification of marginal rice farms in the state. Harvesting of surplus rain water during rainy season enhances opportunity for diversification in space and time dimension. Water productivity is enhanced by about one to two times due to multiple use of pond water compared to farmers' practice of rainfed crop only (Das *et al.* 2013). Ghosh *et al.* (2009) reported increase in cropping intensity, employment generation and farm income owing to rain water harvesting in farm ponds and its efficient recycling. Narayan and Biswas (2012) suggested that rain water harvesting and recycling through a farm pond can successfully be practiced for providing supplemental irrigation during dry spells in monsoon season and available water in the pond can also be utilized for providing pre-sowing/supplemental irrigation to post monsoon/*rabi* season for increasing the growth, yield and water use efficiency in order to augment the productivity of large rainfed areas in the country. Storing of excess rainwater in dug out farm ponds for utilization during the dry spells of monsoon season or for raising a subsequent crop was a promising way to improve the cropping intensity and crop productivities and to stabilize the farming (Ranade, 2014).

The by-products of enterprises in integrated farming system (IFS) serve as valuable manure for recycling to the crop component within the system. The recycling of produce/by-products of any one of the components in the system as input for the other component linked in the farming system could reduce the cost of production leading to increase the net income of the farm as a whole. These complementarities when carefully chosen, keeping in view the soil and environmental conditions, usher in greater dividends (Rangasamy, 1999). This approach helps the marginal farmers to improve their standard of living by providing sufficient employment and money flow. Farming system approach should be adopted to meet the domestic need and mitigate the risks and uncertainties, achieve higher food production and offer a better standard of living (Govindan *et al.,* 1990). The present investigation was undertaken to maximize the productivity and profitability of marginal farm of size 0.8 ha in five clusters of three different agro-climatic zones namely Mid Central Table Land Zone, North Eastern Ghats Zone and Western Undulating Zone of Odisha through farming system approach.

2. MATERIALS AND METHODS

The present investigation was carried out for three consecutive years from April 01, 2010 to March 31, 2013 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 Ghats Zone), Dhenkanal Sadar and Odapada of Dhenkanal district (Mid Central Table Land Zone), Golamunda and Narla of Kalahandi district (Western Undulating Zone) of Odisha. The size of farm is 0.8 ha under shallow submerged low land situations. The experiment aimed at comparing performance of pond based IFS model comprising rice-onion sequence cropping system, pisciculture + on dyke plantation, poultry and mushroom with conventional cropping system of rice-green gram under rainfed condition. 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 to slightly alkaline soil reaction. The soils of Golamunda and Narla were heavy textured with textural class of clay and slightly acidic to slightly alkaline in reaction.

On- farm water harvesting ponds were excavated to provide assured irrigation to rice crop in dry spell during *kharif* season and to raise a second profitable crop of onion during *rabi* season after the harvest of rice crop with practice of multilayer pisciculture. Pond dykes were used for planting of papaya, banana and drumstick. In all the IFS models, high yielding rice cv. '*Lalat'* was used during *kharif* season and onion cv '*N - 53'* during *rabi* in all the years. Under rainfed condition without pond, rice (cv. Lalat) - green gram (cv. Local) cropping system was followed except Khajuripada cluster where mono-cropping of rice was feasible. In IFS models, cropping area was 0.711 ha, whereas in control (no pond), the cropping area was 0.8 ha. In IFS models, 0.08 ha area was diverted for farm pond. The ponds were rectangular in shape with gradually sloping sides, having an average water depth of 1.45 m. Fingerlings of *catla* (*Catla catla* L.), *rohu* (*Labeo rohita* L.) and *mrigal* (*Cirrhinus mrigala* L.) in the ratio of 3:4:3 @ 5000 ha^{-1} were released to the ponds every year in the month of August. The poultry droppings @ 40 kg ha^{-1} (3.2 kg pond^{-1} of size 0.08 ha) was applied daily morning for promoting growth of phytoplankton and zooplankton and increasing body weight of fish in the pond (Kumar and Ayyapan, 1998). Papaya seedlings of cv. '*Red Lady'* numbering 60 were planted in the pond dyke at a linear distance of 2.0 m in the middle of the dyke. Banana plants of cv. *'Bantal'* numbering 56 were planted in the inner side of the pond dyke at a linear distance of 2.1 m. Drumstick cv. '*PKM 1'* seedlings numbering 48 were planted in the outer side of the pond dyke at a linear distance of 2.5 m. Poultry units of size 4.5 x 3.0 m (15'x10') were constructed for rearing 100 broiler birds per batch. One-day old chicks numbering 100 of improved breed '*Vencobb'* were reared with recommended feeding, health care and management. All total five batches were reared in a year. Mushroom shed of size 7.5 x 3.6 m (25'x12') with three-tier arrangement was constructed for raising mushroom. A total of 120 beds of paddy straw mushroom (*Volvariella volvacea*) per month for 8 batches during March to October and 225 bags of oyster mushroom (*Pleurotus sajar-caju)* per two months for 2 batches during November to February could be raised. Since diversified enterprises were taken for study, the yield of each enterprise was converted to REY. Studies on economics of production of each of the enterprises was made by keeping a record on number of labourers engaged, power and input utilized. The standard cost of cultivation was calculated as per rates fixed by government and University. Gross returns were calculated using the prevailing price. Net return per ha was also worked by subtracting cost of cultivation from the gross returns.

System productivity was calculated by computing and adding the productivity of each of the four enterprises in terms of REY. Cost of production, gross return and net return of the system was calculated by adding the corresponding values of each of the enterprises. The benefit:cost (B:C) ratio was calculated and it's the ratio of gross return to the cost of cultivation.

The straw available after processing of paddy was utilized in mushroom production. After harvest of onion, the leaves were weighed and incorporated in the field. The mushroom spent substrates were utilized for compost making which was utilized in the crop components. Poultry excreta of 100 birds along with the litter materials were collected after one cycle of 6 weeks and weighed. Poultry excreta were utilized in the fish pond as fish feed and the remaining excreta was utilized as manure in the cropping enterprise. After the harvest of fish during the month of April, the fish pond was dried and 3000 kg pond silt was collected. The pond silt collected after the 1st and the 2nd year were utilized in the cropping enterprise as compost. The SYI and SVI were computed by using the formula given by Vittal *et al.* (2002).

3. RESULTS AND DISCUSSION

Rainfall

Rainfall is the most important weather element governing the productivity, profitability and sustainability of agricultural systems. During 2010-11, Dhenkanal Sadar and Odapada clusters in Dhenkanal district and Khajuripada cluster in Kandhamal district received sufficient rainfall of 196, 117 and 138 mm, respectively, during May (Table 1). In Narla cluster, very meager amount of 25 mm rainfall was received. Receipt of rainfall in Golamunda during May was moderately satisfactory. During monsoon period, the quantity of rainfall received and distribution was satisfactory in all clusters except Golamunda. Khajuripada, Dhenkanal Sadar, Odapada and Narla received good showers of 86, 114, 206 and 139 mm, respectively, during October after withdrawal of monsoon. Rainfall amounting to 38, 42, 63, 20 and 41 mm in Khajuripada, Dhenkanal Sadar, Odapada, Golamunda and Narla, respectively, during December favoured the succeeding crop of green gram and onion in all the clusters. During 2011-12, pre-monsoon showers of 92, 164 and 91 mm in Khajuripada, Dhenkanal Sadar and Odapada clusters were satisfactory for land preparation and sowing. Heavy downpour of 196, 305 and 205 mm, respectively, in June in Khajuripada, Dhenkanal Sadar and Odapada helped in recharge of farm ponds. During July, early season drought was noticed in four clusters *viz.*, Khajuripada, Dhenkanal Sadar, Odapada and Golamunda. So the quantity of rainfall received and distribution was highly unfavorable during the year in all the clusters. In Golamunda, the distribution was good. In other four clusters, quantity received was either low or high resulting in drought or flood. Pond based models could provide supplementary irrigation during dry spell. The receipt of rainfall during post-monsoon period was very meager. During the year, Dhenkanal Sadar received higher rainfall than the normal, whereas Odapada and Khajuripada received slightly less than the normal. The rainfall in Golamunda was extremely low with 393 mm leading to severe drought and decreased the amount of stored water in water harvesting ponds and decreased fish growth and productivity. During 2012-13, Khajuripada, Dhenkanal Sadar and Odapada received rainfall amounting to 19, 70 and 45 mm during May, respectively. In Golamunda and Narla, there was no appreciable rainfall. During monsoon period, all clusters except Golamunda received very good showers.

Productivity of Crop 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 2). 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 the maximum yield.

Among the clusters, Narla proved to be the best for grain and straw yield of rice in IFS model which was due to presence of moisture retentive vertisol with higher clay content. 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. Over years, supplementary irrigation to rice

Table: 1
Monthly total rainfall (mm) in different clusters during 2010-11, 2011-12 and 2012-13

Months	2010-11					2011-12					2012-13				
	Kpd	Dsr	Opd	Gmd	Nrl	Kpd	Dsr	Opd	Gmd	Nrl	Kpd	Dsr	Opd	Gmd	Nrl
April	20	0	0	16	0	101	55	19	23	18	87	28	7	2	28
May	138	196	117	78	25	92	164	91	14	25	19	70	45	0	2
June	144	195	202	33	94	196	305	205	86	170	130	109	242	69	174
July	299	211	322	152	403	109	135	134	51	217	366	431	304	98	195
August	246	260	200	211	251	460	468	367	120	371	278	387	360	185	314
Sept	265	186	222	173	199	340	431	392	99	264	245	283	355	113	372
Oct	86	114	206	47	139	35	0	5	0	18	86	131	38	14	21
Nov	24	14	8	0	0	0	0	0	0	0	75	102	87	5	13
Dec	38	42	63	20	41	0	0	0	0	0	0	0	0	0	0
Jan	0	0	0	0	0	110	115	96	0	24	0	0	0	0	2
Feb	9	62	62	0	3	0	0	0	0	2	5	0	0	4	10
March	12	0	2	0	0	0	0	0	0	2	0	0	0	0	0
Total	1281	1280	1403	730	1154	1443	1673	1309	393	1110	1291	1540	1437	490	1131

Kpd-Khajuripada, Dsr- Dhenkanal Sadar, Opd- Odapada, Gmd-Golamunda, Nrl-Narla

Table: 2
Productivity(t) of crops in 0.8 ha IFS models and rainfed farms at different clusters

Particulars	Integrated farming system			Conventional cropping system		
	Rice Yield	Straw yield	Onion bulb yield	Grain yield of rice	Straw yield of rice	Grain yield of green gram
Years						
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	3.0	3.3	15.3	2.4	2.8	0.4
CD(P=0.05)	0.02	0.05	0.22	0.06	0.07	0.02
Clusters						
Khajuripada	2.72	3.03	13.94	2.27	2.56	0
Dhenkanal 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
CD(P=0.05)	0.03	0.06	0.28	0.08	0.09	0.02

enhanced grain yield of rice by 23%. Islam and Mandal (1992) reported supplemental irrigation was highly profitable for monsoon rice production and one 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 is required to store enough water for one supplemental irrigation.

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 is a shallow rooted crop with bulb and root situated within 3 cm of top soil. In heavy soil of Kalahandi district, the retention of moisture following irrigation lasted for a longer period. Availability of adequate soil moisture during bulb development (60-70 days stage of the crop) improved the crop productivity. 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 bulb yield of onion which was significantly less due to prevalence of low moisture retentive sandy clay loam soil.

Under conventional rice-green gram cropping system, rice grain and straw yields were the highest during 2010-11. Narla cluster recorded the maximum yield of rice and straw and other clusters recorded significantly less yield of both grain and straw. The second crop of green gram, yield was the highest during 2010-11 and the year 2012-13 was at par with it. The green gram 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*' moong depending on moisture status of the soil at the harvesting time of rice. 'Dhenkanal Sadar ranked the first with respect to green gram productivity. This was due to presence of loamy soil with higher moisture retention and good aeration. The yield declined by 7, 9 and 20% in Odapada, Narla and Golamunda clusters, respectively.

Productivity of Non Crop Enterprises

Total fish yield in all the clusters was the maximum during 2010-11 followed by 2012-13 and 2011-12 (Table 3). Golamunda cluster recorded the minimum fish yield in all the years due to early capture of fish in March due to drying of pond. Dhenkanal Sadar recorded the maximum fish yield of 220 kg due to higher length and weight of different fish species. Singh *et al.* (2004) reported higher level of fish production through recycling of poultry manure owing to better plankton development. 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 msl. Yashouv (1963) reported low growth rate of *catla, rohu* and *mrigal* during November to March attributed to the low water temperature during these months. April to October, when the water temperature ranges from 28.01° to 34.81°C at noon time, was the best period for fish growth.

Papaya, banana and drumstick were planted on the dykes. Banana production in the IFS model was the maximum during 2010-11. Papaya yield was the highest during 2011-12 and drumstick yield was the highest during 2012-13. Das *et al.* (2013) successfully demonstrated fruits like banana and papaya in the pond dykes in farmers' field in Meghalaya. The productivity of papaya was comparatively higher in the 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.

Table: 3
Productivity (kg yr^{-1}) of non crop enterprises from 0.8 ha IFS models

Particulars	Yield from pond unit				Meat yield of poultry	Mushroom yield	
	Fish	Papaya	Banana	Drumstick		Paddy straw	Oyster
Years							
2010-11	222	1481	876	423	840	906	716
2011-12	203	2007	841	551	854	853	698
2012-13	214	1222	812	600	877	945	729
Mean	213	1570	843	525	857	901	714
CD(P=0.05)	3	79	15	26	3	22	11
Clusters							
Khajuripada	209	1457	728	487	887	885	673
D.Sadar	220	1806	952	573	853	1025	766
Odapada	220	1648	900	548	812	967	757
Golamunda	203	1358	759	469	863	825	693
Narla	214	1581	876	546	870	805	684
CD(P=0.05)	4	102	20	33	4	29	14

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 1^{st} year and it declined from year to year due to occurrence of diseases in subsequent years of planting. The maximum banana yield of 952 kg was recorded in Dhenkanal Sadar cluster. The maximum drumstick yield of 573 kg 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 meat yield of poultry was the highest during 2012-13. The maximum productivity of poultry meat of 887 kg in Khajuripada cluster was attributed to congenial atmospheric conditions. The minimum in Odapada was due to high temperature condition prevailing in the cluster. Growth, food intake and physiological response are changed by environmental temperature. Poultry birds, being homoeothermic, could live comfortably only in a relatively narrow zone of thermo neutrality. Both low and high temperatures were stressful and had negative effects on economy of production and animal welfare (Yunianto *et al.,* 1997).

Among three years, the maximum of 945 kg paddy straw mushroom per annum was recorded during 2012-13, while the minimum of 853 kg $annum^{-1}$ was recorded during the 2^{nd} year of experimentation. Among clusters, Dhenkanal Sadar recorded the maximum mushroom production of 1025 kg $annum^{-1}$ closely followed by Odapada cluster due to congenial temperature and relative humidity. Dhar *et al.* (2011) found optimum temperature of 30-35^{0}C to be ideal for cultivation of paddy straw mushroom. Akinyele and Adetuyi (2005) found appreciable mycelia growth of *V. volvacea* between 25 and 40^{0}C with the highest mycelia dry weight (80 mg) obtained at 30^{0}C and the least mycelia weight (0.5 mg) was obtained at 10^{0}C. The two clusters of Kalahandi district *viz.*, Narla and Golamunda recorded low mushroom production of 805 and 825 kg $annum^{-1}$, respectively due to uncongenial weather conditions as compared to other clusters.

Averaged over years, Dhenkanal Sadar cluster recorded the maximum oyster mushroom production of 766 kg $annum^{-1}$ closely followed by Odapada with 757 kg $annum^{-1}$. Khajuripada cluster recorded the minimum mushroom production of 673 kg $annum^{-1}$. The minimum fruiting body in Khajuripada cluster was due to chilling temperature that hindered growth of fruiting bodies. Golamunda and Narla clusters of Kalahandi district recorded the moderate mushroom production of 693 and 684 kg $annum^{-1}$. The optimum growing environment of oyster mushroom (*P. sajor-caju*) was reported as the temperature regime of 14- 27^{0}C with relative humidity of 70-80% by Uddin *et al.* (2011), temperature of 20-26^{0}C and relative humidity 70-90% by Bano and Rajarathnam (1982) and temperature range of 20-28^{0}C by Thakur and Singh (2014). Among three seasons, the maximum of 729 kg $annum^{-1}$ was obtained during 2012-13 and the minimum of 698 kg $annum^{-1}$ during 2011-12.

Component Wise Profitability

Rice

Khajuripada cluster recorded the minimum net return during all the years (Table 4) due to presence of low moisture retentive and percolating soil and all other clusters proved superior to Khajuripada cluster for net return. Averaged over years, Narla cluster recorded the maximum net return of ₹ 19,117 which was due to presence of moisture retentive black soil. Khajuripada, Dhenkanal Sadar, Odapada and Golamunda clusters recorded 35, 8, 21 and 30% less net returns as compared to Narla cluster, respectively. Pond based IFS models and rainfed rice farms differed significantly for net return. Being a shallow rooted crop, rice was highly susceptible to drought and supplemental irrigation through pond favoured growth and development and gave the maximum yield and net return.

In conventional cropping, Narla recorded the highest net return of ₹ 10,326 from rice. In rainfed rice farm, growth and yield of rice was affected due to weather variability.

Onion

The net return from onion was the highest in Narla cluster and the lowest in Khajuripada cluster during all the years. Averaged over seasons, Narla cluster gave a net return of ₹ 62,288 closely followed by Golamunda cluster with ₹ 60,569. This was due to higher productivity in these two clusters and presence of moisture retentive black cotton soil which was quite congenial for the growth of the crop. Khajuripada cluster gave the lowest net return due to the lowest yield as a result of presence of eroded and low fertile soil. Khajuripada, Dhenkanal Sadar and Odapada reduced net return by 26, 16 and 18% as compared to Narla cluster, respectively.

Table: 4
Net return (₹) from cropping in 0.8 ha IFS models and rainfed farms at different clusters

Particulars	Integrated farming system		Conventional cropping system	
	Rice	Onion	Rice	Greengram
Years				
2010-11	12677	32853	6983	4591
2011-12	14159	50703	5260	4392
2012-13	19788	79861	9346	7648
Mean	15541	54473	7196	5544
CD(P=0.05)	577	2604	882	1498
Clusters				
Khajuripada	12504	45887	5626	0
D.Sadar	17567	52661	6675	6581
Odapada	15116	50958	5590	5779
Golamunda	13401	60569	7764	4127
Narla	19117	62288	10326	5687
CD(P=0.05)	745	3362	1139	1934

Green gram

During all the years, Dhenkanal district gave higher net return than Kalahandi district from green gram crop. Dhenkanal Sadar cluster recorded higher net return than Odapada cluster due to higher productivity as a result of congenial soil conditions and Narla cluster recorded higher net return than Golamunda cluster. Golamunda gave the lowest net return due to less yield.

Pisiculture

The net return from fish was the minimum of ₹ 3253 during the 1st year of experimentation and it increased by 25 and 128% during the 2nd and the 3rd year, respectively (Table 5). Averaged over years, Dhenkanal Sadar cluster recorded the maximum net return of ₹ 6627 due to availability of optimum depth of water and congenial thermal environment for the growth of fish throughout the growth period. The net return declined by 2, 31, 44 and 52% in Odapada, Narla, Golamunda and Khajuripada clusters, respectively. The lowest net return was obtained in Khajuripada cluster due to low fish yield as a result of very low temperature during winter inhibiting fish growth severely.

Papaya, Banana and Drumstick

Among the years, 2011-12 recorded the maximum net return of ₹ 8035 from papaya. During 1st and 3rd year, 70 and 32% less net return was obtained. Among the clusters, Dhenkanal Sadar cluster gave the maximum net return of ₹ 6484 due to more congenial atmospheric conditions for flowering and fruiting. Golamunda cluster recorded the minimum net return from the crop due to more desiccating atmospheric conditions in majority periods of the year. The

Table: 5
Net return (₹) from non crop enterprises

Particulars	Pond unit				Poultry unit	Mushroom unit	
	Fish	Papaya	Banana	Drumstick		Paddy straw	Oyster
Years							
2010-11	3253	2385	5969	5968	8362	22071	17727
2011-12	4075	8035	8011	10920	12728	21911	23572
2012-13	7423	5442	10531	15756	12222	30349	30608
Mean	4917	5287	8170	10881	11103	24778	23969
CD(P=0.05)	1175	627	328	829	402	3746	920
Clusters							
Khajuripada	3175	4698	6763	9980	9629	15986	13756
D.Sadar	6627	6484	9490	12117	11714	33396	25144
Odapada	6491	5714	8883	11447	8887	28626	24696
Golamunda	3700	4181	7133	9470	12384	23876	28379
Narla	4592	5360	8582	11393	12903	22007	27870
CD(P=0.05)	1516	809	424	1070	520	4836	1188

net return from banana showed an increasing trend over years. The net return of ₹ 5969 was obtained during 1st year and the value increased by 34 and 77% during the 2nd and the 3rd year in 0.8 ha model. Being a long duration crop, the performance depends on overall climatic conditions during the whole year. Over the years, net return of ₹ 9490 was recorded from IFS model. Khajuripada cluster recorded the minimum net return from banana due to low productivity as a result of poor soil quality in the embankment. The net return from drumstick showed an increasing trend over the years. Averaged over the clusters, the mean net return of ₹ 5968 was recorded in IFS model during 1st year. The net return increased by 83 and 164% during the 2nd and the 3rd year. Over the years, Dhenkanal Sadar cluster gave the maximum net return of ₹ 12,117 in the model followed by Odapada cluster. This was due to favourable weather conditions in these two clusters compared to Narla and Khajuripada.

Poultry

Narla cluster proved the best with net return of ₹ 12,903 closely followed by Golamunda with net return of ₹ 12,384 from poultry due to prevalence of relatively dry weather which inhibited incidence of diseases. Odapada cluster gave the minimum annual net return of ₹ 8887 due to prevalence of warm humid weather followed by Khajuripada cluster due to chilling weather temperature in December that inhibited growth and gave less meat yield. Among the years, 2011-12 gave the maximum annual net return of ₹ 12,728 followed by ₹ 12,222 during 2012-13 and ₹ 8362 during 2010-11.

Paddy Straw Mushroom

Eight batches of paddy straw mushroom were raised during March to October @ 1 batch month^{-1} because optimum temperature was 25 to 38^{0}C for paddy straw mushroom. Among the three years of experimentation, 2012-13 gave the maximum net return of ₹ 30349. The annual net return decreased by ₹ 8278 (27%) and ₹ 8438 (28%) during 2010-11 and 2011-12, respectively. Averaged over the years, Dhenkanal Sadar was the most congenial for paddy straw mushroom production with annual net return of ₹ 33,396 while the cluster located in high altitude 476 m was the least remunerative with annual net return of ₹ 15,986 because of the prevalence of low temperature for majority periods of the year.

Oyster Mushroom

Two batches of oyster mushroom were raised during November-December and January-February because optimum temperature was 20 to 30^{0}C for oyster mushroom. Among three years of experimentation, the net return was the minimum of ₹ 17,727 during 2010-11 and it increased by 33 and 73% during 2011-12 and 2012-13, respectively. Averaged over years, Golamunda was the most remunerative with total net return of ₹ 28,379 closely followed by Narla with net return of ₹ 27,870. Due to higher price of the produce in these two clusters, net return was higher. Khajuripada cluster gave the lowest net return due to low production and extremely low temperature during the period.

System Productivity and Profitability

Over years, the trends for REY was Narla > Dhenkanal Sadar > Golamunda > Odapada > Khajuripada in 0.8 ha IFS model (Table 6). Narla recorded the maximum REY of 18.79 t closely followed by Dhenkanal Sadar with REY of 18.76 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 15.55 t. The 0.8 ha IFS model gave 7.4 times higher REY than respective conventional cropping (Table 7). The farming system constituting crop + dairy + poultry + fishery resulted in the highest system productivity of 123.75 t REY ha^{-1}, which was 1332% higher than the traditional (rice-wheat) cropping sequence. This could be attributed to better management, inclusion of profitable enterprises and efficient recycling of resources from one system to another, which reduced the total input requirement, lowering the cost of production (Singh *et al.*, 2007). Gill *et al.* (2009) reported that diversification of farming system by integration of enterprises in varied farming situations of India enabled to enhance total production in terms of REY ranging from 9.2% in Eastern Himalayan region to as high as 366% in Western-plain and Ghats region when compared to prevailing farming systems of the region. Narla cluster recorded the maximum net return of ₹ 95, 929 with B:C of 1.69 from 0.8 ha IFS model. The mean net return from 0.8 ha IFS model was ₹ 1,61,148 with B:C 1.82 as compared to ₹ 11,631 with B:C 1.37 in conventional rice-green gram cropping system. Ravi Sankar *et al.* (2007) reported lesser cost of production with better productivity of each component

Table: 6
Rice equivalent yield (REY) and economics of farms in different clusters

Clusters	REY(t)	Cost of production (₹)	Net return (₹)	B:C	Labour employment (man-days yr^{-1})
Khajuripada	15.55	108398	65073	1.44	366
D.Sadar	18.76	113834	95423	1.65	399
Odapada	18.04	114105	87063	1.58	400
Golamunda	18.12	113583	88460	1.60	395
Narla	18.79	113502	95929	1.69	394
CD(P=0.05)	0.82	2946	8712	0.04	16

Table: 7
Interaction effects of source of water (S) and year (Y) on productivity and economics

Particulars	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
CD(P=0.05) for S = 0.52; CD(P=0.05) for Y = 0.64; CD(P=0.05) for SxY = 0.90			
Cost of production (₹)			
2010-11	27892	182129	105010
2011-12	30598	191782	111190
2012-13	32472	211233	121853
Mean	30321	195048	112684
CD(P=0.05) for S =1863; CD(P=0.05) for Y = 2282; CD(P=0.05) for SxY =3227			
Net return (₹)			
2010-11	10656	113101	61878
2011-12	8773	156061	82417
2012-13	15464	214281	114873
Mean	11631	161148	86389
CD(P=0.05) for S =5510; CD(P=0.05) for Y = 6748; CD(P=0.05) for SxY =9543			
B:C			
2010-11	1.37	1.62	1.50
2011-12	1.28	1.81	1.55
2012-13	1.47	2.01	1.74
Mean	1.37	1.82	1.59
CD(P=0.05) for S =0.02; CD(P=0.05) for Y = 0.03; CD(P=0.05) for SxY =0.04			
Labour employment (man days year^{-1})			
2010-11	189	593	391
2011-12	195	584	390
2012-13	195	587	391
Mean	193	588	391
CD(P=0.05) for S =11; CD(P=0.05) for Y = NS; CD(P=0.05) for SxY =NS			

integrated in the system increased the returns. Das *et al.* (2013) realized 284 and 176% higher system net return through pig and duck based multiple use of pond water through diversified farming (crop, fruit, livestock and fishery) than the farmers' practice (without integration), respectively.

Employment Generation

Among the clusters, labour requirement varied from 366 in Khajuripada to 400 in Odapada in 0.8 ha IFS model. The IFS model with 0.8 ha size required a total labour of 588 man days annum^{-1}. Labour requirement for conventional rice-green gram cropping system was more or less same in different years with mean of 193. Diversification of rice farm to four enterprise IFS models increased employment opportunity by 205% in 0.8 ha IFS model. Generation of additional employment opportunities under farming system approach was due to the diversification and integration of crops, livestock, fishery and horticulture (Rathore and Bhatt, 2008). Ghosh *et al.* (2009) and Das *et al.* (2013) also reported increase in cropping intensity, employment generation and farm income owing to rain water harvesting and its efficient recycling in farm ponds.

Recyclable Resources

After harvest of fish every year, 3000 kg of pond silt was lifted from the pond of 0.8 ha IFS model (Table 8). The silt deposited in the pond was due to erosion from embankment and also from surrounding fields apart from excreta and feed applied to pond. Desilting was done during May after drying of the ponds to maintain depth of water level in the pond for pisciculture. The silt was used in crop fields for improving soil health. Jeyamangalam *et al.* (2012) reported decrease in bulk density due to application of tank silt. Averaged over years, the maximum annual excreta production of 2207 kg was obtained in Khajuripada cluster and the minimum production of 2016 kg was recorded in Odapada cluster. The maximum excreta yield may be attributed to the maximum consumption of feed and conversion to body weight and excreta. The excreta production declined by 2, 3, 4 and 9% in Narla, Golamunda, Dhenkanal Sadar and Odapada clusters, respectively. Among the years, the excreta production was the maximum during the 3rd year of experimentation. The year 2011-12 ranked the 2nd with excreta production of 2117 kg and year 2010-11 ranked the third with excreta production of 2051 kg. Total mushroom spent production in different clusters showed negligible differences. Among different years, the mean mushroom spent production was the lowest of 12944 kg during 2011-12 and the maximum value was 13103 kg during 2012-13. Averaged over years, mushroom spent was the lowest of 12965 kg in Golamunda to higher of 13076 kg in Odapada cluster. The low variability among clusters was due to use of equal quantity of straw and inputs as per recommendation in all the clusters. The quantity of straw used was 1440 kg batch^{-1}

Table: 8
Recyclable wastes in pond based integrated farming system model

Treatments	Poultry excreta (kg)	Mushroom spent (kg)	Pond silt (kg)
Years			
2010-11	2051	13021	3000
2011-12	2117	12944	3000
2012-13	2219	13103	3000
Mean	2129	13022	3000
CD(P=0.05)	11	40	NS
Clusters			
Khajuripada	2207	13043	3000
D. Sadar	2117	13057	3000
Odapada	2016	13076	3000
Golamunda	2143	12965	3000
Narla	2161	12973	3000
CD(P=0.05)	14	52	NS

for paddy straw mushroom and 562.5 kg batch^{-1} for oyster mushroom. The quantum of mushroom spent straw was higher than sum of straw and inputs because of addition of mycelia. Rangasamy (1999) reported that inclusion of mushroom enterprise as one of the components in IFS with the production capacity of 2 kg day^{-1} utilized about 1800 kg paddy straw and could yield 2340 kg of spent mushroom substrate after the harvest of edible mushroom at the end of one year. The enhancement in the weight in the mushroom spent was due to unharvested mycelia growth.

Resource Recycling

The 0.8 ha IFS model gave 3.0 t grain of rice, 15.3 t of onion, 213 kg fish, 1570 kg papaya, 843 kg banana, 525 kg drumstick, 857 kg poultry meat, 901 kg paddy straw mushroom and 714 kg oyster mushroom for use by the farm family and recyclable wastes of 3.3 t paddy straw, 3000 kg pond silt, 2129 kg poultry excreta and 13 t mushroom spent for recycling in the system and use as input by other units (Fig. 1). Due to efficient recycling of resources, the productivity and profitability of IFS models were higher compared to conventional cropping system. Babalad and Hundekar (1999) reported that in an IFS, it might be possible to reach the same level of yield with proportionately less input and yield would be more sustainable because of waste of one enterprise become the input of another, leaving almost no waste to pollute the environment or to degrade the resource base. Recycling of resources between biotic and abiotic components through various bio-geo-chemical processes occurs in independent IFS units similarly as in larger ecosystems. In the farming system through smaller unit, care is taken for recycling of the by-products from different enterprises. In the present experiment, the cropping enterprise generated by-products like straw. Straw was utilized for mushroom production. The spent mushroom subsequently converted to compost and nutrient and carbonaceous materials were returned back to the crop field. Paddy straw was an ideal substrate for growth of mushroom. Chandrashekar *et al.* (1994) reported

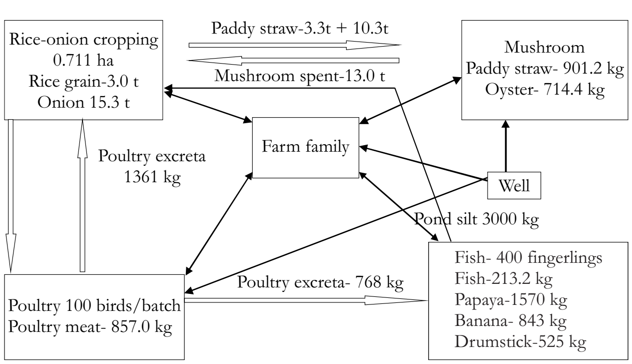

Fig. 1. Resource recycling in 0.8 ha IFS model with crop+fish+ poultry+mushroom integration

that the quality of mushroom grown on paddy straw was highly superior to the mushroom grown in any other substrate. The poultry excreta amounting to 768 kg was utilized in the fish pond for feeding to 400 poly culture fingerlings of IFS pond and surplus amount was utilized in the crop field. Application of excreta favoured the growth of phytoplankton, the primary producer in this recycling process. Ravishankar *et al.* (2007) found that the nutrient content of poultry manure increased manifolds after recycling into compost. The nutrients recycled from poultry and duckery were more in terms of plankton (256 litre^{-1}) development in the ponds for fish growth. Phytoplankton subsequently boosted the growth of zooplankton which served as food for fishes. Several authors have reported the role of poultry manure in enhancing production of phyto and zooplankton promoting growth of fish and ultimately giving higher fish productivity. Tank silt amounting to 3000 kg from the IFS model pond was desilted during summer after drying the pond and utilized in the crop field. The tank silt boosted the organic carbon and content of N, P and K of the soil and improved soil health. The surplus quantity of poultry droppings was converted to manure. Application of poultry compost improved soil health and gave higher yield. Integration of poultry+fish+cropping nourished with recycled poultry manure sustained the productivity of soil through the addition of tank silt (4500 kg in 1 ha model) with better NPK content (1.96, 0.45 and 0.62% N, P and K, respectively) having nutrient supply potential of 88, 20 and 27 kg of NPK, respectively (Jayanthi *et al.*, 2003). Verma and Bhagat (1994) observed that plant growth parameters and yield contributing characters were affected positively by the incorporation of poultry manure and FYM and thus resulted in the highest grain and straw yield of rice.

The water from the well was utilized for family consumption, mushroom unit, poultry unit and for recharging the farm pond at the time of need. The broken grains and rice bran were fed to poultry birds and fishes. In conventional cropping system, the crop residues, by-products and other wastes were not efficiently utilized.

Sustainability of Models

Rainfed agriculture is complex, diverse and risk prone. The SYI and SVI values were lower in rainfed systems as compared to pond based systems (Table 9). In rainfed systems, the SYI values varied from 0.07 to 0.12 in 0.8 ha. The SYI values in 0.8 ha pond based model varied from 0.75 to 0.88. The mean SYI and SVI values were 0.84 and 0.47, respectively, in pond based IFS model as compared to 0.10 and 0.03 in conventional cropping system. Solaiappan *et al.* (2007) got higher sustainability index for combination of enterprises compared to cropping alone for net returns. The SVI values varied from 0.01 to 0.05 in 0.8 ha rainfed farm.

Table: 9
Effect of cluster and source of water on SYI and SVI

Clusters	SYI		SVI	
	No pond	Pond	No pond	Pond
		0.8 ha IFS model		
Khajuripada	0.07	0.75	0.01	0.34
D.Sadar	0.11	0.88	0.04	0.52
Odapada	0.11	0.84	0.03	0.47
Golamunda	0.11	0.85	0.04	0.48
Narla	0.12	0.88	0.05	0.52
Mean	0.10	0.84	0.03	0.47

SYI - Sustainable Yield Index, SVI - Sustainable Value Index

The SVI values in 0.8 ha pond based model varied from 0.34 to 0.52. Thus on-farm water harvesting pond converted unsustainable rainfed farm to sustainable IFS model. In aberrant weather years, pond provided life saving irrigation during the period of partial dry spell and helped in growing of the second crop of onion during *rabi* and ancillary enterprises throughout the year.

4. CONCLUSIONS

In rainfed areas of Odisha, rice growing marginal farmers with average land holding of less than 1.0 ha should diversify compact patch of land to multi-enterprise farming system models to achieve higher productivity and profitability on sustainable basis and ensure food and nutritional security at household level. The 0.8 ha IFS model in rainfed tract of the state gave REY of 31.92 t, net return of ₹ 1,61,148, B:C of 1.82 and employment generation potential of 588 man-days yr^{-1} as compared to REY of 3.78 t, net return of ₹ 11,631, B:C of 1.37 and man-days yr^{-1} of 193 in conventional rice-green gram cropping system. The 0.8 ha IFS model provided recyclable by-products of 3.3 t paddy straw, 3000 kg tank silt, 2129 kg poultry excreta and 13 t mushroom spent for recycling in the system. The SYI and SVI values were 0.84 and 0.47, respectively, in pond based model as compared to 0.10 and 0.03 in conventional cropping system.

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