Agroforest Syst (2014) 88:187–191
DOI 10.1007/s10457-013-9661-6

Tree plantations on a grassland region: effects on methane uptake by soils

**M. E. Priano · V. S. Fusé · J. I. Gere ·
A. M. Berkovic · K. E. Williams · S. A. Guzmán ·
R. Gratton · M. P. Juliarena**

Received: 21 May 2013 / Accepted: 29 November 2013 / Published online: 12 December 2013

Abstract We assessed the rates of methane uptake (CH_4) by soils of different tree plantations and a control to provide information regarding potential greenhouse gas sequestration by tree plantations of pines, mixed deciduous species and eucalyptus in a natural grassland around 37S, 59W (Argentinean Pampa). A naturalized pasture was used as control. All sites had been agricultural and livestock lands. Each site was sampled three times from December 2012 to May 2013, using five static chambers randomly distributed across an area of $\sim 100\ m^2$ in each site. In the control, methane fluxes were very weak; both negative (uptake) and positive (emission) values were found. Below tree plantations, fluxes were always negative, with statistically significant intersite differences. The highest uptake rates were observed in the mixed deciduous plantation (~ 10 ng $m^{-2}\ s^{-1}$), followed by pines and eucalyptus plantations. Intrasite differences associated with spatial variation were also found. A significant inverse correlation between CH_4 uptake and soil water content was found in the pine and deciduous species plantations ($R^2 > 0.94$, $p < 0.1$).

Keywords Soil · Plantation · Methane uptake · Static chamber · Land uses

Introduction

Among the greenhouse gases whose concentrations in air are affected by human activities, methane (CH_4) follows carbon dioxide in order of importance. Currently, the total CH_4 atmospheric budget is about 5,500 Tg. The total input (emission) is about 600 Tg/year, being more than 2/3 the result of agricultural activities and the coal mining industry (Denman et al. 2007). More than 80 % of the methane consumption is the result of the oxidation by hidroxil radicals in the troposphere and the rest occurs by oxidation in the stratosphere and in soils. The latter is estimated between 22–45 Tg/year (Dutaur and Verchot 2007), but may be strongly affected by human activities through changes in the use of soil. For instance, methane uptake in forested soils is generally larger than in grasslands (Price et al. 2004), which could be a reason for recommending to plant a forest for carbon capture (Schoeneberger 2009).Although information

---

M. E. Priano · V. S. Fusé · A. M. Berkovic ·
R. Gratton · M. P. Juliarena (✉)
CIFICEN (CONICET-UNCPBA) Centro de
Investigaciones en Física e Ingeniería del Centro de la
PBA, Tandil, Argentina
e-mail: pjuliarena@exa.unicen.edu.ar

J. I. Gere
CONICET-Consejo Nacional de Investigaciones
Científicas Y Tecnológicas, Buenos Aires, Argentina

K. E. Williams · S. A. Guzmán
UNCPBA-Universidad Nacional del Centro de la PBA,
Pinto 399, C. P 7000 Tandil, Argentina

Table 1 Experimental sites and vegetation description

Site	Location	m.a.s.l (m)	Description	Age of plantation (years)	Area (m^2)	Study area (m^2)
PF	37°19′9.55″S, 59°4′33.50″W	211	Native grassland without fertilisation for many years and subjected to intermittent grazing, with highly variable populations of T*rifolium repens, Festuca arundinacea, Cirsium vulgare, Carduus Acanthoides, Taraxacum sp*	>30	24,000	140
EP	37°19′16.57″S, 59°4′39.05″W	215	Plantation of *Eucalyptus viminalis* with clear-cut areas. Soil with patches covered with *Hedera helix (*creeper, *Poaceae* family)	50	18,700	120
PP	37°21′46.84″S, 59°6′48.78″W	251	Plantation of *Pinus radiate*. Soil covered by needles.	30	1,800	170
DP	37°17′0.90″S, 59°7′0.44″W	184	Plantation of mixed deciduous species, with *Celtis sp*., *Eucalyptus camaldulensis*, *Eucalyptus viminalis*, *Laurus nobilis, Quercus Robur* and *Cedrus sp.* Soil covered with creeper (*Hedera helix, viola odorata*).	90	36,800	130

PF pasture field, *EP* eucalyptus plantation, *PP* pine plantation, *DP* mixed deciduous plantation. *m.a.s.l.* height above mean sea level

on global estimates of carbon capture is available, published data on methane uptake are disperse and scarce for Southern Hemisphere ecosystems.

We measured methane fluxes, by the static chamber method, below plantations of different tree species located in naturalized grasslands of Argentina (Argentinean Pampa). This research report the results of three series of flux measurements carried out under fair weather conditions during December 2012–May 2013. Correlations with some soils parameters were also explored.

Materials and methods

Sites

All sites are located near Tandil city. Average annual temperature is 13.7 °C and average annual precipitation is 889 mm, without defined rain or dry periods (National Weather Service, Tandil station). Soil is a typical *argiudol* from Pampas Region (Panigatti 2010) (Table 1).

Methane flux measurements

Five cylindrical stainless steel chambers were used as samplers (diameter 16 cm, height 17 cm). They were driven into the soil to a depth of 5 cm; the height of the headspace (about 12 cm) was always measured in order to calculate its volume. Chambers were closed with a grilon lid with a fan inside to provide air mixing (Christiansen et al. 2011) and after chamber closure air samples were extracted every 20 min during an hour, between 10:00 and 12:00 am LT (Parkin and Venterea 2010). Gas samples were collected with 20-ml syringes with three-way stopcocks, previously cleaned with pure N_2, and stored at a pressure slightly above 1 bar. Analysis were carried out within 2 or 3 h after sample collection, on a gas chromatograph (GC, Agilent, 7890A) equipped with an FID and a 1.8-m Poropak Q (80/100 mesh) column. The oven, injector, and detector temperatures were at 50, 250 and 250 °C respectively. The flow rate of the carrier gas (He) was 30 ml min^{-1}. Flame gases (H_2 and O_2) were set at 30 and 400 ml min^{-1}, respectively.

Methane fluxes (ng m^{-2} s^{-1}) were calculated using linear regression of the CH_4 concentration in the headspace versus time. To calculate methane mass fluxes, we measured the temperature in the headspace with temperature data loggers and ibutton (DS1921G). All regressions with $R^2 > 0.8$ were considered valid experimental points.

Environmental parameters

During the experiments, air and soil temperatures (°C, at a depth of 5 cm) were measured and recorded as

Table 2 Mean CH_4 fluxes, SD (standard deviation) and environmental parameters in three tree plantations and a control (native grassland)

Site	Date	Mean CH_4 fluxes ($ng/m^{-2}\ s^{-1}$), SD	T_a °C	ΔTc °C	Ts °C (5 cm)	pH	OC (%)	ρ_a (g/cm^3)	WFPS	WC (%)	CA for WC (R^2; *p values)*
PF[a]	Dec-12	1.21 ± 6.89	23.6	0.5	22.4	6.23	4.46	1.18	39.28	18.46	–
	March-13	−3.005 ± 2.75	21.8	2	18.7	7.11	5.04	1.15	40.87	20.32	
	April-13	−1.86 ± 2.61	19.8	1.5	16.9	5.9	4.79	1.22	67.46	29.82	
EP[a-b]	March-13	−3.11 ± 0.74	19.5	−1.5	–	–	–	0.7	23.34	28.68	–
	April-13	−3.56 ± 2.39	18.2	−1.5	14.0	7.32	13.4	0.53	23.28	35.45	
	May-13	−4.02 ± 2.16	14.0	–	10.0	–	–	0.68	25.87	28.67	
PP[b-c]	Dec-12	−3.76 ± 0.79	24.3	3	18	6.01	5.51	1.08	58.28	31.93	0.94; *<0.22*
	March-13	−6.00 ± 1.45	22.1	5	–	6.31	6.24	0.72	20.47	20.94	
	April-13	−8.43 ± 1.58	20.9	0	15.5	6.12	5.69	0.97	27.79	17.98	
DP[c]	Dec-12	−7.05 ± 3.85	22.5	0.5	17.5	7.13	7.81	0.92	67.09	46.82	0.99; *<0.02*
	March-13	−9.73 ± 4.20	20.2	1	–	6.98	9.98	0.88	41.19	31.27	
	April-13	−10.04 ± 2.36	20.7	0	14.5	6.29	8.3	0.94	43.72	30.15	

T_a ambient air temperature, ΔT_c headspace air temperature excursions during measurements, T_s soil temperature at 5 cm depth, *OC* organic content, ρ_a bulk density, *WFPS* water-filled pore space, *WC* soil water content in %, *CA* correlation analysis for CH_4 fluxes and WC (R^2 and *p* values). Letters *a*, *b* and *c* indicate statistically significant intersite differences in CH_4 fluxes. Other references see Table 1 above. At the same time, soil samples at 0–10 cm depth were collected for the analysis of some soil parameters. All samples were kept refrigerated until their analysis by standard methods (USDA 2004).

Statistical analysis

To evaluate intersite differences in CH_4 flux values an ANOVA test was used considering sites and CH_4 flux values ($n = 55$) as independent and dependent variables respectively. In addition, to examine which of the environmental parameters has a major influence over CH_4 fluxes (dependent variable), a *Pearson* correlation analysis (Infostat statistical software) was used considering all the measured environmental parameters ($n = 12$) as independent variables.

Results

Methane fluxes ranged from very weak, positive values, observed in the control, to considerably strong uptakes observed in the tree plantations (Table 2). The headspace air temperature excursions during measurements (ΔT_c in Table 2) did not appreciably affect the mass flux values as compared to the slope indeterminacy, which is currently the main source of errors in this technique (Levy et al. 2011). There were significant intersite differences in CH_4 fluxes in soils below the three forested sites (Table 2). Average fluxes were between -7 and -10 ng CH_4 m^{-2} s^{-1} in DP, -3 and -8 ng CH_4 m^{-2} s^{-1} in PP, and -3 and -4 ng CH_4 m^{-2} s^{-1} in EP. Even in the latter case fluxes were always negative. Instead, in PF, CH_4 fluxes were both negative and positive within the same series and the average flux values were very weak. Considerable intrasite variations of CH_4 fluxes were also found (Table 2). Correlations between CH_4 fluxes and water content (WC) were significant and positive (correlation analysis, Table 2) for pine and deciduous species plantations. No other significant correlation was found between CH_4 fluxes and environmental parameters. As expected, soil temperature variations were lower in forested sites. There was also a general trend of decreasing CH_4 uptake as ambient temperature rises. However, the linear regression presented a $R^2 = 0.57$, $p < 0.12$.

Discussion

Methane flux values below plantations were lower than those reported for pristine forests (Price et al. 2004) but were of the same order as the average values for the Northern Hemisphere (Brumme and Borken 1999; Dutaur and Verchot 2007; MacDonald et al. 1996; Smith et al. 2000). For the same northern latitude, similar values have been reported for a pine wood (Dueñas et al. 1999).

The intrasite variation could be attributed both to the uncertainty in the determination of the slopes of the regression lines (always below 30 %) and to soil spatial variation within the sample area. However, the former cannot explain dispersions which are over 30 % and so soil spatial variation should be significant. This interpretation confirms that absolute intrasite dispersion in ng CH_4 m^{-2} s^{-1} is lower in a single species plantation (PP). With regard to PF, the marked patches-like behavior may be attributed to previous land uses such as grazing or cultivation.

Finally, the negative, significant correlation between CH_4 uptake and WC in PP and DP suggests that high WC reduces CH_4 oxidation rates as it was observed in previous works (Dobbie and Smith 1996; Price et al. 2004; Smith et al. 2000). The low magnitude of the correlation between soil temperature and CH_4 fluxes may be due to the small range of temperature variation in the period of the study. No significant linear correlation was found between CH_4 uptake and the rest of the measured environmental parameters.

Conclusions

Results indicate that tree implanted species may affect CH_4 uptake by the underlying soils. While the soil under EP was a weak sink, the soil below PP and DP presented higher uptakes. The soil of PF showed both very weak, negative and positive, fluxes. However, all the field works were carried out during a relatively short period and they should be extended to include other seasons and eventually other climatic zones.

The results of this research add to the few values reported for the Southern Hemisphere (Dutaur and Verchot 2007; Price et al. 2004), and may contribute to improve the knowledge in this topic. Particularly, they show significant differences in CH_4 uptake among the soils below tree plantations. Differences in CH_4 uptake should be taken into account when selecting species for forestation. In addition, correlations between methane fluxes and other environmental data could be used as input in different models.

Acknowledgments Financial support was provided by PICT 2007–1220 of the National Agency of Scientific and Technological Research (ANPCyT) of the Ministry of Science, Technology, and Innovation (MINCyT), Argentina. The authors gratefully acknowledge Dra. Silvia Mestelan for soils analysis.

References

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

Christiansen JR, Korhonen JFJ, Juszczak R, Giebels M, Pihlatie M (2011) Assessing the effects of chamber placement, manual sampling and headspace mixing on CH_4 fluxes in a laboratory experiment. Plant Soil 343:171–185

Denman KL, Brasseur G, Chidthaisong A et al (2007) Couplings Between Changes in the Climate System and Biogeochemistry. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate Change 2007: the physical science basis. contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Dobbie KE, Smith KA (1996) Comparison of CH_4 oxidation rates in woodland, arable and set aside soils. Soil Biol Biochem 28:1357–1365

Dueñas C, Fernández MC, Carretero J, Liger E (1999) Methane and carbon dioxide fluxes in soils evaluated by 222Rn flux and soil air concentration profiles. Atmos Environ 33:4495–4502

Dutaur L, Verchot LV (2007) A global inventory of the soil CH_4 sink. Glob. Biogeochem. Cy. 21:1944–9224

Levy PE, Gray A, Leeson SR, Gaiawyn J, Kelly MPC, Cooper MDA, Dinsmore KJ, Jones SK, Sheppard LJ (2011) Quantification of uncertainty in trace gas fluxes measured by the static chamber method. Eur J Soil Sci 62:811–821

MacDonald JA, Skiba U, Sheppard LJ, Hargreaves KJ, Smith KA, Fowler D (1996) Soil environmental variables affecting the flux of methane from a range of forest, moorland and agricultural soils. Biogeochemistry 34:113–132

Panigatti, JL (2010). Argentina 200 años, 200 suelos. Ed. INTA Buenos Aires. 345 pp. Ilustraciones y cuadros

Parkin TB, Venterea RT (2010) Sampling Protocols. Chamber-Based Trace Gas Flux Measurements. USDA, Gracenet Sampling Protocols

Price SJ, Sherlock RR, Kelliher FM, McSeveny TM, Tate KR, Condron LM (2004) Pristine New Zealand forest soil is a strong methane sink. Glob Change Biol 10:16–26

Schoeneberger MM (2009) Agroforestry: working trees for sequestering carbon on agricultural lands. Agrofor Syst 75:27–37

Smith KA, Dobbie KE, Ball BC et al (2000) Oxidation of atmospheric methane in Northern European soils, comparison with other ecosystems and uncertainties in the global terrestrial sink. Glob Change Biol 6:791–803

USDA (2004) Soil survey laboratory methods manual. Soil survey investigations report no. 42. Version 4.0. United States Department of Agriculture Natural Resources Conservation Service, Washington. P 213–626