SOIL RESPIRATION AND ITS MAIN LIMITING FACTORS IN A SEMIARID SAND FOREST-STEPPE ECOSYSTEM – RESULTS OF A CLIMATE SIMULATION EXPERIMENT

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Abstract: A stand-scale climate change experiment with passive nighttime warming and rain exclusion treatments was conducted in the semiarid Pannonian sand forest steppe of the Kiskunság, as part of the European VULCAN Project. Response of soil respiration was measured monthly in the vegetation periods between 2003 and 2007. Besides the very low soil carbon efflux rates (0.09 – 1.60 µmol CO₂ m⁻² s⁻¹), close correlation was found between soil respiration rate and soil temperature, while the influence of soil moisture could be detected only below 2.5 vol%, when water stress suppressed the temperature response of soil respiration. The primary temperature effect is obvious from the diurnal changes of soil respiration, even during water-limited periods of the growing season, while the seasonal course is characterized by clear temperature limitation in winter and water limitation in summer. For the soil respiration rate – temperature relationship a bell-shaped function gave the best fit in this ecosystem. Both nocturnal warming and rain exclusion treatments had negative influence on soil respiration, presumably because of the drought imposed by both treatments. These results suggest a decline in the amount of carbon emission from the soil in this ecosystem with the forecasted climate change.

Keywords: experimental warming, soil carbon dioxide efflux, temperature response, water limitation

Introduction

Interactions between the atmosphere and the biosphere are strongly determined by soil carbon dioxide efflux (Schlesinger and Andrews 2000, Anda and Lőke 2006, Lellei-Kovács et al. 2008). Global environmental changes can fundamentally alter these interactions in various ways in the different ecosystems (Davidson et al. 2006, Vágó et al. 2006, Várallyai 2007). Soil respiration is affected by the soil-plant relationships and plant traits, and, particularly in arid ecosystems, by water availability (Tingley et al. 2006, Viliam and Ján 2006). In this study we document and evaluate the effects of limiting factors on soil carbon efflux in a multiyear measurement series.

Materials and methods

A plot-scale climate change simulation experiment was established at the Kiskun Long Term Ecological Research (LTER) site in Central Hungary within the frame of the EU FP5 VULCAN Project (Beier et al. 2004). Passive nighttime warming throughout the year, or rain exclusion in the main vegetation period were applied in 3 plots of 4x5 m size in both treatments. There were also 3 control plots maintained. The vegetation is a forest steppe mosaic developed on coarse, calcic soil with low humus content, extreme heat and water regimes (Kovács-Láng et al. 2000, Várallyai 2006). Soil respiration measurements were conducted once monthly during the vegetation period with one measurement series at dawn and another one during midday, by using an IRGA system with an open air flow soil respiration chamber (98.5 cm², ADC LCA4

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with PLC 2250 Soil hood, ADC BioScientific, Hoddesdon, U.K.). Soil temperature in 1 cm depth and soil moisture in the top 10 cm layer were measured simultaneously with soil respiration. The effects of time and experimental treatments were tested by Repeated Measures ANOVA followed by Tukey post hoc tests for the comparison of means. Soil respiration data were log-transformed to improve homogeneity of variances. Dawn and midday data were analyzed separately. All analyses were performed by using the Statistica 6.0 package.

Results and discussion

Throughout the five years of the study period soil carbon efflux rates remained very low (between 0.09 and 1.60 µmol CO₂ m⁻² s⁻¹) most probably due to the limited biological activity and low substrate content of the calcareous coarse sand soil typical of the Kiskunšág forest steppe. A clear temperature limitation in winter and water limitation in summer was observed, as it is described by Tingley et al. (2006). The primary temperature effect is obvious from the diurnal changes of soil respiration which was significantly lower at dawn than at midday, throughout the study period (Figure 1).

For the close correlation, found between soil respiration rate and soil temperature, a bell-shaped function gave the best fit ($R^2 = 0.31$) in this ecosystem, instead of the widely accepted exponential relationship (Emmett et al. 2004). This function has a maximum value at 33.4°C, based on the five years of our study (Figure 2). As this characteristics applied also to the non water-limited periods, it is probably because of the temporary substrate depletion of the soil caused by the enhanced microbial activity. Szili-Kovács and Török (2005) observed increased microbial respiration as a consequence of addition of various carbon sources in the same ecosystem. Impact of soil water on soil respiration could be detected only below 2.5 vol%, when water stress supressed the temperature limitation of soil respiration, and above 30°C, when temperature limitation was certainly negligible. The water limitation effect, however, is hardly detectable in the field in the coarse sand soil, because of the narrow range of
limiting water content values. The relationship between soil respiration and climatic variables was also investigated by Ács and Breuer (2006) in Hungary for different soil textures, where correlations depended on season and soil type.

![Figure 2. The bell-shaped function of soil respiration and temperature relationship between 2003 and 2007 in the semiarid sand forest steppe experimental site.](image)

Both passive nighttime warming and rain exclusion treatments tended to decrease soil respiration rate, though neither of them had a statistically significant effect on soil carbon dioxide efflux (Table 1, 2).

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The unexpected impact of warming treatment on soil carbon dioxide efflux occurred presumably because of the indirect drought effect of the treatment. On the one hand, dewfall could be excluded by the nighttime sheltering, which is an important water source in particular in this semiarid ecosystem. On the other hand, underground dew formation could be diminished because of the reduced cooling down of the soil in the warming treated plots. Moreover, the evapotranspiration could also be enhanced if compared to the control plots.

Conclusions
The results draw the attention to the importance of the interactive effects of temperature, soil moisture and substrate limitation on soil biological activity in the studied semiarid sand forest steppe ecosystem and suggest a decline in the amount of soil carbon efflux with the forecasted climate change.
Acknowledgements

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