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Chamber measurements of CO_2 exchange in different wetland sites in Biebrza National Park, Poland

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Abstract: Peatlands have historically functioned as important sinks of atmospheric carbon dioxide (CO_2). Understanding the environmental drivers behind spatial and temporal variation in CO_2 flux is therefore crucial for estimation of current carbon balances and forecasting the impact of climate warming. We present preliminary results of CO_2 flux measurements in peatland habitats in the area of Biebrza National Park, Poland. The purpose of the study was to obtain a first season of estimates of CO_2 exchange, and evaluate how fluxes depended on meteorological and biophysical conditions. Daytime measurements of NEE and ecosystem respiration (R_{eco}) were performed by a static chamber method between the end of April and September in 2010. Following parameters: soil moisture, leaf area index (LAI), and biomass were also measured. Altogether, the studied peatlands had a mean seasonal NEE of –156 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$ (a negative value indicates ecosystem uptake). We observed that the largest net uptake of CO_2 occurred during the field campaigns in spring and early autumn. Average NEE measured in these periods approximate –600 and –340 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$, respectively. A net loss of CO_2 was instead observed in the middle of the summer, when rates of R_{eco} also peaked. We found apparent relationships between the variation of daily air temperature, soil moisture, and CO_2 fluxes on the basis of campaign mean values. The switch from average net uptake to net release of CO_2 in midseason is suggested caused by a combination of factors, including warm temperatures, drier soil conditions, and loss of biomass by mowing.

Key words: *Biebrza, chamber method, CO_2 exchange, soil moisture, wetlands*

INTRODUCTION

In view of rising atmospheric concentrations of carbon dioxide (CO_2), understanding the processes that govern different components of the carbon (C) cycle is an important area of scientific research. One outcome of such efforts is the development of methods to measure the exchange of CO_2 between terrestrial ecosystems and the atmosphere. In the context of C cycling, wetland environments are of particular interest due to their historical role as long-term sinks of atmospheric CO_2.

Carbon input to an ecosystem occurs through the process of photosynthesis. The rate of photosynthesis (CO_2 uptake) is referred to as gross primary production

(GPP). CO_2 is in turn released to the atmosphere through respiration. Here, a distinction is made between the respiration by plants (autotrophic), and respiration by microorganisms in the soil (heterotrophic), i.e. decomposition of organic matter. A collective term for the two processes is ecosystem respiration (R_{eco}). The difference between GPP and R_{eco} is referred to as net ecosystem exchange (NEE), which is the largest component of the carbon balance in greater part of ecosystems most of the time (CHAPIN III *et al.*, 2002). By measuring the direction of NEE, one can therefore determine whether a surface is a likely source or a sink of carbon.

In effect, net accumulation of carbon generally occurs in ecosystems where primary production (net photosynthesis) consistently exceeds decomposition. Due to the frequent water saturation of soils in wetlands, low oxygen levels cause slow rates of decomposition. If dead organic matter is not removed by surface water flow, over time, peat (and carbon) accumulates, resulting in the formation of peatlands (KEDDY, 2010). Nevertheless, a given peatland may shift between being a net sink and a source of CO_2, and studies show that large variations in NEE occur both within and between various sites (ROULET *et al.*, 2007). A lot of research is devoted to monitoring the variations in CO_2 exchange and understanding its major environmental controls. Several biophysical factors have been found affect flux rates, for example soil moisture (water table level), soil and air temperature, irradiation, and biomass (see LUND *et al.*, 2010 and references therein). The findings of field studies are applied in modeling of current carbon balances (e.g. ALM *et al.*, 1997; ZAMOLODCHIKOV and KARELIN, 2001), and in studying the impact of climate warming on CO_2 exchange (JOHANSSON *et al.*, 2006; TARNOCAI, 2006).

Common methods of measuring CO_2 flux are the eddy covariance (EC) and Bowen ratio energy balance (BREB) techniques. Both these systems are micrometeorological approaches to flux measurement, and the former is today in use in global monitoring networks (BALDOCCHI *et al.*, 2001). However, the equipment is very expensive and only allows for site specific measurements. Another widely used approach is the application of manual or automated chambers. A great advantage of this method is the possibility of performing spatial measurements (HOLIFIELD COLLINS *et al.*, 2008). Furthermore, by darkening the chamber and shutting off photosynthesis (GPP), one can obtain a direct estimate of R_{eco}.

The aim of the current study was to evaluate a first season of CO_2 flux measurements by chamber method in order to 1) obtain preliminary estimates of CO_2 exchange for studied peatlands, and (2) gain understanding of how CO_2 flux depended on meteorological and biophysical conditions. The study was realized as a part of the ongoing PECS project "Study and implementation of remote sensing techniques for the assessment of carbon balances for different biomasses and soil moistures within various ecosystems" and is the first report on the preliminary results. The results coming from elaboration of satellite data, which come with some delay and give the information about biomass and soil moisture, will be included in the following year. As the title implies, following steps in the project involves connecting point measurements of CO_2 flux and biophysical variables with remotely sensed data. In this way, larger-scale estimations of the spatial variability of CO_2 flux will be attempted in the area of interest.

MATERIALS AND METHODS

SITE AND MEASUREMENT DESCRIPTION

The study was performed in the area of Biebrza National Park, situated in northeastern Poland (22°30'–23°60'E and 53°30'–53°75'N). Measurements were conducted on a variety of vegetation communities with focus on open peatland ecosystems with different compositions of grasses, herbs, sedges, and mosses. A few permanently flooded sites dominated by stands of reed or sedge were also considered. Among the studied sites, only a few can be considered entirely natural ecosystems, i.e. unmanaged by local farmers or park authorities. The sites were classified based on general vegetation composition according to a classification scheme adopted from previous work in the remote sensing department in IGiK (DABROWSKA-ZIELINSKA *et al.*, 2010). In Table 1 the land use categories "semi-natural" and "natural" are also presented, as well as the total number of sites and measurement occasions in respective class. Measurements were performed once or twice a month from the end of April till mid-September in 2010. In total, 9 field campaigns were realized.

Daytime measurements of CO_2 exchange were performed by a simple static chamber method, which is based on placing a transparent chamber over the vegetation and monitoring the change in CO_2 concentration in the chamber headspace.

Table 1. Applied vegetation classes with additional information

Vegetation community class (PL)	Vegetation community class (EN)	Land use category	No. of sites	No. of CO_2 flux estimations
1. Turzyce kępowe	Tussock sedge	natural	5	10
2. Szuwar trzcinowy	Common reeds	natural	3	4
3. Szuwarowo-turzycowa	Sedge swamp	natural or semi-natural	8	17
4. Szuwar tatarakowy	Reeds	semi-natural	1	9
5. Trawiasto-zielna	Grass-herb	semi-natural	16	56
6. Turzycowo-mszysta	Sedge-moss	semi-natural	8	27
7. Trawiasto-zielno-mszysta	Grass-herb-moss	semi-natural	8	15
8. Turzycowo-trawiasta	Sedge-grass	semi-natural	4	14
9. Trawiasta	Grass	semi-natural	4	11
10. Tyrzycowo-trawiasto-mszysta	Sedge-grass-moss	semi-natural	1	3
Total			58	166

Gas concentration and air temperature was registered by a portable non-dispersive infrared (NDIR) sensor (SenseAir®, SE). The most frequently used chamber measured 40×40×35 cm, but at a few occasions a taller chamber (40×40×62 cm) was available for measurements over tall reeds. The chamber was placed on a steel base which was pressed into the peat soil. Air leakage was prevented by pouring water into a groove in the base, and a fan was arranged in the chamber, allowing for air mixing. Under light conditions, net ecosystem exchange (NEE) was measured, immediately followed by a measurement of ecosystem respiration (R_{eco}) after darkening of the chamber. Each measurement lasted 6–10 minutes. CO_2 flux was only measured in daytime, between 9:00–17:00. During some campaigns, two simultaneous replications of the measurement were performed with the use of a second chamber, in which case, the mean of the obtained exchange rates was used in analysis.

At the point sites of CO_2 flux measurement, the following biophysical variables were also considered: volumetric soil moisture (*SM*) measured by TDR at between 5 and 15 cm depth (TRIME-FM, IMKO, Germany), leaf area index (LAI) measured with LAI-2000 Plant Canopy Analyzer (LI-COR, USA), vegetation height, and biomass (dried before weighing). Daily meteorological data was obtained from a stationary weather station by Biebrza Village maintained by the IMUZ research unit in Biebrza. Additional data from temporary stations within the park was provided by researchers from Warsaw School of Life Sciences (SGGW).

CALCULATIONS AND DATA ANALYSIS

CO_2 exchange rate was estimated by assuming a model of the relation between time and registered gas concentration. We applied the common linear model suggested in LIVINGSTON and HUTCHINSON (1995):

$$f = \frac{V}{A}\frac{dCO_2}{dt} \tag{1}$$

where:

- V – the volume of chamber headspace,
- A – the surface area covered by the chamber,
- dCO_2 – the change in concentration,
- dt – the time increment,
- f – the gas flux, ppm·m^{-2}·min^{-1}.

In order to convert the estimated flux rate from mixing ratio (expressed in ppm) to mass units the ideal gas law was used:

$$10^{-3} f \frac{MP}{R(273.15+T)} \tag{2}$$

where:

M – the molar mass of CO_2,
P – air pressure,
R – the gas constant,
T – the air temperature, °C.

P was assumed to be equal to standard atmospheric air pressure and constant.

Gross primary production (GPP) was estimated as the difference between NEE and R_{eco}. In this study negative flux rate is defined as net flow of CO_2 from the atmosphere to the ecosystem, i.e. gain of CO_2 by the ecosystem.

The linear (or close to linear) part of the CO_2 concentration slope of a measurement was used for the above calculation of flux rate, and the credibility of individual measurements were assessed manually. Measurements were sometimes performed during unstable solar irradiance conditions (overcast or varying cloud cover), causing fluctuation in flux rates and non-linearity in the registered CO_2 concentration time series. In such cases, a relatively long time increment (up to 12 min) of the measurement was considered. After processing of the CO_2 flux data, point measurements were excluded if either NEE or R_{eco} were considered likely to be erroneous.

Seasonal means of CO_2 fluxes and measured environmental variables were compared between two groups of merged vegetation community classes. The differences were evaluated by *t*-test for independent samples. Furthermore, the temporal (seasonal) variation of NEE and ecosystem respiration was evaluated with regards to changes in observed environmental conditions. For this, regression analysis was applied considering mean values of the respective campaigns. Calculations and data analyses were performed in Microsoft Excel and Statistica.

RESULTS

METEOROLOGICAL DATA AND ENVIRONMENTAL CONDITIONS

Accumulated precipitation from April through September amounted to 511 mm. The most rain intensive period was late spring, which was followed by dryer conditions in connection with increasing temperatures till the end of July (Fig. 1).

Meteorological data and two of the measured variables for individual campaign periods are presented in Table 2. The seasonal variability of soil moisture seems to conform with the observed patterns of precipitation and air temperature. From July till September, the gradual increase in *SM* was probably directly related

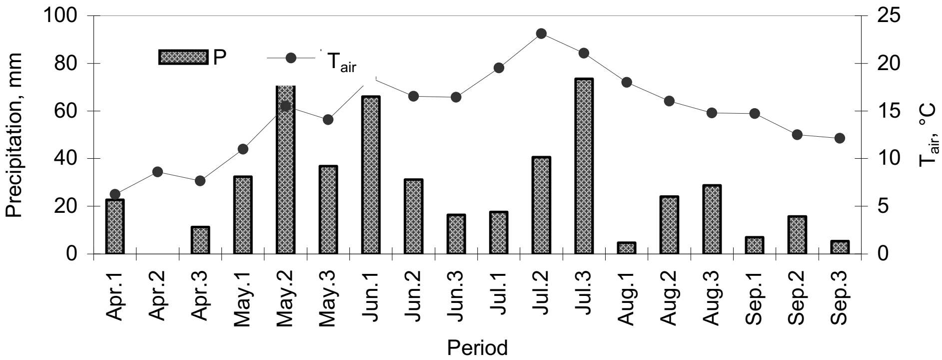

Fig. 1. Mean daily air temperature and accumulated precipitation on a 10-day basis, April through September, 2010 (from Biebrza weather station, IMUZ)

Table 2. Meteorological data and field measurements

Campaign	Dates of CO_2 flux measurements	Biebrza station			Nowy Lipsk and Gugny stations	Field measurements		
		daily T_{air} °C	precipitation mm	sun hours $h \cdot d^{-1}$	solar irradiance $\mu mol \cdot m^{-2} \cdot s^{-1}$	LAI	*SM* %	No. of CO_2 flux estimations
1	29 Apr–1 May	12.9	6.6	3.1	–	1.4	65.4	19
2	13–14 May	17.1	9.6	5.4	234	3.5	77.8	4
3	24–26 May*	9.7	4.5	8.7	477	3.5	77.4	12
4	18, 20–21 Jun	15.1	15.7	5.8	621	–	–	18
5	26 Jun–1 Jul*	18.6	0.0	14.1	648	3.5	60.5	33
6	11–14 Jul	23.0	29.2	10.3	606	4.4	51.4	14
7	4–7 Aug	19.2	0.0	8.5	470	4.1	57.7	17
8	23–27 Aug*	15.0	4.9	9.4	273	4.1	65.1	29
9	16–18 Sep	13.1	0.0	7.8	197	4.4	83.1	13

* For these campaigns, one date, on which only one flux measurement was performed, was excluded from the Biebrza data.

to the corresponding decrease in mean daily air temperature. Solar irradiance (at the time of measurements) rises, peaks, and decreases smoothly in accordance with seasonal progression. The differences in mean daily sun hours and precipitation illustrate the varying weather conditions between the periods of CO_2 flux measurement.

With exception of the first low value, average LAI did not vary much throughout the season (Tab. 2). Seasonal changes in the canopy were instead observed with regards to dry weight biomass and vegetation height (data not shown).

The last column presents number of CO_2, LAI and *SM* measurements during each of the campaigns.

CO_2 FLUX ESTIMATIONS

The observed seasonal variation of daytime NEE, R_{eco}, and calculated GPP with regards to the realized measurement campaigns is displayed in Fig. 2. Considering the season as a whole, the studied peatlands had an average net exchange rate of –156 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$. Point measurements of NEE ranged from –1491 to 1792 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$, and R_{eco} from 57 to 4900 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$. According to the results, the largest CO_2 uptake occurred during the campaigns in May and September. Average NEE measured in these periods approximate –600 and –340 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$, respectively. A net release of CO_2 was instead observed during peak summer (campaigns 5 and 6), when average NEE was 223 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$. The highest rates of R_{eco} were observed in the same period. Measured average R_{eco} was then equal to 2552 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$. With exception of an early spring maximum (campaign 2), the seasonal pattern of calculated GPP followed a flat bell-shaped curve, which culminated during the two midseason campaigns.

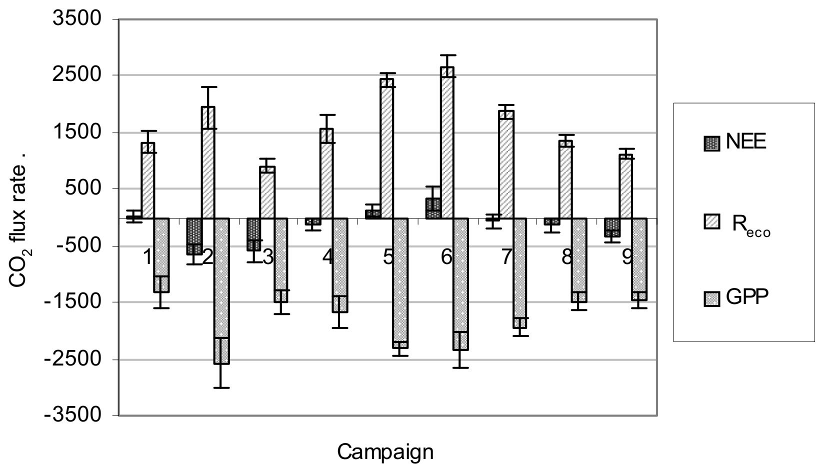

Fig. 2. NEE, R_{eco}, and calculated GPP across the growing season.
The values are campaign means ± standard error expressed in mg $CO_2 \cdot m^{-2} \cdot h^{-1}$

EFFECT OF ENVIRONMENTAL CONDITIONS ON CO_2 FLUXES

Significant differences in mean seasonal flux and environmental conditions were found between two groups of peatland habitats (Tab. 3). The results shows that

Table 3. NEE, R_{eco}, and GPP (in mg $CO_2 \cdot m^{-2} \cdot h^{-1}$) and the environmental variables soil moisture *SM*, dry weight biomass and LAI for two groups of merged vegetation community classes; the values are seasonal means ± standard error

Group	Vegetation communities	NEE	Ecosystem respiration	GPP	*SM* %	Biomass g	LAI
A	grass-herb grass	–61 ± 71	1978 ± 117	–2040 ± 118	56,0 ± 2,1	243 ± 18	3,6 ± 0,21
B	sedge swamp sedge-moss sedge-grass-moss	–173 ± 74	1470 ± 95	–1643 ± 119	73,2 ± 2,4	320 ± 25	3,9 ± 0,25

sedge-dominated habitats (group B) had lower rates of R_{eco} ($p < 0.01$) and lower average GPP ($p < 0.05$) than habitats characterized by grasses and herbs (group A). The former group was associated with wetter soil conditions ($p < 0.001$) and slightly larger biomass ($p < 0.05$). Mean seasonal NEE was also lower (larger net uptake of CO_2) in group B, however the difference is not statistically significant.

With regards to temporal variation, a strong positive correlation was found between ecosystem respiration and daily air temperature (Fig. 3a). Large fluctuation in air temperature was observed during the spring (campaigns 1–4), and R_{eco} varied accordingly. A relationship was also discerned between air temperature and NEE, in which case increasing average daily temperatures were associated with a decrease in net CO_2 uptake (NEE). However, the two earliest spring flux values deviate from this trend (Fig. 3b). A large part of the seasonal variation of NEE seems to be explained by that of ecosystem respiration ($R^2 = 0.92$, $n = 7$).

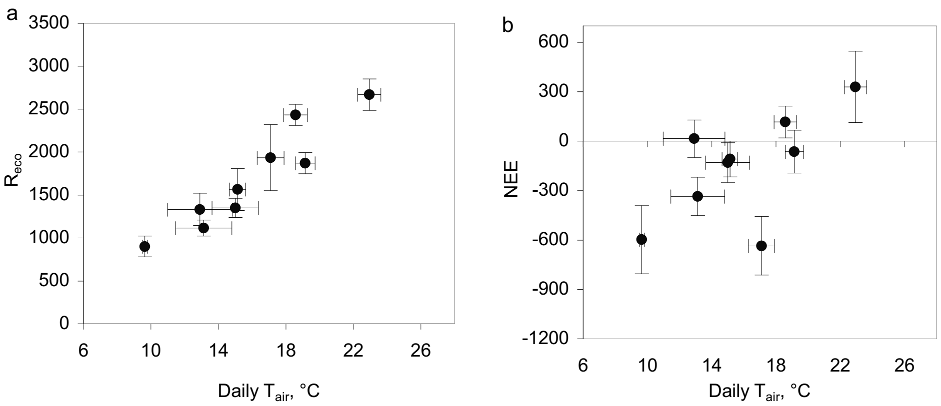

Fig. 3. Ecosystem respiration (a) and NEE (b) plotted as a function of daily air temperature (campaign means ± standard error); the fluxes are in mg $CO_2 \cdot m^{-2} \cdot h^{-1}$; least-square regression lines are not drawn, however $R^2 = 0.89$, $n = 9$ for (a), and $R^2 = 0.42$, $n = 9$ for (b)

Both NEE and R_{eco} also appeared related to the average soil moisture conditions during a given campaign (Fig. 4). The indication that R_{eco} is dependent on *SM* was consolidated through an alternative data analysis, in which individual site flux measurements were grouped and averaged by categories of soil moisture level. In this way, the "averaging process" was not steered by campaign (time) or site (location). The result is an apparent negative correlation – the rate of R_{eco} decreases as soil moisture increases (not shown). By contrast, the trend suggests that net uptake of CO_2 (NEE) increased with wetter soil conditions (Fig 4b).

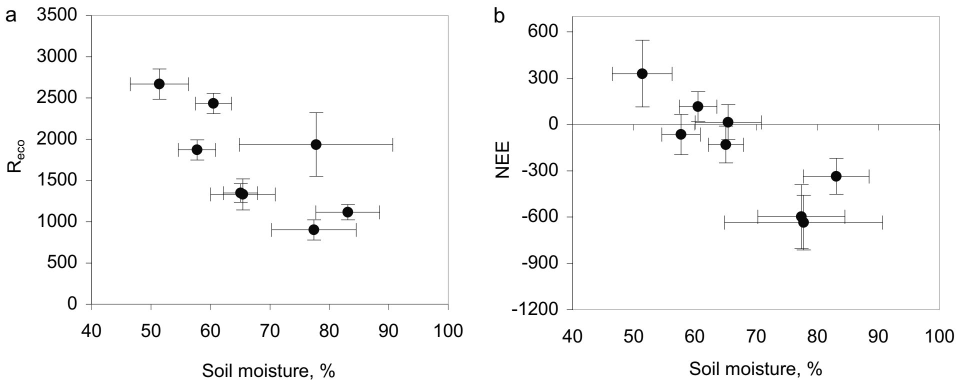

Fig. 4. Ecosystem respiration (a) and NEE (b) plotted as a function of soil moisture (campaign means ± standard error); the fluxes are in mg $CO_2 \cdot m^{-2} \cdot h^{-1}$; least-square regression lines are not drawn, however $R^2 = 0.52$, $n = 8$ for (a), and $R^2 = 0.77$, $n = 8$ for (b)

In the current data set, no apparent relationships were found between CO_2 fluxes and dry weight biomass or LAI across the growing season.

DISCUSSION

The observed range of net CO_2 exchange rates (NEE) is comparable to previous chamber measurements reported for a peatland ecosystem in western Poland (CHOJNICKI *et al.,* 2010). Ecosystem respiration, on the other hand, reaches considerably higher maximums in the current study. This could be due to differences in site properties as well as meteorological conditions. According to a review of tower measurements of CO_2 balance (EC technique) at 12 different northern peatland sites, the largest net uptake of CO_2 typically occurred during peak growing season (LUND *et al*., 2010). Our results show the opposite, an average net release of CO_2 during midseason (represented by campaigns 5 and 6). This implies that R_{eco} at the time exceeded GPP.

The campaigns in question were associated with the highest daily air temperatures and relatively dry soil conditions, which seems to explain the observed peak in ecosystem respiration. The found correlation between R_{eco} and air temperature goes in line with previous findings (CHOJNICKI *et al.,* 2010; ZAMOLODCHIKOV *et al.,* 2000). However, since the pattern of T_{air} is coupled to time of season, the influence of other seasonally dependent factors, such as soil temperature and plant development stage, is likely embedded in this relationship.

NEE is also found correlated to daily T_{air}, although, the average flux rate of the second campaign (realized 13–14 May) clearly diverts from the general trend (Fig. 3b). During this campaign, CO_2 exchange was only measured in four peatland sites (see Tab. 2), which makes the mean value spatially unrepresentative and biased. The lesser diversion of the earliest campaign (realized 29 April – 1 May), can be explained by sparse vegetation growth at the time, confirmed by the low values of biomass and LAI. Campaign 2 also deviates from the trend in terms of the relationship between R_{eco} and soil moisture (Fig 4a).

A decrease in net CO_2 uptake in the middle of the growing season was previously observed in peatland sites in Finland (ALM *et al*., 1997) and southern Sweden (LUND *et al*., 2007). In both studies, lower CO_2 uptake in July was attributed to drier conditions observed in terms of decreasing water table (*WT*) and soil moisture. LUND *et al*. (1997) suggested that warmer temperatures (air and soil) increased respiration, while soil drying lowered GPP by inducing plant water stress (primarily in *Sphagnum* mosses). ALM *et al*. (1997) found that in sites with larger fluctuations in water table, respiration increased with increasing depth of *WT*. Our results seem to indicate that the trend towards average net loss of CO_2 in summertime could be explained by similar causes and effects, involving the influences of air temperature and soil moisture. However, more than one season of measurements is required to better ascertain these initial results.

As one of the components of NEE, the seasonal dynamics of plant productivity must be considered closer. We do not have a direct and independent measure of plant productivity, but in comparison to other studies, we find that our observations of NEE and R_{eco} give a gross primary production with an unusually flat seasonal gradient and unpronounced peak in July. In addition, the results indicate that R_{eco}, rather than GPP, acted as the more dominant flux component with larger impact on the variation of NEE. AURELA *et al.* (2009) suggested that, on a monthly scale, physiological state was the most important determinant of the photosynthetic capacity of vegetation (in studied fens). In the case of Biebrza peatlands, apart from possible negative impact by warm and dry conditions, an additional explanation to why plant productivity may have been suppressed in midseason is the impact of anthropogenic management. During all campaigns, with exception of campaign 2, between 60–70% of the flux measurements were performed in sites that are mowed consistently every year. It was noticed that reduction of biomass by mowing visibly affects average rates of CO_2 flux for a given period. The following simple scenario is suggested: immediately after mowing, the reduction of biomass causes a drastic decrease in photosynthetic capacity (i.e. GPP), and consequently, a net ecosystem release of CO_2. In the recovering canopy, the emerging new vegetation gradually increases its GPP, which eventually leads to a return to net uptake of CO_2. A drop in biomass in the June and July campaigns corresponds with the shift from net uptake to net release of CO_2.

With regards to variation in seasonal CO_2 exchange between peatland sites, close correspondence to biomass (STROM and CHRISTENSEN, 2007) and LAI (LUND *et al.*, 2010; AURELA *et al.,* 2009) have been reported. Higher values of the canopy variables were associated with higher NEE (net CO_2 uptake). Furthermore, BONNEVILLE *et al.* (2008) found strong correlations between aboveground live biomass, green LAI, and average NEE over a growing season in a cattail marsh (*Typha angustifolia*). In the current study, the absence of such relationships is suggested a possible artifact of shortcomings of the data set, which are due to inconsistencies and complications in the realization of the field measurements. The limited variation of LAI observed between campaigns could for example be due to the bundling (averaging) of measurements from different vegetation communities. The changing number and composition of measurement sites from one campaign period to another (see Table 3) is one important example of a data set constraint. In effect, the presented temporal variation of average ecosystem properties and fluxes is spatially inconsistent, i.e. for each campaign the mean values do not represent the same "surface". It remains unclear to what extent inconsistencies and potential measurement artifacts biases the outcome of the data analyses.

Another limitation of the obtained CO_2 flux data is the effect of variation in irradiance. The rate of net photosynthesis by leaves is dependent on solar irradiance, more precisely, the level of photosynthetically active radiation (PAR). In the current study, solar irradiance was not monitored during flux measurements, and for practical reasons, no consideration was taken to significant changes in irradiance between measurements in different sites.

CONCLUSIONS

A first season CO_2 flux measurement by chamber method has been conducted in peatland habitats in Biebrza National Park. The range of NEE is consistent with previous observations in Poland, which implies that the applied measurement method is a useful approach to C balance assessment.

Preliminary results point at daily air temperature and soil moisture being important controls of CO_2 flux. Mean net release of CO_2 observed in the middle of the growing season coincided with warm and relatively dry conditions. It is likely that the prevailing weather conditions during this period was a major cause of net CO_2 release. In general, we find that the temporal variation of R_{eco} seems to have governed NEE to a larger extent than GPP did. By reducing primary production, loss of biomass by mowing appears to be an additional explanatory factor to the observed seasonal variation of NEE.

Measurements will be continued in 2011 and we anticipate that an additional season of data will be valuable for validation purposes, and improve the prospect of reaching more conclusive results. Elaborated satellite data will give spatial information about soil moisture and biomass, which will give proper results of CO_2 flux.

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STRESZCZENIE

Pomiary strumienia wymiany CO_2 w różnych siedliskach bagiennych Biebrzańskiego Parku Narodowego

Słowa kluczowe: *bagna, Biebrza, metoda kloszowa, wilgotność gleby, wymiana CO_2*

Bagna od zawsze stanowiły naturalny rezerwuar atmosferycznego dwutlenku węgla (CO_2). Dlatego właśnie zrozumienie procesów kształtujących zmiany przepływów strumienia CO_2 w czasie i przestrzeni jest niezbędne do szacowania aktualnego bilansu węgla, jak również do analizy jego wpływu na proces globalnego ocieplenia w przyszłości. Artykuł prezentuje wstępne wyniki pomiarów strumienia dwutlenku węgla siedlisk bagiennych Biebrzańskiego Parku Narodowego. Celem przeprowadzonych analiz było uzyskanie wyników pomiarów wymiany strumienia CO_2, przeprowadzonych w pierwszym sezonie pomiarowym (2010 r.), jak również ocena zależności istniejących między strumieniem wymiany CO_2 a warunkami meteorologicznymi i biofizycznymi. Pomiary wymiany strumienia netto (NEE) oraz respiracji ekosystemu (R_{eco}) przeprowadzane były w ciągu dnia, z zastosowaniem metody kloszowej, w okresie: od końca kwietnia do września 2010 r. Metoda polegająca na zastosowaniu przezroczystych kloszy ustawionych nad roślinnością, umożliwia obserwację zmian koncentracji CO_2 emitowanego i pochłanianego przez roślinność i glebę. Dodatkowo wykonywano pomiary: wilgotności gleby, powierzchni projekcyjnej liści (LAI) oraz wysokości roślin, a także wielkości bioma-

sy. Średnia sezonowa wartość NEE dla badanych obszarów bagiennych wyniosła – 156 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$ (wartość ujemna oznacza, że ekosystem pochłaniał więcej CO_2 niż go emitował). Zaobserwowano, że proces pochłaniania CO_2 jest najintensywniejszy w okresie wiosny i wczesnej jesieni. Średnia wartość NEE dla tych okresów wynosiła odpowiednio –600 i –340 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$. Zwiększenie wydzielania CO_2 zaobserwowano w środku lata, kiedy wartości respiracji ekosystemu również uzyskiwały maksymalne wartości. Zauważono widoczne zależności między zmianami temperatury powierza w ciągu dnia, wilgotności gleby oraz strumieniem przepływu CO_2 na postawie średnich wartości otrzymanych z kampanii terenowych. Stwierdzono, że większa emisja CO_2 w środku lata spowodowana jest działaniem grupy czynników, takich jak: wyższa temperatura powietrza, mniejsza wilgotność gleby, a także mniejsza ilość biomasy (koszenie).

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