# Land use effects on soil physical properties in semiarid region of Turkey

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**Abstract:** The conversion of cultivated and grasslands areas to forest has been occurring in Black Sea backward region of Turkey for decades. The legacy of management activity during this transition is reflected in soil physical and chemical properties years after abandonment. The purpose of this research is to compare the soil properties in four adjacent land uses including the cultivated area, the grassland area, the plantation area and the natural forest area in semi-arid region of Black Sea backward region of Turkey. Some of soil properties, including texture, pH, total nitrogen, soil organic matter (SOM), and bulk density were measured at a grid with 50 m sampling distance on the surface soil (0 - 20 cm depth). Disturbed and undisturbed soil samples were taken from one hundred sampling points. According to the results dry bulk density (BD), SOM, and total nitrogen (TN) significantly change with land use. Soil characteristics negatively affected by tillage practices and grazing are BD and SOM. Finally, the findings indicated that tillage and grazing, in semi - arid region, affected adversely on soil properties. On the other hand, success afforestation works have been developing and protecting the surface soil properties.
**Keywords:** Land use, Semiarid, Desertification, Turkey

## 1. Introduction

Several semi-arid areas of the world are vulnerable to environmental changes (Warren *et al.*, 1996) and are degraded (UNEP, 1992), partly due to reduction in the permanent plant cover (Le Houe´rou, 1995). This degradation includes reduced SOC levels, lower soil nutrient content, lower water holding capacity and increased risk of erosion (Batjes, 1999). These degraded areas have a large potential to sequester C in the soil, which may be preferable to storage in vegetation due to their longer residence times and less risk of a rapid release (Lal et al., 1999). Batjes (1999) estimated that between 0.6 and 2 PgC/ year could be sequestered by the large-scale application of appropriate land management in the world's degraded areas. This accounts for 18– 60% of the annual increase of CO2 in the atmosphere. Squieres (1998) estimated the potential sink of dry lands to be 110 PgC / year over the next 50 years. In addition to the removal of atmospheric CO2, increased soil organic matter (SOM) in semi-arid environments could be beneficial to food productivity and erosion control in poor and degraded areas (Ringius, 1999).

Land use change can cause a change in land cover and an associated change in carbon stocks (Bolin and Sukumar, 2000). The change from one ecosystem to another could occur naturally or be the result of human activity, such as for food or timber production. Each soil has a carbon-carrying capacity, i.e. equilibrium carbon content depending on the nature of vegetation, precipitation and temperature (Gupta and Rao, 1994). The equilibrium carbon stock is the result of a balance between inflows and outflows to the pool (Fearnside and Barbosa, 1998). The equilibrium between carbon inflows and outflows in soil is disturbed by land use change until a new equilibrium is eventually reached in the new ecosystem. During this process, soil may act either as a carbon source or as a carbon sink according to the ratio between inflows and outflows. Some studies have reviewed the effects of certain land use changes on soil carbon stocks, such as forest clearing (Allen, 1985), tropical forest clearing (Detwiler, 1986), disturbance and recovery (Schlesinger, 1986), cultivation (Davidson and Ackerman, 1993), deforestation for pasture (Neil and Davidson, 2000), and from cultivation and native vegetation into grasslands (Conant et al., 2001). The main objective of this study was to determine the relationships between LUTLC and soil properties in the semiarid climate zone of Turkey.

## 2. Material and method

### *2.1. Study location*

This study was conducted in the Karataşbağ River stream catchment located Eldivan district of Çankırı province found on in transition zone Black Sea climate to Inner Anatolia semiarid mezzo - thermal climate. Coordinated of study area between 40° 38' - 40°20' N and 33°36' - 33° 25' E (Fig. 1). The study area consists of various topographic features. Due to high slope degree and misuse and mismanagement of fragile natural structure of the study area, severe soil erosion and landslide had been occurred which leads to economic and ecologic destruction on agricultural areas and settlements until 1961. After this phenomenon, catchment was rehabilitated and reforested from 1961 to present.

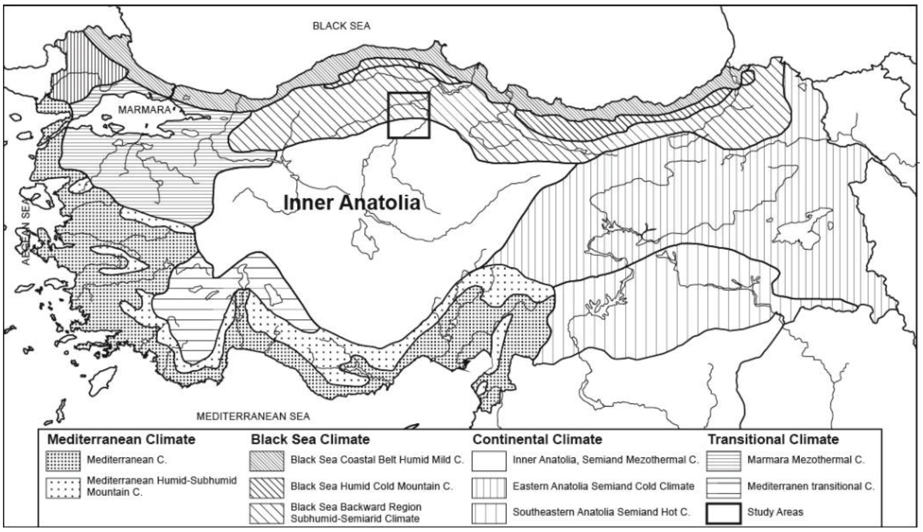


Figure 1. Location of study area in transition zone Black Sea climate to Inner Anatolia semiarid mezothermal climate

The climatic type of the region was determined by using the data from the Eldivan Climate Station (Anonymous, 2016) according to the Thornthwaite method. Climate type at the research area was "arid - subhumid, mesothermal, moderately excessive water during winters, close marine" climate type. The north and south Anatolia mountains ranges block the moist air flow from the sea. Therefore, Central Anatolia receives the least rainfall in Turkey and is the most arid regions. The forests in this region are generally located above 1000 m altitude. These forests are under the pressure of aridity, shallow and unproductive soil characteristics, human activities, and grazing. This situation results in a fragile ecosystem of high mountain forests in Central Anatolia. Grazing fields have created by transforming agricultural lands in steeper hill slopes when soil productivity decreased as intensively crop production. The main ecological factors that determine the soil properties of different land use type and land cover (LUTLC).

The mean annual precipitation of the region is 500 mm, while the mean temperature is 10.4 $^{o}$C. According to the Thornthwaite method research area "semi - dry - moist, mesothermal, in excess of water in the dead of winter, the marine climate in the near influence" with a climate that has emerged on the type. The north and south Anatolia mountains ranges block the moist air flow from the sea. Therefore, Central Anatolia receives the least rainfall in Turkey and is the most arid regions. The forests in this region are generally located above 1000m altitude. These forests are under the pressure of aridity, shallow and unproductive soil characteristics, human activities, and grazing. This situation results in a fragile ecosystem of high mountain forests in Central Anatolia. When the general land use in Central Anatolia is considered, it could be observed that low altitude regions are used for dry farming and dry steppe grassland. High altitude regions are formed of forests, rangeland, plateaus, and marginal agricultural lands.

Research area was formed of Tertiary Oligo - miocene gypsum series. That formation starts with thick and red bottom conglomeras followed by light color clay and marl, stratified with gypsum. Top strata of the gypsum series may include Miocene at many locations. This sequence implies marine regression and replacement of desert climate (Ketin, 1962). Catchment soils were classified as Entisols and Inceptisols according to Soil Survey Staff (1999), (Göl and Dengiz, 2007).

The natural tree species of the sample area are Anatolian Black Pine (*Pinus nigra* subsp. *Pallasiana* var. *Pallasiana* (Arnold*)*), Cedar (*Cedrus libani* A. Richard), oak (*Quercus* sp.), juniper (*Juniperus* sp.), hornbeam (*Carpinus* sp.), willow (*Salix* sp.), linden (*Tilia* sp). The woodland comprises of black pine (Pinus nigra Arn. subsp. nigra var. caramanica (Loudon) Rehder) and Oak. (Quercus cerris L., Q. pubescens Willd). Principal tree species of the plantation, which was replaced by the original woodland forty eigth years ago, is Pinus nigra, which is also principal tree species of the natural forest in the site. (Göl et al., 2010).

*2.2. Soil sampling and Laboratory analyses*

The investigations were carried out within four different adjacent LUTLC namely; natural forest (Anatolian black pine), plantation forest (Anatolian black pine, 57 year - old plantation), grassland, and cultivated land (dry farming).

The distributions of sampling plots in the grid system (50 x 50 m) are total 120 soil samples (4 land use types x 30 surface soil samples) for all three different adjacent LUTLC. Soil samples were collected at surface soil (0 - 20 cm depth) (because of effective depth of soil organic matter accumulation in the study areas). The undisturbed soil samples were taken by a steel core sampler of a 100 cm$^3$ volume for dry bulk density analysis (120 samples). Sampling method was systematic with equal distances between soil samples in this study. Random sampling can generate (Fig. 2).

Soil samples were taken only from the surface soil (0-20 cm depth) and analyzed for particle size distribution (Bouyoucous, 1951), Dry bulk density (BD) was calculated by dividing the oven dry mass at 105°C by the volume of the core (Cassel and Nielsen, 1986). Soil pH and was measured on a 1:5 soil to water ratio suspensions by a pH/conductivity meter (Rhoades, 1996). Carbonate ($CaCO_3$) was determined by pressure calcimeter method (Richard and Donald, 1996). The concentration of soil organic matter (SOM) was determined by using the Walkley and Black method (Nelson and Sommer, 1996). Total nitrogen (TN) was determined by Kjeldahl method (Bremner, 1996).

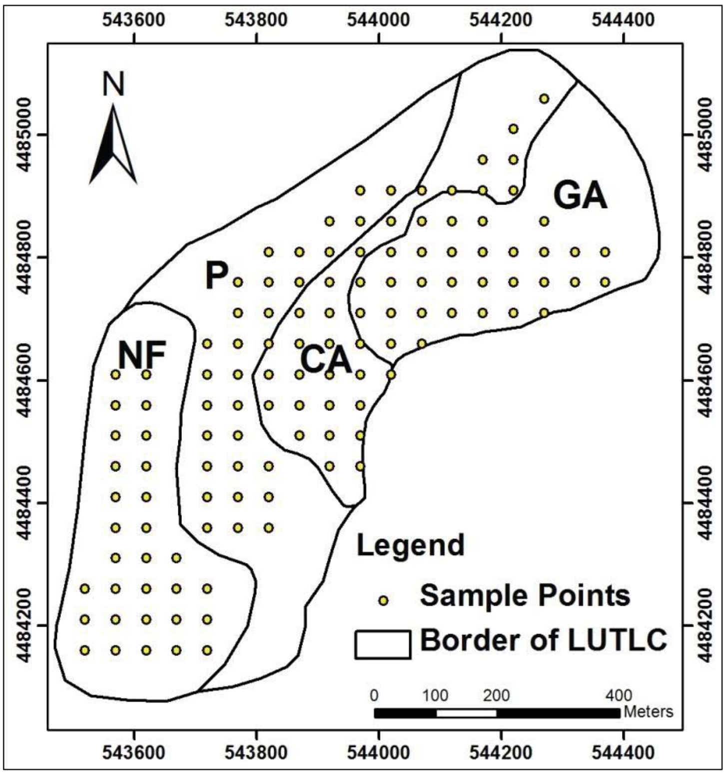


Figure 2. Sampling points in different Land Use Type / Land Cover ( NF - natural forest, P -plantation forest, CA - cultivated area, GA - grassland area)

*2.3. Statistical analysis*

The descriptive statistics (mean, maximum, minimum, standard deviation (SD), coefficient of variation (Cv), skewness, kurtosis coefficient for soil properties in terms of LUTL were calculated using the SPSS® 20.0 (IBM corporation software). Before geostatistical analyze, normality test with Kolmogorov-Smirnov analysis was implemented using SPSS® 20.0 software. The log-transformation was made for providing constant variance because SOM values in our data set showed a non-normal distribution, and the spatial analysis of SOM content were made based on log-transformed values in this study (Webster, 2001). Mean differences between soil organic carbon values of land use types were compared using one-way ANOVA by followed LSD test ($p < 0.05$).

**3. Result and discussion**

The descriptive statistics including mean, min., max., standard deviation (SD) and coefficients of variation (CV) of some observed soil properties are presented in Table 1. On the other hand, soil properties of different LUTLC were determined (Table 2). Soil pH was not significantly different between soils under the all the LUTLC. The results showed that SOM and TN in the soils of cultivated area were significantly lower than in the soils of forest and the grazing areas. LSD analysis revealed that the difference ($p < 0.05$) was due to the variance among all LUTLC. 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; Watson et al., 2000). Conversion of the natural forest into continuous cultivation had resulted in statistically significant decreases of both the concentration and stock of SOM and TN (Göl, 2009).

Soil properties change directly according to land use types. Therefore, SOM content, especially in surface soils alters within a quite wide range. This usually leads to a heavy-tailed distribution. In our data set, the skewness was quite high. Therefore, log-transformation was applied to the data to decrease effect of extreme values (Webster, 2001). Soil texture classes are clay loam, sandy clay loam, sandy loam, silt clay loam and clay in all land uses. The pH values of the forest, grassland and cultivated lands varied significantly from 7.05 to 7.69 (Table 1).

The descriptive statistics for soil organic carbon (SOM) at 0 - 20 cm under different land uses are presented in Table 2. The SOC values vary between 0.26% and 5.34%. The highest and the lowest SOM content in surface soils were found in natural forest and cultivated, respectively. Coefficient of variation (Cv) (%) varied from 33.51 - 46.76% for SOM, and for whole area it was 31.31% (Table 1). Kolmogorov-Simirnov normality test showed that the SOM content distribution deviated from normality ($p < 0.01$). In our study, SOM content in surface soils is statistically different in terms of land use types (p <

0.05). The similar results were found in relevant studies. For instance, Abegaz et al. (2016) reported that differences in organic carbon content among land use types including cropland (Zheng et al., 2016), brush land (DeMarco et al., 2016), grassland (Conant et al., 2016), and forestland (Were et al., 2015) were statistically significant ($p < 0.01$), and greater amounts of carbon were stored in forest soil compared to other land use types in smallholder farming systems, at highlands of Ethiopia. Vågen and Winowiecki (2013) found that the greatest SOM values (0 - 30 cm) were in grassland, while the lowest values were in brush lands and woodlands (croplands to forest) in semi-arid ecosystems. SOM plays a key role in nutrient cycling and can help improve soil structure. SOM is an important source of nutrients for plants.

Table 1. Descriptive statistics of soil properties sampled to a depth of 20 cm in adjacent different LUTLC (Nt = 120).

| Land-use and cover types | Soil Properties | | N | Min. | Max. | Mean | SD | Skewness | Kurtosis | Cv (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Dry Farming | Clay | % | 30 | 22.00 | 53.00 | 40.73 | 8.96 | -0.60 | -0.47 | 22.00 |
| | Silt | % | 30 | 17.00 | 35.00 | 24.63 | 3.65 | 0.95 | 2.43 | 14.83 |
| | Sand | % | 30 | 23.00 | 53.00 | 34.63 | 6.71 | 0.67 | 0.56 | 19.38 |
| | BD | $gr.cm^{-3}$ | 30 | 0.95 | 1.44 | 1.13 | 0.13 | 0.73 | -0.16 | 11.13 |
| | pH | | 30 | 7.21 | 7.75 | 7.40 | 0.12 | 0.89 | 1.42 | 1.62 |
| | SOM | % | 30 | 0.26 | 2.20 | 1.15 | 0.50 | -0.01 | -0.65 | 43.60 |
| | TN | % | 30 | 0.01 | 0.11 | 0.06 | 0.03 | 0.00 | -0.65 | 43.57 |
| Grassland | Clay | % | 30 | 20.00 | 49.00 | 35.80 | 10.93 | -0.07 | -1.76 | 30.52 |
| | Silt | % | 30 | 5.00 | 36.00 | 25.50 | 6.04 | -0.82 | 3.66 | 23.70 |
| | Sand | % | 30 | 26.00 | 55.00 | 38.70 | 8.57 | 0.24 | -1.07 | 22.15 |
| | BD | $gr.cm^{-3}$ | 30 | 0.85 | 1.99 | 1.11 | 0.21 | 2.53 | 10.12 | 18.96 |
| | pH | | 30 | 7.33 | 7.63 | 7.47 | 0.08 | 0.54 | -0.40 | 1.08 |
| | SOM | % | 30 | 0.26 | 2.75 | 1.23 | 0.47 | 0.93 | 2.99 | 38.36 |
| | TN | % | 30 | 0.01 | 0.14 | 0.06 | 0.02 | 0.93 | 3.00 | 38.37 |
| Plantation Forest | Clay | % | 30 | 24.00 | 55.00 | 36.03 | 8.99 | 0.72 | -0.68 | 24.96 |
| | Silt | % | 30 | 12.00 | 35.00 | 25.57 | 4.19 | -0.87 | 3.07 | 16.39 |
| | Sand | % | 30 | 26.00 | 49.00 | 38.73 | 6.71 | -0.16 | -1.16 | 17.32 |
| | BD | $gr.cm^{-3}$ | 30 | 0.74 | 1.16 | 0.98 | 0.12 | -0.42 | -0.92 | 12.43 |
| | pH | | 30 | 7.05 | 7.69 | 7.29 | 0.13 | 0.63 | 2.05 | 1.76 |
| | SOM | % | 30 | 1.03 | 4.86 | 2.44 | 1.14 | 0.65 | -0.76 | 46.76 |
| | TN | % | 30 | 0.04 | 0.24 | 0.12 | 0.06 | 0.57 | -0.81 | 48.88 |
| Nature Forest | Clay | % | 30 | 17.00 | 49.00 | 33.23 | 7.69 | 0.12 | -0.37 | 23.13 |
| | Silt | % | 30 | 18.00 | 31.00 | 23.73 | 4.08 | -0.13 | -1.15 | 17.18 |
| | Sand | % | 30 | 29.00 | 62.00 | 43.03 | 9.61 | 0.46 | -1.14 | 22.33 |
| | BD | $gr.cm^{-3}$ | 30 | 0.71 | 1.13 | 0.92 | 0.09 | -0.35 | 0.60 | 10.01 |
| | pH | | 30 | 7.06 | 7.46 | 7.26 | 0.12 | 0.05 | -1.32 | 1.65 |
| | SOM | % | 30 | 1.17 | 5.34 | 2.87 | 0.96 | 0.63 | 0.03 | 33.51 |
| | TN | % | 30 | 0.06 | 0.27 | 0.13 | 0.05 | 1.04 | 0.89 | 38.13 |

Results of one-way ANOVA test showed that SOM and TN mean values were different by land use types ($F = 28.462$, $p < 0.05$), ordering as natural forest = plantation > grassland = cultivated area (Table 2).

When the dry bulk density (BD) values under different land use types are compared, the lowest value (0.71 g $cm^{-3}$) was measured in natural forest soils and the highest value (1.99 g $cm^{-3}$) was measured in agricultural lands. The differences in BD values of all LUTLC were found to be statistically significant with respect to the land use type ($p < 0.05$).

Bulk density of a soil is a dynamic property that varies with the soil structural conditions. In general, it increases with profile depth, due to changes in organic matter content, porosity and compaction. The bulk density depends on several factors such as compaction, consolidation and amount of SOM present in the soil but it is highly correlated to the organic material content (Chaudhari et al., 2013). Many researchers (Morisada, 2004; Leifeld et al., 2005; Chaudhari et al., 2013) obtained the relationship between organic matter and bulk density of soils and showed strong correlation between them.

Table 2. Comparison of types of land use in terms of soil properties according to one-way ANOVA by followed LSD

| LUTLC | | Sand (%) | BD ($gr.cm^{-3}$) | pH | SOM (%) | TN (%) |
|---|---|---|---|---|---|---|
| | N | M ± Std. Error | M ± Std. Error | M ± Std. Error | M ± Std. Error | M ± Std. Error |
| Dry Area Farming | 30 | $34.63 \pm 6.71^{a}$ | $1.13 \pm 0.1263^{b}$ | $7.39 \pm 0.11^{b}$ | $1.14 \pm 0.50^{a}$ | $0.05 \pm 0.02^{a}$ |
| Grassland | 30 | $38.70 \pm 8.57^{a}$ | $1.10 \pm 0.2103^{b}$ | $7.46 \pm 0.08^{c}$ | $1.22 \pm 0.47^{a}$ | $0.06 \pm 0.02^{a}$ |
| Plantation | 30 | $38.73 \pm 6.71^{a}$ | $0.97 \pm 0.1213^{a}$ | $7.25 \pm 0.12^{a}$ | $2.44 \pm 1.14^{b}$ | $0.12 \pm 0.05^{b}$ |
| Natural Forest | 30 | $43.03 \pm 9.60^{b}$ | $0.92 \pm 0.0922^{a}$ | $7.28 \pm 0.11^{a}$ | $2.86 \pm 0.96^{c}$ | $0.12 \pm 0.04^{b}$ |
| F | | 5.518** | 15.341** | 21.911** | 33.314** | 24.495** |

Abbreviations: BD – dry bulk density, SOM – soil organic material, TN – total nitrogen

** Significant at $p \leq 0.05$, c > b >a, Different letters show that means have statistically significant different ($p < 0.05$)

**Conclusion**

LUTLC led to changes in some of the physical chemical and hydro - physical properties of soils especially. Soil characteristics affirmatively affected by changes of LUTLC are SOM, TN, and BD. Effect of LUTLC on SOM was found to be higher than that of the other soil properties. There was high degree reverse relationship between LUTLC and SOM storage of soil. The results indicate converting grassland or cultivated areas to plantation forest improve soil properties. In our study showed strong relationship between soil properties and LUTLC. Our results demonstrate that, within the 57 - year time frame, both land - use type and forest type have an influence and long - term effects on soil physical properties.

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