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Assessing amount of soil organic carbon and some soil properties under different land uses in a semi-arid region of northern Türkiye

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Abstract: The objective of this study is to investigate the effects of representative land use types and land cover (LUT/LC) of heavily deforested areas on soil properties in semi-arid region of Türkiye. Some of the soil properties have been measured on a grid with a 50 m sampling distance on the top-soil (0-15 cm depth). Data has been analyzed by using Ordinary Kriging/Spherical geostatistical model. Results indicated that the soil properties differed in terms of organic carbon (SOC), pH, bulk density, and the amount of sand, depending on the land uses in the study areas. The SOC concentration of top-soil layers has referred a significant difference (P<0.05) according to the land use type. Top-soil SOC concentrations in the four LUTLCs have been in the following order: cultivated areas < grasslands < Scotch pine stands = Uludağ fir stands. The impacts of LUTLC change on SOC and soil properties have not been restricted to the soil surface; however, relative changes have equally been high in the sub-soil, stressing the importance of sufficiently deep sampling. Furthermore, it has been determined that some physical and chemical characteristics of the natural forest soil have been significantly changed after long term and continuous cultivation. SOC loss is remarkable under the land use conversion while cropland has considerable potential to sequester SOC.
Keywords: Land management, Anthropogenic conversion of ecosystem, Carbon, Soil

Türkiye'nin yarı kurak bir bölgesinde farklı arazi kullanımları altında toprak organik karbon miktarı ve bazı toprak özelliklerinin değerlendirilmesi

Özet: Bu çalışmada Türkiye'nin yarı kurak bir bölgesindeki birbirine komşu farklı Arazi Kullanım Türlerinin ve Arazi Örtüsünün (AKT/AÖ) toprak özellikleri üzerindeki etkileri araştırılmıştır. Toprak özellikleri üst toprakta (0-15 cm derinlik) 50 m örnekleme mesafesine sahip bir grid sistemine göre ölçülmüştür. Veriler, Ordinary Kriging/Spherical jeoistatistiksel model kullanılarak analiz edilmiştir. Araştırma alanında Toprak Organik Karbonu (TOK), pH, hacim ağırlığı ve kum miktarının AKT/AÖ'ne göre istatistiksel bakımdan farklı olduğu belirlenmiştir. Üst topraklar TOK depolama kapasitesi bakımından, AKT/AÖ'ye göre istatistiksel bakımdan önemli (P<0.05) fark göstermiştir. Dört farklı AKT/AÖ'deki TOK depolama sıralaması tarım < mera < sarıçam ormanı = Uludağ göknarı ormanı şeklinde olmuştur. AKT/AÖ değişimi sadece üst topraklarda değil, aynı zamanda alt toprakların özelliklerinde önemli ölçüde değiştirmektedir. Uzun süreli tarımsal faaliyet etkisi ile doğal orman topraklarının bazı fiziksel ve kimyasal özelliklerinin önemli ölçüde değiştiği tespit edilmiştir. AKT/AÖ değişimi TOK depolama kapasitesi bakımından önemli aynı zamanda tarım arazilerini depolama kapasitesinin artırılması da gerekmektedir.
Anahtar kelimeler: Arazi yönetimi, Ekosistemin antropojenik dönüşümü, Karbon, Toprak

1. Introduction

Soil plays an important role in the global carbon cycle. It is recognized as the largest carbon reservoir in the terrestrial ecosystem. Soil organic carbon (SOC) is the main component of soil organic matter (SOM) and as such constitutes the fuel of any soil. SOC is vulnerable to changes in land use and climate (Pugh et al., 2015; Zhou et al., 2019; Berger et al., 2019). SOC and SOM is a crucial contributor to food production, mitigation and adaptation to climate change, and the achievement of the Sustainable Development Goals (SDGs) (Pribyl, 2010; FAO and ITPS, 2018). During the last two centuries, land use practices, such as deforestation and tillage, have resulted in a net loss of soil carbon to the atmosphere (FAO, 2017a). Recent concerns about rising concentrations of carbon dioxide (CO_2) in the atmosphere have led to discussion that a large amount of carbon should be storaged into the soil (Prentice et al., 2001).

The balance between inputs and outputs of SOC influences greenhouse gasses (GHGs) and therefore to the global climate change. Changes in land use type and land cover (LUTLC) are the second source of GHGs emissions to the atmosphere after burning of fossil fuel (IPCC, 2013). As a result, understanding the relationship between land use and SOC dynamics is fundamental for combating land degradation and climate change.

Land use and its various forms of development have become a key determinant of ecosystem health, biological productivity, and water quality in the watersheds. Quinton et al., (2010) state that stabilization of SOC pools increases the primary productivity and decreases soil erosion. Humanity

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has become a major player within the Earth system, particularly by transforming large parts of the land surface and by altering the gas composition of the atmosphere. The conversion of forest and natural grassland to cropland may cause a reduction of SOC (Don et al., 2011; Robertson et al., 2015). Deforestation for agricultural purposes had started thousands of years ago and might have resulted in a detectable human influence on climate much earlier than the industrial revolution. The main causes of degradation include unsustainable logging, agriculture, invasive species, fire, fuel wood gathering, and livestock grazing. (Olofsson and Hickler, 2008; Thompson et al., 2013). A lot of studies (Lal, 2004; Göl, 2009; Houghton and Nassikas, 2018) show decreasing SOC concentrations when native ecosystems have been converted into agricultural land, while SOC concentrations tend to increase in the sequence from cropland to grassland and to forest. Most climate strategies require maintaining or increasing land-based carbon while meeting food demand, which is expected to grow by more than 50 per cent by 2050 (Searchinger et al., 2018). It is poorly understood how future climate and land-use changes will globally combine to alter the health of ecological areas. So, governments should make land-use decisions at least partially directed at reducing GHGs. Globally, SOC loss caused by land-use change has varied from 45 to 114 Pg C (79.5 Pg C on average, 1 Pg = 1015 g) during 1870-2014, mainly due to conversion from natural lands to cultivated areas (Liu et al., 2020). Many studies (Lal, 2004; Harris et al., 2012; Deng et al., 2014; Jeloudar et al. 2014; Wiesmeier et al., 2015; Mukhopadhyay et al., 2015) clearly show that LUTLC changes (especially forest destruction) will directly affect soil carbon pool, thus causes land degradation and global climate change. (Albaladejo et al., 2013) showed that land use was the most important factor controlling SOC concentration in the 0-40 cm depth. The paucity of data on soil carbon distribution in the profile in different landscapes has been identified as one of the major knowledge gaps in soil science (Lal et al., 1998). This is especially significant in the very fragile ecosystems of semiarid regions (Hoffmann et al., 2012).

Land use changes result in bio-geophysical climatic effects through modifications of surface albedo and roughness (Brovkin et al., 2002) and biogeochemical effects through, for example, alterations in vegetation and soil carbon pools which influence atmospheric greenhouse gas levels and global climate (Houghton and Goodale, 2004; Sitch et al., 2008). Globally, two-thirds of terrestrial carbon is stored as organic matter in soil (Köchy et al., 2015). This makes soil one of the world's most important climate regulators (Wasak and Drewnik, 2015).

In most ecosystems worldwide, the conversion of land to agricultural use will drastically change the natural internal nutrient cycling (Batjes, 1996; Stumpf et al., 2018; FAO and ITPS, 2018). In Türkiye, massive deforestation of natural forest and common agricultural use of marginal lands has resulted in soil degradation (Göl, 2009). Despite these risks, there are important gaps still in quantifying and monitoring the forests degradation in semi-arid regions of Türkiye.

Soil properties are the basic data sets that indicate for which purpose the lands will be used. However, the information is insufficient on the effects of land-use change on soil properties in semi-arid regions in northern Türkiye. We hypothesized that in semiarid areas the factors controlling soil properties and SOC levels change with the land use. Therefore, the objectives of this study include (i) determining land-use change effects on SOC stock and some soil properties, (ii) evaluating the most suitable land use to reduce GHGs in the semi-arid regions. Both objectives focus on the context of typical land use changes in Anatolian semi-arid conditions.

2. Materials and methods

2.1. Field description of the study area

This study was conducted in the Tatlıçay catchment which is located in the transition zone of Türkiye from Black Sea region to inner Anatolia. The studied catchment is located between 40º 33'N to 40º 51'N latitude and 33º 17'E to 33º 46'E longitude and having an area of 65468 hectares, and an elevation of 720-1855m above sea level (Fig. 1).

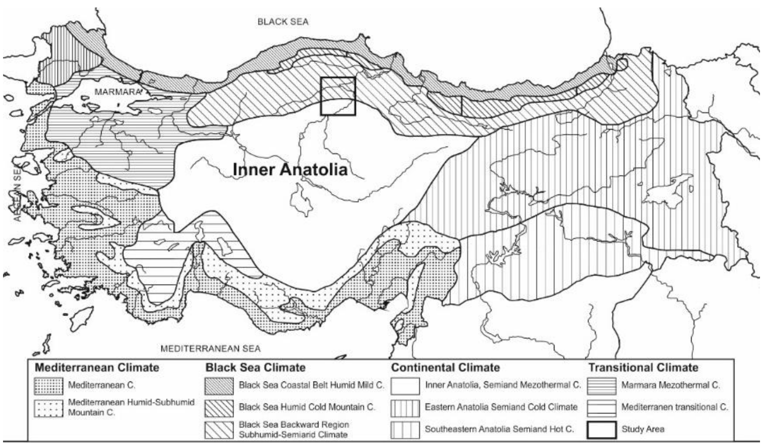

Figure 1. Location of study area is in the transition zone from Black Sea semi-humid climate to Inner Anatolia semi-arid climate

The topographic structure is diverse and shows a constantly changing characteristic. Topographic structure and elevation are the two main determinants of the diverse LUTLC in the catchment. In the upper part of the catchment, land types are not suitable for using agricultural purpose. Land cover has degraded forest type and cattle breeding are common. In the lower part of the catchment, dry land agriculture, degraded pasture and cattle breeding are common.

The catchment has dip slopes and 50% of it consists of steep and vertical fields (Fig. 2). This has significant effects in terms of land use types, land cover, erosion and distribution of settlement areas.

There are two meteorological stations in the catchment and five outside. Long term measurement results collected by these stations show that the catchment has three main climate zones. While the semi-arid climate is dominant in 84% of the catchment, sub-humid climates are dominant in the other 16% of the catchment. The annual average temperature of the catchment is 10.7 ºC. Mean annual rainfall of the catchment is 391 mm and it shows that Tatlıçay catchment is generally under the influence of a semi-arid climate.

Bedrock and soil properties are the main factors that directly affect the water quality and vegetation structure of the catchment. There are two different geological formations (Oligo-miosen gypsum, Miocene series) (Doğan, 2002) in the catchment. Geological structure should be considered in the catchment management planning.

2.2. Soil data set and laboratory analyses

A total of 120 soil samples were collected from the surface (0-15 cm) (since it is effective depth of SOM and SOC accumulation of the study area), according to the grid squares on the 50×50m. Thirty replicate plots were selected in each LUTLC. Sampling from shallow soil layers is still widely adopted today (Olson and Al-Kaisi, 2015; Jiang et al., 2015) including those completely ignored the response of SOC and TN to the LUTLC in deeper soil layers (Lozano-García and Parras-Alcántara, 2014). Soil samples were air-dried and crushed to determine soil properties after transporting to the laboratory. Then these samples were analyzed for particle size distribution (Bouyoucos, 1951), SOM and SOC (Nelson and Sommer, 1996) and total nitrogen (TN) by Kjeldahl (Bremner, 1996), bulk density (BD) (Blake and Hartge, 1986), soil pH (Rhoades, 1996), carbonate ($CaCO_3$-Lime) (Richard and Donald, 1996).

The total SOC storage in the study area was calculated by summarizing the SOC storage for each land-use type, which was calculated by multiplying the average SOC density for each land use type by the corresponding area. The area covered by each different LUTLC was calculated using the land use data in the ArcView software.

The SOC density for each sampling site, *SOCD* ($kg.m^{-2}$), was calculated using the following formula (Eq. 1) (Fang et al., 2012):

$$SOCD = \sum_i^m SOC_i \, BD_i D_i \quad (1)$$

Where SOC_i is the SOC content of the *i*th layer ($g.kg^{-1}$), BD_i is the bulk density of the *i*th layer ($g.cm^{-3}$), Di is the depth of the *i*th layer (m), *m* is the number of the layers. The total SOC (TSOC) storage in the study area, TSOC (kg) can be expressed as follows (Eq. 2.):

$$TSOC = \sum_i^n ASOCD_i \, S_i \quad (2)$$

Where ASOCD*i* is the average SOC density of the *i*th class ($kg.m^{-2}$), S_i is the area of the *i*th class (m^2), n is number of the classes classified according to land use. This calculation excludes particles Ø > 2 mm as they are not a component of bulk density.

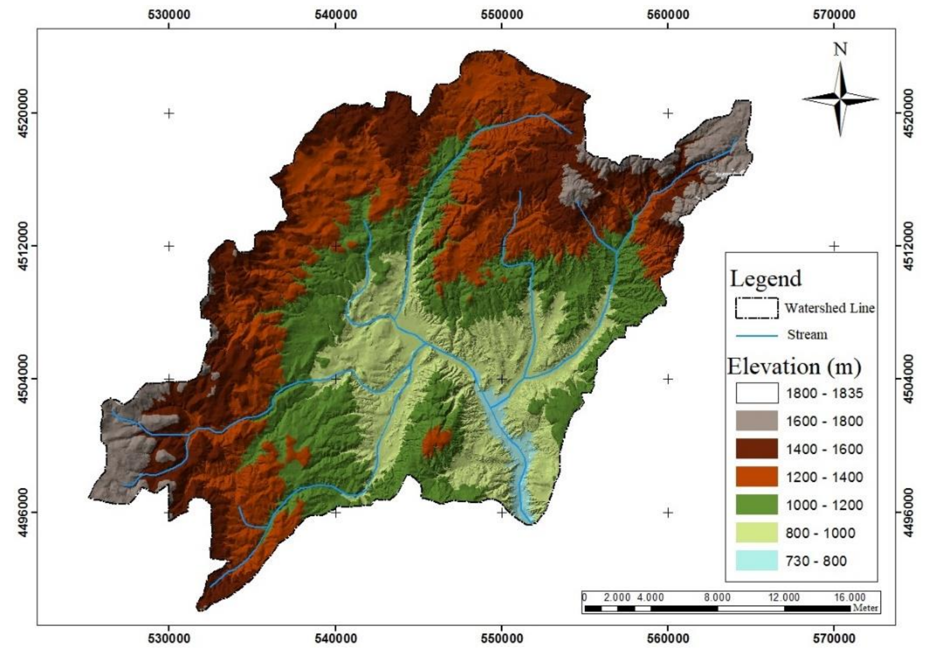

Figure 2. Elevation map of study catchment

2.3. Statistical and geostatistical analyses

Before geostatistical analysis, the normality test with Kolmogorov-Smirnov analysis was implemented by using SPSS® 20.0 software. The descriptive statistics were calculated by using the SPSS® 20.0. An analysis of variance (one-way ANOVA) was performed to evaluate if LUTLC has a relationship with soil properties especially SOC 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.

The block kriging (BK) method ($\gamma(h)$) (Eq. 3.) estimates spatial variability of SOM and SOC content from local area to larger areas. It is an average of all points over a local area. The stock of organic carbon estimates in the 0–15 cm top soil was calculated as follows:

$$\gamma(h) = 1/(2N(h)) \left(\sum_{i=1}^{n} (x_i - x_{(i+h)})^2\right) \quad (3)$$

where: *N(h)* is the number of pairs of observations separated by a given distance *(h)*, x_i and x_{i+h} are observing values at locations, *z* is the random variable.

3. Results

3.1. Land use types and land cover (LUTLC) of Tatlıçay catchment

To determine land use types and land cover (LUTLC) of the study area digital elevation and forest management plan maps were used. According to LUTLC analysis, primary land uses are forest, cultivated land, grassland and settlement (Fig. 4).

Semi-arid climate, soil properties and topography are the main ecological factors that directly affect LUTLC of the catchment. LUTLC in downstream are generally dry land agriculture (wheat, barley, chickpea, sunflower etc.) and degraded grasslands (steppe). Cultivated areas are the highest LUTLC in the catchment and occupied 37%, followed by grassland area (31%), productive, degraded forest and afforestation area (30%) and the others (2%) (Fig. 3).

The dominant tree species of the forest areas in the catchment are: Scotch pine (*Pinus sylvestris* L.), Anatolian black pine (*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe), Uludağ fir (*Abies nordmanniana* (Stev.) Spach. *ssp. bormulleriana* (Mattf.) Code et Cullen). Forestlands are mostly located in north and northeast (upstream) of the catchment (Fig. 3). The forest density in these areas is due to the strong effect of the humid Black Sea climate. There are forests and rich alpine rangeland in the upstream. The soil structure of this area is salty and gypsum-free (GDF 1995a,b). *Xerophytic* plant (Degraded forests, shrub and herbaceous vegetation) exist in the downstream. There is excessive soil erosion in downstream because of the reasons of human impact and overgrazing. There is intense surface erosion in agricultural lands. The soil was dry at the time of the research.

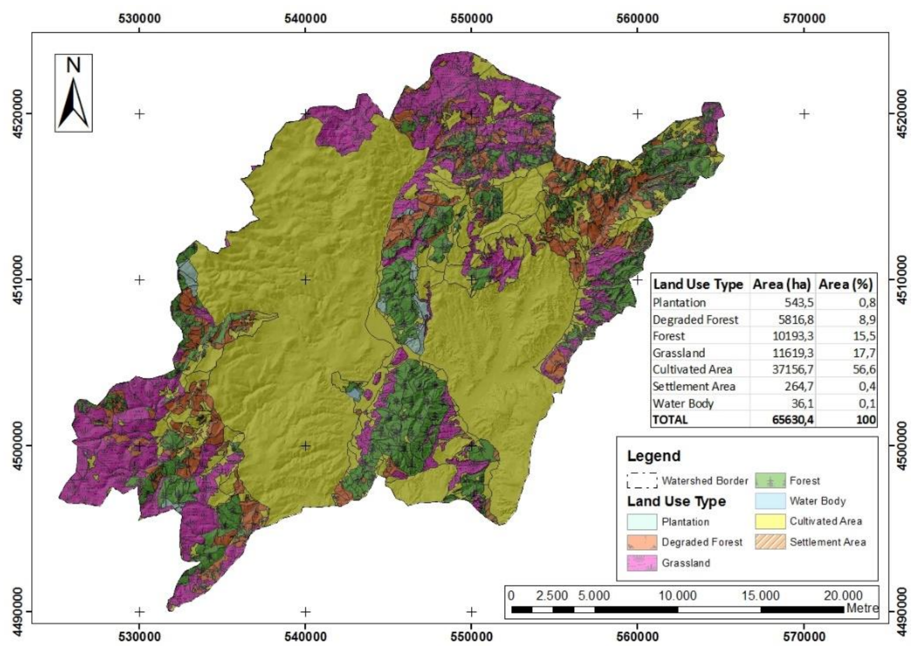

Figure 3. LUTLC spatial distribution of Tatlıçay catchment

3.2. Change of the soil properties under different land uses

The descriptive statics i.e. mean, minimum (min.), maximum (max.), and standard deviation (SD) of observed soil properties were presented in the Table 1. In addition, the soil properties were also determined based on different LUTLC (Table 2).

The pH and lime levels were not significantly different among soil samples under all LUTLC. The results showed that SOM, SOC and TN in the cultivated area were significantly lower than the forest and grazing land. LSD analysis revealed that the difference ($p<0.05$) was due to the variance among all LUTLC. SOC contents were significantly higher in the forest and grassland soils than in the cultivated soils. Long-term cultivation significantly ($p<0.05$) decreased the SOM and SOC content in the top soils (Table 2). Bulk density (BD) under forest was significantly lower than the contents in the cultivated and grazing land soils. At the end of the variance analysis pertaining to BD according to the land use type the result was found statistically significant ($p<0.05$) (Table 2). When LSD test was completed, the cultivated soils were found different than others. With respect to BD, various properties of cultivated, forest and grassland soils were identified in Table 1. The highest (1.44 gr.cm^{-3}) bulk BD was measured in the cultivated soils. The lowest (0.40 gr.cm^{-3}) BD was observed in Uludağ fir forest soils (Table 1).

In the surface soils of the research area, sand, clay, bulk density, lime and pH levels showed low variable (CV<40%) in four different LUTLC. On the other hand, SOM, SOC and TN showed high variable (CV>40%) according to the type of LUTLC. In addition, SOC values of surface soils in Scotch pine forest and Uludağ fir forest showed very variable and min-max SOC content in these soils were 18.45-115.72 Mg.ha^{-1}, 61.76-348.1 Mg.ha^{-1}, respectively (Table 1, Fig. 4).

Except for bulk density, all measured soil properties showed normal distribution in Scotch pine and Uludağ fir forest top soils. Except for lime and pH, all values showed normal distribution in agricultural lands. Sand, lime and pH values showed normal distribution in Scotch pine forests and grassland areas (Table 1).

The highest (60.90%) sand mean value was determined in Scotch pine forest and the lowest (49.06%) in cultivated land soils. According to the bulk density (BD) mean variable, Scotch pine forest and grassland were in the same group, while the highest 1.11 gr.cm^{-3} mean value was obtained in cultivated area, the lowest 0.84 gr.cm^{-3} mean value was determined in Scotch pine forest soils. Soil reactions in the soils of the study area were determined to be moderately acidic (pH 5.76-5.92). The highest mean lime value (1.49%) was determined in cultivated areas, Scotch pine and Uludağ fir forest and grassland soils were in the same group.

The amount of SOM in the research area varies 16.54-1.40%, 15.63-1.03%, and 2.76-1.40%, among forest, grassland and cultivated areas respectively. The highest mean value (9.40%) of SOM was in Uludağ fir forest soils. The lowest mean value (1.75%) of SOM was in cultivated areas soils (Table 2).

Table 1. Descriptive statistics of variables at 0-15 cm soil depths according to different LUTLC

LUTLC	Variable	Unit	Min.	Max.	Mean	SD	Skewness	Kurtosis
Scots pine	Sand	%	52.00	70.00	60.90	3.79	-0.05	0.77
	Clay	%	9.00	21.00	17.20	2.33	-1.62	4.28
	SOM	%	1.14	16.54	3.93	4.24	1.72	2.14
	SOC	gr.kg^{-1}	13.86	42.75	27.18	7.70	0.11	-0.65
	SOC	Mg.ha^{-1}	18.45	115.72	71.27	26.39	-0.08	-0.99
	TN	%	0.06	0.83	0.20	0.21	1.72	2.14
	BD	%	0.40	1.10	0.87	0.20	-0.72	0.20
	Lime	%	0.28	1.69	0.98	0.29	0.30	0.70
	pH		5.23	6.31	5.78	0.24	-0.31	0.87
Uludağ fir	Sand	%	48.00	57.00	52.40	2.43	-0.10	-0.76
	Clay	%	19.00	25.00	22.77	1.77	-0.06	-1.10
	SOM	%	1.07	16.79	9.40	6.09	-0.04	-1.61
	SOC	gr.kg^{-1}	29.41	97.39	62.12	26.57	0.35	-1.86
	SOC	Mg.ha^{-1}	61.76	348.1	162.81	89.41	0.85	-0.67
	TN	%	0.05	0.84	0.47	0.30	-0.04	-1.61
	BD	%	0.63	1.24	0.85	0.16	1.05	0.59
	Lime	%	0.28	1.69	1.05	0.35	-0.08	-0.51
	pH		5.33	6.25	5.77	0.28	-0.02	-1.08
Grassland area	Sand	%	50.00	68.00	58.07	4.55	0.27	-0.63
	Clay	%	11.00	21.00	18.33	2.19	-1.31	3.10
	SOM	%	1.03	17.37	3.85	4.84	2.03	2.89
	SOC	gr.kg^{-1}	7.37	31.15	13.78	4.88	1.75	4.48
	SOC	Mg.ha^{-1}	17.68	84.12	39.11	14.55	1.46	3.02
	TN	%	0.05	0.87	0.19	0.24	2.03	2.89
	BD	%	0.65	1.18	0.95	0.14	-0.35	-0.34
	Lime	%	0.28	1.69	1.13	0.43	-0.41	-1.08
	pH		5.62	6.79	5.93	0.27	1.59	3.05
Cultivated area	Sand	%	45.00	54.00	49.07	2.63	0.22	-0.66
	Clay	%	19.00	28.00	22.73	2.66	0.41	-0.39
	SOM	%	0.66	2.76	1.76	0.56	0.14	-0.72
	SOC	gr.kg^{-1}	3.83	15.64	9.82	2.98	0.25	-0.41
	SOC	Mg.ha^{-1}	15.31	49.19	32.45	10.02	0.01	-1.08
	TN	%	0.03	0.14	0.09	0.03	0.15	-0.71
	BD	%	0.83	1.44	1.11	0.14	0.04	-0.09
	Lime	%	0.42	1.98	1.49	0.33	-1.43	3.10
	pH		5.59	6.92	5.89	0.30	1.86	4.29

SOM-soil organic material, SOC-soil organic carbon, TN-total nitrogen, BD-bulk density SD-standard deviation

Table 2. Comparison of LUTLC in terms of soil properties according to one-way ANOVA by followed LSD (p<0.05).

LUTLC	Sand (%)	Clay (%)	pH	Lime ($CaCO_3$) (%)	SOM (%)	SOC ($gr.kg^{-1}$)	SOC ($Mg.ha^{-1}$)	TN (%)	BD ($gr.cm^{-3}$)
	Means±SD	Means±SD	Means±SD	Means±SD	Means±SD	Means±SD	Means±SD	Means±SD	Means±SD
Scots pine	60.90±3.79^{d}	17.20±2.33^{a}	5.78±0.24^{b}	0.98±0.29^{a}	3.92±4.24^{a}	71.18±7.70^{b}	71.27±26.39^{b}	0.19±0.21^{a}	0.86±0.20^{b}
Uludağ fir	52.40±2.43^{b}	18.33±1.77^{b}	5.76±0.28^{a}	1.04±0.35^{a}	9.40±6.09^{b}	62.12±26.57^{c}	132.82±89.41^{c}	0.47±0.30^{b}	0.84±0.16^{a}
Grassland	58.06±4.55^{c}	18.33±2.19^{b}	5.92±0.27^{c}	1.13±0.43^{a}	3.84±4.84^{a}	13.78±4.88^{a}	39.11±14.55^{a}	0.19±0.24^{a}	0.94±0.14^{b}
Cultivated	49.06±2.63^{a}	22.73±2.66^{b}	5.88±0.30^{b}	1.49±0.33^{b}	1.75±0.56^{a}	9.82±2.98^{a}	32.45±10.02^{a}	0.08±0.03^{a}	1.11±0.14^{c}
F						85.02	48.05		

Abbreviations: pH-soil reaction, L-lime ($CaCO_3$), SOM-soil organic matter, SOC-soil organic carbon, TN-total nitrogen, BD-bulk density, SD- standart deviation, Lower case letters indicate statistically significant differences among soil properties affected by the different LUTLC (p < 0.05), The same letter means that land use types are not statistically different, d > c > b > a

3.3. Spatial variation of soil C

The change of SOC showed significant difference under different land use types in our study. Experimental semi-variograms were fitted using the Spherical model in the interpolation of SOC. Carbon contents of soils in different land-use types were interpolated for unsampled areas. Subsequently, the surface map of SOC for the study area was prepared by ordinary kriging (OK) (Fig. 4). The OK including organic matter as auxiliary variable showed the best performance among the methods used in this study (Root mean square error: 0.917, correlation coefficient (R2) is: 0.862, Pearson's correlation coefficient(r) is: 0.929 mean absolute error: 0.639).

The ordinary kriging model predicted SOC values more stable in agriculture and grassland areas. The range of variation in SOC values measured in forest soils is high (Fig. 5). Near-natural LUTLC classes (grasslands and forest) stock significantly (P<0.005) higher topsoil SOC concentration than cultivated areas. On the other hand Uludağ fir forest soils showed low SOC concentration than Scotch pine forest soils.

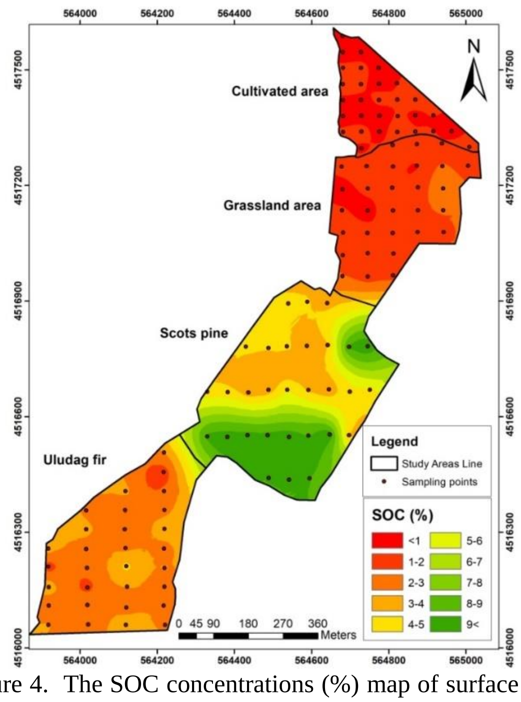

Figure 4. The SOC concentrations (%) map of surface soils in the different LUTLC

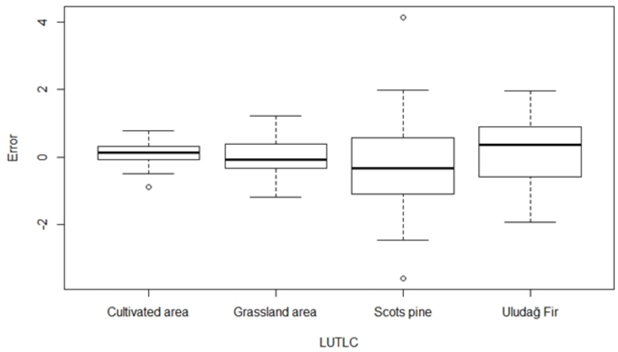

Figure 5. Boxplot of ordinary kriging (OK) method errors for different LUTLC. Hollow circles (○) denote the outliers and extreme outliers.

4. Discussion and conclusion

We investigated soil organic carbon (SOC) concentrations with respect to four adjacent land use types, which represent permanent and dynamic land use of forest-grass- cropland conversions in semi-arid region of Türkiye.

The world's soils are rapidly degraded after population growth and industrialization. Land-use type/land cover (LUTLC) change and consequent land degradation are considered the second greatest cause of carbon emission after fuel consumption (Quadrelli and Peterson, 2007; Schulp and Verburg 2009; FAO and ITPS, 2018).

The climate has a major influence on SOC at the global scale (Bird et al., 2001). At the local level several other factors of soil properties (soil texture, bedrock type, nutrients status, water holding capacity, aerobic microbial respiration etc.) geomorphology, soil erosion modulate the distribution of SOC across the landscape. The role of various natural and anthropogenic disturbances in modifying SOC inventories has received increasing attention in recent decades owing to the large role that LUTLC change plays in determining the magnitude of transfer between the terrestrial carbon sink and atmospheric CO_2 reservoir (Govers et al., 2013; Scharlemann et al., 2014; FAO, 2017b; FAO and ITPS, 2018). Therefore, it is suggested that the effect of LUTLC change on SOC accumulation should be taken into account in future studies to better understand the role of LUTLC change in the global C dynamics. Sustainable land management contributes to climate change mitigation depending on soil management practices.

LUTLC changes are the second-largest source of human-induced greenhouse gas emissions (GHGs), mainly due to deforestation all over the world. The conversion of native vegetation to agricultural systems caused the highest SOC losses among all land use change types (Liu et al., 2017; Chatterjee et al., 2018). SOC has also long been used as an indicator of soil health, due to its capacity to improve the structural stability of soil, effecting porosity, aeration and water filtration capacities to supply clean water. However, SOC mineralization can be an important source of GHGs emissions. SOC dynamics under different LUTLC are still poorly understood, especially when the data collected from extensive areas and from different climatic zones (Schillaci et al., 2017). This means that changing SOM (and hence SOC) not only changes the provision of ecosystem services required for crop production, but also affects soils capacity to buffer against environmental changes, as it regulates the resilience of agricultural systems to climate change (FAO and ITPS, 2018).

The SOC storage is influenced by different factors such as climate, geology and soil biomass. On the other hand, the most important human effect on the rate of changes in SOC is attributed to land use conversion. LUTLC conversion from forest to cultivated or grazing land reduced soil carbon stock. In Türkiye most of LUTLC changes occur from forest to marginal agriculture and grazing lands. Semi-arid ecosystems in Türkiye are very fragile. On the other hand, insufficient rainfall and shallow soil are the most prominent properties of semi-arid regions of Türkiye. The main cause of soil erosion is the destruction of natural vegetation in these regions (Göl, 2009; Göl et al., 2017; Göl and Yılmaz, 2017). Rural population living in these regions has no income other than agriculture and animal husbandry. This situation causes natural areas to be rapidly destroyed.

Changes in LUTLC have a drastic effect on the physical, chemical, and biological properties of soil and hence it changes the soil quality (Liu et al., 2020; Kooch and Noghre, 2020). During the last few decades, as a result of increasing demand for agriculture and settlement area, particularly forest and grasslands are being cleared and converted to degraded areas. Studies about the impact of deforestation (Yazdanshenas et al., 2021) on SOC dynamics are particularly interesting as degradation affects large areas of forest in mountain areas all over the world (Seeber and Seeber, 2005; Barua and Haque, 2013; Zhou et al., 2018). The review of Guo and Gifford, (2002) pointed to a decrease of 59% in SOC due to a change from pasture to cropland. At regional scales, Vagen et al. (2005) report a decrease from 0% to 63% of soil organic C following deforestation in sub-humid and semi-arid savannas. In China (Wu et al., 2003; Zhou et al., 2019) reductions of 10% to 40% of the SOC in cultivated soils compared with the non-cultivated soils have been reported, the soils showing the highest losses being located in the semi-arid and sub-humid areas of that country (Boix-Fayos et al., 2009).

There have been a considerable number of studies on the dynamics of SOC concentration and its stock across the world (Friedlingstein et al.,2008; Poeplau et al., 2011; Wei et al., 2014; Pugh et al., 2015; Zhou et al., 2019; Kooch and Noghre, 2020). The results of our study show that, carbon content of the top soil section in forest and natural areas are higher than in cultivated soils because of LUTLC change. Similar results have also been reported that cultivation land had a 58% lower SOC level compared to forest land in inner Mongolia (Binyong et al., 2012), and 63% lower SOC level in cropland compared to forest after 30 years of cultivation period in the southern highlands of Ethiopia (Assefa et al., 2017). The SOC mean level in grassland topsoil (1.46 $Mg.ha^{-1}$) is less than the adjacent Uludağ fir forest topsoil (162.81 $Mg.ha^{-1}$) and scocts pine fir forest soil (71.27 $Mg.ha^{-1}$). In this study, Assefa et al. (2017) found that conversion of natural forest to grazing land also significantly reduced SOC stock in the soil by 53%. Bewket and Stroosnijder (2003) showed that grazing land had 48% lower levels of SOM than natural forest. Similarly, in our study, cultivated areas carbon stock 32.45 $Mg.ha^{-1}$ in top soils was very low compared to the adjacent forest and grassland areas carbon stock. This research has shown that carbon storage is decreasing as a result of overgrazing in grassland areas. Poor management of grasslands led to a decrease in SOC even in semi-arid areas. Since there is not enough rainfall in semi-arid areas of Türkiye, the use of fertilizers is very low. The increase of SOC stock in enclosures area indicates that an increase of vegetation growth and input of carbon can begin to restore SOC stocks (Li et al., 2012).

The conversion of forests to cultivated areas has had a negative impact on the SOC storage capacity of the topsoil the study area. It has been shown that cultivation exerts a negative role on SOC accumulation in various environments (Francaviglia et al., 2017). Similar results have been reported in the world (FAO and ITPS, 2018; Zhou et al., 2019; Liu et al., 2020; Kooch and Noghre, 2020).

The carbon stock of soils of Türkiye does not mirror the common problems of land-use changes. In semi-arid regions of Türkiye, the lack of knowledge on SOC dynamic is due to drought conditions and insufficient land management system.

This research will help to clarify how land-use change affects the soil properties and resulting carbon cycles dynamics. Land use contributes to SOC change more than temperature and precipitation change in semi-arid regions of Turkey. The SOC concentrations and some soil properties were statistically analyzed in relation to the land-use dynamics. The SOC, TN and BD of soil are strongly correlated with land use management practices. The Statistically significant differences in SOM, SOC, TN and BD were detected among the soils of grassland, forest and cultivated areas. These results demonstrate that the effect of land use and land cover change on BD was limited to shallower depths in the soil profiles. As far as I understand, the sentence could be as: The above results indicate that converting natural forests to grasslands and cultivated areas reduces SOC and SOM in soils. All these findings highlight that soil is the most important carbon sink area if suitably managed. On the other hand, when the soil is poorly managed, it will be the most important source of GHGs.

This study reveals that land-use change had a significant effect on soil organic carbon and soil properties. Our results refer the emission of GHGs under inappropriate land-use change. Conversion of forest to agriculture or grassland negatively affects the carbon storage of the surface soils.

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