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Research Article

Difference Analysis of Different Land Use Types on Soil Organic Carbon in Loess Gullied-Hilly Region of China

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Abstract: The cycles of carbon in terrestrial ecosystems has received increasing attention worldwide. Because the balance between inputs and outputs of carbon to the soil has an important influences on the atmospheric CO_2 and global climate. With the increasing deforestation and overgrazing, the impact of human disturbances on carbon storage and fluxes have exceeded the rate and extent of effects from natural variability, this could significantly raise the CO_2 concentration in the atmosphere. Thus, accurate estimations of land use and land cover in soil ecosystem have become increasingly important for estimating the carbon balance of regions. One of the greatest uncertainties concerning the influence of human activities is changes in soil carbon stock. In this study, soil samples were collected form farmland, orchard, woodland, grassland, wasteland five different land use types. Each soil sample core was separated into 0-10, 10-20, 20-40 and 40-60 cm depth. The study revealed the difference of soil carbon pool storage and mass effect in different land use styles by the contrast analysis of total organic carbon, labile organic carbon and carbon management index in number, distribution and changes. The results showed that there were big differences for the density of Total Organic Carbon (TOC) among different land use types, which means soil organic carbon storages were different. The extent of variation of the mass fraction of TOC and LOC was increase with the increase of soil depth and 0-20 cm layer was significantly greater than 20-60 cm layer. Relative to wasteland, the density of LOC and NLOC, total organic carbon storage and carbon management index for other four land use types were higher, especial for woodland and grassland. The woodland use type and grassland use type were significantly increased the carbon management index and improved the quality of soil carbon pool. The change of soil organic carbon reserve is huge influenced by human land use.

Keywords: Carbon management index, carbon pool, land use, LOC, NLOC, SOC

INTRODUCTION

The cycles of carbon in terrestrial ecosystems has received increasing attention worldwide. Because the balance between inputs and outputs of carbon to the soil has an important influences on the atmospheric CO_2 and global climate (Post *et al*., 1990). Soil Organic Carbons (SOC) have been recognized as an important source and sink in the global carbon cycle (Ellert and Bettany, 1995). The sensitivity of decomposition of SOC to global change drivers is receiving increasing attention. However, with the increasing deforestation and overgrazing, the impact of human disturbances on carbon storage and fluxes have exceeded the rate and extent of effects from natural variability, this could significantly raise the CO_2 concentration in the atmosphere. Thus, accurate estimations of land use and land cover in soil ecosystem have become increasingly important for estimating the carbon balance of regions (Gregorich *et al*., 1998). One of the greatest uncertainties concerning the influence of human activities is changes in soil carbon stocks (Murty *et al*., 2002).

The changes of land use affect soil carbon storage by altering the input rates of organic matter, changing the decomposition of organic matter inputs that increase the light fraction organic carbon (Cambardella and Elliott, 1992), transporting organic matter deeper in the soil either directly by increasing belowground inputs or indirectly by enhancing surface mixing by soil organisms and enhancing physical protection through either intra-aggregate or organic mineral complexes (Degryze *et al*., 2004; Post and Kwon, 2000; Richter *et al*., 1999). Most studies have demonstrated that the conversion of land use results in a significant variation in the distribution and storage of organic carbon in soils.

Most conventional methods used in soil organic carbon determination have been developed to maximize oxidation and recovery of C. However, total organic carbon measurements might not be sensitive indicators of changes in soil quality: small changes in total SOC

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are often difficult to detect because of natural soil variability and the more labile pools have used as sensitive indicators of changes in response to land use management. So, more and more research attention to the Labile Organic Carbon (LOC) (Xue *et al*., 2009; Partyka and Hamkalo, 2010; Vieira *et al*., 2007), which can respond to the influence of the short-term land management measures. Labile has several characters: transform fast, poor stability, easy oxidation and mineralization. It is more sensitive than total organic carbon in soil carbon pool change. It can be used as a rapid judgment soil carbon pool change and effective means to improve the soil quality (Leifeld and Kögel-Knabner, 2005). For different labile carbon group, the domestic and foreign researchers tend to use readily oxidation carbon (Soil organic carbon which can be oxidized by 333 mmol/L $KMnO_4$) as a characterization of soil carbon pool turnover and changes (Partyka and Hamkalo, 2010; Tirol-Padre and Ladha, 2004). Through LOC can compute the Carbon Management Index (CMI) (Blair *et al*., 1995; Xu *et al*., 2006). It is the dynamic response of soil carbon pool update degree and the quality change of effective index. In this study, soil samples were collected form farmland, orchard, woodland, grassland, wasteland five different land use types.

Each soil sample core was separated into 0-10, 10-20, 20-40 and 40-60 cm depth. The study revealed the difference of soil carbon pool storage and mass effect in different land use styles by the contrast analysis of total organic carbon, labile organic carbon and carbon management index in number, distribution and change.

MATERIALS AND METHODS

Description of study site: Soil samples collected from six locations in Loess gullied-hilly region of China. There are six locations: Feima River Valley (E107°28′-111°15′, N33°43′-39°40′) in Yanan City Shaanxi Provence, Gaoquangou Valley (E104°31′-104°34′, N35°22′-35°25′) in Dingxi City Gansu Provence, Nianzhuanggou Valley (E109°26′15″-109°37′30″, N36°37′00″-36°45′00″) in Yanan City Shaanxi Provence, Nihegou Valley (E108°10′-108°31′, N34°43′-35°03′) in Xanyang City Shaanxi Provence, Zhifanggou Valley (E109°13′-109°16′, N36°42′-36°46′) in Yanan City Shaanxi Provence and Shanghuang village (E106°26′-106°30′, N35°59′-36°02′) in Guyuan City Ningxia Hui Autonomous Region.

Soil sampling collection and analyses: Every location has 5 different land-use type soil samples. Land-use type: farmland, orchard, woodland, grassland, wasteland. Each land-use type has 20 plots. Size of each plot: 1 m×1 m. Each plot collects 5 soil samples. Soil samples were collected randomly. Each soil sample was collected at 0-10, 10-20, 20-40 and 40-60 cm depths. The total soil organic carbon was measured by the Walkley-Black wet-chemical oxidation method (Nelson and Sommers, 1982). The labile organic carbon was measured by $KMnO_4$ oxidation method (Blair *et al*., 1995). The exact approach is: Samples of soil containing 15 mg C were weighed into 30 mL plastic screw top centrifuge tubes and 25 mL of 333 mM $KMnO_4$ were added to each vial. Blank samples, containing no soil and samples of a standard soil were analysed in each run. The centrifuge tubes were tightly sealed and tumbled for 1 h, at 12 rpm, on a tumbler with a radius of 15 cm. The tubes were centrifuged for 5 min at 2000 rpm (RCF = 815 g) and the supernatants diluted 1:250 with deionized water. The absorbances of the diluted samples and standards were read on a split beam spectrophotometer at 565 nm. The change in the concentration of $KMnO_4$ is used to estimate the amount of carbon oxidized, assuming that 1 mM MnO_4 is consumed in the oxidation of 0.75 mM, or 9 mg, of carbon. The results are expressed as mg C g^{-1} soil. The two fractions are Labile C (C_L) = the C oxidized by 333 mM $KMnO_4$ and non-labile C (C_{NL}) = the C not oxidized by 333 mM $KMnO_4$. Post and Kwon (2000) according to the change of concentration of $KMnO_4$ calculate the labile organic carbon mass fraction of the soil sample. The non-labile organic carbon is equal to the total organic carbon and the difference value of labile organic carbon.

Laboratory analysis: Soil Organic Carbon Density (SOCD) is a certain thickness per unit area of the soil organic carbon quality. It can indicate soil carbon pool storage. The calculation method of soil organic carbon density was put forward by Ellert and Bettany (1995). The method can avoid the differences of carbon storage which caused by the different of per unit volume of soil quality. It can more accurately reflect the different land use measures on the short-term effects of organic carbon storage. It was calculated as follows:

$$M_{element} = M_{soil} \times C_{onc} \times 0.001 \tag{1}$$

$$M_{soil} = P_b \times T \times 1000 \tag{2}$$

where,

$M_{element}$ = Soil organic carbon mass per unit area (mg*hm^{-2})
M_{soil} = Soil mass per unit area (mg*hm^{-2})
C_{onc} = Soil organic carbon mass fraction (g*kg^{-1})
P_b = Field bulk density (g*cm^{-3})
T = Thickness of soil layer (m)

According to the formula can get the soil quality in every soil layer. Use the maximum value of different land use types as the standard value. Then, the additional soil thickness required to attain this equivalent mass in lighter soil layers was calculated as follows:

$$T_{add} = (M_{soil,equiv} - M_{soil,surf}) \times 0.001 / P_{subsurfac} \qquad (3)$$

where,

T_{add} = Additional thickness of subsurface layer required to attain the equivalent soil mass (m)
$M_{soil, eouiv}$ = Equivalent soil mass = mass of heaviest horizon (mg*hm^{-2})
$M_{soil,surf}$ = Sum of soil mass in surface layer(s) or genetic horizon(s) (mg*hm^{-2})
$P_{subsurface}$ = Bulk density of subsurface layer (g*cm^{-3})

Masses of soil organic carbon per unit area in an equivalent soil mass were calculated by summing the soil organic carbon in surface layers or horizons, plus those in the additional thickness of subsurface layer required to attain the equivalent soil mass:

$$M_{element,equiv} = M_{element,surf} + M_{element,Tadd} \qquad (4)$$

where,

$M_{element, equiv}$ = Soil organic carbon mass per unit area in an equivalent soil mass (mg*hm^{-2})
$M_{element,surf}$ = Sum of soil organic carbon mass in surface layer(s) (mg*hm^{-2})
$M_{element,Tadd}$ = Element mass in the additional subsurface layer (mg*hm^{-2})

Lability of C, Lability Index, Carbon Pool Index and Carbon Management Index are the embodiments of the soil organic carbon pool and labile organic carbon pool. They can be more comprehensive and dynamic indicate different land use measures on soil carbon pool quantity and quality (Blair *et al*., 1995; Xu *et al*., 2006). They were calculated as follows (Blair *et al*., 1995; Xue *et al*., 2009):

$$CPI = C_{T,sample} / C_{T,reference} \qquad (5)$$

$$L = C_L / C_{NL} \qquad (6)$$

$$LI = L_{sample} / L_{referenc} \qquad (7)$$

$$CMI = CPI \times LI \times 100 \qquad (8)$$

where,

CPI = Carbon Pool Index
$C_{T, sample}$ = Soil total organic carbon mass fraction of soil sample (g*kg^{-1})
$C_{T, reference}$ = Soil total organic carbon mass fraction of reference soil sample (g*kg^{-1})
L = Lability of C
C_L = Soil labile organic carbon mass fraction of soil sample (g*kg^{-1})
C_{NL} = Soil non-labile organic carbon mass fraction of soil sample (g*kg^{-1})
LI = Lability Index, L_{sample} = L of soil sample
$L_{reference}$ = L of soil reference sample
CMI = Carbon Management Index

RESULTS AND DISCUSSION

Soil Organic Carbon (SOC) content in different soil layers were showed in Table 1. The means and standard deviations of the mass fraction of the Total Organic Carbon (TOC) and Labile Organic Carbon (LOC) were significantly decreased with the increase of soil depth. However, the Coefficient of Variations (CV) of the mass fraction of TOC and LOC were significantly increased with the increase of soil depth. In different land use types, the soil management practices, soil water and heat status were different. This may the reason for the distribution characteristic of the SOC in Table 1.

The mass fraction of soil organic carbon change due to different of land use types. In 10-20 cm layer, the distribution trend of the mass fraction of SOC was the farmland>woodland>grassland>orchard> wasteland (Fig. 1). The mass fraction of TOC in 10-20 cm layer was significantly greater than other layers (Fig. 1). The mass fraction of SOC in five land use types was significantly decreased with the increase of soil depth (Fig. 1). In all the land use types, the extent of variation of the mass fraction of SOC in 0-20 cm layer was significantly greater than 20-60 cm layer (Fig. 1). In 0-10 cm layer, the mass fraction of TOC in wasteland was the least; the woodland was 1.93 times for wasteland; the grassland was 1.53 times for wasteland; the farmland was 1.09 times for wasteland; the orchard was 1.01 times for wasteland (Fig. 1). The distribution trend of the LOC in different land use types was the woodland>grassland>orchard>farmland>

Table 1: The overall distribution of total and labile organic carbon

	Soil depth	Mean (g*kg^{-1})	Max (g*kg^{-1})	Min (g*kg^{-1})	StdEv (g*kg^{-1})	CV
Total organic carbon	0-10 cm	7.86	14.83	3.30	2.76	35
	10-20 cm	5.77	13.03	1.96	2.06	36
	20-40 cm	3.81	8.17	1.41	1.44	38
	40-60 cm	2.86	6.93	1.14	1.10	38
Labile organic carbon	0-10 cm	2.71	5.56	0.84	1.04	38
	10-20 cm	1.89	4.60	0.48	0.78	41
	20-40 cm	0.89	2.25	0.28	0.41	46
	40-60 cm	0.63	1.79	0.23	0.30	48

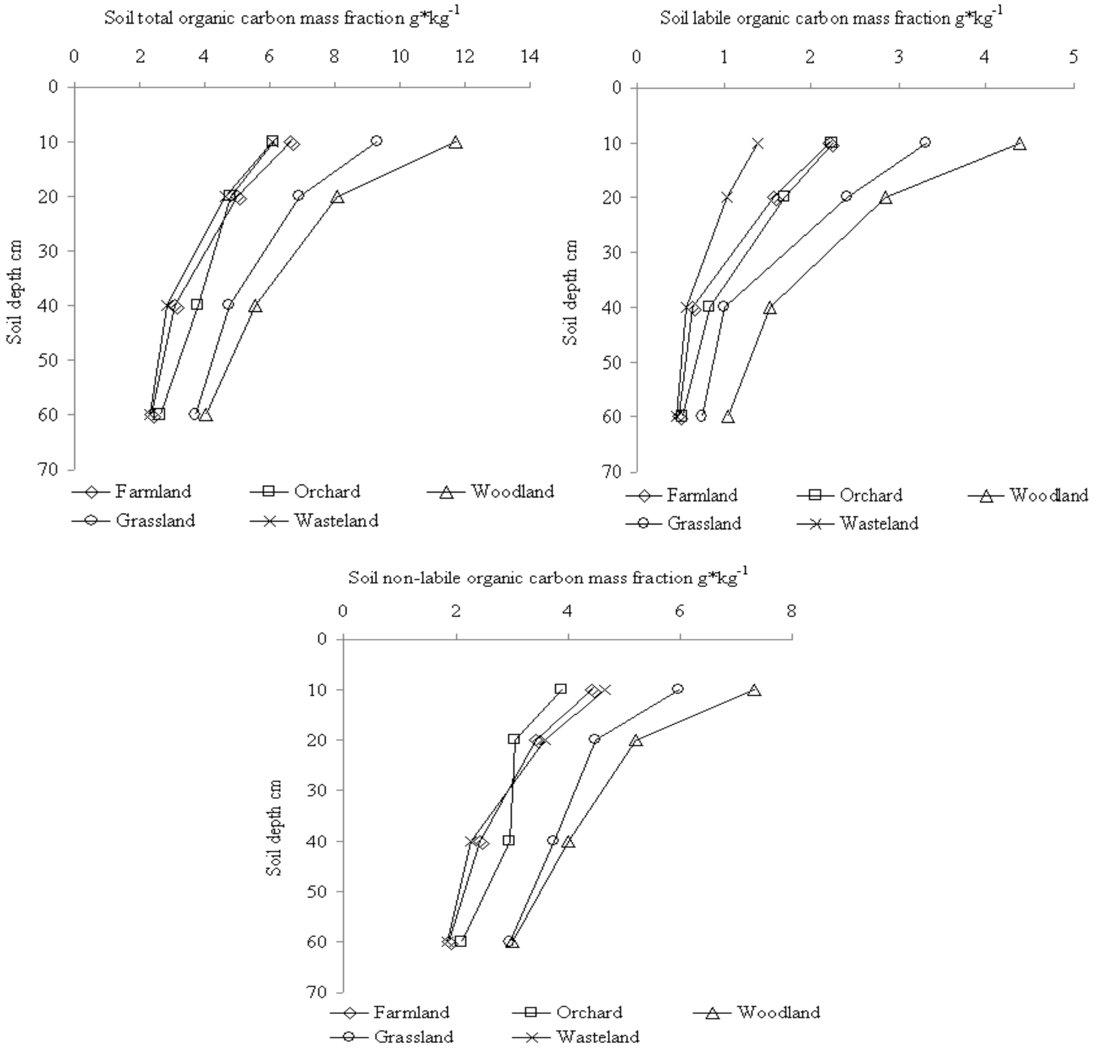
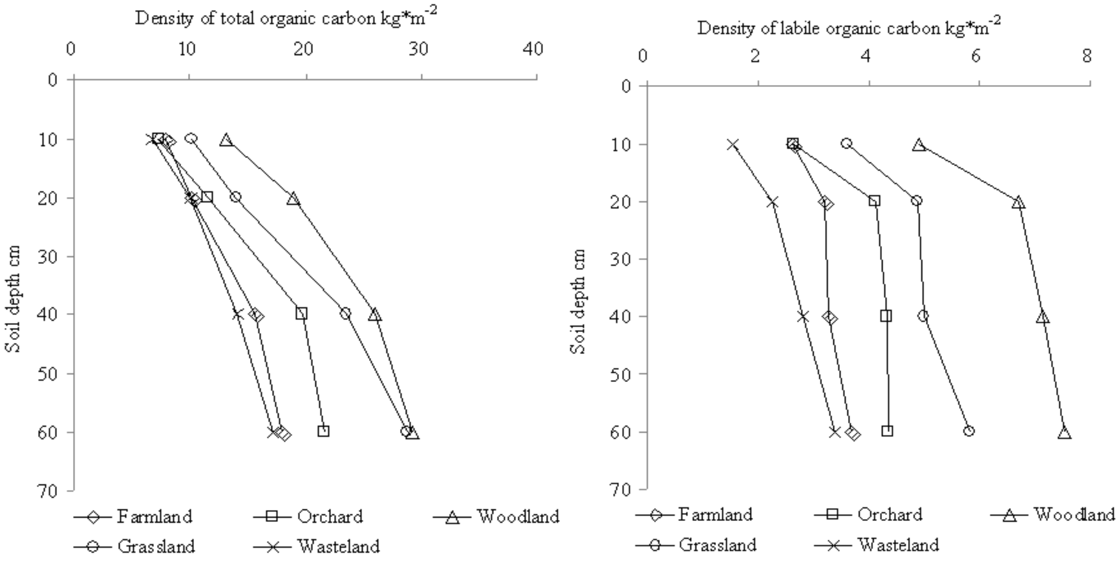


Fig. 1: Content of total organic carbon, labile organic carbon and non-labile organic carbon in different land use types



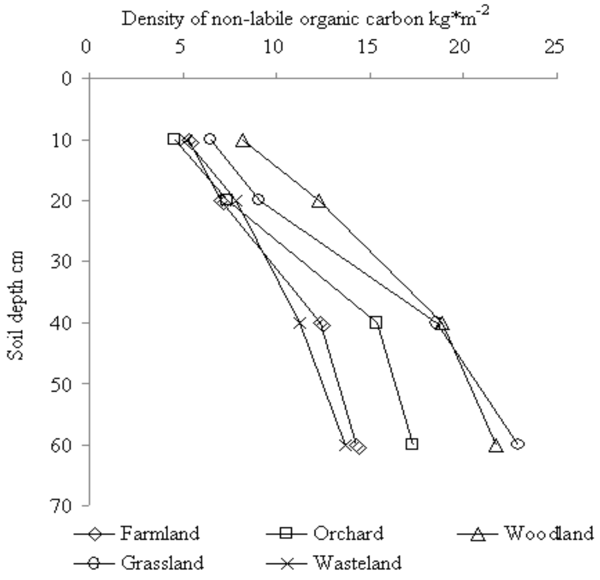


Fig. 2: Density of total organic carbon, labile organic carbon and non-labile organic carbon in different land use types

Table 2: Carbon management index of different land use type

Soil depth	Land use type	LOC/TOC	L	CMI
0-10 cm	Farmland	0.33	0.50	183
	Orchard	0.37	0.58	195
	Woodland	0.38	0.60	389
	Grassland	0.36	0.56	285
	Wasteland	0.23	0.30	100
10-20 cm	Farmland	0.31	0.46	172
	Orchard	0.36	0.56	199
	Woodland	0.35	0.55	330
	Grassland	0.35	0.54	278
	Wasteland	0.22	0.29	100
20-40 cm	Farmland	0.21	0.27	115
	Orchard	0.22	0.28	151
	Woodland	0.28	0.38	296
	Grassland	0.21	0.27	181
	Wasteland	0.20	0.25	100
40-60 cm	Farmland	0.21	0.26	106
	Orchard	0.20	0.25	115
	Woodland	0.26	0.35	245
	Grassland	0.20	0.25	165
	Wasteland	0.20	0.25	100

wasteland. This was the same as the distribution trend of the TOC. In all the land use types, the mass fraction of LOC in 0-20 cm layer was significantly greater than 20-60 cm layer. The impact of the land use on the mass fraction non-labile organic carbon (NLOM) of was decrease with the increase of soil depth.

The density of Total Organic Carbon (TOC), Labile Organic Carbon (LOC) and Non-Labile Organic Carbon (NOC) in different land use types were showed in Fig. 2. In the surface soil, there were big differences for the density of Total Organic Carbon (TOC) among different land use types. In 0-40 cm layer and 0-60 cm layer, the densities of SOM for woodland and grassland were no obvious difference and higher than other land use types. The density of SOM for wasteland was lowest, the density of SOM for woodland was lowest and the woodland was 1.71 times for wasteland. There were big differences for the density of Labile Organic Carbon (LOC) among different land use types. In 0-40 cm layer and 0-60 cm layer, the densities of LOC for woodland and grassland were no obvious difference and higher than other land use types. In 0-40 cm layer, the density of LOC for wasteland was lowest; the woodland was 2.53 times for wasteland; the grassland was 1.76 times for wasteland; the orchard was 1.53 times for wasteland; the farmland was 1.16 times for wasteland. In 0-60 cm layer, the density of LOC for wasteland was lowest; the woodland was 2.22 times for wasteland; the grassland was 1.71 times for wasteland; the orchard was 1.28 times for wasteland; the farmland was 1.08 times for wasteland. The density of LOC for all the land use types was decrease with the increase of soil depth. The densities of NLOC for woodland, grassland, farmland and orchard were higher than woodland. In 0-60 cm layer, the density of NLOC for grassland was highest and it was 1.67 times for wasteland. The density of NLOC for all the land use types was decrease with the increase of soil depth.

Carbon management index of different land use types were showed in Table 2. The proportion of labile organic carbon to total organic carbon was decrease with the increase of soil depth for all land use types. The mean values for 0-10 cm, 10-20 cm, 20-40 cm and 40-60 cm layer were 0.33, 0.32, 0.22 and 0.21, respectively. Relative to wasteland, the proportion of labile organic carbon to total organic carbon for woodland was largest. The proportion of LOC to TOC for woodland was 1.63, 1.57, 1.36 and 1.29 times for wasteland in 0-10 cm, 10-20 cm, 20-40 cm and 40-60 cm layer, respectively. The carbon pool activity was showed as 0-10 cm>10-20 cm>20-40 cm>40-60 cm. Relative to wasteland, the carbon management index for other four land use types were higher. The carbon management index for both woodland and grassland was significantly higher in each layer. The carbon management index for farmland and orchard was higher in 0-20 cm layer than 20-60 cm layer. The woodland use type and grassland use type were significantly increased the carbon management index and improved the quality of soil carbon pool.

The change of soil organic carbon reserve are influenced by manifold factors, such as Climate conditions, hydrothermal conditions, soil properties, vegetation conditions, land use, etc. Among these conditions, Land use is the comprehensive reflection of land use by human. Land use can change the land vegetation condition; affect the plant litter and residual volume, cause the change of the soil management practices, thereby resulting in the changes of soil organic carbon. In this research, the densities of SOC for woodland and grassland were higher than other land use types. The reason was that lots of litter and extensive root system in woodland and grassland could improve organic matter content. The litter and root system are the main soil organic carbon input form. The densities of SOC for farmland and orchard were lower than woodland and grassland, because of deep tillage made soil loose which made SOC decompose and mineralize easy. And long-term using inorganic fertilizers are also one of causes. In orchard, there are less undergrowth plants and it’s not conducive to soil organic material input. The surface plant is sparse and plant roots distribute shallowly in wasteland, so the woodland has the least SOM.

CONCLUSION

There were big differences for the density of Total Organic Carbon (TOC) among different land use types, which means soil organic carbon storages were different. The extent of variation of the mass fraction of TOC and LOC was increase with the increase of soil depth and 0-20 cm layer was significantly greater than 20-60 cm layer. Relative to wasteland, the density of LOC and NLOC, total organic carbon storage and carbon management index for other four land use types were higher, especial for woodland and grassland. The woodland use type and grassland use type were significantly increased the carbon management index and improved the quality of soil carbon pool. The change of soil organic carbon reserve is huge influenced by human land use.

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