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Amendment Modified Organic Carbon - Nutrient Dynamics in Red Sandy Loam Soils Cultivated With Okra

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Abstract

A study was conducted on the impact of amendments on organic carbon-nutrient dynamics and growth of okra at instructional farm of College of Agricuture, Padannakkad (Nileswar) from October to December 2021. Experimental field was laid in randomized block design with eight treatments and three replications using 'Arka Anamika' okra variety as the test crop in red sandy loam soils. Eight treatments tested include T_1 (control), T_2 (KAU POP (2016) fertilizers + FYM), T_3 (soil test-based fertilizers), T_4 (soil test-based fertilizers + lime), T_5 (KAU organic POP-based FYM + lime), T_6 (T_5 + soil test-based fertilizers), T_7 (KAU organic POP-based vermicompost + lime) and T_8 (T_7 + soil test-based fertilizers). There was significant effect of treatments on okra growth and yield. Treatment T_8 (T_7 + Soil test based fertilizers) was superior in its effect on plant height, dry matter and fruit yield. Soil analysis at different stages showed significant treatment effects on parameters such as active carbon, inorganic nitrogen, total phosphorus, inorganic phosphorus, total sulfur, inorganic sulfur, soil microbial biomass carbon, pH, available potassium, calcium, magnessium, iron, manganese and boron. Integrated application of vermi compost based organic and soil test based inorganic amendments (T_8) was found to be having the most positive impact on these parameters. Plant nutrient content was also significantly influenced by treatments. The plants under FYM based integrated nutrient management treatment (T_6) were having the highest plant N, K, Ca, S and Mn contents. KAU based integrated nutrient management practice (T_2) had the highest plant Mg value, while vermi compost based INM practice (T_8) had the highest plant Zn and B contents. The study revealed that integrated application of lime, FYM / vermi compost and soil test-based fertilizers had a significant positive effect on the organic carbon nutrient dynamics and growth of okra in red sandy loam soils.

Keywords : Organic carbon pools, Nutrient dynamics, Integrated nutrient management, Okra, Red sandy loam soils

Okra is a major crop in India having high nutrient requirements that needs to be met by chemical fertilizers. Excessive use of these chemical fertilizers may cause deterioration of soil health and may adversely affect the sustainability. Hence proper understanding of the organic carbon dynamics needs to be conducted and management practices that can sustain these dynamics in relation to other nutrient pools have to be evolved. Soil organic matter contains labile, less labile and recalcitrant C pools. Labile C pools are easily decomposable and serve as a nutrient source, while less labile and recalcitrant C pools are crucial for C sequestration in soil. Water extractable organic C (WEOC), microbial biomass C (MBC), potassium permanganate oxidizable organic C ($KMnO_4$-C) and oxidizable organic C fractions are important labile C pools (Benbi *et al*., 2012). Changes in C input can quickly affect these total organic C (TOC) pools (Bolinder *et al*., 1999). Labile pool is sensitive and is easily affected by environmental changes and rapidly decomposes. (Haynes, 2005). Non-labile SOC (stable and recalcitrant fraction) forms organic-mineral complexes and decomposes slowly (Wiesenberg *et al*., 2010). Labile SOC pools serve as a better indicator of soil quality for assessing variations due to land use changes, while non-labile SOC pools add to total organic carbon stocks (Vieira *et al*., 2007 and Chan *et al*., 2001).

Organic manure with fertilizer nutrients increases soil organic carbon levels (Li *et al*., 2010), as nutrient management stimulates crop residue production and retention in soil after harvest (Schuman *et al*., 2002). Few studies have investigated the effects of different soil management practices on labile pools of soil organic carbon (SOC) in tropical and subtropical regions, unlike in cooler and temperate regions (Wu *et al*., 2003 and Majumder *et al*., 2007). Restoring soil carbon has multiple benefits, including improving soil health and food security, as well as mitigating climate change (Minasny *et al*., 2017 and Lal, 2006). Soil carbon management is a crucial aspect of managing soil fertility and productivity, as well as sequestering carbon to combat climate change (Lal, 2010). A scientific understanding of soil carbon pools and their interactions with agro-management practices is necessary for effective management of global climate change and soil fertility. Much studies has so far conducted on integrated nutrient management (INM) in okra cropping systems, but little is known about related short-term carbon sequestration and soil carbon fraction changes. This necessitates the study to assess effect of amendments on short term organic carbon-nutrient dynamics and growth of okra in red sandy loam soils.

Material and Methods

Experimental Site

A field experiment was conducted in Randomized Block Design with eight treatments and three replications at College of Agriculture, Padannakkad, Kerala Agricultural University, Kerala during October to December 2021. The experimental site is geographically located at 12° 14’45" North latitude, 75° 8’6" East longitude and 9 m above mean sea level. The soil of the experimental site is sandy loam in texture.

Treatments and Sampling

The treatments are as follows

T_1 : Control

T_2 : KAU POP(2016) based fertilizers + FYM

T_3 : Soil test-based fertilizers

T_4 : Soil test based fertilizers + Lime

T_5 : KAU organic POP based FYM + Lime

T_6 : T_5 + Soil test-based fertilizers

T_7 : KAU organic POP based vermicompost + Lime

T_8 : T_7 + Soil test-based fertilizers

Note : FYM (@ 20 t ha^{-1} in T_2 and @ 25 t ha^{-1} in T_5 and T_6. Lime (@ 500 kg ha^{-1} in T_5, T_6, T_7 and T_8) and Vermicompost (@ 25 t ha^{-1} in T_7 and T_8). NPK fertilizers applied @ 55, 35 and 70 kg/ha as basal dose in T_2 (No top dressing). In all the treatments, only the basal application of inputs was done (No Top dressing).

Soil sampling were done before sowing, at flowering and after harvest and analysed for parameters such as pH, EC (dS/m), organic carbon fractions (active, slow and passive pools), microbial biomass carbon (MBC), organic and inorganic pools of N, P and S, available K (kg/ha), Ca, Mg, S, Fe, Mn, Zn, Cu and B (mg/kg). Plant sampling was done after harvest for N, P, K (%), Ca, Mg, S, Fe, Mn, Zn, B, Cu (mg/kg) analysis. Biometric observations were taken after harvest for parameters such as plant height, total dry matter production, fruit weight and total fruit yield.

Soil and Plant Analysis

The pH and electrical conductivity of soil samples were measured on soil water suspension made at 1:2.5 ratio. The procedure described by Blair *et al*. (1995) was used to measure labile (active) carbon in soil, which refers to the quantity of carbon that can be oxidized by 333 mM $KMnO_4$. The quantity of passive carbon pool present in a soil sample was determined by subjecting 5g of the soil to boiling with

6N HCl for a duration of 16 hours (Leavitt *et al*, 1996). The slow carbon pool was determined by subtracting the combined amount of active and passive carbon from the total carbon content in the soil. Total nitrogen in soil was determined through the Kjeldahl method, following H_2SO_4 digestion with the assistance of a K_2SO_4 - $CuSO_4$ catalyst, as described by Bremner (1960). The inorganic N pool was determined by Keeney and Nelson, 1982 method. By subtracting inorganic nitrogen from total nitrogen in soil, organic nitrogen was estimated. Total phosphorus in moist soil samples was determined by digestion and colorimetric estimation (Olsen and Sommers, 1982). Dalai (1977) stated that the difference in P content between samples that have been ignited and those that haven't is what determines the quantity of organic P content. Inorganic phosphorus determined by subtracting organic phosphorus from total. Soil's inorganic S content was found using a 0.15 per cent $CaCl_2$ solution extraction. (Massouni and Cornfield, 1963). Soil microbial biomass carbon (MBC) was measured by applying the chloroform fumigation extraction (CFE) technique on fresh soil samples stored at 4 °C, assuming a recovery factor of 0.45 (Jenkinson and Powlson, 1976). For plant sample, total nitrogen was analyzed using the modified Kjeldahl digestion method as described by Jackson (1958), total phosphorus by using Piper's (1966) vanadomolybdate yellow color method, total potassium using flame photometry following Jackson's (1958) method, total calcium and magnesium by titration with EDTA following Hesse's (1971) method, total sulfur using the turbidimetric method described by Bhargava and Raghupathy (1995), total iron and manganese using atomic absorption spectroscopy according to Piper's (1966) method, total zinc and copper by atomic absorption spectroscopy following Emmel *et al*. (1977) method and total boron using the azomethine-H colorimetric method as described by Jackson (1958). The initial physico chemical properties of the experimental site are given in Table 1.

TABLE 1

Initial Soil properties

Parameter	Value
pH (1:2.5)	5.24
EC (dS/m)	0.027
Organic carbon (%)	0.49
Available N (kg/ha)	149.89
Available P (kg/ha)	47.18
Available K (kg/ha)	104.5
Available Ca (mg/kg)	303.89
Available Mg (mg/kg)	124.21
Available S (mg/kg)	15.72
Available Fe (mg/kg)	107.75
Available Mn (mg/kg)	21.82
Available Zn (mg/kg)	3.087
Available Cu (mg/kg)	1.08
Available B (mg/kg)	0.190

RESULTS AND DISCUSSION

Soil Organic Carbon, Nitrogen, Phosphorus and Sulphur Pools

Soil Carbon Pools

The Table 2 shows the organic carbon pools in the red sandy loam soils during flowering and after harvest. Passive carbon pool remained constant across treatments due to its slow turnover rate and resistance to microbial decomposition. It should not be used as an indicator of soil quality, but rather as a component of total carbon stock (Sahoo *et al*., 2019). Slow carbon pool also remained stable, as it is physically stabilized with a mean residence time of 25-50 years (Jha *et al*., 2012). However, active carbon pool showed significant differences among treatments at flowering stage and after harvest. Treatment, T_8 had the highest active C pool content during the flowering stage and after harvest, which was statistically on par with treatments T_2, T_5, T_6 and T_7 during the flowering stage. This might be due to greater influence of organic materials with wider C/N ratios such as FYM and crop residue had on the relatively stabilized fractions of SOC, while those with narrower C/N

TABLE 2

Organic carbon pools in soil

Treatment	At flowering (%)			At harvest (%)		
	Active C	Slow C	Passive C	Active C	Slow C	Passive C
T_1	0.054 d	1.308	0.026	0.012 e	1.016	0.029
T_2	0.082 ab	0.883	0.037	0.069 bc	0.976	0.024
T_3	0.070 cd	0.922	0.033	0.054 d	1.073	0.041
T_4	0.072 bc	0.949	0.068	0.056 d	1.069	0.031
T_5	0.076 ab	0.892	0.049	0.067 c	1.021	0.018
T_6	0.085 ab	1.036	0.061	0.071 abc	1.058	0.027
T_7	0.086 a	0.847	0.062	0.073 ab	0.912	0.034
T_8	0.089 a	1.016	0.056	0.075 a	1.107	0.024
CD (0.05)	0.014	NS	NS	0.005	NS	NS
S.E (m)	0.005	0.125	0.073	0.002	0.11	0.007

ratios, such as vermicompost, had a greater influence on the active fractions of SOC (Verma *et al*., 2010). Organic manures led to an increase in labile pools of organic carbon and enhanced root biomass yield, which in turn increased labile C in soil, as roots exude labile C compounds (Purakayastha *et al*., 2008).

Nitrogen Pools

The total nitrogen and organic nitrogen pool did not show significant variations in any crop growth stage. However, inorganic nitrogen varied significantly with treatments during the flowering and after harvest stages as depicted in Table 3. The application of vermicompost or farmyard manure in combination with inorganic fertilizers has caused increase in available nitrogen with treatment T_8. Ghimire *et al*. (2012) and Gupta *et al*. (2019) reported similar results based on their studies.

Phosphorus Pools

Dynamics of phosphorus pools with time and levels of treatment is given in Table 4. Total P content

TABLE 3

Nitrogen pools in soil

Treatment	At flowering (mg kg^{-1})			At harvest (mg kg^{-1})		
	Total N	Org.N	Inorg.N	Total N	Org.N	Inorg.N
T_1	892.333	835.712	56.621 e	906.667	851.267	55.400 f
T_2	1011.000	933.387	77.613 abc	970.333	895.94	74.393 b
T_3	1080.667	1010.18	70.492 cd	1008.333	939.841	68.492 cd
T_4	1083.000	1010.67	72.333 bcd	1006.667	937.239	69.761 c
T_5	1073.000	1005.08	67 .924 d	1001.333	934.418	67.248 de
T_6	1124.333	1044.67	79.662 ab	1023.333	947.877	75.456 b
T_7	968.333	899.74	68.593 d	943.667	877.806	65.861 e
T_8	1037.333	955.705	81.628 a	989.667	912.367	77.300 a
CD (0.05)	NS	NS	8.207	NS	NS	1.508
S.E (m)	6.486	7.657	2.706	6.699	6.226	0.497

TABLE 4

Phosphorus pools in soils

Treatment	At flowering (mg kg^{-1})			At harvest (mg kg^{-1})		
	Total P	Org.P	Inorg.P	Total P	Org.P	Inorg.P
T_1	650.667 ^{d}	95.467	555.200 ^{e}	640.400 ^{d}	103.767	536.633 ^{f}
T_2	894.477 ^{ab}	132.5	761.977 ^{b}	828.670 ^{ab}	120.98	707.690 ^{bc}
T_3	832.623 ^{bc}	122.623	720.000 ^{c}	795.342 ^{bc}	105.375	689.967 ^{cd}
T_4	851.513 ^{b}	127.633	723.880 ^{c}	808.300 ^{abc}	102.63	705.670 ^{c}
T_5	772.333 ^{c}	123.133	684.200 ^{d}	780.433 ^{c}	116.2	664.233 ^{e}
T_6	902 ^{ab}	131.567	770.433 ^{b}	832.690 ^{ab}	104.056	728.634 ^{b}
T_7	840.215 ^{bc}	125.548	714.667 ^{c}	788.067 ^{bc}	114.39	673.677 ^{de}
T_8	954 ^{a}	137.5	816.500 ^{a}	854.667 ^{a}	92.743	761.924 ^{a}
C.D. (0.05)	72.588	NS	13.442	47.944	NS	21.547
S.E(m)	23.931	11.315	4.432	15.823	8.487	7.104

significantly vary with different levels of treatment at flowering and after harvest. Highest total P was obtained in Treatment T_8 at flowering and harvest which was on par with treatments T_6, T_2 and T_4. According to Ahmed *et al.* (2019), chemical fertilizers combined with manure significantly increase soil total phosphorus, which might be due to the direct addition of manures with soil test-based fertilizers. Organic P showed no significant variation among treatments at any crop growth stage which was in conformity with the findings of Chater and Mattingly (1980). Treatment, T_8 had the highest inorganic P content at the flowering and harvest stages. Kaur *et al.* (2015) observed a more noticeable increase in the inorganic P fraction with integrated fertilizer treatment than with chemical fertilizers alone and untreated plots. The addition of organic manure may have increased the inorganic P concentration in the soil solution by reducing phosphorus fixation and releasing more P from binding sites.

Sulphur Pools

Sulphur pools at various stages and treatments are given in Table 5. Highest total S content was obtained

TABLE 5

Effect of treatment on sulphur pools

Treatment	At flowering (mg kg^{-1})			At harvest (mg kg^{-1})		
	Total S	Org.S	Inorg.S	Total S	Org.S	Inorg.S
T_1	106.667 ^{c}	90.567	16.100 ^{f}	120.800 ^{f}	108.733	12.067 ^{d}
T_2	181.167 ^{ab}	151.300	29.867 ^{bc}	156.567 ^{bc}	133.267	23.300 ^{ab}
T_3	175.367 ^{ab}	149.534	25.833 ^{cd}	152.623 ^{cd}	134.256	18.367 ^{bc}
T_4	177.033 ^{ab}	148.233	28.800 ^{bc}	155.200 ^{bcd}	133.967	21.233 ^{abc}
T_5	152.067 ^{b}	132.367	19.700 ^{ef}	137.633 ^{e}	121.609	16.024 ^{cd}
T_6	209.067 ^{a}	176.200	32.867 ^{ab}	164.550 ^{a}	140.183	24.367 ^{a}
T_7	161.933 ^{b}	140.109	21.824 ^{de}	148.073 ^{d}	130.947	17.126 ^{cd}
T_8	189.233 ^{ab}	153.093	36.140 ^{a}	161.067 ^{ab}	135.634	25.433 ^{a}
CD (0.05)	42.106	NS	5.574	7.786	NS	5.21
S.E (m)	13.882	15.402	1.838	2.567	3.359	1.718

in treatment, T_6 during the flowering and harvest stages, which was statistically similar to treatments T_8 and T_2. This could be due to the application of organic and inorganic fertilizers containing nitrogen, phosphorus and potassium, which improve the soil's total sulphur content. Similar results were reported by Gao *et al*. (2017). Organic S did not vary significantly in any treatment at any crop growth stage. Treatments have significant effect on the inorganic S pools during the flowering and harvest stages, with the highest content observed in treatment T_8 and the lowest in T_1. Organic manure with fertilizers cause balanced fertilization, increased soil microbial activity and led to more inorganic S in T_8 treatment. This is supported by Reddy *et al*. (2001). Lime can also increase SO_4^{2-} in soil solution due to pH-dependent adsorption. (Förster *et al*., 2012)

Growth and Yield

The effects of treatments on the growth and yield of okra are represented in the Tables 6. Treatments significantly affected plant height and dry matter production. Treatment T_8 had highest plant height and dry matter production, attributed to consistent N uptake from inorganic and organic sources. Similar findings were reported by Mishra *et al*. (2020). Maximum dry matter production in T_8 may be due to increased nutrient availability and microorganism groups in vermicompost, favouring vegetative growth and dry matter production. This was in conformity with the findings of Mal *et al*. (2013). The effect of treatments on yield of okra was analysed. Significantly higher fruit yield was recorded in treatment T_8. Higher yield might be due to the effect of the application of vermicompost in combination with inorganic fertilizers which have improved the labile carbon fractions in soil resulting good soil fertility and nutrients being released over short time periods. Similar results have been reported by Ghosh *et al*., (2021) in rice under integrated nutrient management.

Effect on Soil Microbial Biomass Carbon

Microbial biomass carbon content varied significantly between flowering and harvest stages as shown in Table 7. Treatment T_6 showed the highest increase in MBC content at both stages, possibly due to the use of FYM or organic amendments with NPK fertilizers. A similar outcome was found by Kumar *et al*. (2018).

TABLE 6
Effect of treatments on growth and yield parameters of okra

Treatment	Plant height (cm)	Total dry matter production (kg ha^{-1})	Total fruit yield (kg ha^{-1})
T_1	74.873 ^{f}	572.930 ^{h}	1906.701 ^{h}
T_2	95.917 ^{c}	4050.154 ^{c}	13500.403 ^{c}
T_3	82.867 ^{e}	2100.592 ^{g}	7001.920 ^{g}
T_4	85.303 ^{e}	2313.315 ^{f}	7710.550 ^{f}
T_5	89.497 ^{d}	3540.077 ^{e}	11800.770 ^{e}
T_6	100.347 ^{b}	4260.090 ^{b}	14200.897 ^{b}
T_7	92.533 ^{cd}	3750.037 ^{d}	12500.373 ^{d}
T_8	105.450 ^{a}	4336.318 ^{a}	14456.510 ^{a}
C.D.(0.05)	4.101	36.532	106.398
SE(m)	1.352	12.044	35.078

TABLE 7
Effect of treatments on soil microbial biomass carbon in soil

Treatment	SMBC (mg kg^{-1})		
	Before sowing	At flowering	After harvest
T_1	224.500	265.885 ^{d}	270.409 ^{d}
T_2	289.487	450.561 ^{ab}	388.341 ^{ab}
T_3	281.840	315.173 ^{c}	342.341 ^{c}
T_4	261.253	361.110 ^{c}	351.408 ^{c}
T_5	237.473	472.897 ^{ab}	468.296 ^{ab}
T_6	285.060	582.290 ^{a}	518.077 ^{a}
T_7	283.633	479.491 ^{ab}	493.133 ^{ab}
T_8	293.753	537.748 ^{ab}	508.035 ^{ab}
C.D. (0.05)	NS	90.953	73.397
SE(m)	18.635	29.986	24.198

Nutrient Pools in Relation to Organic Carbon Pool Dynamics

From Table 2, it is clear that the slow and passive carbon pools of organic carbon do not change significantly on short term impact of management practices. But the active carbon pools change significantly with the management practices and thus can be used as an indicator of soil health status in relation to other nutrient pool dynamics.

Total N, P, S Pools in Relation to Active C Pool Dynamics

Total nutrient pools (N, P, S) in mg kg^{-1} soil were interpreted in relation to corresponding levels of active carbon content (%) before sowing, at flowering, and after harvest of the crop duration. The findings indicated that there was no much correlation between total N and active C content at different stages. For total P, the highest value was observed in treatment T_8 at flowering and after harvest, which might be attributed to the addition of vermicompost. Similarly, the addition of manure and fertilizers led to an increase in active carbon content in treatment T_8. The results also showed that total S values increased in relation to active C pool content at flowering and after harvest which was similar to the findings reported by Yang *et al*. (2006) and Prakash *et al*. (2016).

Organic (N, P, S) Pools in Relation to Active C Pools

The study found no significant effect of treatments (management practices) on the organic pools of N, P and S before treatment, at flowering and after harvest. Hence these pools are not susceptible to significant changes with change in active c pool dynamics.

Inorganic (N, P, S) Pools in Relation to Active C

Application of vermicompost and soil test based inorganic fertilizers (T_8) resulted in the highest inorganic N and active C contents in soil at flowering and harvesting stages, followed by treatments T_6 and T_2 (Table 2 and 3). This correlation may be due to the increased microbial activity by increase in active carbon in soil. This might have led to more N mineralisation from added manures and thus increases inorganic N in soil in addition to inorganic N added through fertilizers as reported by Franzluebbers and Arshad (1997). Treatment T_8 had the highest inorganic P also at flowering and harvesting stages, followed by T_6, T_2, T_4, T_3, T_7, T_5 and T_1. The high values may be due to the release of organic acids from organic manures and the integrated application of manures and fertilizers, which increase active C in soil and stimulate microbial activity, resulting in phosphorus solubilization (Ghosh *et al*., 2021 and Verma *et al*., 2010). Treatment T_8 had the highest inorganic S contents at flowering and harvest due to balanced fertilization from organic manure and fertilizers, increasing soil microbial activity and mineralization. Similar results were reported by Reddy *et al*. (2001) and the addition of lime can increase SO_4^{2-} in soil solution. Integrated use of manure and fertilizers can also increase active C as reported by Verma *et al*. (2010) and Forster *et al*. (2012). Hence the inorganic pools of N, P and S are found to be positively correlated with the active carbon pools in soil.

Organic carbon, Nitrogen, Phosphorus and Sulphur Pools in Relation to Yield of Okra

Active carbon pool differed significantly with treatments during flowering and harvesting phases, with T_8 having the highest values. The highest yield of okra (14456 kg ha^{-1}) was also observed in T_8 (Table 7). Organic manures alone or with inorganic fertilizers led to more organic pool accumulation. Active pools are a good indicator of soil quality, providing accessible food for microbes and delivering nutrients through decomposition, resulting in increased yield (Joshi *et al.,* 2017; Kumari *et al.,* 2011).

Treatment T_8 had the highest inorganic N also at flowering and after harvest (Table 3). FYM or vermicompost combined with chemical fertilizers increased inorganic nitrogen in soil and plant uptake, leading to significant yield increase as reported by Gupta *et al*., (2019)

At flowering and after harvest, treatments showed significant differences in total phosphorus and inorganic phosphorus (Table 4). Treatment T_8 had the highest total P and inorganic P at flowering and after harvest. The addition of manure and chemical fertilizers increased total phosphorus and inorganic P in treatment T_8 leading to higher yields which was in conformity with the findings of Ahmed *et al*. (2019) and Ghosh *et al*. (2021).

Treatment T_8 had the highest total S and inorganic S (Table 5). Organic and inorganic fertilizers improved soil S content and increased yield due to enhanced microbial activity (Gao *et al*., 2017). Due to addition of organic manure with fertilizers in treatment T_8 increased soil microbial activity and mineralisation of S occured. Similar results were reported by Reddy *et al*. (2001) and SO_4^{2-} adsorption is pH dependent and is high at low soil pH. Integrated application of manures and fertilizers increases active C in soil (Verma *et al*., 2010) leading to higher microbial activity and S mineralisation, resulting in higher yield. (Forster *et al*., 2012)

The present study demonstrated that integrated use of lime, vermicompost and soil test based fertilizer increased active carbon pools, inorganic N, P, S pools significantly and ultimately yield of crop. The study also revealed that active carbon pools of the soil are better indicators of soil quality while considering short term effect of management practices. These active carbon pool dynamics are related to the dynamics of nitrogen, phosphorus and sulphur pools and can thus influence the yield of crops. Non labile organic carbon pools are in equilibrium with the organic nutrient pools and enhancing these pools through carbon sequestration strategies can ensure better productivity and sustainability of the soils.

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