Volume 52(1):213-216, 2008
Acta Biologica Szegediensis
http://www.sci.u-szeged.hu/ABS

ARTICLE

The measurement of yearly C-, N- and CH_4 balance in characteristic Hungarian wetland ecosystems. Preliminary results

Szilárd Czóbel[1]*, László Horváth[2], Tibor Szerdahelyi[1], János Nagy[1], Orsolya Szirmai[3], Bernadett Gál[1], Dániel Cserhalmi[1], Gábor Fogarassy[1], Zsolt Ürmös[1], Evelin Ramóna Péli[3], Balázs Grosz[4]

[1]Institute of Botany and Ecophysiology, Szent István University, Gödöllő, Hungary, [2]Hungarian Meteorological Service, Budapest, Hungary, [3]"Plant Ecology" Research Group of Hungarian Academy of Sciences, Institute of Botany and Ecophysiology, Szent István University, Gödöllő, Hungary, [4]Institute of Chemistry, Eötvös Loránd University, Budapest, Hungary

ABSTRACT Wetlands macro-vegetation plays an important role in bio-filtration processes. Global warming is anticipated to modify many water ecosystems of the Earth. In submerged plants especially, the photosynthetic rate may be limited by a low availability of dissolved inorganic carbon. Our study demonstrates one of the first results for stand Net Ecosystem CO_2 Exchange (NEE) rates for characteristic European aquatic vegetation types based on in situ measurements. To measure NEE of aquatic (floating and submerged) associations at stand level a self-developed, portable, floating open chamber system (d=60cm) was used. Soil fluxes of methane and nitrous oxide were also determined for different wetland ecosystems representing a moisture gradient in Bodrogköz wetlands. As the direction of N_2O and methane fluxes (emission or uptake) depends on the soil water content characteristics bi-directional fluxes were observed. Our study demonstrated, based on production analyses and NEE measurements, that from the carbon-dioxide point of view the lakes and streams characterized by significant living plant biomass can be counted as a carbon sequester on a yearly horizon due to the intensive carbon sequestration of submerged and floating vegetations. The majority of examined fluxes and parameters varied considerably among the studied years.
Acta Biol Szeged 52(1):213-216 (2008)

KEY WORDS

wetland
carbon-dioxide
methane
nitrous oxide
measurement, balance

Wetlands are valuable ecosystems that occupy about 6% of the world's land surface or a minimum of 12 million km^2. They comprise both land habitats that are strongly influenced by water and aquatic ecosystems with special characteristics due to shallowness and proximity to land (Roggeri 1995; Finlayson et al. 1999).

Two per cent of the total territory of Hungary is wetland. There is an intensive exchange of greenhouse gases within the atmosphere and the biosphere including wetlands. Among them, most important greenhouse gases are the carbon dioxide (CO_2) the methane (CH_4) and the nitrous oxide (N_2O) (Tuba 2005). Carbon dioxide exchange between Hungarian grass and forest ecosystems and atmosphere has already been studied (Czóbel et al. 2005a; Nagy et al. 2007; Németh et al. 2008). Beside carbon dioxide nitrous oxide (N_2O) and methane (CH_4) play also important role in the growing greenhouse effect. Though atmospheric concentrations of N_2O and CH_4 are much lower than that of CO_2, global warming potential of N_2O and CH_4 is approximately 298 and 25 times higher, respectively, compared to the CO_2. Their share in the radiation forcing are 17 and 5 per cent, respectively (IPCC 2001).

Methane (CH_4) is produced in the soils by decomposition of organics by bacteria under anaerobic conditions. Methane production is controlled by C-mineralization, reduction of alternative (to oxygen) terminal electron acceptors and the dynamics of methanogenic activity (Segers 1998). The main regulator of soil methane production is the anaerobic carbon mineralization (Segers and Kengen 1998). Beside the gas diffusion controlled by the structure and wetness of the soil, the methane decomposition depends also on temperature, organic N-content and organic matter content (e.g. Crill et al. 1994; Bodelier and Laanbroek 2004).

Two mechanisms are responsible for nitrous oxide (N_2O) production in soils the nitrification (as an aerobic process) and dominantly the denitrification (in anaerobic condition; e.g. Butterbach-Bahl et al. 1997; Knowles 2000). Nitrous oxide is one of the intermediate gaseous products (NO, N_2O, N_2) of these processes that can be volatilised from soils. Most important parameters controlling the soil production and emission of N_2O are the aeration, the organic N-content and the pH

*Corresponding author. E-mail: Czobel.Szilard@mkk.szie.hu

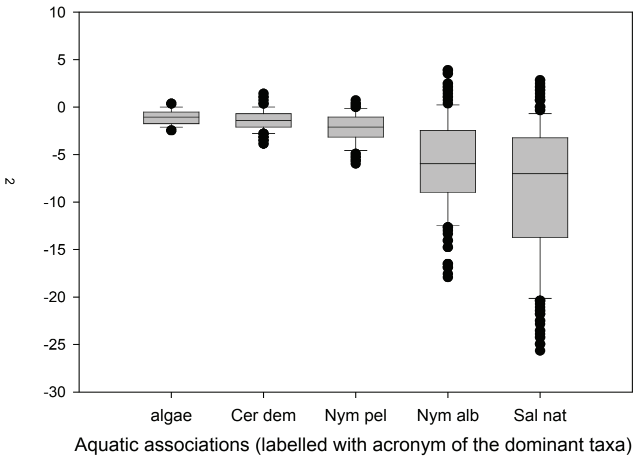

Figure 1. Net Ecosystem CO_2 Exchange of selected submerged, rooted and floating aquatic plant communities of Füred ox-bow, Hungary (Tiszafüred, 2004 September). Acronyms indicate the dominant plant species of the communities.

(e.g. Granli and Bøckmann 1994; Vor et al. 2003) and the temperature. The ratio of different intermediate products (NO, N_2O, N_2) varies depending on the soil water content (SWC). In dry, well aerated soils the production of NO, in soils with medium-high water content the production of N_2O while in saturated soils the N_2 production dominates (Davidson 1991). According to newer findings the soil may also be a sink for N_2O (Chapuis-Lardy et al. 2007).

Our aim was to measure the net fluxes and estimate the yearly balance of these greenhouse gases above different wetland ecosystems of Bodrogköz and Füred oxbow (for NEE) in Hungary.

Materials and Methods

Study sites and vegetation description

The first in situ NEE measurements was conducted at a large dead channel of River Tisza, called Füred ox-bow (Hungary, 44°38'N, 20°45'E), near Tiszafüred in 7th and 8th of September, 2004. The selected aquatic communities were the fast-growing Salvinio-Spirodeletum, the macrophytes dominated Ceratophyllo-Nymphaeetum albae, Nymphoidetum peltatae and the dense community submerged Ceratophylletum demersi.

Parallel with biomass collection NEE measurements were episodically also carried out in 8 distinct plant communities (Salvinio-Spirodeletum, Nymphaeetum albo-luteae, Trapetum natantis, Lemno-Utricularietum, Ceratophylletum demersii, Hydrocharitetum morsus-ranae, Stratiotetum aloidis) of the Hungarian Bodrogköz (Tuba 1995). The measurements were conducted in Ó-Bodrog and Kengyel oxbow and in Török channel in 2006 and 2007.

Soil fluxes of methane and nitrous oxide were determined for five different plant communities (Senecioni sarracenci-Populetum albae, Fraxino pannonicae-Ulmetum, Circaeo-Carpinetum, Typhetum latifoliae, Elatinetum alsinastri) in Bodrogköz, Hungary. This paper show the first methane and N_2O flux results measured in 2006.

Applied methods

Stand level CO_2-flux measurements were carried out episodically during the vegetation period using chamber technique operating in open system and Ciras 2 and LCA2 ADC infrared gas-analysers (See Czóbel et al. 2005b). Percent cover for each species within the chamber was estimated using the relevé method (Mueller-Dombois and Ellenberg 1974; Van Der Maarel 1979). The biomass was removed (in minimum three replications) at peak biomass after the intensive growing period in August and October.

Soil N_2O and CH_4 flux samplings were carried out by 5-10 parallel static soil chambers with a constant height of h=5 cm. Samples were taken at t=0 and 30 min. after closure of the chambers by syringe into evacuated vials. Concentration changes in chambers in half an hour of samplings after closure were determined by gas chromatography-mass spectrometry and gas chromatography-electron capture detector (GC-ECD), for nitrous oxide and methane, respectively.

Results

Carbon balance and related measurements

The yearly estimated carbon balance of the studied aquatic vegetation based on mainly biomass data was 109 gC m^{-2} $year^{-1}$, with significant standard deviation (71 gC m^{-2} $year^{-1}$). This value based on production data of rooted, submerged and floating communities. The lowest value of mass and carbon content of biomass per unit face area was found in submerged vegetation while the highest of these occurred in rooted aquatic vegetation. The calculated average value fits to the range, which were measured in European (including Hungarian) grasslands by eddy covariance technique. However, the growing season of the Pannonian aquatic vegetation is much shorter than the Hungarian and temperate grasslands, thus their significant C-fixation potential is remarkable. Despite the well known fact, that in contrary with grassland ecosystems the aquatic vegetation were not affected by water deficit stress our NEE measurements showed that high temperature stress (35°C<) also decreased the carbon sink activity of floating vegetations. It follows that a part of sequestered carbon could disappear during heat summer periods similarly to grasslands.The mean and maximal C-uptake of characterictic aquatic vegetation patches dominated by different plant taxa could differ significantly. Under similar and near optimal circumstances T_{water} <20°C, T_{air} 20 – 30°C) the NEE value of submerged plant community (dominated by *Ceratophyllum*

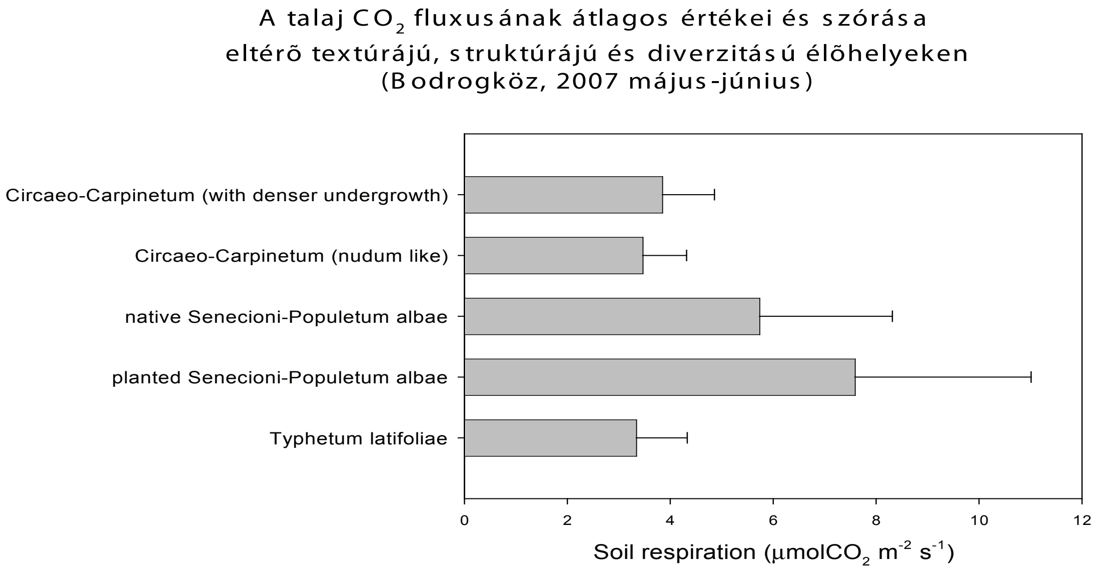

Figure 2. Soil respiration of different wetland habitats (Bodrogköz, 2007 May & June).

and *Utricularia*) ranged between -1 and -2 µmol CO_2 m^{-2} s^{-1}: The same parameter ranged between -5 és -15 µmol CO_2 m^{-2} s^{-1} in floating (*Salvinia*) and rooted (*Nuphar*, *Nymphaea*) vegetations.

Mainly the reduced ligh conditions resulted the mentioned difference, which characterizing the submerged taxa. The measured mean NEE rates show similar values (Fig. 1) than other mesoscale studies related to wetland CO_2 flux measurements (Larcher 2001). The Pmax rate of the measured floating and submerged associations in the same range (Fig. 1) as found in other studies based on other indirect methods (see e.g. Larcher 2001). The similarity of NEE values and its range provide further evidence for the reliability of this technique. There was no significance difference between the average NEE and production data (per unit) of lower and higher plants due to the similar leaf area and presumably the number of pigment-protein complexes. The year to year variation of NEE in aquatic ecosystem was limited because of the near similar and stable circumstances.

The average yearly soil CO_2 respiration was 624 tC km^{-2} $year^{-1}$ (standard deviation: 185 tC km^{-2} $year^{-1}$) in non-arborescent and 963 tC km^{-2} $year^{-1}$ (standard deviation 232 tC km^{-2} $year^{-1}$) in forested (including both hard- and soft-wood associations) vegetations. During the summer drought the intensity of soil respiration decreased in most vegetation types (by 28-61%) compared to spring values. Lower soil respiration average but higher standard deviation characterized the waterside herbaceous vegetation compared to woody communities. The soil respiration values of temporarily occurring Nanocyperetalia community (Elatinetum alsinastri) was higher than other more stable herbaceous communities (Glicerietum maximae, Typhetum latifoliae) characterized by less intensive dynamics, even at smaller SWC. In case of woody vegetations the average and standard deviation of soil CO_2 respiration of soft-wood community (5,48 – 7,59 µmolCO_2 m^{-2} s^{-1}) /dominated by Poplars/ were higher in late spring and summer periods than observed in the more closed hardwood community (3,47–5,13 µmolCO_2 m^{-2} s^{-1}) /Fig. 2./.

Estimated yearly N and CH_4 balance and its variability

Average soil nitrous oxide emission flux of the examined sites and for the period of 2006 was 0.8 µg N m^{-2} h^{-1} and varied between -3 and 5 µg N m^{-2} h^{-1} in different plant communities. These weak values indicate that bi-directional nitrous oxide fluxes can be observed in Hungarian wetland soils. The average N_2O emission of non arborescent associations characterized by higher seasonal variability slightly exceeded the forested communities. The highest soil nitrous oxide emission was observed in the first part of the growing season, during the early summer period (June-July) in most studied vegetation type.

Methane flux varies within a wide range of -30 to 40 µg CH_4 m^{-2} h^{-1}, thus similarly to N_2O bi-directional methane fluxes was observed in wetland soils of Bodrogköz. The magnitude and the direction (emission or uptake by soil) strongly depend on the soil moisture (SWC) and on the temperature. Data show that wetland soils not just source of methane but are able to sink it in certain circumstances. Uptake can be observed at high soil moisture (50%<). Below 5% of SWC the methane uptake inhibited by the water stress for methanotroph bacteria. Average soil methane emission flux of the examined sites and for the period of 2006 was 2 µg CH_4 m^{-2} h^{-1}. Average values show weak CH_4 source activity (4,96 kg C-CH_4 km^{-2} $year^{-1}$) in non-arborescent habitats in contrary with similarly weak methane sink (-3,11 kg C-CH_4 km^{-2} $year^{-1}$) in wetland forests. Both the highest methane flux emission and seasonal variability was observed in Elatinetum alsinastri community where after the peak methane emission period (June) the measured values decreased continuously parallel with the decreasing soil water content. From September 2006 till the end of the growing season this area turned to methane sink. The smallest seasonal variability for methane was found int he hardwood forests (Circaeo-Carpinetum).

Acknowledgements

The study was supported by the national KLIMAKKT and by the international NitroEurope IP (017841-2) project.

References

Bodelier PLE, Laanbroek HJ (2004) Nitrogen as a regulatory factor of methane in soils and sediments. Nitrogen as a regulatory factor of methane oxidation in soils and sediments. FEMS Microbiol Ecol 47:265-277.

Butterbach-Bahl K, Gasche R, Breuer L, Papen H (1997) Fluxes of NO and N_2O from temperate forest soils: Impact of forest type, N deposition and of liming on the NO and N_2O emissions. Nutr Cycl Agroecosys 48:79-90.

Chapuis-Lardy, Wrage LN, Metay A, Chottes J-L, Bernoux M (2007) Soils, a sink for N_2O? A review. Global Change Biol.13:1-17.

Crill PM, Martikainen PJ, Nykanen H, Silvola J (1994) Temperature and N-fertilization effects on methane oxidation in a drained peatland soil. Soil Biol Biochem 26:1331-1339.

Czóbel Sz, Fóti Sz, Balogh J, Nagy Z, Bartha S, Tuba Z (2005a) Scale analysis in grassland vegetation. A novel approach. Photosynthetica 43:267-272.

Czóbel Sz, Balogh J, Szirmai O, Tuba Z (2005b) Floating chamber a potential tool for measuring CO_2 fluxes of aquatic plant communities. Cer Res Comm 33:165-168.

Davidson EA (1991) Fluxes of nitrous oxide and nitric oxide from terrestrial ecosystems. In Roger JE, Whitman WB eds., Microbial production and consumption of greenhouse gases: Methane, nitrogen oxides and halomethanes. Am Soc Microbiol Washington DC., pp. 219-235.

Finlayson CM, Davidson NC, Spiers AG, Stevenson NJ (1999) Global wetland inventory – current status and future priorities. Marine Freshwater Res 50:717-727

Granli T, Bøckmann OC (1994) Nitrous oxide from agriculture. Norw J Agric Sci 12:1-128.

IPCC (2001) Intergovernmental Panel on Climate Change (IPCC): The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge Univ. Press, New York, 2001. pp. 944.

Knowles R (2000) Nitrogen cycle. In: J. Lederberg (ed): Encyclopedia of Microbiology vol. 3, 2nd ed. Academic, San Diego, Calif. pp. 379-391.

Larcher W (2001) Ökophysiologie der Pflanzen. Verlag Publisher, Stuttgart.

Mueller-Dombois D, Ellenberg H (1974): Aims and Methods of Vegetation Ecology. John Wiley & Sons, New York Chichester Brisbane Toronto. pp. 45-66.

Nagy Z, Pintér K, Czóbel Sz, Balogh J, Horváth L, Fóti Sz, Barcza Z, Weidinger T, Csintalan Zs, Dinh NQ, Grosz B, Tuba Z 2007. The carbon budget of semi-arid grassland in a wet and dry year in Hungary. Agric Ecosys Environ 121:21-29.

Németh Z, Nagygyörgy ED, Czóbel Sz, Péli ER, Szirmai O (2008) Changing soil respiration in a geophyte-rich Pannonian forest from snowmelt until peak leafing. Cer Res Comm 36:1967-1970.

Roggeri H (1995) Tropical freshwater wetlands. Kluwer Academic Publishers. London

Segers R (1998) Methane production and methane consumption: a review of process underlying wetland methane fluxes. Biogeochem 41:23-51.

Segers R, Kengen SWM (1998) Methane production as a function of anaerobic carbon mineralization: a process model. Soil Biol Biochem 30:1107-1117.

Tuba Z (1995) Overview of the flora and vegetation of the Hungarian Bodrogköz. Tiscia 29:11-17.

Tuba Z (2005) Ecological Responses and Adaptations of Crops to Rising Atmospheric Carbon Dioxide. Haworth Press Inc., New York, USA, p. 414.

Van Der Maarel E (1979) Transformation of cover-abundance values in phytosociology and its effects on community similarity. Vegetatio 39: 97-114.

Vor T, Dyckmans J, Loftfield N, Beese F, Flessa H (2003) Aeration effects on CO_2, N_2O, and CH_4 emission and leachate composition of a forest soil. J Plant Nutr Soil Sci 166:39-45.