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Sources of nitrous oxide production among European coniferous and deciduous forest types

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Background and objectives
Forests are important sources for emissions of nitrous oxide (N_2O) into the atmosphere. In the soil, N_2O is produced as an intermediate or end product from biological nitrification and denitrification. The strength of each process for producing N_2O is strongly influenced by environmental parameters such as soil chemical and physical properties, climate and vegetation. To predict future N_2O emissions it is therefore necessary to identify and characterize the processes important for N_2O production associated with different land use. Previous work has shown that the N_2O source strength can be related to forest type (Butterbach-Bahl et al. 1997), but little is known about the processes. In this study we examined the relationship between N_2O production, soil inorganic N availability and gross rates of mineralization and nitrification in different European forest sites.

Methods
Gross mineralization (NH_4^+ supply) and gross nitrification (NO_3^- supply) was measured in combination with N_2O emission after addition of ^{15}N-labelled NH_4^+ and NO_3^- to intact soil columns collected from the top 0-10 cm mineral soil layer. We included a total of 11 sites in the study. The sites comprised 4 deciduous forest sites (Bosco negri-I, Schottenwald-A, Ticino-I, Sorø-DK) and 8 coniferous forest sites (Achenkirch-A; Glencorse-GB; Höglwald-D; Hyytiälä-SF; Nyirjes-HU; San RossoreI; Speulderbos-NL). Each site was visited twice during one growing season, *viz*. once in the spring and once in the autumn. Two sites, Hyytiälä and Sorø, were observed four times through the season.

Results

Emissions of N_2O in samples treated with NO_3^- varied considerably (range $<1 - 467$ μg N m^{-2} h^{-1}) between the different sites. The highest emissions were observed in sites dominated by deciduous trees (Bosco negri, Schottenwald and Sorø). Several of the coniferous sites showed little or no emissions of N_2O (e.g. San Rossore, Speulderbos and Hyytiälä). A similar effect of tree species was also observed in soil cores without N-additions and in soil cores treated with NH_4^+.The overall ratio of N_2O emissions from deciduous soils vs. coniferous soils averaged 3.6. The N_2O emissions increased ca. 3.5 times upon NO_3^--additions and ca. 1.4 times upon NH_4^+-additions.

In experiments with $^{15}NO_3^-$-labelling the ^{15}N enrichments of N_2O closely reflected that of the NO_3^--pool. In all but one (Achenkirch) experiments with $^{15}NH_4^+$-labelling, the N_2O was substantially lower enriched than the NH_4^+-pool. Among all sites it was calculated that NO_3^- accounted for 60% of the N_2O produced independent of vegetation type. About 14% of the evolved N_2O could be linked to the NH_4^+-pool with a trend showing that NH_4^+ was a more important source for N_2O production in the deciduous sites than in the coniferous sites.

In agreement with this observation, it was found that N_2O emissions in the deciduous forests were positively correlated to gross nitrification, with an average N_2O:nitrification ratio of 0.025. There was a similar trend for the coniferous soils (ratio 0.005), but the relationship was not significant. Nitrous oxide emissions were weakly, but significantly ($P<0.05$), related to gross mineralization in the coniferous soils, but no relationship was observed for the deciduous soils.

Discussion and conclusions

The experiment does indicate that N_2O production was dominated by denitrification at almost all sites. An exception to this general pattern was the Achenkirch site that showed significant responses to the NH_4^+-treatment. Achenkirch also had the highest gross nitrification rate, emphasizing nitrification as an important process for N_2O production here. We observed a significant relationship between gross nitrification and N_2O emissions in the deciduous forests, however, the isotopic footprints did not confirm this relationship. It is therefore likely that the role of nitrification was as precursor of NO_3^- for denitrification rather than N_2O production per se. Production of N_2O from N-mineralization has never been documented. The positive relationship between N_2O and gross mineralization in the coniferous sites thus probably expresses a relationship between the potentials for N_2O loss and N-cycle characteristics. That is, ecosystems with “open” N-cycles, characterized by high turnover rates, are more likely to loose N_2O compared with “closed” N-cycle systems, characterized by low turnover rates. In summary, we conclude that i) deciduous soils emitted ca. 4 times more N_2O than coniferous soils, ii) 60% of the N_2O was derived from the NO_3^- pool (denitrification)

and 14% from the NH_4^+ pool (nitrification), iii) gross nitrification was a significant predictor of N_2O emission in deciduous soils with a N_2O:nitrification ratio of 0.025, and iv) N_2O emissions were positively related to gross mineralization in coniferous soils.

References

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