Volume 52(1):119-122, 2008
Acta Biologica Szegediensis
http://www.sci.u-szeged.hu/ABS

ARTICLE

Measurement of methane and nitrous oxide fluxes in Bodrogköz, Hungary; preliminary results

László Horváth[1]*, Balázs Grosz[2], Szilárd Czóbel[3], Zoltán Nagy[3], Evelin Péli[4], Tibor Szerdahelyi[3], Orsolya Szirmai[4], Zoltán Tuba[3,4]

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

ABSTRACT Soil fluxes of methane and nitrous oxide were determined for five different plant communities in Bodrogköz, Hungary. As the direction of methane flux (emission or uptake) depends on the soil characteristics (mostly on soil moisture) bi-directional fluxes were observed in 2006 and 2007, the sink and source processes were practically balanced. Average soil nitrous oxide emission fluxes for the period of 2006-2007 was 1.2 μg N m^{-2} h^{-1} for tall vegetation while for low vegetation it was 2.4 μg N m^{-2} h^{-1}. Taking into account the total atmospheric N-input, 0.7 to 1.6 per cent of deposited nitrogen is emitted from the soils in the form of N_2O as an intermediate product of soil denitrification processes. **Acta Biol Szeged 52(1):119-122 (2008)**

KEY WORDS

nitrous oxide,
methane,
soil flux,
Bodrogköz

As it is well known, there is an intensive exchange of greenhouse gases within the atmosphere and the biosphere. Beside carbon dioxide, as the most important greenhouse gas, 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 (IPCC, 2007). Their share in the radiation forcing are 17 and 5 per cent, respectively.

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).

Soils may also act as a sink for methane in aerated soil where methane can be oxidized by methanotrophic bacteria in the mineral layer (Steinkamp et al. 2001). These microbes are often residing in a relationship with many native plants. Beside the gas diffusion controlled by the structure and wetness of the soil, the methane decomposition depends also on temperature, on organic N-content and on organic matter content (Born et al. 1990; Dörr et al. 1993; Crill et al. 1994; Castro et al. 1995; Whalen and Reeburgh 1996; Brumme and Borken 1999; Bodelier and Laanbroek 2004). On global scale well aerated soils may be responsible for the 10% of methane sinks (Prather 1995). As soils are either a potential source or sink for atmospheric methane, positive flux (emission) and negative flux (deposition) can also be observed above soils. The magnitude and direction of the methane flux is mainly controlled by soil temperature and moisture (van den Pol-van Dasselaar et al. 1998).

Two mechanisms are responsible for nitrous oxide (N_2O) production in soils: namely the nitrification (as an aerobic process) and dominantly the denitrification (in anaerobic condition; Firestone and Davidson 1989; 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 (Granli and Bøckmann 1994; Bouwmann 1996; Del Grosso et al. 2000; Simojoki and Jaakkola 2000; 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).

The net N_2O and CH_4 exchange fluxes within soils and the atmosphere are controlled by the balance of concurrent production and consumption mechanisms in the soil. Our aim was to estimate the net fluxes of these greenhouse gases at five selected sites in Bodrogköz, Hungary, described in section 2.

---

*Corresponding author. E-mail: horvath.l@met.hu

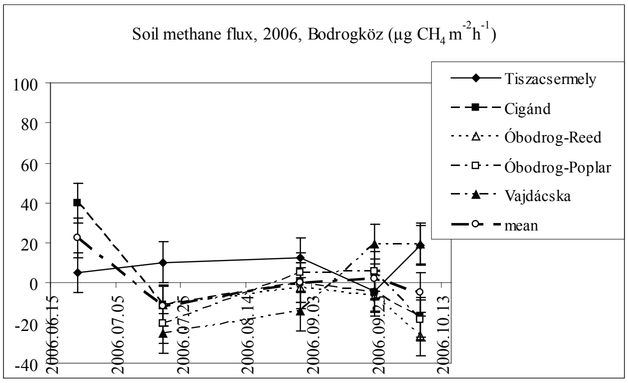

Figure 1a. Soil flux of methane in Bodrogköz in 2006 (positive=emisssion, negative=deposition).

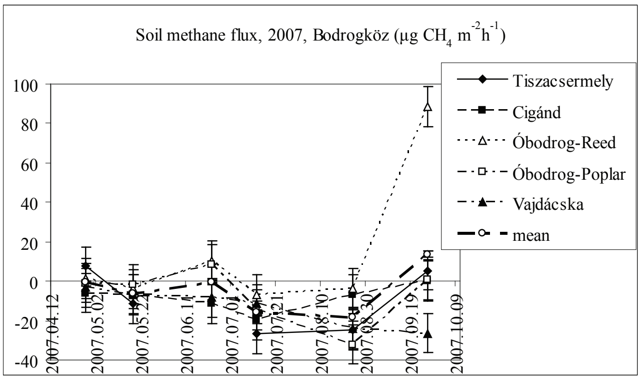

Figure 1b. Soil flux of methane in Bodrogköz in 2007 (positive=emisssion, negative=deposition).

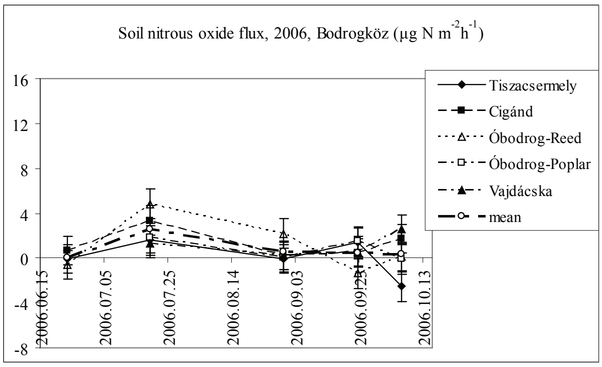

Figure 2a. Soil flux of nitrous oxide in Bodrogköz in 2006 (positive=emisssion, negative=deposition).

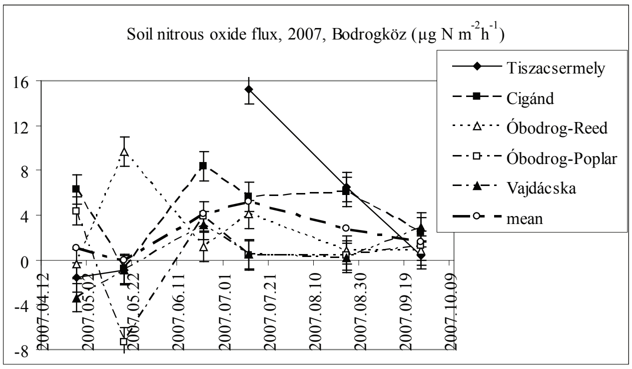

Figure 2b. Soil flux of nitrous oxide in Bodrogköz in 2007 (positive=emisssion, negative=deposition).

Field sites

a) Tiszacsermely, Fraxino pannonicae-Ulmetum Soó in Aszód 1935 corr. 1963. Location: near Tiszacsermely at the flood-plain of Tisza River. The stands can be observed mainly on the highest points of the flood-plain (Tuba 1995). The investigated stands are the consotiation of *Fraxinus angustifolia* ssp. pannonica and *Quercus robur*. The well developed layer of shrubs is composed by *Ulmus laevis*, *Acer campestre*, *Fraxinus angustifolia* ssp. pannonica and *Sambucus nigra*. Some invasive plants like *Amorpha fruticosa*, *Robinia pseudo-acacia* are present in the layer. In the field layer mostly the *Rubus caesius* and *Glechoma hederacea* are dominant, but *Aristolochia clematitis, Circaea lutetiana*, *Iris pseudacorus*, and *Sambucus nigra* can reach higher abundance values as well.

b) Cigánd, Elatinetum alsinastri (Nagy et al. 2006) hoc loco – new association.

Location: near Cigánd settlement. The investigated stand was located near Cigánd, in a navvy hole connecting to a plough-land. (Nagy et al. 2006). In the stand the *Elatine alsinastrum* was totally monodominant. A species-poor, pioneer community. All of the constant species are mire specie like *Alisma lanceolatum*, *Alopecurus aequalis*, *Polygonum lapathifolium*, *Typha latifolia*.

c) Óbodrog-Reed, Typhetum latifoliae (G. Lang 1973). Location: at the bank of Ó-Bodrog oxbow, near Sárospatak town. In its highest layer the *Typha latifiolia* is dominant, but in its two sample quadrats *Nuphar lutea* creates facies. Locally *Utricularia vulgaris* can form a submerged layer.a) Senecioni sarracenci-Populetum albae Kevey in Borhidi and Kevey (1996).

d) Óbodrog-Poplar, Location: at the bank of Ó-Bodrog oxbow, near Sárospatak. At the Bodrogköz section of Upper-Tisza this community means the last point of the zonation of flood-plain associations (Gál et al. 2006). In Bodrogköz the stands are mixed with Populus x canescens. In the canopy layer the Populus x canescens is dominant. The shrublayer is rich is species, mainly the *Cornus sanguinea*, *Fraxinus*

Table 1. Mean soil fluxes fluxes of nitrous oxide and methane in Bodrogköz.

	Mean N_2O flux (µg N m^{-2} h^{-1})		SD		Mean CH_4 flux (µg CH_4 m^{-2} h^{-1})		SD	
location	2006	2007	2006	2007	2006	2007	2006	2007
Tiszacsermely	0.1	3.9	1.6	7.1	8.6	-10.0	8.6	16.2
Cigánd	1.3	4.7	1.3	3.3	1.5	-8.5	22.4	6.7
Óbodrog-Reed	1.0	2.7	2.5	3.7	-11.6	14.4	10.5	36.9
Óbodrog-Poplar	0.8	0.5	1.0	4.2	-6.9	-6.6	14.3	14.6
Vajdácska	1.2	0.4	1.0	2.4	0.0	-13.5	23.2	9.6
mean	0.8	2.5	1.0	2.0	1.8	-4.5	12.7	11.7

pennsylvanica, *Ulmus laevis* and *Viburnum opulus* are dominant. In the field layer the *Rubus caesius*, *Cornus sanguinea* and *Lithrum salicaria* are the most frequent. The protected Maianthemum bifolium can be found in the stand as well.

e) Vajdácska, Circaeo-Carpinetum (Borhidi 2003). Location: Long Forest (Long-erdő) Vajdácska-Sárospatak, Bodrogköz. The stands can occur mostly on the places of dried out oxbows at the inner parts of the Bodrogköz, e.g. in Long-Forest. In the canopy layer the *Quercus robur*, *Acer campestre* and *Carpinus betulus* are dominant, while in the shrub layer mostly the *Acer campestre* and *Fraxinus angustifolia* ssp. pannonica has the highest abundance. In the field layer *Circaea lutetiana*, *Convallaria majalis*, *Rubus caesius* and *Viola sylvestris* are dominant or subdominant. In consequence of cool microclimate conditions the speciality of this stand is the well developed *Fagus sylvatica* species - the remnants of Bükk I. Age - located on 90-95 m altitude above sea level, giving a mountain character to this place (Tuba 1995; Gál et al. 2006).

Sampling and measurement

Soil N_2O and CH_4 flux samples were taken in the vegetation period of 2006 and 2007, for N_2O and CH_4, daytime, by 5-10 parallel static chambers with a constant height of h=5 cm and a surface of 80 cm^2. 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 after closure of samplings were determined by gas chromatography-electron capture detector (GC-ECD) and flame ionisation detector (GC-FID), for nitrous oxide and methane, respectively. Fluxes were calculated as: $F_{N2O} = 3.5*\Delta C/t*f$ and $F_{CH4} = 2*\Delta C/t*f$, where F is the flux [µg N m^{-2} h^{-1} or µg CH_4 m^{-2} h^{-1}], respectively, $\Delta C=C_{30}-C_0$ is the difference in mixing ratios [ppb] in chambers at t=30 and t=0, t is the sampling time t [30 min], f is the factor taking into account the residual pressure in the evacuated tubes (varies between 1.090 and 1.233). According to statistical analysis the non-systematic bulk error (coefficient of variation) of sampling and analysis estimated using parallel samplings was below 10% for both components.

Results and Discussion

Methane

The results of individual measurements of methane soil flux can be seen in Figure 1a and 1b. Methane flux varies within a wide range of -30 to 90 µg CH_4 m^{-2} h^{-1} (-3 to 8 kg CH_4 ha^{-1} yr^{-1}). The magnitude and the direction (emission or uptake by soil) strongly depend on the soil moisture (SWC) and on the temperature. Maximum uptake can be observed at high soil temperature and medium soil moisture (20-35% w/w). Below 5% of SWC the methane uptake inhibited by the water stress for methanotroph bacteria. Above higher than 50% SWC methane production dominates against the methane uptake (van den Pol-van Dasselaar et al. 1998). Parallel with the variation of SWC and temperature the direction of methane flux varies as well. As Table 1 demonstrates, methane fluxes show high SD with low mean methane flux (either sink and source) in comparison to the wide range of variation of individual measurements. In other words the methane emission and uptake are practically balanced for the observed two years above soils.

Nitrous oxide

The results of individual measurements of nitrous oxide soil emission fluxes can be seen in Figure 2a and 2b. The nitrous oxide flux varies within a range of -7 and 15 µg N m^{-2} h^{-1} (-0.6 to 1.3 kg N ha^{-1} yr^{-1}). Nitrous oxide fluxes (Table 1) show great variation among different years and ecosystems. In most of cases the N_2O flux is positive (emission). Mean fluxes are generally lower by a factor of two for tall vegetation (1.2 µg N m^{-2} h^{-1} at forested areas in Tiszacsermely, Óbodrog-Polar and Vajdácska) comparing to the short vegetation (2.4 µg N m^{-2} h^{-1}, Cigánd and Óbodrog-Reed) in the average of the two years. If we suppose that most of nitrous oxide is emitted from the soil in the warmer veetation period the rates are 0.21 kg N ha^{-1} yr^{-1} and 0.10 kg N ha^{-1} yr^{-1} for short and tall vegetation, respectively. Atmospheric deposition that is generally the only N-source for non-fertilized ecosystems are 13 and 15 kg N ha^{-1} yr^{-1} for Hungarian grasslands and forests, respectively (Horváth et al. 2006; Kugler et al. 2008). Thus, only a negligible part (0.7 to 1.6%) of deposited nitrogen is emitted from the soil into the atmosphere in the form of N_2O as an intermediate product of soil denitrification processes.

References

Born M, Dörr H, Levin I (1990) Methane consumption in aerated soils of the temperate zone. Tellus 42B:2-8.

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

Bouwman AF (1996) Direct emission of nitrous oxide from agricultural soils. Nutr Cycl Agroecosys 46:53-70.

Brumme R, Borken W (1999) Site variation in methane oxidation as affected by atmospheric deposition and type of temperate forest ecosystem, Global Biogeochem Cycles 13:493-501.

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.

Castro MS, Steudler PA, Melillo JM, Chapman JW (1995) Factors controlling atmospheric methane consumption by temperate forest soils. Global Biochem Cycles 9:1-10.

Chapuis-Lardy L, Wrage N, Metay A, Chottes J-L, Bernoux M (2007) Soils, a sink for N_2O? A review. Global Change Biol13:1-17.

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.

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

Del Grosso SJ, Parton WJ, Mosier AR, Ojima DS, Kumala DS, Phongpan S (2000) General model for N_2O and N_2 gas emissions from soils due to dentrification. Global Biogeochem Cycles14:1045-1060.

Dörr H, Katruff L, Levin I (1993) Soil texture parameterization of the methane uptake in aerated soils. Chemosphere 26:697-713.

Firestone MK, Davidson EA (1989) Microbiological basis of NO and N_2O production and consumption in soil. Andrea MO and Schimel DS eds, Exchange of trace gases between terrestrial ecosystems and the atmosphere, John Wiley & Sons Ltd., Chichester, UK.

Gál B, Szirmai O, Czóbel Sz, Cserhalmi D, Nagy J, Szerdahelyi T, Ürmös Zs, Tuba Z (2006) Jellegzetes gyep- és erdőtársulások a magyarországi Bodrogközben (Grassland and forest plant communities of the Hungarian Bodrogköz). Folia Historico Naturalia Musei Matraensis 30:43-62.

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

Horváth L, Führer E, Lajtha K (2006) Nitric oxide and nitrous oxide emission from Hungarian forest soils; linked with atmospheric N-deposition. Atmos Environ 40:7786-7795.

IPCC (2007) Intergovernmental Panel on Climate Change (IPCC): The Scientific Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge Univ Press, New York, 2007.

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

Kugler Sz, Horváth L, Machon A (2008) Estimation of nitrogen flux between the atmosphere and aquatic/terrestrial ecosystems in Hungary. Environ Poll 150, doi:10.1016/j.envpol.2007.10.017 in press.

Nagy J, Szerdahelyi T, Gál B, Czóbel Sz, Szirmai O, Tuba Z, Cserhalmi D, Ürmös Zs (2006) Új növénytársulások a magyarországi Bodrogközben: előzetes közlemény (New plant communities of the Hungarian Bodrogköz). Folia Historico Naturalia Musei Matraensis 30:63-69.

van den Pol-van Dasselaar A, van Beusichem ML, Onema O (1998) Effects of soil moisture content and temperature on methane uptake by grasslands on sandy soils. Plant Soil 204:213-222.

Prather M, Drewent D, Enhalt P, Fraser E, Sanhueza E, Zhou X (1995) Other trace gases and atmospheric chemistry. In Houghton J et al. eds., Climate Change,1994. Cambridge Univ Press, Cambridge pp. 77-126.

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.

Simojoki A, Jaakkola A (2000) Effect of nitrogen fertilization, cropping and irrigation on soil air composition and nitrous oxide emission in a loamy clay. Europ J Soil Sci 51:413-424.

Steinkamp R, Butterbach-Bahl K, Papen H (2001) Methane oxidation by soils of an N limited and N fertilized spruce forest in the Black Forest, Germany. Soil Biol Biochem 33:145-153.

Szirmai O, Nagy J, Gál B, Czóbel S, Szerdahelyi T, Cserhalmi D, Tuba Z, Ürmös Zs (2006) A magyarországi Bodrogköz jellemző vízi és vízparti növénytársulásai (Aquatic and littorial plant communities of the Hungarian Bodrogköz). Folia Historico Naturalia Musei Matraensis, 30:75-89.

Szirmai O, Tuba, Z (2008) Potametalia. In Makra O ed., Vegetation and fauna of Tisza River Basin II., Tiscia Monograph Series 8, Szeged in press.

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

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.

Whalen SC and Reeburgh WS (1996) Moisture and temperature sensitivity of CH_4 oxidation in boreal soils. Soil Biol Biochem 28:1271-1281.