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# Effects of deforestation on soil properties and organic carbon stock of a hillslope position land in Black Sea Region of Turkey

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## Abstract

The effects of deforestation on soil properties and soil organic C (SOC) stock in adjacent pasture and forest areas located on the same hillslope position were investigated. The soil properties measured in the forest site had higher coefficient of variation compared with pasture site. Deforestation made almost 50 years ago significantly increased bulk density (Db), soil pH, exch. Mg and significantly decreased total porosity (F), gravimetric moisture content (W), EC, exch. K, soil organic matter (OM), SOC stock in 0-15 cm soil depth in pasture site. Mean Db increased fom 1.24 g/cm$^3$ in forest to 1.42 g/cm$^3$ in pasture while mean values of OM and SOC stock depleted from 4.41% and 30.70 ton/ha in forest to 1.89% and 15.55 ton/ha in pasture, respectively. The reduction ratios in some soil properties by changing land use type from forest to pasture were determined in the following order; OM (57.14%) > exch. K (55.88%) > SOC (49.35%) > EC (45.65%) > W (28.96%) > exch. Na (18.75%) > F (11.32%) > exch. Ca (4.07%). The values of OM and SOC stock had significant positive relations with F, W, EC, exch. K, and significant negative relations with Db, pH, exch. Mg. After deforestation, abandoning cultivated land to pasture had negative impact on the soil properties and depleted SOC stock in 0-15 cm soil layer.

**Keywords**: Land use, pasture, deforestation, soil organic C, soil properties.

## Introduction

Clearing forests for agricultural use is a historical cause of deforestation in many areas of the world (Gorte and Sheikh, 2010). Deforestation has negative impacts on global climate change, loss in biodiversity and environmental sustainability. In the most study, it was reported that after deforestation and subsequent land use including pasture deteriorate soil physical, chemical and biological properties (Lu et al., 2002; Sahani and Behera, 2001; Rasiah et al., 2004; Zhang et al., 2004).

Many soil quality parameters interact each other related with land use, land characteristics and management practices (Karaca and Gülser, 2015; Karaca et al., 2018; Doğan and Gülser, 2019; Doğan and Gülser, 2020; Karaca et al., 2021). Gülser et al. (2020) found that under a hot and dry climatic condition, reduced tillage system decreased bulk density and increased total porosity with conserving soil OM due to preventing from rapid mineralization. The land use changes, including conversion of forestland into cropland, pasture land, and settlement areas generally cause soil degradation, soil organic carbon (SOC) and nutrient losses (Wang et al. 2001; Dinesh et al., 2003). The loss of soil OC due to deforestation has negative effects on soil quality parameters by influencing soil physical, chemical and biological, properties (Sun et al., 2015; Qi et al., 2018). Vera et al. (2007) studied the effect of deforestation and replacement by pasture in the rainforests of the Venezuelan Andes on soil properties. They reported that there were major differences in the microstructure

and porosity, as well as in the characteristics of the fine fraction and organic constituents, together with other soil properties in the natural or altered forest landscape. Lemenih et al. (2005) reported that soil OC and total N contents in the surface soil layer under cultivation in 53 years decreased significantly compared with the natural forest. Koutika et al. (1997) studied on organic matter dynamics and aggregation in soils under rain forest and pastures of increasing age for 7, 12 and 17 years in the eastern Amazon Basin. They found that the effects of deforestation and pasture establishment on both clay and carbon contents were not significant, whereas significant differences were recorded for aggregate fabric porosity, water retention and reduction in total porosity with increasing pasture age. Organic material addition to soil increases basal soil respiration (BSR), aggregate stability and soil OC content which is significantly related with EC, total porosity, and bulk density (Gülser and Candemir, 2015; Gülser et al., 2017).

Many researchers indicated that the most important effect on soil organic carbon (SOC) stock rate is the change of land use type (Guo and Gifford, 2002; Liu et al., 2002; Don et al., 2007; Assefa et al., 2017). It has been reported in many studies that the conversion of natural vegetation to cropland often causes to a reduction of SOC stocks (Hajabbasi et al. 1997; Liu et al., 2002; Assefa et al., 2017). Del Galdo et al. (2003) determined that SOC content in the top 10 cm layer of cropland soils was 48% lower than that of permanent grassland soils.

Saikh et al. (1998) reported that deforestation in the tropic areas has a serious problem in soil because of the reduction in cation exchange capacity (CEC) and the consequent losses of nutrients from the soils. They found that grasslands and cultivated lands have statistically similar CEC but levels are higher in deciduous forest soils and the highest in evergreen forest soils in where only the soil organic C can significantly increase the CEC. Hajabbasi et al. (1997) found that deforestation and subsequently tillage practices resulted in 20% increase in bulk density, 50% decrease in organic matter and total nitrogen, between 10 and 15% decrease in soluble ions when compared the undisturbed forest soil.

Clearance of forests for agricultural purpose and grazing is widespread, especially in highlands of Turkey (Celik, 2005). There are several cultivation areas abandoned to pasture lands after deforestation in Black Sea Region of Turkey. Therefore, the objective of this study was to compare the long term effects of deforestation on soil properties and SOC stock in adjacent pasture and forest areas located on the same hillslope position in Samsun-Turkey.

## Material and Methods

Two different lands were selected including a natural oak forest (*Quercus brontii*) ($41^0$ 25,800' N, $36^0$10,425' E) and a pasture ($41^0$21,534' N, $36^0$10,449' E ) land on 25% hillslope position about 320 m altitude with an average annual temperature of $14,6^0$C and 720 mm of precipitation in Atakum, Samsun-Turkey. The soil in the study area is formed on basalt parent material. Forest clearance had been made more than 50 years ago by the local farmers to gain a field for cultivation. The field was abandoned as a pasture field later.

Disturbed and undisturbed six surface soil samples (0-15 cm) for each land use type were taken from the adjacent pasture and forest lands located on the same hillslope position. The soil depth is about less than 20 cm in both land uses. Bulk density (Db) values were determined on undisturbed soil core samples, and total porosity values were calculated using the following equation; F = [1 – (Db/2.65)] (Demiralay, 1993). After air drying the samples, soil particle size distribution was determined according to Bouyoucos hydrometer method (Demiralay, 1993), soil reaction (pH) and electrical conductivity ($EC_{25°C}$) values in 1:1 soil:water suspension, soil organic matter (OM) by 'Walkley-Black' method and exchangeable cations (Ca, Mg, K, Na) by ammonia acetate extraction method (Kacar, 1994). Soil organic C (SOC) stock in both land use was estimated for a volume of soil (1500 $m^3$/ha) in 15 cm soil depth using the equation given below,

$$\text{SOC (ton/ha)} = \text{volume of soil (m}^3\text{/ha)} \times \text{Db (ton/m}^3\text{)} \times (\text{OM (\%)})/172.4$$

Descriptive statistical analyses including mean, standard deviation, coefficient of variation (CV), skewness and kurtosis, and one way analysis of variance (ANOVA) were done using SPSS statistical programme.

## Results and Discussion

The soil textural class in both land use was clay loam according to the particle size distribution of soils in forest (28.12% clay, 26.97% silt, 44.90% sand) and pasture (35.03% clay, 22.37% silt, 42.59% sand) lands. Descriptive statistical results of the soil physical and chemical properties of both land uses are given in Table 1. Gravimetric water content and SOC stock values showed the highest standard deviation in forest and pasture land, respectively. In both land use types, coefficient of variation (CV) values, except exch. K and Na in forest, were lower than 35%. Although it shows the homogeneity of samples and the accuracy of experiment (Ogunkunle and Eghaghara, 2007), the CV values of the properties determined in forest land

always higher than that in pasture land (Figure 1). It indicates that according to the measured soil properties, the soil samples from forest site had less homogeneity or higher variability than that from pasture site. While the soil pH had the lowest CV, exchangeable K content generally had the highest CV among the soil properties.

Table 1. Descriptive statistics of some soil properties in forest and pasture sites.

|  | Land use | Minimum | Maximum | Mean | Std. Dev. | CV, % | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| **Db, g/cm³** | Forest | 1,04 | 1,44 | 1,24 | 0,18 | 14,17 | 0,13 | -2,26 |
|  | Pasture | 1,37 | 1,53 | 1,42 | 0,06 | 4,21 | 1,91 | 3,86 |
| **F** | Forest | 0,46 | 0,61 | 0,53 | 0,07 | 12,53 | -0,04 | -2,29 |
|  | Pasture | 0,42 | 0,48 | 0,47 | 0,02 | 5,04 | -1,88 | 3,59 |
| **W, %** | Forest | 22,00 | 36,65 | 27,14 | 5,85 | 21,54 | 0,84 | -0,31 |
|  | Pasture | 16,45 | 20,83 | 19,28 | 1,53 | 7,93 | -1,55 | 2,79 |
| **pH (1:1)** | Forest | 6,44 | 6,75 | 6,56 | 0,10 | 1,57 | 1,30 | 2,97 |
|  | Pasture | 6,77 | 7,02 | 6,88 | 0,10 | 1,46 | 0,25 | -1,25 |
| **EC, dS/m** | Forest | 0,32 | 0,63 | 0,46 | 0,14 | 30,82 | 0,50 | -2,22 |
|  | Pasture | 0,23 | 0,28 | 0,25 | 0,02 | 7,38 | 1,24 | 1,17 |
| **OM, %** | Forest | 3,20 | 5,86 | 4,41 | 1,21 | 27,42 | 0,11 | -2,92 |
|  | Pasture | 1,59 | 2,19 | 1,89 | 0,23 | 12,04 | 0,31 | -1,14 |
| **SOC, ton/ha** | Forest | 25,28 | 39,38 | 30,70 | 5,16 | 16,81 | 0,93 | 0,52 |
|  | Pasture | 12,76 | 19,41 | 15,55 | 2,44 | 15,70 | 0,76 | -0,32 |
| **Ca, cmol/kg** | Forest | 20,91 | 27,24 | 22,38 | 2,41 | 10,79 | 2,30 | 5,42 |
|  | Pasture | 18,95 | 24,39 | 21,47 | 2,02 | 9,39 | 0,27 | -1,09 |
| **Mg, cmol/kg** | Forest | 8,65 | 11,53 | 9,80 | 1,20 | 12,27 | 0,60 | -1,51 |
|  | Pasture | 10,48 | 13,76 | 12,10 | 1,51 | 12,48 | 0,11 | -2,80 |
| **K, cmol/kg** | Forest | 0,21 | 1,03 | 0,68 | 0,29 | 43,38 | -0,64 | -0,04 |
|  | Pasture | 0,21 | 0,49 | 0,30 | 0,10 | 32,50 | 1,82 | 3,87 |
| **Na, cmol/kg** | Forest | 0,16 | 0,57 | 0,32 | 0,14 | 44,19 | 1,28 | 2,47 |
|  | Pasture | 0,21 | 0,34 | 0,26 | 0,06 | 21,76 | 0,75 | -1,65 |

CV: Coefficient of variation, Db: Bulk density, F: Total porosity, W: Gravimetric water content, OM: Organic matter, SOC: Soil organic carbon stock in 15 cm soil depth.
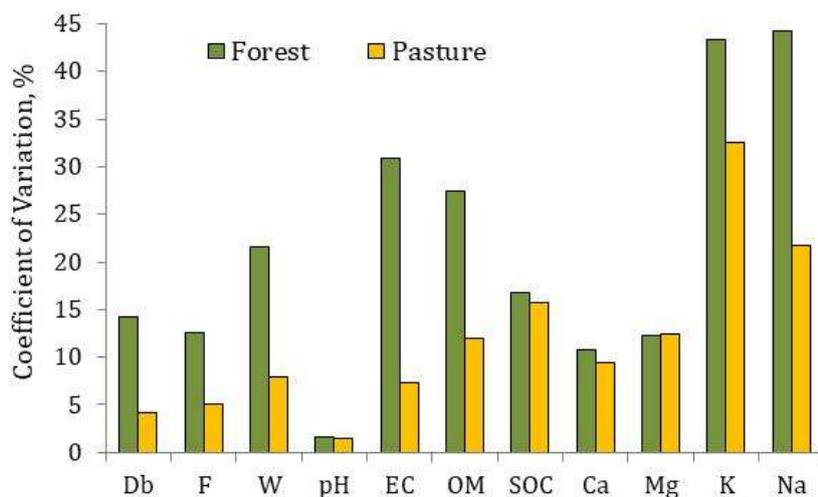


Figure 1. Comparison of the coefficient of variation values of soil properties in forest and pasture sites.

The variance analyses results for the long term effect of deforestation on soil properties and SOC stock in adjacent pasture and forest areas located on same hillslope land position are given in Table 2. Except, exch. Ca and Na content, the soil properties measured in forest site were significantly different from that in pasture site. While W, pH, EC, OM and OC stock measured in forest and pasture sites were significantly different each other at 1% level, Db, F, exch. Mg and K contents were significantly different each other at 5% level.

Table 2. The F-test values of one way variance analyses results for soil properties in different land use type.

| Db | F | W | pH | EC | OM | SOC | Ca | Mg | K | Na |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.45* | 5.58* | 10.14** | 29.10** | 13.06** | 25.19** | 42.26** | 0.50 | 8.50* | 8.77* | 0.85 |

**significant at 1% level, *significant at 5% level, Db: Bulk density, F: Total porosity, W: Gravimetric water content, OM: Organic matter, SOC: Soil organic carbon stock in 15 cm soil depth.

## Effect of land use change on some soil physical properties

The percent changes in mean values of soil properties due to changing the land use from forest to pasture are given in Figure 2. Deforestation caused significant increases in Db, pH and exch. Mg values while it significantly decreased the other soil properties in pasture soil. The mean Db value significantly increased from 1.24 g/cm$^3$ in forest site to 1.42 g/cm$^3$ in pasture site with a 14.52% increment while the mean F value significantly decreased from 0.53 in forest site to 0.47 in pasture site with an 11.32% reduction. Chen et al. (2009) reported that the increase in macro pores significantly lowers bulk density, and the mean macro pores is the highest in the forest soils and lowest in the cultivated and grassland soils. Hajabbasi et al. (1997) determined that the surface soil (0-30 cm) of forest and deforested sites had the lowest (1.13 g/cm$^3$) and the highest (1.28 g/cm$^3$) bulk density, respectively. Similarly, many researchers reported that bulk density in the forest at surface soil layer was lower than that in cultivated plots and the pasture (Rasiah et al., 2004; Puget and Lal, 2005; Assefa et al., 2017). The mean W content (27.14%) in pasture site had a 28.96% reduction compared with forest site (19.28%). Chen et al. (2009) reported that when the forest was cut to become an agricultural field or bare soils, soil moisture content would be reduced by 32.1%. Magliano et al. (2017) found that at similar bulk density values after changing land use, pastures had a 20% reduction in volumetric water content at field capacity (16.3%) compared with woodlands (19.7%).
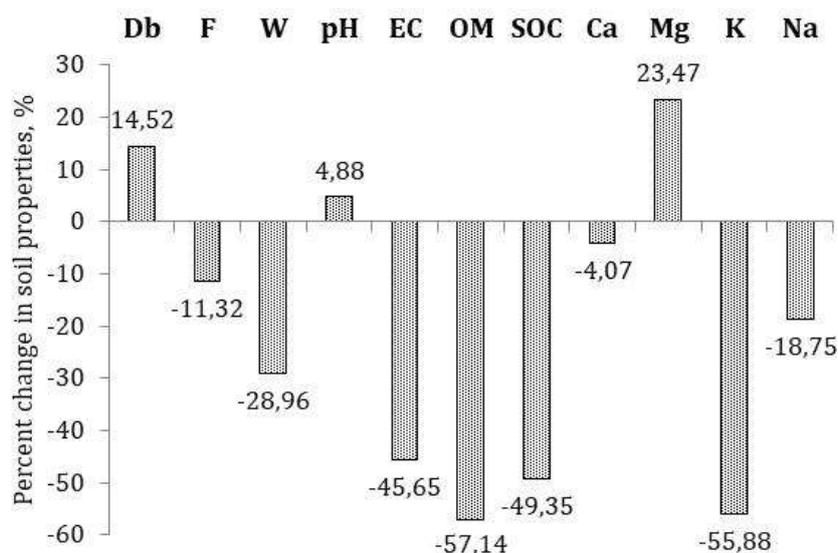


Figure 2. The percent changes in mean values of soil properties after deforestation.

## Effect of land use change on some soil chemical properties and SOC stock

The mean soil pH value significantly increased from 6.56 in forest site to 6.88 in pasture site with a 4.88% increment while the mean EC value significantly decreased from 0.46 dS/m in forest site to 0.25 dS/m in pasture site with a 45.65% reduction. Liu et al. (2002) found that deforestation caused an increase in soil pH from 5.67 in forest to 6.27 in cultivated site while soil nutrients decreased in cultivated site of humid mountainous areas.

Soil OM content significantly decreased from 4.41% in forest to 1.89% in pasture site. After deforestation and abandoning cultivated land to pasture, soil OM showed the highest percentage reduction among the soil properties with 57.14%. Similarly, SOC stock in 15 cm surface soil depth significantly decreased from 30.70 ton/ha to 15.55 ton/ha with 49.35% depletion after conversion of forest to pasture site. Assefa et al. (2017) found that 60% of the total SOC in forest was determined in the upper 10 cm soil depth, and total SOC varied between land use systems with ranging from 3.1 kg C/m$^2$ in croplands to 23.9 kg C/m$^2$ in natural forest. Khormali et al. (2009) reported that the average OC stock (184.8 ton/ha) of the 0–60 cm depth of the forest was almost 3 times higher than that (58.8 ton/ha) of the deforestation site. Soil tillage affects the soil OM contents associated with aggregates and SOC sequestration in no till is greater than conventional tillage due

to slower turnover of macro aggregates in no till (Six et al., 1999). Organic matter in cultivated soils has less physical protection than that in the uncultivated soils due to removal of biomass during land clearing and also reduced tillage system conserves soil OM with preventing from rapid mineralization (Barber, 1995; Gülser et al., 2020). Bruce et al. (1999) reported that OC losses in former grassland and forest soils by conventional tillage practices ranged from 20 to 50% of the initial content of cultivation zone within the first 40–50 years.

Exch. Mg content only significantly increased from forest (9.80 cmol/kg) to pasture (12.10 cmol/kg) site with a rate of 23.47%, while exchangeable Ca, K and Na decreased from forest (22.38, 0.68 and 0.32 cmol/kg) to pasture (21.47, 0.30 and 0.26 cmol/kg) site with the rates of 4.07%, 55.88% and 18.75%, respectively. Sharma et al. (2009) determined that Mg content was greatest (4.71 cmol/kg) in agroforestry system, whereas the least (2.46 cmol/kg) amount was recorded in arable land. Hajabbasi et al. (1997) similarly found that Mg content of the surface soil for the deforested site was significantly higher than the forest and cultivated forest sites. They also indicated that Ca contents of the all three land use sites were significantly similar, but the average K content of the forest site was significantly higher than the other sites. In this study, exch. K content showed the highest decrease among the other cations. Khormali et al. (2009) reported that available K content had significant decrease in the deforestation site (54.6 mg K/kg) compared to that of forest site (64.2 mg K/kg). Sharma et al. (2009) also found that mean exchangeable K was greatest (0.23 cmol/kg) in agroforestry system and least (0.15 cmol/kg) in arable land.

### Correlations among the soil properties

The relationships among the soil properties are given in Table 3. The soil OM content gave higher correlations with the all soil properties compared with the SOC stock in surface soil (0-15 cm). Soil OM content had significant positive correlations with SOC, F, W, EC, K, and significant negative correlations with Db, pH, Mg. Increasing soil OM content in the forest site decreased soil pH, bulk density, and increased EC, exch. K, total porosity, soil moisture content compared with that in the pasture site. The similar relationships among the soil properties had been found in many researches (Gülser, 2006; Candemir and Gülser, 2010; Demir and Gülser, 2015; Karaca et al., 2018; Demir and Gülser, 2021).

Table 3. The correlation matrix among the soil properties.

|        | F        | W        | pH       | EC       | OM       | SOC      | Ca      | Mg       | K        | Na      |
|--------|----------|----------|----------|----------|----------|----------|---------|----------|----------|---------|
| **Db** | -0.999** | -0.941** | 0.701*   | -0.930** | -0.836** | -0.683*  | -0.478  | 0.647*   | -0.694*  | 0.251   |
| **F**  |          | 0.946**  | -0.709** | 0.936**  | 0.836**  | 0.683*   | 0.493   | -0.640*  | 0.700*   | -0.236  |
| **W**  |          |          | -0.761** | 0.965**  | 0.888**  | 0.775**  | 0.363   | -0.670*  | 0.759**  | -0.183  |
| **pH** |          |          |          | -0.798** | -0.842** | -0.838** | -0.445  | 0.608*   | -0.659*  | -0.025  |
| **EC** |          |          |          |          | 0.920**  | 0.819**  | 0.466   | -0.720** | 0.852**  | -0.102  |
| **OM** |          |          |          |          |          | 0.969**  | 0.247   | -0.834** | 0.886**  | -0.064  |
| **SOC**|          |          |          |          |          |          | 0.135   | -0.824** | 0.858**  | 0.061   |
| **Ca** |          |          |          |          |          |          |         | 0.132    | 0.296    | 0.217   |
| **Mg** |          |          |          |          |          |          |         |          | -0.714** | 0.244   |
| **K**  |          |          |          |          |          |          |         |          |          | 0.061   |

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level

## Conclusion

The soil properties measured in the forest site showed the higher CV values than that in pasture site. Changing the land use type from forest to pasture after deforestation on the same hillslope position significantly increased Db, soil pH, exch. Mg and significantly lowered F, W, EC, exch. K, OM, SOC stock in 0-15 cm soil depth in pasture site. The highest decrease was obtained in soil OM content with 57.14%. Mean SOC stock in pasture site also decreased 49.35% after deforestation. The soil OM and SOC stock values similarly gave significant positive relations with F, W, EC, exch. K, and significant negative relations with Db, pH, exch. Mg content. Changing land use type or deforestation had negative impact on the soil properties and depleted SOC stock in 0-15 cm soil layer of pasture soil, and deteriorated most soil physical and chemical properties. This study shows that soils under forest vegetation should not be cleared or cultivated for agricultural production and should be protected for sustainable soil management especially on deep slope positions.

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