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Resource Recycling for Farm Productivity and Profitability in Integrated Farming System under Rainfed Situation in Odisha, India

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Authors' contributions

This work was carried out in collaboration among all authors. Authors HKS and BB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AP and BB managed the analyses of the study. Authors HKS and AP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out in 0.8 ha rainfed farm from April 2010 to March 2013 with two sources of water *i.e.* no pond/rainfed and pond/irrigated 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 0.8 ha Integrated Farming System (IFS) model farm recorded 31.92 q Rice Equivalent Yield (REY) which was 7.4 times higher productivity than conventional rice-greengram system. The net return in IFS model was Rs. 1,61,148/- as compared to Rs. 11,631/- in conventional rice-greengram cropping system. The recyclable wastes of 3.3 t paddy straw, 3000 kg pond silt, 2129 kg poultry excreta and 13 t mushroom spent in IFS model were used as input by other units. Due to efficient recycling of wastes, the productivity and profitability of IFS models were

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higher compared to conventional cropping system. Thus, almost no waste was left to pollute the environment or to degrade the resource base where as the wastes in conventional system were not utilized effectively.

Keywords: Productivity; profitability; recyclable waste; waste recycling.

1. INTRODUCTION

Integrated Farming System provide ways to recycle products and waste materials of one component as input through another linked component and reduce the cost of production of the products which will finally raise the total income of the farm. The farm wastes are better recycled for productive purposes. A judicious combination of agricultural enterprises like dairy, poultry, mushroom cultivation, piggery, fishery etc. suited to local agro-climatic conditions and socio- economic status of farmer would bring in prosperity to the farmers. Further, some of the wastes of these enterprises serve as valuable manure for recycling to the crop component within the system. In this system, waste materials are effectively utilized by linking complementary components and thus utilizing the byproducts as organic manures, which will ultimately improve the fertility status of the soil by averting pollution, reducing green house gas (GHG) emission and making the system climate smart. Thus, energy obtained from an IFS in various forms is much higher than energy input, as the by-products /wastes of these allied enterprises provide all the raw material and energy required for the food chain in another system. These complementarities when carefully chosen, keeping in view the soil and environmental conditions, usher in greater dividends (Rangasamy, 1999 [1]). 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

An investigation was carried out in 0.8 ha farm for three consecutive years from April, 2010 to March, 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, 84°24’ E Longitude, 20°26’ N Latitude and 476 m above mean sea level (AMSL) of Kandhamal district (North Eastern Ghats Zone), Dhenkanal Sadar (85°38’ E Longitude, 20°40’ N Latitude and 56 m AMSL) and Odapada (85°26’ E Longitude, 20°45’ N Latitude and 56 m AMSL) of Dhenkanal district (Mid Central Table Land Zone), Golamunda (83°01’ E Longitude, 19°49’ N Latitude and 254 m AMSL) and Narla (83°22’ E Longitude, 20°03’N Latitude and 254 m AMSL) of Kalahandi district (Western Undulating Zone) of Odisha. The soils of Khajuripada were sandy clay loam in texture and mostly acidic in reaction. The soils of Dhenkanal Sadar and Odapada were clay loam in texture with slightly acidic to slightly alkaline in soil reaction. The soils of Golamunda and Narla were heavy textured with textural class of clay and slightly acidic to slightly alkaline in reaction. 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-greengram under rainfed condition. On- farm water harvesting ponds of size 0.08 ha 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. Under rainfed condition without pond, rice - greengram 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. 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. The poultry droppings @ 40 kg/ha (3.2 kg for pond 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 [2]). 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 Rice Equivalent Yield (REY).

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.

3. STATISTICAL INTERPRETATION

The yields of rice grain and straw recorded during post harvest stage were compiled and analyzed statistically as per the standard procedure prescribed for factorial randomized block design (Gomez and Gomez, 1984) [3]. Standard error of mean value was computed in all cases, but critical difference values were worked out at 5% level of significance.

4. RESULTS AND DISCUSSION

4.1 System Productivity and Profitability

Over years, the trends for REY was Narla>Dhenkanal Sadar>Golamunda>Odapada>Khajuripada in 0.8 ha IFS model (Table 1). 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 2). The farming system constituting crop + dairy + poultry + fishery resulted in the highest system productivity of 123.75 t REY/ ha, 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) [4]. Gill et al. (2009) [5] 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 Rs. 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 Rs. 1,61,148 with B:C 1.82 as compared to Rs.11,631 with B:C ratio 1.37 in conventional rice-greengram cropping system. Ravisankar et al. (2007) [6] reported lesser cost of production with better productivity of each component integrated in the system increased the returns. Das et al. (2013) [7] 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. Goverdhan *et al.*, 2020 [8] reported that the IFS approach was better than traditional system in its contribution to productivity, profitability, economics and employment.

4.2 Recyclable Wastes

After harvest of fish every year, 3000 kg of pond silt was lifted from the pond of 0.8 ha IFS model (Table 3). 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) [9] 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 3rd year of experimentation. The year 2011-12 ranked the 2nd with excreta production of 2117 kg and year 2010-11ranked 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 for paddy straw mushroom and 562.5 kg /batch for oyster mushroom. The quantum of mushroom spent straw was higher than sum of straw and inputs because of addition of mycelia. Rangasamy (1999) [1] reported that inclusion of mushroom enterprise as one of the components in IFS with the production capacity of 2 kg/day 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.

4.3 Waste Recycling

The 0.8 ha IFS model gave 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. Due to efficient recycling of wastes, the productivity and profitability of IFS models were higher compared to conventional cropping system. Babalad and Hundekar (1999) [10] 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. Similar findings also reported by Vinodakumar et al., 2017 [11]. 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 byproducts 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) [12] reported 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) [5] found that the nutrient content of poultry manure increased manifolds after recycling into compost. The nutrients recycled from poultry and duckeries were more in terms of plankton (256/litre) 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

Table 1. Rice equivalent yield (REY) and economics of IFS farms in different clusters

Clusters	REY (t)	Net return (Rs.)	B:C
Khajuripada	15.55	65073	1.44
Dhenkanal Sadar	18.76	95423	1.65
Odapada	18.04	87063	1.58
Golamunda	18.12	88460	1.60
Narla	18.79	95929	1.69
CD(P=0.05)	0.82	8712	0.04

Table 2. 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 S x Y = 0.90	
Net Return (Rs.)			
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 S x Y = 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 S x Y = 0.04	

Table 3. Recyclable wastes in pond based integrated farming system model

Treatments	Paddy straw (t)	Poultry excreta (kg)	Mushroom spent (kg)	Pond silt (kg)
Years				
2010-11	3.12	2051	13021	3000
2011-12	3.30	2117	12944	3000
2012-13	3.42	2219	13103	3000
Mean	3.30	2129	13022	3000
CD (P=0.05)	0.05	11	40	NS
Clusters				
Khajuripada	3.03	2207	13043	3000
Dhenkanal Sadar	3.42	2117	13057	3000
Odapada	3.26	2016	13076	3000
Golamunda	3.10	2143	12965	3000
Narla	3.60	2161	12973	3000
CD (P=0.05)	0.06	14	52	NS

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) [13] and similar findings were also reported by Goverdhan et al., 2020 [14]. Verma and Bhagat (1994) [15] 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 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.

5. CONCLUSION

In the crop-fish-poultry-mushroom based Integrated farming system model, the waste materials of one enterprise was used as input for another enterprise resulting in decreased environmental pollution. No waste material was left for green house gas (GHG) emission to the atmosphere. The demand for external inputs decreased. This led to reduced cost of cultivation and enhanced rice farm profitability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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