Respiration of the sandy soil of Kiskunság in the light of climate change

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Abstract

In the Kiskunság, near Fülöpháza, we established a climate simulation experiment in 2001, where passive nighttime warming and a decrease in precipitation in the vegetation period were simulated. In present work the results of our six-year study on soil respiration in this experimental site are reported.

Introduction

Soil respiration is an important part of the atmosphere-ecosystem interactions, while it accounts for the second largest carbon flux between ecosystem and atmosphere. Therefore, responses of soil respiration to climate change have considerable impacts on climate predictions. Our knowledge, however, on the carbon balance of arid and semiarid ecosystems with transient type of vegetation is very limited. Transient climate zones of terrestrial ecosystems are supposedly highly sensitive to climate change. On the other hand, such ecosystems are usually exposed to frequent climatic or weather fluctuations, therefore they could possess higher adaptive capacity to fluctuations of this sort. For this paradox, the functioning of these habitats can be understood only in long-term studies.

Soil respiration, as an indicator of soil biological activity, is strongly influenced by temperature and soil moisture. By climate predictions further warming, and in the vegetation period enhanced drought is expected in Hungary for the next period (MIKA 2003). Near Fülöpháza, in a sandy forest-steppe patch with white poplar sprouts, we have launched a climate simulation experiment in the frame of the EU FP5 VULCAN project, applying passive nighttime warming and rain exclusion in the peak vegetation period (BEIER et al. 2004). Since 2003, we have been investigating soil respiration within this experiment, to estimate ecosystem responses to changing climatic conditions (LELLEI-KOVÁCS et al. 2008). We monthly measure soil respiration and soil surface temperature by infrared gas analyser, while monthly soil moisture is measured by TDR handheld device.

In this study we aimed at the quantification of 1) soil respiration rate in the semiarid temperate sand forest-steppe ecosystem; 2) the daily, seasonal and yearly courses of the intensity of CO_2 emission from the soil; and 3) the magnitude of the effects of heat and drought treatments applied in accordance with forecasted changes in climate.

Variability of environmental factors affecting soil respiration

Weather of the studied six year between 2003 and 2008 varied highly, offering a good opportunity to compare weather and soil respiration rates between years. The highest interannual variability appeared in the amount of precipitation between April and June (in the peak vegetation period). Soil temperature changed significantly with months, time of the day and years, often exceeding 50°C in summer, while the lowest values were recorded around 0°C at the beginning (in March) or at the end (in November) of the growing season.

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Between 2003 and 2008 passive nighttime warming reduced cooling down at 1.7°C on soil surface at dawn, while this difference totally disappeared by noon. Volumetric soil moisture content of the sandy soil of high infiltration rate and low water holding capacity ranged from 0.0 to 14.4% during the six years. Warming treatment and drought treatment decreased soil moisture content during the year with an average of 0.5 and 1.0 vol%, respectively. Directly under the drought treatment, this reduction reached 2.3 vol%.

Effects of years, months and daytime on soil CO_2 efflux

During the six years of the field experiment soil respiration rate was very low, between 0.09 and 1.94 µmol CO_2 m^{-2} s^{-1}. Mean soil respiration rate varied significantly with years, months and time of the day. The seasonal course of soil respiration showed clear temperature limitation in winter and moisture limitation in summer, in all treatments. During the day significantly (about 54%) lower values are characteristic at dawn than those at midday.

Effects of heat or drought treatments on soil CO_2 efflux

Surprisingly, both warming and drought treatment had decreasing effects on soil respiration (**Figure 1**). Only the extent of the effects was depending on the given part of the day. At dawn, soil respiration was decreased by both warming and drought treatment at 13% to control, while at daytime, warming and drought treatment decreased soil respiration at 8% and 20%, respectively.

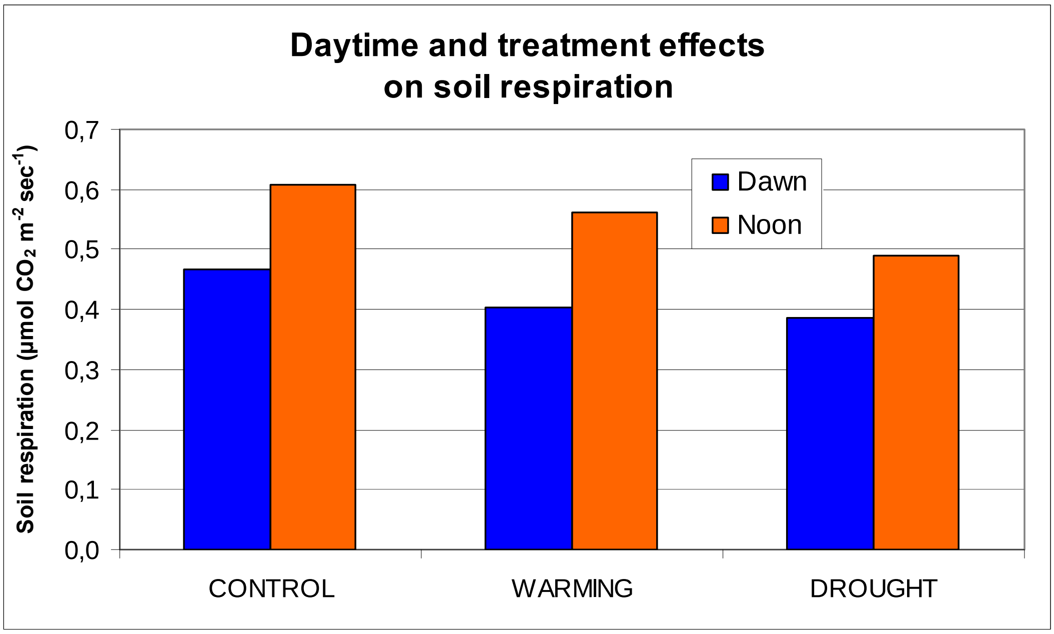

Figure 1. *Impacts of daytime and treatments on soil respiration*

Investigating the individual years separately, a more detailed pattern emerges (**Figure 2**). During the exceptionally dry and hot 2003 not only the drought treatment, but also the control suffered severe drought. Soil respiration differed not significantly between the treatments in this year. Also in the relatively cool and rainy 2004, soil respiration responded neither to the heat nor to the drought treatments in the studied period despite the relatively large amount of precipitation excluded in drought treatment. Between 2005 and 2008, however, drought treatment decreased daytime soil respiration significantly, at least in the treatment period.

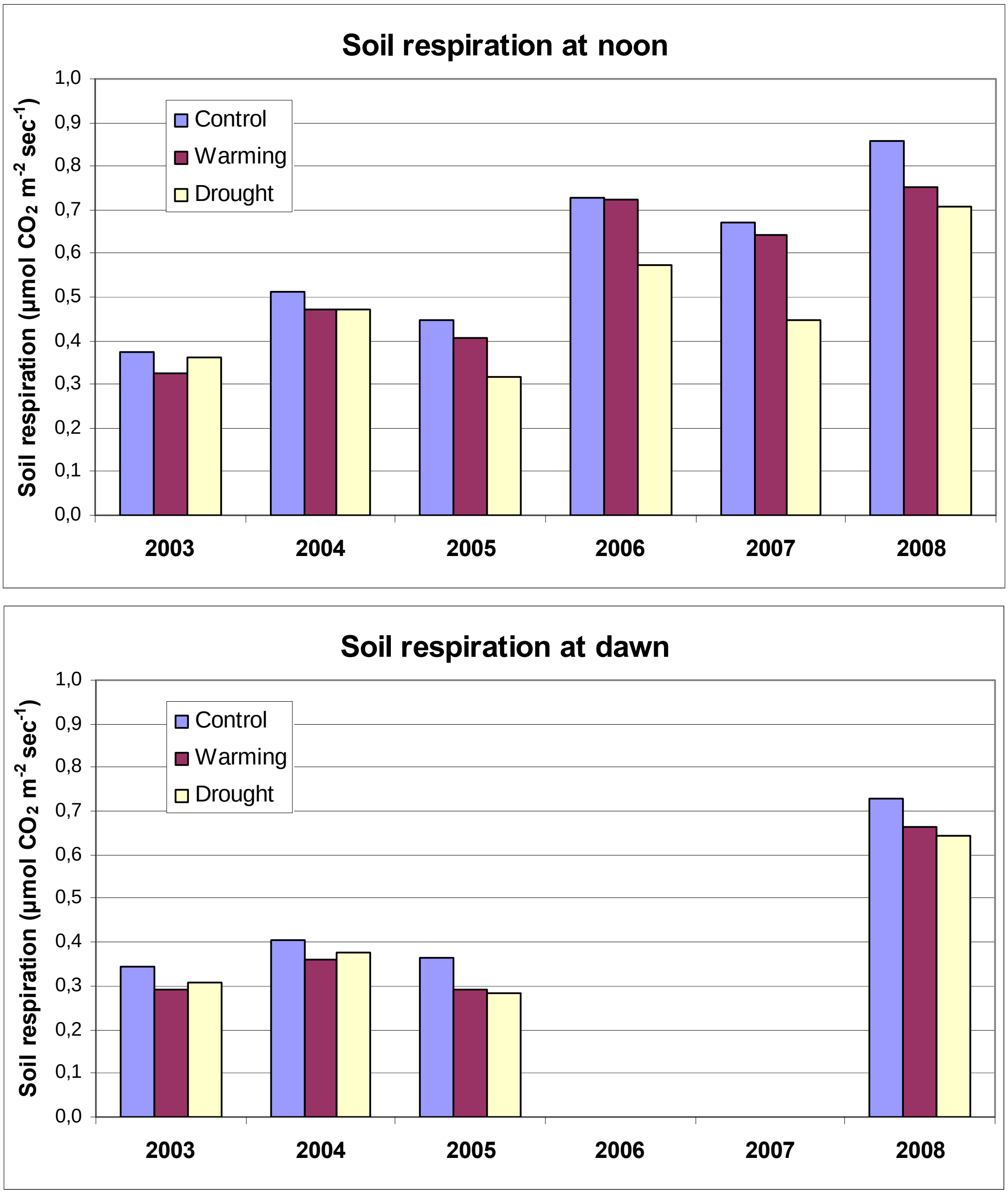

Figure 2. *Annual averages of soil respiration values at dawn and at noon*

Conclusions

Soil respiration is controlled by numerous environmental factors as temperature, soil water content, substrate availability, vegetation pattern, and by the spatial and temporal variation of each of them. Our six-year study was conducted in a spatially heterogenous vegetation, in a patch of the forest-steppe mosaic, within various temperature and moisture conditions, which is characteristic for the climate of the Pannonian region and also derives from the physical characteristics of the sandy substrate. Measured soil respiration rates in this temperate semiarid vegetation were rather low, related to other temperate grasslands or shrublands. These data, however, are understandable considering the extreme environmental conditions and very low organic matter content of the soil. Since microbial activity is closely associated with the surface of roots in this system, the heterotrophic (mostly bacterial and fungal) and autotrophic (root) respiration cannot be separated. Under such extreme conditions, soil respiration rate can be one or two orders of magnitude lower than that in soils of higher biological activity.

In the Pannonian forest-steppe, soil respiration displays a characteristic, annually repeated seasonal course. Seasonal course of soil respiration, however, may be controlled not only by temperature but also seems to be closely associated with water availability and the seasonal activity pattern of vegetation, reaching its peak in spring and autumn and having a summer water-limited and a winter temperature-limited period.

Contrary to expectations, nocturnal warming did not enhance soil respitration relative to control in our six-year experiment, although soil surface at dawn was tempered by an average of 1.6°C as a consequence of nocturnal sheltering, what should create more beneficial temperature conditions for soil respiration. Heat treatment, however, had an indirect effect as well, i.e., decreasing the soil moisture content of the topsoil relative to control, and this could outrange the expected positive effect of the rising temperature on soil respiration. The simultaneous drying effect of the heat treatment could be caused by the exclusion of dewfall by the roofs covering the plots at night, and on the other hand, from the presumed reduction in water vapor condensation and underground dew formation. The latter is a direct consequence of the restrained cooling down of the soil surface. Higher evaporation rate at night due to higher temperature on the treated plots could also contribute to the lower water content of the soil.

The degree of the changes in soil respiration due to treatments, however, was different in the different years. Weather extremities (severe drought and hot spring in 2003, and unusually high rainfall in 2004) damped the effects of treatments of the given extent while in the more or less average years of 2005 and 2006 treatment effects were more pronounced. It seems that rather the relative, than the absolute amount of excluded precipitation determines the significance of the treatment effects. Supposedly, to reach a significant effect, at least the half amount of the total precipitation should be excluded, on the other hand, the extreme water condition of the control may have also an important role. This also draws attention to the importance of the effects of weather extremities during climate change.

Acknowledgements

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