Greenhouse gas emissions from soils under organic management

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ABSTRACT

Land emissions of N_2O, CO_2 and NH_3 have been subject to little study under organic systems, yet form important aspects of sustainability of such systems. We describe innovative methods developed at SAC to assess trace gas emission using both automatic closed chamber systems (intensive, short term monitoring) and manually-operated closed chamber systems (occasional, long term monitoring). Long-term data were collected from organic ley-arable rotation trials in North-east of Scotland. Short term data were collected to show the effect of timing and depth of ploughing-out of the ley phase on gas emissions. Ploughing gave a short-term stimulation of CO_2 and, more markedly, of N_2O emission. Emissions of N_2O from organic grass-clover leys were considerably lower than from conventional grass. However, some N_2O emissions from organic arable are higher than from conventional systems, particularly in the first year after ploughing out ley. Ammonia emissions after spreading manure on grass were significant in the summer, though only short-lived.

Keywords: organic farming; rotation; nitrous oxide; ammonia; carbon dioxide; closed chamber

INTRODUCTION

Greenhouse gas emissions are strongly influenced by land use, particularly crop type. The range of crops grown within organic rotations implies that it is likely that emission will vary with crop type. Land use effects on CO_2 emission are dominated by tillage, with ploughing being the main short-term stimulator of emissions. Longer term effects of land use are generally smaller than short-term effects. For nitrous oxide (N_2O), fertilised grassland is the land use commonly responsible for the highest emissions (Skiba *et al*., 1996). However the ploughing-in of residues can also stimulate both CO_2 and N_2O emissions (Scott *et al*., 2000). Few data are available on the effects of organic farming on CO_2 and N_2O emission. Similarly, few data are available on emissions of ammonia (NH_3) from organic manure spreading. Our main objective was to study the long-term emissions of N_2O from organic rotations and the short term N_2O and CO_2 emissions following ploughing of ley and thereby assess the importance of controlling gaseous losses in maintaining the fertility of ley-arable rotations.

MATERIALS AND METHODS

N_2O and CO_2 fluxes were measured using closed chamber systems (Scott et al., 1999). The atmosphere immediately above the soil surface is enclosed by the chamber and is sampled 1h after closure. Gas was sampled either manually or automatically. Manually operated chambers enclosed an area of 0.125 m^2. Gas samples were taken in gas-tight sampling tubes and subsequently analysed in the laboratory by chromatography. Automatically operated chambers enclosed an area of 0.5 m^2. They have a motor-driven lid-closing system. Samples are taken by pumping into one of 24 aluminium tubes. These are arranged in a removable assembly within a weatherproof box. The automated chambers were programmed to close for 1 h starting at 04:30 hrs and remain open for 7 h, thereby giving three flux assessments per day. Samples are analysed for N_2O and CO_2 concurrently, and automatically, by gas chromatography. Ammonia was analysed using a flow-through chamber technique. A plastic chamber enclosing 0.06 m^2 was placed on the plot; air entering the chamber was scrubbed of ammonia using an acid trap. Chamber air was pumped through a vial containing 0.7 M H_2SO_4 and the collected NH_4^+ was determined by the indo-phenol blue method.

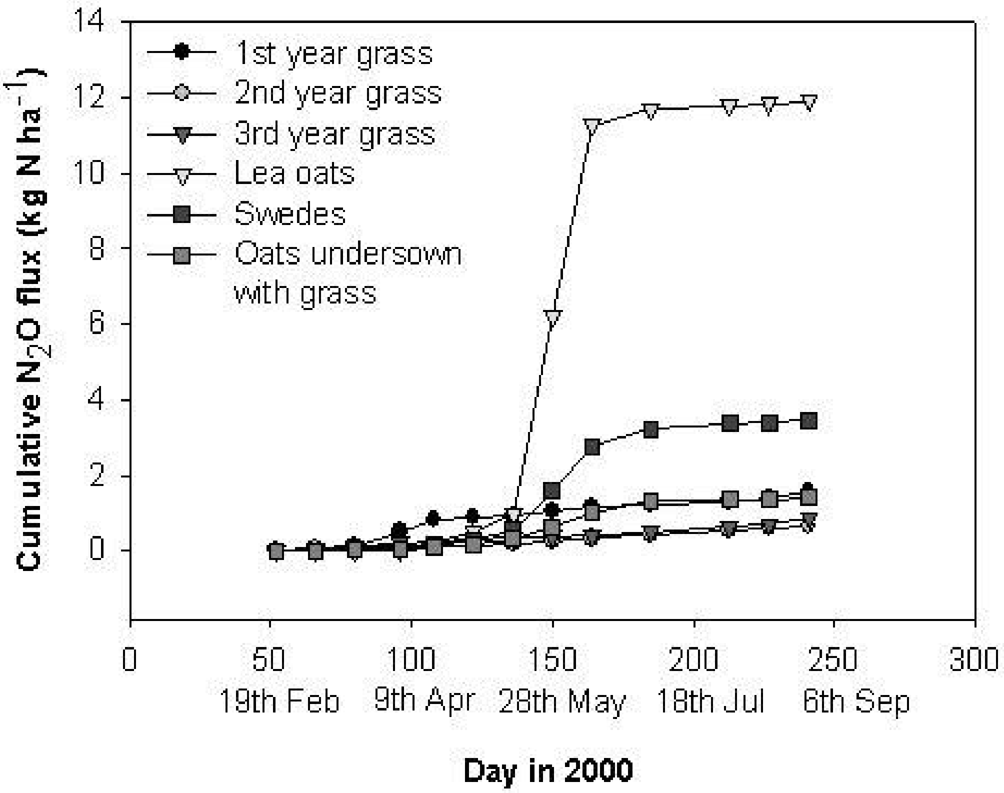
We studied the replicated ley-arable rotation experiments at Tulloch, Aberdeen and at Woodside, Elgin in North-east Scotland. Within the rotations, management practices are based on Soil Association organic standards (The Soil Association, 1999). Both soils are freely drained sandy loams. The rotational sequence was first, second and third year grass/white clover (*Lolium perenne/Trifolium repens)*, ley oats (*Avena sativa)*, swede turnips (*Brassica napus napobrassica)* and oats undersown with grass and clover. Manual gas measurements were made at Tulloch on one plot of the entire grass/clover phase and one plot of the entire arable phase from 1996 –1999. Subsequently, manual measurements were made at fortnightly intervals throughout the 2000 growing season on all phases of the rotation. Ammonia measurements were made in June 2000 on grassland immediately after manure application. Our third site, under conversion to arable, was a 2-year ley at Bush, Edinburgh on an imperfectly drained loam. This was ploughed in autumn 2001, either in August or in October. Automated gas measurements were made in the 2-month period after ploughing.

RESULTS AND DISCUSSION

The long-term monitoring of the arable and the ley phase in the rotation indicated that there was little difference between crops in the overall cumulative flux (~9 kg N ha^{-1}) at the end of the three years (Ball et al., 2002). The ley phase showed no marked peaks associated with manure application in contrast to inorganically fertilised grassland. The first arable crop of oats gave a high contribution to the overall flux. The net result was that differences in N_2O flux between crops were less marked than in conventional agriculture. We also observed that seasonal rainfall had a major influence on cumulative emissions of N_2O. Hence we decided to monitor all components of the rotation in one season in order to compare phases adequately, and to study in greater detail the gas emissions after ploughing.

N_2O flux from individual components of the Tulloch rotation in 2000 are given in Fig. 1. Of the crops, the greatest loss was from the lea oats, the first arable crop after three years of grass. This occurred some time after ploughing and sowing. The very high fluxes are associated with heavy rainfall towards the end of April, followed by high temperatures in May. In contrast, at Woodside, where the rainfall is lower and the soil is drier, coarser textured and contains less organic matter, N_2O emissions were lower, with no substantive loss from the lea oats. CO_2 emissions throughout the season were similar at both sites and were fairly constant from the grassland. Emissions were least from the swedes and from the undersown oats where growth was least vigorous and crop cover lower (due to later sowing of the swedes).

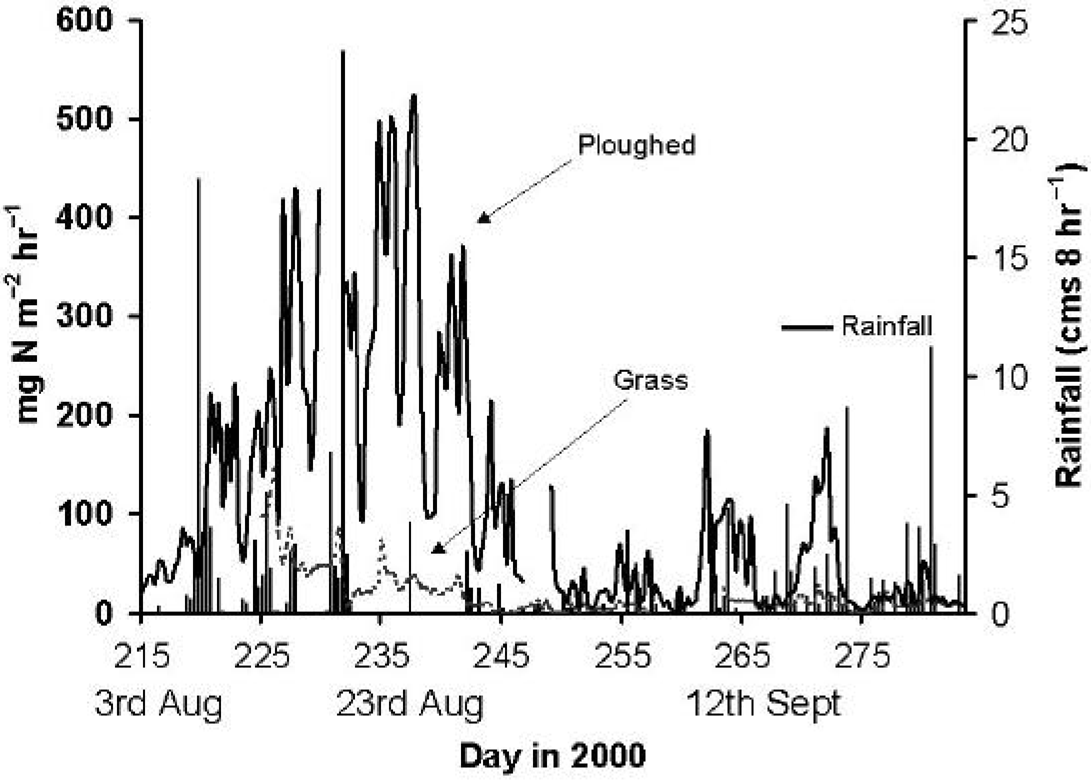
Fig. 1 N_2O flux in the rotations experiment at Tulloch, 2000



Automated measurements of N_2O flux after ploughing at Bush are given in Fig. 2. Fluxes increased after rainfall in a manner similar to that observed by Scott et al (2000) after sewage sludge application. Fluxes remained high for 20 days during which mineralisation and denitrification of N were likely to have been rapid. The peaks observed were of similar size to those observed after spring fertiliser application. CO_2 flux was also stimulated by ploughing, though the peak lasted only for about 1 week.

Ammonia measurements from grassland freshly amended with organic manure were made at Woodside in summer 2000. These were high initially and dropped off rapidly in the week after manure application to background levels. Differences in flux reflected the volume of manure entrapped by the chamber.

Fig. 2 N_2O emissions after ploughing on 30th July at Bush



CONCLUSIONS

Within these particular organic systems, differences between the ley and arable phases were less marked than in the ley/arable phases that have been analysed in conventional agriculture. The crop most likely to give high fluxes, particularly of N_2O, is lea oats, the crop following ploughing out of grass. Substantial fluxes of N_2O and CO_2 can occur in the 2-6 week period after ploughing. Seasonal rainfall, soil type and spatial variability had strong influences on gas emissions.

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REFERENCES

Ball, B C; McTaggart, I P; Watson, C A (2002) Influence of organic ley-arable management and afforestation in sandy loam to clay loam soils on fluxes of N_2O and CH_4 in Scotland. *Agriculture, Ecosystems and Environment* (in press).

Scott, A; Crichton, I; Ball B C (1999) Long-term monitoring of soil gas fluxes with closed chambers using automated and manual systems. *Journal of Environmental Quality* **28**, 1637-1643.

Scott, A: Ball, B C; Crichton, I J; Aitken, M N (2000) Nitrous oxide and carbon dioxide emissions from grassland amended with sewage sludge. *Soil Use and Management* **16**, 36-41.

Skiba U; McTaggart I P; Smith K A; Hargreaves, K; Fowler, D (1996) Estimates of nitrous oxide emissions from soil in the UK. *Energy Conservation and Management* **37**, 1303-1308.

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