Catena 84 (2011) 47–53

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

The effects of restoration on soil properties in degraded land in the semi-arid region of Turkey

Turan Yüksek [a,*], Filiz Yüksek [b]

[a] Department of Landscape and Ornamental Plants, Rize University, Pazar Vocational School, 53300-Pazar-Rize/Turkey
[b] Pazar Forest Management Directorate 53300-Pazar-Rize/Turkey

ARTICLE INFO

Article history:
Received 1 May 2010
Received in revised form 27 August 2010
Accepted 6 September 2010

Keywords:
Semi-arid
Eroded site
Black locust
Stone pine
Soil restoration
Soil properties

ABSTRACT

This study investigated the effects of black locust (*Robinia pseudoacacia* L.), mixed species plantation (MSP) [black locust (*R. pseudoacacia* L) and stone pine (*Pinus pinea* L.)] on surface soil properties in eroded clay soils. Three land use types were selected; black locust plantation area (BLP), mixed species plantation (MSP), and adjacent bare fields (control site) (ABA), in a semi-arid region in Artvin, Turkey. The experimental design at each site was a randomized complete block with four replications in each study area. Five disturbed and five undisturbed soil samples were randomly taken at a soil depth of 0–10 and 10–20 cm in each plot. At 0 to 10 cm soil depth in the BLP and MSP sites, and compared to the control site, field capacity (FC), permanent wilting point (PWP), plant available water (PAW), saturated hydraulic conductivity (Ksat), soil organic matter (SOM), total nitrogen (TN), P_2O_5, Ca were significantly greater, while bulk density (Db) and C:N ratio were significantly lower. SOM, PAW, TN, Ec, Mg and Ksat decreased significantly in both sites (BLP and MSP), while clay increased significantly in MSP, and PWP and Db increased significantly with soil depth in BLP site. As a result: Althought these species didn't showed good growth in the study area black locust plantation (BLP) and mixed species plantation (MSP) had a positive impact on surface soil properties in clay soils in eroded sites. The planting of “black locust” and “black locust + stone pine” can be useful in soil reclamation projects in this type of eroded site in semi-arid regions.

© 2010 Elsevier B.V. All rights reserved.

1. Introduction

Land conversion and degradation are very serious environmental problems, not only in Turkey but also across the world. The causes, trends, and impacts of land conversion are all closely interrelated. Causes of land conversion are broadly categorized as related to population, personal preferences, policies, and economic considerations, and result in impacts such as environmental degradation. Much of the pressure to convert forests to agricultural uses comes from increasing population growth and developmental demands. Between 1950 and 2000 in Turkey, forest and pasture area decreased by approximately 16%, from 47 to 42 million hectares (Mha), while arable crop land increased by approximately 41% from 16 to 27 Mha (DPT, 2007). Soil erosion is one of the most widespread forms of land degradation resulting from such changes in land use. The soil erosion process affects 83% of Yusufeli County and has significant consequences for the dry region ecosystem (Anonymous, 1990).

Soil physical and hydrological properties are related to vegetation type (Martinez-Meza and Whitford, 1996), tree planting has played a pivotal role in renewing the battered landscape of many of the world's arid and semi-arid areas (Ginsberg, 2000). The physical structure of 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). Afforestation can conserve soil on degraded land by reducing soil erosion (Oscar, 2001), increasing soil organic matter (Thapa, 2003) and nutrient concentrations, and improving the soil structure (Burke et al., 1987), providing wildlife habitat (Chazan and Cotter, 2001), improving the landscape (Franco et al., 2003) and the climate (Kursten, 2000), and promoting the livelihood of farmers by permitting agroforestry that can reduce the pressure on forested lands. Studies of soil erosion on the arid and semi-arid areas of Turkey have focused on soil erosion processes and erosion control in severely eroded regions, where vegetation over the past centuries has been completely destroyed.

The aim of this study was to determine the changes in physical and chemical properties of the soil and plant growth in Pamukcular watershed in Artvin city, 10 years after the plantation of black locust and mixed species (black locust + stone pine), which were used for rehabilitation of the semi-arid eroded sites in this area.

* Corresponding author. Tel.: +90 4646127315; fax: +90 4646127316.
E-mail address: turan53@yahoo.com (T. Yüksek).

0341-8162/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.catena.2010.09.002

2. Materials and methods

2.1. Site description and history

The study was conducted in Artvin city, in northeastern Turkey. The study area, Pamukçular watershed, is located 40° 46′ 24″–40°46′ 29″ N and 41°49′ 10″–41°49′ 15″. The altitude of the area is between 940 and 1000 m a.s.l., (See Fig. 1). The soil types of the area were classified as brown forest soil (Anonymous, 1990). The geological formation in the study area consists of two stratigraphic units: (i) a lower unit of pillowed and massive basalt and basaltic andesite intercalated with some thin-bedded silts and shales, and (ii) an upper unit of shallow-water sedimentary rocks with some interbedded basic volcanic rocks. Lower–Middle Jurassic shales and sandstones (Hamurkesen formation) Upper Juarassic-Lower Cretaceous carbonates (Berdiga formation) and lithology consist of Limestone (Dokuz, 2000). In the Lower Jurassic sediments, there is a strong textural dependency upon chemical composition. SiO_2, K_2O, Zr and Rb contents are enriched, whereas Al_2O_3, MgO, CaO, Cr, Ni are depleted in shales relative to associated sandstones. These elemental distributions suggest that the existence of a relatively high energy level, which impeded the accumulation of clay-sized sediments during deposition of the shales. CIA (chemical index of alteration) values for the Lower Jurassic shales and associated sandstones range from 36 to 60 (Dokuz and Tanyolu, 2006). Since there was no stable meteorological station in the study area, the nearest meteorological stations in Yusufeli town were taken into account. According to the 1974–2000 record of Yusufeli meteorological station, 40 km far away from the study area, which is the nearest station to Pamukçular watershed, annual precipitation was 350 mm. According to the data of the Yusufeli meteorological station 22.41% of the annual precipitation occurs in spring, 18.45% occurs in summer, 25.77% occurs in fall and 33.37% occurs in winter. According to the climate diagram of the study area by Thornthwaite, there was strongly a water deficiency from May 15th to November (See Fig. 2). The annual average temperature was 15.40 °C, average temperature in summer (June–July–August period) varied between 23 and 27 °C, average highest temperature varied between 29 and 34 °C. Further data are taken from a portable pluviometer erected in the study area in Pamukçular locality between 2005 and 2008 (within the scope of Project no: TOVAG-104O116). This indicates that annual total precipitation was 450 mm (Yüksek et al., 2009a). Based on this figure, it is understood that in the last three years total annual precipitation increased approximately by 22%. The Yusufeli–Pamukçular locality has a semi-arid climate. The area has one of the lowest rainfalls in Turkey and some of the highest levels of soil erosion. There is no acceptable land use and management plan for the study area and its close environment. According to reports from local people in Pamukçular between 1940 and 1990, the majority of the forest community was damaged due to illegal cutting and area was subjected to erosion. Pamukçular locality currently has an anthropogenic character. Between the years 1996 and 1999, Artvin Afforestation Administration, under the Ministry of Forestry of that time, conducted afforestation activities in 935 ha of a 1091 ha eroded area for

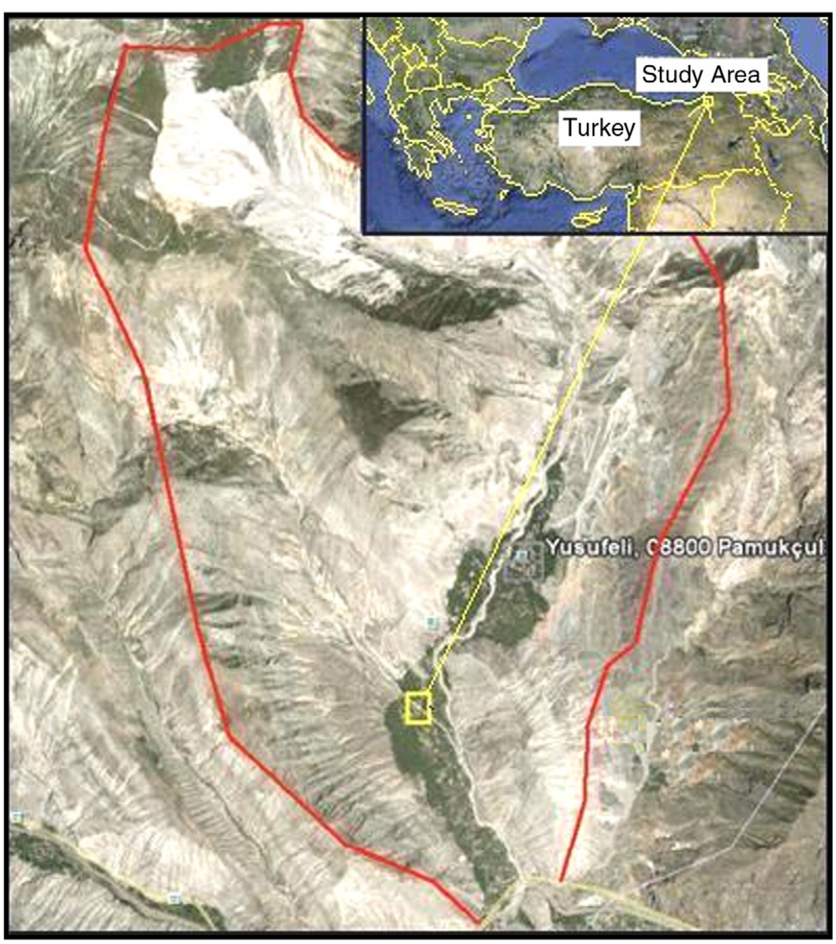

Fig. 1. Study area and experimental sites in Pamukcular watershed.

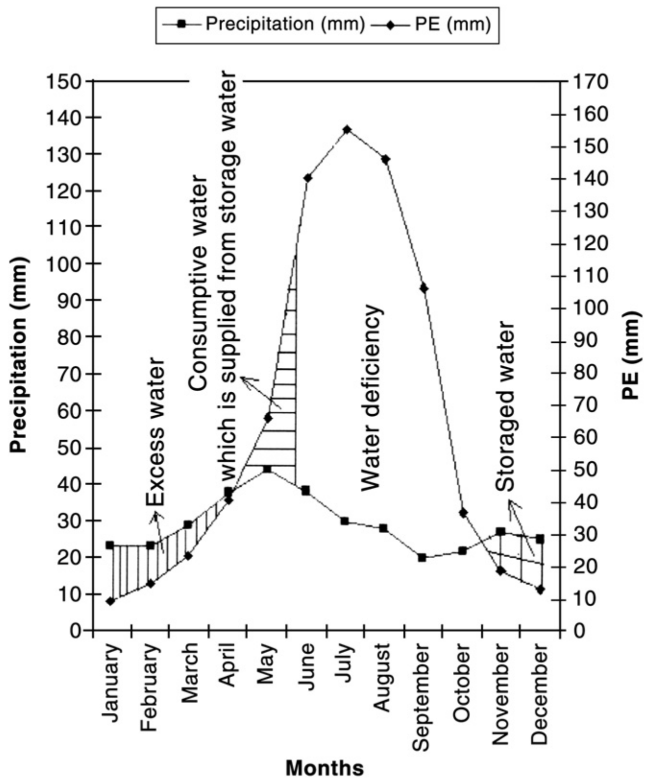

Fig. 2. Climate diagram of Yusufeli area by Thornthwaite (period 1974–2000).

rehabilitation purposes and terraces were established in the study area. The treatments were the following:

BLP: Black locust (*Robinia pseudoacacia* L) planted at a spacing of 3 m.
MSP: Mixed species plantation: Black locust (*R. pseudoacacia* L) and stone pine (*P. pinea* L.) were planted at a spacing of 3 m. Mixture in a proportion of 3:1 between black locust (*R. pseudoacacia* L) and stone pine (*P. pinea* L.)

The afforested areas around Pamukçular region were conserved by fencing and, 3 years after the plantation, any dead seedlings were replaced.

2.2. Experimental design and soil sampling

Three land use types were selected, black locust plantation (BLP) area, mixed species plantation (MSP) area and adjacent bare area (ABA) in Pamukçular. In each land use type, four replicates (20 m × 20 m) were established. In each replicate five soil pits were opened and the disturbed and undisturbed soil samples were taken at 0–10 cm and 10–20 cm soil depth. A total of 120 soil samples (3 land use types × 4 replicates × 5 soil pits × 2 soil depth layer) were collected in April and May 2008. The undisturbed soil samples were obtained using a steel core sampler of 98.16 cm^3 volume (5 cm in diameter and 5 cm in height). Prior to analysis of soil physical and chemical characteristics, all samples were air-dried at room temperature and disturbed soil samples passed through a 2 mm soil sieve.

2.3. Sampling of some plant properties

In each experimental site (20 × 20 m) the diameter (the diameter approximately 3 cm above the soil surface) and height of 30 randomly selected seedlings were measured.

2.4. Laboratory analysis

The soil particle size distribution was determined by using disturbed soil samples sieved through a 2 mm by the Bouyoucos hydrometer method (Bouyoucos, 1962). The field capacity (FC) was measured by subjecting saturated soil samples <2 mm to tensions of 1/3 b, and permanent wilting point (PWP) was measured at 15 b until equilibrated in pressure membrane and pressure plate extractors (Cassel and Nielsen, 1986). The plant available water (PAW) content was calculated from the difference between the field capacity and the permanent wilting point (Klute, 1986). The bulk density, total porosity and saturated hydraulic conductivity were determined from the undisturbed soil samples. The dry bulk density (Db) was determined by the core method (Blake and Hartge, 1986; 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-Db/Dp) × 100] Where St is total pore spaces, Db is bulk density and Dp is soil particle density (Flint and Flint, 2002). The saturated hydraulic conductivity (Ksat) was measured by the falling-head method according to Klute and Dirksen (1986). Soil pH was determined from a mixture of 1:2.5 soil: water by volume using an Orion 420 A pH meter (Karaöz, 1989). Electrical conductivity (EC) (of the saturation) was measured by the method proposed 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. Ca, Mg, Na, and K were measured with the atomic absorption spectrophotometric (AAS) method and P_2O_5 was measured sodium bi carbonate method (pH>7.0) (Kacar, 1996).

2.5. Statistical analysis

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

3. Results and discussion

The GLM showed that land use and soil depth affected the PWP, PAW, pH, EC, total lime, SOM, TN, C:N, P_2O_5, Mg and Na, while land use affected sand, clay, FC, Db and St. The combination of these two factors also had a significant interactive effect on sand, clay, FC, PAW, pH, EC, SOM, TN, C:N, P_2O_5, Mg, Na, K ratios ($p<0.05$) (Tables 1 and 2).

3.1. Soil physical properties

According to the international soil classification system, the research field mixed species plantation (MSP) and adjacent bare area (ABA) soils are of light clay (LC) texture, and the black locust soils are heavy clay (at 0–10 cm depth) and light clay (at 10–20 cm depth). The highest sand content was present in ABA at a depth of 0–10 cm, and the lowest sand content was present in BLP at a depth of 0–10 cm (Table 3).

Under normal conditions, a change in land use would not be expected to produce a large change in the sand and clay ratios. However, with field transformation in the research field, terraces

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

Source of variation	df	Sand	Clay	Silt	FC	PWP	PAW	Dp	Db	St	Ksat
Land use (LU)	2	0.000	0.000	0.365	0.000	0.000	0.000	0.64	0.01	0.030	0.19
Depth (D)	1	0.599	0.151	0.107	0.763	0.000	0.000	0.53	0.62	0.670	0.01
LU x D	2	0.000	0.001	0.477	0.000	0.464	0.000	0.10	0.70	0.316	0.82

LU: land use, D: depth, FC: field capacity, PWP: permanent wilting point, PAW: plant available water, Dp: particle density, Db: bulk density, St: total porosity, Ksat: saturated hydraulic conductivity.

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

Source of variation	df	pH	EC	Tot. lime	SOM	TN	C:N	P_2O_5	Mg	Na	K
Land use (LU)	2	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.272
Depth (D)	1	0.034	0.000	0.005	0.000	0.000	0.044	0.000	0.000	0.034	0.746
LU x D	2	0.001	0.000	0.638	0.000	0.000	0.000	0.000	0.000	0.000	0.000

EC: electrical conductivity, SOM: soil organic matter, TN: total N.

approximately 60–90 cm wide were formed, stones larger than 10 cm were removed from the terraces and black locust seedlings were set after discombobulating the soil. In this area, where the flora that protects the soil is significantly damaged, a significant part of the topsoil was transported due to erosion. It is suggested that this is another significant factor in the changes in soil texture. Many previous studies have noted that discombobulation changes the soil texture, especially in the top part of the soil profile (Querejeta et al., 2000; Yüksek et al., 2009b). Brye et al. (2006) reported that land leveling significantly altered soil particle-size fractions, but the soil textural class remained a silt loam.

Table 3
Effects of land use and soil depth on soil physical properties 10 years after reforestation.

Soil properties	Soil depth (cm)	Land uses		
		BLP	MSP	ABA
Sand (%)	0–10	32.68^{bB}	41.68^{A}	41.78^{aA}
	10–20	36.60^{aB}	40.20^{A}	38.25^{ABb}
	Overall	34.64	40.94	39.97
Clay (%)	0–10	46.01^{aA}	37.19^{bB}	37.19^{bB}
	10–20	42.39^{b}	40.44^{a}	41.08^{a}
	Overall	44.20	38.82	39.14
Silt (%)	0–10	21.31	21.13	21.03
	10–20	21.01	19.36	20.67
	Overall	21.12	20.23	20.88
FC (% vol.)	0–10	24.33^{A}	25.34^{aA}	16.75^{bB}
	10–20	24.27^{A}	24.04^{Ab}	18.37^{aB}
	Overall	24.30	24.69	17.56
PWP (% vol.)	0–10	13.72^{bA}	13.64^{A}	8.66^{bB}
	10–20	14.98^{aA}	14.23^{A}	9.91^{aB}
	Overall	14.35	13.93	9.28
PAW (% vol.)	0–10	10.61^{aA}	11.70^{aA}	8.09^{B}
	10–20	9.29^{ABb}	9.81^{Ab}	8.46^{B}
	Overall	9.93	10.75	8.27
Db (gcm^{-3})	0–10	1.18^{bB}	1.20^{bB}	1.29^{bA}
	10–20	1.23^{aB}	1.25^{aB}	1.32^{aA}
	Overall	1.21	1.21	1.31
Dp (gcm^{-3})	0–10	2.42	2.41	2.45
	10–20	2.51	2.50	2.48
	Overall	2.47	2.48	2.51
St (%)	0–10	51.24	50.21	47.35
	10–20	50.99	50.00	46.77
	Overall	51.11	50.10	47.06
Ksat (mmh^{-1})	0–10	18.99^{aA}	13.94^{aB}	10.15^{aC}
	10–20	12.17^{bA}	10.02^{bA}	7.90^{bB}
	Overall	15.58	12.48	9.05

BLP: black locust plantation, MSP: mixed species plantation (black locust + stone pine plantation), ABA: adjacent bare area, FC: field capacity (% vol.), PWP: permanent wilting point (% vol.), PAW: plant available water (% vol.), Dp: particle density (gcm^{-3}), Db: bulk density (gcm^{-3}), St: total porosity (%), Ksat: saturated hydraulic conductivity (mmh^{-1}), means in the same column followed by the same small lowercase letter are not significantly different at $P \leq 0.05$. Means in the same row followed by the same lowercase letter are not significantly different at $P \leq 0.05$.

The highest field capacity (FC) was seen in the top MSP soil, and the lowest FC and plant available water (PAW) content was seen at a depth of 0–10 cm in the ABA soil. Compared to the ABA site, the permanent wilting point (PWP) and PAW values of the soil increased significantly a depth of 0–10 cm in BLP and MSP sites. As the soil in the ABA site was mainly bare, raindrops significantly affected the porosity and pore network structure of the topsoil. As a result, water penetration into the soil slowed down and the FC and PAW values of the soil were decreased. The decrease in the amount of organic materials can be seen as a reason for the lower field capacity and plant available water content in the BLP and MSP soils with increasing depth. As the amount of organic material decreases, the water holding and available water capacities of the soil decrease (Iqbal et al., 2005; Yüksek, 2009). The Db values in the BLP, MSP and ABA soils increased significantly depending on the depth, while Dp values increased slightly depending on the depth level (Table 3). The highest Db ($1.32\ g\ cm^{-3}$) was seen in the $10-20$ cm depth level of ABA soils, and the lowest Db ($1.18\ gcm^{-3}$) was seen in the 0–10 cm depth level of the BLP top soil. The average total porosity varied between 50.99 and 51.24% in the BLP soils, 50 and 50.21% in the MSP soils and 46.77 and 47.35% in the ABA soils (Table 3). The total porosity (St) decreased slightly depending on the depth in all experimental sites.

The average Ksat values were 12.17 and 18.99 mmh^{-1} in the BLP, 10.02 and 13.94 mmh^{-1} in the MSP and 7.90 and 10.15 mmh^{-1} in ABA soils. The highest Ksat level was seen in the top BLP soil and the lowest Ksat level was seen in the bottom ABA soil. At all experimental sites, Ksat values decreased significantly with soil depth (Table 3). 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 which are strongly influenced by land use and management even though the soil classification may be the same. As a result of the processes applied to the ABA soils, with the deformation of the texture and structure, the macro pores and the pore network were destroyed. Soil degradation (erosion, compaction etc.) and the increase of Db caused the Ksat values to decrease. The root structure and the low root density compared to the BLP and MSP soils also contributed to low Ksat values. On the other hand, after the afforestation of the eroded site with BLP and MSP, soil properties (such as soil organism activity, root dynamics, and formation of cracks at the surface during dry periods, etc.) were improved to some extent. This possibly caused Ksat values in the BLP and MSP sites to be higher when compared to ABA. Vegetation type and quality has a large influence in the hydraulic property changes of the soils. The root system (thin and thick roots) of BLP and MSP, their greater underground biomass and their ability to penetrate deeper into the soil possibly increased macro porosity and facilitated the formation of more extensive pore meshes (pore network). This might cause the BLP soils to have better infiltration, saturated hydraulic conductivity and water holding capacities as compared to the ABA soils. Gutierrez et al. (1995) reported that vegetation type was found to alter soil hydrological characteristics, including infiltration capacity, hydraulic conductivity and water retention. It was reported that soil organism activity, root dynamics and formation of cracks at the surface during dry periods, all contribute to the dynamic nature of soil hydraulic properties in different soils (Rasse et al., 2000).

3.2. Soil chemical properties

The average soil organic matter (SOM) values ranged between 2.09 and 3.57% in the BLP soils, 0.77 and 2.37% in MSP soils and between 0.68 and 0.87% in ABA soils. The SOM content decreased significantly with soil depth in all experimental sites. Compared to the control site (ABA), soil organic matter (SOM) was significantly greater in the BLP and MSP soils. The highest total nitrogen (TN) content was found in the top layers of the black locust soil, and the lowest total nitrogen (TN) content was seen at a depth of 10–20 cm in the ABA soil. Compared to the ABA site, total nitrogen (TN) content significantly increased in the BLP, and MSP soil. The highest C:N ratio was seen at a depth of 10–20 cm in the ABA soil, and the lowest C:N ratio was seen at a depth of 10–20 in the MSP soil. Compared to the BLP and MSP sites, the C:N ratio significantly increased in the ABA soil. The SOM and total nitrogen content decreased significantly with soil depth in all experimental sites, (Table 4).

The most important organic matter sources in soil are plant and animal wastes. At the ABA site, where the protective flora was significantly damaged, above-ground soil biomass was significantly lower than at the BLP and MSP sites. This possibly had an negative impact on the low amount of organic matter found at the ABA site. In addition, it can be suggested that transport of organic matter and the top soil of this area with erosion can have an effect on the low organic matter amount. The acidic nature of pine litter and the semi-arid climate (high actual evapotranspiration with maximum temperature in the driest season) are among the worst possible scenarios for decomposition and the incorporation of organic matter into the mineral horizons of the soil. This possibly contributed to the lower organic matter content in the MSP plantation site when compared to BLP site. Previous researchers reported that, due to the root nodules of the black locust, it binds the free nitrogen in the air to the soil (Uluocak, 1984; Werner, 1992; Larcher, 1995). This property of black locust might have a significant role in the high nitrogen amount in the BLP area. Rice et al. (2004) investigated the influence of the exotic nitrogen-fixing black locust (*R. pseudoacacia*) on nitrogen cycling in a pitch pine (*Pinus rigida*) and scrub oak (*Quercus ilicifolia*, *Q. prinoides*) ecosystem. Within paired pine-oak and adjacent black locust stands that were the result of a 20–35 year-old invasion, they evaluated soil nutrient contents, soil nitrogen transformation rates, and annual litterfall biomass and nitrogen concentrations. In the A horizon, black locust soils had 1.3–3.2 times greater nitrogen concentration relative to soils within pine-oak stands. Net nitrification rates were 25–120 times greater in black locust than in pine-oak stands.

It can be stated that, due to decomposition of the organic wastes in BLP and MSP plantations which were planted later, the nitrogen that mixed into the soil might have an effect in producing the high nitrogen content recorded in the present study. It was reported that, due to damage of natural flora, humus and nitrogen content decreased (Navarrete and Tsutsuki, 2008; Yüksek, 2009) and, due to the erosion in these damaged areas, organic matter, N, P and K content in the soil decreased (Chonghuan and Lixian, 1992; Gregorich et al., 1998).

The highest P_2O_5 was seen at a depth of 0–10 cm in the BLP, the lowest P_2O_5 was seen at a depth of 10–20 cm in the ABA soil. The P_2O_5 content significantly decreased with soil depth in BLP and ABA sites, while it was slightly lower in the MSP site. Compared to the ABA site, Ca content significantly increased in the BLP and MSP sites, while it was slightly increased with soil depth at the BLP and ABA sites. The highest Mg content was seen at a depth of 0–10 cm in the BLP site, while the lowest Mg content was seen in the ABA site. The Mg content decreased significantly with soil depth at all sites. The K content decreased significantly with soil depth in the MSP sites, while it was significantly increased in the ABA sites (Table 4). Calcium content in the soil largely depends on soil type, decomposition and leaching degree of the main material (Güneş et al., 2007). It can be suggested that a high degree of leaching and surface flow in an area with bare soils might have an effect on the lower calcium and Mg contents in this site.

Table 4
Effects of land use and soil depth on soil chemical properties 10 years after reforestation.

Soil properties	Soil depth (cm)	Land uses		
		BLP	MSP	ABA
pH (1/2.5 H2O)	0–10	7.48	7.45	7.50
	10–20	7.94^{A}	7.48^{B}	7.47^{B}
	Overall	7.94	7.90	7.97
E.C ($dS.m^{-1}$)	0–10	0.42^{aA}	0.36^{aB}	0.36^{aB}
	10–20	0.36^{bA}	0.30^{bB}	0.21^{bC}
	Overall	0.39	0.33	0.29
Total Lime (%)	0–10	35.78^{A}	36.57^{A}	7.62^{aB}
	10–20	35.74^{A}	34.76^{A}	6.86^{Bb}
	Overall	35.76	35.66	7.24
SOM (%)	0–10	3.57^{aA}	2.37^{aB}	0.87^{aC}
	10–20	2.09^{bA}	0.77^{bB}	0.68^{bB}
	Overall	2.83	1.57	0.77
Total N (TN) (%)	0–10	0.18^{aA}	0.15^{aA}	0.02^{aB}
	10–20	0.10^{bA}	0.10^{bA}	0.01^{bB}
	Overall	0.14	0.12	0.01
C:N	0–10	19.83^{B}	15.80^{Ca}	43.50^{Ab}
	10–20	20.90^{B}	7.70^{Cb}	68^{Aa}
	Overall	20.21	11.95	55.75
P_2O_5 (ppm)	0–10	23.50^{aA}	13.66^{B}	10.66^{aC}
	10–20	11.91^{bA}	12.00^{A}	7.83^{bB}
	Overall	17.70	12.83	9.25
Ca (me/100gr)	0–10	28.63^{A}	26.92^{A}	21.65^{B}
	10–20	29.40^{A}	26.42^{B}	22.68^{C}
	Overall	29.01	26.67	22.16
Mg (me/100gr)	0–10	1.47^{aA}	1.28^{aB}	1.26^{aB}
	10–20	1.35^{bA}	1.22^{bB}	1.12^{bC}
	Overall	1.41	1.25	1.61
Na (me/100gr)	0–10	$0.07b^{A}$	0.07^{aA}	0.05^{bB}
	10–20	0.08^{aA}	0.06^{bB}	0.06^{aB}
	Overall	0.07	0.06	0.05
K (me/100gr)	0–10	0.47^{AB}	0.49^{aA}	0.40^{bB}
	10–20	0.45^{B}	0.38^{bC}	0.54^{aA}
	Overall	0.46	0.44	0.47

BLP: black locust plantation, MSP: mixed species plantation (black locust + stone pine plantation), ABA: adjacent bare area E.C: electrical conductivity, SOM: soil organic matter, SOC: soil organic carbon, TN: total N.), means in the same column followed by the same small lowercase letter are not significantly different at $P \leq 0.05$. Means in the same row followed by the same lowercase letter are not significantly different at $P \leq 0.05$.

3.3. Plant growth

In 1998, black locust and stone pine seedlings were planted in experimental sites. In 1999 and 2000, any dead seedlings were re-planted with new ones. Information about the seedlings in the experimental site was given in Table 5, based on measurements recorded in September 2008.

As indicated in Table 5, seedling growth in both BLP and MSP was not at the desired level. Furthermore, height and diameter development of black locust planted with stone pine was lower than in the areas in which only black locust was planted. The native range of black locust is classified as humid, with two local areas of super humid

Table 5
Growth of seedlings in experimental sites in the study area.

Plantation	Plantation year	Seedlings survival rate (%)	Height of seedlings (cm)	Mean height of seedlings (cm)	Diameter class* (cm)	Mean diameter of seedlings* (cm)
BLP	1998	74.10	50–117	95.82	1.0–3.5	2.82
MSP	1999	67.56	45–111	91.30	0.94–3.2	2.70

BLP: black locust plantation, MSP: mixed species plantation (black locust + stone pine plantation).
* Since the height of the seedlings were smaller than 1.30 m, on 30 seedling samples, the diameter above the soil was measured.

climate (total precipitation, 1020 to 1830 mm). Black locust is very sensitive to poorly drained or compact plastic soils. Excessively dry sites are also poor for the species (Huntley, 2008). However, in Pumukçular, annual precipitation varies between 350 mm (between 1974 and 2000) and 450 mm (between 2005 and 2008). These figures indicate that precipitation within the Pamukçular locality is insufficient, which had a negative effect on seedling growth. Furthermore, the fact that the soil texture in the study area was slightly-heavy clayey and that it had a damaged drainage structure might have a negative effect on seedling growth. Salehi et al. (2007) conducted a study of black locust seedlings at an arid site in Iran, and reported that black locust seedlings grew taller after irrigation. Raffaelli (2004) reported that drought is a major constraint worldwide to the production of common vegetation types such as forests. In particular, revegetation of arid regions is primarily water-limited (Ginsberg, 2000), and growth reductions caused by drought can significantly affect afforestation success, particularly if a lack of moisture reduces survival after planting (Graciano et al., 2005).

4. Conclusions

Rehabilitation of the degraded lands in arid and semi-arid areas has a significant effect on soil protection and sustainable nutrient cycle in the soil. In addition, it should be remembered that the methods applied for rehabilitation of these kinds of lands have a significant effect on the success of rehabilitation activities. In this study it was found that, in rehabilitation of slight and heavy clayey soils in semi-arid areas, black locust plantations were more successful than mixed species plantations. Nearly 10 years after the plantation, statistically significant improvements were observed in some physical, hydro-physical and chemical properties of the soil. In Çoruh River (this river flows through the Artvin province), where numerous dams were constructed, land degradation and sediment transport is a serious problem. These problems mostly affect Pamukçular lower basin. Rehabilitation activities in these kinds of basins will prevent erosion, soil properties can be improved. In these lands, which are degraded by erosion, new and different techniques (for example inoculation of mulching on the terrace, the combined use of herbaceous and ligneous species etc.) can contribute to the success of rehabilitation activities.

References

Anonymous, 1990. Available Land Properties of City of Artvin. Ankara: Publications of General Offices of Villages Foundation, Report No, 08. [in Turkish].
Blake, G.R., Hartge, K.H., 1986. Bulk density, In: Miller, A.L., Keeney, R.H. (Eds.), Methods of Soil Analysis. Part I, second ed. : Physical and Mineralogical Methods, Agronomy Monogr, 9. Madison, Wisconsin. 363–374 pp.
Bouyoucos, G., 1962. Hidrometer method improved for making particle size analysis of soils. Agronomy Journal 54, 464–465.
Bremner, J.M., 1965. Total nitrogen. In: Black, C.A. (Ed.), Methods of soil analysis. Part 2. Agron. Monogr., 9. ASA, Madison, Wisconsin. 1149–1178 pp.
Brye, K.R., Slaton, N.A., Richard, N.J., 2006. Soil physical and biological properties as affected by land leveling in a clayey aquert. Soil Science Society of America Journal 70, 631–642.
Burke, I.C., Reiners, W.A., Sturges, D.L., Matson, P.A., 1987. Herbicide treatment effects on properties of mountain big sagebrush soils after fourteen years. Soil Science Society of America Journal 51, 1337–1343.
Cassel, D.K., Nielsen, D.R., 1986. Field capacity and available water capacity, In: Klute, A. (Ed.), Methods of Soil Analysis, Part 1, 2nd ed. : Physical and Mineralogical Methods — Agronomy Monograph, no. 9. Madison, Wisconsin. 901–926 pp.
Chazan, D., Cotter, A.A., 2001. Evaluating the Impacts of Proposed Land Conversion: A Tool for Local Decision-Making, Center for Sustainable Systems. University of Michigan, Report No. CSS01-02.
Chonghuan, N., Lixian, W.A., 1992. Preliminary study of soil erosion and land degeneration. Erosion, debris flows and environment in mountain regions. (Proceedings of the Chengdu Symposium). IAHS Publ. No. 209.
Dokuz, A., 2000. Geology, geotectonics, geochemistry and petrogenesis of magmatic and metamorphic rocks in Yusufeli (Artvin–Turkey)]. Ph.D Thesis, 311 p., Karadeniz Technical University, Trabzon–Turkey [in Turkish, unpublished].
Dokuz, A., Tanyolu, E., 2006. Geochemical constraints on the provenance, mineral sorting and subaerial weathering of lower jurassic and upper cretaceous clastic rocks of the eastern Pontides, Yusufeli (Artvin), NE Turkey. Turkish Journal of Earth Sciences 15, 181–209.
DPT, 2007. Toprak ve Su Kaynaklarının Kullanımı ve Yönetimi (Dokuzuncu Kalkınma Planı 2007–2013). Yayın No: 2718, OIK:671, Ankara (in Turkish).
Flint, A., Flint, L.E., 2002. Particle density. In: Dane, J.H., Topp, G.C. (Eds.), Methods of Soil Analysis, Part 4-Physical Methods, Madison, Wisconsin, SSSA book series no 5. 229–240 pp.
Franco, D., Mannino, I., Zanetto, G., 2003. The impact of agroforestry networks on scenic beauty estimation. Landscape and Urban Planning 62, 119–138.
Ginsberg, P., 2000. Afforestation in Israel: a source of social goods and services. Journal of Forestry 98 (3), 32–36.
Graciano, C., Guiam´et, J.J., Goya, J.F., 2005. Impact of nitrogen and phosphorus fertilization on drought responses in Eucalyptus grandis seedlings. Forest Ecology and Management 212, 40–49.
Gregorich, E.G., Greer, K.J., Anderson, D.W., Liang, B.C., 1998. Carbon distribution and losses: erosion and deposition effects. Soil Tillage Research 47, 291–302.
Grossman, R.B., Reinsch, T.G., 2002. The solid phase, bulk density and linear extensibility. In: Dane, J.H., Topp, G.C. (Eds.), Methods of Soil Analysis, Part 4–Physical Methods, SSSA book series no 5. Madison, Wisconsin. 201–228 pp.
Güneş, A., Alpaslan, M., İnal, A., 2007. Plant Nutrition and Fertilization. A.U. Faculty of Agriculture, Publication NO:1551, Ankara, 576 pp. (in Turkish).
Gutierrez, J., Sosebee, R.E., Spaeth, K.E., 1995. Spatial variation of runoff and erosion under grass and shrub cover on a semiarid rangeland. In: Ward, T.J. (Ed.), Watershed Management — Planning for the 21st Century. American Society of Civil Engineers, San Antonio, TX, pp. 11–20.
Huntley, J.C., 2008. Black Locust – Robinia pseudoacacia Leguminosae – Legume family. http://www.wildwnc.org/education/trees/black-locust-robinia-pseudoacacia-leguminosae-legume-family (Accessed December 1, 2008).
Iqbal, J., Thomasson, J.A., Jenkins, J.N., Owens, P.R., Whisler, F.D., 2005. Spatial variability analysis of soil physical properties of alluvial soils. Soil Science Society of America Journal 69, 1338–1350.
Kacar, B., 1996. Soil Analyses (Chemical Anaysis of Plant and Soil III), Ankara Üniversitesi Ziraat Fakültesi Eğitim, Araştırma ve Geliştirme Vakfı Yayınları No: 3, Ankara. (in Turkish).
Karaöz, Ö., 1989. Analyze methods of some chemical soil properties (pH, carbonates, salinity, organic matter, total nitrogen, available phosphorus), 39. Review of the Faculty of Forestry, University of Istanbul, pp. 64–82. [in Turkish].
Klute, A., 1986. Water retention, In: Klute, A. (Ed.), Methods of soil analysis, part 1: physical and mineralogical methods, agronomy monograph no. 9, 2nd ed. ASA and SSSA, Madison, Wisconsin. 635–662 pp.
Klute, A., Dirksen, C., 1986. Hydraulic conductivity and diffusivity, In: Klute, A. (Ed.), Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods — Agronomy Monograph no. 9, 2nd ed. ASA and SSSA, Madison, Wisconsin. 687–734 pp.
Kursten, E., 2000. Fuelwood production in agroforestry systems for sustainable land use and CO2-mitigation. Ecological Engineering 16, 69–72.
Larcher, W., 1995. Physiological plant ecology, Third ed. Springer, Verlag–Berlin Heilderberg. 506 pp.
Martinez-Meza, E., Whitford, W.G., 1996. Stemflow, throughfall and channelization of stemflow by roots in three Chihuahuan desert shrubs. Journal of Arid Environments 32, 271–287.
Navarrete, I.A., Tsutsuki, K., 2008. Land-use impact on soil carbon, nitrogen, neutral sugar composition and related chemical properties in a degraded Ultisol in Leyte, Philippines. Soil Science and Plant Nutrition 54 (3), 321–331.
Nelson, D.W., Sommers, L.E., 1996. Total carbon, organic carbon and organic matter, In: Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnson, C.T., Sumner, M.E. (Eds.), Methods of Soil Analysis, Part 3, 3 rd ed. SSSA, Book Ser. No. 5. Madison, Wisconsin. 961–1010 pp.
Oscar, C., 2001. An analysis of externalities in agroforestry systems in the presence of land degradation. Ecological Economics 39, 131–143.
Querejeta, J.I., Roldán, A., Albaladejo, J., Castillo, V., 2000. Soil physical properties and moisture content affected by site preparation in the afforestation of a semiarid rangeland. Soil Science Society of America Journal 64, 2087–2096.

Raffaelli, D., 2004. Ecology: how extinction patterns affect ecosystems. Science 306, 1141–1142.
Rasse, D.P., Smucker, A.J.M., Santos, D., 2000. Alfalfa root shoot mulching effects on soil hydraulic properties and aggregation. Soil Science Society of America Journal 64, 725–731.
Rhoades, J.D., 1996. Salinity: Electrical conductivity and total dissolved salts, In: Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnson, C.T.and Sumner, M.E. (Eds.), Methods of Soil Analysis, Part 3. 3rd ed. SSSA, Book Ser. No. 5, Madison, Wisconsin. 417–435 pp.
Rice, S., Westerman, B., Federici, R., 2004. Impacts of the exotic, nitrogen-fixing black locust (*Robinia pseudoacacia*) on nitrogen-cycling in a pine-oak ecosystem. Plant Ecology 174 (1), 97–107.
Salehi, A., Tabari, M., Mohammadi, J., Ali-Arab, A.R., 2007. Growth of black locust trees irrigated with municipal effluent in gren space of South Tehran. Research Journal of Environmental Sciences 1 (5), 237–243.
Thapa, R., 2003. Agroforestry can reverse land degradation in Nepal. Appropriate Technology 30, 40–41.
Uluocak, N., 1984. Toprak koruması ve yem niteliği bakımından Türkiye'nin önemli doğal otlak bitkileri II Baklagiller. İ.Ü. Orman Fakültesi Yayın No: 358, İstanbul. (in Turkish).
Werner, D., 1992. Physiology of nitrogen-fixing legume nodules: compartments and functions. In: Stacey, G., Burris, R.H., Evans, H.J. (Eds.), Biological nitrogen fixation. Chapman&Hall, New York. 399–431 pp.
Yüksek, T., 2009. Effects of land use management on surface soil properties, erosion indices and green tea yield in humid Blacksea region. Fresenius Environmental Bulletin 18 (No. 5b), 848–857 (FEB).
Yüksek, T., Göl, C., Yüksek, F., Yüksel, E.E., 2009b. The effects of land-use changes on soil properties: the conversion of alder coppice to tea plantations in the humid northern Blacksea region. African Journal of Agricultural Research 4 (7), 665–674.
Yüksek, T., Yüksek, F., Özalp, M., Ölmez, Z., 2009a. Comparing soil protection abilities of caper (Capparis ovata Desf.) and Sainfoin (Onobrychis viciifolia Scop.) in Pamukçular region, Artvin. TOVAG Project Report No: 104O116 (in Turkish).