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Effects of soil types and land use - land cover on soil organic carbon density at Madendere watershed

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Abstract

Identifying the primary factors influencing watershed scale soil organic carbon (SOC) spatial distribution is critical for improving the accuracy of SOC stock estimates. The primary objective of the current study is to determine the effects of soil type and land use-land cover on SOC in Maden Dere Watershed. To determine land use and land cover of the study area, Geoeye satellite image was used. Four main land use and land cover that are forest, pasture, orchard and cultivated land were determined. Results indicate soil types and land use-land cover were two influencing factors of SOC density spatial variation. SOC density of soil profiles, Haplustept (37.58 kg/m^2) was significantly higher than other soil great groups. Main reasons of this result are indicated as profile depth and pedological development. In addition, it was determined land use and land cover affect on SOC by taking soil samples. For surface soils SOC density, the lowest average carbon storage (5.05 kg/m^2) was found in cultivated soils. In conclusion, it should be developed proper land use policy and sustainable soil management and cropping practices to combat the ongoing soil degradation and improve soil fertility in the study area.

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Introduction

Soil is also the major terrestrial pool of soil organic carbon (SOC) due to its carbon storage potential which is generally greater than that of vegetation (Post and Kwon, 2000). SOC content plays a crucial role in sustaining soil quality, crop production, and environmental quality (Bauer and Black, 1994; Robinson et al., 1994) due to their effects on soil physical, chemical, and biological properties (Sbih et al., 2012; Gülser and Candemir, 2012; Kussainova et al., 2013). Cultivation practices disturb soil physical properties and release physically protected soil organic matter resulting to oxidation of soil organic matter (Plante and McGill, 2002; Shang and Tiessen, 2003). Stabilization of soil aggregate including aggregate formation has greater control on soil organic carbon content (Christensen, 2001). The interaction of physical, chemical, and biological processes in soils manages aggregate formation and stabilization (McCarthy et al., 2008). Furthermore, cultivation of permanent grassland in semiarid climate also reduced soil organic C 16% at second year and 32% at 14 years of cultivation (Noellemeyer et al. 2008).

The type of land use system is an important factor that controls SOC levels. Changes of land use and management practices influence the amount and rate of soil organic carbon losses (Guggenberger et al., 1995). Many research results have confirmed that soil organic carbon associated with different land uses varies dramatically at the regional or catchment scale (White et al., 2009; Zhang et al., 2011; Jaiarree et al.,

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2011). Based on 1407 soil profiles in Laos, Chaplot et al. (2009) found that median SOC density under forestland (112.0 Mg ha^{-1}) is significantly (P < 0.05) higher than that found under fallow (109.2 Mg ha-1) and continuous cultivation (108.8 Mg ha^{-1}) management at 0-30 cm depth. Chiti et al. (2011) found that mean SOC density under rice field soils (63.3Mg ha^{-1}) is significantly (P < 0.05) greater than arable land soils (53.1 Mg ha^{-1}) at 0-30 cm depth in Italy, using a database created from the national project and regional map reports. Land use can reflect differences in regional scale SOC spatial distribution, expressing its dominant influence at the hillside and catchment level (Fang et al., 2012). The primary objective of the current study is to determine the effects of soil type and land use-land cover on SOC in Maden Dere Watershed.

Material and Methods

Field Description of the Study Area

The study area located in Maden Dere Watershed of Kocaeli-Kartepe district is coordinated at 4515500-4518000 N and 262400-264800 E (UTM-m) and the total area is approximately 5.5 km^2. Mean sea level altitude of the watershed is 415 m (Figure 1). Average annual precipitation and temperature of the study area are 730.4 mm and 11.3 ^{o}C, respectively (Table 1). Land use and vegetation of the study area are generally, covered by forest, arable land and pasture.

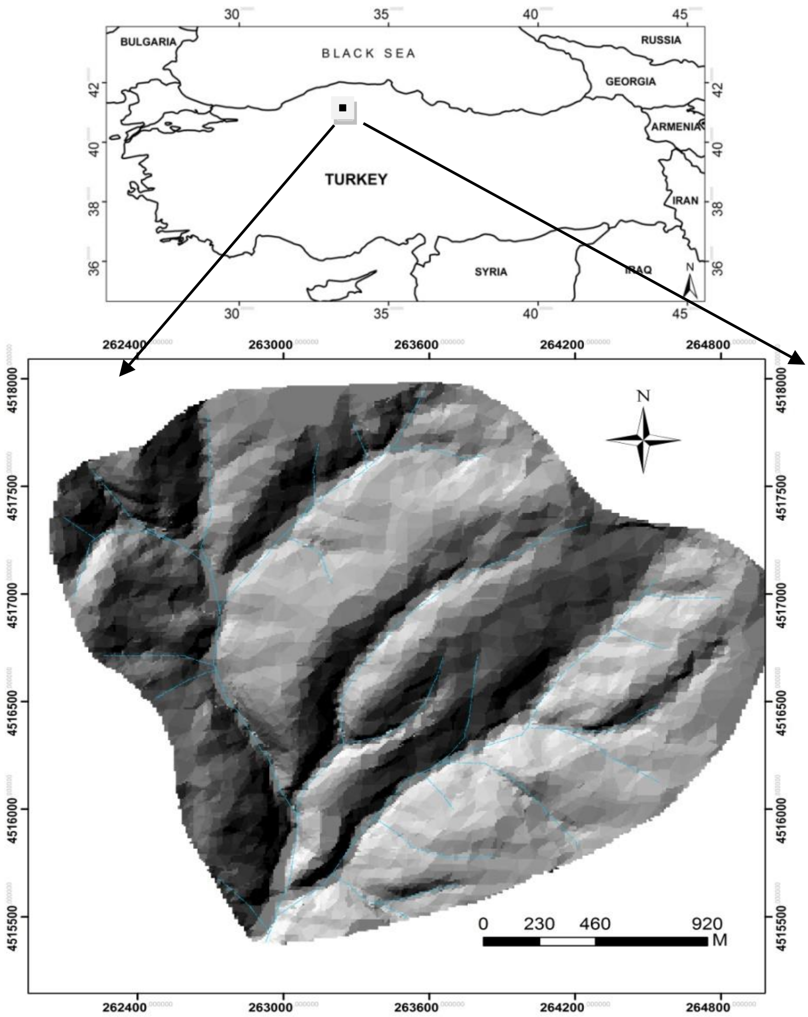

Figure 1. Location map of the study area

Table 1. Meteorological data of the study area

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
T ^{o}C	0.0	2.0	5.8	11.0	15.5	19.5	22.0	21.5	18.0	12.2	6.5	1.9	11.3
P (mm)	92.8	82	78.9	76.3	57.7	40.3	14.6	15.1	26.6	54.7	85.4	106	730.4

A range of soil types are present because of the significant differences in climate, geomorphology, vegetation, complicated geohydrologic conditions, parent materials, and cultivation. According to Soil Taxonomy (1999), soils of the study area were classified as Dystrustept, Ustorthent, Haplustept, Haplustalf, Calciustept based on great group level by taking into consideration of pedological development.

Soil Sampling

Two kinds of soil sampling method which are surface and profile were used to determine soil organic carbon density. Soil samples were obtained from surface divided into 300 x 300 m grid squares (Figure 2). 71 soil samples were collected from surface (0-20 cm) for each land use and land cover. In addition, 12 soil profiles were investigated and 46 soil samples were taken from each horizon of profiles.

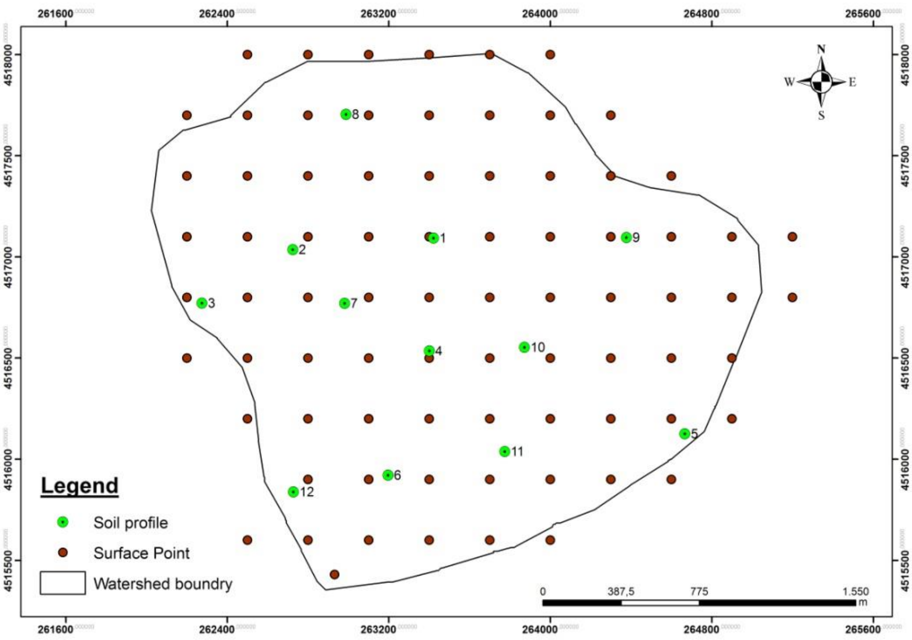

Figure 2. Soil surface sampling design and soil profile on the study area

The samples were transported to the laboratory. The soil samples were crumbled gently by hand without root material. These samples were used to determine some physico-chemical properties such as bulk density and organic matter. Selected soil properties were determined by the following methods: Bulk density (Blacke and Hartge, 1986) and organic matter was determined in air-dry samples using the Walkley-Black wet digestion method (Nelson and Sommers, 1982).

Soil organic carbon density estimation

For each profile, SOC density (SOCD) was estimated in the soil layer of profile (0-100 cm), surface (0-20 cm), with the following equation:

$$SOCD_D = \sum_{i=1}^{n} \frac{(1-\delta i\%) x\ \rho i\ x\ Ci\ x\ Ti}{100}$$

Where; $SOCD_D$ represents the SOC density of a soil profile with a depth D (cm); n is the number of pedogenic horizons in the soil survey, δi % represents the volumetric percentage of the fraction > 2 mm (rock fragments), ρi is the bulk density (g cm^{-3}), Ci is the SOC content (g kg^{-1}), and Ti represents the thickness (cm) of the layer i. The organic carbon content. The SOC was estimated to a maximum depth of 100 cm.

Statistical analysis

All statistical analysis was carried out in SPSS13.0 (SPSS Inc. Chicago I11inois, USA). An analysis of variance (ANOVA) was performed to evaluate if soil type and land use have a relationship with soil carbon that is significant beyond that which would expected by chance. If there was a significant effect (P <0,05), least significant difference (LSD) post hoc multiple comparisons were used to compare means between different groups within each categorical variable, tested with a = 0.05. Prior to analysis of variance, all the data were logarithm transformed to conform to a normal distribution

Results and Discussion

To determine land use and land cover of the study area, Geoeye satellite image that has 0.5 m x 0.5 m spatial resolution and dated 2013 were used. According to remote sensing analysis, primary land uses are forest, cultivated land, pasture, orchard and settlement (Figure 3). Forest is the highest land cover in the study area and has about 38.6 % of the total area (211.11 ha), followed by orchard (35.5%-192.22 ha), pasture (12.8%-70.14 ha), cultivated land (9.5% 52.02 ha) and settlement (3.6% 19.74 ha).

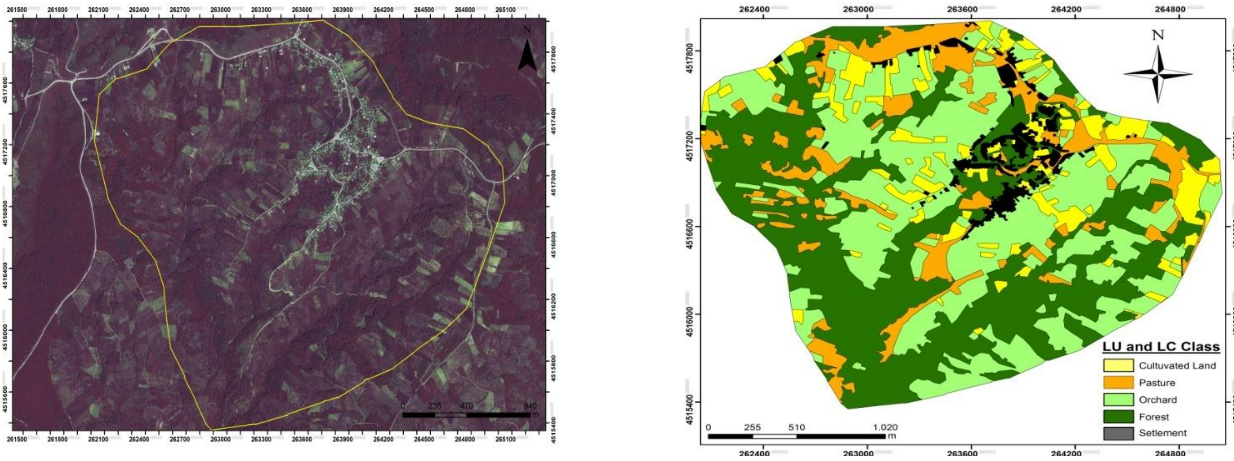

Figure 3. Geoeye image and land use Land Cover maps of the study area

Twelve soil profiles classified as Dystrustept, Haplustalf, Haplustept, Calciustept and Ustorthent were investigated to determine SOC density based on soil depth and pedological development under different land use and land covers. SOC density of soil profiles and their great groups were given Table 2. According to Table 2, SOC density of soil profile, Haplustept (37.58 kg/m^2) was significantly higher than other soil great groups, flowed by Haplustalf (16.11 kg/m^2), Dystrustept (10.20 kg/m^2), Calciustept (5.69 kg/m^2), and Ustorthent (3.78 kg/m^2). There were two important cases affected on SOC density. One of them is pedological development and soil layers' depth. Namely, although most of the soils have high SOC density under forest and pasture covers, Usorthent soils include the lowest SOC density. The horizon orders of the Usorthent were defined to be A-R or A-C horizons. This means this profile has no diagnostic subsurface horizons and low pedogenetic development. Therefore, this soil can be defined as a young soil. Another factor is land use - land cover. As it can be compared land use and land cover even it can be taken the same soil group, it were found different SOC density for each land use and land cover. Such as Haplustept that were represented as 8, 4, 11 soil profiles and located at cultivated land, pasture, and forest respectively has different SOC densities (4.74, 12.42, and 17.23 kg/m^2).

Table 2. SOC density of the Soil Great Group Cover Different Land Cover and Land Use

Soil Profiles	Land Use/Land Cover	Soil Great Group	SOCD (kg m^{-2})
1	Orchard	Dystrustept	4,13
5	Orchard	Dystrustept	6,07
6	Orchard	Haplustalf	5,03
12	Forest	Haplustalf	11,08
4	Pasture	Haplustept	12,42
7	Pasture	Haplustept	8,27
8	Cultivated land	Haplustept	4,74
9	Cultivated land	Haplustept	4,92
11	Forest	Hapustept	17,23
10	Orchard	Calciustept	5,69
2	Pasture	Ustorthent	1,06
3	Forest	Ustorthent	2,72

Results of the surface soils' SOC density under four different land use and land cover were given in Table 3. According to grid system, distributions of soil samples are 13, 23, 15 and 20 for each land use and land covers that are cultivated land, orchard, pasture and forest, respectively. The descriptive statistics as minimum, maximum, mean, and coefficients of variation of SOC density surface soil samples were presented in Table 3. The values of forest widely ranged between 2.84 and 7.94, whereas pasture had a minimum value of 4.22 and a maximum value of 6.79. The lowest values of minimum and maximum belong to cultivated land and changes between 2.88 and 5.05. Analysis of variance indicates that land use has a significant influence on SOC density. The mean SOC density varied significantly by land use (P < 0.05). For the mean SOC density of land use and land cover, forests (6.30 kg/m^2) is highest, followed by pasture (5.17 kg/m^2), orchard (4.69 kg/m^2), with cultivated land (3.85 kg/m^2) being the lowest .

Table 3. SOC density for the surface samples for each land use and land cover

Land use/Land Cover	Mean	Min	Max	SD	CV	n
Cultivated land	3.85^{c}	2,88	5,05	0.77	20.11	13
Orchard	4.69^{b}	1,11	6,54	1.38	29.51	23
Pasture	5.17^{ab}	4,22	6,79	0.80	15.52	15
Forest	6.30^{a}	2,84	7,94	1.26	19.95	20

N: number of sample; SD: standard deviation; CV: Coefficint of Variance (%); Significant differences are indicated by the different letters at P < 0.05.

Conclusion

Results from the present study demonstrate that types of soil and land use systems and vegetation cover exert a profound influence on soil organic carbon in soils. Accordingly, cultivated soils had lower amounts of organic carbon than other land use and land cover systems, suggesting the need for sustainable cropping systems such as crop rotation, addition of organic matter and crop residues to reverse the situation. The low carbon input from the agricultural crop could not compensate for the large mineralization of organic matter in cultivated fields. Variation of organic carbon among different land use and land covers were minimal on the lower soil layer as compared to the surface soil layer, implying that the surface soil layer was most affected by different management practices. On the basis of the above findings, there is a need to develop proper land use policy and sustainable soil management and cropping practices to combat the ongoing soil degradation and improve soil fertility in the study area.

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