



## Change of Soil Respiration among Different Vegetations- Results by the year of 2012

Musa Akbaş<sup>1</sup>, Aydın Tüfekçioğlu<sup>2</sup>, and Mehmet Küçük<sup>1</sup>

<sup>1</sup>Res. Asst., Artvin Coruh University, Artvin, Turkey; <sup>2</sup>Prof., Artvin Coruh University, Artvin, Turkey

E-Mail: [musakbas15@artvin.edu.tr](mailto:musakbas15@artvin.edu.tr)



### Abstract:

*In this study, the influence of species type and sampling time on soil respiration in young and old oriental spruce (*Picea orientalis* (L.) Link.) stands without understory and with a *Rhododendron ponticum* L. understory and in adjacent grasslands were investigated in Kafkasör region, Artvin, Turkey. For this purpose, three sampling areas were chosen from each vegetation types. Soil respiration was measured at 12 trial courts approximately monthly from May'12 to November'12 using the soda-lime technique. Mean daily soil respiration across all sites ranged from 0,08 to 6,64 g C m<sup>-2</sup> d<sup>-1</sup>. Generally mean soil respiration was higher than others at grasslands and was lower than the others at spruce with a *Rhododendron ponticum* L. understory. Changes in soil respiration were strongly related to soil temperature, soil moisture and sampling time changes. Overall, grasslands had significantly higher soil respiration rates than did adjacent old forests, indicating greater biological activity within the grasslands.*

*Key Terms: Soil biological activity, soil respiration, grasslands, C cycle*

### Introduction:

Increasing atmospheric CO<sub>2</sub> 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). One of the main pathways of fluxes in the global carbon cycle is soil respiration. Soil respiration is the release of CO<sub>2</sub> from soil to the atmosphere. Soils release 75 - 80 Pg of CO<sub>2</sub>-C to the atmosphere annually by soil respiration (Raich and Potter, 1995). Almost 10% of the atmosphere's CO<sub>2</sub> passes through soils each year. This is more than eleven times the current rate of CO<sub>2</sub> 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%.

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<sub>2</sub> (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). Soil respiration varies with vegetation type, management practices, environmental conditions and land use type (Raich and Tufekcioglu, 2000; Frank et al. 2006). Raich and Tufekcioglu (2000) found higher rates of soil respiration in grasslands than in forests and in grasslands and forests than in adjacent croplands. Tufekcioglu and Küçük (2004) found higher rates of soil respiration in grasslands than in spruce stands.

Also change in structure, age, management type and mixture of stand influence soil respiration rates. Young stands may have higher rates of soil respiration with the help of grasses and high rate of decomposition in soil surface. Therefore, continuous or periodic monitoring and measurement of soil respiration in young and old stands provide very valuable data for calculation of annual carbon release from these stands.

The aims of this study were to compare rates of soil respiration among young oriental spruce stands (SSYs), old oriental spruce stands with no understory (SSOs), old oriental spruce

stands with a *Rhododendron ponticum* L. understory (SSRs) and in adjacent grasslands, and to identify the underlying environmental variables most likely causing differences in soil respiration among sites, and among seasons within sites. We also wanted to investigate the change in soil respiration rates after 8 years in the same vegetation types. We hypothesized that grasslands have higher rates of soil biological activity, and therefore higher rates of soil respiration than do adjacent spruce stands.

### Materials and Methods:

The study site is located at Genya Mountain in Artvin, Turkey. The study site were subject to same study in 2004 (Tufekcioglu and Küçük, 2004). The site with a northern aspect and gentle slope (10-20%), ranges in elevation from 1490 m to 1510 m. Soil at the site is a podsolc well-drained sandy-loam. Soil respiration levels were measured in SSYs, in SSOs, in SSRs and in adjacent grasslands. Young stands were around 25 years old and were established after clearcutting by planting and natural regeneration. Old stands were around 100 years old with normal canopy cover. Plot sizes were 20 x 20 m. 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.) and *Festuca* spp. Grassland sites were under heavy grazing until year 2002 when grazing was stopped.

Soil samples were taken randomly from 0-15 cm and 15-35 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 Gülçur (1974). Soil pH was determined by a combination glass-electrode in H<sub>2</sub> O (soil-solution rati 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. Soil respiration rates were measured approximately monthly in 3 randomly selected locations in each of the 3 plots per site from May 2012 to November 2012 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. 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.

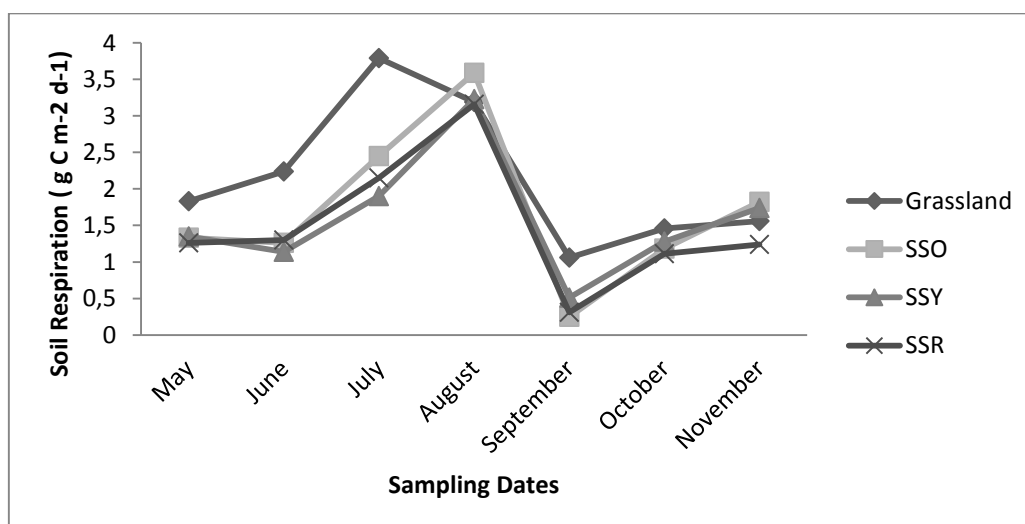
Statistical comparisons were made using SPSS. We used ANOVA to compare soil respiration

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

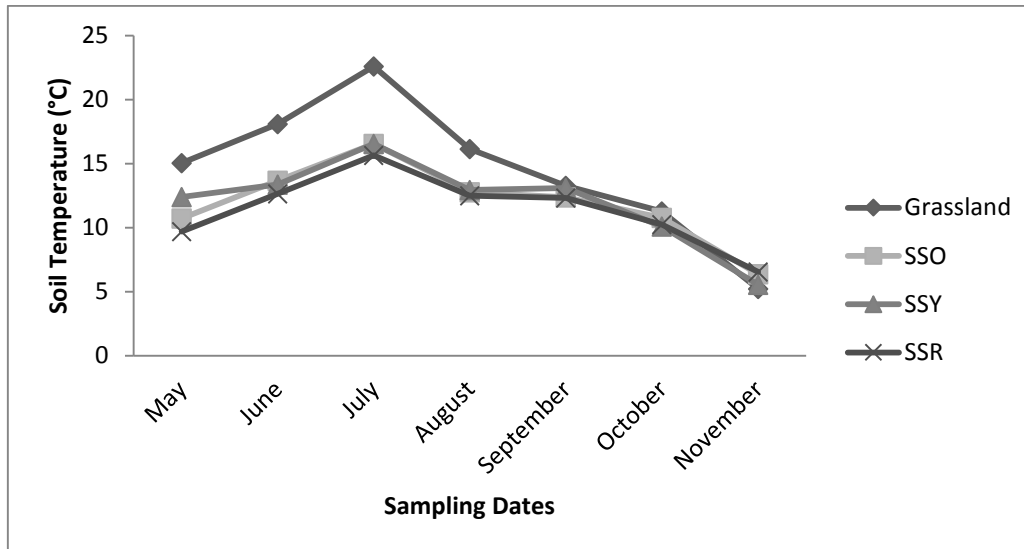
### Results and Discussion:

Mean daily soil respiration ranged from 0.25 to 3.79 g C m<sup>-2</sup> d<sup>-1</sup> among all sites (Figure 1). 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), Hudge and Yavitt (1997), Tufekcioglu et al. (2001) and Tufekcioglu and Küçük (2004). The highest rates were observed in mid-july for grassland and in mid-August for other sites, when soil temperatures were high, while the lowest rates were observed in September, when soil temperatures were minimal (lower) (Figure 2). Soil respiration increased from spring to summer and decreased from summer to fall, as is typical in temperate latitudes (for example, Kowalenko et al., 1978; Hudgens and Yavitt, 1997). Our

results indicated that temperature was limiting during the fall and spring and that moisture was limiting during the summer. Also soil respiration ranges of fall are near to ranges of spring, despite of soil temperature of fall was lower than ranges of spring. According to us, this situation is because of increasing soil moisture during fall. Tüfekçioğlu and Küçük (2004) reported an increase from September to October in the SSYs, SSOs and SSRs sites at the same study area and expressed that difference was probably driven by moisture and temperature differences among sites. Soil respiration varied significantly among the sites ( $P < 0.01$ ). Soil respiration was significantly lower in spruce stands than in grassland sites (Table 2). Similar results were reported by Raich and Tufekcioglu (2000) and Tufekcioglu and Küçük (2004). They reported that grasslands had ~20% and ~100% higher soil respiration rates than did comparable forest stands respectively. Higher soil respiration rates in grassland sites were probably due to higher soil temperatures and lowest soil respiration rates in spruce stands were probably due to lower soil temperatures 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).



**Figure 1.** Mean monthly ( $\pm 1$  SE) soil respiration rates in young (SSY) and old oriental spruce stands with understory (SSR) and without understory (SSO) and in adjacent grasslands in 2012

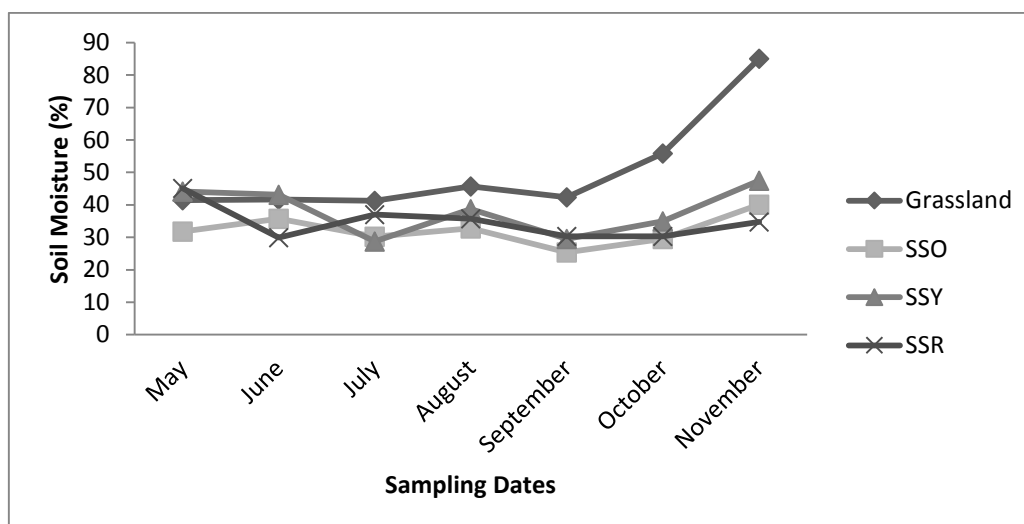


**Figure 2.** Mean monthly ( $\pm 1$  SE) soil temperature in young (SSY) and old oriental spruce stands with understory (SSR) and without understory (SSO) and in adjacent grasslands in 2012

There were significant differences in soil respiration among sampling dates. Soil respiration increased from May to July in grasslands while decreasing from May to June, and increasing from June to August in the other sites. Tufekcioglu and Küçük (2004) reported that these differences in temporal patterns of soil respiration were probably driven by moisture and temperature differences among sites. Soil respiration decreased from August to September and increased from September to November in all sites. There was an up-and-down change in soil moisture content between 25-45% from May to September and an increasing from September to November in all sites, but the rate of increase in grasslands was about 100% while in the other sites was about 15-60%. Transpiration from the aboveground tissues and interception of rain by the forest canopy might account for these soil moisture differences among sites. The temperature decrease from August to October in forest sites was more gradual compared to grassland sites.

Soil temperature varied significantly among the sites and sampling dates ( $P < 0.01$ ) (Figure 2). Soil temperatures in the grassland sites were significantly different from those in the other sites ( $P < 0.05$ ) (Table 2). There were no other significant temperature differences among sites. Averaged over all sites, soil temperatures were significantly higher in July than in November.

Soil moisture content differed significantly between sampling dates. Overall soil moisture contents were significantly higher in November than in the other months ( $P < 0.05$ ) (Figure 3). Mean soil moisture contents (average of 5 sampling dates) in grasslands, in SSO, SSY and SSR sites were 50,47%, 32,21%, 38,09% and 34,75%, respectively (Table 2). Higher soil moisture contents in July and August in grassland sites compared to spruce stand sites were probably the result of higher canopy interception in the forest stands than in grasslands. Çepel (1971) reported that interception ranged from 17 to 31% for forest stands and from 6 to 17% for grasslands in Turkey.



**Figure 3.** Mean monthly ( $\pm 1$  SE) soil moisture contents (0-5 cm depth) in young (SSY) and old oriental spruce stands with understory (SSR) and without understory (SSO) and in adjacent grasslands.

Within sites, seasonal changes in soil respiration were correlated most highly with soil temperature. When all sites were considered together, mean daily soil respiration varied with soil temperature ( $r^2 = 0.14$ ,  $P < 0.001$ ):

$$SR = 0.108 T + 0.386$$

where SR is the soil respiration rate ( $g C m^{-2} d^{-1}$ ), T is morning surface-soil (0-5 cm depth)

temperature ( $^{\circ}C$ ). All 3 parameters were significant ( $P < 0.01$ ). According to stepwise regression results, 38% of variation in soil respiration was explained by soil temperature. This indicated that soil temperature was the most important determinant of soil respiration in these high elevation sites.

Among sites, mean annual soil respiration rate wasn't correlated positively or negatively with other parameters ( $P < 0.05$ ) (Table 1).

**Table 1.** Pearson correlation coefficients among measured variables in the study area ( $n = 12$ ).

	Sand	Clay	Silt	pH	Org. Mat.	S.Resp.
Sand	1	-,932**	-,651**	0,259	0,205	-0,086
Clay	-,932**	1	,333*	-,338*	-0,061	0,075
Silt	-,651**	,333*	1	0,03	-,406*	0,067
pH	0,259	-,338*	0,03	1	-0,097	0,229
Org. Mat	0,205	-0,061	-,406*	-0,097	1	-0,023
S.Resp.	-0,086	0,075	0,067	0,229	-0,023	1

Soil properties belong to the surface 0-15 cm. Asterisks refer to the level of significance; \*,  $P < 0.05$ ; \*\*,  $P < 0.01$ ; \*\*\*,  $P < 0.001$

Soil respiration, soil temperature and soil organic matter varied significantly among sites with-in seasons. This indicates that soil respiration differences among sites were driven by organic matter differences among sites. In a native prairie, belowground litter contributed 20- 25%, root respiration contributed 25-30%, and decay of organic matter contributed 30-35% of the total soil respiration (Buyanovsky et al. 1987).

When the results of this study compared with the previous study(Tufekcioglu and Küçük, 2004) done in the same sites; they showed some differences after 9 years (Table 2). Soil respiration and fine root biomass rates had increased at all sites. Change of rates are for soil respiration were 35%, 98%, 46% 171% and for root biomass 21%, 112%, 47%, 97% in grassland, in SSO, SSY and SSR sites, respectively. The increase in soil respiration rates could be the result of fine root biomass

increases through time. There was no big difference between soil temperature and soil

moisture rates of years.

**Table 2.** Mean values of soil respiration, soil temperature, soil moisture, soil organic matter, soil sand, clay and silt content, pH and root biomass in the 4 sites investigated in both study (n = 3 plots per site). Root data refer to the surface 35 cm of soil

Vegetation types	Grassland		Old spruce with no understory		Young spruce stand		Old spruce with understory	
	2003	2012	2003	2012	2003	2012	2003	2012
<b>YEARS</b>								
Mean soil respiration (g C m <sup>-2</sup> d <sup>-1</sup> )	1,68	<b>2,27</b>	0,89	<b>1,76</b>	1,13	<b>1,65</b>	0,59	<b>1,60</b>
Mean soil temperature (°C)	16,6	<b>15,7</b>	11,7	<b>12,6</b>	13,1	<b>13,0</b>	12,5	<b>12,1</b>
Mean soil moisture(%)	35,3	<b>45,3</b>	31,4	<b>29,9</b>	35,1	<b>35,2</b>	27,1	<b>35,7</b>
Mean soil organic matter (%)	5,58	<b>8,08</b>	7,57	<b>6,78</b>	6,54	<b>6,52</b>	6,11	<b>6,52</b>
Mean sand content (%)	66,4	<b>72,9</b>	57,5	<b>74,7</b>	58,2	<b>75,8</b>	52,3	<b>74,0</b>
Mean clay content (%)	16,8	<b>14,3</b>	25,5	<b>13,9</b>	24	<b>12,2</b>	23,2	<b>14,6</b>
Mean silt content (%)	16,9	<b>12,8</b>	17,1	<b>11,4</b>	17,8	<b>12,1</b>	24,5	<b>12,1</b>
Mean soil pH	5,33	<b>4,94</b>	5,29	<b>4,63</b>	5,41	<b>4,96</b>	4,98	<b>4,78</b>
Mean fine root biomass (<2 mm) (kg/ha)	7850	<b>9501</b>	4980	<b>10579</b>	5640	<b>8297</b>	4040	<b>7964</b>

### Conclusions:

In this study, grasslands had higher rates of soil respiration than did adjacent old forest sites. These higher rates of soil respiration are evidence of the high rates of biological activity and C cycling through the soil. Our results suggest that old forests might be better than grasslands in terms of carbon accumulation into the soil and forest floor in these high elevation sites.

### References

- Buyanovsky, G.A., C.L. Kucera and G.H. Wagner. 1987. Comparative analyses of carbon dynamics in native and cultivated ecosystems. *Ecology* 68; 2023-2031.
- Dugas, W.A., M.L. Heuer, H.S. Mayeux. 1999. Carbon dioxide fluxes over bermudagrass, native prairie and sorghum. *Agric. For. Meteorol.* 93; 121-139.
- Çepel, N. 1971. Toprak yüzeyine varan yağış miktarına bitkilerin yaptığı etki ve Belgrad Ormanında yapılan bir araştırmaya ait beş yıllık sonuçlar. *İ.Ü. Orman Fakültesi Dergisi*, XXI, 2/B, s. 54-59.
- Edwards, N. T. 1982. The use of soda-lime for measuring respiration rates in terrestrial systems. *Pedobiologia* 23; 321-330.

- Ewel, K.C., W.C. Cropper and H.L. Gholz. 1987. Soil CO<sub>2</sub> evolution in Florida slash pine plantations. I. Changes through time. *Can. J. For. Res.* 17; 325-329.
- Frank, A.B, M.A. Liebig, D.L. Tanaka. 2006. Management effects on soil CO<sub>2</sub> efflux in northern semiarid grassland and cropland. *Soil Till. Res.* 89; 78-85.
- Grogan, P. 1998. CO<sub>2</sub> flux measurement using soda-lime: Correction for water formed during CO<sub>2</sub> adsorption. *Ecol.* 79; 1467-1468.
- Gülçür, F. 1974. Toprağın Fiziksel ve Kimyasal Analiz Metodları. İ.Ü. Orman Fakültesi Yayın No: 201, İstanbul.
- Hanson, P.J., S.D. Wullschleger, S.A.D.E. Bohlman. 1993. Todd Seasonal and topographic patterns of forest floor CO<sub>2</sub> effects from an upland oak forest. *Tree Physiol.* 13; 1-15
- Hanson, P.J., N.T. Edwards, C.T. Garten, J.A. Andrews. 2000. Separating root and soil microbial contributions to soil respiration: Rev. methods and observations. *Biogeochem.* 48; 115-146.
- Harris, W.F., R.S. Jr. Kinerson, and N.T. Edwards. 1977. Comparison of belowground biomass of natural deciduous forest and Loblolly pine plantations, p. 27-29. In: *The Belowground Ecosystem: A Synthesis of Plant-Associated Processes.*

- (Ed. JK Marshall). Range Science Department, Science Series No: 26, Fort Collins, Colorado, USA.
- Haynes, B.E. and S.T. Gower. 1995. Belowground carbon allocation in unfertilized and fertilized red pine plantations in northern Wisconsin. *Tree Physiol.* 15; 317-325.
- Hudgens, D.E. and J.B. Yavitt. 1997. Land-use effects on soil methane and carbon dioxide fluxes in forest near Ithaca, New York. *Ecoscience* 4(2); 214-222.
- Kalra, Y.P. and D.G. Maynard. 1991. *Methods Manual for Forest Soil and Plant Analysis*. Forestry Canada, Northern Forestry Publications. Alberta, Canada.
- Kelting, D.L., J.A. Burger and G.S. Edwards. 1998. Estimating root respiration, microbial respiration in the rhizosphere, and rootfree soil respiration in forest soils. *Soil Biol. Biochem.* 30; 961-968.
- Kowalenko, C.G., K.C. Ivarson and D.R. Cameron. 1978. Effect of moisture content, temperature and nitrogen fertilization on carbon dioxide evolution from field soils. *Soil Biol. Biochem.* 10; 417-423.
- Kucera, C.L., D.R. Kirkham. 1971. Soil respiration studies in tall grass prairie in Missouri. *Ecol.* 52; 912-915.
- Norman, J.M., R. Garica, S.B. Verma. 1992. Soil surface CO<sub>2</sub> fluxes and the carbon budget of a grassland. *J. Geophys. Res.* 97; 18845-18853.
- Parkin, T.B., J.W. Doran, E. Franco-Wizcaino. 1996. Field and Laboratory tests of soil respiration. In: *Methods for Assessing Soil Quality*. Ed. J.W. Doran and A.J. Jones. Soil Sci. Soc. Am. special publication no 49, Madison, Wisconsin, USA.
- Raich, J.W., R.D. Bowden and P.A. Steudler. 1990. Comparison of two static chamber techniques for determining carbon dioxide efflux from forest soils. *Soil Science Society of America Journal* 54: 1754-1757.
- Raich, J.W., Potter CS 1995. Global patterns of carbon dioxide emissions from soils. *Global Biogeochem. Cycles* 9: 23-26.
- Raich, J.W., A. Tufekcioglu. 2000. Vegetation and soil respiration: Correlations and controls. *Biogeochem.* 48(1); 71-90.
- Raich, J.W., C.S. Potter, D. Bhagawati. 2002. Interannual variability in global soil respiration, 1980-1994. *Global Change Biol.* 8; 800-812.
- Rochette, P., L. Desjardings, E.G. Gregorich, E. Pattey, R. Lessard. 1992. Soil respiration in Barley (*Hordeum vulgare* L.) and fallow fields. *J. Soil Sci.* 72; 591-603.
- Singh, J.S., S.R. Gupta. 1977. Plant decomposition and soil respiration in terrestrial ecosystems, *Bot. Rev.* 43; 449-528.
- Tüfekçioğlu, A., J.W. Raich, T.M. Isenhardt and R.C. Schultz. 1999. Fine root dynamics, coarse root biomass, root distribution, and soil respiration in a multi species riparian buffer in Central Iowa, USA. *Agroforestry Systems* 44; 163-174.
- Tufekcioglu, A, J.W. Raich, T.M. Isenhardt, R.C. Schultz. 2001. Soil respiration within riparian buffers and adjacent crop fields, *Plant and Soil* 229; 117-124.
- Tüfekçioğlu, A., J.W. Raich, T.M. Isenhardt and R.C. Schultz. 2003. Biomass, carbon and nitrogen dynamics of multi-species riparian buffers within an agricultural watershed in Iowa, USA. *Agroforestry Systems* 57; 187-198.
- Tufekcioglu, A. and M. Kucuk. 2004. Soil respiration in young and old oriental spruce stands and in adjacent grasslands in Artvin, Turkey. *Turk. J. Agric. For.* 28; 429-434.
- Tufekcioglu, A., A.K. Ozbayram, M. Kucuk. 2009. Soil respiration in apple orchards, poplar plantations and adjacent grasslands in Artvin, Turkey. *J. Environ. Biol.* 30(5); 815-820.