Evaluation of Artvin- Murgul Black Locust Plantations in Terms of Biomass Production, Carbon Storage, Soil Quality Improvement and Erosion Control Compared to Adjacent Grassland Areas

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Abstract: Black locust plantations in Artvin-Murgul (established in 1996) were investigated for the purposes of: 1) wood production, 2) above- and belowground biomass, 3) carbon storage, 4) soil quality improvement, 5) erosion control and economic value. For these purposes, soil samples were taken from black locust plantation sites and adjacent grassland (control) sites, and soil respiration, soil infiltration, surface runoff, sediment removal, water holding capacity, soil organic matter, texture, pH, N, P, K, Ca, and Mg contents were determined in both areas. Sample trees were cut to determine aboveground biomass and carbon storage. Root samples were taken to determine root biomass and root carbon storage. Surface runoff and erosion were five-fold lower in black locust stands compared to controls (grasslands). Soil quality improvements in black locust areas were not significantly higher than in grasslands. Grasslands had higher soil respiration rates compared to black locust areas. Soil organic matter did not differ significantly between grasslands and black locust areas. Above- and belowground carbon storage were higher in black locust areas than in grasslands.

Keywords: Black locust, root biomass, production, carbon storage, erosion, soil respiration

1. INTRODUCTION

Black locust is one of the important foreign tree species of Turkey. It has been widely used in the reforestation of the semi-dry regions in Turkey. It is native to southeastern North America and now naturalized extensively in the temperate regions of North America, Europe and Asia (Barret et al. 1990). It grows up to 35 m height and 1 m diameter in its native areas, survives droughts and severe winters, and tolerates infertile and acidic soils (Miller et al. 1987). It produces livestock feed nutritionally equivalent to alfalfa (*Medicago sativa* L.) (Baertsche et al. 1986). Black Locust wood is resistance to decay and its flowers attract bees. It also fixes free nitrogen by means of symbiotic bacteria (*Rhizobium sp.*) living in its roots. All of these beneficial characteristics make black locust a perfect species to use in erosion control plantations in Turkey.

The amount of nitrogen added to soil by means of nitrogen fixing bacteria varies from 75 to 200 kg ha^{-1} in black locust stands. This is more than the amount fixed in alder stands (50-150 kg.ha^{-1}) (Brady and Weil 1999). Black locust has a very dense wood with a wood density value of 0.68 gr.cm^{-3} which is well above the mean value of North American trees (0.51 gr cm^{-3}) (Hanover 1993). Its wood has a high heating value (4570 kcal. kg^{-1}) (Duke 1983; Bozkurt 1986).Moreover, it is also a good species for carbon sequestration purposes because of its fast growth in the juvenile phase.

Black locust has been widely used in Artvin for reforestation, wood production and erosion control purposes because of the positive aspects mentioned above. It is also used in reclamation of acid rain-effected sites in Murgul-Artvin. In this study, black locust plantations in Artvin-Murgul (established in 1996) have been investigated for the purposes of: 1) wood production, 2) above- and belowground biomass, 3) carbon storage, 4) soil quality improvement, 5) erosion control, and 6) economic value. To compare the results, adjacent overgrazed grasslands have been taken as control sites. Results of the study will provide valuable data for ecological and economical evaluation of black locust reforestation studies in the region.

2. MATERIAL AND METHODS

The study site is located at Murgul-Artvin, in the northeastern part of Turkey. The elevation of the site is 600 m. and mean slope is between 30 and 60%. Mean annual rainfall is around 1200 mm. Soil type is brown forest soil. Black locust plantations were established in 1996. Twelve sampling sites were chosen both in southern (6 sites) and northern slopes (6 sites) in black locust planted areas and in the adjacent grassland areas as a control. In both the north and south, grassland sites were under heavy grazing. Soil respiration, soil pH, soil organic matter, soil texture, some soil nutrients, surface runoff, sediment removal, biomass and carbon storage properties were determined in each sampling site.

Soil samples were taken from 0-15, 15-30, 30-50 and 50-70 cm soil depths by digging a soil pit in each plot. Soil samples were air-dried, ground and passed through 2 mm mesh-sized sieve. Organic matter contents of the soils were determined according to wet digestion method described by Kalra and Maynard (1991) (modified Walkley-Black method). Soil texture was determined by Bouyoucos` Hydrometer Method described by Gulcur (1974). Soil pH was determined by a combination glass-electrode in H_2O (soil-solution ratio 1: 2.5) (Kalra and Maynard 1991). Soil phosphorus content was determined according to Bray's (dilute acid-fluoride) procedure (Bray and Kurtz 1945; Kalra and Maynard 1991). Exchangeable cations (Na^+,Ca^{++}, Mg^{++}, K^+) were extracted from the neutral ammonium acetate solution and measured by atomic absorption spectrophotometry according to Kacar (1996).

Soil respiration rates were measured approximately monthly in three randomly selected locations in each sampling plot from November 2006 to November 2007 using the soda-lime method (Edwards 1982; Raich et al. 1990). The soda-lime method may underestimate actual soil respiration rates at high flux rates (Ewel et al. 1987; Haynes and Gower 1995). However, the method does distinguish between higher and lower flux rates and, therefore, it is an appropriate method for comparing sites.

Surface runoff was determined in twelve 1.5 x 4.5 m plots. The plots were bordered with a 200-mm galvanized sheet metal forced approximately 100 mm into the soil.Runoff samples were collected after each rainfall event that produced surface runoff. Soil infiltration rate was determined in spring, summer and fall using cylinder infiltrometer method described by the Okatan (1987).

The biomass of fine (0-2 mm) and small (2-5 mm) roots were assessed by collecting six 35-cm deep, 6.4-cm diameter cores per plot in spring and fall (Harris et al. 1977 and Tufekcioglu et al. 2003). Roots were separated from the soil by soaking in water and then gently washing them over a series of sieves with mesh sizes of 2.0 and 0.5 mm. Coarse root biomass was determined by excavation method. Roots were sorted into diameter classes of 0-2 mm (fine root), 2-5 mm (small root) and 5-10 mm (coarse root) root classes. The roots from each size category were oven-dried at 65 °C for 24 h and weighed.

Destructive sampling of the trees was used to develop allometric equations based on height and diameter at breast height (dbh) to estimate aboveground biomass of black locust. Fifteen trees were cut and dry weights of their stems, branches and leaves were determined. Stem, branch and leaf C concentrations were determined on three independently collected samples. Economical value of fuel wood in black locust plantation and planting costs were roughly estimated using current rates of planting costs and fuel wood prices for economic analysis of black locust plantation. Statistical comparisons were made using SPSS.

3. RESULTS AND DISCUSSION

3.1. Soil respiration

Mean soil respiration rates are presented in *Figure 1*. Soil respiration varied significantly with vegetation type. Grassland sites had significantly higher soil respiration than black locust sites ($P<0.001$). Similar results have been observed by Tufekçioğlu et al. (2001 and 2004). Northern slopes had higher soil respiration values compared to southern slopes but the difference wasn't significant. Soil temperature was significantly higher in grassland sites compared to black locust stands.

Higher soil respiration rates in grassland sites were probably due to higher soil temperatures and fine root biomass values in these sites. Soil temperature and fine root biomass are significant determinants of soil respiration in temperate latitudes (Kelting et al. 1998; Tufekcioglu et al. 2001).

3.2. Soil Organic Matter

Mean soil organic matter data are presented in *Figure 2*. Organic matter decreased significantly with soil depth. There were no significant differences in soil organic matter between vegetation types and different aspects.

3.3 Soil pH

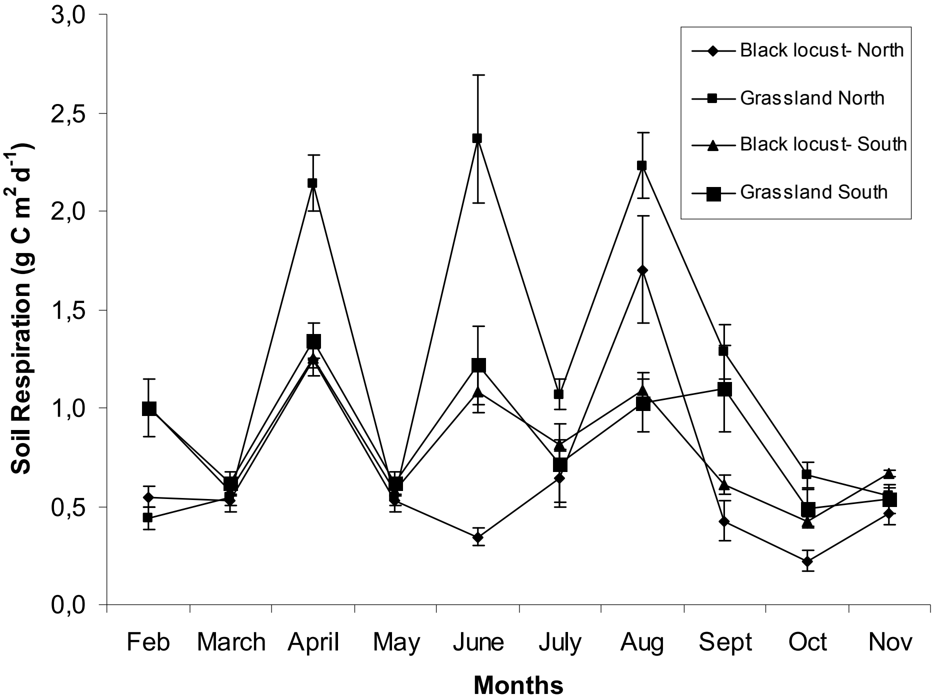
Mean soil pH values are presented in *Figure 3*. Soil pH increased with soil depth. There was a significant difference in pH between northern and southern aspects. There was no significant difference in pH between vegetation types.

3.4. Soil Texture

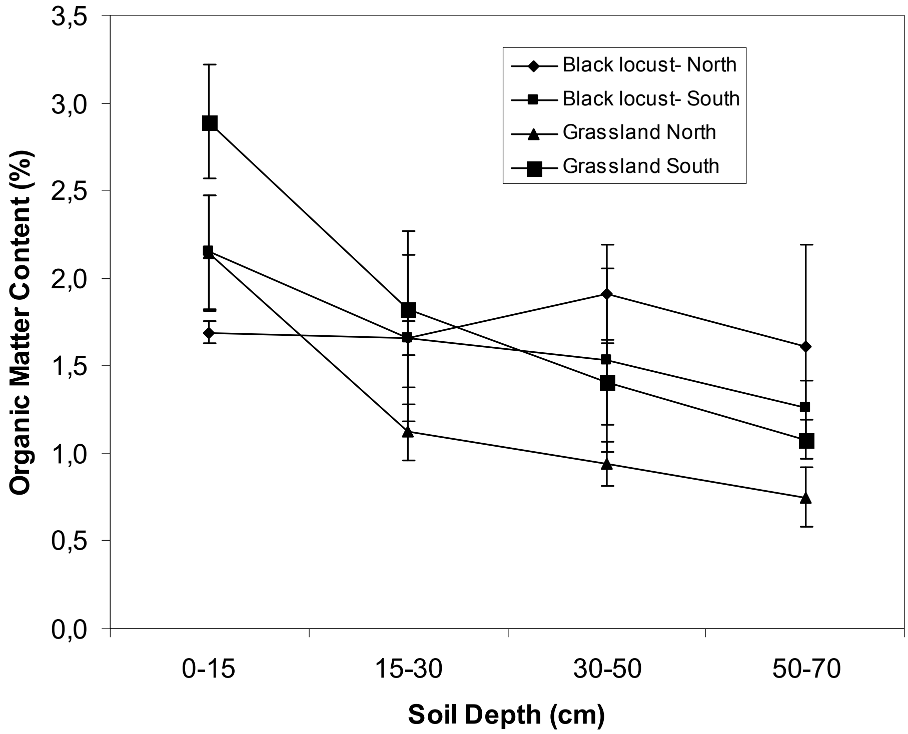
Soil sand content in 0-15 cm soil depth was significantly higher in grassland sites than in black locust sites *(Figures. 4 & 5).* In contrast, clay content was significantly lower in grassland sites compared to black locust sites. This indicates strong clay leaching in grassland sites due to acid rain effect. Soil sand content decreased with soil depth while clay content increased indicating a possible leaching effect of acid rain in the study area (Kalay et al. 1995).

3.5. Soil nutrient contents

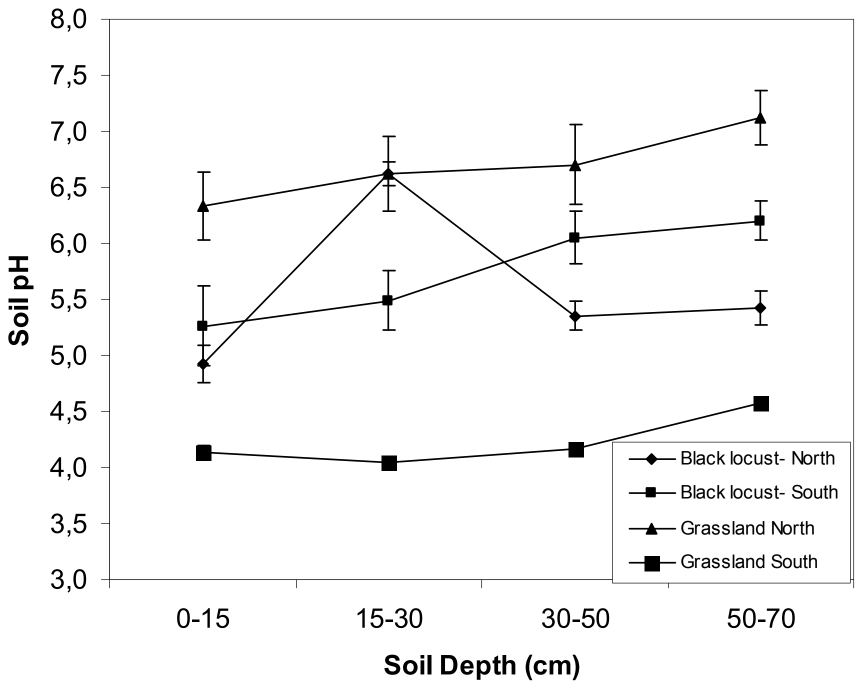
Mean soil N, P, K, Ca and Mg values are recorded in *Table 1*. There was no significant difference in soil N contents between different soil depth classes, vegetation types and aspects. Mean soil phosphorus content was significantly higher in grasslands than in black locust stands. Similarly, it was significantly lower in southern slopes and surface soil



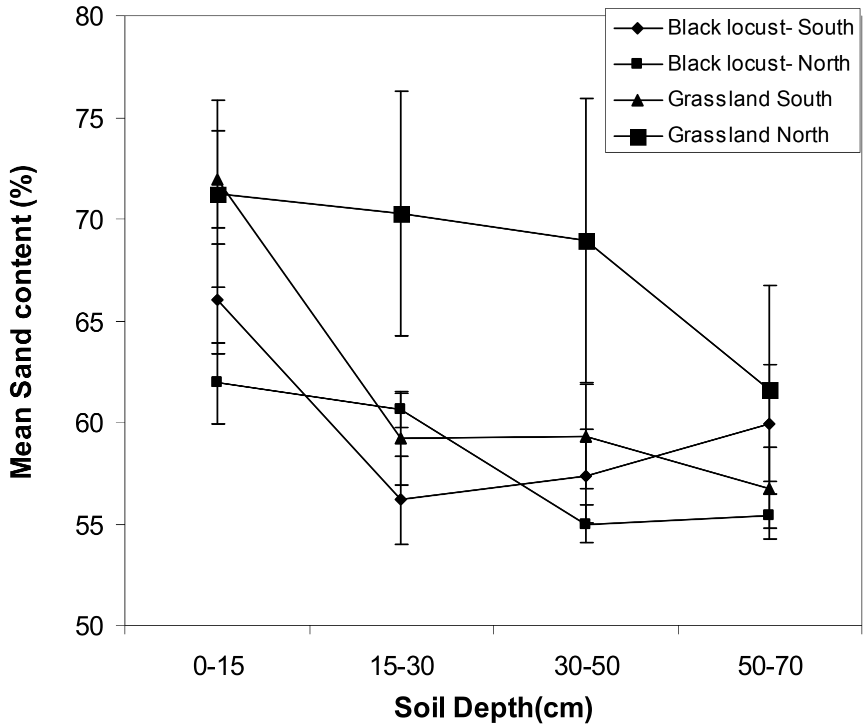
(Figure 1) Soil respiration rates in black locust and grassland sites.



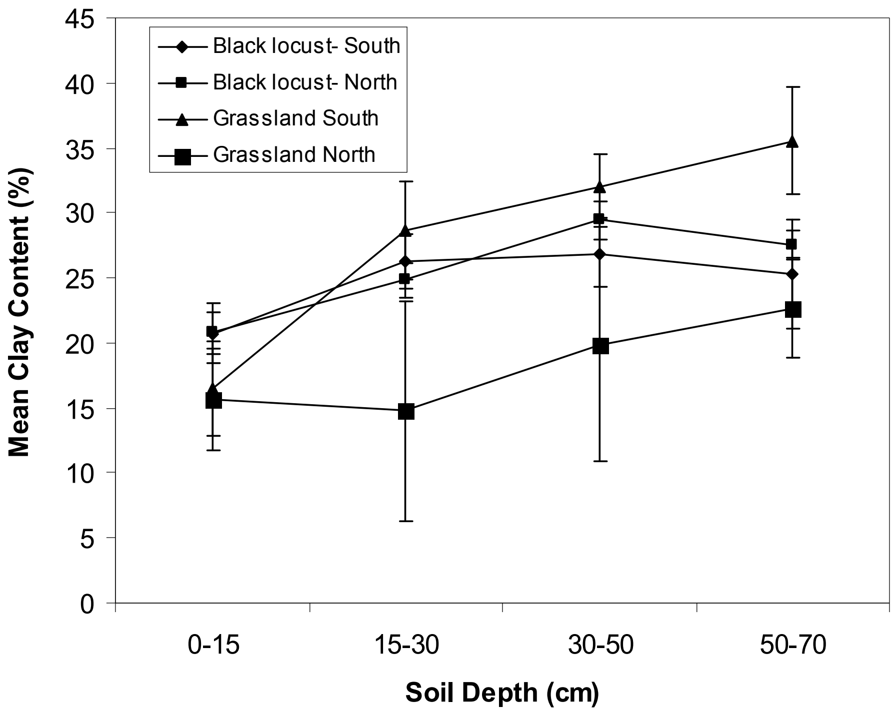
(Figure 2) Soil organic matter contents in black locust and grassland sites.



(*Figure 3) Soil pH in black locust and grassland sites.*



(Figure 4) Soil sand contents in black locust and grassland sites.



(Figure 5) Soil clay contents in black locust and grassland sites.

(Table 1) Soil nutrient concentrations in black locust and grassland sites.

Vegetation types	Depth cm	N (%)	P (%)	Ca (%)	Mg (%)	K (%)
Black locust-South	0-15	0,069	0,035	0,161	0,009	0,009
Black locust-North	0-15	0,133	0,050	0,077	0,008	0,008
Grassland-South	0-15	0,030	0,081	0,010	0,003	0,004
Grassland-North	0-15	0,142	0,026	0,099	0,007	0,009
Black locust-South	15-30	0,057	0,021	0,187	0,010	0,008
Black locust-North	15-30	0,134	0,045	0,141	0,010	0,007
Grassland-South	15-30	0,115	0,057	0,007	0,002	0,006
Grassland-North	15-30	0,188	0,042	0,052	0,005	0,006
Black locust-South	30-50	0,172	0,017	0,275	0,010	0,007
Black locust-North	30-50	0,153	0,033	0,147	0,010	0,006
Grassland-South	30-50	0,140	0,053	0,009	0,003	0,007
Grassland-North	30-50	0,094	0,020	0,118	0,007	0,006
Black locust-South	50-70	0,062	0,025	0,282	0,010	0,006
Black locust-North	50-70	0,119	0,025	0,075	0,008	0,007
Grassland-South	50-70	0,035	0,061	0,018	0,004	0,006
Grassland-North	50-70	0,000	0,014	0,099	0,007	0,006

horizons compared to northern slopes and deeper horizons. Mean soil Ca, Mg and K contents were significantly greater in black locust stands than in grassland sites.

3.6. Infiltration rate

Infiltration rate differed with vegetation type, aspect and sampling time. Black locust sites had greater cumulative infiltration than grasslands sites *(Table 2)*. Infiltration rate was higher in spring and fall than in summer. Higher infiltration rates in black locust sites could be the result of surface litter in black locust stands and soil compaction in grassland sites due to heavy grazing.

3.7. Surface runoff and sediment transport

Mean surface runoff in northern black locust, southern black locust, northern grasslands and southern grasslands sites were 37.7, 25.7, 192.8 and 428 kg/ha, respectively. Mean sediment transport in northern black locust, southern black locust, northern grasslands and southern grasslands sites were 9.6, 11.7, 35.5 and 71.2 kg/ha, respectively. Surface runoff and sediment transport were five-fold greater in grassland sites than in black locust sites. The highest runoff and sediment transport occurred in October and November.

3.8. Aboveground biomass and carbon storage

Total amounts of aboveground biomass and carbon stock in black locust stands were 94738 and 43780 kg ha^{-1}, respectively. Stem, branch and leaf biomass accounted for 74.5, 18.3 and 5.6%, respectively. Mean aboveground biomass in northern and southern slopes were 110 and 79 ton ha^{-1}, respectively. Aboveground biomass in grassland sites were ignored due to heavy grazing.

(Table 2) Infiltartion rate in black locust stands and adjacent grassland sites.

Vegetation type	Cumulative infiltration (cm)			
	Spring	Summer	Fall	Mean
Black locust-South	34.2	30.0	36.3	33.5
Black locust-North	59.3	30.8	45.9	45.3
Grassland-South	31.3	23.9	28.4	27.9
Grassland-North	24.1	15.2	36.0	25.1
Mean	37.2	25.0	36.7	32.9

3.9. Belowground biomass and carbon storage

Total amount of coarse root (>5 mm) biomass and coarse root carbon storage in black locust stands were 4018 and 1591 kg ha^{-1}, respectively *(Table 2)*. Surface 0-20 cm soil depth accounted for 71% of total coarse roots while 20-40 cm soil depths accounted for 22% of it. Small root (2-5 mm) biomass and small root carbon storage were 389 and 159 kg ha^{-1}, respectively.

Fine root (<2 mm) biomass varied with season. Fine root biomass was greater in fall than in spring. Mean fine root biomass in northern and southern black locust and grassland sites were 1471, 1425, 2615 and 1535 kg ha^{-1}, respectively. Fine root production based on maximum-minimum method in northern and southern black locust and grassland sites were 252, 1565, 1680 and 1689 kg ha^{-1}year, respectively. Corresponding annual carbon storage values were 93, 576, 618 and 621 kg ha^{-1}year, respectively.

Mean total amount of biomass and carbon storage in black locust sites were 100.5 and 46.1 Mg ha^{-1}, respectively. Belowground biomass accounted for 5.8% of total biomass in black locust stands.

3.10. Economic analysis of black locust plantation

The economical value of fuel wood in black locust plantation was estimated to be $4300 and planting costs was estimated at $1900 based on current rates of planting costs and fuel wood prices. Taking into account only wood production, black locust plantation provided $1400 of income for the forest service.

4. CONCLUSIONS

Soil respiration was higher in grasslands sites than in black locust sites. This indicates that grassland sites have higher soil biological activity compared to black locust stands. Black locust stands had greater soil infiltration rates compared to grasslands. Surface runoff and sediment transport were five-fold higher in grasslands than in black locust stands. Black locust stands stored a greater amount of carbon in above- and belowground biomass compared to grasslands.

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