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ECOSYSTEM SCALE CARBON DIOXIDE BALANCE OF TWO GRASSLANDS IN HUNGARY UNDER DIFFERENT WEATHER CONDITIONS

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The carbon balance of the sandy pasture (Bugac) and the mountain meadow (Mátra) varied between –171 and 96 gC m^{-2} $year^{-1}$, and –194 and 14 gC m^{-2} $year^{-1}$, respectively during the study period (2003–2009). Large part of interannual variability of net ecosystem exchange (NEE) was explained by the variation of the annual sum of precipitation in the sandy grassland ecosystem, while this relationship was weaker in the case of the mountain meadow on heavy clay soil. These different responses are largely explained soil texture characteristics leading to differences in soil water contents available to plants at the two grasslands. The grassland on the heavy clay soil was more sensitive to temporal distribution of rainfall for the same reason. The mountain meadow therefore seems to be more vulnerable to droughts, while the sandy grassland is better adapted to water shortage. The precipitation threshold (annual sum), below which the grassland turns into source of carbon dioxide on annual basis, is only 50–80 mm higher than the 10 years average precipitation sum. In extremely dry years (2003, 2007 and 2009), even the sandy grassland ecosystem was not stable enough to maintain its sink character.

Keywords: Grassland – net ecosystem exchange – soil type – eddy covariance – effect of drought

INTRODUCTION

From the industrial revolution on the composition of the atmosphere is changing due to anthropogenic influence, mainly the concentration of carbon dioxide (CO_2), methane (CH_4) nitrous oxide (N_2O) and halocarbons has increased. Due to this changed composition the greenhouse effect is becoming more intensive, the global mean temperature is rising and the spatial and temporal distribution of rainfall is also changing [5]. Carbon dioxide – the concentration of which is mostly affected by anthropogenic activity – is circulating continuously between the atmosphere, the oceans and the terrestrial biosphere. According to present estimations 30 per cent of carbon dioxide of anthropogenic origin was absorbed by oceans [8] further 25 per cent was absorbed by the terrestrial ecosystems, namely in the vegetation growing in the deforested areas [1].

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Mainly there are two types of feedback between climate and CO_2 concentration, for example, in dry areas, where water availability and warming may both limit net primary production and hence CO_2 absorption. In colder climates, on the other hand, warming enhances net primary production and CO_2 absorption [2]. Furthermore, CO_2 emission by soils may increase in response to warming. The real danger is posed by the positive feedback between warming and respiration [1]. Several international research projects aims to measure and model the global carbon balance (FLUXNET, GreenGrass, Carbomont, CarboOcean, CarboEurope-IP). In this study, we present the Hungarian results related to international research project.

MATERIALS AND METHODS

The first measuring tower of the Department of Botany and Plant Physiology was established in the Kiskunság National Park, near the settlement Bugacpuszta to the Hungarian Great Plain in the framework of GreenGrass (FP5). The measuring tower (46.69°N, 19.60°E, 111.4 m a.s.l.) is situated next to a gray cattle farm on a sandy pasture (most common species: *Festuca pseudovina* Hack. ex Wiesb., *Carex stenophylla* Wahlbg. and *Salvia pratensis* L.). The soil at the pasture is chernozem type sandy soil with high humus content, and its sand content is about 785 g/kg. The 10-years mean temperature is 10.4 °C and the sum of precipitation is 562 mm.

The second measuring site (47.85°N, 19.73°E, 300 m a.s.l.) is in operation from June 2003 in the Mátra Mountains, near Szurdokpüspöki. The soil in this area differs markedly from the previous one, it is a brown forest soil with high clay content (346 g/kg). The sample site was partly grazed and partly mowed previously. The most common species of the grassland are: *Festuca pseudovina* Hack. ex Wiesb, *Arrhenatherum elatius* L., *Poa pratensis* L. and *Plantago lanceolata* L.. The long term mean annual temperature was 10.2 °C, while the long term average precipitation sum was 622 mm in the area.

The most common micrometeorological method to measure the carbon dioxide exchange between the ecosystem and the atmosphere (net ecosystem exchange, NEE) – the eddy-covariance technique – is used at our both sites. The method gives the resultant of respiration and photosynthesis on half-hourly basis. Furthermore, several environmental parameters (e.g. temperature, precipitation, global and photosynthetic active radiation, soil water content etc.) are measured half-hourly at both sites. The two most important instrument of an eddy-covariance tower are the sonic anemometer, which measures the 3 component (u, v, w) of wind speed 10 times per second and the gas analyzer, which is able to detect the water vapour and carbon dioxide of air at the same rate. The station at Bugac was equipped with a GILL-Solent Anemometer (Gill Instruments, U.K.) at the beginning , but later, in June, 2005, was replaced by a CSAT3 sonic anemometer. At the Mátra site a CSAT3 is in operation from the beginning. The concentration of water vapour and carbon dioxide is detected by a Li-Cor 7500 open path IRGA at both sites.

The half-hourly fluxes are calculated from the 10 Hz raw data set with a code written in IDL which is based on the code of Zoltán Barcza [3]. Detailed description of the calculations, quality assurance of data (filtering) and gap-filling is available in [7].

RESULTS AND DISCUSSION

Meteorological conditions

The annual mean temperature ranges from 9.2 °C to 11.1 °C at Bugacpuszta and from 9.7 °C to 11.6 °C at Szurdokpüspöki, 2007 being the hottest year. The sum of precipitation was less than the 10 years mean in 2002, 2003 and 2007 at Bugacpuszta and in 2003 and 2007 at Szurdokpüspöki. There is about 270 mm difference between the annual precipitation sums considering the driest (2002) and the wettest (2004) years, respectively, at Bugacpuszta, this difference is smaller (ca. 230 mm) in the case of the mountain site.

Carbon dioxide balance

Firstly, we have to clarify that the sign convention in micrometeorology is the opposite of the one used in biology (i.e. the balance is considered from the point of view of the atmosphere), and the respiration is a positive value, and photosynthesis is negative. Cumulative NEE characterises integrally the carbon dioxide balance, as it gives the sum of NEE from the first day of the year until a given day (Fig. 1). Usually grasslands are sources of CO_2 in winter (daily sums are positive), i.e. the cumulative curve is rising. Conversely, the amount of CO_2 absorbed during daytime dominates the daily sum from spring on, so the cumulative sum (and the curve also) starts to decrease.

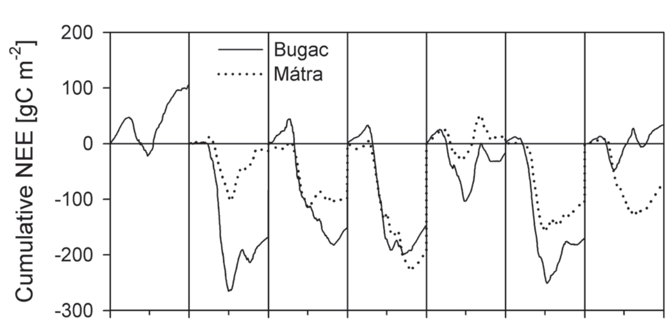

Fig. 1. Annual cumulative sum of net ecosystem exchange (NEE) at two Hungarian grasslands (Bugac – solid line; Mátra – dotted line) from 2003 to 2009. Negative slope indicates the dominance of carbon dioxide absorption on daily scale, positive means the dominance of respiration

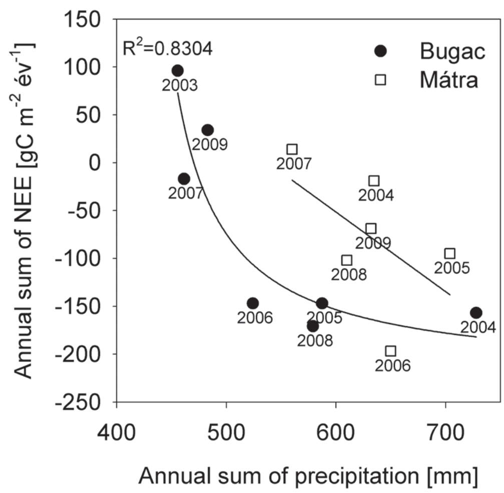

Fig. 2. Relationship between the annual sum of precipitation and net ecosystem exchange (NEE) at two Hungarian grasslands (Bugac – filled circles; Mátra – empty squares). The function is a Michaelis-Menten type at the sandy grassland (Bugac) and the fit is statistically significant ($R^2 = 0.8304$. On the other hand, the points of the mountain meadow (Mátra) does not show saturation, so linear function was fitted, but is was not significant statistically

A distinct feature of the cumulative NEE was found at our both grasslands, namely an interim source period took place in the middle of summer almost in every year in the study period, then, from the end of August or beginning of September, a new – secondary – growing (sink) period started. Though the amount of CO_2 absorbed in this secondary growing period varied significantly in different years depending on the weather conditions, it affected seriously the annual sum. For example, the cumulative sum was positive already at the end of summer, but due to the amount of CO_2 absorbed in the secondary growing period (32 gC m^{-2} at Bugac and 41 gC m^{-2} at Mátra) the yearly sum turned to be negative. On the contrary, no secondary growing period happened in the extreme dry year, 2003.

The annual carbon dioxide balance showed strong interannual variation, and it varied between –171 and 106 gC m^{-2} $year^{-1}$ and between –197 and 14 gC m^{-2} $year^{-1}$ at the sandy pasture, and the mountain meadow with clay soil, respectively (negative value indicate uptake). Involved in our investigations, we have searched for determining factors of the annual sum of NEE. We found strong correlation between the annual sum of precipitation and NEE in the case sandy pasture, where a Michaelis-Menten type equation was fitted on to the points (Fig. 2). In the case of the mountain meadow there seems to be a linear relationship between the two variables, but the correlation was poor. Based on this fit, we might define a threshold, below which the grassland is expected to be source of CO_2 on annual scale, in the case of the sandy pasture this threshold (460 mm) was 10 percent below the 10-years average, while the variance of the annual precipitation sum in the last 6 years was about the half of it. Since the fitted curve of the relation between precipitation and NEE is fairly steep (sandy pasture), small amount of precipitation might be of key importance. As the correlation is weak in the case of the data measured in Mátra, no further description is provided.

Interannual variability of NEE at the sandy pasture is mainly controlled by the annual sum of precipitation, temporal distribution proved to be an additional factor at the meadow at heavy clay soil. The amount of precipitation necessary to reach field capacity in these two contrasting soils is very different. Furthermore, the amount of water available for plants (18.1 and 9.8% at Bugac and Mátra, respectively [6]) differs markedly in the case of this two soil types, which certainly limits the annual sum of NEE and the intensity of carbon dioxide uptake in the main growing season at the measuring site with lower amount of available water(heavy clay soil). Additionally, if the heavy clay soil dries out, its conductivity decreases, and the rate of runoff increases. For the same reason, high intensity rainfall (shower, thunderstorm) is inefficient in refilling soil with water compared to low intensity precipitation. For another thing, plant available water in the sandy soil is higher, the water conductivity of the soil is also higher, so it is more efficient in use of high intensity precipitation, than the heavy clay soil.

The above mentioned facts are verified by the more intensive carbon dioxide uptake and the lower amount of precipitation at the sandy grassland as compared to the other grassland on heavy clay soil. Since, according to predictions, the frequency of droughts and high intensity rainfalls is expected to increase, it seems that the grassland on heavy clay soil is exposed to more dramatic carbon loss as compared to the sandy pasture.

CONCLUSIONS

The carbon dioxide balance showed strong interannual variation, and it varied between –171 and 106 gC m^{-2} $year^{-1}$ and between –197 and 14 gC m^{-2} $year^{-1}$ at the sandy pasture, and the mountain meadow with clay soil, respectively (negative value indicate uptake). Interannual variation of NEE was fully explained by annual precipitation in the sandy grassland and not in the grassland on heavy clay. Owing to these soil characteristics, the clay grassland may be more vulnerable to droughts in terms of decreased C-assimilation and (soil) carbon losses under the predicted drier summers even if the annual precipitation sum was higher by 10.7% on average for the mountain compared to the sandy grassland. The annual precipitation sum is close to the threshold, below which the grasslands may turn into source of carbon. While in one hand this can be viewed as an example of ecosystem scale adaptation to available water, drought events also involve loss of soil carbon and a potential positive feedback between source activity and decreasing net primary production, on the other.

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