GHG emissions and agronomic feasibility for forage production on inverted peat soil

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Abstract

We studied greenhouse gas (GHG) emissions (CH_4 and N_2O), agronomic performance and soil conditions in a grassland on an inverted peat soil that was earlier cultivated and tile-drained, and compared it with grassland on conventionally tile-drained peat. A neighbouring undrained peat was used as a reference for GHG emissions. Preliminary results (2-year field data) revealed reduced GHG emissions from the inverted peat relative to the tile-drained peat, mainly caused by lower CH_4 emissions. Our data suggest that peat inversion can improve the agronomic feasibility of forage production in cool-moist areas with abundant organic soils, and can offer a way of agronomic adaptation to a climate with increased precipitation. At the same time it may reduce the GHG footprint of forage production.

Keywords: Greenhouse gas mitigation, peat soil, drainage, adaptation

Introduction

Many grasslands in Western Norway are situated on former bogs, posing agronomic and environmental challenges. In some regions, grasslands are established on cultivated tile-drained peat soils situated on top of a self-draining mineral soil covered by a thin layer of impermeable mineral soil. In such regions, peat inversion can be a viable strategy to ameliorate cultivated peatland for forage production, and to protect the peat from further decomposition. The peat soil is covered with mineral soil while maintaining connectivity to the self-draining subsoil by means of tilted mineral soil layers (Fig.1). The objective of the present study was to investigate if peat inversion (IP-soil) could reduce CH_4 and N_2O emissions relative to tile-drained peat (TD-peat), while at the same time improving its agronomic performance. We hypothesised that peat inversion would result in higher grass yields, better soil aeration, more efficient infiltration and drainage, lower ground water tables, and less N_2O and CH_4 emissions, relative to tile-drained peat. To assess the overall effect of peat cultivation on CH_4 and N_2O emissions, an uncultivated peatland was included in the study.

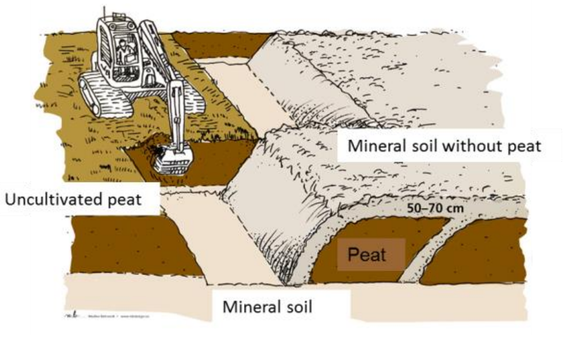

Figure 1. Principle for peat inversion.

Materials and methods

In 2014, grassland fields were established on an IP-soil that was previously a TD-peat, and a neighbouring TD-peat at Fræna in western Norway (62°96'N, 7°14'E). N fertilizer was applied as 30 tonne cattle slurry (54 kg NH_4-N ha^{-1}) and 150 kg NH_4NO_3-N ha^{-1} in 2014 (establishing year). In 2015, only mineral fertilizer was used (260 kg N ha^{-1}), and split between spring (150 kg N ha^{-1}) and after first harvest (110 kg N ha^{-1}). To be comparable to normal farming practise, the grasslands were compacted with three passes wheel by wheel per year by a tractor (5.2 tonne), as the grasslands were cut with a two-wheel weeper.

We investigated grass yields, soil physical conditions, depth to ground water table, and N_2O and CH_4 emissions throughout two growing seasons. GHG measurements on uncultivated peat were carried out in 2015, only. All three peat sites were situated in close vicinity to each other on top of a silty sand. N_2O and CH_4 fluxes were measured by closed chamber technique approximately weekly throughout the growing season (starting from summer 2014, when the field was established), with six chambers in each of the two grasslands, and two chambers on the uncultivated peat. During a period of two weeks after fertilizer application, more frequent flux measurements were performed, whereas measurements were less frequent in autumn.

To check for CH_4 accumulation in the inverted peat body, we installed porous suction cups at the same location as the flux chambers in 2015, probing the top of the buried peat layer (95–105 cm below soil surface). Two more cups were installed 20 and 40 cm above this in the silty sand above the peat. Pore size distribution and aeration properties of the topsoil were determined in undisturbed 100 ml cylinder cores taken from 5-10 cm depth. Depth to the ground water table (GWT) was measured at every gas sampling by a tape measure in perforated vertical PVC tubes, permanently installed close to the chambers.

Results and discussion

The total pore volume was largest in the TD-peat, but the air-filled porosity was smaller than in the IP-soil. In the TD-peat the water infiltration after rain was slow, resulting in periods with waterlogged soil. During 2015, GWT in the TD-peat varied between 0 and -117 cm, with an average of - 68 cm. In the IP-soil, the GWT in the tilted layers of silty sand were mostly below 130 cm. In contrast to the TD-peat, the top soil of the IP-soil was never waterlogged.

In both fields, the grass yields were high compared with the average in the district, being 14.9 and 11.2 t dry matter per ha on IP-soil and TD-peat, respectively, in 2015. Cumulative N_2O emissions were slightly lower in TD-peat than in IP-soil in the warm and dry summer of 2014 (1.5 versus 2.0 kg N_2O-N ha^{-1} in fertilized plots), whereas in the wet year of 2015, N_2O emissions were greater in TD-peat (4.3 versus 3.6 kg N_2O-N ha^{-1} in fertilized plots; Fig.2). In 2015, N_2O peak emissions in TD-peat were observed shortly after fertilization (max 1900 µg N_2O-N m^{-2} h^{-1}), whereas IP-soil had smaller peaks that lasted longer (max 330 µg N_2O-N m^{-2} h^{-1}). The reason for the higher fluxes shortly after the fertilization in TD-peat is likely the rapid denitrification of added NO_3 in the wet peat, fuelled by easily available carbon from the degrading peat. A similar pattern of N_2O emissions was observed in another poorly drained peat soil in western Norway (Hovlandsdal, 2011). Only small N_2O emission was observed in unfertilized TD-peat (Fig.2). This may be due to the poor drainage (with periodical waterlogging) and/or low nutrient content of the peat.

CH_4 emissions were much larger in the TD-peat than in the IP-soil. In 2014, CH_4 emissions were high in late autumn, whereas in the wet year of 2015, high emissions were observed throughout the whole summer. There were large variations in CH_4-emissions between the measurement locations. The average cumulated emissions in TD-peat and IP-soil were 52 and 0.2 kg CH_4-C ha^{-1}, respectively in 2014, and 170 and 0.6 kg CH_4-C ha^{-1} in 2015. In the IP-soil, there were periods with a net uptake of CH_4. High concentrations of CH_4 in the soil air right above the buried peat (up to 45 vol %) indicated substantial CH_4 production in the buried peat, but only a minor part of the CH_4 reached the surface. This is likely because the mineral cover layer acted as an efficient scrubber for CH_4 by supporting growth and activity of microbial CH_4-oxidizers. In the uncultivated peat, the CH_4-emissions were small (4.1 kg CH_4-C ha^{-1} in 2015), but higher than in the IP-soil. Calculated as global warming potential (GWP) in CO_2 eq. per ha, the GWP based on CH_4 and N_2O emissions was higher in the TD-peat than in the IP-soil. This was most evident in 2015 (Fig.2).

Conclusion

Our case study suggests that inversion of earlier TD-peat can improve agronomic feasibility while reducing CH_4 emissions. More investigations, including C-flux measurements, are needed to prove that peat inversion reduces GHG emissions and slows down peat degradation relative to grassland cultivation on TD-peat drained peat.

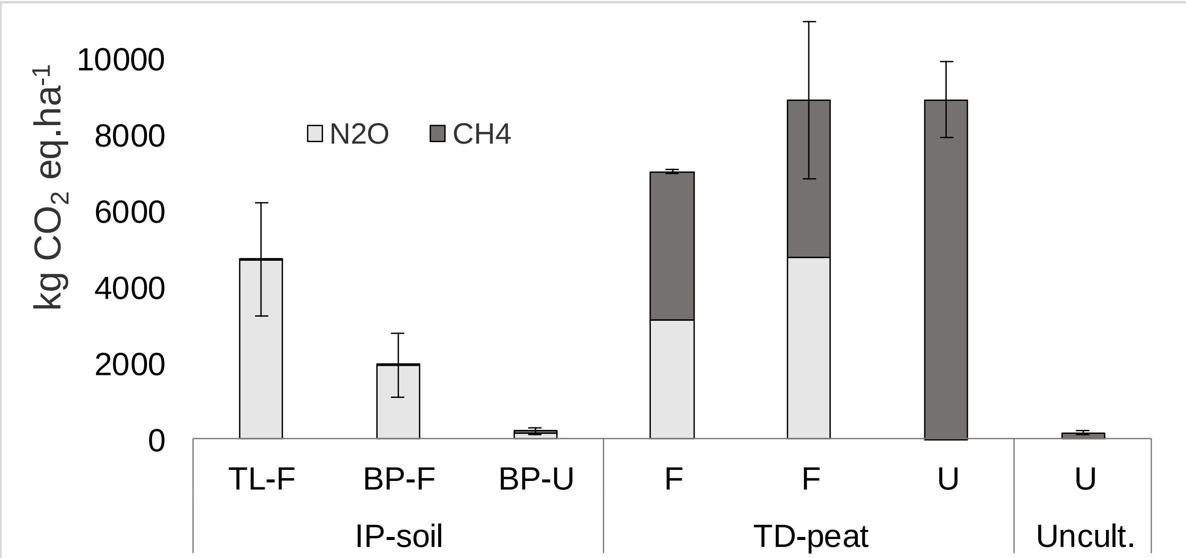

Figure 2. Cumulated GHG emissions from grassland on IP-soil and TD-peat, and an uncultivated peat the growing season 2015. The measurement locations on IP-soil are on the top of tilted mineral layer (TL), on the top of buried peat (BP), either fertilized (F) or unfertilized (U), and on the TD-peat, either fertilized (F) (two locations) or unfertilized (U). Emissions of N_2O and CH_4 are calculated as CO_2 equivalents per ha. The values are means of two parallel chambers at each location, with min and max level indicated by the vertical line.

References

Hovlandsdal, L. (2011). Long term effects of liming on nitrous oxide emissions from cultivated organic soil. Master thesis NMBU 2011. 43 p.

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