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Soil properties and root biomass responses to prescribed burning in young corsican pine (*Pinus nigra Arn.*) stands

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Abstract: *Fire is an important tool in the management of forest ecosystems. Although both prescribed and wildland fires are common in Turkey, few studies have addressed the influence of such disturbances on soil properties and root biomass dynamics. In this study, soil properties and root biomass responses to prescribed fire were investigated in 25-year-old corsican pine (Pinus nigra Arn.) stands in Kastamonu, Turkey. The stands were established by planting and were subjected to prescribed burning in July, 2003. Soil respiration rates were determined every two months using soda-lime method over a two- year period. Fine (0-2 mm diameter) and small root (2-5 mm diameter) biomass were sampled approximately bimonthly using sequential coring method. Mean daily soil respiration ranged from 0.65 to 2.19 g C m^{-2} d^{-1} among all sites. Soil respiration rates were significantly higher in burned sites than in controls. Soil respiration rates were correlated significantly with soil moisture and soil temperature. Fine root biomass was significantly lower in burned sites than in control sites. Mean fine root biomass values were 4940 kg ha^{-1} for burned and 5450 kg ha^{-1} for control sites. Soil pH was significantly higher in burned sites than in control sites in 15-35 cm soil depth. Soil organic matter content did not differ significantly between control and burned sites. Our results indicate that, depending on site conditions, fire could be used successfully as a tool in the management of forest stands in the study area.*

Key words: *Forest fire, Root biomass, Soil respiration, Soil properties*
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Introduction

Global temperature rises have increased the frequency and intensity of forest fires (Neary *et al*., 1999). A potential climate warming may seriously affect Turkey, especially the semi-arid regions of the country, such as central and south-eastern Turkey. According to ReGCM3 climate prediction model, mean annual temperatures could rise 3-6°C in next century in the western part and 2-4 °C in the eastern part of the Turkey (Anonymous, 2007). This will cause significant increases in the number of forest fires in the country in the future.

Fire changes biomass and nutrient dynamics of forest ecosystems. The process of burning not only helps increase the decomposition of organic matters but also causes the plant nutrients bound to vegetation and organic dead material to get into soil and inflicts changes on the biological, physical and chemical properties of soil (Debano *et al*., 1998; Certini, 2005). Fire acts as a rapid mineralizing agent that releases nutrients instantaneously as contrasted to natural decomposition processes, which may require years or, in some cases, decades (Debano *et al*., 1998). Changes taken place in soils and their status over time are extremely important for the success of the vegetation that will establish on the site after fire. Some of these changes are: increases in soil pH, dead root biomass, soil biological activity and availability of some cations and, decrease in soil organic matter content (Debano *et al*., 1998; Tufekcioglu *et al*., 1999; Altun *et al*., 2004).

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Soil respiration plays an important role in carbon (C) cycling in forest ecosystems, comprising approximately 49-55% of gross primary production (Raich and Tufekcioglu, 2000). The main components of soil respiration include root respiration (autotrophic) and microbial respiration (heterotrophic) (Hanson *et al*., 2000; Kulkarni *et al*., 2007). The contribution of root respiration to soil respiration depends on plant phenology, nitrogen content and mycorrhizal association (Hanson *et al*., 2000; McCarthy and Brown, 2006). Microbial respiration primarily depends on the availability of substrate and community composition (Raich and Tufekcioglu, 2000; McCarthy and Brown, 2006). Both components are affected by temperature, moisture, and soil physical and chemical properties (McCarthy and Brown, 2006).

Fire effects on forest soils and fertility have been studied intensively in the different parts of the world, but there hasn't been much work done in Turkey (Altun *et al*., 2004; Neyisci, 1989). Similarly, there are no studies done on how fire influence root biomass and soil respiration dynamics in forest ecosystems in Turkey. However, both soil respiration and root dynamics are important components of nutrient cycles in forest ecosystems. Also, 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*., 1997). In addition, Parkin *et al*. (1996) stated that soil respiration is a good indicator of soil quality.

The objectives of this study were to compare soil respiration rates, root biomass and some soil properties (pH and organic matter) in burned and unburned stands of Corsican pine (*Pinus nigra* Arn.) and identify the underlying environmental variables most likely causing differences in measured variables.

Materials and Methods

The study site is located at Merkez Forest District area in Kastamonu, Turkey. The elevation of the site is 1050 m from the sea level and mean slope is 10%. Mean annual rainfall is 597 mm and mean annual temperature is 8.5°C. Soil type is brown forest soil. The study area has a continental climate type with cold winters and dry summers (Anonymous, 1990).

The study was done in young (25 years old) corsican pine stands established by planting. The stands were burned in July, 2003. First soil samples were taken from both control (3 sites) and burned sites (3 sites). After that, samples were taken in every two to three months for two years (no sample taken during winter due to snow coverage). Soil samples were taken randomly from 0-15 cm and 15-35 cm soil depths by digging four soil pits in each plot in each sampling time. Soil samples were air-dried, ground and pass 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). Soil pH was determined by a combination glass-electrode in H_2O (soil-solution ratio 1: 2.5) (Gulcur, 1974).

The biomass of fine (0-2 mm) and small (2-5 mm) roots was assessed by collecting six 35-cm deep, 6.4-cm diameter cores per plot in every two to three months for two years (Harris *et al*., 1977; 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 hr and weighed.

Soil respiration rates were measured approximately bimonthly in three randomly selected locations in each of the three plots per sites using the soda-lime method (Edwards, 1982; Raich *et al*., 1990; Tufekcioglu *et al*., 2009). 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 hr the tins were removed, oven dried at 105° C for 24 hr, and 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 5 cm soil depth adjacent to each chamber in the morning. Gravimetric soil moisture was determined by taking soil samples at 0-5 cm depth and drying them at 105°C for 24 hr on the day that the soda-lime tins were removed from the plots.

Statistical comparisons were made using SPSS program. We used ANOVA to compare soil respiration rates, soil temperatures, soil moisture contents, root biomass, soil organic matter and soil pH in burned and unburned sites. Differences between specific sampling dates were determined with a least significant difference test at α=0.05. The possible effects of soil temperature and soil moisture on soil respiration rates were evaluated with correlation analysis.

Results and Discussion

Mean daily soil respiration ranged from 0.65 to 2.19 g C m^{-2} d^{-1} among all sites (Fig. 1A). These values are within the ranges reported by Jurik *et al.* (1991); Lessard *et al.* (1994), Hudgens and

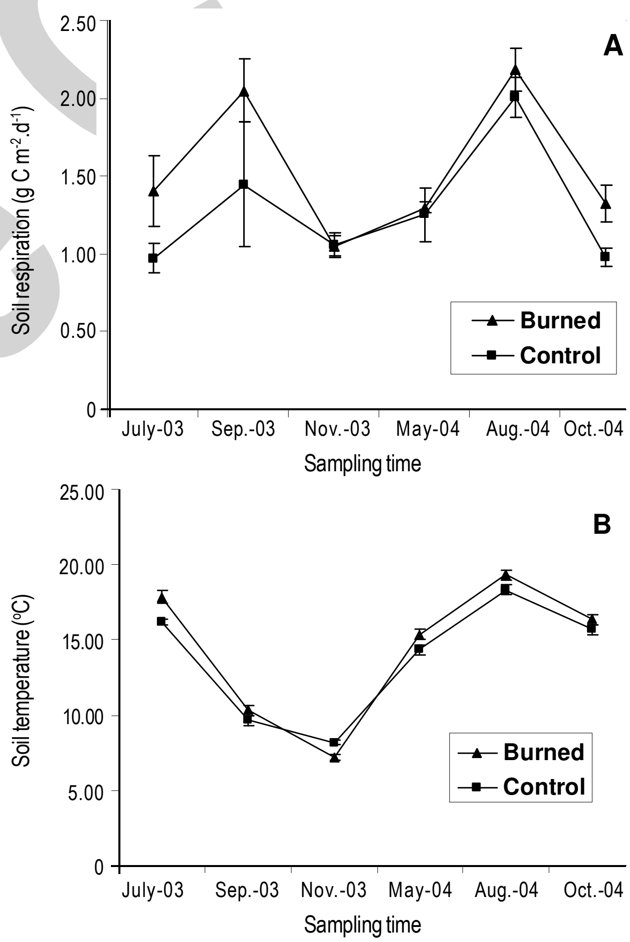

Fig. 1: Soil respiration (A) and soil temperature (B) in burned and control sites

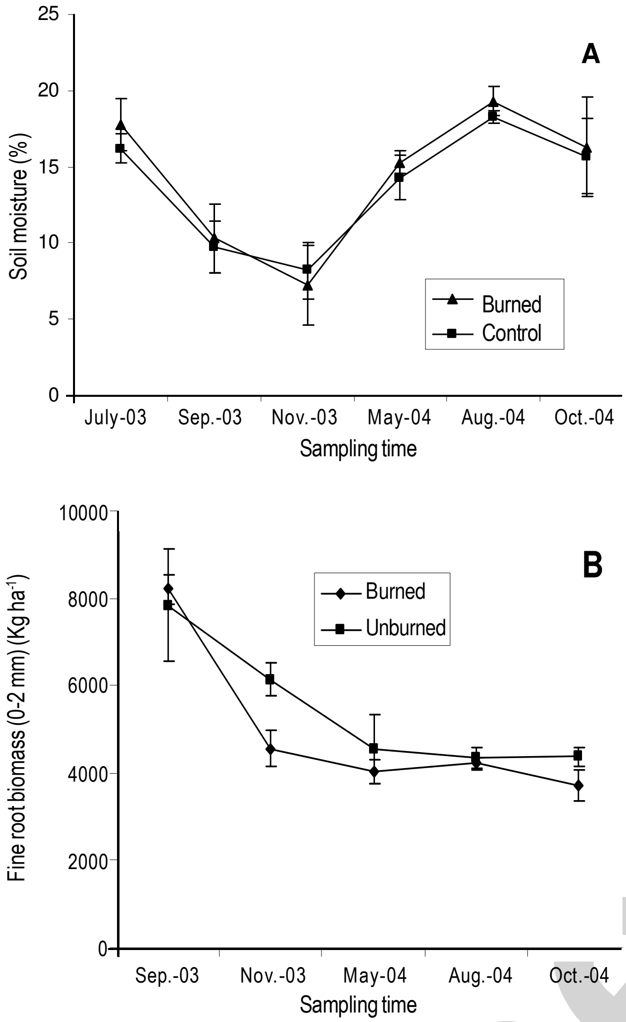

Fig. 2: Soil moisture contents (A) and fine root biomass (B) in burned and control sites

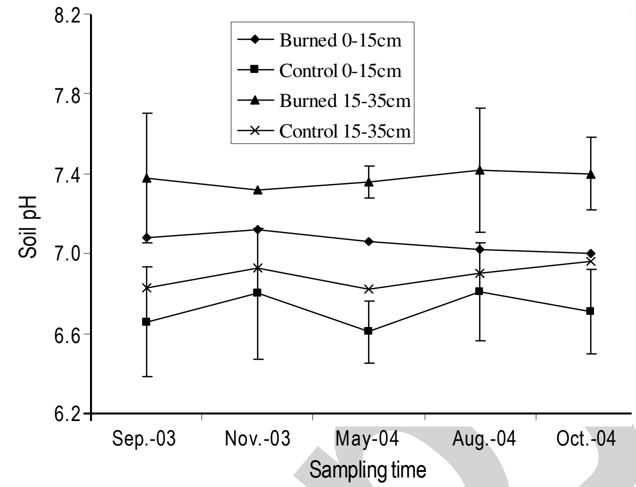

Fig. 3: Soil pH in burned and control sites. Error bars of control 15-35 cm and burned 0-15cm soil depths haven't been put to improve clarity in the figure

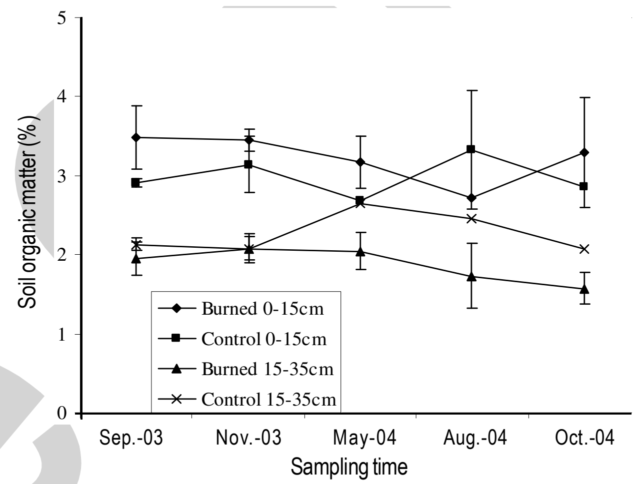

Fig. 4: Soil organic matter content in burned and control sites. Some of the error bars haven't been put to improve clarity of the figure

Yavitt (1997), Tufekcioglu *et al.* (2001), Tufekcioglu and Kucuk (2004). Highest rates were observed in August and September when soil temperatures were high, while lowest rates were observed in November when soil temperatures were minimal (Fig. 1B). Soil respiration increased from spring to summer and decreased from summer to fall, as is typical in temperate latitudes (Kowalenko *et al.*, 1978; Hudgens and Yavitt, 1997). Our results indicated that temperature was limiting during the fall and spring and moisture was limiting during the summer and fall. Kowalenko *et al.* (1978) reported that temperature was limiting during the winter and spring and moisture was limiting during the summer or fall on soil respiration in field soils in Canada.

Soil respiration varied significantly between burned and controls sites (p<0.01). Soil respiration rates were significantly higher in burned sites than in controls (Fig. 1A). Similar results were reported by Schuur and Trumbore (2001) and Wütrich *et al*. (2002). Decomposition of dead roots, increased input of some nutrients by ash and relatively higher soil temperatures, soil moistures and soil pH rates in burned sites could be the reasons behind these higher rates.

There were significant differences in soil respiration among sampling dates. Soil respiration increased from May to August in all sites and it decreased from August to October. These differences in temporal patterns of soil respiration were probably driven by soil moisture and temperature differences among sites.

Soil temperature and soil moisture content differed significantly among sampling dates (p<0.01) (Fig. 1B, 2A). There were no significant soil temperature and soil moisture differences among sites.

Within sites, seasonal changes in soil respiration were correlated most highly with soil temperature. When all sites were considered together, mean daily soil respiration positively correlated with soil temperature (r = 0.28, p<0.001).

Fine root biomass varied significantly between burned and control sites (p<0.02) (Fig. 2B). Fine root biomass was significantly lower in burned sites except in September. Mean fine root biomass values were 4940 kg ha^{-1} for burned and 5450 kg ha^{-1} for control sites. Burning probably increased the mortality of live roots and the decomposition of dead roots. Tufekcioglu *et al.* (1999) reported higher dead root biomass in burned prairie sites than in unburned sites. Fine root biomass differed significantly among sampling times ($p<0.01$). Peak values of fine root biomass were observed in September. Fine root biomass in September significantly differed from the other sampling times. There was no significant difference in small root biomass between control and burned sites. Mean small root biomass was 1730 kg ha^{-1} in burned sites and 1820 kg ha^{-1} in control sites.

Soil pH differed significantly between burned and control sites in 15-35 cm soil depth (Fig. 3). Soil pH was significantly higher in burned sites than in control sites in 15-35 cm soil depth. Similar results were observed by Ubeda *et al.* (2005), Altun *et al.* (2004), Mitros *et al.* (2002), Ulery *et al.* (1993), Neal *et al.* (1965). There was no significant difference in pH between control and burned sites in 0-15 cm soil depth.

Soil organic matter content did not differ significantly between control and burned sites (Fig. 4). Mean soil organic matter contents were 3.22% for burned and 2.98% for control sites in 0-15 cm soil depth. For 15-35 cm soil depth, mean soil organic matter contents were 1.87% for burned and 2.27% for control sites. Analyzing data from 48 observations, Johnson and Curtis (2001) found a positive long-term effect of forest fires on the content of soil organic carbon. The authors suggested four reasons for this increase: (1) the incorporation in the mineral soil of unburnt residues that, consequently, are more protected from biochemical decomposition, (2) the transformation of fresh organic materials to more recalcitrant forms, (3) the frequent entrance in the burnt areas of N-fixer species and (4) the decline of the mineralisation rate. Our mean surface soil organic matter results were consistent with this finding.

For summary comparisons, annual soil respiration rates were estimated by calculating the average soil respiration rate per month over the duration of the study and assuming January and February respiration equaled the average of the March and December rates. Annual soil respiration totaled 435 g C m^{-2} for burned and 377 g C m^{-2} for control sites. Annual carbon release values found in this study are within the ranges reported by others for grassland ecosystems. Our values were close to those observed by Risser *et al.* (1981) (660 g C m^{-2} y^{-1}), Kucera and Kirkham (1971) (450 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.

In conclusion, prescribed fire has altered root dynamics and soil properties in young corsican pine stands. Burned sites had lower fine root biomass compared to unburned sites. Soil respiration and soil pH (in 15-35 cm soil depth) were significantly higher in burned sites compared to control sites. Higher rates of soil respiration and lower fine root biomass in burned stands suggest that fire has improved soil biological activity in burned stands compared to control stands. From soil biological point of view, our results indicate that fire could be successfully used in the management of these forest stands.

References

Altun, L., E. Bilgili, B. Saglam, O. Kucuk, M. Yilmaz and A. Tufekcioglu: Soil organic matter, soil pH and soil nutrient dynamics in forest stands after fire. *In*: Proceedings Book of International Soil Congress (ISC) on "*Natural Resource Management for Sustainable Development*", June 7-10, 2004, Erzurum/Turkey. pp. 67-73 (2004).

Anonymous: Annual Report of General Directorate of Meteorology. Report No. 135, Ankara, Turkey (1990).

Anonymous: UNDP Turkey Report on Climate Change and Turkey: Impacts, Sectoral Analyses, Socio-Economic Dimensions. UNDP Turkish Branch Publications, Ankara, Turkey (2007).

Buyanovsky, G.A., C.L. Kucera and G.H. Wagner: Comparative analyses of carbon dynamics in native and cultivated ecosystems. *Ecology*, **68**, 2023-2031 (1987).

Certini, G.: Effects of fire on properties of forest soils: A review. *Oecologia*, **143**, 1-10 (2005).

Debano, L.F., D.G. Neary and P.F. Ffolliot: Fire Effects on Ecosystems. Wiley, New York, USA (1998).

Edwards, N.T.: The use of soda-lime for measuring respiration rates in terrestrial systems. *Pedobiol.*, **23**, 321-330 (1982).

Ewel, K.C., W.C. Cropper and H.L. Gholz: Soil CO_2 evolution in Florida slash pine plantations. I. Changes through time. *Can. J. For. Res.*, **17**, 325-329 (1987).

Grogan, P.: CO_2 flux measurement using soda-lime: Correction for water formed during CO_2 adsorption. *Ecology*, **79**, 1467-1468 (1998).

Gulcur, F.: Physical and Chemical Analyzing Methods of Soil. Istanbul.Unvs. Publications, Pub. No: 201, Istanbul, Turkey (1974).

Hanson, P.J., N.T. Edwards, C.T. Garten and J.A. Andrews: Separating root and soil microbial contributions to soil respiration: A review of methods and observations. *Biogeochem.*, **48**, 115-146 (2000).

Harris, W.F., R.S. Kinerson and N.T. Edwards: Comparison of belowground biomass of natural deciduous forest and Loblolly pine plantations. *In*: The belowground ecosystem: A Synthesis of Plant-Associated Processes (*Ed.*: J.K. Marshall). Range Science Department, Science Series No: 26, Fort Collins, Colorado, USA. pp. 27-29 (1977).

Haynes, B.E. and S.T. Gower: Belowground carbon allocation in unfertilized and fertilized red pine plantations in northern Wisconsin. *Tree Physiol.*, **15**, 317-325 (1995).

Hudgens, D.E. and J.B. Yavitt: Land-use effects on soil methane and carbon dioxide fluxes in forest near Ithaca, New York. *Ecosci.*, **4**, 214-222 (1997).

Johnson, D.W. and P.S. Curtis: Effects of forest management on soil C and N storage: Metal analysis. *For. Ecol. Manage.*, **140**, 227-238 (2001).

Jurik, T.W., G.M. Briggs and D.M. Gates: Soil respiration of five aspen stands in Northern Lower Michigan. *Am. Mid. Nat.*, **126**, 68-75 (1991).

Kalra, Y.P. and D.G. Maynard: Methods Manual for Forest Soil and Plant Analysis. Forestry Canada, Northern Forestry Publications. Alberta, Canada (1991).

Kowalenko, C.G., K.C. Ivarson and D.R. Cameron: Effect of moisture content, temperature and nitrogen fertilization on carbon dioxide evolution from field soils. *Soil Biol. Biochem.*, **10**, 417-423 (1978).

Kucera, C.L. and D.R. Kirkham: Soil respiration studies in tallgrass prairie in Missouri. *Ecology*, **52**, 912-915 (1971).

Kulkarni, N.S., J.V. Jaiswal and M.G. Bodhankar: Influence of agro-waste amendment on soil microbial population in relation to plant growth response. *J. Environ. Biol.*, **28**, 623-626 (2007).

Lessard, R., P. Rochette, E. Topp, E. Pattey, R.L. Desjardins and G. Beaumon: Methane and carbon dioxide fluxes from poorly drained adjacent cultivated and forest sites. *Can. J. Soil Sci.*, **74**, 139-146 (1994).

McCarthy, D.R. and K.J. Brown: Soil respiration responses to topography, canopy cover, and prescribed burning in an oak-hickory forest in southeastern Ohio. *For. Ecol. Manage.*, **237**, 94-102 (2006).

Mitros, C., S. Mcintyre and B. Moscato-goodpaster: Annual burning affects soil pH and total nitrogen content in the cera oak woodlands. *Tillers*, **3**, 29-32 (2002).

Neal, J., L. Wright and W.B. Bollen: Burning Douglas – Fir slash; physical, chemical and microbial effects in the soil. Forest Research Laboratory, Research Paper No. 1 Oregon State University Corvallis-USA (1965).

Neary, D.G., C.C. Klopatek, L.F. DeBano and P.F. Ffolliott: Fire effects on belowground sustainability: A review and synthesis. *For. Ecol. Manage.*, **122**, 51-71 (1999).

Neyisci, T.: Influence of prescribed burning on soil properties and seedling growth in brutian pine stands. Forest Research Institute Publications, Technical Bulletin, No: 205, Ankara. p. 56 (1989).

Parkin, T.B., J.W. Doran and E. Franco-Wizcaino: Field and laboratory tests of soil respiration. *In*: Methods for assessing soil quality (*Eds.*: J.W. Doran and A.J. Jones). Soil Science Society of America special publication no 49, Madison, Wisconsin, USA (1996).

Raich, J.W., R.D. Bowden and P.A. Steudler: Comparison of two static chamber techniques for determining carbon dioxide efflux from forest soils. *Soil Sci. Soc. Am. J.*, **54**, 1754-1757 (1990).

Raich, J.W. and A. Tufekcioglu: Vegetation and soil respiration: Correlations and controls. *Biogeochem.*, **48**, 71-90 (2000).

Risser, P.G., E.G. Birney, H.D. Blocker, S.W. May, W.J. Parton and J.A. Wiens: The True Prairie Ecosystem. US/IBP Synthesis Series, 16, 155-187. Hutchison Ross Publishing Company. Stroudsburg/ Pennsylvania, USA (1981).

Rochette P., B. Ellert, E.G. Gregorich, R. Desjardins, L. Pattey, E.R. Lessard and B.G. Johnson: Description of a dynamic closed chamber for measuring soil respiration and its comparison with other techniques. *Can. J. Soil Sci.*, **77**, 195-203 (1997).

Schuur, E. and S. Trumbore: The radiocarbon signature of soil respiration following fire in Alaskan Boreal Forest: Does disturbance release old soil carbon to the atmosphere? Ecosystem Ecology, ESA 2001 Annual Meeting (2001).

Tufekcioglu, A., J.W. Raich, T.M. Isenhart and R.C. Schultz: Fine root dynamics, coarse root biomass, root distribution and soil respiration in a multi-species riparian buffer. *Agrofor. Sys.*, **44**, 163-174 (1999).

Tufekcioglu, A., J.W. Raich, T.M. Isenhart and R.C. Schultz: Soil respiration within riparian buffers and adjacent crop fields. *Plant Soil*, **229**, 117-124 (2001).

Tufekcioglu, A., J.W. Raich, T.M. Isenhart and R.C. Schultz: Biomass, carbon and nitrogen dynamics of multi-species riparian buffers within an agricultural watershed in Iowa, USA. *Agrofor. Sys.*, **57**, 187-198 (2003).

Tufekcioglu, A. and M. Kucuk: Soil respiration in young and old oriental spruce stands and in adjacent grasslands in Artvin/Turkiye. *Turk. J. Agric. For.*, **28**, 429-434 (2004).

Tufekcioglu, A., A.K. Ozbayram and M. Kucuk: Soil respiration in apple orchards, poplar plantations and adjacent grasslands in Artvin, Turkey. *J. Environ. Biol.*, **30**, 815-820 (2009).

Ubeda, X., M. Lorca, L.R. Outeiro, S. Bernia and M. Castellnou: Effects of prescribed fire on soil quality in mediterranean grassland (Prades Mountains, North-east Spain). *Int. J. Wildland Fire*, **14**, 379-384 (2005).

Ulery, A.L., R.C. Graham and C. Amrhein: Wood-ash composition and soil pH following intense burning. *Soil Sci.*, **156**, 358-364 (1993).

Wutrich, C., D. Schaub, M. Weber, P. Marxer and M. Condera: Soil respiration and soil microbial biomass after fire in a sweet chestnut forest in southern Switzerland. *Catena*, **48**, 201-215 (2002).