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CHANGE IN SOIL LABILE CARBON POOL UNDER DIFFERENT CROPPING SYSTEMS IN ACID ALFISOL OF KANGRA DISTRICT OF HIMACHAL PRADESH

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ABSTRACT
Global Positioning System (GPS) based soil samples were collected randomly from different cropping systems (cereal, vegetable and oilseed) practised in Kangra district of Himachal Pradesh to study the effect of cultivation on soil labile carbon. Surface soil samples from the uncultivated land adjacent to the cultivated land were also collected as reference to study the change in soil labile carbon pool and to evaluate the sustainability of cropping systems using the Carbon Management Index (CMI). The total carbon under cereal, vegetable and oilseed based cropping systems ranged from 5.3 to 26.9, 4.5 to 32.8 and 1.8 to 30.1 g kg^{-1}, respectively and labile carbon ranged from 315 to 1260, 360 to 1350 and 400 to 1260 mg kg^{-1}, respectively. The CMI ranged from 0.33 to 2.57, 0.25 to 2.58 and 0.46 to 1.59 for cereal, vegetable and oilseed cropping systems with mean values of 0.92 ± 0.4, 1.09 ± 0.5 and 0.94 ± 0.3 respectively. About 48 per cent of samples under vegetable based cropping system have CMI higher than 1.00, which indicates that it is more sustainable as compared to cereals (28 %) and oilseed (30 %) based cropping system.

INTRODUCTION

Soil organic carbon (SOC) is an important component of agricultural soil and is considered to be the major key indicator for assessing soil health and quality. Land uses play a major role in soil organic carbon (SOC) stock build-up through organic matter input (Pandey *et al.,* 2010). Knowledge about the effect of land use change on SOC is essential for understanding carbon cycles and for predicting the consequences of conversion of natural ecosystems to agricultural lands.

Intensive cultivation can decline soil organic carbon (Geraei *et al.*, 2016). Traditionally, organic carbon (OC) or total organic carbon (TOC) was used in the studies on soil organic matter (SOM) dynamics but, changes in TOC as a result of management practices or land use are usually small in short period of few cropping seasons and hence are seldom detectable because of high background levels and natural soil variability (Blair *et al.,*1995; Carter, 2002). In contrast, labile carbon which is readily decomposable, easily oxidizable and susceptible to microbial break down, generally, is sensitive to management induced changes in SOC, thus, serves as an indicator for better management of soil organic carbon in short to medium term effect than total carbon alone. Parton *et al.* (1987) defined soil labile carbon as the fraction of SOC with a turnover time of less than a few years as compared to recalcitrant carbon with a turnover time of several thousand years.

The carbon management index (CMI) that encompasses both the soil organic carbon pool and lability, originally proposed by Blair *et al.* (1995) provides a useful measure to assess the ability of management practices to improve or deteriorate soil quality (Ghosh *et al.,* 2016). Carbon management index serves as a yardstick in evaluating different management practices, cropping systems or land uses for their impacts on soil organic carbon and soil health. When monitored over time or a new management practice is introduced, it indicates if the system is deteriorating or being rehabilitated. However, there is no ideal value of CMI but, it is a sensitive measure of the rate of change in soil carbon dynamics relative to a standard reference. A high CMI value is an indicator of the improvement in quantity and quality of soil organic carbon stocks and hence the soil health and sustainability of the system. The objectives of the present study was to assess the labile carbon content of soils under different cropping systems (cereal, vegetable and oilseed) and to evaluate the CMI for determining the improvement or deterioration in soil quality as a result of land use changes.

MATERIALS AND METHODS

Site Description

Present study was carried out in three cropping systems (cereal, vegetable and oilseed) practised in Kangra district of Himachal Pradesh which lies between 31°2 to 32°5 N latitude and from 75° to 75°45 E longitude. The elevation ranges from less than 600 m to more than 1300 m above mean sea level. This area is characterised by the existence of acid Alfisols under high rainfall conditions.

Soil Sampling and Analysis

Global positioning system (GPS) based soil samples were collected randomly from three cropping systems (cereal, vegetable and oilseed) scattered over Kangra district. A total of 50 surface (0-0.15 m) samples were collected from each cropping system. In addition, surface soil samples from the uncultivated land adjacent to the cultivated land were also collected as reference to study the impact of different cropping systems on carbon dynamics and the CMI. The collected soil samples were air dried and ground using a wooden pestle and mortar and subsequently sieved through a 2 mm sieve. The various methods used for analysis are given in Table 1.

Estimation of Carbon Management Index

The CMI for different cropping systems was calculated from the values of total carbon (C_T) and labile carbon (C_L). Various carbon indices were worked out following the method given by Blair *et al.* (1995).

Carbon Management Index (CMI)

$$CMI = CPI \times CLI$$

Carbon Pool Index (CPI)

$$CPI = \frac{C_T \text{ sample}}{C_T \text{ reference}}$$

Carbon Lability Index (CLI)

$$CLI = L_C \text{ sample} / L_C \text{ reference}$$

$$L_C = \frac{C_L}{C_{NL}}$$

$$C_{NL} = C_T - C_L$$

where, L_c sample and L_c reference is the lability of carbon in cultivated soils and reference soils (adjacent uncultivated soils), respectively and C_{NL} is the non- labile carbon.

Statistical analysis

Correlations were worked out to establish the relationship between soil properties and soil labile carbon as per the procedure outlined by Gomez and Gomez (1984). Significance was tested at 1 and 5 per cent level of significance.

RESULTS AND DISCUSSION

Data on physico- chemical properties of soils under different cropping systems are presented in Table 2. The bulk density of soils under different land use study varied from a minimum of 0.83 in uncultivated soils to a maximum of 1.50 Mg m^{-3} in uncultivated soils adjacent to cereal growing soils. In cereal, vegetable and oilseed based cropping systems; about 60, 50 and 66 per cent of samples were having higher bulk density values in cultivated soils as compared to uncultivated soils. It

Table 1: Methods followed for the determination of different soil properties

Soil property	Method	Reference(s)
Bulk density	Core method	Singh 1980
Soil reaction (pH)	1:2.5 (soil: water) suspension using glass electrode pH meter	Jackson 1967
Cation Exchange Capacity (CEC)	Neutral normal ammonium acetate extraction method	Jackson 1967
Available nitrogen	Alkaline permanganate method	Subbiah and Asija 1956
Available phosphorus	0.5M $NaHCO_3$(pH 8.5) extraction	Olsen *et al.*, 1954
Available potassium	Neutral normal ammonium acetate extraction method	Jackson 1967
Total carbon	Loss on ignition method	Ben-Dor and Banin 1989
Soil labile carbon	Alkaline $KMnO_4$ oxidation method	Weil *et al.* (2003), a modified method from Blair *et al.*, 1995

Table 2: Physico- chemical properties of soils under different land uses

Soil property	Cereal based cropping system		Vegetable based cropping system		Oilseed based cropping system	
	I*	II*	I*	II*	I*	II*
Bulk density (Mg m^{-3})	0.93-1.35 (1.18±0.08)	0.83-1.50 (1.14±0.11)	0.87-1.29 (1.14±0.09)	0.94-1.30 (1.15±0.08)	0.90-1.45 (1.16±0.12)	0.89-1.36 (1.13±0.13)
CEC cmol(p$^+$) kg^{-1}	7.4-14.2 (10.8±1.41)	7.8-15.6 (11.8±1.67)	9.4-15.8 (11.7±1.4)	7.8- 15.6 (11.7±1.7)	7.4-14.2 (10.8±1.4)	8.2-16.2 (11.7±1.8)
pH	4.5-5.9 (5.2±0.3)	4.7-5.9 (5.3±0.3)	4.7-6.1 (5.2±0.3)	4.8-5.8 (5.3±0.3)	4.7-6.4 (5.4±0.4)	5.0-6.0 (5.4±0.3)
Available N kg ha^{-1}	63-346 (146.8±57.5)	31-251 (142.4±43.6)	32-340 (151.6±57.7)	31-251 (136.8±43.3)	63-243 (134.7±38.7)	53-235 (137.3±42.5)
Available P kg ha^{-1}	4.5-25.9 (14.0±5.2)	4.5-26.9 (14.7±5.2)	4.5-26.9 (15.1±4.7)	4.5-24.3 (14.1-±5.02)	4.5-29.1 (14.1±4.9)	4.5-26.9 (13.5±5.2)
Available K kg ha^{-1}	62-291 (167.6±52.4)	78-330 (184.6±62.0)	78-297 (189.4±66.9)	78-295 (180.8±58.3)	78-283 (158.3±53.0)	78-295 (177.5±53.10
Total carbon g kg^{-1}	3.4-28.6 (13.3±5.5)	4.3-34.3 (16.6-±6.2)	4.5-32.8 (18.3±6.8)	5.4-36.4 (17.6±6.8)	1.8-30.1 (14.1±5.8)	4.5-34.3 (16.5±6.5)
Labile carbon mg kg^{-1}	315-1260 (807.3±250.7)	360-1575 (984.6±345.3)	360-1350 (894.6±249.2)	360-1530 (905.6±312.5)	400-1260 (733.3±196.6)	400-1575 (845.9±317.90

I* cultivated, II* adjacent uncultivated soils; Values in the parenthesis are mean ± SD

Table 3: Relationship between soil labile carbon and soil properties (bulk density, CEC, pH and total carbon)

Cropping system	Site	Bulk density	pH	CEC	Total carbon
Cereal	Cultivated	-0.271**	0.266**	0.517**	0.424**
	Uncultivated	-0.410**	0.225*	0.711**	0.467**
Vegetable	Cultivated	-0.168	-0.125	0.507**	0.648**
	Uncultivated	-0.280**	-0.094	0.700**	0.434**
Oilseed	Cultivated	-0.279**	-0.164	0.277**	0.337**
	Uncultivated	-0.353**	0.017	0.688**	0.540**

* Significant at 5 per cent and ** significant at 1 per cent level of significance

Table 4: Relationship between soil labile carbon and available macronutrients (N, P and K)

Cropping system	Site	N	P	K
Cereal	Cultivated	0.372**	0.389**	0.226*
	Uncultivated	0.372**	0.433**	0.248*
Vegetable	Cultivated	0.118	0.142	0.307**
	Uncultivated	0.377**	0.323**	0.314**
Oilseed	Cultivated	0.369**	0.344**	0.253*
	Uncultivated	0.543**	0.384**	0.394**

* Significant at 5 per cent and ** significant at 1per cent level of significance

was also observed that in all the three cropping systems, the adjacent uncultivated soils recorded lower mean values of bulk density in comparison to the cultivated soils which may be ascribed to the presence of higher organic matter content in uncultivated soils. Moreover, the undisturbed pore distribution may have resulted in higher soil volume, thus, the lower bulk density.

Soil pH ranged from 4.5 in cereal cultivated soils to 6.5 in uncultivated soils adjacent to oilseed growing soils which indicated that soils under different land uses were acidic to slightly acidic. Cation exchange capacity (CEC) under different land uses ranged from a minimum value of 7.4 in cereal and oilseed growing soils to a maximum value of 16.2 cmol (p^+) kg^{-1} in uncultivated soils adjacent to oilseed growing area. The CEC was higher in uncultivated soils as compared to cultivated soils. Vegetable growing soils showed higher CEC as compared to cereal and oilseed growing soils. This might be due to higher application of organic matter in vegetable growing soils (Kumawat *et al.,* 2016).

The available macronutrients decreased after cultivation. Available nitrogen content of soils were low (96 %) to medium (4 % only) in all the different land uses and only 38, 58 and 42 per cent of the samples had higher available nitrogen in cereals, vegetable and oilseeds cultivated soils, respectively, over uncultivated soils. The soils of the study area were low (23%) to medium (75%) with respect to available phosphorus. In cereal, vegetable and oilseed based cropping systems; only 36, 56 and 38 per cent of samples had higher available phosphorus in cultivated soils in comparison to adjacent uncultivated soils, respectively. Similarly, the soils of the study area were low (20%) to medium (73%) with respect to available potassium and only 7 per cent samples recorded high available potassium. About 67 per cent of uncultivated soils had higher available potassium in comparison to the corresponding cultivated soils. Vegetable growing soils recorded highest available K in comparison to other land uses. Among the three cropping systems, vegetable based cropping system showed higher available macronutrients in comparison with cereal and oilseed based cropping systems which might be attributed to higher application of organic matter.

The total organic carbon of the soils in all the land uses ranged from minimum value of 1.8 in oilseed growing soils to a maximum value of 36.4 g kg^{-1} in uncultivated soils adjacent to vegetable growing area. In cereal, vegetable and oilseed based cropping systems, only 24, 44 and 24 per cent of samples were having higher total carbon in cultivated as compared to uncultivated soils, respectively. About 70 per cent of samples were found to be higher in total carbon under uncultivated soils in comparison to cultivated soils. The lowest soil labile carbon content in all the land uses was found to be 315 mg kg^{-1} in cereal growing soils and a highest value of 1575 mg kg^{-1} was recorded from uncultivated sites adjacent to cereal and oilseed growing areas. In cereal, vegetable and oilseed based cropping systems; only 26, 50 and 30 per cent of samples had higher labile carbon in cultivated as compared to adjacent uncultivated soils, respectively. About 65 per cent of sample showed higher labile carbon in uncultivated soils in comparison to corresponding cultivated soils. Continuous cultivation might have lowered the soil total and labile carbon content. The decline of soil total and labile carbon after cultivation was also reported by Blair *et al.* (1999) and Singh *et al.* (2016). The lower values of total and labile carbon in cultivated soils can be associated with aggregate disruption and greater organic matter oxidation in conventional agricultural systems based on ploughing and harrowing (Huang *et al.*, 2015).

Carbon Management Index (CMI)

Carbon Management Index (CMI) is a cumulative index that compares the changes that occur in total and labile carbon as a result of cropping system. This value of CMI itself is not important but the differences reflect how different land uses are affecting the systems (Blair *et al.,* 1995). The CMI value under the three cropping systems ranged from a minimum of 0.25 to a maximum of 2.63 in vegetable based cropping system. The CMI varied from 0.33 to 2.57, 0.25 to 2.63 and 0.46 to 1.62 for cereal, vegetable and oilseed cropping systems with the mean value of 0.92 ± 0.4, 1.09 ± 0.5 and 0.94 ± 0.3, respectively. The sustainability of various systems can be arranged in the order: vegetable based cropping system followed by oilseed and cereal based cropping systems. Under cereal and oilseed based cropping systems, there was decline in total and labile carbon, so, these systems have low CMI values, whereas, these properties of soils are better in vegetable based cropping system which might be due to the continuous addition of organic manures in vegetable growing soils (Padbhushan *et al.,* 2015).

Therefore, it can be concluded that in cereal and oilseed based cropping systems, there is a need to increase organic manure addition to the recommended levels so that the productivity of these soils can be maintained. High residue input with other management practices like no tillage, inclusion of legume in cropping system etc. can be the suitable management strategies to improve soil quality and making the agricultural system more sustainable (Mazzoncini *et al.,* 2016, Li *et al.,* 2016).

Correlation Studies

Correlation coefficients of soil labile carbon with soil properties *viz*., bulk density, pH, CEC, available macronutrients (N, P and K) and soil total carbon were worked out and presented in Table 3 and table 4.

The soil labile carbon had significant and negative relationship with bulk density in all the land uses except in vegetable growing soils where there was no significant correlation. This might be due to presence of high matter which lowered the bulk density. Soil pH was found to bear no relationship with soil labile carbon in all land uses except in cereal growing soils and its adjacent uncultivated soil where the labile carbon was found to be positively correlated. Under all land uses, soil labile carbon showed positive and significant relationship with CEC and soil total carbon. Similar were the findings of Lodge and King (2006). Labile carbon content increased with increased amount of added organic matter and, therefore, the CEC also increased. Available macronutrients (N, P and K) showed significant positive relationship with soil labile carbon irrespective of land uses, whereas, the labile carbon of vegetable cultivated soils did not bear any relationship with available N and P. Soil organic matter is an important source of plant nutrients. Thus, higher organic matter might have increased available plant nutrients.

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