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Influence of Agricultural Land Use on Soil Organic Carbon Fractions in an Arid Ecosystem

V. Mahajan[1], D. Vasu[2*], P. Tiwary[2], P. Chandran[2]

[1] *Dr Panjabrao Deshmukh Krishi Vidyapeeth, Krishi Nagar, Akola-440 104, Maharashtra*
[2]*ICAR-National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur – 440 033, Maharashtra*

Abstract: This study aims to determine the effect of land-use systems on soil organic carbon (SOC) and its fractions in an arid agro-ecosystem (Kachchh District, Gujarat). SOC fractions (very labile, labile, less labile, and non-labile) and pools (active and passive) from six pedons (two each from mango orchards, sorghum, and cotton cultivated fields) were estimated. The results showed that SOC and its fractions, except the labile fraction, were significantly affected by land-use up to 20 cm depth. Further, land use significantly affected the absolute content of active carbon pool at 0-10 and 10-20 cm ($p<0.05$) depth, whereas the effect was significant at 20-50 cm depth at $p<0.1$. The higher passive carbon pool under the mango plantations indicates plantation crops' potential to increase the carbon sequestration in the soils. The soils under sorghum with higher passive carbon pool suggest that high-root density crops can increase the carbon storage in the arid regions.

Key words: *Land use, organic carbon, active carbon pool, passive carbon pool, carbon lability index*

Introduction

Soil organic carbon (SOC) is the largest carbon in the terrestrial ecosystem (Batjes 1996). It is the primary source of energy for soil microorganisms and the basis of soil fertility. SOC is a strong determinant of soil quality and crop productivity. SOC is important in the arid and semi-arid regions where soils are inherently low in organic carbon content (Lal 2004). SOC consists of various C fractions with different stabilities and chemical compositions differently affected by temperature and rainfall. SOC fractions reflect the status and composition of SOC and have implications for the change and retention of SOC. SOC is divided into four different fractions according to their decreasing order of oxidizability or lability. They are very labile C (VLOC), labile C (LOC), less labile C (LLOC) and non-labile or recalcitrant C (NLOC) fractions (Chan *et al.* 2001; Yu *et al.* 2017). The proportion of labile C to total SOC, rather than the total SOC influences SOC sequestration and soil health (Blair *et al.* 1995). Therefore, total organic carbon measurement might not be a sensitive indicator of soil quality, particularly in arid regions.

Knowing the influence of land uses on SOC fractions representing SOC pools is crucial, since it leads to a better understanding of SOC dynamics than the total SOC study (Chan *et al.* 2001; Gabarron-Galeote *et al.* 2015). Several studies indicated that labile C fractions were sensitive to soil management practices (Barreto *et al.* 2011), while few studies found no significant effect of land use on labile C fractions (Wang *et al.* 2014). There is a need to understand how the cropping system changes may alter SOC pools in the arid climate.

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*Corresponding author: (Email: d.plantdoctor@gmail.com)

At present, there is a paradigm shift in the carbon sequestration research with the focus shifting from total SOC to its various fractions. The passive C pool contributes to the accumulation of carbon in the soils, whereas the active C pool contributes to the emissions (Priyanka and Anshumali 2018; Jat *et al.* 2019). A better understanding of the SOC pools' response to land use management in the major soil types is vital for reducing GHG emissions in India. For soil carbon management, passive pools have received increasing attention in the recent past. Moreover, the active pool is considered as soil quality indicators. However, only a few studies have attempted to fractionate the oxidizable SOC and its vertical distribution under various land-use systems. Therefore, it is important to study the influence of land use on soil organic carbon fractions in arid ecosystems.

The effect of climatic variables such as rainfall and temperature on soil organic carbon is well established. However, the effect of land-use systems on SOC fractions under various climatic conditions is poorly understood. This study hypothesized that the land-use systems significantly affect SOC fractions, and the study was carried out to determine the effect of three major land-use systems on SOC fractions in the arid region of Gujarat, India.

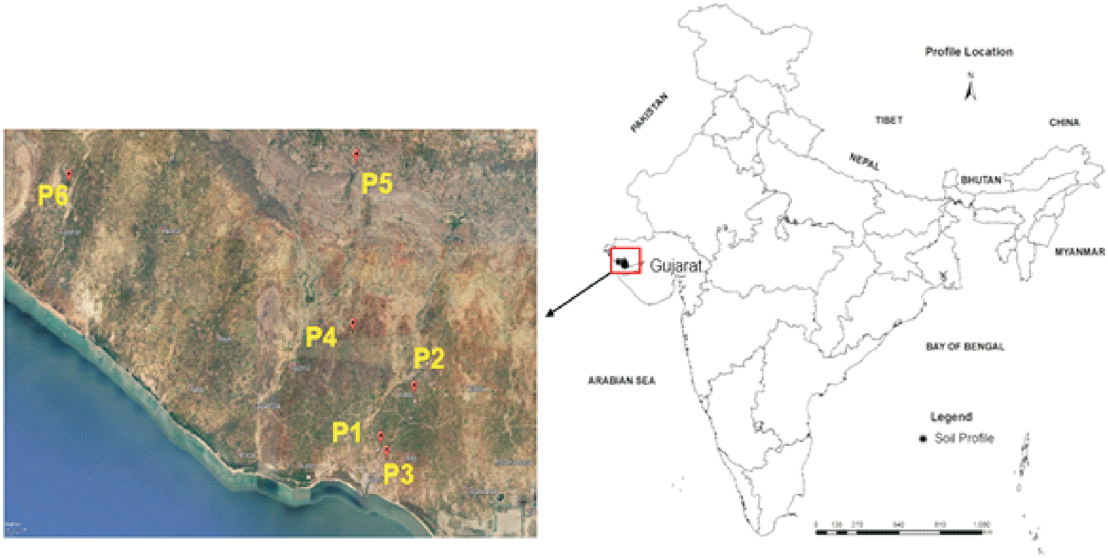

Fig. 1. Map showing location of soil profiles in Kachchh district of Gujarat

Materials and Methods

This study aimed to determine the effect of different agricultural land-use systems on soil organic carbon fractions. Therefore, two soil profiles each from mango orchards, sorghum and cotton cultivated fields were studied (Fig. 1). The horizon-wise morphological properties, including depth, colour, structure, texture, gravels, consistence, and occurrence of nodules, were described using USDA soil description guidelines (Soil Survey Division Staff 2015). Soil samples were collected from all the horizons from the studied profiles.

Particle-size analysis was carried out using hydrometer method (Gee and Bauder 1986); bulk density (BD) by core method (Blake and Hartge 1986); Soil pH and electrical conductivity were measured in 1:2 soil: water ratio. $CaCO_3$ equivalent (%) was determined by the method described by Piper (1966). Cation exchange capacity (CEC) and exchangeable cations were estimated using 1 *N* ammonium acetate (buffered at pH 7.0) by standard procedures (Schollen berger and Simon 1945; Sumner and Miller 1996). Base saturation (BS) was estimated as the ratio of total exchangeable bases to CEC.

Soil organic carbon fractions

The content of organic carbon (OC) and its different fractions in the soil were determined following the Walkley and Black (1934) method as modified by Chan *et al.* (2001) using 5, 10 and 20 mL of concentrated (18.0 mol L^{-1}) H_2SO_4 and $K_2Cr_2O_7$ solution. This resulted in three acid-aqueous solution ratios of 0.5:1, 1:1 and 2:1 that corresponded to 6.0, 9.0 and 12.0 mol L^{-1} H_2SO_4, respectively, and produced different amounts of heat of reaction to bring about oxidation of SOC of varying oxidizability. The amounts of OC thus determined allowed separation of SOC into the following four fractions of decreasing oxidizability as defined by Chan *et al.* (2001).

Fraction I (very labile, VLOC): Organic C oxidizable with 6.0 mol L^{-1} H_2SO_4.
Fraction II (labile, LOC): Difference in OC oxidizable with 9.0 mol L^{-1} and that with 6.0 mol L^{-1} of H_2SO_4
Fraction III (less labile, LLOC): Difference in OC oxidizable with 12.0 mol L^{-1} and that with 9.0 mol L^{-1} of H_2SO_4 (12.0 mol L^{-1} H_2SO_4 is equivalent to the standard Walkley and Black method).
Fraction IV (non-labile, NLOC): Residual organic C after oxidation with 12.0 mol L^{-1} H_2SO_4 when compared with SOC.

The total of VLOC and LOC is considered as active pool of organic carbon (ACP) and the total of NLOC+LLOC is considered as passive pool (PCP).

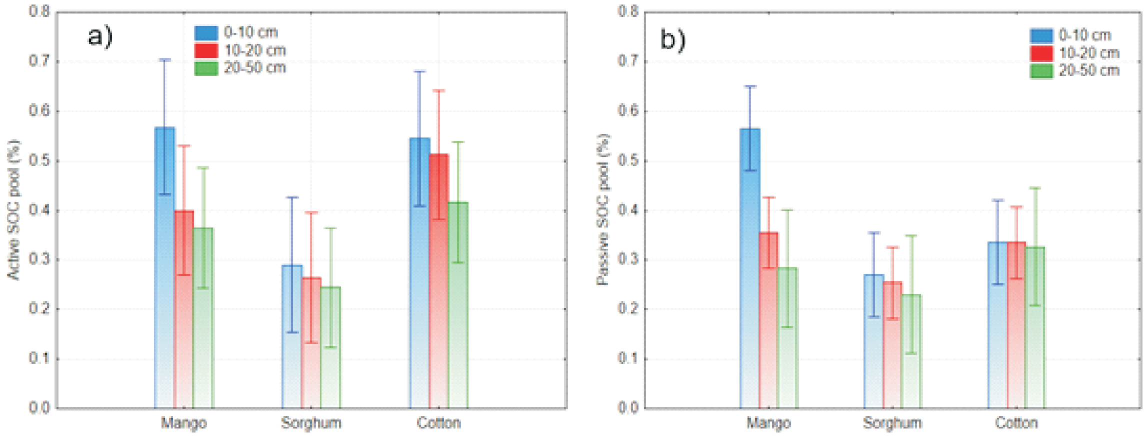

Fig. 2. Active and passive SOC pool in different depths under selected land-use types

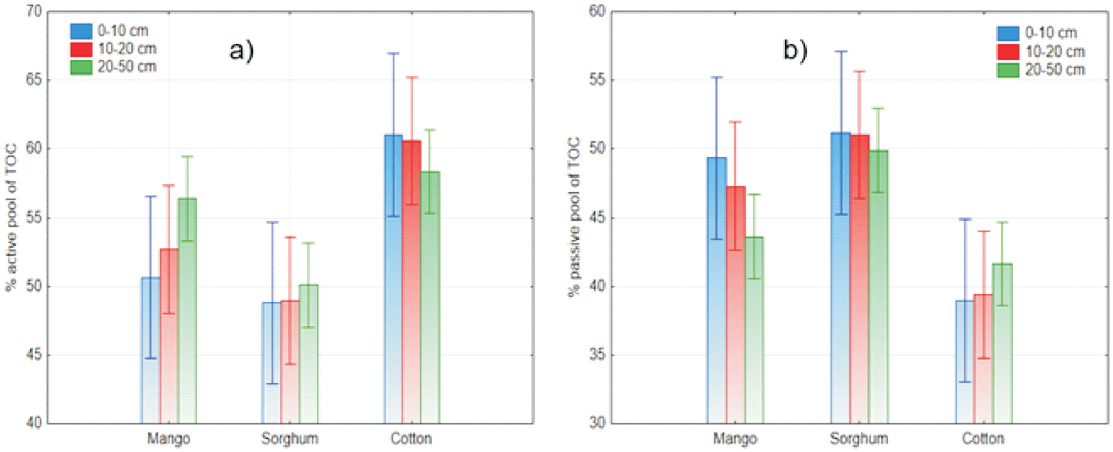

Fig. 3. Percent active and passive SOC pool in different depths under selected land-use types

Carbon liability and Recalcitrant indices

The lability and recalcitrant indices were computed using the following formulas:

Carbon Lability Index (CLI) = (VLOC + LOC + LLOC / SOC)

Recalcitrant Index = PCP/ACP

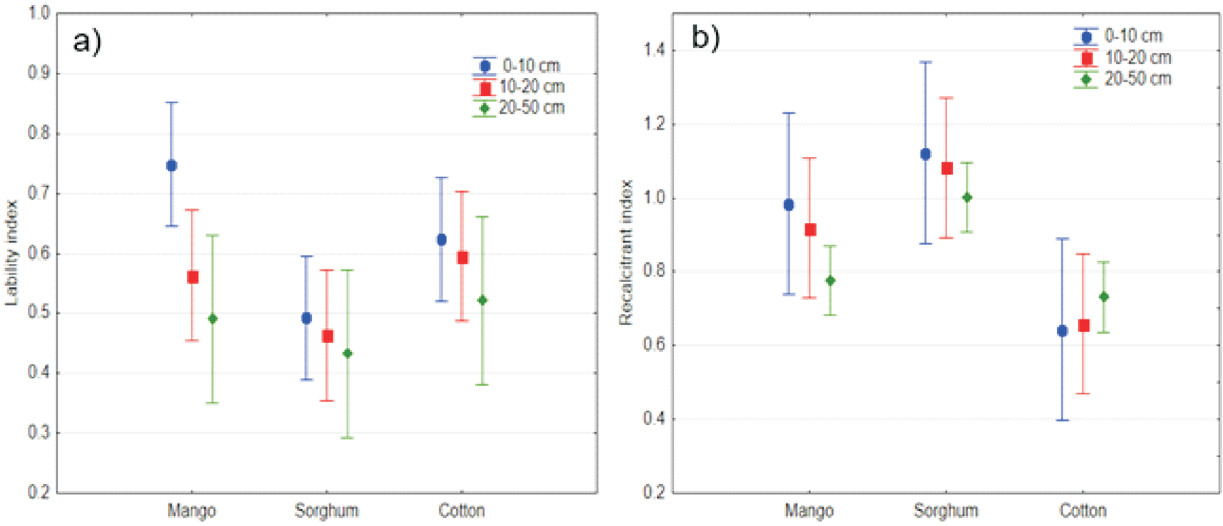

Fig. 4. Carbon lability index and recalcitrant index in different depths under selected land-use types

Statistical analysis

Weighted mean was calculated for 0-10, 10-20, and 20-50 cm depth intervals with respective SOC content and its fractions since the depth of the horizons and total soil depth of the six profiles varied. Analysis of variance (One-way ANOVA) was performed using SPSS 20 to determine the effect of land use on SOC and its fractions, lability index and recalcitrant index. The means were compared using least significant difference.

Results and Discussion

Clay content in the studied soils varied from 10.9 to 40.4%; BD from 1.3 to 1.62 Mg m^{-3}; soil pH from 8.1 to 9.5; EC from 0.12 to 1.54 dS m^{-1}; CaCO$_3$ from 2.8 to 26.1%; base saturation from 17.8 to 100%; CEC from 7.2 to 44.5 cmol (p$^+$) kg^{-1} (Table 1). Organic carbon varied from 0.39% (pedon 5) to 1.35% (pedon 1) in surface and from 0.21% (pedon 6) to 2.78% (pedon 2) in the sub-

Table 1. Descriptive statistics of some properties of the studied pedons

Statistic	Minimum	Maximum	Mean	Variation coefficient (CV)
Sand (%)	32.9	83.9	71.5	0.1
Silt (%)	2.1	26.7	6.9	0.8
Clay (%)	10.9	40.4	21.5	0.3
Bulk density (Mg m^{-3})	1.3	1.6	1.4	0.1
pH	8.1	9.5	9.0	0.1
Electrical conductivity (dS m^{-1})	0.1	3.8	0.8	0.9
CaCO$_3$ (%)	2.1	26.1	9.2	0.8
SOC(%)	0.2	2.8	0.7	0.8
Cation Exchange Capacity (cmol (p+) kg^{-1})	6.4	44.5	20.0	0.5
Base saturation (%)	15.6	114.3	55.6	0.5

Table 2. Soil organic carbon and its fractions in the studied pedons

Pedon	**Depth (cm)**	**Horizon**	**SOC**	**VLOC**	**LOC**	**LLOC**	**NLOC**	**Carbon Lability index**	**Recalcitrant Index**
			----------------------------%-------------------						
P1	0-9	Ap	1.35	0.55	0.09	0.30	0.42	0.69	1.13
	9-23	Bw	0.71	0.22	0.11	0.15	0.22	0.68	1.12
	23-68	Bt1	0.55	0.14	0.17	0.07	0.17	0.69	0.77
	68-105	Bt2	0.35	0.1	0.07	0.07	0.11	0.69	1.03
	105-122	Bt3	0.28	0.07	0.08	0.04	0.09	0.69	0.84
P2	0-8	Ap	1.01	0.35	0.19	0.16	0.31	0.69	0.88
	8-23	Bw	0.82	0.33	0.14	0.09	0.25	0.68	0.72
	23-57	Bt1	0.71	0.31	0.10	0.09	0.22	0.70	0.75
	57-89	Bt2	0.59	0.25	0.10	0.06	0.18	0.69	0.68
	89-123	Bt3	0.28	0.11	0.04	0.03	0.10	0.64	0.87
P3	0-12	Ap	0.74	0.3	0.13	0.08	0.23	0.69	0.73
	12-34	Bw1	0.66	0.27	0.09	0.10	0.20	0.69	0.85
	34-57	Bt	0.62	0.2	0.12	0.11	0.19	0.69	0.96
	57-95	Bw2	0.39	0.14	0.01	0.11	0.12	0.68	1.51
P4	0-17	Ap	1.13	0.3	0.43	0.05	0.35	0.69	0.56
	17-48	Bw1	1.15	0.26	0.36	0.18	0.36	0.69	0.87
	48-70	Bw2	0.47	0.2	0.07	0.06	0.15	0.69	0.74
P5	0-16	Ap	0.39	0.14	0.01	0.11	0.12	0.68	1.51
	16-42	Bw1	0.33	0.13	0.03	0.07	0.10	0.70	1.09
	42-78	Bw2	0.25	0.09	0.03	0.06	0.08	0.71	1.12
	78-90	Bw3	0.19	0.04	0.04	0.04	0.06	0.68	1.20
P6	0-17	Ap	0.62	0.3	0.06	0.07	0.19	0.69	0.73
	17-44	Bw1	0.37	0.23	0.02	0.01	0.12	0.70	0.52
	44-73	Bw2	0.33	0.16	0.02	0.06	0.10	0.70	0.91
	73-117	Bw3	0.29	0.09	0.03	0.08	0.09	0.71	1.47
	117-130	Bw4	0.21	0.06	0.03	0.06	0.06	0.70	1.36

surface (Table 2). It generally decreased with depth, except in P4 where it was slightly higher (1.15%) in the Bw horizon than the A horizon (1.13%). Many earlier studies also reported a decrease in SOC content with depth across land-use types (Liu *et al.* 2020; Caili *et al.* 2016). The highest OC content (2.78%) recorded in the bottom-most horizon of P2 may be due to marine deposits with high organic matter in the coastal plain region during the earlier climate and partly due to active roots of mango plantations. The low to medium OC content of the pedons may be due to rapid OM decomposition under arid conditions and less biomass addition (Bhattacharyya *et al.* 2000).

Soil organic carbon fractions

VLOC of the soils varied from 0.14 (pedon 5) to 0.55% (pedon 1) in surface and from 0.06 (pedon 6) to 0.33 % (pedon 2) in the sub-surface (Table 2). It generally decreased with depth. The higher VLOC in the surface soils could be due to the high input of residues and fine root concentration (Caili *et al.* 2016). Similarly, Liu *et al.* (2020) also reported a decrease in VLOC with depth in different land-use types in China. The LOC varied from 0.01 (pedon 5) to 0.43 % (pedon 4) in surface and from 0.01 (pedon 3) to 0.36% (pedon 4) in the sub-surface (Table 2). It decreased with depth in pedon 2 and pedon 4 and increased with depth in pedon 5 and irregularly distributed in pedon 1, pedon 3 and pedon 6. Similar to VLOC, the higher amounts of labile OC in topsoil than the other soil layers may be due to high residue inputs (Leifeld and Kögel-Knabner 2005).

The LLOC varied from 0.05 (pedon 4) to 0.30% (pedon 1) in surface and from 0.01 (pedon 6) to 0.18% (pedon 4) in the sub-surface. It generally decreased with depth in pedon 1, pedon 2 and pedon 5 and increased in pedon 3. In pedon 4 and pedon 6 it showed an irregular trend (Table 2). Similarly, Caili *et al.* (2016) reported the irregular trend of LLOC in the soil profiles of Loess Plateau. The NLOC of the soils varied from 0.12 (pedon 5) to 0.42 % (pedon 1) in surface and from 0.06 (pedon 6) to 0.36% (pedon 4) in the sub-surface. It generally decreased with depth, except in P4 where it was slightly higher (0.36%) in the Bw horizon than the A horizon (0.35%) (Table 2).

Carbon Lability Index (CLI)

Carbon lability index varied from 0.68 (pedon 5) to 0.69 (pedon 1) in surface and from 0.64 (pedon 2) to 0.71 (pedon 5) in the sub-surface (Table 2). It is nearly same with depth except in P4, where it showed variability.

Table 3. Depth distribution of soil organic pools in the studied pedons

Pedon	Depth (cm)	Horizon	Active C pool	Passive C pool	% AP to SOC	%PP to SOC
			VLOC+LOC	LLOC+NLOC		
P1	0-9	Ap	0.64	0.72	47.0	53.0
	9-23	Bw	0.33	0.37	47.2	52.8
	23-68	Bt1	0.31	0.24	56.4	43.6
	68-105	Bt2	0.17	0.18	49.2	50.8
	105-122	Bt3	0.15	0.13	54.4	45.6
P2	0-8	Ap	0.54	0.47	53.3	46.7
	8-23	Bw	0.47	0.34	58.2	41.8
	23-57	Bt1	0.41	0.31	57.2	42.8
	57-89	Bt2	0.35	0.24	59.4	40.6
	89-123	Bt3	0.15	0.13	54.6	45.4
P3	0-12	Ap	0.43	0.31	57.8	42.2
	12-34	Bw1	0.36	0.30	54.1	45.9
	34-57	Bt	0.32	0.30	50.9	49.1
	57-95	Bw2	0.15	0.23	39.8	60.2
P4	0-17	Ap	0.73	0.41	64.3	35.7
	17-48	Bw1	0.62	0.54	53.4	46.6
	48-70	Bw2	0.27	0.20	57.3	42.7
P5	0-16	Ap	0.15	0.23	39.8	60.2
	16-42	Bw1	0.16	0.17	48.0	52.0
	42-78	Bw2	0.12	0.13	47.2	52.8
	78-90	Bw3	0.08	0.10	45.4	54.6
P6	0-17	Ap	0.36	0.26	57.8	42.2
	17-44	Bw1	0.25	0.13	65.7	34.3
	44-73	Bw2	0.18	0.16	52.5	47.5
	73-117	Bw3	0.12	0.17	40.6	59.4
	117-130	Bw4	0.09	0.12	42.4	57.6

Recalcitrant Index (RI)

Recalcitrant index varied from 0.56 (pedon 4) to 1.51 (pedon 5) in surface and from 0.52 (pedon 6) to 1.51 (pedon 3) in the sub-surface (Table 2). The depth distribution of RI was generally irregular, except in P3 where it increased with depth.

Soil organic carbon pools

Active carbon pool (ACP) varied from 0.15 (pedon 5) to 0.73 % (pedon 4) in surface and from 0.08 (pedon 5) to 0.62% (pedon 4) in the sub-surface. It generally decreased with depth, except in P5, where it is slightly higher (0.16%) in the Bw horizon than the A horizon (0.15 %) (Table 3). Earlier studies also reported a similar decrease in ACP with depth under different land-use types (Liu *et al.* 2020; Caili *et al.* 2016). Passive carbon pool (PCP) varied from 0.23 (pedon 5) to 0.72% (pedon 1) in surface and from 0.10 (pedon 5) to 0.54% (pedon 4) in the sub-surface. It generally decreased with depth, except in P4 and P6, where it showed an irregular trend (Table 3). Similarly, Liu *et al.* (2020) also reported an irregular distribution of recalcitrant carbon pool with depth in soils of China under different land use.

Percent ACP (APP) to SOC varied from 39.8 (pedon 5) to 64.3 (pedon 4) in surface and from 39.8 (pedon 3) to 65.7 (pedon 6) in the sub-surface. The depth distribution of APP to SOC was generally irregular, except in P3, where it decreased with depth (Table 3). Yu *et al.* (2017) reported that SOC in soils of North-eastern China constituted of APP by 40%. Per cent PCP (PPP) to SOC varied from 35.7 (pedon 4) to 60.2 (pedon 5) in surface and from 34.3 (pedon 6) to 60.2 (pedon 3) in the sub-surface. The depth distribution of PPP to SOC was generally irregular, except in P3, where it increased with depth (Table 3). Similarly, Ding *et al.* (2012) observed that the proportion of passive pool in total SOC varied from 54.0% to 59.3% in North-eastern China.

Effect of land use on SOC fractions

The amount of different organic carbon fractions could play a significant role in SOC accumulation in the arid soils. Further, studies of the SOC fractions have been limited to shallow soil depths. This study evaluated how the fractions respond to different land-use up to 50 cm depth. One-way ANOVA was used to determine the effect of land use on SOC fractions in three soil depth intervals

Table 4. Analysis of variance results for the effect of land use on SOC fractions at different depths

SOC fraction	Depth (cm)	F	Sig.	Model efficiency (adjusted R^2)
VLOC	0-10	11.120	0.039*	0.835
	10-20	6.200	0.084**	0.772
	20-50	3.847	0.149	0.587
LOC	0-10	2.078	0.282	0.350
	10-20	2.066	0.283	0.348
	20-50	1.887	0.308	0.307
LLOC	0-10	11.442	0.038*	0.839
	10-20	18.844	0.019*	0.899
	20-50	3.823	0.150	0.585
NLOC	0-10	19.295	0.018*	0.901
	10-20	13.560	0.030*	0.863
	20-50	6.834	0.074**	0.745

* Significant at $p<0.05$

** Significance at $p<0.1$

(Table 4). The results showed that land use significantly affected VLOC, LLOC and NLOC at 0-10 and 10-20 cm depth intervals. Further, the NLOC at 20-50 cm depth was significantly influenced by land use at $p<0.1$. The LOC was not influenced by land use. Similarly, Yu *et al.* (2017) reported a significant effect of land use types on VLOC, LLOC and LOC but not on NLOC. The ANOVA model R^2 decreased with depth, thereby indicating the contribution of soil properties on SOC fractions in the sub-soils. Similar results were obtained by Liu *et al.* (2020). Caili *et al.* (2016) reported that the VLOC and LOC highly varied under grasslands and NLOC highly varied under cropland and LLOC varied little in China's arid soils. Natural grasslands had the highest NLOC. Jha *et al.* (2012) also reported that soils under mango orchard had higher VLOC and LOC fractions than the soils under soybean-wheat cropping system. Pang *et al.* (2019) also reported that tree-based cropping increased the NLOC content in China's arid soils, thereby increasing the SOC sequestration.

Effect of land use on SOC

Land use affected SOC significantly up to 20 cm depth ($p<0.05$). The model efficiency R^2 was higher in the surface, decreasing with depth (Table 5). The SOC decreased with depth under all the three land-use types. The variation with depth was minimum under sorghum and cotton, whereas it was maximum under mango. The soils under mango plantation had higher average SOC content (1.15%) in the 0-10 cm surface layer than the other two land-use types. The soils under cotton had higher SOC content in the 10-20 and 20-50 cm depth intervals than the other two land use. Soils under sorghum had the lowest SOC content at all the depth intervals. Jat *et al.* (2019) reported that soils under conservation

Table 5. Analysis of variance results for the effect of land use on SOC and its pools at different depths

C pool	Depth (cm)	F	Sig.	Model efficiency (adjusted R^2)
SOC	0-10	19.2	0.018*	0.901
	10-20	13.5	0.030*	0.863
	20-50	6.8	0.074	0.745
Active pool (VLOC+LOC)	0-10	12.6	0.033*	0.854
	10-20	9.6	0.048*	0.811
	20-50	8.2	0.058	0.784
Passive Pool (LLOC+NLOC)	0-10	23.1	0.014*	0.917
	10-20	19.5	0.018*	0.902
	20-50	5.6	0.094	0.700
% AP to SOC	0-10	82.8	0.002**	0.976
	10-20	136.0	0.001**	0.985
	20-50	322.2	0.000**	0.994
% PP to SOC	0-10	62.7	0.003**	0.969
	10-20	98.3	0.002**	0.980
	20-50	217.0	0.001**	0.991

* Significant at $p<0.05$
** Significance at $p<0.01$

agriculture practice with minimum tillage (equated to mango plantation in the present study) had higher SOC content than the soils under other conventional agricultural systems. Similarly, Chivhane and Bhattacharyya (2010) reported that soils under horticultural land-use had higher SOC than the soils under cotton in the central region of India. Jha *et al.* (2012) also reported that the Vertisols of central India had higher SOC content under >20 years old mango plantation than the soybean-wheat cropping system.

The higher SOC content in the surface under mango plantations could be due to less oxidation favoured by micro-climate with reduced temperature because of higher canopy cover. Moreover, the addition of leaf litter coupled with minimum tillage operations in the decades' old mango orchards is another reason for higher SOC in the surface layer. Moreover, the recalcitrance of the litter and root biomass may be another reason, which prevented the microbial decomposition of the organic matter (Jha *et al.* 2012). The SOC at 20-50 cm depth under mango plantation is higher than the SOC at the surface layer of soils under sorghum, indicating that the higher microbial activity, biomass carbon and root system plays a major role in increasing organic carbon in the deeper soil layers. The lowest SOC content under the sorghum crop could be attributed to less growing period with sorghum cultivation as fodder crop under rainfed conditions, negligible biomass addition, continuous tillage and arid climate. The higher SOC content in the subsurface layers of cotton may be due to irrigated cultivation, deep root system, soil texture, and landform characteristics.

Effect of land use on SOC pools

The ACP and PCP's absolute content was affected by land use up to 20 cm only ($p<0.05$). However, the APP to SOC and the PPP to SOC were significantly affected by land use at all the depth intervals ($p<0.01$). The model efficiency (R^2) decreased with depth for the absolute ACP and PCP, whereas it increased with depth for APP and PPP (Table 5). The R^2 was higher for APP and PPP to SOC than for their absolute contents in the soil. Land use significantly affected ACP's absolute content at 0-10 and 10-20 cm ($p<0.05$) whereas the effect is significant at 20-50 cm if the $p<0.1$. The ACP content generally decreased with depth under all the three land-use types (Fig. 2a). The soils under mango plantation had higher ACP content in the 0-10 cm layer than the soils under sorghum and cotton. It decreased from 0.56% at 0-10 cm to 0.40% at 10-20 cm and 0.36% at 20-50 cm depth. Similar decrease was observed in the soils under cotton. However, the soils under cotton had higher AP content in the 10-20 cm and 20-50 cm layers than the soils under mango and sorghum.

The soils under sorghum had the lowest ACP content, and it did not vary much with depth. Chivhane and Bhattacharyya (2010) also observed that soils under horticulture land use had higher AP content than the soils under cotton. Jha *et al.* (2012) reported that Vertisols of central India under mango orchard had higher AP in the surface soils than the soils under the soybean-wheat system. Similarly, Geraei *et al.* (2016) reported that conversion of forest plantations into agriculture land use decreased the ACP content in the arid soils of Iran.

Land use significantly affected the absolute content of PCP at 0-10 and 10-20 cm ($p<0.05$) (Table 5). The PCP decreased with depth in the soils under mango plantation (Fig. 2b). A drastic reduction of 63% PCP from 0-10 cm layer to 10-20 cm layer was observed in soils under mango. However, soils under cotton had similar PCP contents at both 0-10 and 10-20 cm depth with a slight decrease at 20-50 cm. The soils under sorghum had the lowest PP content and did not vary significantly with depth.

The APP increased with depth in the soils under mango and sorghum, whereas it decreased with depth in the soils under cotton. The increase with depth was significant in the soils under mango, whereas the soils under sorghum and cotton had similar APP in the 0-10 and 10-20 cm layers (Fig. 3a). The soils under cotton had the highest APP followed by the soils under mango and sorghum at all the depth intervals.

The PPP decreased with depth in soils under mango and sorghum, whereas it increased with depth in the soils under cotton. The decrease with depth in the soils under mango was significant, but the soils under sorghum and cotton had similar PPP in the 0-10 and 10-20 cm layers (Fig. 3b). The soils under sorghum had the highest PPP, whereas the cotton soils had the lowest. However, Datta *et al. (*2015) reported an increase in PPP with depth in the sodic soils of northwest India under mango plantation. This study's opposite result may be due to poor stabilisation of SOC due to less chemical and biochemical reactions under arid climate.

Effect of land use on Carbon Liability Index

Land use significantly affected the CLI at 0-10 and 10-20 cm depth intervals. The CLI decreased with depth under all the three land-use types (Fig. 4a). The soils under mango had the highest CLI (0.75) in the surface layer (0-10 cm) whereas the soils under sorghum had the lowest LI (0.49). The LI varied with depth significantly in the soils under mango and cotton, however, it exhibited little variation with depth in the soils under sorghum.

Effect of land use on Recalcitrant Index

The recalcitrant index (RI) decreased with depth in the soils under mango and sorghum whereas it increased with depth in the soils under cotton. The soils under sorghum had the highest RI followed by mango and cotton (Fig. 4b). A significant variation in RI with depth was observed in the soils under mango, but the RI in the soils under sorghum and cotton exhibited little variation with depth.

Conclusion

Soils of the arid region of the Kachchh district from different agricultural land use systems were studied to determine the influence of land use on SOC fractions. The results showed that land use affects SOC in the topsoil but not in the sub-soil. The higher passive carbon pool under the mango plantations indicates the potential of plantation crops to increase the carbon sequestration in the soils. Further, the soils under sorghum with higher passive carbon pool suggest that high-root density crops can increase the carbon storage in the arid regions.

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