Title: The Effects of Litter Production and Litter Depth on Soil Microclimate in a Central European Deciduous forest.

Concise title: Effects of Litter Production and Litter Depth on Soil Microclimate

Authors: István Fekete[1], Csaba Varga[2], Borbála Biró[3], János Attila Tóth[4], Gábor Várbíró[5], Kate Lajtha[6], Gergely Szabó[7], Zsolt Kotroczó[3*]

Institute: [1]Institute of Environmental Sciences, College of Nyíregyháza, H-4400 Nyíregyháza, Sóstói u. 31./B, Hungary

[2]Department of Land Management and Rural Development, College of Nyíregyháza, H-4400 Nyíregyháza, Sóstói u. 31./B, Hungary

[3]Department of Soil Science and Water Management, Corvinus University of Budapest, H-1118 Budapest, Villányi út 29-43, Hungary

[4]Department of Ecology, University of Debrecen, H-4032 Debrecen, Egyetem tér 1, Hungary

[5]MTA Centre for Ecological Research, Department of Tisza River Research, H-4026 Debrecen, Bem tér 18./C, Hungary

[6]Department of Crop and Soil Science, Oregon State University, Corvallis, OR 97330, USA

[7]Department of Physical Geography and Geoinformatics, University of Debrecen, Egyetem tér 1, Hungary

***Corresponding author:** Department of Soil Science and Water Management, Corvinus University of Budapest, H-1118 Budapest, Villányi út 29-43, Hungary. E-mail: kotroczo.zsolt@gmail.com; Tel: +36 1 482-6464 Fax: +36 1 482-6336

Abstract

Aims: We examined the influence of litter quality and litter depth on soil microclimate in the detrital manipulation plots in the Síkfőkút DIRT (Detrital Input and Removal Treatments) experiment.

Methods: DIRT manipulations include two litter addition (Double Litter and Double Wood), three litter removal (No Litter, No Input and No Root), and one Control treatment. Soil temperature was measured with ONSET StowAway TidbiT type data loggers and soil moisture content at 12 cm depth was determined with a FieldScout TDR 300.

Results: There were significant differences detected among plots in winter and summer soil mean temperatures as well as in the number of frost-free days. The highest annual soil temperature variation was detected in litter removal treatments, while the lowest variation was in Double Litter plots with the thickest litter layer. The root exclusion treatments had significantly greater soil moisture contents than other treatments due to loss of transpiration. The wetter and low in organic matter plots showed lower winter temperatures.

Conclusion: These differences in soil microclimate may have a highly significant, but unrecognized effect on soil carbon balance through effects on microbial processing of litter and soil C, and thus soil CO2 release and soil C sequestration.

Keywords: microclimate, soil temperature, soil moisture, detritus manipulation, DIRT, climate change

Introduction

Changes in temperature and precipitation patterns that are predicted under future scenarios of global warming will have profound effects on primary productivity, plant species diversity and composition, and ecosystem function (Wang et al., 2011; Rózsa and Novák, 2011; Williams et al., 2012; Serrano et al., 2015). All of these factors independently will feed back to alter the quality and quantity of detrital inputs to soils, further altering patterns of nutrient cycling (Biró et al., 2012; Tóth et al., 2013) and soil organic matter (SOM) content and dynamics. Indirect changes to soil temperature and moisture regimes from global climate change will also affect the processing of litter by microbes (Chapin et al., 2009; Bond-Lamberty and Thomson, 2010; Hagedorn et al., 2010; Wang et al., 2014). While both of these factors – litter production, and soil warming and/or drying - are included in most models of soil carbon balance, indirect effects of litter production and surface litter depth on soil microclimate, and thus microbial processing of litter and SOM, are less well studied. Detritus thus plays two major roles in terrestrial ecosystems: on one hand, above- and belowground litter is the source of stabilized SOM, and on the other hand, litter forms a layer on the soil surface that affects microclimate (Sayer et al., 2006).

The aim of this work was to explore effects of changing detrital inputs on soil microclimate in a *Quercetum petraeae-cerris* community in northeast Hungary. The Síkfőkút DIRT (Detritus Input and Removal Treatments) experiment constitutes an important part of a long-term international project that involves five experimental sites in the USA (Andrews Experimental Forest, Bousson Experimental Forest, Harvard Forest, University of Michigan Biological Station, Santa Rita Experimental Range) and one in Germany (Universität Bayreuth BITÖK). The overall objective of the DIRT project is to explore how changes in the quality and quantity of detrital inputs affect soil physical, chemical and biological parameters (Nadelhoffer et al., 2004; Lajtha et al., 2005).

Several studies have already examined the effects of global warming on our experimental site. Longer and more severe drought periods are expected in the near future for several Central European ecosystems. The long-term meteorological data have clearly indicated that the climate of the forest has become drier and warmer over the past few decades with annual precipitation decreasing by 15-20% in many Hungarian territories (Antal et al., 1997; Galos et al., 2009). The summer climate of the Carpathian Basin has shifted towards a more Mediterranean like climate (Domonkos, 2003; Bartholy et al., 2007). The species composition and structure of the Síkfőkút forest has changed since the early 1970's (Tóth et al., 2007): 68% of sessile oak (*Quercus petraea*) and 16% of Turkey oak (*Quercus cerris*) died. The percentage of field maple (*Acer campestre*) has increased from 0% to 28% (Kotroczó et al., 2007). This also entails several changes in detritus amount and composition (Bowden et al. 2006). Mean leaf-litter production was 4060 kg ha^{-1} y^{-1} between 1972 and 1976, and 3540 kg ha^{-1} y^{-1} between 2003 and 2010 (Kotroczó et al., 2012).

We hypothesized that detrital litter layer thickness would significantly affect annual, seasonal and daily temperature fluctuations of surface mineral soils by acting as a buffer that would also affect soil moisture levels. We also hypothesized that differences in soil moisture content among treatments would affect daily soil temperature range (DTR), with soils from plots without roots having greater soil moisture content and thus greater DTR.

Material and methods

Site description

We carried out our research in the Síkfőkút Experimental Forest in northeastern Hungary. The project area (27 ha) is located in the southern part of the Bükk Mountains at altitude of 325-345 m (47°55’N; 20°26’E). The area has been protected and is part of the Bükk National Park since 1976. According to Antal et al. (1997) the mean annual temperature is 10°C and the mean annual precipitation is 553 mm. This forest is a semi-natural stand (*Quercetum petraeae-cerris* community) with no active management since 1976 (Jakucs, 1985). In this previously coppiced forest the Sessile oak and Turkey oak species that make up the overstory are a hundred years old. Based on the data from 2003 to 2006, litter production consists of the following tree species in decreasing order: Sessile oak (*Quercus petraea*), Turkey oak (*Quercus cerris*), Field maple (*Acer campestre*), and Cornelian cherry (*Cornus mas*). During the same period the average dry leaf-litter production was 3585 kg ha^{-1} and the average amount of total aboveground dry detritus (including branches, twigs, fruit and buds) was 6230 kg ha^{-1} (Tóth et al., 2007). The soils according to the WRB Soil Classification are Luvisols (Świtoniak et al., 2014) with a pH_{H2O} in surface soils (0-15 cm) without detrital manipulation of 5.2 and with soil organic carbon ranging between 2.96% and 4.42% depending on the detritus treatment (Tóth et al., 2013; Fekete et al., 2014).

The experimental detrital manipulation plots were established in the Síkfőkút DIRT site in November 2000. We established six treatments, each with three 7×7m replicate plots (Table 1) (Fekete et al., 2011). We applied 2 litter addition treatments Double Litter (DL) and Double Wood (DW), and 3 detritus removal treatments No Litter (NL), No Roots (NR), No Input (NI), and Control (CO) treatments. The surface solar radiation was approximately the same in all treatments, as the distribution and slope of land did not show great differences (average slope of 5 degrees) and the site faced south, so the climatic effect was same in all plots. Moreover, the plots were established at random, thus reducing the effects of incidental minor differences.

Soil temperature was measured with ONSET StowAway TidbiT type data loggers (Onset Computer Corporation, USA) placed into the middle of each plot at 10 cm depth. Air temperature was measured 0.5 meters above the ground with the same type of data loggers. Data loggers were programmed to measure soil and air temperature every hour from 06.17.2004 to 06.16.2008. The temperature data were grouped into seasons (*winter:* December, January, February; *spring:* March, April, May; *summer:* June, July, August; *autumn:* September, October, November). Soil moisture content at 12 cm depth was determined with a FieldScout TDR 300 (Spectrum Technologies Inc., USA) in all plots, every month.

Statistical analyses

Statistical analyses were performed using Statistica 7.0. Random sampling and the independence of samples were ensured by the experimental design. Experimental data were statistically evaluated by one-way ANOVA (assumptions were tested by Levene's test for homogeneity of variances and Chi-square test for normality), linear regression and one-way ANCOVA. When groups were significantly different, ANOVAs were followed with Tukey's HSD test. We analyzed the effects of air temperature on soil temperature in the treatments by linear regression, and differences among slopes were tested using one-way ANCOVA.

Results

The effects of detritus treatments on soil temperature and soil moisture content

Detritus treatments significantly influenced soil microclimate. The annual mean temperature values did not show any significant differences between the treatments (Table 2). However, the differences were significant within the winter ($F_{(6;2191)}$=70.31; $p<0.01$) and the summer periods ($F_{(6;2583)}$=65.2; $p<0.01$) (Table 3 and 4), but there were no significant differences the transitional seasons (autumn and spring). In summer, air temperature was significantly higher than in all soil treatments, and soil temperatures in the root exclusion treatments (NR, NI) were significantly higher than in the any other soil treatments, and NL was significantly higher than in CO and the litter addition treatments. In contrast, air temperature was significantly lower than all soil treatments in winter. The temperatures in the aboveground litter exclusion treatments (NL and NI) were significantly lower than the CO, and litter addition treatments in winter. Similarly, the number of frost days, when the soil temperature was below 0°C, was significantly different among treatments (Table 2). Therefore, the annual fluctuation of soil temperature was much higher in the detritus exclusion treatments than in CO or litter addition treatments, and air temperature showed higher fluctuations seasonally than did soil temperature in the different treatments (Table 2, 3 and 4).

The relationship between air temperature and soil temperature in the six treatments was shown by regression analyses. Air temperature and soil temperatures were significantly related when analyzed within each season based on daily averages (Tables 5 and 6). Soil daily mean temperatures in the root exclusion treatments (NR, NI) were most responsive to air daily mean temperature in summer, and soil daily mean temperatures in surface litter exclusion treatments (NL, NI) were most responsive to air daily mean temperatures in winter. The correlation was stronger in summer than in winter for all treatments. The regression analysis between air daily mean temperatures and soil daily mean temperatures exhibited significantly higher slope values in the regression equation in case of the NR and NI soil of the treatments than in the CO and litter addition plots in summer (Table 5). However, there were not significantly different slope values for the winter periods (Table 6).

Soil moisture contents were significantly higher in root exclusion treatments (NR and NI) than in the other treatments ($F_{(5,240)}= 18.21$; $p<0.001$) (Table 2). There were no other differences in soil moisture among the other treatments (Table 3 and 4). Regarding moisture content values, the quotients of the upper and lower quartiles were the lowest in root exclusion treatments, which showed that soil moisture content varied the least in these soils.

The effects of detritus on daily soil temperature range (DTR)

Hourly soil and air temperature readings were used to determine minimum and maximum daily temperatures, and the differences among minimum and maximum temperatures were used to calculate DTR. DTR of air was always significantly higher than DTR of the soils in all treatments ($F(_{6;1526})=812.8$; $p<0,001$). The detrital treatments significantly affected soil DTR fluctuation (Table 7). In winter, when the average daily temperature of the air is lower than daily minimum temperature of soil treatments, the soil temperatures often show a steady decline or do not change. In this case, the air DTR does not affect the temperature of the soil, especially the leaf litter-covered plots. As temperatures in winter fell to below 0°C, rapid temperature decreases were first seen in plots not covered by litter, followed by CO and DW plots; soil temperatures below freezing were not observed in DL plots. As temperatures rose above freezing, frozen soils had a 2-3 day lag due to isolating ability of the frozen upper soil layer, in winter, there were no significant differences in soil DTR among plots. In spring and summer, soil DTR was significantly smaller in plots with a litter layer (DL, DW and CO) than in detritus removal plots (NL, NR, and NI). In autumn, DTR was significantly smaller in DL, DW and CO than in NR and NI.

Discussion

Changes in soil temperature and moisture content

Various detritus treatments and soil biological processes both directly and indirectly influence soil microclimate (Tejedor et al., 2004; Sayer 2006). Therefore, the significant differences in temperature among the soils of the treatments during the winter and summer periods are considered to be the consequences of detritus treatments. In winter (especially when there is no snow) the thickness of the detritus layer had a profound effect on soil temperature. This “insulating effect” was observed in DL treatments, as temperatures in DL soils never fell below 0°C. Soil temperature may also be influenced by soil biochemical processes (Raich and Tufekcioglu, 2000; Bernhardt et al., 2005); decomposition of organic matter and other microbial processes can release a significant amount of heat. In the colder periods exothermic decomposition processes were significantly greater in litter addition treatments and CO than in detritus removal treatments, as shown by soil respiration values (data in Fekete et al., 2014; Kotroczó et al., 2014). These higher respiration rates could both be partially due to higher temperatures in litter addition plots due to insulation effects, and could also contribute to warmer conditions. In contrast, in summer NR plots had the highest soil respiration values among the treatments and had the highest soil temperature and moisture content as well. Because the NR treatment had no labile root inputs and no root turnover, the higher respiration rates were clearly due to microclimate effects.

NL and NI soils had lower albedo values than the lighter color surface covered by dry detritus, so they certainly absorbed more heat in summer, when solar radiation was intense. This was especially true for NI plots, whose soil was much darker due to its higher moisture content. The soil moisture values also showed large differences among the detritus treatments (Veres et al., 2013). Due to the lack of transpiration, the soils in the root exclusion treatments (NR and NI) were significantly wetter than soils in the other treatments, and they stayed moist even under severe summer drought (Fekete et al., 2012). A similar trend was found in the American DIRT sites. The soil moisture content of NR had higher with 86% than CO in Síkfőkút DIRT site, while this difference was 9.3% in Andrews DIRT site in Oregon (USA) and 17.5% in Bousson DIRT site in Pennsylvania (USA) (Brant et al., 2006). These differences between the American and Hungarian DIRT sites may be explained by climate factors. Annual precipitation at Síkfőkút is much lower than that at the US DIRT sites (Andrews: 2370 mm yr^{-1}; Bousson: 1050 mm yr^{-1}), and rainfall is more seasonally distributed (Sulzman et al., 2005; Crow et al., 2009). Moreover, the annual mean temperature at Síkfőkút is higher than that at the US DIRT sites, so here's higher evaporation.

The surface litter layer also regulates the soil water content (Ogée and Brunet, 2002), on the one hand reduces the evaporation of the mineral soil, on the other hand it absorbs a certain amount of precipitation water, which thus does not penetrate into the soil. Soil moisture content may also influence soil thermal conductivity; the higher the soil moisture content, the higher its thermal conductivity (Blackburn et al., 1998; O'Donnel et al., 2009). In contrast, the heat of evaporation cools the soil surface, and this effect is greater in moister soils. The differences among the DTR in the soils of the treatments likely reflected this evaporation effect. The litter layer of the NR plots are similar to CO plots, but the DTR is significantly higher in NR than in CO.

In addition, the absence of trees and shrubs in NR and NI plots leads to a lack of a shading effect. Therefore, it was the two root exclusion treatments that showed the highest temperature values in summer and the lowest ones in winter – in this latter case along with NL. Many factors in addition to soil water content, such as organic matter content, also influence soil thermal conductivity (Blackburn et al., 1998; Al-Shammary and Al-Sadoon, 2014). Soil mineral particles have much higher thermal conductivity than soil organic matter, e.g. quartz has 14 times as high conductivity as soil organic particles (Farouki, 1986; Perry et al., 2011). Thus soils with higher organic matter content warm more slowly than those with lower organic matter and higher mineral matter contents – provided other parameters are the same. Soil organic carbon was 67.3 g kg^{-1} dry soil in the upper 5 cm soil layer in DL which was 58.6%, 46.8% and 61.1% higher than in NL, NR and NI (Fekete et al., 2014).

Clearly detrital thickness can reduce the effects of soil temperature extremes and moderate minimum and maximum temperature values, creating a more balanced microclimatic for soil organisms. Soil moisture may also significantly affect soil temperature. If the climate becomes warmer and drier litter production may decrease, creating a thinner litter cover, which may increase daily and seasonal temperature extremes. The effects of litter layer thickness on soil processes is important to include in earth system models that aim to predict soil carbon stocks and soil respiration.

References

Al-Shammary A.A.G., Al-Sadoon J.N.A., 2014. Influence of tillage depth, soil mulching systems and fertilizers on some thermal properties of silty clay soil. Global Journal of Agricultural Research 2, 18-32.

Antal E., Berki I., Justyák J., Kiss Gy., Tarr K., Vig P., 1997. A síkfőkúti erdőtársulás hő- és vízháztartási viszonyainak vizsgálata az erdőpusztulás és az éghajlatváltozás tükrében. Debrecen 83. (*in Hungarian*)

Bartholy J, Pongrácz R., Gelybó G., 2007. Regional climate change expected in Hungary for 2071-2100. Applied Ecology and Environmental Research 5, 1-17.

Bernhardt E.S., Barber J.J., Pippen JS, Taneva L., Andrews J.A., Schlesinger W.H., 2005. Long-term effects of free air CO_2 enrichment (FACE) on soil respiration. Biogeochemistry 77, 91-116.

Biró B., Kádár I., Lampis S., Gullner G., Kőmíves T., 2012. Inside and outside rhizosphere parameters and dose-dependent stress alleviation at some chronic metal exposures. Acta Phytopathologica et Entomologica Hungarica 47, 373-384.

Blackburn E., Liangl X., Wood E.F. 1998. The Effect of Soil Thermal Conductivity Parameterization on Surface Energy Fluxes and Temperatures. Journal of the Atmospheric Science 55, 1209-1224.

Bond-Lamberty B., Thomson A., 2010. Temperature-associated increases in the global soil respiration record. Nature 464, 579-583.

Bowden R.D., Nagel L., Kotroczó Zs., Krakomperger Zs., Papp M., Tóth J.A., 2006. Long-term change in vegetation composition and biomass in a Central European oak forest at the Síkfőkút International Long-Term Ecological Research (ILTER) Site, Hungary. Mid-Atlantic Ecology Conference. Ecology in the Field. New Jersey School of Conservation. Branchville, New Jersey. Mid-Atlantic Chapter of the Ecological Society of America (MAESA) 2-3.

Brant J.B., Myrold D.D., Sulzman E.W. 2006. Root controls on soil microbial community structure in forest soils. Oecologia Volume 148, (4) 650-659.

Chapin F.S.I., McFarland J., McGuire A.D., Euskirchen E.S., Ruess R.W., Kielland K., 2009. The changing global carbon cycle: linking plant-soil carbon dynamics to global consequences. Journal of Ecology 97, 840-850.

Crow S.E., Lajtha K., Filley T.R., Swanston C.W., Bowden R.D., Caldwell B.A., 2009. Sources of plant-derived carbon and stability of organic matter in soil: implications for global change. Global Change Biology 15, 2003-2019.

Domonkos P. 2003. Recent precipitation trends in Hungary in the context of larger scale climatic change. Natural Hazards 29, 255-271.

Farouki O.T., 1986. Thermal Properties of Soils. Series on Rock and Soil Mechanics 11, Trans Tech: 136.

Fekete I., Kotroczó Zs., Varga Cs., Nagy P.T., Várbíró G., Bowden R.D., Tóth J.A., Lajtha K., 2014. Alterations in forest detritus inputs influence soil carbon concentration and soil respiration in a Central-European deciduous forest. Soil Biology and Biochemistry 74, 106-114.

Fekete I., Varga Cs., Kotroczó Zs., Tóth J.A., Várbiró G., 2011. The relation between various detritus inputs and soil enzyme activities in a Central European deciduous forest. Geoderma 167-168, 15-21.

Fekete I., Kotroczó Zs., Varga Cs., Hargitai R., Townsend K., Csányi G., Várbiró G., 2012. Variability of organic matter inputs affects soil moisture and soil biological parameters in a European detritus manipulation experiment. Ecosystems 15, 792-803.

Galos B., Goettel H., Haensler A., Preuschmann S., Matyas Cs., Jacob D., 2009. Do forest cover changes have any feedback on temperature and precipitation extremes over Hungary? Geophysical Research Abstracts 11. EGU2009-7687-1.

Hagedorn F., Martin M., Rixen C., Rusch S., Bebi P., Zürcher A., Siegwolf R.T.W., Wipf S., Escape C., Roy J., Hättenschwiler S., 2010. Short-term responses of ecosystem carbon fluxes to experimental soil warming at the Swiss alpine treeline. Biogeochemistry 97, 7-19.

Jakucs P. (*ed*) 1985. Ecology of an Oak Forest in Hungary I. - Akadémiai Kiadó, Budapest, pp. 23, 69.

Kotroczó Zs., Veres Zs., Fekete I., Papp M., Tóth J.A., 2012. Effects of climate change on litter production in a *Quercetum petraeae-cerris* forest in Hungary. Acta Silvatica et Lignaria Hungarica 8, 31-38.

Kotroczó Zs., Veres Zs., Fekete I., Krakomperger Zs., Tóth J.A., Lajtha K., Tóthmérész B. 2014. Soil enzyme activity in response to long-term organic matter manipulation. Soil Biology and Biochemistry 70, 237-243.

Kotroczó Zs., Krakomperger Zs., Papp M., Bowden R.D., Tóth J.A., 2007. Long-term change in the composition and structure of an oak forest at Síkfőkút, North Hungary. Természetvédelmi Közlemények 13, 93-100. (*Hungarian with English abstract*)

Lajtha K., Crow S.E., Yano Y., Kaushal S.S., Sulzman E., Sollins P., Spears J.D.H., 2005. Detrital controls on soil solution N and dissolved organic matter in soils: a field experiment. Biogeochemistry 76, 261–281.

Nadelhoffer, K., Boone, R., Bowden, R.D., Canary, J., Kaye, J., Micks, P., Ricca, A., McDowell, W., Aitkenhead, J., 2004. The DIRT experiment. *In:* Foster D.R., Aber D.J., (*eds*) Forests in Time. Yale University Press: Michigan.

O'Donnell J.A., Romanovsky V.E., Harden J.W., McGuire A.D., 2009. The Effect of Moisture Content on the Thermal Conductivity of Moss and Organic Soil Horizons From Black Spruce Ecosystems in Interior Alaska. Soil Science 174, 646-651.

Ogée J., Brunet Y., 2002. A forest floor model for heat and moisture including a litter layer. Journal of Hydrology Volume 255, 212–233.

Perry D.A., Oren R., Hart S.C., 2011. Forest Ecosystems, Johns Hopkins University Press, Baltimore, USA p: 267

Raich J.W., Tufekcioglu A., 2000. Vegetation and soil respiration: correlations and controls Biogeochemistry 48, 71-90.

Rózsa P., Novák T., 2011. Mapping anthropic geomorphological sensitivity on global scale. Zeitschrift für Geomorphologie 55, 109–117.

Sayer E.J., 2006. Using experimental manipulation to assess the roles of leaf litter in the functioning of forest ecosystems. Biological Reviews 81, 1-31.

Sulzman E.W., Brant J.B., Bowden R.D., Lajtha K., 2005. Contribution of aboveground litter, belowground litter, and rhizosphere respiration to total soil CO2 efflux in an old growth coniferous forest. Biogeochemistry 73, 231-256.

Świtoniak M., Charzyński P., Novák T.J., Zalewska K., Bednarek R. 2014, Forested hilly landscape of Bükkalja Foothill (Hungary). *In*: Świtoniak M, Charzyński P (*eds*) 2014, Soil sequences atlas. Nicholaus Copernicus University Press, Torun. pp: 169-181.

Tejedor M., Jiménez C., Rodríguez M., Morillas G., 2004. Effect of soil use change on soil temperature regime. Conserving Soil and Water for Society: Sharing Solutions. 13th International Soil Conservation Organisation Conference, Brisbane, July 2004 Paper No. 648, 1-4.

Tóth J.A., Lajtha, K., Kotroczó Z., Krakomperger Z., Caldwell, B., Bowden, R.D., Papp M., 2007. The effect of climate change on soil organic matter decomposition. Acta Silvatica et Lignaria Hungarica 3, 75-85.

Tóth J.A., Nagy P.T., Krakomperger Zs., Veres Zs., Kotroczó Zs., Kincses S., Fekete I., Papp M, Mészáros I., Viktor O. 2013. The effects of climate change on element content and soil pH (Síkfőkút DIRT Project, Northern Hungary). *In*: Kozak, J., et al. (*eds*), The Carpathians: Integrating Nature and Society Towards Sustainability, Environmental Science and Engineering. Springer-Verlag, Berlin, Heidelberg, 77-88.

Veres Zs., Kotroczó Zs., Magyaros K., Tóth J.A., Tóthmérész B., 2013. Dehydrogenase Activity in a Litter Manipulation Experiment in Temperate Forest Soil. Acta Silvatica et Lignaria Hungarica 9, 25-33.

Vicente-Serrano, S.M., Camarero, J.J., Zabalza, J., Sangüesa-Barreda, G., López-Moreno, J.I., Tague, C.L. 2015. Evapotranspiration deficit controls net primary production and growth of silver fir: Implications for Circum-Mediterranean forests under forecasted warmer and drier conditions. Agricultural and Forest Meteorology. 206, 45–54

Wang F., Xu Y.J., Dean T.J., 2011. Projecting Climate Change Effects on Forest Net Primary Productivity in Subtropical Louisiana, USA. Ambio 40, 506-520.

Wang X., Liu L., Piao S., Janssens I.A., Tang J., Liu W., Chi Y., Wang J., Xu S. 2014. Soil respiration under climate warming: differential response of heterotrophic and autotrophic respiration. Global Change Biology 20, 3229-3237.

Williams C.A., Collatz G.J., Masek J., Goward S.N., 2012. Carbon consequences of forest disturbance and recovery across the conterminous United States. Global Biogeochem. Cycles 26, GB1005.

Tables legends

Table 1. The applied DIRT (Detritus Input and Removal Treatments) treatments in the Síkfőkút site, Hungary**.**

Table 2. Soil and air properties in the Síkfőkút DIRT treatments. Different letters indicate significant difference

Table 3. Air and soil temperature and standard error values in the Síkfőkút DIRT treatments during summer periods; (June, July, August);. N per treatment = 370. Different letters indicate significant difference.

Table 4. Air and soil temperature and standard error values in the Síkfőkút DIRT treatments during winter periods (December, January, February). N per treatment = 314. Different letters indicate significant difference.

Table 5. The relationship between the air temperature and soil temperature of the different treatments in the summer periods from 2004 to 2008. Different letters indicate significant difference slope values ($p<0.001$). (soil temperature=a+b*air temperature; where a is a constant and b is the slope)

Table 6. The relationship between the air temperature and soil temperature of the different treatments in the winter periods from 2004 to 2008 ($p<0.001$). (soil temperature=a+b*air temperature; where a is a constant and b is the slope)

Table 7. Air and soil values of the daily fluctuation of the temperature in the Síkfőkút site based on the means of all treatments. (Based on 219 randomly choosed values from 17.03. 2004 to 29.02. 2008)

Table 1. Soil and air properties in the Síkfőkút DIRT treatments. Different letters indicate significant difference

	DL	DW	CO	NL	NR	NI	Air
m. a. t.[I.]	10.3±0.07	10.2±0.08	10.2±0.07	10.2±0.08	10.3±0.08	10.2±0.08	10.1±0.09
b. days[II.]	0	17	17	70	29	77	143
a. days[III.]	17	16	16	30	96	72	141
fluct.[IV.]	20.03	22.12	22.12	25.88	26.61	28.3	42.5
moisture[V.]	23.6a±0.61	25.8a ±0.61	24.5a ±0.61	25.3a ±0.60	36.9b ±0.50	34.5b ±0.54	-

[I.] mean annual temperature from the daily mean temperature values 06.17.2004 -06.16.2008 (in °C)

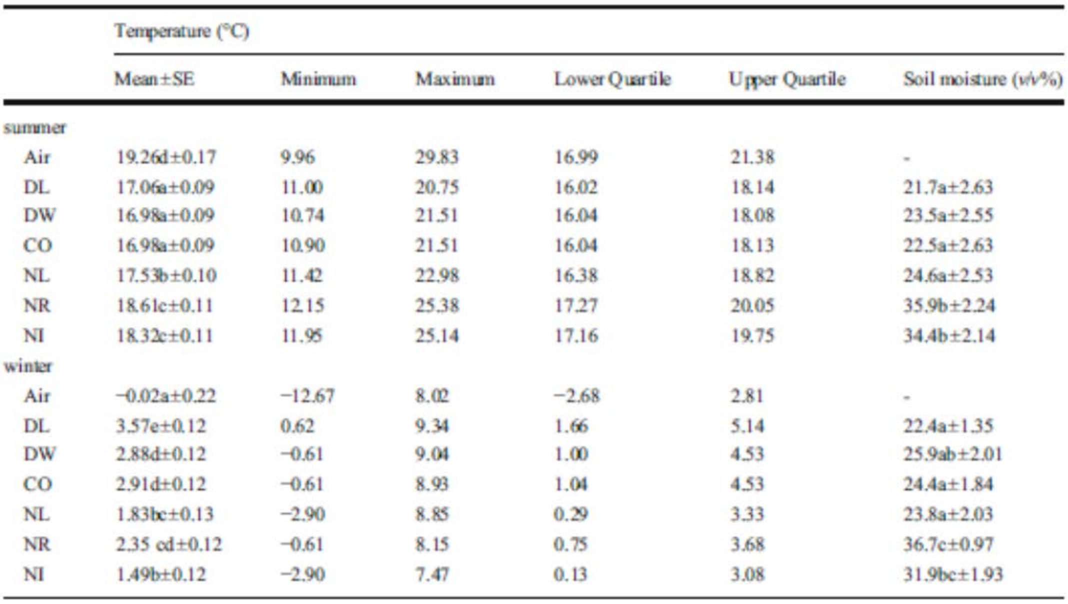
[II.] The number of days when the daily mean temperature was below 0°C

[III.] The number of days when the daily mean temperature was above 20 °C

[IV.] Maximum fluctuation of the temperature of the examined period (in °C),

[V.] The average of soil moisture content between 2004-2008 (%v/v) was determined once every month in the year

Table 2. Air and soil temperature and standard error values in the Síkfőkút DIRT treatments during summer periods; (June, July, August; N per treatment = 370) and winter periods (December, January, February; N per treatment = 314). Different letters indicate significant difference.



	Temperature (°C)					
	Mean±SE	Minimum	Maximum	Lower Quartile	Upper Quartile	Soil moisture (v/v%)
summer						
Air	19.26d±0.17	9.96	29.83	16.99	21.38	-
DL	17.06a±0.09	11.00	20.75	16.02	18.14	21.7a±2.63
DW	16.98a±0.09	10.74	21.51	16.04	18.08	23.5a±2.55
CO	16.98a±0.09	10.90	21.51	16.04	18.13	22.5a±2.63
NL	17.53b±0.10	11.42	22.98	16.38	18.82	24.6a±2.53
NR	18.61c±0.11	12.15	25.38	17.27	20.05	35.9b±2.24
NI	18.32c±0.11	11.95	25.14	17.16	19.75	34.4b±2.14
winter						
Air	−0.02a±0.22	−12.67	8.02	−2.68	2.81	-
DL	3.57e±0.12	0.62	9.34	1.66	5.14	22.4a±1.35
DW	2.88d±0.12	−0.61	9.04	1.00	4.53	25.9ab±2.01
CO	2.91d±0.12	−0.61	8.93	1.04	4.53	24.4a±1.84
NL	1.83bc±0.13	−2.90	8.85	0.29	3.33	23.8a±2.03
NR	2.35 cd±0.12	−0.61	8.15	0.75	3.68	36.7c±0.97
NI	1.49b±0.12	−2.90	7.47	0.13	3.08	31.9bc±1.93

Table 3 The relationship between the soil temperature (°C) and air temperature of the different treatments in the summer and winter periods from 2004 to 2008

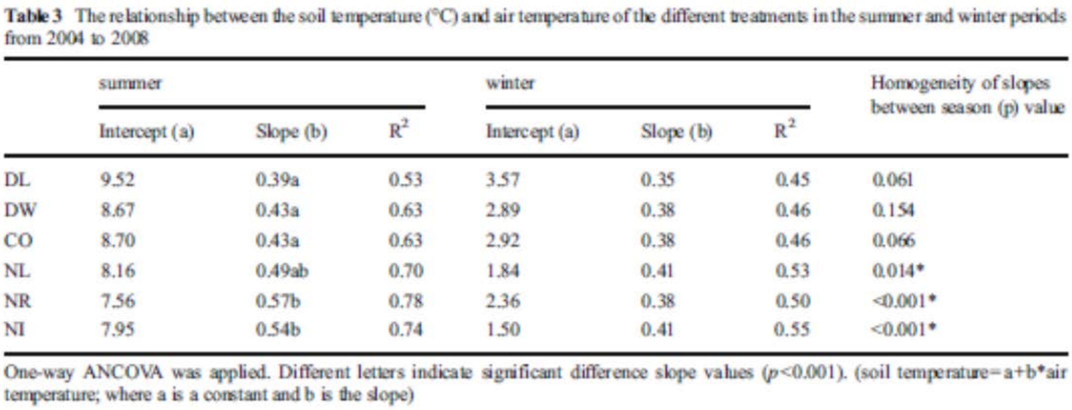


Table 3 The relationship between the soil temperature (°C) and air temperature of the different treatments in the summer and winter periods from 2004 to 2008

	summer			winter			Homogeneity of slopes between season (p) value
	Intercept (a)	Slope (b)	R^2	Intercept (a)	Slope (b)	R^2	
DL	9.52	0.39a	0.53	3.57	0.35	0.45	0.061
DW	8.67	0.43a	0.63	2.89	0.38	0.46	0.154
CO	8.70	0.43a	0.63	2.92	0.38	0.46	0.066
NL	8.16	0.49ab	0.70	1.84	0.41	0.53	0.014*
NR	7.56	0.57b	0.78	2.36	0.38	0.50	<0.001*
NI	7.95	0.54b	0.74	1.50	0.41	0.55	<0.001*

One-way ANCOVA was applied. Different letters indicate significant difference slope values ($p<0.001$). (soil temperature=a+b*air temperature; where a is a constant and b is the slope)

Table 4. Air and soil values of the daily fluctuation of the temperature in the Síkfőkút site based on the means of all treatments (Based on 219 randomly choosed values from 17.03. 2004 to 29.02. 2008)

treatments and air	**daily average in all period**	**daily maximum**	**daily average in spring**	**daily average in summer**	**daily average in autumn**	**daily average in winter**
DL	0.63a±0.02	1.63	0.75a±0.05	0.79a±0.04	0.51a±0.03	0.39a±0.05
DW	0.74a±0.03	2.58	0.71a±0.05	0.92a±0.05	0.66a±0.04	0.57a±0.08
CO	0.85a±0.04	2.46	1.06a±0.07	0.96a±0.05	0.65a±0.04	0.64a±0.14
NL	1.46b±0.07	5.04	2.38bc±0.17	1.54bc±0.06	0.85ab±0.06	1.01a±0.12
NR	1.48b±0.06	3.82	2.06b±0.11	1.87bc±0.09	1.14b±0.05	0.66a±0.07
NI	1.87c±0.07	6.04	2.96c±0.18	1.99c±0.07	1.16b±0.06	1.18a±0.14
Air	7.23d±0.18	16.02	7.43d±0.35	8.37d±0.25	5.92c±0.28	6.45b±0.48

Fig. 1 Temporal variation of the summer soil temperature for Double Litter, Control and No Imput treatments

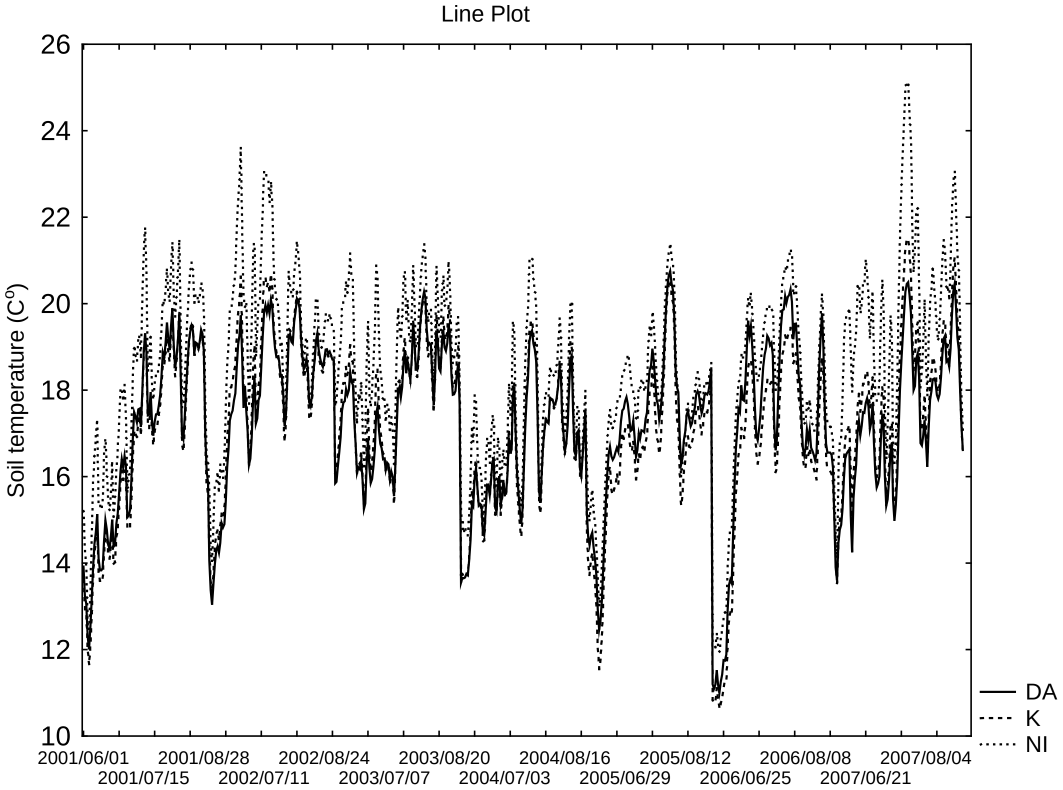


Fig. 1 Temporal variation of the winter soil temperature for Double Litter, Control and No Imput treatments

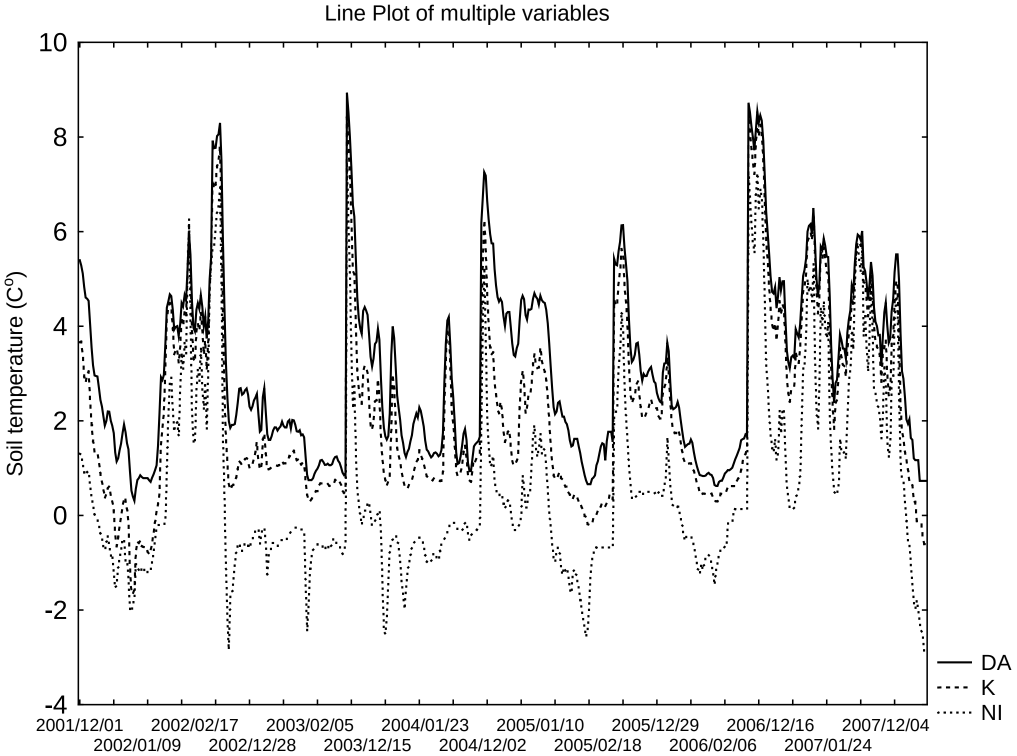


Fig. 3 Summer hourly temperature profile of the soil temperature in the different treatments and the profile of air temperature between 06. 01. 2005 and 09. 30. 2005