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The effects of land use change on soil properties and organic carbon at Dagdami river catchment in Turkey

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Abstract: *This research was carried out in Dagdami river catchment located in the highlands of the Black sea region of Turkey. The objective of this study was to investigate the effects of representative land-use and land-cover types of largely deforested areas of Black sea region on soil properties. We measured these effects by quantifying some soil analyses were done on soil samples were taken at two depths (0-5 and 5-15 cm) and two aspects (N and S). According to the results of statistical analysis, satured hydraulic conductivity (K_{sat}), bulk density (BD), water stable aggregates (WSA), soil organic matter (SOM), soil organic carbon (SOC) and total nitrogen significantly change with land use type and aspect. Results have shown significantly higher values of saturated hydraulic conductivity (K_{sat}) in natural forest top soil (82.4 $cm^3.h^{-1}$ on average) compared to grasslands soils (8.4 $cm^3\ h^{-1}$) and hazelnut garden soils (11.5 $cm^3\ h^{-1}$) and corn field soils (30.0 $cm^3.h^{-1}$). It was determined that WSA was greater in the pasture and forest soils than in cultivated soils. In addition, K_{sat} was found the highest value in the forest soils at all aspects while, SOM and SOC of forest soils are higher than other land use types. On the other hand, amount of SOM and SOC of soils of grassland, hazelnut garden and corn field are low level and close to each other. Soils under hazelnut garden (1.1 g cm^{-3}) and grassland (1.1 g cm^{-3}) have higher bulk density than the adjacent soils under forests (0.7 g cm^{-3}) and corn field (1.0 g cm^{-3}) for two different aspects. Furthermore, after long term continuous cultivation of the natural forest soil, it was determined that some physical and chemical characteristics of it has been significantly changed.*

Key words: *Soil properties, Land use change, Long-term cultivation, Deforestation*
PDF of full length paper is available online

Introduction

The dynamics of terrestrial ecosystems depend on interactions between a number of biogeochemical, particularly carbon, nutrient, and hydrological cycles all of which may be modified by human actions. Terrestrial ecological systems in which carbon is retained in live biomass, decomposing organic matter, and soil play an important role in the global carbon cycle. Human activities change carbon stocks in these pools and the atmosphere through land use types, land-use changes, and forestry, among other activities (Anonymous, 2000). On the other hand, effects of land use changes on impervious surface increase are directly linked to changes in stream flow such as increased runoff volumes, increased peak discharges, greater runoff velocities, increased flooding and decreased base flow (Kim *et. al.,* 2005). Most changes in land use affect the amount of carbon held in vegetation and soil, thereby, either it releasing carbon dioxide (a greenhouse gas) to, or removing it from the atmosphere. The greatest fluxes of carbon result from conversion of forests to open lands (and vice versa) (Houghton and Goodale, 2004). Soil organic matter and soil organic carbon (SOC) play an important role in enhancing crop production (Stevenson and Cole, 1999) and mitigating greenhouse gas emissions (Lal *et al*., 1995; Flach, *et al.,* 1997). Sequestration of atmospheric CO_2 into soil and SOC dictates acquisition of the research data on equilibrium level of SOC pool under different land uses and associated soil management practices and the rate of change of SOC pool with change in land use and management (Hao *et al*., 2002). In addition, SOC contents of aggregates influence aeration, water movement, and nutrition, while the SOC content of bulk soil affects water-holding capacity. Therefore, maintaining adequate soil organic matter content and proper soil structure are required for the sustainability of the land-use systems. The effects of land use and soil management practice on SOC and other soil properties on an aspect need to be studied on a catchment scale (Symeonakis *et al*., 2007).

The effects of cropping systems and management practices on soil properties provide essential information for assessing sustainability and environmental impact (Ishaq and Lal, 2002). In addition many researchers reported that change of land use, implemented locally such as long term cultivation, deforestation, overgrazing and mineral fertilization can cause significant variations in soil properties, terrestrial cycles and reduction of output (Conant, *et al*., 2003; Tate *et al*., 2004; Fraterrigo *et al*., 2005; Hacisalihoglu, 2007; Saraswathy *et al*., 2007). Soils can also take centuries to form because of low organic matter turnover rates and the relatively slow acting effects of leaching. Because of this, it is widely believed that past land-use legacies can affect soil composition and vegetation for extended periods of time (Compton *et al*., 1998; Compton and Bone, 2000; Goodale and Aber, 2001; Eberhardt *et al*., 2003). Soil properties particularly hydro physical properties (Liu *et al*., 2000) are important for both crop growth and maintaining soil quality. The soil hydrological effects of land clearing and subsequent land use in a wide selection of fields have been studied in some detail (Ghuman *et al*., 1991; Alegre and Cassel, 1996; Gijsman and Thomas, 1996; Arevalo *et al*., 1998; Horowitz *et al*., 1999; Bonell and Molicova, 2003), whereas the hydrological response to secondary growth is virtually unknown (Ziegler *et al*., 2004); the same argument applies

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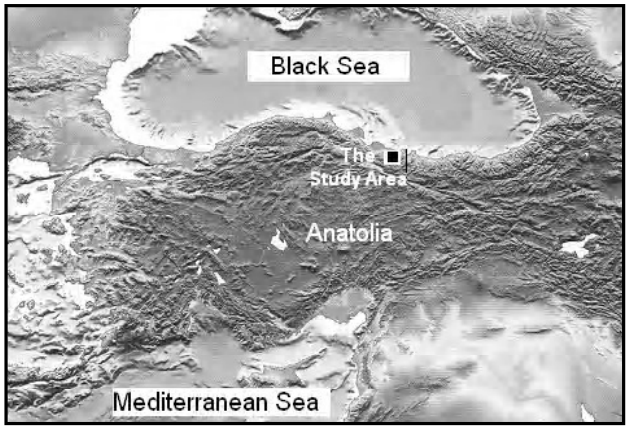

Fig. 1: Location of the study area

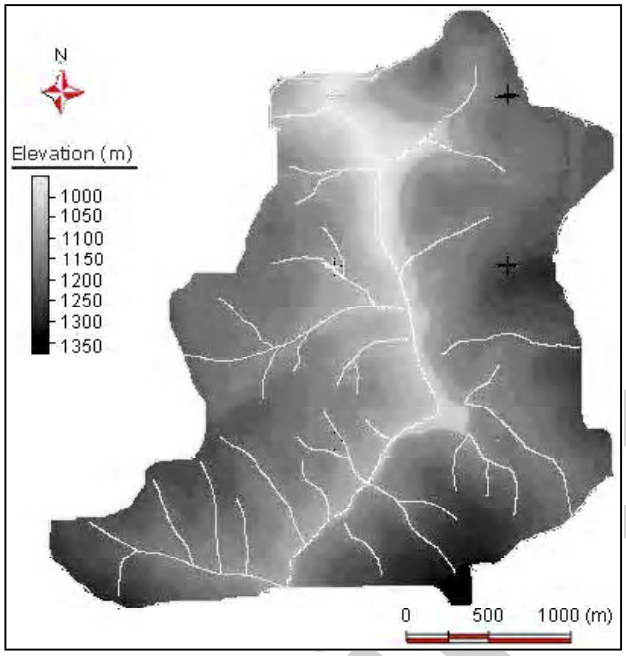

Fig. 2: Elevation map of the catchment

to plantation forests (Bruijnzeel, 2004). Factors such as land use type, tillage (Pagliai *et al*., 1995) and aspect can affect all soil properties. Soil aggregate stability (AS) is a dynamic property of soil that changes over time (Coote *et al*., 1988). Continuous tillage and production may cause a reduction in soil WSA. Soils with stable surface aggregates resist to water and wind erosion better than soils with unstable aggregates (Lehrsch, 1998).

Turkey covers approximately 20.7 Mha forest, corresponding to 26.6 % of Turkey's land area of which 9 Mha is classified as normal (productive) forest and 11 Mha as degraded forest (TMEF, 2006).

The greatest part of forestland also lies within high land mountain ecosystems in Turkey. However, increasing public demand for various needs has led to the conversion of natural forestlands to other uses. It can be used in the overall multi-objective forest management planning, but, it should be limited to the conditions for which the data were gathered (Misir *et al.,* 2007). And, this case put ecological sustainability of the natural resources at risk in northern Anatolian mountain forestland. Most of the hazelnut orchard places have been generally converted from natural forest land. Turkey, has twenty percent of the country's hazelnut production (Reis and Yomralioglu, 2006), about 77% of world hazelnut production and 75% of world hazelnut trade (Anonymous, 2007).

In the study area, land use types have been mostly changed in the past 50 years. The objective of this research was to trace the influence of aspects and land use types on soil properties in Dagdami river catchment, Golkoy-Ordu.

Materials and Methods

Description of the study area: The study area is located in Ordu province, Golkoy district, Dagdami river catchment (40° 32'N, 37° 27'E, 1150 m about sea level) in the eastern Black sea region of Turkey (Fig. 1). Study area is above the sea level between the altitudes of 1100-1350 m (Fig. 2).

According to the Thornthwaite water-balance model, the prevailing climate is moist, mega-thermal, humid climate that has intensive water surplus in winter and that was coded with $BA'rS_2$. The mean annual temperature is 8.4°C and precipitation is 1683 mm (Anonymous, 2005). Topography and slope show great variations and hilly and rolling physiographic units are particularly common in the study area.

Dominant tree species of natural forest are Oriental beech (*Fagus orientalis* Lipsky) and Birch hornbeam (*Carpinus betulus* L.) (Anonymous, 1998a). Most part of natural forest has been fragmented and degraded by human disturbances such as clearance for agriculture, pasture and hazelnut garden. Forest has been cultivated at least 50 years with corn, vegetable and especially hazelnut in a rational manner (Fig. 3). Soil orders associated with this morphstructural unit are Inceptisols on steep slopes and Entisols along streams (Soil Survey Staff, 1996) . On average, physiological and absolute soil depth vary 50-100 and 30-70 cm respectively. Soil types are clay loam, sandy clay loam, sandy loam, silt clay loam and clay and pH varies from 5.0 to 6.

Soil sampling and analysis: Disturbed and undisturbed soil samples were collected from different land uses at two aspects. Soil samples were selected from three replicates (upper, middle, and lower slope positions) sites in each of four adjacent land use types which are native forest, pasture and cultivated fields with corn and hazelnut. Soil samples were taken at 0-5 and 5-15 cm depths. Twenty four disturbed and twenty four undisturbed soil samples were taken to investigate for their physical and chemical properties in the laboratory. Undisturbed soil samples were taken by a steel core sampler of a 100 and 400 cm^3 volume.

Particle size distribution was determined by the hydrometer method (Bouyoucous, 1951). A wet sieving method was used to determine the coarse fragments and WSA (Kemper and Rosenau, 1986). Soil water retention Field capasity (FC), wilting point (WP) and available water capacity (AWC) at 0.33 and 15 bar tension were determined using a pressure plate (Blake and Hartge, 1986), BD and K_{sat} were determined by the core method (Cassel and

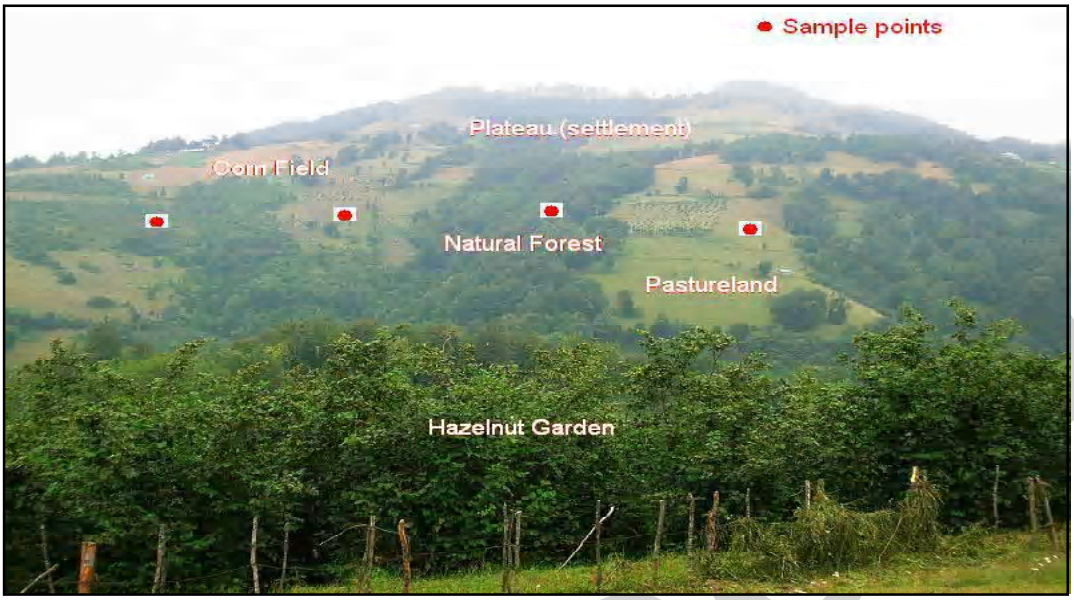

Fig. 3: A view of the study area that shows the general land use in catchment

Nielsen, 1986). Soil pH and electrical conductivity (EC) were measured by a pH/conductivity meter (Rhoades, 1996). Total nitrogen (TN) was determined by Kjeldahl (Bremner, 1996) method. Carbonate ($CaCO_3$) was determined by pressure calcimeter method (Richard and Donald, 1996). The concentration of SOM and SOC were determined by Walkley-Black method (Nelson and Sommer, 1996).

All data were analyzed using SPSS statistical software. Analysis of variance (ANOVA) was carried out using two-factor randomized complete plot design. Significant *F*-values were obtained, differences between individual means were tested using the LSD (Least Significant Difference) test.

Results and Discussion

Conversion of the natural forest into continuous cultivation had resulted in statistically significant decreases of both the concentration and stock of SOM and TN. Soil characteristics have changed in the past 50 years with the land use change. Long-term cultivation significantly ($p<0.05$) decreased the SOM content in the soils. Due to long-term anthroponization, WSA in plough horizon degraded. Soil reaction (pH), coarse fragments, lime and salinity were not influenced by land use and aspect, with a significant interaction effect (Table 1).

Water stable aggregates were influenced by land use and aspect, with a significant interaction. Hazelnut garden soils were statistically less stable. Water stable aggregates were significantly larger in the forest and pasture soils than in the cultivated soils (Fig. 4). Water stable aggregate values can be used as indicators of soil structural quality (Six *et al*., 2000).

Deforestation can lead to changes in the hydrologic regime, loss of topsoil increased sediment and nutrient loads in waterways and decreased soil fertility (Schultz *et al*., 2004).

Results have shown significantly higher values of saturated hydraulic conductivity (K_{sat}) in natural forest top soil (82.4 $cm^3 h^{-1}$ on average) compared to grasslands soils (8.4 $cm^3 h^{-1}$) and hazelnut garden soils (11.5 $cm^3 h^{-1}$) and corn field soils (30.0 $cm^3 h^{-1}$) (Fig. 4). Forests are generally known for a high soil infiltration capacities and hydraulic conductivity, enhancing base flow (Buytaert *et al.,* 2007). K_{sat} was significantly greater in the natural forest than in other land uses. This indicates a specific significance of natural forest in regards to water transport processes in landscape. Results of the analysis indicate that conversion from natural forest land use to grassland or cultivated (corn field or hazelnut garden) land decreases the value of K_{sat}. The forest, corn field and hazelnut garden generate the highest amount of $K_{sat,}$ whereas grassland land use produce the least K_{sat} value. In catchment scale thus, forest areas may positively influence from relevant hydrological functions like infiltration, percolation, and base flow that subsequently affect the water regime in a catchment.

K_{sat} was influenced by land use and aspect, with a significant interaction (Table 1). K_{sat} could be ordered as forests > corn field >hazelnut garden > grassland. Hydraulic conductivity correlated significantly with bulk density and clay content. Soils under hazelnut garden (1.1 g cm^{-3}) and grassland (1.1 g cm^{-3}) have higher bulk density than the adjacent soils under forests (0.7 g cm^{-3}) and corn field (1.0 g cm^{-3}) for two different aspects (Fig. 5). The natural forest has the lowest bulk density value at the North aspect, whereas, the grassland and hazelnut garden has the highest bulk density values at the either aspect.

Soil water content is another factor affected by land use type because of changes produced in infiltration, surface runoff, and evaporation (Zhai *et al*., 1990; Demir *et al*., 2007). The increase in soil water storage under conservation tillage can be attributed to reduced evaporation (Jones *et al*., 1968), greater infiltration, and soil protection from rainfall impact.

Available water capacity in forest soil (16-20%) is the highest value and is lowest value (10-14%) is for hazelnut garden soils (Fig. 5). Soil organic matter enhanced the available water capacity. Each

Table - 1: Summary statistics of soil properties for four land uses at two aspects (n= 12 for North aspect, n= 12 for South aspect)*

	Aspect	pH	EC_e	WSA (%)	SOM (%)	TN (%)	AWC (%)	K_{sat} (cm h^{-1})	BD (g cm^{-3})
Corn field	North	6.5±0.1	1.1±0.1	48.6±5.4	$5.2±0.2^{Ab}$	0.3±0.0	$17.6±1.1^{A}$	$19.4±4.7^{Bb}$	0.9±0.0
	South	6.2±0.5	1.6±0.3	44.7±5.0	$3.1±0.2^{Bab}$	0.1±0.0	$14.4±0.8^{Bb}$	$40.7±10.7^{Ab}$	1.0±0.1
	Mean	6.3±0.2	$1.3±0.1^{a}$	$46.7±3.4^{a}$	4.1±0.5	$0.2±0.0^{b}$	16.0±0.9	30.0±7.1	$1.0±0.1^{a}$
Hazelnut garden	North	5.7±0.1	0.4±0.1	42.0±4.7	$2.9±0.1^{Ac}$	0.1±0.0	15.6±0.8	$12.3±1.1^{b}$	1.1±0.0
	South	5.9±0.1	1.0±0.1	42.7±9.4	$2.9±0.3^{Ab}$	0.1±0.0	$15.8±0.9^{b}$	$10.7±1.5^{c}$	1.1±0.0
	Mean	5.8±0.1	$0.7±0.1^{b}$	$42.3±5.2^{a}$	2.8±0.1	$0.1±0.0^{c}$	15.7±0.6	11.5±0.9	$1.1±0.0^{a}$
Grassland	North	5.7±0.3	0.6±0.1	65.6±8.1	$4.8±0.5^{Ab}$	0.2±0.0	17.8±1.0	$9.1±2.9^{b}$	1.0±0.1
	South	6.1±0.2	0.8±0.1	55.3±10.3	$2.8±0.5^{Bb}$	0.1±0.0	$15.6±0.9_{b}$	$7.7±1.9^{c}$	1.1±0.1
	Mean	5.9±0.2	$0.7±0.1^{b}$	$60.4±7.2^{a}$	3.7±0.5	$0.2±0.0^{bc}$	16.7±0.8	8.4±1.6	$1.1±0.0^{a}$
Natural forest	North	5.7±0.3	0.6±0.1	83.6±2.7	$7.6±0.8^{Aa}$	0.4±0.0	$16.4±0.2^{B}$	$88.5±3.1^{a}$	0.8±0.1
	South	5.7±0.1	0.6±0.0	75.3±5.5	$4.4±0.4^{Ba}$	0.2±0.1	$19.5±0.9^{Aa}$	$76.2±1.5^{a}$	0.7±0.0
	Mean	5.7±0.1	$0.6±0.1^{b}$	$79.4±3.2^{b}$	6.0±0.8	$0.3±0.0^{a}$	17.9±0.8	82.4±3.1	$0.7±0.0^{b}$

*Abbreviations: ECe - Electrical conductivity, WSA-water stable aggregate, SOM-Soil organic matter, TN-Total Nitrogen, AWC-Available water capacity, K_{sat}- Saturated hydraulic conductivity, BD-Bulk density. Lower case letters indicate statistically significant differences among soil properties affected by the different land uses ($p<0.05$). Upper case letters show statistically significant differences between land use for the cases that there were interactions between land use type and aspect ($p<0.05$)

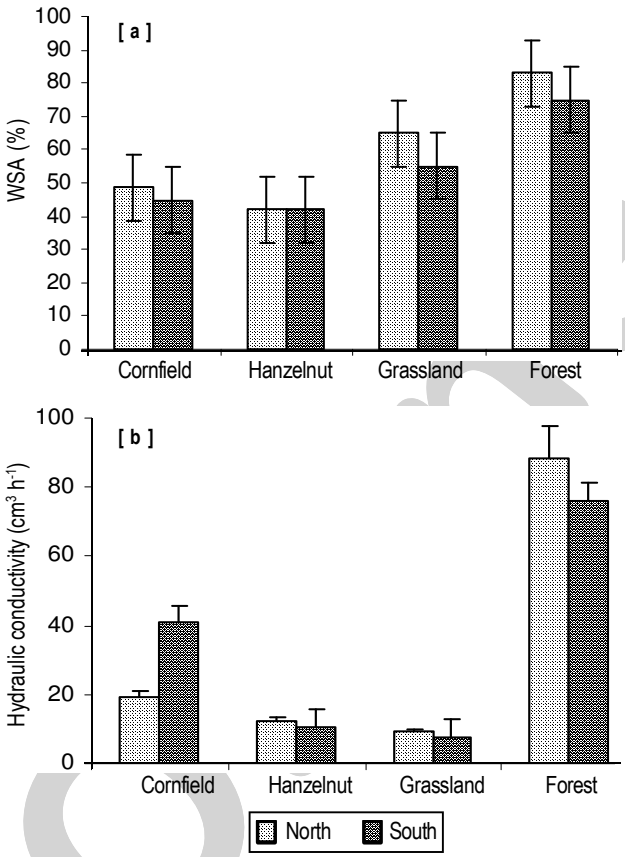

Fig. 4: a-Water stable aggregate(WSA), b- Hydraulic conductivity (K_{sat}) values of soil. Bars represent standard errors

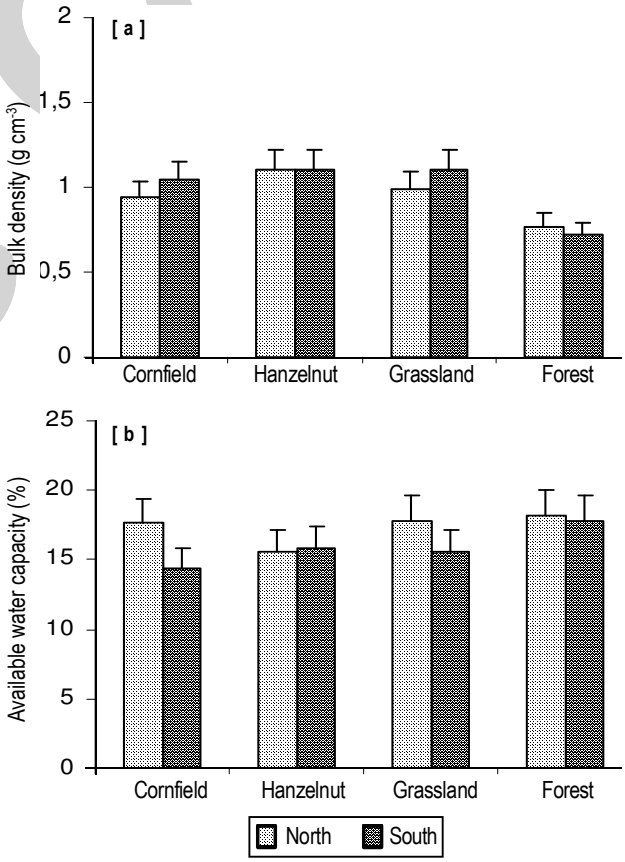

Fig. 5: a- Bulk density (BD); b- Available water capicity (AWC) values of soil. Bars represent standard errors

1 percent of organic matter adds about 1.5 percent to available water capacity. Bulk density plays an important role through its control of the pore space that retains available water. High bulk densities for a given soil tend to lower the available water capacity (Anonymous, 1998b).

There was significant difference in the bulk density between grassland and corn field. This difference was not easily explainable but might be ascribed to the compaction of the topsoil due to overgrazing of the grassland. The loss of soil organic matter (SOM) by the

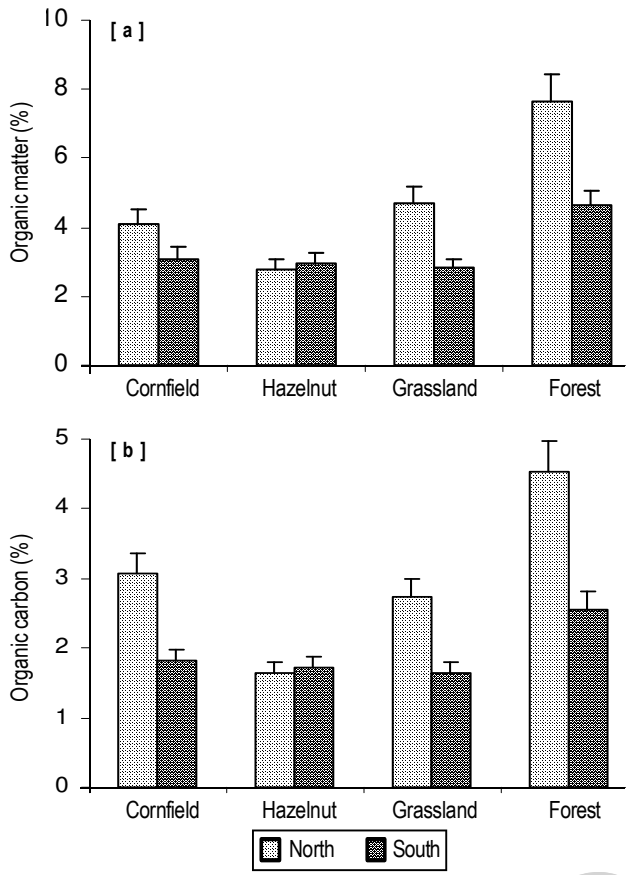

Fig. 6: a- Soil organic matter (SOM); b- Soil organic carbon (SOC) values of soil. Bars represent standard errors

conversion of the grassland into cultivated fields probably caused a higher bulk density in the cultivated soils (Fig. 6). In addition, following conversion from the natural forest, a decline in soil aggregation resulted in the increased bulk density. This process could get worse by the continuous use of machinery either for conversion or cultivation (Lal *et al.*, 1997). Similar findings that deforestation and subsequent tillage practices resulted in nearly a 20% increase in bulk density and a 50% decrease in SOM for a soil depth of 0-30 cm over 20 years in the central Zagrous Mountain in Iran were reported by Hajabbasi *et al.* (1997).

The SOC pool at the Dagdami catchment can be decreased by increased tillage intensity, converting forest and grassland to continuous corn. Slope position of the catchment can exert a significant effect on SOC pool where cultivation was constantly applied. The stable SOC pools in the managed soils of 0-15 cm depth could be from a low 39% for conventional moldboard till continuous corn (MTC) to a high 106% for NTC-A of the SOC pool (46.1 Mg ha^{-1}) of the undisturbed native forest (Hao *et al*., 2002). After natural forest land conversion into cultivated land, decreases of organic matter have crucial effects on soil physical and chemical properties. It explained the vulnerability of the structure and function of the natural forest system. The SOC content in cropland is strongly correlated with crop and soil management practices (Hao *et al*., 2002). The SOC was influenced by land use and aspect, with a significant interaction effect. Soil organic carbon was the highest under natural forest (Table 1; Fig. 6). The analysis of surface samples (from 0 to 15 cm) showed that hazelnut garden had the lowest average total carbon content while forest had the highest. Conversion of forest to grassland, hazelnut garden or corn field can decrease SOC pool. Changed from forest to grassland, hazelnut garden and corn field is important for conversion of SOC content. Conversion of forest to grassland, hazelnut garden or corn field can decrease SOC pool. Especially using of N fertilizer and animal manure in corn field to gather more products, increases SOC.

This research will help to clarify how land use change affects soil properties and resulting hydrologic and carbon cycles dynamics. The SOC, K_{sat} BD and WSA of soil are strongly correlated with land use management practices. Our research focuses on assessing the impact of land use and land cover change (primary natural forest to pasture/grazing to hazelnut garden to cultivated area) on soil properties (SOM, SOC and subsurface K_{sat}). Statistically significant differences in SOM, SOC, WSA and K_{sat} were detected between the grassland and forest and cultivated area soils. These results demonstrate that the effect of land use and land cover change on K_{sat} was confined to shallower depths in the soil profile.

Long-term tilled areas, in the absence of regular crop ration, lead to a strong impainment of aggregate composition of top soil. Under the influence of anthropogenization there occured a great decrease of WSA. The above results indicate converting natural forest to hazelnut garden, grassland and corn field decrement SOC and SOM in soils of the all aspect. The other damages of deforestation are soil erosion increment decrease of yield.

The data obtained in this study can be useful in directing farming practice, hazelnut garden and policy making process for SOC sequestration and other soil properties especially for the Black Sea region in sloping landscape.

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