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*Full Length Research Paper*

# The effects of land-use changes on soil properties: The conversion of alder coppice to tea plantations in the Humid Northern Blacksea Region

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**Over the last century, the conversion of natural ecosystems to agricultural production is one of the primary factors in environmental degradation. As in most parts of the world, forest soils in the north-east of Turkey are being seriously degraded and destroyed due to extensive agricultural activities. This study investigated the effects of changes in land-use on some soil properties in Rize, Turkey. Two adjacent sites were studied: One had been converted 60 years previously from alder coppice to tea cultivation (TC); the other remained as alder coppice (AC). The experimental design at each site was a randomized complete block with four replications in the study area. Four disturbed and four undisturbed soil samples were taken randomly at soil depths of 0 -10 cm, 10 - 30 cm and 30 - 50 cm in each plot in the study area. When the alder coppice was converted into tea cultivation, the bulk density (Db) increased from 0.84 g cm$^{-3}$ to 1.02 g cm$^{-3}$, soil penetrometer resistance (SPR) increased from 0.94 to 1.27 MPa, the soil organic matter (SOM) decreased from 5.14 to 4.06%, saturated hydraulic conductivity (Ksat) decreased from 40.64 to 16.33 mm h$^{-1}$ at 0 to 10 cm depth of soil. According to soil depth steps the mean PAW, St, Ksat, SOM and total N content decreased linearly in alder coppice (AC) and tea cultivation (TC). The results indicated that the change in land use and introduction of cultivation had a significant effect on soil properties.**

**Key words:** Land-cover change; alder coppice; tea cultivation; soil properties.

## INTRODUCTION

In most parts of the world, agriculture is the primary cause of land use change. Much of the pressure on convert forests, agricultural uses comes from increasing population growth and developmental demands. During the 1990s, 14.6 million hectares (ha) of forest per year was converted to agricultural or urban usage. However, 5.2 million ha per year was gained in plantations, reforestation, and natural forest expansion, for a net loss of 9.6 million ha of forest per year (FAO 2001).

Land use conversion affects both the amount and spatial pattern of forest habitat, which in turn can affect the ecological function and future development of remaining forest lands. The impacts of land conversion are broadly categorized as environmental, economic, and social and can be both positive and negative. For example, habitat fragmentation and transportation corridors can create migration barriers or inhospitable habitats for wildlife and interfere with other ecological processes (Chazan and Cotter, 2001). Small ownership parcels also complicate management and cooperation at landscape and watershed scales. Within a landscape, hydrology reflects the balance between independent factors of geology and climate and dependent factors including topography, soils and vegetation (Horton, 1932). These dependent factors are interrelated, and a sudden change in one causes adjustment to the others. On seemingly uniform slopes, hydrology is determined by interactions with vegetation and soil properties, affecting processes such as infiltration response and patterns of water penetration (Wagenet et al., 1994). It is important to ana-

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lyze soil characteristics within landform elements rather than isolated pedons (Slater et al., 1994). Because soil physical and hydrological properties are related to vegetation type, vegetation conversion can alter these properties. The physical structure of the vegetation canopy and roots affects rainfall disposition by controlling how water is channeled into and through the soil (Martinez-Meza and Whitford, 1996). Vegetation type has been shown to alter soil hydrological characteristics, including infiltration capacity, hydraulic conductivity and water retention (Gutierrez et al., 1995).

The eastern part of the Blacksea region is characterized by a rolling topography, and is highly dissected by small streams. Therefore, only 2% of the total land area of the east Blacksea region is suitable for agriculture. Much of the productive lands located in the coastal area have been converted into urban settlements, industry and an airport (Yüksek et al., 2004).

Tea (Camelia sinensis L.) is an important cash crop in the northern part of the Blacksea region, and because of its economic value, many farmers have replaced their traditional annual and food crops with tea. Moreover, many of the farmers have replaced their traditional annual and food crops with tea. Moreover, since 1952, many farmers have converted their private coppice forest into tea cultivation. Tea acreage continues to increase each year in the northern part of the Blacksea region. Although tea plantations remain productive for long periods (25+ years), yields tend to decline in later years. This drop in productivity is traditionally attributed to natural aging of plants.

The total area given over to tea cultivation in Turkey is approximately 77,000 ha, of which approximately 65% (50,000ha) is located in Rize. The land area in Rize given over to tea cultivation increased from 2800 ha in 1951, to 49968.5 ha at present, representing 12.74% of the total land area in Rize (Anonymous, 2006). Of 9255 ha of tea plantation is in land which is suitable for land use classes (according to Turkish Land Use Classification System) (between I - IV) (Anonymous, 1993) while the remainder of tea cultivation area is maintained on unsuitable land. Degradation in soil quality is often associated with the type of intensive land use involved in tea production. Any degradation of the soil can be expected to adversely affect the stability of system. Evaluation of soil quality changes during long-term tea production which could therefore help to improve the sustainability of tea cultivation in the study area. Yüksek and Kalay (2002) studied the effects of converting alder (*Alnus glutinosa* L. Gaertner subsp barbata) forests into tea plantations and possible changes in soil characteristics and erosion rate. They found that the risk of soil erosion actually doubled after the conversion. Similar results have been reported in the Pazar area, where deforestation and establishment of tea plantations has led to more frequent and larger flood events, causing greater damage to life and property (Yüksek et al., 2004).

Tea (*Camellia sinensis* L.) is a globally important crop and is unusual because it both requires an acid soil and acidifies soil. Tea stands tend to be extremely heavily fertilized in order to improve yield and quality, resulting in a significant potential for diffuse pollution (Han et al., 2007). Assessing land use-induced changes in soil systems is therefore essential for addressing the problem of agroecosystem transformation and sustained land productivity (Tchienkoua and Zech, 2004).

The aim of this study was to determine the long term effects of conversion from forest coppice (*A. glutinosa* L. Gaertner subsp barbata) to tea cultivation (*C. sinensis* L.), in terms of changes in soil physical, hydrological and some chemical properties. The trends observed were used to evaluate the impacts of tea cultivation on soil attributes and as indicators of the sustainability of the tea cultivation management. A small agricultural catchment located in Pazar watershed in Rize, Turkey, was chosen as the study area.

## MATERIALS AND METHODS

### Site description and history

The study was conducted in Pazar watershed, in Rize, located in the north eastern part of the Blacksea region of Turkey. The study area is located at 40° 52' 45 N and 40° 45'27 E. The altitude of the area is between 40 -150 m above sea level. The mean annual temperature is 14℃ with an average annual precipitation of 2019 mm (Anonymous, 2007). The soils of the area were classified as yellow red podsol according to the International Soil Classification System (ISCS) (Anonymous, 1993; Aydınalp and FitzPatrick, 2004). The rock mass is extensively volcanically disrupted and the main material is andesite (Yüksek, 2001). The forest type within the study area is mainly composed of A. glutinosa L. Gaertner subsp barbata (Yüksek and Kalay, 2004). Approximately 5 ha of alder stand was clear cut in 1954, 1955 and 1956. Terraces were then constructed, between 40 - 60 m length and 0.6 - 0.9 m width and soils in the terraces were tilled into 0.6 m ferrtilizer [(500 kg/ ha NPK (2:1:1)] was applied to tea plantation areas during March every year. Tea was harvested three times during the vegetation season, (in May, July and September) and plantations were weeded before harvesting. The area adjacent to the tea plantation is mainly composed of alder stands (*A. glutinosa* L. Gaertner subsp. barbata) with small numbers of Rubus platyphyllos, Urtica sp., Frangula alnus Miller beneath the tree canopy, and annual forage plants (Yüksek, 2001). The alder forest has been clear-cut every 20 years since 1925, leaving old root sprouts to regenerate naturally. The annual forage plants were harvested until 1990. Leaves were collected for animal bedding. At the end of the coppicing cycle, there are 2 - 4 sprouts per stool, which belong to one or

**Table 1.** Result of the two-way analysis of variance in physical properties of the soils under the two land uses and the three depth.

| | df | Sand | Clay | Silt | F.C | PWP | PAW | Dp | Db | St | WSA | Ksat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Land use (LU)** | 1 | .000 | .000 | .082 | .166 | .822 | .027 | .000 | .000 | .000 | .718 | .000 |
| Depth (D) | 2 | .004 | .020 | .013 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| LUxD | 2 | .071 | .013 | .468 | .578 | .522 | .590 | .476 | .176 | .009 | .241 | .000 |

LU: Land use, D: Depth, F.C: Field capacity, PWP: Permanent wilting point, PAW: Plant available water, Dp: Particle density, Db: Bulk density, St: Total porosity, WSA: Water stable aggregate, Ksat: Saturated hydraulic conductivity.

two diametric-classes (8 - 15 cm and 15 - 35 cm). This type of traditional management has been conducted for at least 80 years in the study area. The mean average seedbed was 160 unit/ha$^{-1}$ and mean density (Ø > 5 cm dbh) was 1085 trees ha$^{-1}$ in the study area.

### Experimental design and soil sampling

The experimental design at each site was a randomized complete block with four replications in each study area. The experimental plots taken were from neighboring forest and tea cultivation regions with an area of 400 m$^2$ (20m x 20 m). Soil samples were collected from forest and tea cultivated sites (Soils were collected from near the planting holes of tea plantations on terrace). Four disturbed and four undisturbed soil samples were taken randomly at a soil depth of 0 -10 cm, 10 - 30 cm and 30 - 50 cm in each plot in study area. Plots in the two sample areas had the same physiographic conditions such as landscape position and slope (%). The undisturbed soil samples were taken by using a steel core sampler of a 100 cm$^3$ volume (5 cm in diameter and 5 cm in height). A total of 96 soil samples (2 land use types X 4 replicates X 4 soil pits X 3 soil depths) were collected in April and May, 2007.

### Laboratory analysis

The particle size distribution was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962). The field capacity (FC) and permanent wilting point (PWP) were measured using pressure membrane and pressure plate extractors. The Plant available water (PAW) content was calculated from the difference between the field capacity and the permanent wilting point (Klute, 1986). The dry bulk density (Db) was determined by the core method (Grossman and Reinsch, 2002). The particle density (Dp) was determined by the pycnometer method. The total porosity (St) was calculated from the following equations: $[St (\%) = (1-D_b/D_p) \times 100]$ where St is total pore spaces, Db is bulk density and Dp is soil particle density (Flint and Flint, 2002). A wet sieving method was used to determine the water stable aggregates (WSA) (Kemper and Rosenau, 1986). The saturated hydraulic conductivity (Ksat) was measured by the falling-head method according to Klute and Dirksen (1986). The soil penetration resistance (SPR) (Bradford, 1986) was measured 0 to 40 cm depth. Measurements were recorded at depth intervals of 5 cm, using by a manual (hand-pushed) 13 mm diameter cone (30°) penetrometer and 20 of measurements were made at each plot. Soil pH was determined in a soil water mixture (1: 2.5 by volume) (Karaoz, 1989a). Electrical conductivity (EC) (of the saturation) was measured by the method developed by Rhoades, 1996. The concentration of soil organic matter (SOM) and soil organic carbon (SOC) were determined by the Walkley-Black method (Nelson and Sommers, 1996). Total Nitrogen (TN) was determined by the Kjeldahl method (Bremner, 1965). The C: N ratio was calculated from the following equations: [C: N = (SOC: Total N)] (1) Where C is carbon, N is total nitrogen, SOC is soil organic carbon, and total N is total nitrogen.

### Statistical analysis

Statistical analysis was performed using SPSS software (version 11.0 for Windows). Soil properties were grouped and summarized according to the land uses and soil depths. Statistical differences were tested using two-way analysis of variance (ANOVA) following the general linear model (GLM) procedure within SPSS. Duncan's significance test was used for mean separation when the analysis of variance showed a statistically significant difference ($p < 0.05$). Mean values found for all properties are shown in relevant tables. The data were analyzed for correlation using SPSS.

## RESULTS

The GLM showed that land use and soil depth were significant factors in determining sand and clay content, PAW, Db, Dp, St, Ksat, pH, SOM, SOC, and total N ratios significantly ($p < 0.005$). The E.C and C: N values differed according to the land use type whereas the silt, FC, PWP and WSA values differed depending on the sampling depth. The combination of these two factors also had a significant interactive effect on clay content, St, Ksat, E.C, SOM, SOC, and C:N ratios ($p < 0.05$) (Table 1 and 2).

**Table 2.** Result of the two-way analysis of variance in chemical properties of the soils under the two land uses and the three depth.

| | df | pH | E.C | Sal | SOM | SOC | T- N | C:N |
|---|---|---|---|---|---|---|---|---|
| Land use (LU) | 1 | .000 | .002 | .070 | .000 | .000 | .000 | .034 |
| Depth (D) | 2 | .011 | .187 | .038 | .000 | .000 | .000 | .321 |
| LUxD | 2 | .543 | .000 | .038 | .011 | .001 | .625 | .000 |

E.C: Electrical conductivity, Sal: Salinity, SOM: Soil organic matter, SOC: Soil organic carbon, T-N: Total N.

## Soil texture and water characteristics

The soils within the tea plantation site are of sand-clay loam (SCL) texture, and the alder coppice soils are of loamy sand (LS) texture. The highest sand content was present in the AC soil at a depth of 30 - 50 cm, and the lowest sand content was found in the TC soil at a depth of 0 -10 cm. Average silt amount was the highest in the TC soil (in all three depth levels). The clay content in forest soil change irregularly depending on the depth. The highest clay content was present in the 2nd depth level and the lowest clay content was present in the 1st depth level. The change of the clay content between the 1st and the 2nd levels were statistically significant (Table 3).

The highest FC was seen in the top soil at the AC site, and the lowest FC and PAW content was seen at a depth of 30 - 50 cm in the TC soil (Table 3).

## Bulk density (Db), particle density (Dp), soil penetration resistance (SPR), total porosity (St), water-stable aggregates (WSA) and saturated hydraulic conductivity (Ksat)

The Db and Dp values in the AC and TC soils showed statistically significant increase with greater depth (Table 3). The highest Db (1.18 gcm$^{-3}$) was seen at the 3rd depth level of TC site, and the lowest Db (0.84 gcm$^{-3}$) was seen in the 1st depth level of the forest top soil (Table 3). The particle density in the tea soils showed a statistically significant variation based on depth. The average total porosity was 37.69 - 51.91%, in the tea soils and 50.41 - 59.45% in the forest soils (Table 3). Both the AC and TC soils showed a statistically significant variation in soil pore volume, according to sampling depth ($p < 0.007$).

The average WSA content ranged from 64.45 - 69.40% in the tea soils and from 65.50 - 70.65% in the forest soils. The WSA values of the forest and tea soils showed a statistically significant decrease with depth (Table 3). The SPR levels in the tea and forest soils increased with depth (Figure 1).

As shown in Figure 1, the SPR value of the tea soils showed a linear and statistically significant increase with depth. The average Ksat values were 10.92 - 40.64 mmh$^{-1}$ in the forest soils and 4.31 - 16.33 mmh$^{-1}$ in the tea soils. If the depth level factor was omitted, the difference between the Ksat values of the AC and TC soils were found to be statistically significant (Table 3).

## Soil organic matter and soil organic carbon, total N, C:N ratio

The average SOM values range between 2.39 - 4.06% in TC soils and between 2.95 - 5.14% in AC soils; the average organic carbon values vary between 1.62 - 2.57% in TC soils, and between 2.09 - 2.97% in AC soils. SOM and SOC content of the TC soils showed a statistically significant variation according to depth. SOM value in the AC soils significantly decreased whereas the change in the organic carbon values was disordered.

The highest total N (T-N) content was present in the top forest soils; the lowest total N content was present in the 3rd depth level tea bottom soils. The difference between the total N values of the upper (depth 1) and the lower (depth 3) levels of the TC and AC soils was found to be statistically significant (Table 4). The depth dependent C: N values in the tea soils first decreased and then increased; whereas in the forest soils they first increase and then decrease (Table 4).

The mean SOC levels varied significantly with soil depth (Figure 2). At a depth of 0 -10 cm the dominant source of carbon is humus, while at a depth of 3 (30 -50 cm) the dominant source of carbon is inorganic calcium and magnesium carbonates. For each incremental soil sampling depth, SOC levels for TP soils declined by 25 - 35%, compared with a decline of 32% in AC soils. These results are similar to those for total N.

## pH and E.C

The soil pH in both the forest and tea soils was found to be higher in the bottom soils. Electrical conductivity dropped with depth in the tea soils, whereas it first increased and then decreased in the alder soils. The difference in the pH and E.C values of the forest and tea soils were statistically significant according to depth (Table 4).

## DISCUSSION

A big change in the sand and clay ratios is not expected with the change of the land usage type under normal con-

**Table 3.** Land use and soil depth effects on soil physical properties (mean ± S.E.).

| Soil Properties | Land Uses | Depth (cm) | | | Overall |
|---|---|---|---|---|---|
| | | 0 - 10 | 10 - 30 | 30 - 50 | |
| Sand (%) | Forest | 70.35 ± (2.20) | 67.19 ± (1.45) | 71.03 ± (1.57) | 69.52 ± (1.03)a |
| | Tea Plantation | 58.25 ± (1.34) | 60.10 ± (1.08) | 65.96 ± (1.40) | 61.44 ± (.84)b |
| | Overall | 64.30 ± (1.61)a | 63.64 ± (1.06)a | 68.49 ± (1.11)b | |
| Clay (%) | Forest | 11.93 ± (1.30) | 17.01 ± (1.15) | 13.63 ± (1.07) | 14.19 ± (.72)b |
| | Tea Plantation | 22.17 ± ( 1.17) | 21.26 ± (.99) | 18.56 ± (.75) | 20.66 ± (.59)a |
| | Overall | 17.05 ± (1.19)ab | 19.13 ± (.82)a | 16.09 ± (.75)b | |
| Silt (%) | Forest | 17.70 ± (2.02) | 15.89 ± (.70) | 15.33 ± (.84) | 16.31± (.76) |
| | Tea Plantation | 19.57 ± (.79) | 18.62 ± (.60) | 15.42 ± (.91) | 17.87± (.50) |
| | Overall | 18.63 ± (1.08)a | 17.26 ± (.50)ab | 15.38 ± (.61)b | |
| FC (% vol.) | Forest | 33.19 ± (.75) | 31.79 ± (.75) | 29.01 ± (.65) | 31.33 ± (.46) |
| | Tea Plantation | 31.70 ± (.82) | 31.79 ± (.75) | 28.04 ± (.56) | 30.51 ± (.46) |
| | Overall | 32.45 ± (.56)a | 31.79 ± (.52)a | 28.52 ± (.43)b | |
| PWP (% vol.) | Forest | 16.40 ± (.37) | 17.54 ± (.38) | 16.36 ± (.42) | 16.76 ± (.23) |
| | Tea Plantation | 16.21 ± (.38) | 18.14 ± (.41) | 16.17 ± (.40) | 16.84 ± (.25) |
| | Overall | 16.30 ± (.26)b | 17.84 ± (.28)a | 16.26 ± (.29)b | |
| PAW (% vol.) | Forest | 16.79 ± (.49) | 14.05 ± (.40) | 12.60 ± (.37) | 14.48 ± (.33) |
| | Tea Plantation | 15.49 ± (.65) | 13.65 ± (.37) | 11.87 ± (.25) | 13.67 ± (.32) |
| | Overall | 16.14 ± (.41)a | 13.85 ± (.27)b | 12.23 ± (.22)c | |
| Dp (gcm-3) | Forest | 2.45 ± (.02) | 2.54 ± (.03) | 2.62 ± (.02) | 2.54 ± (.01)b |
| | Tea Plantation | 2.57± (.03) | 2.60 ± (.03) | 2.75 ± (.03) | 2.64 ± (.02)a |
| | Overall | 2.51 ± (.02)b | 2.57 ± (.02)b | 2.68 ± (.02)a | |
| Db (gcm-3) | Forest | .840 ± (.03) | .95 ± (.03) | .98 ± (.02) | .93 ± (.01)b |
| | Tea Plantation | 1.02 ± (.01) | 1.06 ± (.02) | 1.18 ± (.03) | 1.09 ± (.01)a |
| | Overall | .93 ± (.02)c | 1.01 ± (.02)b | 1.08 ± (.02)a | |
| St (%) | Forest | 59.45 ± (1.18) | 52.40 ± (.75) | 50.41± (.91) | 54.09 ± (.74)a |
| | Tea Plantation | 51.91 ± (.87) | 44.78 ± (.96) | 37.69 ± (.95) | 44.79 ± (.92)b |
| | Overall | 55.68 ± (.94)a | 48.59 ± (.85)b | 44.05 ± (1.20)c | |
| WSA (%) | Forest | 70.65 ± (1.27) | 66.15 ± (.79) | 65.50 ± (.99) | 66.93 ± (.69) |
| | Tea Plantation | 69.40 ± (1.32) | 65.35 ± (.79) | 64.45 ± (.71) | 67.23 ± (.59) |
| | Overall | 70.02 ± (.91)a | 66.25 ± (.55)b | 64.97± (.62)b | |
| Ksat (mmh-1) | Forest | 40.64 ± (.77) | 22.53 ± (.67) | 10.92 ± (.28) | 24.70 ± (1.63)a |
| | Tea Plantation | 16.33 ± (.44) | 4.85 ± (.28) | 4.31 ± (.19) | 8.49 ± (.74)b |
| | Overall | 28.49 ± (1.99)a | 13.69 ± (1.46)b | 7.61 ± (.55)c | |

LU: Land use, D: Depth, F.C: Field capacity, PWP: Permanent wilting point, PAW: Plant available water, Dp: Particle density, Db: Bulk density, St: Total porosity, WSA: Water stable aggregate, Ksat: Saturated hydraulic conductivity, S.E: Standart error.

ditions. However, when the TC site was converted to cultivation, terraces were formed at an approximate width of 60 - 90 cm. Stones larger than 10 cm were removed from the terraces and tea seedlings were set after discombobulating the soil. Bean and corps were seeded in the newly set tea terraces and the soil was hoed. It can be concluded that these operations mixed the original topsoil within the soil profile, thereby altering the texture and the structure of the soil. Many previous researchers have concluded that discombobulating the soil, particularly the top part of the soil profile, changes the soil's texture (Querejeta et al., 2000). Brye et al. (2003) reported that land leveling significantly altered soil particle-size fractions. In the tea plantations converted from forest, the soil protection ability against erosion is lower compared to alder plantation and as a result, some of the topsoil had been removed by surface flow. This is another factor which leads to changes in the soil texture.

In the top soil of the TC site, the volume weights and the penetration values of the soil were significantly higher,

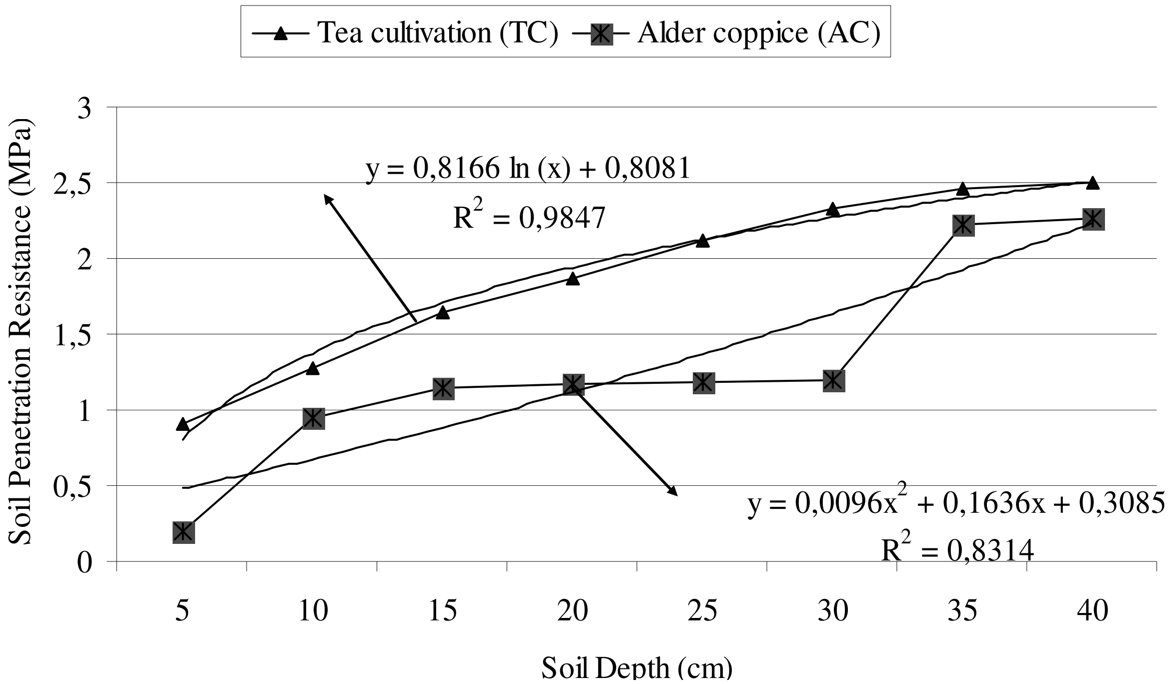

**Figure 1.** Soil penetration resistance (MPa) according to soil depth on alder coppice and tea cultivation in the study area.

**Table 4.** Land use and soil depth effects on soil chemical properties (mean ± S.E.).

| **Soil properties** | **Land Uses** | **Soil Depth (cm)** | | | **Overall** |
|---|---|---|---|---|---|
| | | **0 - 10** | **10 - 30** | **30 - 50** | |
| pH<br>(1/2.5 H2O) | Forest | 4.35 ± (.09) | 4.41 ± (.06) | 4.57 ± (.06) | 4.44 ± (.04)a |
| | Tea Plantation | 3.73 ± (.03) | 3.86 ± (.06) | 3.88 ± (.06) | 3.82 ± (.03)b |
| | Overall | 4.04 ± (.06)b | 4.13 ± (.06)ab | 4.23 ± (.06)a | |
| E.C<br>(dS.m-1) | Forest | .26 ± (.01) | .38 ± (.01) | .34 ± (.01) | .33 ± (.01)a |
| | Tea Plantation | .36 ± (.01) | .27 ± (.00) | .26 ± (.02) | .29 ± (.01)b |
| | Overall | .31 ± (.06) | .32 ± (.01) | .30 ± (.01) | |
| Salinity<br>(%) | Forest | .010± (.00) | .010 ± (.00) | .010 ± (.00) | .010 ± (.00) |
| | Tea Plantation | .012 ± (.001) | .010 ± (.00) | .010 ± (.00) | .011 ± (.00) |
| | Overall | .011 ± (.000) | .010 ± (.00) | .010 ± (.00) | |
| SOM<br>(%) | Forest | 5.14 ± (.22) | 4.28 ± (.18) | 2.95 ± (.14) | 4.12 ± (.15)a |
| | Tea Plantation | 4.06 ± (.14) | 2.71 ± (.18) | 2.39 ± (.10) | 3.05 ± (.12)b |
| | Overall | 4.60 ± (.15)a | 3.50 ± (.17)b | 2.67 ± (.09)c | |
| SOC<br>(%) | Forest | 2.81 ± (.13) | 2.97 ± (.09) | 2.09 ± (.09) | 2.62 ± (.08)a |
| | Tea Plantation | 2.57 ± (.11) | 1.94 ± (.10) | 1.62 ± (.06) | 2.04 ± (.07)b |
| | Overall | 2.69 ± (.08)a | 2.45 ± (.10)b | 1.86 ± (.06)c | |
| Total N (T-N)<br>(%) | Forest | .25 ± (.01) | .22 ± (.01) | .19 ± (.01) | .22 ± (.01)a |
| | Tea Plantation | .21 ± (.00) | .20 ± (.01) | .15 ± (.01) | .19 ± (.00)b |
| | Overall | .23 ± (.00)a | .21 ± (.01)b | .17± (.01)c | |
| C:N Ratio | Forest | 11.45 ± (.31) | 13.68 ± (.58) | 11.20 ± (.35) | 12.11± (.28)a |
| | Tea Plantation | 12.42 ± (.69) | 9.91± (.64) | 11.11± (.59) | 11.14 ± (.38)b |
| | Overall | 11.93 ± (.38) | 11.80 ± (.52) | 11.15± (.33) | |

E.C: Electrical conductivity, SOM: Soil organic matter, SOC: Soil organic carbon, T-N: Total N, S.E: Standart error.

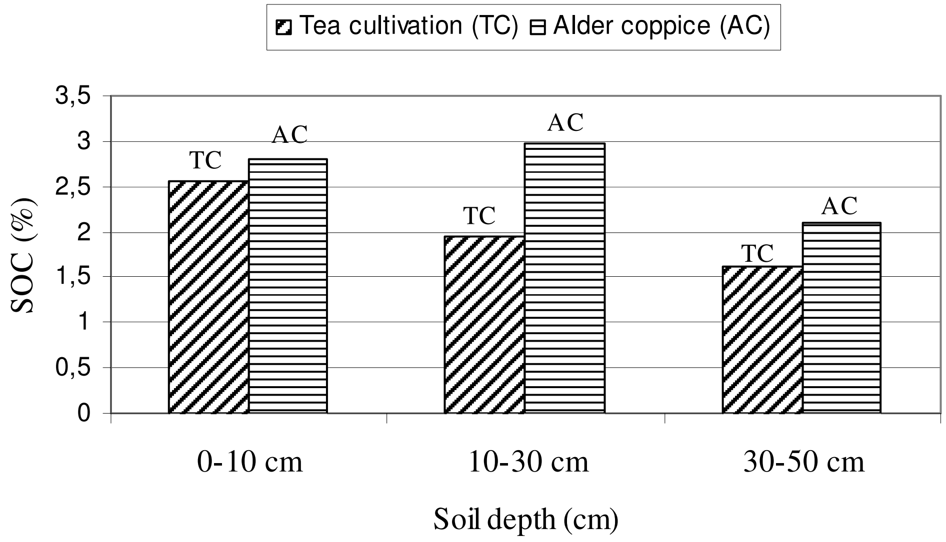

**Figure 2.** Soil organic carbon according to soil depth steps on alder coppice and tea cultivation in the study area.

while the total porosity and the net structure of the pores were destroyed, due to heavy field traffic and hoeing. As a result, water penetration into the soil was slower and the FC and PAW values of the soil were decreased. The field capacity and plant available water in the tea and forest soils decreased with increased depth, partly due to the decrease in soil organic matter at greater depths. As the soil organic matter decrease, the water retention and available water capacities of the soil decrease (Hudson, 1994).

The construction of terracing using human power and the application of high levels of organic fertilizers in the initial years of the tea plantation help increase the plant available water capacity of the soil. The use of organic amendments and the application of additional organic mater in the terraces increases the water resistant aggregate stability of the soil. In these terraces, the volume weight of the soil decreases compared to terraces in which no organic amendments is used, whereas the water holding capacity, plant available water and hydraulic conductivity increase (Querejeta et al., 2000). The herbaceous plants growing beneath the alders are also harvested and used as animal food or animal bedding. These practices reduce the organic inputs and cause a loss of soil nutrients within the forest ecosystem and have negative effects on the soil properties. Le Bissonnais (1996) mentions that the aggregate stability of soil increases in line with the soil organic matter. Yüksek (2001) mentions that the water capacity of the soils decrease and the flowing water amount increases as a result of using the organic wastes collected from the forest for different purposes.

In the upper levels of the tea soils, dense trampling and soil processing decreases the total pore volume especially in the topsoils, and causes the volume weight to increase. Under normal conditions, as a result of heavy field traffic and cultivation operations, the porosity in the tea top soils would be expected to be low and the volume weight would be expected to be high. The organic fertilizers applied to the tea terraces improve the structure of the topsoils to some extent. This avoids reduction in the pore volume and causes the volume weight to increase further. Most previous researchers have concluded that compost and animal fertilizers applied to the topsoil decrease the volume weight (Aggelides and Londra, 2000) and increase WSA and total porosity (Aoyama et al., 1999). Organic amendments decrease soil bulk density due to the "dilution effect" of the added organic matter with the denser mineral fraction, and by influencing soil aggregation, which can lead to greater porosity (Garnier et al., 2004). The application of organic fertilizers to the tea cultivation site is a factor in the increase of WSA. Campbell et al. (2001) mention that the WSA content of the agricultural soils may increase as a result of adding organic fertilizer addition. Another possible reason is that the relatively high clay content and low organic matter content of the tea plantations may have increased the wettability of soil aggregates causing the aggregates to suffer more slaking on sudden wetting. It is well-known that there is a positive correlation between soil organic matter and aggregate stability (Chenu et al., 2000).

Soil hydraulic properties, including soil hydraulic conductivity function and water retention characteristics, are affected by soil texture, bulk density, soil structure, and organic carbon content. Many of these factors are strongly influenced by land use and management even though the soil classification may be the same. As a re-

result of the soil processes applied at the TC site, with the deformation of the soil texture and structure, the macro pores and the pore network were destroyed.

Jamming and the increase of Db caused the Ksat values to decrease. The root structure and the low root density compared with the forest soils also contributed to the low Ksat values. The temporal change of land use and management, or natural disturbances and cycles such as diurnal and seasonal changes can affect soil hydraulic properties. Soil compaction caused by human trampling, wheel traffic or animal grazing can destroy large pores and therefore reduce saturated or near-saturated hydraulic conductivity (Drewry and Paton, 2005).

The depth dependent C:N values in the tea soils first decreased and then increased; whereas in the forest soils they first increase and then decrease. The depth dependent clay contents in the forest soils first decrease and then increase; whereas in the tea soils they decrease linearly. The change in land use type and the cultivation practices applied in the tea terraces reduce the organic material content, especially in the tea topsoils. However, the regular application of organic fertilizer maintains the soil organic matter content of the tea topsoils. This prevents the decrease of organic material content in the tea topsoils to some extent. Land-use change (Desjardins et al., 2004) and long-term cultivation may lead to changes in SOM quantity and quality (Brady and Weil, 2002). For each incremental soil sampling depth, SOC levels for TP soils declined by 25 - 35%, compared with a decline of 32% in AC soils. These results are similar to those for total N. This decline was due to declining humus levels with increasing soil depth. Soil carbon loss first occurs predominantly by mineralization after conversion of virgin land to cultivation, followed in subsequent years by soil erosion as the dominate soil carbon loss process (Gregorich et al., 1994). Since the organic wastes collected from the forest and stable fertilizers are applied to the tea terraces, the total nitrogen content in the tea top soils was high. Also, with the help of the organic wastes applied to the tea terraces, the removal of N and P with surface flow was partially prevented. This was effective in maintaining a relatively high total N value. Indeed, by applying mulch to the soil, the amount of N carried with surface flow is reduced (Linde et al., 1997). Navarrete and Tsutsuki (2008) reported that land conversion decreased the soil carbon and nitrogen content. It may be concluded that the humidity of the research region (annual average rainfall approximately 2000 mm) and the soil management process applied to the terraces caused some leaching of N. Different types of fertilizer were applied to the tea cultivation soils. In the first 15 years after conversion from alder forest, compost + stable fertilizer were applied; in the next 10 years, stable fertilizer was applied; in the final 30 years, chemical fertilizers (ammonium, sulfate, ammonium nitrate and N-P-K) were applied. The initial application of compost during the first years prevented acidification of the tea soils. However, the large amounts of chemical fertilizers applied in subsequent years and the effects of leaching increase the acidity level of the tea soils.

In general a strong positive relationship between the clay content of the soils and their water holding capacity is expressed (Rhoades et al., 1989). In this study, the clay content in the forest soils first increases with depth and then drops again. In other words, there is a positive relationship between the clay content and EC. In the tea soils, the clay content and the FC decrease with depth. It is likely that decrease causes a drop in the EC values. Also, it may be said that the application of compost to the tea soils increases EC. The movement of electrons through bulk soil is complex. Electrons may travel through soil water in macropores, along the surfaces of soil minerals (i.e. exchangeable ions), and through alternating layers of particles and solution (Rhoades et al., 1989).

Vegetation type and quality has a large influence on the hydraulic property variations of soils. Although the alder coppice waterside thicklets cannot protect the soil as well as the natural old-growth forest-cover, they do better than the tea cultivations (Yüksek and Kalay, 2002). Also, their root system (thin and thick roots), their greater underground biomass and their ability to penetrate deeper into the soil than the tea roots, increase the macro porosity of the soil and facilitate improved pore meshes (pore network). This might cause the alder soils to have better infiltration, saturated hydraulic conductivity and water holding capacities compared to the tea soils.

## Conclusıons

Over several decades, the land cover in the Rize settlement regions has changed from alder coppice forests to tea cultivation. The present study showed that land use has a significant influence on the chemical and physical soil properties and hydrological processes in the research area. One major impact of cultivation on soils is the reduction of total porosity and saturated hydraulic conductivity due to reduced abundance and activity of soil organisms. The increase of surface runoff, reduction of field capacity (due to soil loss) and evaporation cause an increase of water yield in the catchments used for agriculture. Another important effect of field transformation is the increased acidity level while the organic material and total nitrogen content decrease. This change probably reduces the quality and efficiency of tea cultivation in that region. A reduction in yields or income obtained from tea cultivation may lead to greater socio-economic pressure to convert remaining areas of coppice to agriculture. In order to meet the needs of the increasing population, it is necessary to increase agricultural production. However, the soil management system needs to be sustainable in order to maintain the balance of ecosystem functions. This requires that the global problem of unregulated field transformations should be prevented and the necessary legal and policy framework should be created to regulate land-use. The sustainability of existing plantations may be improved by greater organization of agricultural activities and the adoption of agro-ecological land-use zoning.

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