Winter N_2O accumulation in sub-boreal grassland soil depends on clover and pH

Erin Byers[1], Marina Bleken[1] and Peter Dörsch[1]

[1] Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, Ås, Norway

E-mail: erin.byers@nmbu.no

Abstract

Legumes such as clovers are included in grassland mixtures to improve nitrogen use efficiency. However, clover may fuel freeze-thaw N_2O emissions, which are important in temperate to boreal regions. We investigated whether liming with dolomite mitigates this effect. Previous lab studies have shown that raising pH lowers the N_2O/N_2 ratio of denitrification. Subsoil air probes, soil moisture and temperature loggers, and surface fast-chamber flux estimates gave detailed data over winter in a liming trial in southeast Norway. Pure clover had the highest subsoil N_2O accumulation during snow cover and prolonged anoxia. The pH effect was less clear.

Keywords: nitrous oxide emissions, liming, grassland mixtures, legumes

1. N2O emissions as affected by freeze-thaw, legumes, and pH

In climates experiencing freeze-thaw conditions, roughly half of N_2O in croplands may be produced in the winter and early spring (Kaiser 1998, Flessa et al., 1995). Including legume species in grassland mixtures may increase N_2O emissions (Basche 2014). It is unknown how clover affects winter N_2O emissions; aboveground clover biomass is N-rich and frost sensitive compared to grass, and belowground biomass includes N-rich root nodules.

Raising the pH of slightly acidic soil by liming should improve the ability of denitrifiers to reduce N_2O all the way to N_2 – potentially lowering N_2O emissions (Bakken 2012), also over winter (Russenes 2016). To our knowledge, pH effects on winter N_2O emissions associated with clovers has not been tested.

2. Methodology

A detailed study of subsoil air and surface emissions was conducted November 2017-April 2018 in Ås, SE-Norway, coverintg grass, grass-red clover mixture, and pure red clover stands, untreated (pH 5.18) or dolomite-limed in 2014 (pH 6.09). We installed porous-tipped subsoil air probes at 5, 24, and 40 cm depths, analyzing concentrations of N_2O, O_2, and CO_2 weekly. Soil moisture and temperature probes were installed at similar depths. We estimated surface N_2O flux by robotized fast-chamber technique whenever conditions allowed. No measurements made in deep snow cover.

After interpolating missing soil air measurements, we estimated the total amount of N_2O accumulating in soil using Henry's Law with Van't Hoff temperature correction. Ice-filled volume was excluded.

3. Results

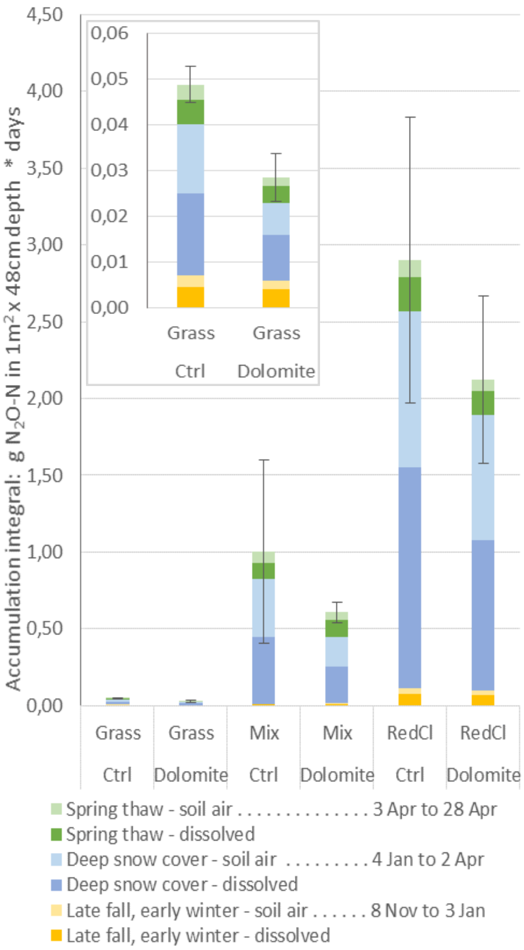

Fig. 1: Sub-surface N_2O accumulation for each treatment (g N_2O * days, ±SE over whole study). Accumulation shown per off-season period. Lighter color indicates soil air fraction, darker indicates fraction dissolved in soil water. (Insert: grass shown separately for scale).

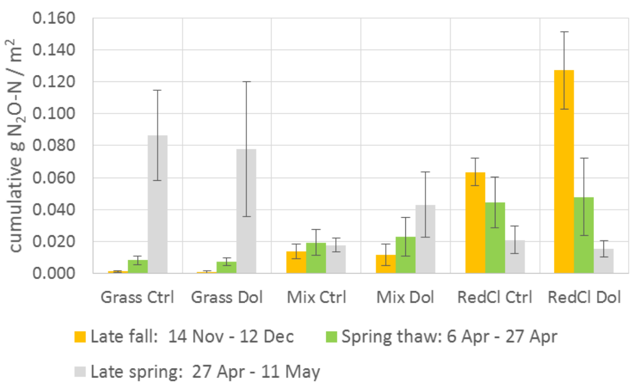

Fig. 2: Average N_2O surface flux (±SE) in different treatments and periods.

Sub-surface N_2O accumulated most during anoxia under deep snow cover. Pure red clover accumulated the most N_2O (Tukey α=0.05), while the grass-clover mixture accumulated more than grass (Tukey α=0.30).

Dolomite-limed grass plots accumulated less subnivean N_2O than the grass control (p=0.036), mainly during deep snow cover. pH effect in grass-clover mixture (p=0.55) and pure red clover (p=0.51) was less clear.

The magnitude of N_2O emissions in late fall and spring thaw corresponded to the proportion of clover, while grass-only had highest fluxes in late spring, after spring thaw. pH effect on cumulative N_2O fluxes was less clear.

References

Bakken, L.R., Bergaust, L., Liu, B., Frostegard, A., 2012. Regulation of denitrification at the cellular level: a clue to the understanding of N_2O emissions from soils. Philosophical Transactions of the Royal Society B: Biological Sciences 367, 1226–1234. https://doi.org/10.1098/rstb.2011.0321

Basche, A.D., Miguez, F.E., Kaspar, T.C., Castellano, M.J., 2014. Do cover crops increase or decrease nitrous oxide emissions? A meta-analysis. Journal of Soil and Water Conservation 69, 471–482. https://doi.org/10.2489/jswc.69.6.471

Flessa, H., Dörsch, P., Beese, F., 1995. Seasonal variation of N_2O and CH_4 fluxes in differently managed arable soils in southern Germany. Journal of Geophysical Research 100, 23115. https://doi.org/10.1029/95JD02270

Kaiser, E.-A., Kohrs, K., Kücke, M., Schnug, E., Munch, J.C., Heinemeyer, O., 1998. Nitrous oxide release from arable soil: importance of perennial forage crops. Biology and Fertility of Soils 28, 36–43. https://doi.org/10.1007/s003740050460

Russenes, A.L., Korsaeth, A., Bakken, L.R., Dörsch, P., 2016. Spatial variation in soil pH controls off-season N_2O emission in an agricultural soil. Soil Biology and Biochemistry 99, 36–46. https://doi.org/10.1016/j.soilbio.2016.04.019