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Effects of nitrogen fertilization and grazing on the emission of nitrous oxide from grassland

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Abstract

In the Netherlands, managed grasslands are potentially a large source of nitrous oxide (N_2O), because of the large nitrogen (N) input and the relatively high groundwater levels. To provide insight into the major factors that contribute to N_2O emission from grassland and to provide quantitative N_2O emission rates, a monitoring study was carried out on four sites, during March 1992 to March 1994.

Fluxes of N_2O increased after N fertilizer application and grazing, especially during wet conditions. Fluxes were higher from peat soils than from sand and clay soils. Fluxes were low during the winter periods. Total N_2O losses were 2 to 4.5 times higher on grassland fertilized with 160-460 kg N ha^{-1} yr^{-1} than on unfertilized grassland. Losses from grazed grasslands were 1.5 to 3.5 times higher than losses from mown grassland. This study shows that management practice of grassland and soil type are major factors controlling N_2O emission from grasslands.

1. INTRODUCTION

On a global scale, soils are a major source of nitrous oxide (N_2O). In soils, N_2O is produced during the microbial processes nitrification and denitrification, primarily controlled by the availability of mineral nitrogen (N), oxygen (O_2) and mineralizable carbon (C) in the soil [1].

In the Netherlands, intensively managed grasslands are possibly a large source of N_2O because grasslands cover 30 % of the total surface area, the N input via fertilizer and animal excretions is high and many soils are relatively wet due to the shallow groundwater level. Furthermore, about 30% of the grasslands are situated on peat soils. Due to the high contents of organic N and C and due to the shallow groundwater levels, it is expected that especially grasslands on peat soils are a major source of N_2O.

In the present study, the effects of N fertilization, grazing, and soil type on N_2O emission from grasslands were investigated. The aim was to provide insight into the major factors that contribute to N_2O emission from managed grassland and to provide quantitative N_2O emission rates, obtained from field measurements.

2. MATERIALS AND METHODS

Fluxes of N_2O were measured weekly in the period March 1992 to March 1994 on four contrasting grassland sites in the Netherlands, namely on a sand soil in Heino, a clay soil in Lelystad and two peat soils in Zegveld [2]. Peat soil I had a mean groundwater level of 35 cm below soil surface and peat soil II had a mean groundwater level of 50 cm below soil surface. Perennial ryegrass (*Lolium perenne* L.) was the dominant grass species in all swards.

At each site, the experiments had a complete randomized block design, with three treatments in three replicates. The plots were 2.5 x 20 m. The treatments were mown grassland without N fertilizer applications, mown and N fertilized grassland and predominantly grazed and N fertilized grassland. Fertilizer N was applied as calcium ammonium nitrate (CAN), in six or seven dressings during the growing season. The economic optimum application rates of N fertilizer were assessed by using an interactive fertilization system based on a combination of modelling and measuring soil mineral N and N uptake. The application rates for the grazed grasslands were equal to those of the mown grasslands. Total N input by urine and dung of the grazing cattle was calculated using standard calculation procedures [3].

Fluxes of N_2O were measured using vented closed flux chambers made of PVC cylinders with an internal diameter of 20 cm and height of 15 cm. Concentration of N_2O in the headspace of the flux chambers was measured in the field at 0, 10, 20 and 30 minutes after closing, using a photo-acoustic spectroscopic infra-red gas analyzer, directly attached to the flux chambers. All fluxes were measured in six replicates. Mean N_2O fluxes were calculated as arithmetic means and total N_2O losses were calculated by integration of the mean N_2O fluxes over time [2].

3. RESULTS AND DISCUSSION

Fluxes of N_2O increased after application of N fertilizer and grazing. The N_2O flux pattern of fertilized grassland depicted in Figure 1 is typical for N_2O fluxes from grasslands fertilized in several N dressings. This pattern is mainly due to fluctuations in mineral N content in the soil, caused by a combination of fertilizer N application, N uptake by the grass roots and microbial biomass and N losses by leaching, denitrification and volatilization. The magnitude of the N_2O flux after N application was also dependent on soil moisture content, because during dry periods the effect of N application on N_2O loss was much smaller than during wet periods. During the winter periods, fluxes were much lower than during the growing seasons, probably due to the low temperatures and low mineral N contents in the soil (not shown).

Generally, both flux magnitude and duration were higher for the peat soils than for the sand and clay soils and those from peat soil II were higher than those from peat soil I. The higher N_2O fluxes from the peat soils than the sand and clay soils were likely due to higher organic C and N contents, higher denitrification potentials and higher groundwater levels of the peat soils (data not shown).

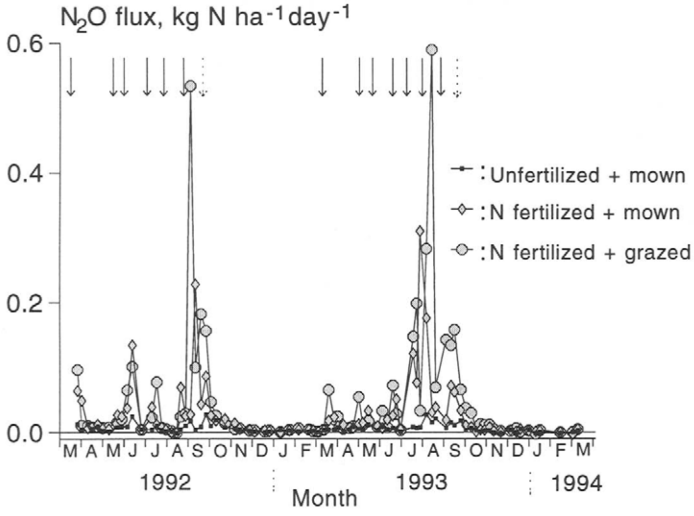

Figure 1. Time course of N_2O flux from grassland on peat soil I, for the three management practices. Arrows indicate time of N application and grazing. Dotted arrows indicate grazing without N application.

For all sites, both the order in total N input via fertilizer, dung and urine, and the order in total N_2O losses was: unfertilized and mown < N fertilized and mown < N fertilized and grazed grasslands (Figures 2A and 2B). Total N_2O losses were 2 to 4.5 times higher on N fertilized grassland than on unfertilized grassland and 1.5 to 3.5 times higher on grazed grassland than on mown grassland. Losses from the peat soils were higher than from the sand and clay soils, for all treatments. Remarkably, N_2O losses from peat II, the soil with lowest N input, were highest, indicating the large effect of soil type on N_2O losses.

On the sand soil, 1.0% of the fertilizer N applied on mown grassland and 1.5% of the urine and dung N deposited on grazed grassland was lost as N_2O, during the two year period. This was 0.9 and 3.3% on the clay soil, 1.9 and 2.3% on peat soil I and 3.9 and 9.8% on peat soil II, respectively. The higher grazing derived losses than fertilizer derived losses, in terms of % of the N input, suggests that the effect of grazing on N_2O losses was not only an effect of the higher N input. Several mechanisms may have contributed to the high grazing derived N_2O losses:

- the much higher nitrate contents of grazed grasslands than mown grasslands (data not shown) may have increased N_2O emission more than proportionally, because N_2O becomes a more important end product of denitrification at increasing nitrate contents [1];
- compaction of the soil by treading of the grazing cattle decreases O_2 diffusion into the soil and may enhance production of N_2O;
- high ammonia concentrations in urine patchess may inhibit nitrification, which may enhance production of N_2O;
- urine and dung contain mineralizable C, which may increase denitrification rate.

In conclusion, this study shows that both soil type and practice of grassland management are major factors controlling N_2O losses from grasslands. The high grazing derived N_2O losses indicate that, besides N fertilizer application, also grazing has to be considered in N_2O budget studies.

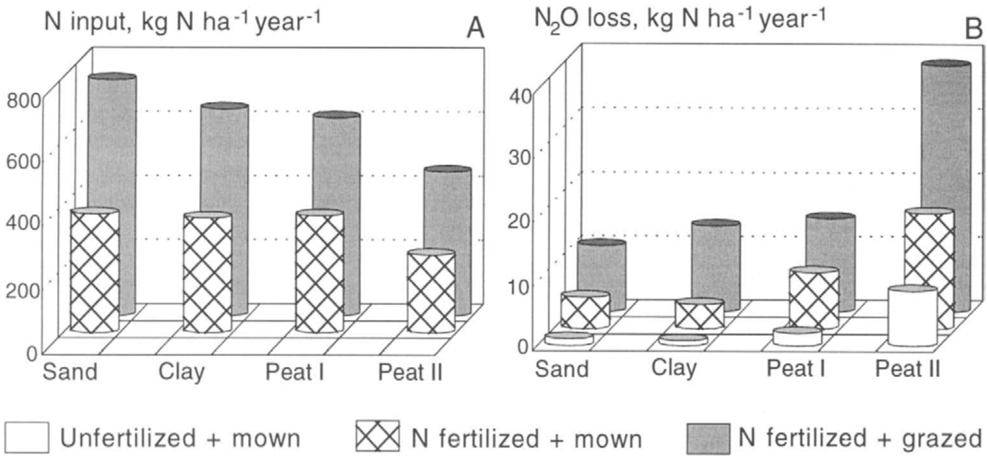

Figure 2. Total annual N input via fertilizer, urine and dung (A), and total annual N_2O losses (B), for all sites and treatments. Averages of two years.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

1 E.A. Davidson, Fluxes of nitrous oxide and nitric oxide from terrrestial ecosystems. p. 219-235 In: J.E. Rogers and W.B. Whitman, Microbial production and consumption of greenhouse gases: methane, nitrogen oxides, and halomethanes, American Society for Microbiology, Washington D.C (1991).
2 G.L. Velthof and O. Oenema, Nitrous oxide fluxes from grassland in the Netherlands: II. Effects of soil type, nitrogen fertilizer application and grazing. Submitted to European Journal of Soil Science.
3 D.W. Bussink, Relationships between ammonia volatilization and nitrogen application rate, intake and excretion of herbage nitrogen by cattle on grazed swards, Fertilizer Research 38 (1994), 111-121.