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THE EFFECTS OF LAND USE CHANGE ON SOIL LOSS AND CARBON STOCK AMOUNTS

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ABSTRACT

Owing to the land use change, vegetation cover, ecosystem functions and soil properties are affected and changing. Such a change on the land use forms is also the fact in this study area. The main purpose in this study was to determine the effects of land use change on the soil properties, soil loss and carbon stock. As a result, the land use change caused significant (P<0.001) alteration in soil loss (0.6 t/ha/yr in forest, 3.6 t/ha/yr in pasture). Soil carbon (150.4 t/ha in pasture, 174.3 t/ha in forest) and total carbon stock amounts (151.1 t/ha in pasture, 202.4 t/ha in forest) have also changed significantly (P<0.001). As well as soil organic matter, pH and EC in forest were found significantly different (P<0.01) in land use groups. According to the land use scenario which was established by utilizing the average values obtained in the research, it is expected that there will be about 2.1 t/ha/yr of soil loss amount per year in this area and about 15% of this is caused from the forest area and about 85% from the pasture. In other words, the effect of pasture lands on total soil loss is about 6 times higher than the forest lands.

KEYWORDS:
Land use change, Soil loss, Carbon stock, Oriental beech

INTRODUCTION

The war between man and the natural environment, under various land use, continues without losing momentum. Environmental problems have increased due to the urbanization in parallel with the development of the industry and technology [1, 2]. At the forefront of today's most important environmental problems are the global warming, climate change and land degradation [3,4]. These problems are significantly affected by the land use [5, 6]. Therefore, the concept of land use change is vital in environmental and ecological assessments [7, 8].

The land use term is mostly expressed by human activities and it is at the center of ecosystem function and dynamics [9]. The ecological, sociological and economic structure of a region is the most important parameter that determines the land use and its affects [10, 11]. There is a strong relationship between land use pattern and vegetation type and soil fertility, erosion sensitivity, carbon binding potential and other soil characteristics [12, 6, 13, 14, 15, 16].

Soil which is classified as non-renewable natural resource, can heal itself over time [17, 18]. Conversion of agricultural land to pastureland or open areas into forests in a basin also increases soil and water quality [19]. Natural transition process and plantation activities play an important role in improving the area where land use changed. It has been determined that positive changes in soil quality indicators (bulk density, aggregate stability, organic matter content) increased with the abandonment of an active farming area to its natural state [20].

Carbon stock potential of the soils has also an important effect on environmental problems [21]. It is also an important parameter in reducing the soil loss [22]. Soil erosion is also considered as a variable of determining land use change [23]. Generally, under the same ecological conditions, annual soil loss in a hectare is expected to be highest in the treated agricultural land, then in the pasture, and at least in the forested area, depending on the plant cover. A land, used as a pasture, can be turned into a forest area after years if the ecological conditions are suitable. This may increase the carbon-binding potential and reduce the susceptibility of the soils to erosion [24]. By the plantation efforts, carbon stock of the soils can be increased and soil erosion can be reduced. The physical, chemical and biological properties of the soils may be changed in a positive way by planting a damaged area with conifer species. In this way, the carbon stock potential can be increased and the susceptibility to soil erosion can also be reduced [25].

There have been major changes on the land use forms from past to present in Turkey. Despite the increase in forest area, half of them are considered as unproductive due to degradation caused by human activities such as illegal cutting, grazing and unplanned using for many years. This study was carried out to understand and determine the situation in the study area. The study area where the study took place was used as a cropland until 1970s. With time, with the loss of the fertility, the croplands have been abandoned, some of which have been turned into pasture

and some of which have been turned into forest (with the plantation studies in the 1980s). The main purpose of this research is to determine the effects of the land use change on the basic soil properties, soil loss amounts and carbon stock amounts.

MATERIALS AND METHODS

Study area. The study area is placed in the Middle Eastern Black Sea Region of Turkey in the village Goksu Unye, Ordu (40°53`36" N - 36°57`77" E, Elevation: between 1200 m - 1300 m asl) (Figure 1). The main aspect of the study areas is shady and study areas extend in the north to northeast aspect direction.

There are two different land use types in the study area (Figure 2). The main tree species in the forested (which have been planted in 1970s and are about 35-45 years old nowadays) area is the oriental beech (*Fagus orientalis* Lipsky.) and there are also pasture areas which are mostly over grazed and unfavorable.

The study area is located within the *Fagetum* zone according to Mayr's forest zone [26] classification. The indicator tree of this zone is the *Fagus orientalis* Lipsky. (Oriental beech) which is spread out mostly in Caucasus, Northern Iran, Turkey and North-East Europe. In Turkey, it stretches from the Istranca mountains in the west to the Georgia border in the east in a narrow and expanding belt and is usually located between 0 to 1800 m above the sea level.

Climate data (1970-2015) was obtained from the nearest meteorological station (Unye) to the study area. This data was interpolated into the study area conditions [27] and a climate diagram was created according to Walter [28]. In accordance with Walter climate diagram, the study area is related to the humid oceanic climate type. There is no water shortage in the environment and no dry period is observed throughout the year (Figure 3). In addition, the study area is "semi-humid" according to De Martonne [29] climate classification and is in "B3 Humid" climate type according to Thornthwaite [30].

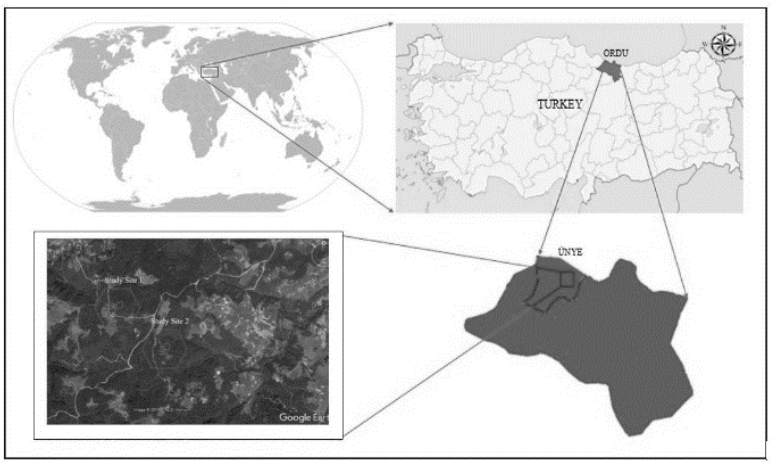

FIGURE 1
Study area and study sites.



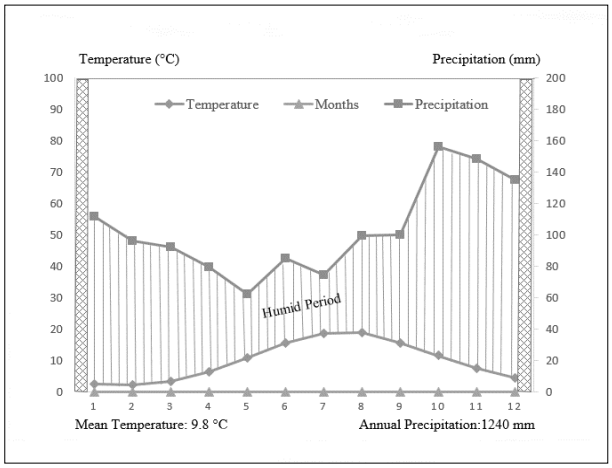

FIGURE 3
Walter climate diagram of the research area.

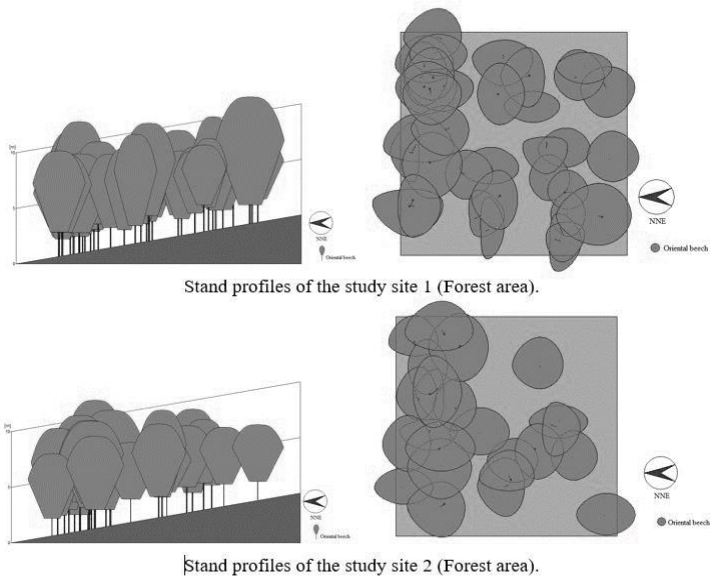

FIGURE 4
Stand structures of the study sites.

The topography in the research area is usually rough terrain where the hilly terrain changes frequently. Especially in the south of the study area are extremely steep slopes. Geological characteristics of the study area and its surroundings are represented by volcanic and sedimentary rocks of the middle - upper Eocene, and clastics and carbonates [31].

Data collection. Stand Structure. The stand profiles taken from forested area were determined and painted by using the "ARGUS Forstplanung" simulation program [32]. Vertical stand profiles were used to determine the canopy closure in each sample plot (20 m x 20 m). Slope, aspect, distribution of trees in the coordinate axis (x, y), diameter at breast height (*DBH*), tree height, crown width and living crown height were measured in sampling plots to quantify canopy closure. Height characteristics were measured with Vertex Forester device. All trees were classified as either dominant or suppressed trees using the classification of IUFRO [33].

Canopy closure was about 70-80 % and more homogenous in the study site 1 (Figure 4). However, the percentage of gaps in the canopy is much higher in study site 2 than study site 1. Canopy closure was about 50-60 % in study site 2 (Figure 4). Mean *DBH* was 11.8 cm in study site 1 and 12.0 cm in study site 2. Both trees in two sample stands were of >8 cm *DBH*. So, sample stands had entered to pole stage with *DBH* values ranging from 8.0 to 19.9 cm.

Soil Sampling. Two study sites were identified in the study area (Figure 1). Both study sites were

divided into two different types of land use including forest and pasture. Two sample plots (55m x 55 m) were taken from each study site (one in the forest and one in the pasture). Two soil profiles were opened in each sample plots (two in the forest and two in the pasture). In this way, totally 8 soil profiles were opened and 40 soil samples were taken and pooled in every plot from 5 different soil depth stages for further analysis. Physical, chemical and hydrological analyses were carried out on each soil sample in the laboratory.

Altitude above sea level (asl) was assessed with an altimeter and the bedrock was derived from the existing geological maps [31]. Landscape position, surface roughness and landform were recorded at sight. Surface stoniness (%), slope (%), aggregate classes etc. were assessed in each study site respectively according to [34]. The slope exposition, measured in degrees relative to N with a compass. Permeability and the other hydraulic soil specifications were determined according to Saxton et al. [35]. Soil depth was measured in each soil profile. Soil texture according to Bouyoucos hydrometer method [36] and organic matter content depend on Walkley-Black wet oxidation method [37] were determined in the laboratory.

Soil Loss Predicting with the ABAG (Allgemeine Boden Abtrags Gleichung). *ABAG* is the international version (where the values are turned in to metric system and adapted to the European conditions) of the simulation model *USLE* (Universal Soil Loss Equation) [38] used to determine the soil loss amounts according to Schwertmann et al. [39].

Most of the erosion assessments performed in North America and around the world during the past two decades have used the USLE. This model was derived empirically from approximately 10,000 plot-years of data [38] and may be used to calculate erosion at any point in a watershed that experiences net erosion. The USLE is written as follows (1):

$$A = R \times K \times L \times S \times C \times P \quad (1)$$

where A is the average annual soil loss (t/ha per year), R the rainfall erosivity factor, K the soil erodibility factor, L the slope length factor, S the slope steepness factor, C the cover management factor and P is the supporting practice factor. Climate erosivity is represented by R and can be estimated from the rainfall intensity and amounts data which were taken from Dogan and Gücer [40]. The soil erodibility monograph has been used to predict the K value [39]. The topography and hydrology effects on soil loss are characterized by the L and S factors. For direct USLE applications, a combined LS factor was evaluated for each land cell [38]. Land use and management are represented by P and can, with some difficulty, be inferred using remote sensing combined with ground-trusting.

Carbon Stock. Two sample plots (each plot (20x20 m) within the soil sample plots (55 m X 55 m) covers an area of 400 m^2) were taken from planted oriental beech stands in each study site. Two woody debris quadrats (1x1 m) were randomly located within both forest and pasture areas in each study site. Species type and diameter at breast height (*DBH*) were recorded for every living tree (*DBH* ≥8 cm, height ≥1.3 m) in sample plots. It was also planned to measure tree height and *DBH* of every dead standing tree (*DBH*≥5 cm, height ≥1.3 m) within the sample plots. But there was no standing dead tree in sample plots. In each quadrat (1x1 m), all plants including seedlings (height ≤1.3 m), saplings, shrubs, herbs and woody species were destructively harvested. In destructive sampling, the vegetation in each area is cut and weighed (fresh weight), and subsamples of parts of the vegetation are taken, weighed fresh in the field, and weighed again after oven-drying. Biomass of each ground vegetation component was oven-dried during 72 h at 65 °C, to calculate dry biomass and carbon content on an area basis.

In each sample plot, four samples of litter, consisting of leaves, fruits, buds, barks, branches and twigs (*DBH*<1cm) were sampled using 25 cm x 25 cm metal quadrats. The four quadrats were systematically distributed in each 400 m^2 plot. All material of litter was collected inside the quadrats. To minimize contamination with mineral soil, the samples were soaked and washed in water. All components of litter were oven-dried during 48 h at 65°C and weighed, analyzed for carbon content.

To estimate belowground biomass and carbon stock we used the roots directly measured in sample plots. The roots were separated in three groups (fine, small and coarse). The carbon stock of fine (0-2 mm), small (2-5 mm) and coarse (5< mm) roots were assessed in two soil profiles plots. The roots were separated from the soil by soaking in water and then gently washing them over a series of sieves with mesh sizes of 2 and 5 mm. The roots were sorted into diameter classes 0-2 mm, 2-5 mm and 5 mm < root classes. The roots from each sizes category were oven-dried at 65 °C for 24 h, weighed, analyzed for carbon content.

The carbon stock was estimated for living trees, woody debris, roots and litter in forested area. The living tree biomass C stock was obtained directly using algorithmic C equation for oriental beech [41] (2).

$$LTC = 0.025672 \times DBH^{2.775} \quad (2)$$

In the equation LTC is living tree carbon stock and *DBH* is diameter at breast height (cm). Soil carbon stock expressed in t ha^{-1} were calculated for the soil depth intervals 0–10 cm, 10–30 cm, 30-60 cm, 60-90 cm and 90–120 cm. Soil organic carbon stock (SOCS) was computed as the product of three variables, BD, soil sampling depth (cm) and carbon concentration (C%) calculated as a function of OM (%).

SOCS (t ha^{-1}) was estimated as follows (3, 4):

$$C\ \% = 0.58 \times OM \quad (3)$$

and

$$SOCS = BD \times C\ \% \times D \quad (4)$$

In the equation *OM* is organic matter, *BD* is soil bulk density (g cm^{-3}), and *D* is soil sampling depth (cm) [42].

Statistical methods. Associations among the variables were analyzed. The compatibility with normal distribution of all variables analyzed was evaluated using the Kolmogorov–Smirnov test. Results are expressed as means ± SD (Standard deviation). Statistical analyses were performed with SPSS version 23.0 software package [43]. Differences between groups were established by Student's *t* -test for normally distributed values and by Mann-Whitney *U*-test for nonparametric values. Pearson's correlation coefficient was searched to examine the relation between normally distributed variables. Spearman's correlation coefficient was used for non-normally distributed values. Statistical significance was defined as *P* was <0.05.

RESULTS AND DISCUSSION

Many different variables have been measured and determined to obtain the requirements of the used soil loss predicting model, the carbon stock and stand structure profiles.

The negative effects of the human activities on the soil loss event [44, 45] are also effective in the study area. According to the measurement results the average slope is about 19 % in the sample plots. It is well known that a positive and strong correlation exists between the slope gradient, slope length and soil loss [38, 46, 47].

Soil hydro-physical properties including soil texture (sand, silt, clay), permeability, bulk density and surface stoniness were found non-significant between forest and pasture area (P>0.05). However, organic matter, electrical conductivity (EC) and soil acidity pH were statically significant (P<0.01). In addition, some important soil function indicators like soil loss, soil carbon and total carbon were found statistically significant among the groups (Table 1, Figure 5). In other words, according to the results, there is a significant statistical relationship (P <0.001) between the soil carbon stock and total carbon stock due to land use. There is also a significant statistical relationship (P <0.001) between the soil loss and land use (Table 1).

There is also a significant negative correlation between the predicted soil loss amounts and organic matter content in the study area (r= - 0.88, P<0.01, A3). Organic matter contents of the sampled soils are in average 2.5 % in forest land and 2.2 % in pasture land (Table 1). It is known that organic matter content of the top soils has a very positive effect on the physical, chemical, hydrological soil characteristics. There is also a positive relation with the organic matter content and soil and total carbon stock (r=0.976 and r=0.981, P<0.001) respectively.

Predicted soil loss amounts in the study are in average 0.6 t/ha/yr in forest land and 3.6 t/ha/yr in pasture land (Table 1, Figure 5). Erskine et al. [48] determined close soil loss values (3.3 t/ha/yr in pasture area and 7.1 t/ha/yr in agricultural area) in their study. Mahmoudzadeh et al. [49] have also reported the soil loss amounts in their study as 3.1 t/ha/yr in agricultural land, 2.2 t/ha/yr in pasture land and 0.8 t/ha/yr in forest land.

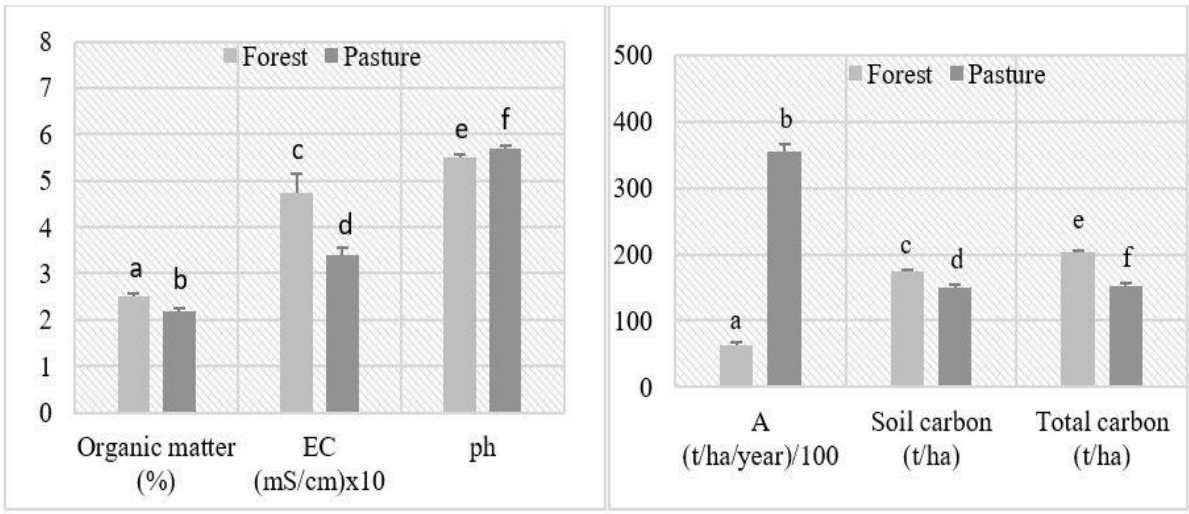

FIGURE 5
Some soil characteristics according to the land use groups.

TABLE 1
Average values of some soil characteristics according to land use groups (n=8, mean ± SD).

Variables	Forest	Pasture	P value
Sand (%)	55.1±6.8	53.3±8.0	*NS*
Silt (%)	20.5±1.1	23.9±3.0	*NS*
Clay (%)	24.3±6.1	22.8±5.0	*NS*
Organic Matter (%)	2.5±0.1	2.2±0.1	*P*<0.001
EC (mS/cm)	47.3±4.2	33.9±1.8	*P*<0.01
pH (H_2O)	5.5±0.1	5.7±0.1	*P*<0.01
Permeability (cm/hr)	19.7±7.8	19.1±8.3	*NS*
Bulk Density (gr/cm^3)	1.5±0.03	1.4±0.01	*NS*
Surface Stoniness (%)	44.5±8.1	49.9±2.9	*NS*
A (t/ha/year)	0.6±0.1	3.6±0.1	*P*<0.001
Soil C (t/ha)	174.3±2.0	150.4±4.9	*P*<0.001
Total C (t/ha)	202.4±2.9	151.1±4.9	*P*<0.001

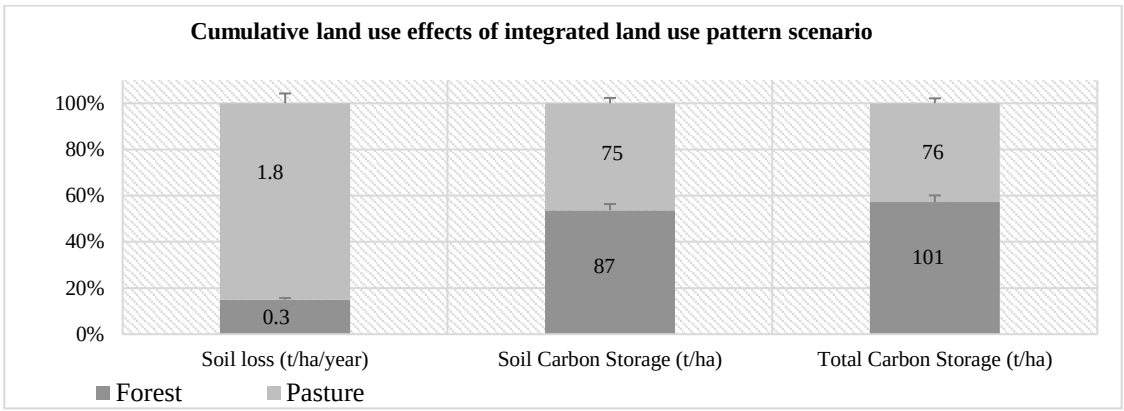

FIGURE 6
The amount of soil loss, soil carbon and total carbon in 1 hectare integrated land.

TABLE 2
The parameters used in the scenario.

Land use	Forest (0.5 ha) (1)	Pasture (0.5 ha) (2)	∑ (1.0 ha) (1+2)	Forest effects (%)	Pasture effects (%)
Soil loss (t/ha/year)	0.3	1.8	2.1	15	85
Soil Carbon Stock (t/ha)	87	75	162	54	46
Total Carbon Stock (t/ha)	101	76	177	57	43

The soil loss values in forest lands in the study area are quite low beside the values in pasture lands. But the average soil loss amounts in the forest lands are higher than expected [46, 50]. The predicted soil loss in forest area is negligible erosion in terms of soil erosion sensitivity classes [51].

These values indicate that the ecological conditions will turn in to natural structure in the forest lands, in time. But it is not the fact in pasture lands, because of the over grazing and non-protective soil loss trends which also affects the land use and plant cover. Golosov et al. [52] reported that the soil loss amounts decreased 3.2 t/ha/yr in the forests lands and increased 0.7 t/ha/yr in pasture lands in a period of 32 years.

It is determined in this study that the soil carbon stock amounts in the forest lands are in average 174.3 t/ha and 150.4 t/ha in pasture lands (Table 1, Figure 5). Wasak and Drewnik [53] found the soil organic carbon stock values are 63.5 t/ha in a forest area and 47.5 t/ha in a pasture area.

It is known that soils represent the most important long-term organic carbon (OC) reservoir which is mostly based on the organic matter [54,55]. The results in this study confirm this knowledge (Table 1). Total carbon stock (soil + biomass) is higher in the forest lands and lower in pasture lands as expected. This situation in the pasture lands is because of the very low biomass.

An integrated land use scenario was established by utilizing the average values obtained in the research (Table 1, Figure 5). In this scenario (totally 1 ha), it is assumed that 50% of the area is pasture and 50% is forest (Table 2).

In this case, it is expected that there will be about 2.1 tons of soil loss per year in this area (Table 2). It is observed that about 15% of this soil loss amount is coming from the forest area and about 85% from the pasture. In other words, the effect of pasture lands on total soil loss is about 6 times higher than the forest lands (1.8 / 0.3) (Figure 6). Erskine et al. [48] was pointed that soil loss in pasture lands is 3-5 times higher than in forest lands.

In such an area, the amount of carbon stock in the soils is about 162 t/ha, while the total carbon stock amount (soil + biomass) is 177 t / ha. The effect of forest area on soil carbon storage is 54% (87 t / ha) whereas the effect of pasture is 46% (75 t /ha). Similarly, the total carbon storage effect of the forest land is 57% (101 t/ha), while the pasture land effect is 43% (76 t/ha) (Figure 6). This difference can be explained by the scarcity of biomass.

CONCLUSIONS

In this study, it has been found that soil loss by erosion, soil carbon stock and total carbon stock in a unit area are significantly affected by vegetation cover depending on land use change. And there is a trend of positive change in soil characteristics in areas converted into forest by plantation. Previous studies have reported that the soil loss amount by erosion in forest area tends to decrease over time while reverse trend exist in pasture and open areas [52]. This indicates that, in the long run, soil quality increases in the forest area and will may decrease in the pasture area.

Land use and soil characteristics are the main factors determining and affecting soil loss by erosion. However, rainfall regime included climatic factors is the most important parameter that is effective in soil loss in hilly areas. In addition, in this study, soil organic matter, soil acidity and electrical conductivity were significantly affected by changes in the amount of plant biomass in the unit area, while no significant change in the basic hydro-physical properties of the soil was observed due to land use over a period of 30-40 years. Soil organic matter, soil acidity and electrical conductivity are classified into important soil quality indicators [56]. Therefore, in the coming period, it is obvious that the quality of the forest land in this region will increase further. And according to created scenario, it is observed that differences in soil loss and organic matter accumulation is due to the litter and plant cover in the forest area. This effect is at the lowest level in pasture areas that are open to excessive and irregular grazing.

As a result, the process of healing is continuing in these areas, which were used for agricultural purposes until 1970s and then abandoned (some of them have been turned into the pasture and some have been turned into forest by plantation). The recovery process in forest areas is progressing much faster. Especially soil loss and total carbon storage values support this result. This process is progressing more slowly in pasture areas. It is considered that the improvement process in these areas will accelerate the recovery process.

ACKNOWLEDGEMENTS

This study was investigated with the transportation support of the Unye Forest Directorate and with the technical and laboratory support of the Karadeniz Technical University Faculty of Forestry. A special thanks to Hasan Fahri Gunkur for their efforts in the land and laboratory works.

APPENDIX

TABLE 3
Correlations between some variables.

Soil Characteristics	Sand (%)	Silt (%)	Clay (%)	Organic Matter (%)	EC (Ms/cm)	pH
Sand (%)	*					
Silt (%)	-0.810*	*				
Clay (%)	-0.714*	0.262*NS*	*			
Organic Matter (%)	-0.095 *NS*	-0.381*NS*	0.619*NS*	*		
EC (Ms/cm)	-0.476 *NS*	-0.833*	0.119*NS*	0.786*	*	
pH	-0048 *NS*	0.524 *NS*	-0.643*NS*	-0.881**	-0.762*	*
Permeability (cm/hr)	0.976***	-0.690*NS*	-0.762*	-0.167 *NS*	0.357*NS*	0.047 *NS*
Bulk Density (gr/cm^3)	0.903 **	-0.638*NS*	-0.861**	0.157 *NS*	0.347*NS*	0.009 *NS*
Surface Stoniness (%)	-0.723*	0.552 *NS*	0.667 *NS*	-0.317 *NS*	-0.333 *NS*	0.160 *NS*
A (t/ha/yr)	0.238 *NS*	0.333 *NS*	-0.762*	-0.880**	-0.643*NS*	0.857**
Soil C (t/ha)	0.138 *NS*	-0.564*NS*	0.115*NS*	0.976***	0.786*	-0.838 **
Total C (t/ha)	0.157 *NS*	-0.618*NS*	0.119*NS*	0.981***	0.786*	-0.861**

Soil Characteristics	Permeability (cm/hr)	Bulk Density (gr/cm^3)	Surface Stoniness (%)	A (t/ha/yr)	Soil C (t/ha)	Total C (t/ha)
Sand (%)						

Silt (%)						
Clay (%)						
Organic Matter (%)						
EC (Ms/cm)						
pH						
Permeability (cm/hr)	*					
Bulk Density (gr/cm^3)	0.902 **	*				
Surface Stoniness (%)	-0.711*	-0.883**	*			
A (t/ha/yr)	0.357 *NS*	0.252 *NS*	-0.119 *NS*	*		
Soil C (t/ha)	0.066 *NS*	0.331*NS*	-0.458*NS*	-0.690*	*	
Total C (t/ha)	0.075 *NS*	0.327 *NS*	-0.481 *NS*	-0.690 *	0.991 ***	*

NS: Correlation is non-significant., *****: Correlation is significant at the 0.05 level, ******: Correlation is significant at the 0.01 level, *******: Correlation is significant at the 0.001 level.

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Received: **04.04.2017**
Accepted: **10.08.2017**

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