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Long Term Fertilizer Management Effect on Nutrient Dynamics in Rainfed Rice-lentil System in Transect 4 of IndoGangetic Plain

Jitendra Kumar[1], Nirmal De[1*], R. S. Meena[1], Pallab Sharma[2], A. K. Pradhan[3] and G. Ravindra Chari[4]

[1]Institute of agricultural Science, Banaras Hindu University, India.
[2]Bishwanath College of Agriculture, Assam Agriculture Univercity, India.
[3]S. G. College of Agriculture, Jagdalpur, Indira Gandhi Krishi Vishwavidhalaya, India.
[4]AICRP on Dry Land Agriculture, CRIDA, Hyderabad, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study analyzed the effect of different organic and inorganic fertilizers on soil nutrient dynamics in a long-term field experiment under rainfed rice-lentil system. The experiment was operative at Agricultural Research Farm, Institute of Agricultural Sciences, B.H.U Varanasi, Uttar Pradesh, India. Carbon dynamics was investigated on surface soil on the basis of distribution of Walkley & Black Carbon, in active pool (AP) or labile carbon (oxidisable at low concentration of H_2SO_4) in relation to passive pool (PP) or non labile carbon (oxidisable at high concentration of H_2SO_4) and its indices carbon management index (CMI). The effect of eight different treatments including unfertilized, 100% N from farm yard manure, 100% recommended dose of fertilizer, 50% RDF + 50% N Foliar), 50% RDF, 50% RDF + 50% N FYM), 50% N FYM and Farmers practices *i.e.* application of 20kg N ha^{-1} The availability & uptake of major nutrients were studied. The results revealed: That mixed application of inorganic fertilizers and FYM substantially increase the soil

Corresponding author: E-mail: nirmalde.soil@bhu.ac.in;

organic carbon pool, sustainability index over remaining treatments. Higher fertilizer application rates resulted in higher and sustained crop yields which had been reflected in sustainability yield index. A significant Pearson correlation was found between SOC, AP, PP, exchangeable K_2O content, soil microbial biomass carbon and SYI. (The result indicated to adopt conjunctive use of nutrient management which promote the SOC more labile and, induce availability of other nutrients coupled with SMBC that translate into higher crop yields.

Keywords: Labile carbon; sustainability yield index; carbon management index; active pool and passive pool.

1. INTRODUCTION

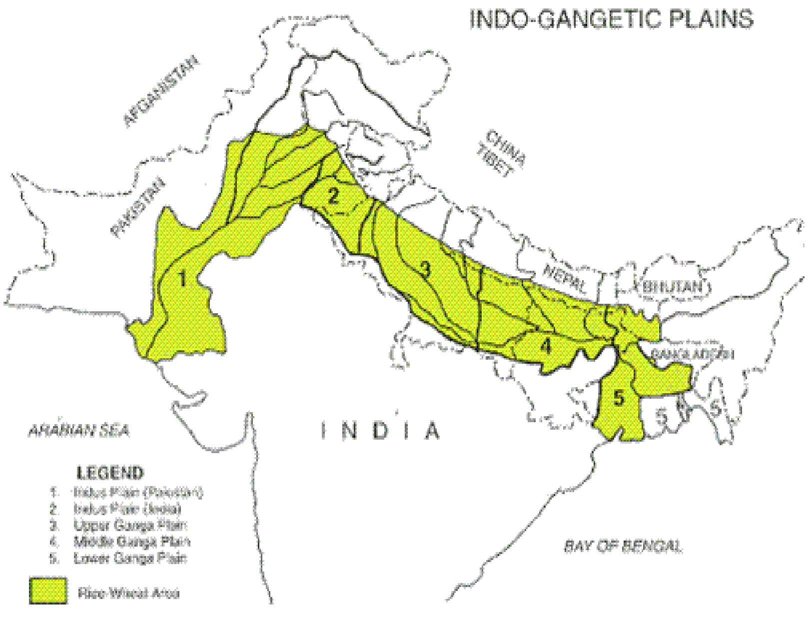
Rainfed agriculture occupies about 51 percent of country's net sown area and accounts for nearly 40 percent of the total food production. Rainfed agriculture is complex, highly diverse and risk prone. The soils of these areas have an inherent low stock of soil organic carbon (C) on contrary these soils contain a significant amount of inorganic C, of a persistent nature, mainly present in the form of soil carbonates [1]. Given the almost nonexistent chance for expanding irrigation in most rainfed agro ecosystems, other ways of land use optimization need to be identified [2].

Soil organic carbon (SOC) dynamics play a major role in intensive agricultural and natural ecosystem. Pools of SOC are dynamic on time scales that can range from decades to millennium [3]. The factors controlling the rates and processes for SOC accumulation and loss include climate, topographic position, parent material, potential biota, time, and human activity; these are also the factors that govern soil formation in general. For soils and from a geographical perspective, a change in any of these state factors leads to a different SOC mass balance [3]. The proper management of this Soil C pool should make it possible to increase the efficiency of use of both soil and fertilizer nutrients. Management induced changes in total soil organic carbon (TSOC) are not easy to detect as its changes occur slowly and are relatively small because of large background levels and natural variability [4]. However, intensive cultivation could alter the dynamics of labile and active organic C pools in soil [5]. Total organic C in soil is comprised of several dynamic pools, broadly grouped as labile pool or active pool, slow pool and passive recalcitrant pool. The labile pools consist of soil microbial biomass C, water soluble C, water soluble carbohydrates etc. [6]. These pools have been used as sensitive indicators for judging C dynamics in soil in short to medium term basis [7,8], and for this reason it can be used as an indicator of management quality and agriculture sustainability [9]. Proposed a C management index (CMI) the passive pools are comparatively more stable than labile pool and are slowly decomposable having a larger turnover period. So, instead of quantification of passive or slow C pools, C management index (CMI) derived by integrating labile and non-labile C fractions have been recently used as an indicator for C and nutrient dynamics and soil quality in response to soil management practices [10,11,12]. In the present study, we assessed the impact of nutrient management practices involving the application of inorganic fertilizers along with FYM for 12 years on CMI and changes in soil C pools in rice–Lentil system.

2. MATERIALS AND METHOD

The experiment was carried out in rainfed condition at Agricultural Research Farm, Institute of Agricultural Sciences, B.H.U Varanasi (82.52ºE longitude and 25.10ºN latitude and 76.19 m above mean sea level), the experiment was started in 1984 Uttar Pradesh, In the present study data from 2006 to 2017 were analyzed and interpreted. The soil of the transect 4 of the Gangetic plain region is alluvial *Typic Ustochrept* (Soil taxonomy of USDA, 1999) with particle composition of (Clay 32% Silt 12% Sand 56%). Selected soil properties were measured at the start of the experiment.

The annual average precipitation was 1080 mm with nearly all occurring between June and September and the annual average temperature was 26.1°C. The experiment utilized the Randomized block design. There were eight treatments and the experimental area was 0.40 ha. Each plot was 10 m x 10 m (Length X Width).



Map 1.

Table 1. Characteristics of the 0–15cm layers of the soil at the beginning (2006) of the experiment plot, Varanasi, India

Soil Parameters	Value
pH (1:2)	7.8
EC (dS/M)	0.22
CaCO3 (%)	5.6
Organic carbon (%)	0.33
Available N (kg/ha)	118
Available P (kg/ha)	16.12
Ammonium acetate extractable K (kg/ha)	139.3
CaCl2 extractable S (mg/kg)	16
Exchangeable Ca(meq/100 g)	3.6
Echangeable Mg (meq/100 g)	1.6

Soil samples were collected from the top soil layer of each plot once a year after the rice crop harvested, samples were mixed to make composite sample by quartering method for each field replicates. Soil samples were stored in refrigerator (4°C) for measurement of soil microbial biomass carbon (SMBC).Slow pool of organic C, i.e., Walkley and Black oxidizable carbon (WBC) content was determined by wet digestion method [13]. Different fractions of soil organic Carbon (SOC) were determined under an increasing gradient of oxidizing condition using three sulphuric acid concentration aqueous solution ratio of 0.5:1, 1:1 and 2:1 respectively [14]. The amount of carbon thus estimated leads to partition of SOC into the following four different organic carbon pools of decreasing oxidisability. Fraction I (very labile): organic carbon oxidisable under 0.5:1 H_2SO_4 Fraction II (labile): The difference in carbon oxidisable under 1:1 and 0.5:1 H_2SO_4 Fraction III (less labile): the difference in carbon oxidisable under 2:1 and 1:1 H_2SO_4 Fraction IV (non-labile): the difference between Soil organic Carbon and carbon oxidisable under 2:1 H_2SO_4 . Active pool of organic carbon was computed by adding fraction I and fraction II, whereas, passive pool of organic carbon was determined by addition of fraction 3 and fraction 4. Active pool of organic carbon represents amount of organic carbon present in easily oxidisable form in soil. Whereas, passive pool of organic carbon is resistant to decomposition. The other soil nutrient viz., potassium permanganate oxidizable soil N (KMnO4-N) [15], available phosphorus [16], available potassium [17], of soil was estimated standard techniques.

2.1 Carbon Management Index

The CMI was estimated by using the empirical equation given by Blair et al. [9],

$$\mathrm{CMI} = \mathrm{CPI} \times \mathrm{LI} \times 100 \quad (1)$$

Where, CPI is the C pool index and LI is the lability index. The CPI and the LI were estimated as follows,

$$\mathrm{CPI} = \mathrm{Total\ soil\ organic\ C\ in\ treated\ \ ample/Total\ soil\ organic\ C\ in\ the\ control} \quad (2)$$

Where Total Soil Organic Carbon is Walkley Black carbon (SOC)

$$\mathrm{LI} = \mathrm{Lability\ of\ C\ in\ treated\ sample/Lability\ of\ C\ in\ the\ control;} \quad (3)$$

Where, Lability of C (L) = C $\mathrm{Fraction\ I\ (very\ labile): organic\ carbon\ oxidisable\ under\ 12.0\ N\ H2SO4} +$ $\mathrm{Fraction\ II\ (labile): the\ difference\ in\ carbon\ oxidisable\ under\ 18.0\ N\ and\ 12.0\ N\ H2SO4)/}$ $\mathrm{III\ (less\ labile): the\ difference\ in\ carbon\ oxidisable\ under\ 24.0\ N\ and\ 18.0\ N\ H2SO4\ Fraction\ IV\ (non} -$ $\mathrm{labile): the\ difference\ between\ SOC\ and\ carbon\ oxidisable\ under\ 24.0\ N\ H2SO4;}$ (4)

2.2 Sustainable Yield Index

The sustainable yield index (SYI) [18] was estimated as

$$\mathrm{SYI} = \mathrm{Y} - \mathrm{sd/Ymax} \quad (5)$$

Where, Y is the average yield of rice over year, and sd refers to the standard deviation from mean and Ymax is the observed maximum yield in the experiment.

2.3 Statistical Analysis

All ANOVA, regression, and multivariate analyses were conducted in SAS 9.3. Treatments were analyzed by one-way ANOVA and significant differences between means were judged by Duncan's Multiple Range test Pearson's correlations matrix was used to evaluate the relationships between different pools of organic C.

3. RESULTS AND DISCUSSION

3.1 Sustainable Yield Index and Yield

The fertilizers application alone or in combination with FYM was substantially increased in the yield of the rice over time in all the treatments, moreover the yield obtained from treated plot was significantly higher than control (no fertilizer) and farmers practices (20 kg ha^{-1}) over time domain. The highest increase of yield was recorded in 100% N through Farm yard Manure (FYM) followed by T_6 conjunctive use of fertilizer of inorganic fertilizer 50% and FYM 50% and which obviously inorganic fertilizer increase the crop yield (Fig. 1).This obviously indicate with progression of the years of cultivation the confirm effect of inorganic + FYM was more effective for yield increase [19,20,21].

Sustainable yield index as a quantitative measure to assess sustainability of an agricultural system and is the derivative of actual yield over years. SYI values were higher in 100% FYM, 50% RDF + FYM treatments compared with other treatment (Fig. 1). The 100% FYM treated plot and conjunctive use of fertilizer of inorganic fertilizer 50% and FYM 50% showed SYI value higher than 0.6 that indicating that the yield of these treatments was sustainable. Lowest SYI value was recorded in farmer's practices followed by control. Higher value of SYI in the FYM indicating better soil health in terms of supplying providing nutrients and better soil physical environment.

3.2 Soil Organic Carbon

The SOC content of soil varied from 3.03 ± 0.02 to 4.77 ± 0.02 g Kg^{-1} under different nutrient management treatments at top soil layer (Table 2). Applications of FYM and FYM + RDF significantly increased the SOC over control and farmers practices. The highest was maintained in 100% (N) FYM. and in 50%(N) FYM +50% RDF. Higher SOC concentrations in FYM and FYM

+RDF fertilized plots compared to control and farmers practices on surface soil resulted for greater input of root and shoot biomass from FYM as well as from the growing crops. Higher yield and associated greater amount of root residues and higher rhizosphere activities resulted in significantly greater SOC in FYM and FYM+RDF Plot. The results were consistent with many other earlier studies [5,22,23]. Superiority of FYM in increasing SOC content in soils could be explained as the higher content of lignin and phenol in FYM, which aggravated formation of stable C complexes with proteins of plant origin [24]. Though average. Similar effects on soil organic C were reported in long term experiments at Rothamsted (UK) and other places [25,26].

3.3 Organic Carbon Fractions of Different Degree of Oxidisability

Highest value of oxidisable fraction in C found in 50% N through FYM followed by 50%RDF+50% (N) FYM followed by 100% (N) FYM treatment respectively 57, 57 and 52% increase over control treatment indicating that application of FYM alone or combination with fertilizer considerably increase the highly oxidisable C fraction. The highest value of Fraction II C was found in the treatment comprising 50% RDF + 50%(N) FYM (Table.2) followed by 100% (N) FYM and 50% (N) FYM the more oxidisable carbon over control was found in the treatment comprising FYM i.e 100% (N) FYM and 50% (N) FYM and the remaining treatment showing decrease in oxisable carbon fraction compare to the control. The less labile carbon had a different kind of pattern and it was found that the highest value (0.154±0.010) was found in the 50% RDF and lowest in the control. The non labile Carbon fraction IV was highest in 50% (N) FYM +50%RDF (0.149±0.008) followed by 100% (N) FYM and (0.135 ±0.035) owing to the highest SOC in these treatment. Considerable variation was also found in the active and passive pool of soil organic carbon as a result of variation of management module induces differences among different carbon fraction.

3.4 Carbon Management Index

CMI value was calculated to obtain indications of the C dynamics of the system and provide an integrated measure for quantity and quality of SOC [9]. Soils with higher CMI values are considered as better managed [27]. We found that CMI values of 100% (N) FYM (206.94) was more than double over control (100) followed by the 50%RDF+ 50% FYM(149.8) and 50% FYM (141.65)(Table 3) lowest was recorded in farmers practice that indicating that need to improve the soil management practices. The value itself is not important but the differences reflect how different treatments are affecting the systems [9] (Blair et al. 1995). The regular addition of organic matter in case of FYM addition proved increased potential to increase the CMI by increased inputs and lower losses [28], Similarly, [29] showed that long term balanced fertilization (organic amendments combined with chemical fertilizers) significantly enhanced CMI over chemical fertilizer alone under both maize-wheat and rice-wheat systems. Application of FYM with 100% dose resulting in increased of Lability Index (LI) over control there was negligible increase in LI in 100% RDF treatment and remaining all the treatment there was less LI values compare to the control. Carbon management index is a cumulative index that can be effectively used as a sensitive indicator in C dynamics study in

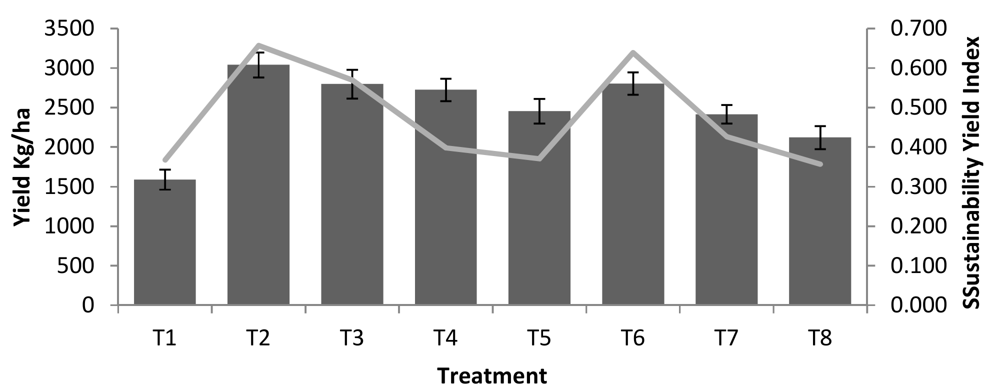


Fig. 1. Yield and sustainable yield index of paddy as affected by conjunctive use of fertilizer

response to nutrient management [11,30]. If the value of CMI is greater than 100, then management practices is considered sustainable and impart good soil quality [9].

3.5 Nutrient Dynamics

The exchangeable K_2O (AK) was significantly affected by the conjunctive use of nutrient. The highest AK was recorded under 100% N through FYM (Fig. 2) followed by 100% RDF *i.e* all the Nutrient was supplied through the said treatment inorganic Fertilizers. The AK content was higher where treatment FYM alone or combination with inorganic fertilizer as compare to only inorganic fertilizer. The increment was due to higher solubilization of K from non-exchangeable sources and increase and due to addition of FYM [31].

Alkaline KMnO4-N at surface soil was significantly higher in all treatments as compared to control (Fig. 2).. Availability of N was also increased in 100% FYM plot (232 kg ha^{-1}) in comparison to the control 106 kg ha^{-1}). As incorporation of FYM enhanced N status by to gradual build up of SOC [32] with time.

Available P was varied from 8.9 to 16.9 $kgha^{-1}$(Fig..3). At surface soil layer (0-15cm), 100% FYM maintained significantly higher P level (16.9.5 kg ha^{-1}) followed by 100% NPK. The lowest available P was recorded in unfertilized plot. A significant build up of available P was noted in soil under conjunctive use of nutrients. Application of 100% NPK + FYM had greater influence on availability of AP which was reported by Moharana et al. [7].

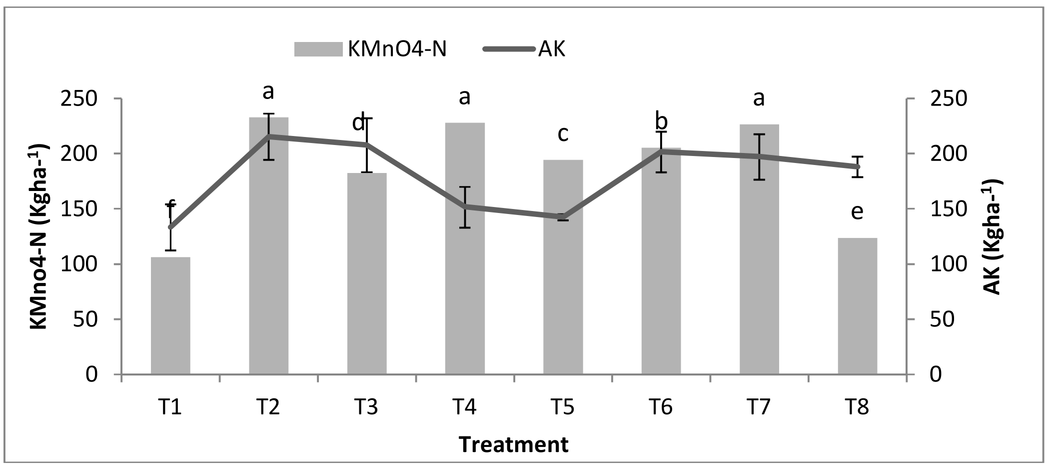


Fig. 2. Available nitrogen and potassium as affected by fertilizer

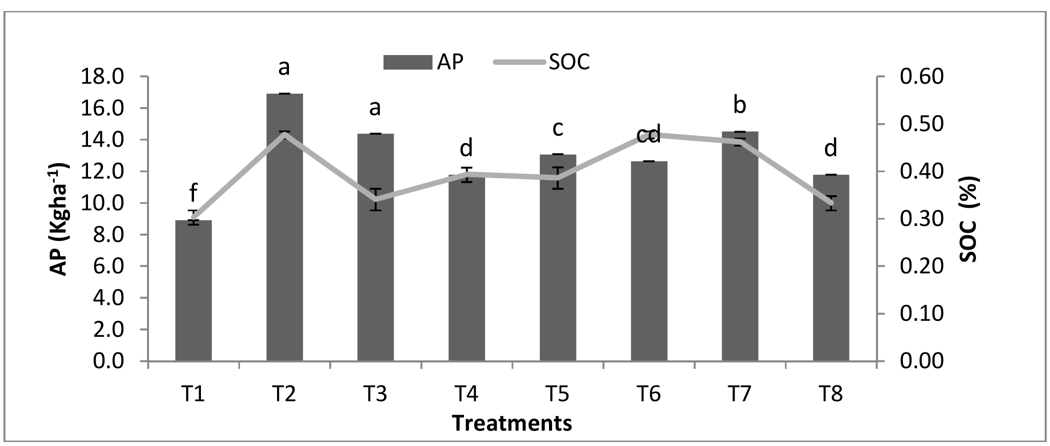


Fig. 3. Available phosphorus and soil organic carbon as affected by conjunctive use of fertilizer

Table 2. Organic carbon fractions (g kg^{-1} soil) (Mean ± SD) of different degree of oxidisability of surface soil affected by different fertilizer management practices

Treatments±	SOC	SE	Fraction I	SE	Fraction II	SE	Fraction III	SE	Fraction IV	SE	AP	SE	PP	SE
Control	0.303	±0.015	0.382	±0.300	0.089	±0.010	0.046	±0.031	0.097	±0.028	0.160	±0.013	0.143	±0.002
100% N (FYM)	0.477	±0.008	0.469	±0.384	0.199	±0.000	0.058	±0.027	0.135	±0.035	0.284	±0.000	0.193	±0.008
100% RDF	0.341	±0.023	0.375	±0.307	0.113	±0.013	0.134	±0.013	0.026	±0.023	0.181	±0.013	0.160	±0.010
50% RDF (Soil) + 50 % N (Foliar)	0.333	±0.015	0.184	±0.157	0.143	±0.004	0.071	±0.063	0.089	±0.056	0.173	±0.008	0.160	±0.007
50% RDF	0.386	±0.023	0.264	±0.247	0.166	±0.007	0.154	±0.010	0.033	±0.023	0.200	±0.010	0.186	±0.012
50% RDF + 50% N (FYM)	0.477	±0.008	0.051	±0.017	0.210	±0.012	0.097	±0.026	0.149	±0.008	0.231	±0.026	0.247	±0.033
50% N (FYM)	0.462	±0.008	0.527	±0.462	0.154	±0.043	0.107	±0.026	0.119	±0.008	0.236	±0.026	0.226	±0.018
Farmers practice (20 Kg N ha-1)	0.333	±0.015	0.225	±0.184	0.131	±0.017	0.127	±0.001	0.034	±0.001	0.172	±0.017	0.161	±0.002
LSD														
CD at 5%	0.494		0.344		0.619		1.001		0.995		0.574		0.437	

Table 3. Carbon pool, liability index and carbon management index of soil affected by different fertilizer management practices

Treatments	CPI	LI	CMI
Control	1.00	1.00	100.00
100% N (FYM)	1.58	1.31	206.94
100% RDF	1.13	1.01	113.41
50% RDF (Soil) + 50% N (Foliar)	1.10	0.96	105.88
50% RDF	1.28	0.96	121.82
50% RDF + 50% N (FYM)	1.58	0.95	149.80
50% N (FYM)	1.53	0.93	141.65
Farmers practice (20 Kg N ha^{-1})	1.10	0.95	104.25

Table 4. Pearson correlation coefficients indicating relationship among the soil parameters and sustainable yield index of paddy

	SOC	Active pool	Passive pool	AK	$KMnO_4$-N	AP	SMBC	SYI
SOC	1.000	0.9351**	0.917*	0.459	0.692	0.507	0.847*	0.789*
Active Pool		1.000	0.701	0.679	0.685	0.483	0.705	0.369
Passive Pool			1.000	0.786	0.585	0.452	0.436	0.486
AK				1.000	0.467	0.490	0.406	0.139
$KMnO_4$-N					1.000	0.874*	0.654	0.146
AP						1.000	0.417	0.121
SMBC							1.000	0.160
SYI								1.000

3.6 Correlation Matrix

Data on Pearson's correlation matrix revealed significant and positive correlation among different soil C pools (Table 4). In our study higher correlation values of Active Pool LBC and SMBC with SOC indicated that these C pools mostly affected by long term nutrient management practices.

4. CONCLUSION

The results of the present study indicated that the CMI could be used to identify management practices will a have positive effects on soil organic carbon build up in soil . The use of the CMI as a tool can help in differentiating the good agricultural practices that improve the soil carbon pool and yielded into a sustainable production. In the present study, application FYM and FYM with inorganic fertilizer comprising half each translated into substantially good SYI, Soil carbon pool and nutrient status.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Denef K, Stewart CE, Brenner J, Paustian K. Does long-term center-pivot irrigation increase soil carbon stocks in semi-arid agro-ecosystems? Geoderma 2008;145:21-129.
DOI: 10.1016/j.geoderma.2008.03.002
2. Hall AJ, Richards RA. Prognosis for genetic improvement of yield potential and water-limited yield of major grain crops. Field Crop Res. 2013;143:18-33.
DOI: 10.1016/j.fcr.2012.05.014
3. Amundson R. The carbon budget in soils. Annual Review of Earth and Planetary Sciences 2001;29:535-562.
4. Carter MR. Soil quality for sustainable land management: Organic matter and aggregation interactions that maintain soil functions. Agron J. 2002;94:38-47.
5. Bhattacharyya P, Roy KS, Neogi S, Dash PK, Nayak AK, Mohanty S, Baig MJ, Sarkar RK, Rao KS. Impact of elevated CO^2 and temperature on soil C and N dynamics in relation to CH_4 and N_2O emissions from tropical flooded rice (*Oryza sativa* L.). Sci Total Environ. 2013a; 461:601-611.

6. Bhattacharyya P, Roy KS, Das M, Ray S, Balachandar D, Karthikeyan S, Nayak AK, Mohapatra T. Elucidation of rice rhizosphere metagenome in relation to methane and nitrogen metabolism under elevated carbon dioxide and temperature using whole genome metagenomic approach. Sci Total Environ. 2016;542(Part A):886-889.
7. Moharana PC, Sharma BM, Biswas DR, Dwivedi BS, Singh RV. Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6-year-old pearl millet-wheat cropping system in an Inceptisol of subtropical India. Field Crops Res. 2012;136:32-41.
8. Liu MY, Chang QR, Qi YB, Liu J, Chen T. Aggregation and soil organic carbon fractions under different land uses on the table land of the Loess plateau of China. Catena. 2014;115:19-28.
9. Blair GJ, Lefroy RDB, Lisle L Soil carbon fractions based on their degree of oxidation and the development of a carbon management index for agricultural systems. Australian Journal of Agricultural Research. 1995;46:1459-1466.
10. Blair N, Faulkner RD, Till AR, Poulton PR. Long-term management impactions on soil C, N and physical fertility, part-I: Broadbalk experiment. Soil Tillage Res. 2006;91:30-38.
11. Mandal N, Dwivedi BS, Meena MC, Singh D, Datta SP, Tomar RK, Sharma BM. Effect of induced defoliation in pigeon pea, farmyard manure and sulphitation press mud on soil organic carbon fractions, mineral nitrogen and crop yields in a pigeon pea-wheat cropping system. Field Crops Res. 2013;154:178-187.
12. Ghosh BN, Meenab VS, Alama NM, Dograa P, Bhattacharyya R, Sharma NK, Mishra PK. Impact of conservation practices on soil aggregation and the carbon management index after seven years of maize-wheat cropping system in the Indian Himalayas. Agril Eco and Env. 2016;216:247-257.
13. Walkley AJ, Black CA. An estimation of the digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934;37:29-38.
14. Chan KY, Booowman A, Oates A. Oxidizible organic carbon fractions and soil quality changes in an oxic paleustalf under different pasture leys. Soil Sci. 2001;166:61-67.
15. Subbiah BV, Asija GL. A rapid procedure for the determination of available nitrogen in soils. Current Science. 1956;25:259-260.
16. Olsen SR, Cole CV, Watanable FS, Dean LA. Estimation of available phosphorus in soils by extracting with sodium bicarbonate (Circular No. 939). Washington (D.C.): U.S. Department of Agriculture; 1954.
17. Hanway JJ, Heidel H. Soil analyses methods as used in Iowa state college soil testing laboratory. Iowa Agriculture. 1952;57:1-31.
18. Singh RP, Das SK, Bhaskara Rao UM, Narayana Reddy M. Sustainability index under different management. Annual Report, CRIDA, Hyderabad (India). 1990;106.
19. Li Z, Liu M, Wu X, Han F, Zhang T. Effects of long-term chemical fertilization and organic amendments ondynamics of soil organic C and total N in paddy soil derived from barren land in subtropical China. Soil Tillage Res. 2010;106:268-274.
20. Ghosh S, Wilson B, Ghosal S, Senapati N, Mandal B. Organic amendments influence soil quality and carbon sequestration in the Indo-Gangetic plains of India. Agric Ecosyst Environ. 2012a;156:134-141.
21. Shahid M, Nayak AK, Shukla AK, Tripathi R, Kumar A, Mohanty S, Bhattacharyya P, Raja R, Panda BB. Long-term effects of fertilizer and manure applications on soil quality and yields in a sub-humid tropical rice-rice system. Soil Use and Manage. 2013;29:322-332.
22. Purakayastha TJ, Rudrappa L, Singh D, Swarup A, Bhadraray S. Long term impact of fertilizers on soil organic carbon pools and sequestration rates in maize–wheat–cowpea cropping system. Geoderma. 2008;144:370-378.
23. Bandyopadhyay PK, Saha Subita MS. Comparison of soil physical properties between a permanent fallow and a long term rice-wheat cropping with inorganic and organic inputs in the humid subtropics of Eastern India. Commun Soil Sci Plant Anal. 2011;42:435-449.
24. Tian G, Kang BT, Brussaard T. Biological effects of plant residues with contrasting chemical compositions under humid tropical conditions: decomposition and nutrient release. Soil Biol Biochem. 1992;24:1051–1060.

25. Jenkinson DS. The rothamsted long-term experiments: Are they still of use? Agron J. 1991; 83:2–10.
26. Ma L, Yang LZ, Xia LZ, Shen MX, Yin SX, Li YD. Long-term effects of inorganic and organic amendments on organic carbon in a paddy soil of the Taihu Lake region, China. Pedosphere. 2011;21:186–196.
27. Diekow J, Mielniczuk J, Knicker H, Bayer C, Dick DP. Carbon and nitrogen stocks in physical fractions of a subtropical Acrisol as influenced by long-term no-till cropping systems and N fertilization. Plant Soil. 2005;268:319-328.
28. Blair N. Impact of cultivation and sugar-cane green trash management on carbon fractions and aggregate stability for a Chromic Luvisol in Queensland, Australia. Soil and Tillage Research. 2000;55:183-191.
29. Verma S, Sharma PK. Effect of long-term manuring and fertilizers on carbon pools, soil structure and sustainability under different cropping systems in wet-temperate zone of northwest Himalayas. Biol Fertile Soils. 2007;19:235-240.
30. Ghosh PK, Venkatesh MS, Hazra KK, Kumar N. Long term effect of pulses and nutrient management on soil organic carbon dynamics and sustainability on an Inceptisol of Indo-Gangetic plain of India. Exp Agric. 2012b;48:473-487.
31. Mazumdar SP, Kundu DK, Saha AR, Majumdar B, Saha R, Singh AK, Barman D, Ghosh D, Dey R, Behera MS, Mitra S, Bhattacharyya P. Carbon and nutrient dynamics under long-term nutrient management in tropical rice-wheat-jute system. Archives of Agronomy and Soil Science 2018;64(11):1595-1607.
DOI: 10.1080/03650340.2018.1446521
32. Majumdar B, Saha AR, Ghorai AK, Sarkar SK, Chowdhury H, Kundu DK, Mahapatra BS. Effect of fertilizer treatments on jute (*Chorchorus olitorius*), microbial dynamics in its rhizosphere and residual fertility status of soil. Ind J Agric Sci. 2014;84:503-508.

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