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*Full Length Research Paper*

# Land - use type and slope position effects on soil respiration in black locust plantations in Artvin, Turkey

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**In this study, influences of aspect, land-use type, and sampling time on soil respiration were investigated in black locust plantation and adjacent grassland sites in Murgul-Artvin, Turkey. Both sites were heavily affected from acid rain produced by a nearby copper smelter. Soil respiration was measured approximately monthly in three sampling plots in each sites from January 2005 to November 2005 using the soda-lime technique. Mean daily soil respiration ranged from 0.22 to 2.37 g C $m^{-2}$ $d^{-1}$. Mean soil respiration in black locust plantations and grassland sites were 0.74 and 1.03 g C $m^{-2}$ $d^{-1}$, respectively. Soil respiration was significantly higher in grassland sites than in black locust plantation sites. Seasonal changes in soil respiration were related to soil moisture and temperature changes. Mean annual soil respiration rate correlated positively with surface soil (0-15 cm) sand ($P < 0.05$) and organic matter content ($P < 0.1$), and correlated negatively with mean surface soil clay and silt contents ($P < 0.1$). Overall, our results indicate that grassland sites have higher soil biological activity compared to black locust plantation sites.**

**Key words:** Soil biological activity, black locust plantations, grasslands, C cycle, Artvin.

## INTRODUCTION

Increasing atmospheric $CO_2$ concentrations and global climate change have created a strong need for data and information on the global C cycle in terrestrial ecosystems (Tufekcioglu et al., 2009). The rapid increase of carbon dioxide concentration due to fossil fuel burning and ecosystem disturbance is likely to cause large changes in the structure and function of terrestrial ecosystems. In temperate ecosystems, mineral soil and forests account for almost 45% of total ecosystem carbon storage. One of the main pathways of fluxes in the global carbon cycle is soil respiration. Soil respiration is the release of $CO_2$ from soil to the atmosphere. Soils release 75 - 80 Pg of $CO_2$-C to the atmosphere annually by soil respiration (Raich and Potter, 1995). Almost 10% of the atmosphere's $CO_2$ passes through soils each year. This is more than eleven times the current rate of $CO_2$ released from fossil fuel combustion (Raich et al., 2002).

There are two main sources of soil respiration in soils: root respiration and soil microbial respiration (Hanson et al., 2000). Kucera and Kirkham (1971) reported 40% of total soil flux was due to root respiration, Dugas et al. (1999) estimated that 90%, Norman et al. (1992) estimated 15 - 70% and Hanson et al. (1993) estimated 50%. In a review article, Hanson et al. (2000) stated that root/rhizosphere respiration can account for as little as 10% to greater than 90% of total *in situ* soil respiration depending on vegetation type and season of the year. Studies which have integrated percent root contribution to total soil respiration throughout an entire year or growing season show mean values of 45.8 and 60.4% for forest and non forest vegetation, respectively (Hanson et al., 2000). Soil respiration is a sensitive indicator of several essential ecosystem processes, including metabolic activity in soil, persistence and decomposition of plant residue in soil, and conversion of soil organic carbon to atmospheric $CO_2$ (Rochette et al., 1992; Tufekcioglu et al., 2001). In addition, Parkin et al. (1996) stated that soil respiration is a good indicator of soil quality. Soil respiration is strongly influenced by soil moisture and soil temperature (Singh and Gupta, 1977; Raich and Potter, 1995; Raich and Tufekcioglu, 2000). Rochette et al. (1992)

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observed that soil respiration in moist soil was 2 to 3 times greater than that in drier soils. Most researchers also reported an increase in soil respiration with increasing soil temperature (for example, Kowalenko et al., 1978). Soil respiration varies with vegetation type, management practices, environmental conditions and land use type (Raich and Tufekcioglu, 2000; Frank et al., 2006). However, analyzing published soil respiration data, Raich and Tufekcioglu (2000) found no predictable significant ($P < 0.05$) differences in soil respiration between cropped and vegetation-free soils, between grassland and cropped soils or between forested and cropped soils. They did, however, find higher rates of soil respiration in grasslands than in forests and in grasslands and forests than in adjacent croplands. Estimates of soil respiration have been made in a variety of ecosystems and have been summarized in reviews by Schlesinger (1977), Singh and Gupta (1977), Raich and Schlesinger (1992) and Raich and Tufekcioglu (2000). Despite the considerable body of information on soil respiration in different parts of the world, there has been no soil respiration study done in black locust plantation and adjacent grassland ecosystems that heavily effected from acid rain in Turkey (Tufekcioglu and Kucuk, 2004; Tufekcioglu et al., 2006a, 2006b and 2009).

The objectives of this study were to compare rates of soil respiration between sites of black locust and grassland located in northern and southern aspects and to identify the underlying environmental variables most likely causing differences in soil respiration among sites, aspects and among seasons within sites. We hypothesized that grasslands have higher rates of soil biological activity, and therefore higher rates of soil respiration than do adjacent black locust plantation sites.

## MATERIALS AND METHODS

The study site is located at Murgul town in Artvin, Turkey. The site has an elevation of 530 m from sea level and soils at the sites are well drained, sandy loam Inceptisols. Mean annual precipitation is 1010 mm and temperature is 13.5°C. Soil respiration levels were measured both in southern and northern slopes in black locust plantations and adjacent grasslands (controls) (total of 12 sites, 3 replicates per site). Black locust plantations were established by planting in 1996. Dominant grass species in the grassland sites were smooth brome (*Bromus inermis* Leysser.), *Agrostis tenuis* L., timothy (*Phleum pratense* L.), Kentucky bluegrass (*Poa pratensis* L.), *Festuca spp* and *Cynodon dactylon*. Grassland sites were under heavy grazing. Plot sizes were 20 x 20 m.

Soil respiration rates were measured approximately monthly in 3 randomly selected locations in each of the 3 plots per site from January to November using the soda-lime method in 1995 (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. Buckets 20 cm tall and 27.5 cm in diameter were used as measurement chambers. One day prior to measurements, plastic rings with the same diameter were placed over the soil and carefully pushed about 1 cm into the soil. All live plants inside the plastic rings were cut to prevent aboveground plant respiration. Carbon dioxide was absorbed with 60 g of soda-lime contained in 7.8 cm diameter by 5.1 cm tall cylindrical tins. In the field, the plastic rings were removed, measurement chambers were placed over the tins of soda-lime, and the chambers were held tightly against the soil with rocks. After 24 h the tins were removed, and the contents oven dried at 105°C for 24 h and then weighed. Blanks were used to account for carbon dioxide absorption during handling and drying (Raich et al., 1990). Soda-lime weight gain was multiplied by 1.69 to account for water loss (Grogan, 1998).

Soil temperature was measured at a 5 cm soil depth adjacent to each chamber in the morning. Diurnal variations in soil temperature were expected to be smaller at these sites because of shading of sunlight by the plant canopy. Gravimetric soil moisture was determined by taking soil samples at 0 - 5 cm depth and drying them at 105°C for 24 h on the day that the soda-lime tins were removed from the plots.

Soil samples were taken randomly from 0-15 cm and 15-30 cm soil depths by digging a soil pit in each plot in October. Soil samples were air-dried, ground and passed through a 2 mm mesh-sized sieve. Organic matter contents of the soils were determined according to the 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). The biomass of fine (0 - 2 mm) roots was assessed by collecting six 35 cm deep, 6.4 cm diameter cores per plot in October (Harris et al., 1977; Tufekcioglu et al., 1999; 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. 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 then weighed. Statistical comparisons were made using SPSS. We used ANOVA to compare soil respiration rates, soil temperatures, and soil moisture contents among sites. Paired comparisons among sites and sampling dates were determined using the least significant difference test at $\alpha = 0.05$. Step - wise multiple regression analysis was performed to evaluate the importance of soil temperature and soil moisture on seasonal soil respiration rates. The possible effects of soil properties and fine root biomass on soil respiration rates were evaluated with correlation analysis.

## RESULTS AND DISCUSSION

Mean daily soil respiration ranged from 0.22 to 2.37 g C $m^{-2}$ $d^{-1}$ among all sites (Figure 1A). These values are within the ranges reported by Kucera and Kirkham (1971), Coleman (1973), Singh and Gupta (1977), Jurik et al. (1991), Lessard et al. (1994), Hudgens and Yavitt (1997), Raich and Tufekcioglu (2000), Tufekcioglu et al. (2001), Tufekcioglu et al. (2006a), Tufekcioglu et al. (2006b) and Tufekcioglu et al. (2009). Soil respiration differed significantly among sites ($P < 0.01$). Soil respiration was significantly higher in grassland sites than in black locust plantation sites (Table 1). In a review article, Raich and Tufekcioglu (2000) reported that grasslands had ~20% higher soil respiration rates than did comparable forest stands. Higher soil respiration rates in grassland sites were probably due to higher fine

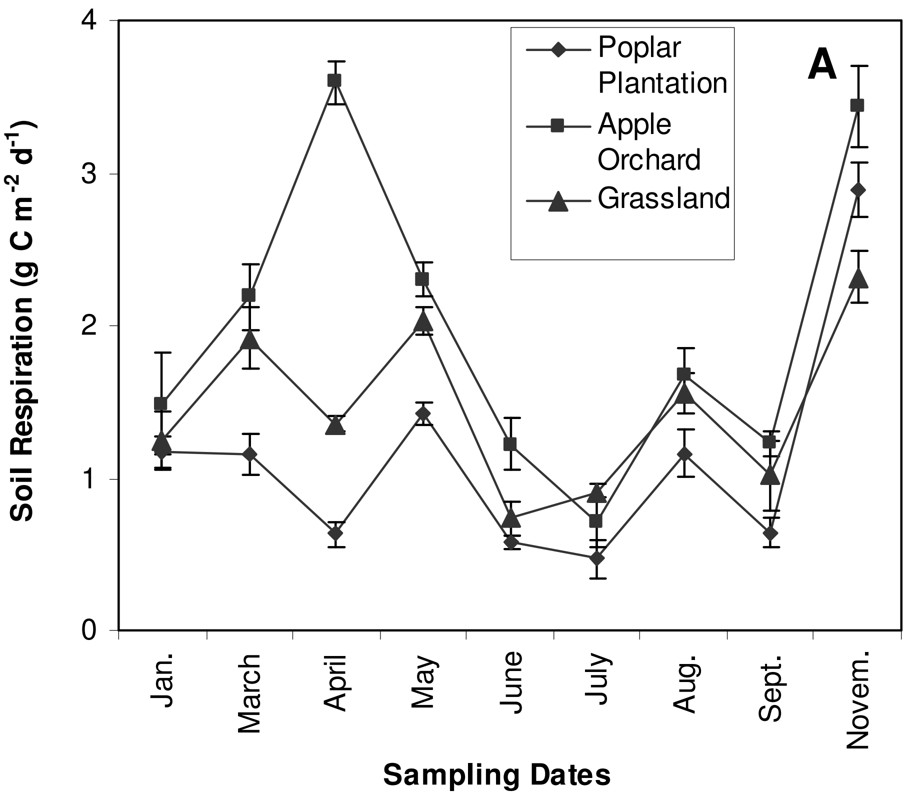


**Figure 1(A).** Mean monthly (± 1 SE) soil respiration rates in black locust plantations and grasslands sites.

**Table 1.** Mean soil respiration, soil temperature, soil moisture, soil organic mater, soil sand, clay and silt content, pH and root biomass in the four sites investigated in this study (n = 3 plots per site). Root data refer to the surface 35 cm of soil.

| Vegetation type | Black locust plantations | | Grassland sites | |
|---|---|---|---|---|
| | South | North | South | North |
| Mean soil respiration ( g C $m^{-2}$ $d^{-1}$) | 0.81 | 0.66 | 0.87 | 1.18 |
| Mean soil moisture (%) | 21.5 | 16.4 | 23.3 | 13.3 |
| Mean soil temperature ($^{o}$C) | 14.4 | 13.5 | 17.6 | 15.9 |
| | | | | |
| Mean soil organic matter (%) | | | | |
| 0-15 cm | 2.15 | 1.69 | 2.81 | 2.14 |
| 15-35 cm | 1.66 | 1.61 | 1.82 | 1.09 |
| | | | | |
| Mean sand content (%) | | | | |
| 0-15 cm | 62.7 | 61.3 | 67.0 | 71.2 |
| 15-35 cm | 57.2 | 59.5 | 59.1 | 63.5 |
| | | | | |
| Mean clay content (%) | | | | |
| 0-15 cm | 21.9 | 20.8 | 19.2 | 15.6 |
| 15-35 cm | 25.5 | 23.9 | 28.7 | 20.5 |
| | | | | |
| Mean soil pH | | | | |
| 0-15 cm | 5.26 | 4.92 | 4.14 | 6.33 |
| 15-35 cm | 5.49 | 4.84 | 4.05 | 6.70 |
| Mean fine root biomass (<2 mm) ( g $m^{-2}$) | 1425 | 1534 | 1471 | 2615 |

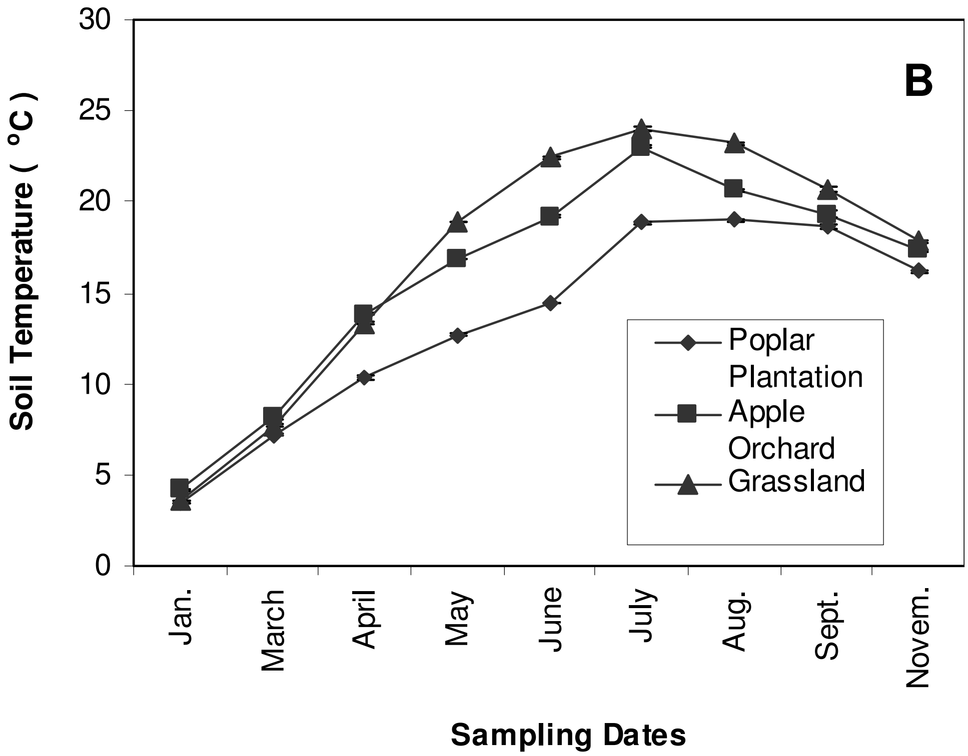


**Figure 1(B).** Mean monthly soil temperature in black locust plantations and grasslands sites.

root biomass and higher soil temperature values in spring and fall. Both soil temperature and fine root biomass are significant determinants of soil respiration in temperate latitudes (Kelting et al., 1998; Raich and Tufekcioglu, 2000; Tufekcioglu et al., 2001; Tufekcioglu and Kucuk, 2004). In a review article, Hanson et al. (2000) stated that root/rhizosphere respiration can account for as little as 10 percent to greater than 90% of total in situ soil respiration depending on vegetation type and season of the year.

Soil respiration differed significantly with sampling time ($P < 0.01$). The highest rates were observed in spring and summer when the soil temperature was relatively high. The lowest rates were observed during fall and winter when the soil temperature was relatively low (Figure 1B and 2). This pattern corresponded well with the annual patterns of temperature in temperate latitudes (Raich and Tufekcioglu, 2000; Tufekcioglu et al., 2001). Similarly, Kowalenko et al. (1978) reported that temperature was limiting during the winter and spring and that moisture was limiting during the summer and fall on soil respiration in field soils in Canada. Soil temperature varied significantly among sites and sampling dates ($P < 0.01$) (Figure 1). Mean soil temperatures were 14.0 and 16.7 in black locust and grassland sites, respectively. Soil temperatures in grassland sites were significantly higher than in the poplar sites ($P<0.05$) (Table 1). Southern slopes had significantly higher temperatures than northern slopes had ($P<0.05$). Soil moisture content differed significantly between slopes and sampling dates. Northern sites had significantly higher soil moisture content than southern sites had. There were no significant soil moisture differences between black locust and grassland sites. Overall soil moisture contents were significantly higher in northern slopes than in southern slopes. Within sites, seasonal changes in soil respiration were correlated most highly with soil moisture. When all sites were considered together, mean daily soil respiration varied with soil temperature and moisture ($r^2 = 0.15$, $P < 0.05$):

$$SR= 0.21\ M +0.035\ T - 0.046$$

Where SR is the soil respiration rate (g C $m^{-2}$ $d^{-1}$), T is morning surface-soil (0 - 5 cm depth) temperature (°C) and M is surface-soil (0 - 5 cm depth) gravimetric moisture content (% $H_2O$). All three parameters were significant ($P < 0.01$). Among sites, mean annual soil respiration rate correlated positively with surface soil (0 - 15 cm) sand ($P < 0.05$) and organic matter content ($P < 0.1$), and correlated negatively with mean surface soil clay and silt contents ($P < 0.1$). Soil respiration and soil sand content were positively correlated, suggesting that high soil temperatures were associated with sandy soils (Kantarci, 2000). Negative correlations with soil clay and silt contents indicate poor soil aeration due to high clay contents in soil. Similar results have been observed by Tufekcioglu et al. (2009) in the same region. For summary comparisons, annual soil respiration rates were

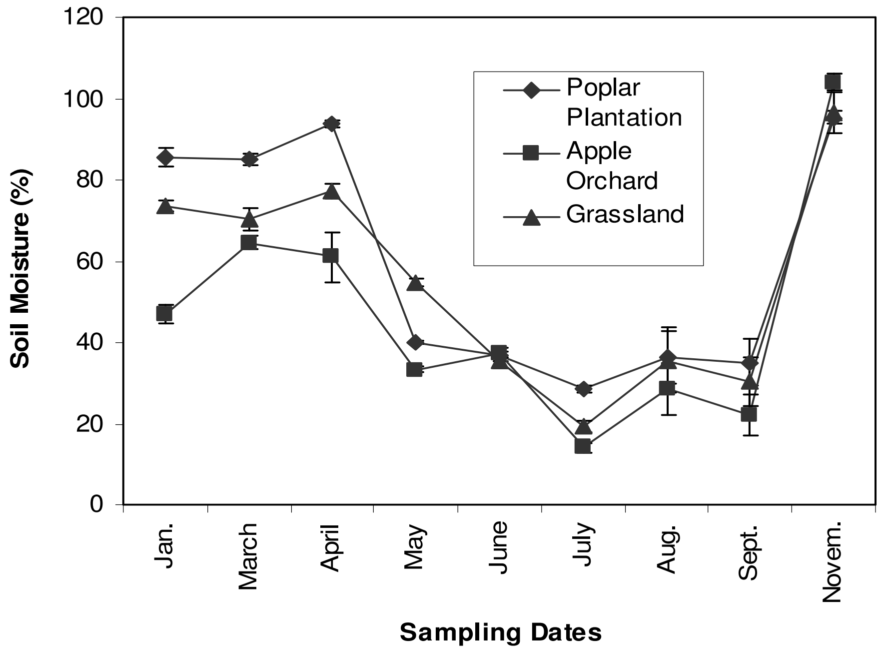


**Figure 2.** Mean monthly (± 1 SE) soil moisture contents (0-5 cm depth) in black locust plantations and grasslands sites.

estimated by calculating the average soil respiration rate per month over the duration of the study and assuming December and February respiration equaled the averages of the months before and after them. Annual soil respiration totaled 389 g C $m^{-2}$ for grassland-north, 312 g C $m^{-2}$ for grassland-south, 299 g C $m^{-2}$ for black locust-south, and 234 g C $m^{-2}$ for black locust-north sites. Annual carbon release values found in this study (234-389 g C $m^{-2}$ $y^{-1}$) are generally lower than the values reported by the others. Our black locust plantation values were lower than those found in poplar plantations in Iowa, USA (1140 g C $m^{-2}$) (Tufekcioglu et al., 2001) and in Florida (845 g C $m^{-2}$) (Lee and Jose, 2003). Our grassland values were lower than those found in riparian grasslands in Iowa (1185 g C $m^{-2}$) (Tufekcioglu et al., 2001), in Artvin-Turkey (Tufekcioglu et al., 2009) (452-732 g C $m^{-2}$) and in tall grass prairie by Risser et al. (1981) (660 g C $m^{-2}$ $y^{-1}$), and Buyanovsky et al. (1987) (490 g C $m^{-2}$ $y^{-1}$), who also used static, closed chamber techniques. Rates in prairie ecosystems measured with dynamic IRGA-based systems include 450 g C $m^{-2}$ $y^{-1}$ in Missouri (Kucera and Kirkham, 1971), 720 g C $m^{-2}$ $y^{-1}$ in Wisconsin (Wagai et al., 1998), and 1100-2100 g C $m^{-2}$ $y^{-1}$ in Kansas (Bremer et al., 1998; Knapp et al., 1998).

In this study, grasslands had higher rates of soil respiration than did adjacent black locust plantations. These higher rates of soil respiration are evidence of the high rates of biological activity and C cycling through the soil in grassland sites compared to black locust sites. Seasonal changes in soil respiration were significantly correlated with soil moisture. Our results indicated that temperature was limiting during the winter and spring (cold and moist) and moisture was limiting during the summer as was typical under Mediterranean climate.

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