

# Effects of aspect and changes in land use on organic carbon and soil properties in Uludere catchment, semi-arid region: Turkey

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**Abstract** The aim of this research is to determine the effects of topographic aspect and changes in land use type and land cover (LUTLC) on soil organic carbon (SOC) and soil properties in Uludere catchment. Therefore, adjacent three land use types were chosen, including natural forest, grassland and cultivated area, to determine the effects of changes of LUTLC on SOC and soil properties in the upper soil layer (0–20 cm). The results showed that significant differences between types of land use in terms of bulk density (BD), soil organic matter (SOM), total nitrogen (TN), and SOC. Soils from the grassland had the second highest levels of SOM and SOC. However, soils from the cultivated area had a very low amount of SOM, SOC and TN. It seems that agricultural practices have an extractive effect on soil properties and SOC accumulation. The soils of forest had the lowest BD values, whereas the soils of cultivated areas had the highest BD at both aspects. BD of the grassland was significantly higher than that of forest but lower than that of cultivated areas. The most appropriate land cover type to protect the soil qualities and to combat desertification in semi-arid region is natural vegetation.

**Keywords** Land use · Soil · Carbon · Semi-arid · Catchment

## 1 Introduction

Effects of changes in global land use on soil properties are critical for monitoring human impacts on the Earth ecosystems. Properties of surface soils are particularly sensitive to the human activities and changes in land use (Leifeld et al. 2005). Human-driven land use changes include increased cultivated areas and degraded areas and decreased grassland and forest areas. These effects of human on land resources have increased the need to appraise effects of changes in land use on soil properties. Land degradation resulting from improper land use and management is a major cause of declined productivity in the arid environment (Mohawesh et al. 2015; Recanatesi 2015; Tsegaye et al. 2010; Zhao et al. 2016). Changes in land cover have a drastic effect on physical, chemical, and biological properties of soil and, hence, change the quality of soil (Jaiarree et al. 2011; Kussainova et al. 2013). Land-use changes initiated by anthropogenic activities alter the cover type and productivity of vegetation firstly, and then affect soil basic physical and chemical properties (Irshad et al. 2015; Shi et al. 2012). Natural forests and grassland areas have been changed to degraded areas (Deng et al. 2014; Houghton et al. 1999; Lal 1990; Watson et al. 2000) as a result of increasing demand for agriculture and settlement areas (Ferrara et al. 2015). Improper or intensive agricultural activities in unsuitable marginal areas have resulted in various types of land degradation in semi-arid regions of Turkey.

Improper land use (Abbasi et al. 2007; Li et al. 2009) is one of the main factors of soil erosion and land degradation. These changes, especially cultivation of deforested land, may rapidly diminish the soil quality (Singh et al. 2014) such as ecologically sensitive components (Zhang et al. 2013) of the semi-arid ecosystem. Many studies

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(Kussainova et al. 2013; Mohawesh et al. 2015; Tesfahunegn 2013; Tsegaye et al. 2010; Yao et al. 2010) have found that strong and statistically significant relationships between soil qualities and land use. The physical properties of soil (Shukla et al. 2006) are influenced by changes in land use and land cover or agricultural practices. On the other hand, many studies determined that topsoil is more susceptible to land use and cover changes (Chang et al. 2012; Deng et al. 2016; Franzluebbers and Stuedemann 2010; Shi et al. 2012). For example, improper agricultural practices and overgrazing reduce the soil to the forces of erosion (Alkharabsheh et al. 2013; García-Ruiz 2010; Pickup and Chewings 1994), increase compaction (Batey 2009) and decrease accumulation of soil organic matter (Parmar et al. 2016). Understanding changes in soil quality resulting from changes in land use is important as it provides information on effectiveness of different land use options and, hence, modifies land management practices as needed to maintain or sustainable land use. Effects of changes in land use on soil properties are inherently regional and highly dependent on the soil type (Abuhashim et al. 2016) and climate (Teferi et al. 2016). Thus, there is need to do more researches for understanding the effects of land use changes on soil properties in different regions.

The results of many studies demonstrated that the land use change has a profound effect on soil physical and chemical properties in the semi-arid ecosystem. Therefore, particularly in semi-arid region, land management plans should be revised in the near future according to the scientific methods and local ecological conditions.

## 2 Materials and methods

### 2.1 Study location

The research area located in Uludere catchment of Çankırı, Yapraklı town is coordinate at 40°45′–40°52′N and 33°37′–33°52′E. It is located within the transition zone between the humid climate of the Black Sea and the semi-arid climate of the Inner Anatolia. The research area is established between 1200 and 1846 m heights. The mean elevation of the catchment is 1610 m (Fig. 1).

The average annual precipitation and temperature of the study area are 530.8 mm and 9.1 °C, respectively (Table 1). The climate of the catchment is subhumid-semi-arid in the Black Sea backward region. According to Thornthwaite's method, it has been determined that it is "semi-arid, micro-thermal having abundant water supply in winter".

In the study area, the ground base was composed of ophiolitic series and basalt. Ipsilateral sea gray marls

(eosen), large red color conglomerates (oligosen), evaporate series and pliocene chipping grit stone (miosen) are determined as the most common rocks in the catchment (Çalapkulu 1967). The catchment area is mostly covered by forest (73%). Dominant tree species of the natural forest are Uludağ fir (*Abies bornmulleriana* Mattf), Scotch pine (*Pinus sylvestris* L), and Anatolian black pine (*Pinus nigra* subsp. *pallasiana*, Arnold). According to Staff (1999), soils of the catchment have been classified as Entisolls, Inceptisol and Mollisols (Dengiz et al. 2011).

### 2.2 Soil sampling and laboratory analyses

The distributions of soil samples in the grid system (50 × 50 m) are total 180 sample points for all different LUTLC (forest, grassland and cultivated area) at two aspects (north–south). The undisturbed soil samples (180 samples) were collected with a steel cylinder (100 cm<sup>3</sup>) for bulk density analysis and the disturbed soil samples (180 samples) were gathered from 0 to 20 cm depth (because of effective depth of SOM and SOC accumulation) for all adjacent different LUTLC from two aspects (north–south). Soil analysis methods are: texture (Bouyoucos 1951), texture triangle (Staff 1999), dry bulk density (BD) (the mass of dry solids in a given bulk volume of soil) (Blake and Hartge 1986), soil pH (Rhoades 1996), calcium carbonate (CaCO<sub>3</sub> - Lime) (Richard and Donald 1996), soil organic matter (SOM) by modified Walkley–Black method and soil organic carbon (SOC) by Kjeldahl method (Nelson and Sommers 1982) and total nitrogen (TN) by Kjeldahl method (Pansu and Gautheyrou 2007).

### 2.3 Statistical analyses

All statistical analyses were calculated using the SPSS<sup>®</sup> 20.0 (IBM corporation software) statistical software. Analysis of variance (ANOVA) was used to detect the significant differences in the measured variables ( $p < 0.05$ ) among land-use types or between two aspects. Differences among means of LUTLC and between north and south were considered significant at the  $p < 0.05$  level using the least standard difference (LSD) multiple comparisons test.

## 3 Results and discussion

Forest management plan maps were used to determine for distribution of LUTLC of the catchment. According to LUTLC analysis, most common land use types were forest, grassland, cultivated area and settlement (Fig. 2). Productive forest and degraded mixed forests had the highest land cover in the study catchment and involved about (2995 ha) 73% of the total area, followed by grassland area (18%-

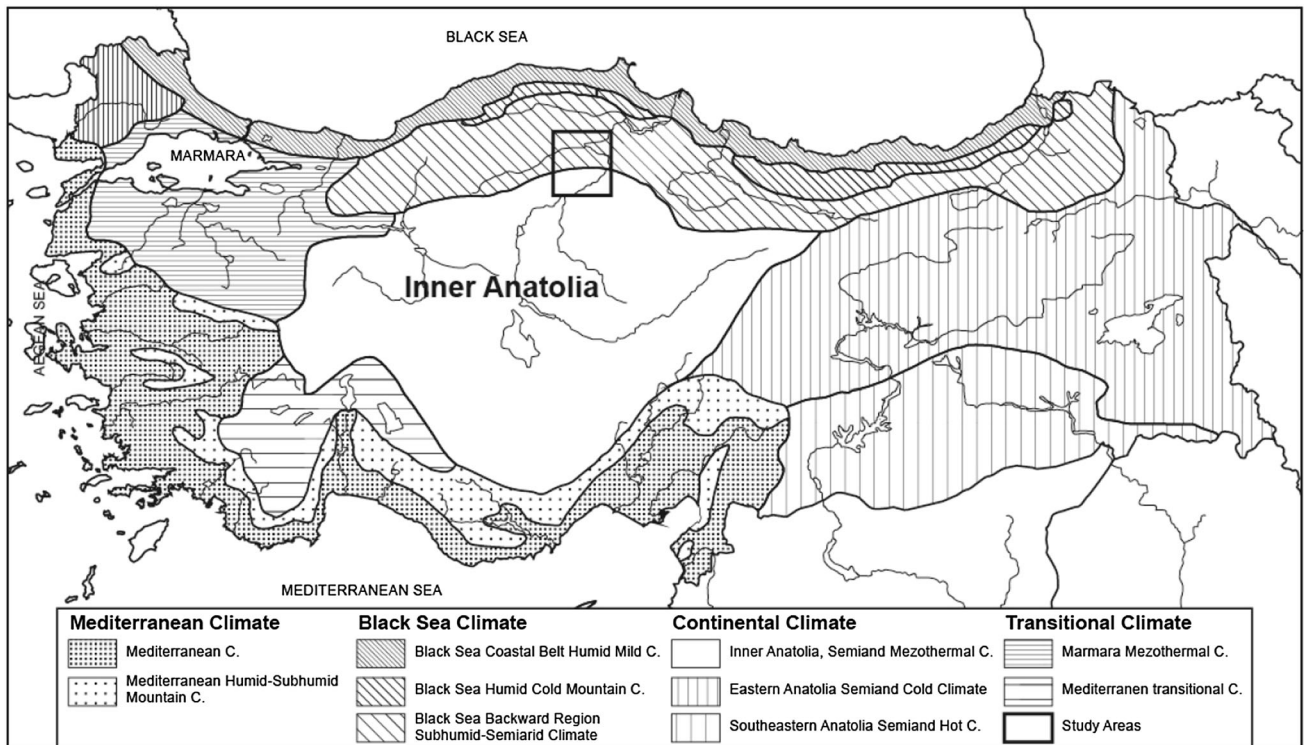


Fig. 1 Location map of the research area

Table 1 Mean precipitation and temperature data of the study area

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
T °C	-2.6	-0.8	3.8	9.0	12.8	16.6	19.5	19.5	16.2	11.1	4.2	-0.5	9.1
P (mm)	57.3	38.0	45.2	62.2	79.9	51.2	27.9	18.2	17.5	35.2	39.2	59.0	530.8

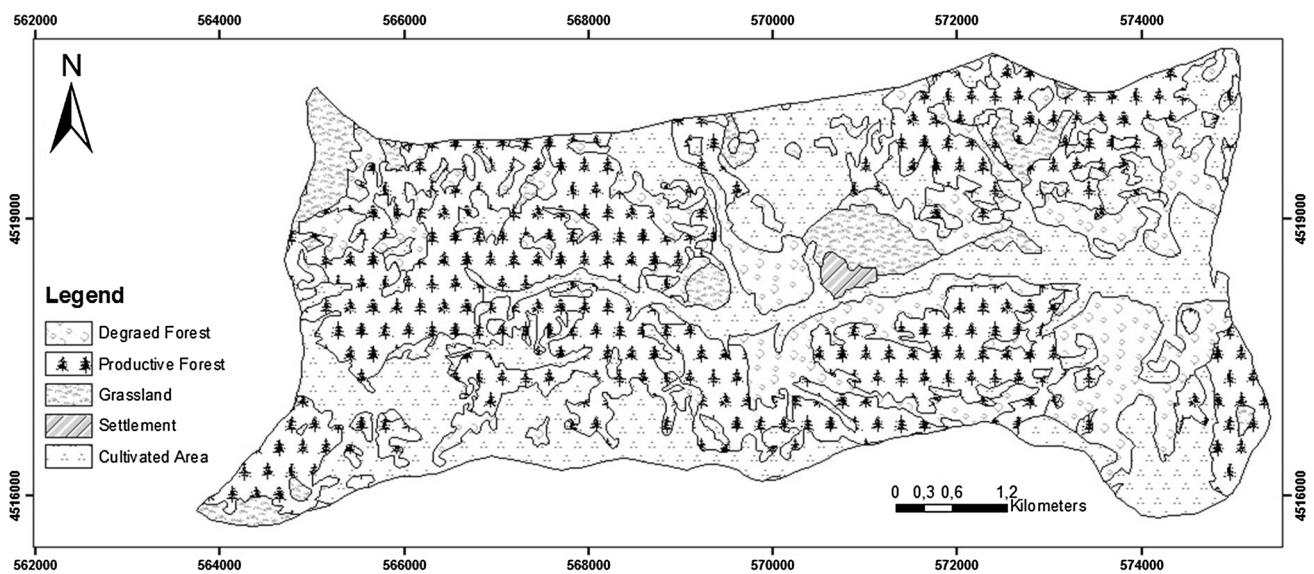


Fig. 2 LUTLC spatial distribution of Uludere catchment

**Table 2** Land use–land cover spatial distribution of the study area

Land use-land cover	Area	
	(ha)	(%)
Productive forest	1804	44.0
Degraded mixed forest	1191	29.0
Grassland	758	18.0
Cultivated area	344	8.9
Settlement	35	0.1
Total	4132	100

758 ha), cultivated area (8.9%-344 ha) and settlement (0.1%-35 ha) (Table 2).

Scotch pine and Uludağ fir were the dominant tree species in the research area. Grassland areas were destructed by excessive pasturage. Agriculture was usually in the form of fallow dry agriculture. Especially, in rainy periods, leaving the land rough led to erosion. Topography and slope are intense variable factors and change from low to high slope. In agricultural lands, intense surface erosion keeps on. During the period when the research was performed, soil was in a dry nature.

The descriptive statistics including mean, min., max., standard deviation (SD) and coefficients of variation (CV) of some observed soil properties are presented in Table 3. On the other hand, soil properties of different LUTLC were

determined based on two aspects (Table 4). Soil pH and lime were not significantly different between soils under the all the LUTLC. The results showed that SOM, SOC, and TN in the soils of cultivated area were significantly lower than those in the soils of forest and the grassland areas. LSD analysis revealed that the difference ( $p < 0.05$ ) was due to the variance among all LUTLC. SOC contents were significantly higher in the soils of forest and grassland than those in the cultivated soils. Long-term cultivation significantly ( $p < 0.05$ ) decreased the SOM and SOC content in the top soils (Table 2). Our results were compatible with some studies (Chang et al. 2012; Eid et al. 2016; Liu et al. 2014; Mohawesh et al. 2015). In our study, significant SOM and SOC decrease after cultivation in two aspects. In recent years, many studies have shown that cultivation practices increased soil organic matter decomposition rate and caused the loss of SOC from the soils of the agricultural ecosystem (Abbasi et al. 2007; Behera and Shukla 2015; Ross et al. 2016; Watson et al. 2000). Bulk density of soils under the forest was significantly lower than the contents in the soils of cultivated and the grassland areas. In general, it increases with profile depth, due to changes in organic matter content, porosity and compaction (Aşkin and Özdemir 2003; Chaudhari et al. 2013). In the variance analysis pertaining to BD, land use type was found statistically significant ( $p < 0.05$ ) (Table 3). LSD test showed that the soils of cultivated areas were different

**Table 3** The descriptive statistics of soil properties (60 soil samples for each LUTLC) in terms of different LUTLC

Soil properties	Land use-land cover	Mean	Min	Max	SD	CV (%)
pH	Forest	6.71 <sup>a</sup>	6.07	7.45	0.57	8.49
	Grassland	6.71 <sup>a</sup>	6.44	7.17	0.26	3.87
	Cultivated land	7.26 <sup>a</sup>	6.79	8.23	0.51	7.02
Lime (%)	Forest	0.57 <sup>a</sup>	0.38	0.72	0.13	8.81
	Grassland	0.47 <sup>a</sup>	0.01	0.91	0.31	5.96
	Cultivated land	0.38 <sup>a</sup>	0.01	0.66	0.31	9.58
SOM (%)	Forest	5.35 <sup>a</sup>	4.81	10.32	2.16	40.37
	Grassland	2.94 <sup>b</sup>	1.56	6.55	1.16	39.46
	Cultivated land	2.11 <sup>b</sup>	0.61	4.42	1.41	66.82
SOC (%)	Forest	1.16 <sup>a</sup>	0.95	2.05	0.26	22.41
	Grassland	0.54 <sup>b</sup>	0.23	1.13	0.12	22.22
	Cultivated land	0.19 <sup>c</sup>	0.12	0.52	0.06	31.58
TN (%)	Forest	0.32 <sup>a</sup>	0.17	0.52	0.12	37.50
	Grassland	0.26 <sup>a</sup>	0.24	0.33	0.06	23.08
	Cultivated land	0.10 <sup>b</sup>	0.12	0.22	0.08	80.00
BD (g cm <sup>-3</sup> )	Forest	0.93 <sup>b</sup>	0.75	1.06	0.11	11.83
	Grassland	1.02 <sup>ab</sup>	0.84	1.21	0.14	13.73
	Cultivated land	1.19 <sup>a</sup>	1.06	1.41	0.12	10.08

SD standard deviation, CV coefficient of variance (%), SOM soil organic matter, SOC soil organic carbon, TN total nitrogen, BD bulk density

The different letters (a > b > c) show statistically significant differences between mean variables of soil properties at  $p < 0.05$

**Table 4** Comparison of soil properties in terms of two aspects

Soil properties	Aspect	Land use-land cover		
		Forest $n = 60$ Mean $\pm$ Std. Error	Grassland $n = 60$ Mean $\pm$ Std. Error	Cultivated area $n = 60$ Mean $\pm$ Std. Error
pH	N	6.48 $\pm$ 0.18 <sup>a</sup>	6.75 $\pm$ 0.21 <sup>a</sup>	7.05 $\pm$ 0.06 <sup>a</sup>
	S	6.94 $\pm$ 0.43 <sup>a</sup>	6.66 $\pm$ 0.12 <sup>a</sup>	7.48 $\pm$ 0.42 <sup>a</sup>
Lime (CaCO <sup>-3</sup> ) (%)	N	0.59 $\pm$ 0.08 <sup>a</sup>	0.63 $\pm$ 0.15 <sup>a</sup>	0.44 $\pm$ 0.21 <sup>a</sup>
	S	0.55 $\pm$ 0.09 <sup>a</sup>	0.31 $\pm$ 0.17 <sup>a</sup>	0.32 $\pm$ 0.17 <sup>a</sup>
SOM (%)	N	5.98 $\pm$ 0.42 <sup>a</sup>	3.19 $\pm$ 0.23 <sup>a</sup>	2.20 $\pm$ 0.44 <sup>a</sup>
	S	4.73 $\pm$ 0.73 <sup>b</sup>	2.69 $\pm$ 0.82 <sup>b</sup>	2.03 $\pm$ 1.20 <sup>a</sup>
SOC (%)	N	1.58 $\pm$ 0.6 <sup>a</sup>	0.69 $\pm$ 0.3 <sup>a</sup>	0.23 $\pm$ 0.2 <sup>a</sup>
	S	1.09 $\pm$ 0.6 <sup>b</sup>	0.41 $\pm$ 0.3 <sup>b</sup>	0.16 $\pm$ 0.2 <sup>a</sup>
TN (%)	N	0.39 $\pm$ 0.02 <sup>a</sup>	0.25 $\pm$ 0.01 <sup>a</sup>	0.12 $\pm$ 0.03 <sup>a</sup>
	S	0.23 $\pm$ 0.03 <sup>b</sup>	0.19 $\pm$ 0.07 <sup>b</sup>	0.09 $\pm$ 0.06 <sup>a</sup>
BD (g cm <sup>-3</sup> )	N	0.87 $\pm$ 0.07 <sup>b</sup>	0.97 $\pm$ 0.04 <sup>a</sup>	1.26 $\pm$ 0.08 <sup>a</sup>
	S	0.98 $\pm$ 0.04 <sup>a</sup>	1.07 $\pm$ 0.11 <sup>a</sup>	1.12 $\pm$ 0.03 <sup>a</sup>

*pH* soil reaction, *L* lime (CaCO<sup>-3</sup>), *SOM* soil organic matter, *SOC* soil organic carbon, *TN* total nitrogen, *BD* dry bulk density, *N* north, *S* south

The different letters (a > b) show statistically significant differences between mean variables of soil properties at  $p < 0.05$

from the other soils of LUTLC. With respect to BD, various properties of the cultivated soils, the forest and the grassland soils were identified and the cultivated soils were found to have a higher bulk density. BD determined that the lowest value in the forest soils at two aspects. BD of forest soils was found below 1.0 g cm<sup>-3</sup>, whereas in the cultivated soils it was found higher than that value. SOM of the surface soils of forest in two aspects was measured much higher than other land use type soils. Many studies (Chaudhari et al. 2013; Leifeld et al. 2005; Quiroga et al. 2006; Sakin et al. 2011) have shown that the strongest relationship between SOM and bulk density. (Aşkin and Özdemir 2003) inferred that increase in organic matter decreases the bulk density of soil. BD was the lowest (0.87 g cm<sup>-3</sup>) in the north aspect of the forest soil and the highest (1.26 g cm<sup>3</sup>) in the north aspect of the cultivated soil (Table 4). Taken together, the forest soils at the north aspect were found to have the lowest BD in all LUTLC (Tables 3, 4). Our studies determined that the SOM increases in the surface soils of the natural forest areas and the bulk density of soils decreases. Soil bulk density is essential for soil management, and information about it is important in soil compaction as well as in the planning of modern farming techniques (Chaudhari et al. 2013).

Of all the investigated variables in this study, total nitrogen (TN) in surface soils of the cultivated area had the highest coefficient of variation with 80.0% and pH in the grassland and the cultivated area had the lowest coefficient of variation with 3.87 and 7.02%, respectively (Table 3).

The amounts of SOM, SOC and TN showed that a significant difference in both aspects. The variance analysis

for pH and lime in terms of two aspects did not show significant results (Table 4). A comparison of soil properties in terms of two aspects is given in Table 4. The variance analysis related to SOM, SOC and TN properties for aspect showed significant results ( $p < 0.05$ ), (Table 3). As a consequence, while comparing the average values related to land use rates at each aspect, it will be measured independently and at each difference for the aspect, measurement average levels should be carried out at every level of land use independently. In the northern aspect, there was a difference between the grassland and the cultivated area and between the forest and the cultivated soils; the cultivated area had the lowest values. However, in the southern aspect, no difference was found between land use types. In the northern and the southern aspects, there were variations in the agriculture soils. SOM and SOC in the northern aspect forest soils were found to be higher than that in the others (Table 4). Total N content showed a similar trend and pattern to the one observed for SOC. It was the highest in the forest soils and the lowest in the cultivated area soils. By taking the average values across the different land use and two aspects, the TN mean content of the soils collected from the forest, the grassland and the cultivated area was 0.32, 0.26 and 0.10%, respectively. It is clear that soils of the forest had more TN than the adjacent soils under the grassland and the cultivated area.

Variance analysis carried out for pH and lime for aspect did not reveal significant results. The variation between northern and southern aspects was statistically significant and status remained constant at the forest, the grassland and the cultivated area. When the analysis results were

evaluated, SOM and SOC in the northern aspect were found higher than ever (Table 4). For all land use types, amounts of SOM and SOC were evaluated. The northern aspect forest soil was found to have the highest levels of SOM and SOC (5.98 and 1.58%, respectively) and the southern aspect cultivated soil was found to have the lowest levels of SOM and SOC (2.03 and 0.16%, respectively) (Table 4). Especially, SOM and SOC of surface soils from the forest in two aspects were much higher than those in soils from the other land use types (Table 3). Total N of three sites at two aspects is presented in Table 3. It is obvious that soils of the forest had significantly more TN than the other soils at two aspects. In all land use types, SOM, SOC and TN were observed to decrease from the northern aspect to the southern aspect.

#### 4 Conclusion

This study comprises the analysis of the effects of aspect and changes in land use on soil properties at a regional scale in semi-arid areas of Turkey. There are strong and mutual relationships between the land use and soil physical and chemical properties such as organic carbon, total nitrogen, bulk density, porosity and compaction. Both physical and chemical characteristics of soil determined for different LUTLC at two aspects showed remarkable differences in SOM, SOC, TN and BD. Soils of the forest and the grassland showed that superiority by having high concentrations of SOM, SOC and TN and better physical properties. The current study revealed that soils of the cultivated area had lower amounts of SOM, SOC and TN than other land uses. Differences in soil properties (e.g., pH, lime) were minimal between soils from northern land use and those from southern land use. The results obtained from this study indicate the severity of the suitable land use management is necessary to prevent land degradation in semi-arid areas. On the other hand, it is a foremost factor for the accumulation of soil organic C and improves soil qualities.

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