Indian Journal of Agricultural Sciences **91** (1): 44–8, January 2021/Article

Impact of integrated farming system on residue recycling, nutrient budgeting and soil health

VENKATESH PARAMESH*, E B CHAKURKAR, TEJASVI BHAGAT, G B SREEKANTH, H B CHETAN KUMAR, SOLOMON RAJKUMAR, P P GOKULDAS, GOPAL R MAHAJAN, K K MANOHARA and N RAVISANKAR

ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa 403 402, India

Received: 6 November 2019; Accepted: 4 December 2020

ABSTRACT

In this study, the effects of integrated farming system on residue recycling and soil quality in rice-based integrated farming systems have been examined. The effective nutrient budget for nitrogen was found higher with rice-fish-poultry-cowpea and the negative values were obtained for rice-chili and rice-baby corn systems. However, the effective budgets for phosphorus and potassium were negative in all these cropping systems. The results indicated that, about ten tonnes of organic matter was recycled, and the major share was from the dairy unit (~52%) in the form of dung and cow urine. Total internal nutrient supply due to recycling was estimated at 55 kg of nitrogen, 17 kg phosphorus and 76 kg of potassium, which is equivalent to 118 kg urea, 106 kg single super phosphate and 126 kg muriate of potash, thus reduction in cost of inputs. In the rice+fish+poultry-cowpea system, the indices of soil quality showed higher values, which indicated the improvement in soil fertility due to availability of poultry manure, plankton production, and the continuous fish activity. The current study confirmed that available N, DHA, Zn, B and Fe as the key indicators of soil quality under humid tropics of west coast India, which greatly influence the soil functions and soil productivity. The study conclusively reveals that integration of dairy, fishery, poultry components with diversified cropping systems in coastal lowland ecosystem is essential to improve the nutrient use efficiency and for enrichment of soil fertility.

Key words: Composting, Farming system, Goa, Lowland, Nutrient dynamics

The integrated farming system (IFS) offers various benefits, they guarantee high production with nutritional security, diversifying the farmer's income and, preserving the natural resources, and provides climatic and economic resilience of the agricultural production system (Paramesh *et al.* 2019). IFS enhance nutrient recycling and food production per unit of area and inputs, by promoting greater efficiency of fertilizers and natural resources. This is mainly due to the presence of the animal and fish components, which modifies the nutrient fluxes in the soil, plant and atmosphere interface. Soil is the main centralizing compartment of the several synergic processes that occur in the agroecosystem. While the different agricultural production systems incorporate nutrients and energy, the animals act as catalysts by introducing variability and new pathways of nutrient and water flows (Paramesh *et al.* 2020). The extent to which the processes and nutrient fluxes are affected will depend on the type of crops in the cropping system, crop nutrient management, and livestock component. Crop rotation is another important factor to consider in the diversification of integrated farming system (IFS) arrangements, since it allows the introduction of plants with different nutritional requirements and root structure, which can increase the nutrient cycling and reduce nutrient losses (Tiecher *et al.* 2017), as well improve soil quality (Karlen *et al.* 2006). In this context, inclusion of crops like cowpea, moong, baby corn and chili in rotation after rice is an important strategy to obtain the benefits of crop rotation, mainly because they present different production potentials, root systems, and waste inputs.

Studies on significance of IFS on nutrient recycling and soil quality are still scarce in west coast of India. However, they are very essential in order to know the changes in the dynamics of nutrient fluxes, and subsequently in the soil health, affected by the livestock and agricultural systems. Thus, the present study was carried out with the objective of evaluating the impact of the integrated crop-livestock system on the soil quality indicators and to assess the nutrient budget in an alfisol, conducted for 3 years (2015-2018) under lowland situation of west coast India.

MATERIALS AND METHODS

Experimental site and details: The study was undertaken as a part of All India Coordinated Research Project on

*Corresponding author e-mail: parameshagron@gmail.com

Integrated Farming System, under lowland ecology at ICAR-Central Coastal Agricultural Research Institute, Old Goa, and Goa, India. The period of observations was from 2015–18 to assess the effect of different components in rice-based MFS. The IFS model was established in a 0.5 ha area with components like rice-based cropping systems such as rice-cowpea, rice-moong, rice-baby corn, and rice-chili. The animal component includes dairy, fishery, and poultry with boundary plantation of banana, papaya and forage crops and a small kitchen garden. All the crop residues were incorporated *in situ* after the harvest. The appropriate package of practices was followed as per the crop requirement for rice, cowpea, moong, baby corn, and chili.

Nutrient budget and Analysis of soil, manures, and effluents: In order to calculate the nutrient budget, all inputs of nutrients (NPK) via fertilizers and farmyard manure (FYM) and all exits exported by grains (crop uptake) were quantified. The soil nutrient budget was computed considering the initial and final soil contents, using the available N, P, and K for the 0–15 cm soil layer. Soil samples were collected from the field after the completion of each sequence and analysis was carried out. The soil bulk density (BD) was determined by core method and Modified Walkey and Black method was followed to estimate the soil organic carbon (SOC). Soil nutrient analysis was done using standard procedures. The soil microbial parameters such as microbial biomass carbon (MBC), basal soil respiration (BSR) dehydrogenase activity (DHA), phosphatase (PHT) and urease activity were also measured using standard protocols. The dairy effluents, cow shed waste, and farmyard manure (FYM) were analysed at regular intervals using standard procedures. Soil quality index was developed by non-linear programming method using different physical, chemical, and biological soil properties.

Carbon stock: The soil sample was collected from different cropping systems in five replications at 0–15 cm soil depth. The soil samples were analysed for SOC and BD was determined using core sampler. The carbon stock (Mg C/ha) from 0-15 cm soil depth was estimated using the following equation.

$$\text{Carbon stock (Mg C/ha)} - \text{SOC (\%)} \times \text{BD (Mg/m}^3) \times \text{Soil depth (cm)} \quad (1)$$

Statistical analysis: The effect of different cropping systems on the soil properties and SQI was subjected to analysis of variance (ANOVA) using a randomized block design in SAS package. The results were tested at 5 percent level of significance.

RESULTS AND DISCUSSION

Nutrient budget: The soil nutrient budget for N was found higher for rice-fish-poultry-cowpea cropping system followed by rice-moong and rice-cowpea, the similar trend has been observed for soil nutrient budget for P (Table 1). The lower values of soil nutrient budget for N and P were noticed with rice-chili and rice-baby corn systems. This is mainly due to because of exhaustive nature of baby corn and chili crops than cowpea and moong. The nitrogen fixation capability of cowpea and moong improved the soil N budget compared to chili and baby corn systems. Similarly, the soil nutrient budget for K was found lower with rice-chilli and rice-baby corn systems. This trend is mainly attributed to low cation exchange capacity of the lateritic soil coupled with higher K uptake of baby corn and chilli systems. The effective nutrient budget for N was found higher with rice-fish-poultry-cowpea system followed by rice-moong and rice-cowpea and the negative values were noticed with rice-chili and rice-baby corn systems. However, the effective budget was found negative for P and K in all the cropping system. In general, the nutrients budget was more affected by the amount of nutrient uptake by crops and quantity of nutrients applied.

Nutrient recycling potential of the system: The residue from cowpea and moong, FYM and cow urine were found rich in nitrogen (Table 2). The higher P concentration was observed in fish pond effluent followed by moong residue and the higher K concentration was observed in rice straw, cowpea residue and moong residue. The cow urine and cowshed effluent were directly used in the kitchen garden, fodder unit, and in the main field as a nutrient supplement. From the unit, on an average 10 t of organic material was

Table 1 Budget of available N, P and K, for the 0–15 cm soil layer comparing the effect of crop systems after 3 years in an integrated crop-livestock system experiment

Cropping system	Initial Soil 2015	Input (kg)	Output (kg)	Final Soil 2018	Soil budget	Effective budget
Nitrogen						
Rice-Baby corn	134.9	39.8	33.1	129.5	-5.4	-12.1
Rice-Chili	134.9	45.0	37.1	117.8	-17.1	-25.0
Rice-Cowpea	134.9	30.7	24.3	142.8	7.9	1.5
Rice-Moong	134.9	30.3	24.1	154.6	19.7	13.5
Rice-Fish-Cowpea	134.9	23.8	18.3	164.9	30.0	24.4
Phosphorus						
Rice-Baby corn	12.9	18.2	2.9	13.9	1.0	-14.4
Rice-Chili	12.9	20.3	3.5	11.1	-1.8	-18.6
Rice-Cowpea	12.9	18.4	2.3	14.5	1.6	-14.6
Rice-Moong	12.9	18.2	2.1	16.2	3.3	-12.8
Rice-Fish-Cowpea	12.9	10.4	4.3	16.9	4.0	-2.1
Potassium						
Rice-Baby corn	158	39.8	26.3	99.5	-35.4	-29.2
Rice-Chili	158	45.0	26.9	89.3	-45.6	-39.6
Rice-Cowpea	158	30.7	18.0	112.8	-22.1	-20.3
Rice-Moong	158	30.3	17.5	119.2	-15.7	-14.4
Rice-Fish-Cowpea	158	23.8	16.6	130.4	-4.5	-3.2

Table 2 Nutrient concentration in different residues and effluents and soil quality parameters as influenced by different cropping systems

Cropping system	pH	SOC	BD	N	P	K	B	Cu	Zn	Fe	Mn	MBC	BSR	DHA	PHT	Urease	CS
Rice-Baby corn	5.53	0.94	1.31	129.5	13.9	99.5	1.38	5.53	11.7	49.4	38.8	189.0	43.6	169.8	267.5	2.8	18.5
Rice-Chili	5.57	0.87	1.33	117.8	11.1	89.3	1.46	5.54	12.2	50.5	37.1	167.2	51.2	112.0	322.2	1.9	17.3
Rice-Cowpea	5.73	1.20	1.26	142.8	14.5	112.8	1.45	5.87	11.6	51.2	46.4	316.4	43.7	222.8	341.0	2.9	22.7
Rice-Moong	5.68	1.16	1.24	154.6	16.2	119.2	1.45	6.21	11.3	50.4	49.0	300.6	37.3	220.5	363.4	3.2	21.5
Rice-fish-cowpea	5.85	1.26	1.23	164.9	16.9	130.4	1.46	6.34	12.2	51.2	48.5	377.6	40.8	267.2	418.0	4.1	23.2
SEM±	0.07	0.03	0.02	3.21	0.32	1.86	0.05	0.33	1.5	1.5	1.7	12.1	1.4	6.5	9.6	0.1	0.67
CD (P=0.05)	0.20	0.10	0.06	9.61	0.95	5.59	0.14	0.98	4.4	4.6	5.2	36.3	4.1	19.6	28.9	0.3	2.00

Nutrient				*Nutrients percent*				*mg/l*	*Total (kg)*
	Residue/ by-product	*Rice straw*	*Cowpea residue*	*Moong residue*	*Baby corn Stover*	*Farmyard manure*	*Fish pond silt*	*Cow urine*	*Cowshed effluent*
N	0.29	0.69	0.72	0.26	0.53	0.47	1.15	155	
P	0.12	0.21	0.25	0.11	0.22	0.33	0.16	0.9	
K	1.2	1.6	1.35	0.68	0.66	0.57	0.09	6	
Amount of nutrients recycled in the system (kg)									
N	8.4	2.2	2.0	3.1	17.4	0.6	21.0	0.02	54.8
P	3.5	0.7	0.7	1.3	7.2	0.4	2.9	0.00	16.7
K	34.8	5.2	3.7	8.2	21.7	0.7	1.6	0.01	76.0

Note: SOC, soil organic carbon (%); BD, bulk density (kg/m^3); N, P, K: available nitrogen, phosphorus, potassium (kg/ha); Zn, Fe, Cu, Mn, B: zinc, iron, copper, manganese, boron (mg/g); MBC, microbial biomass carbon ((ug/g soil)); BSR, basal soil respiration (µg CO_2 evolved/g/day); DHA, dehydrogenase activity (mg TPF/h/g); PHT, Phosphatase (µg/g/h); CS, Carbon stock, (Mg C/ha).

recycled, and dairy unit alone contributed nearly 52 % of organics to the system. About 4.8 t of dry biomass from different cropping systems were also recycled through composting, mulching and as dry fodder to feed the dairy animals. About 55 kg of N, 17 kg P and 76 kg of K were recycled, which reduced the use of synthetic fertilizers and thereby the cost of fertilisation. The integration of crops with livestock can enhance the residue and nutrient cycling and sustainable utilization of available resources, as also argued in Petersen *et al.* (2007) and Watson *et al.* (2005). The nature and quantity of biomass produced in the IFS coupled with the suitability of the crops and livestock to the local climate results in increased availability of residue for recycling. Walia and Kaur (2013) reported the significance of the application of livestock manure to improve soil organic matter, water infiltration rate, and water holding capacity in IFS.

Soil quality (SQ): Cropping systems had a significant effect on all the tested soil quality parameters (Table 2). Significantly higher soil *p*H, SOC, soil available NPK, soil microbial properties such as MBC, DHA, PHT and urease were observed in the rice-fish-cowpea cropping system, and the least values were noticed with the rice-chili system. All the soil parameters were considered for PCA with varimax rotation. N, DHA B, Zn, and Fe was selected as MDS. We have used non-linear and weighted additive soil quality indexing method to understand the effects of treatments on the SQ in the present investigation. The SQ was affected significantly ($P<0.01$) due to different cropping systems. The SQI of different cropping systems were in the order of rice-fish-cowpea < rice-moong < rice-cowpea < rice-baby corn < rice-chili with a value of 0.91, 0.75, 0.69, 0.37 and 0.19, respectively. The rice-fish-cowpea cropping systems exhibited 79% increase in SQI in the system over the rice-chili system. The increase in soil chemical and biological properties in the rice-fish-cowpea system might be due to continuous movement and churning of soil by the fish and addition of faecal matter in the pond by poultry birds (Nayak *et al.* 2018). The increase in microbial activity and SOC might be due to the loading of organic matters (fish and poultry droppings) and faster decomposition of organic residues (root and remaining rice straw) in the integrated fields. In all the cropping system, the SOC was enhanced, except in rice-chili system, showing exhaustive nature of the chili crop. The soil carbon stock also improved significantly in the rice-fish-cowpea system over other cropping systems. It is mainly due to higher SOC and lower BD in the soil. The rice-fish culture has not only improved the SOC but also reduced the soil BD considerably. The increased soil carbon stock in rice-fish-cowpea system can be attributed to factors like reduced soil temperatures, slow decomposition rate of organic matter, type of land use practices and continuous *in situ* root decay of rice and cowpea (Manjunath *et al.* 2018). The study has clearly indicated that under humid tropics of west coast India, available N, DHA, Zn, B and Fe as the key indicators of soil quality (SQ) which greatly influence the soil functions and overall soil health.

Integrated crop-livestock systems involving cereals, pulses, vegetables integrated with dairy, poultry and fishery were found more efficient in the use of nutrients, thus making the effective nutrient budget less negative over time. Furthermore, rice-based lowland IFS is found to be efficient in terms of soil fertility, and soil carbon stock. Further, with an increase in nutrient recycling under rice+fish+poultry-cowpea systems, the use of chemical fertilizer can be reduced substantially. The improvement in soil nutrient dynamics in integrated farming indicates eco-friendly and sustainable farming system. Thus, the results obtained in the present study demonstrate that when integrated crop-livestock production systems are well planned, using appropriate crop rotations and in integration with livestock component they will improve the nutrient recycling and improve the soil quality.

REFERENCES

Bhatt B P and Bujarbaruah K M. 2007. Intensive integrated farming system: A sustainable approach of land use in Eastern Himalaya. (*In*) *Shaping Agrarian Prosperity through Integrated Intensive Farming*. ICAR Research Complex for NEH Region, Umiam, Meghalaya.

Chinnadurai C, Gopalaswamy G and Balachandar D. 2014. Long term effects of nutrient management regimes on abundance of bacterial genes and soil biochemical processes for fertility sustainability in a semi-arid tropical Alfisol. *Geoderma* **232**: 563–72.

Karlen D L, Hurley E G, Andrews S S, Cambardella C A, Meek D W, Duffy M D and Mallarino A P. 2006. Crop rotation effects on soil quality at three northern corn/soybean belt locations. *Agronomy Journal* **98**(3): 484–95.

Manjunath B L, Paramesh V, Mahajan G R, Reddy K V, Das B and Singh N P. 2018. A five years study on the selection of rice based cropping systems in Goa, for west coast region of India. *Journal of Environmental Biology* **39**: 393–99.

Nayak P K, Nayak A K, Panda B B, Lal B, Gautam P, Poonam A, Shahid M, Tripathi R, Kumar U and Mohapatra S D. 2018. Ecological mechanism and diversity in rice based integrated farming system. *Ecological Indicators* **91**: 359–75.

Petersen S O, Sommer S G, Béline F, Burton C, Dach J, Dourmad J Y, Leip A, Misselbrook T, Nicholson F, Poulsen H D, Provolo G, Sørensen P, Vinnerås B, Weiske A, Bernal M P, Böhm R, Juhász C and Mihelic R. 2007. Recycling of livestock manure in a whole-farm perspective. *Livestock Science* **112**: 180–91.

Teng Q, Hu X F, Cheng C, Luo Z, Luo F, Xue Y, Jiang Y, Mu Z, Liu L and Yang M. 2016. Ecological effects of rice-duck integrated farming on soil fertility and weed and pest control. *Journal of soils sediments* **16:** 2395–2407.

Thomas D, Zerbini E, Parthasarathy Rao P and Vaidyanathan A. 2002. Increasing animal productivity on small mixed farms in South Asia: a systems perspective. *Agricultural Systems* **71**: 41–57.

Tiecher T, Calegari A, Caner L and Rheinheimer D S. 2017. Soil fertility and nutrient budget after 23-years of different soil tillage systems and winter cover crops in a subtropical Oxisol. *Geoderma* **308**: 78-85.

Varughese K and Mathew T. 2009. Integrated farming systems for sustainability in coastal ecosystem. *Indian Journal of Agronomy* **54**(2): 120–7.

Walia S S and Kaur N. 2013. Integrated farming system-an ecofriendly approach for sustainable agricultural environment—a review. *Greener Journal of Agronomy, Forestry and Horticulture* **1**: 1–11.

Watson C A, Oborn I, Eriksen J and Edwards A C. 2005. Perspectives on nutrient management in mixed farming systems. *Soil Use Management* **21**: 132–140.

Paramesh V, Parajuli R, Chakurkar E B, Sreekanth G B, Chetan Kumar H B, Gokuldas P P, Mahajan G R, Manohara K K, Reddy K V and Ravisankar N. 2019. Sustainability, energy budgeting, and life cycle assessment of crop-dairy-fish-poultry mixed farming system for coastal lowlands under humid tropic condition of India. *Energy* **188**: 116101.

Paramesh V, Sreekanth G B, Chakurkar E B, Chethan Kumar H B, Gokuldas P P, Manohara K K, Mahajan G R, Rajkumar R S, Ravisankar N, Panwar A S. 2020. Ecosystem network analysis in a smallholder integrated crop–livestock system for coastal lowland situation in tropical humid conditions of India. *Sustainability* **12**(12): 5017.