Skogssällskapet

Slutrapport

Projektrubrik: Towards climate-responsible forestry: Assessing the greenhouse gas balances of drained and restored peatland forests in boreal Sweden
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Populärvetenskaplig sammanfattning

In countries like Sweden, where between 1.5 and 2.0 million hectares of natural peatlands have been drained for forestry, knowledge on biosphere-atmosphere greenhouse gas (GHG) exchanges from these areas is needed for national GHG accounting as well as for identifying suitable management strategies to reduce GHG emissions. The overarching goal of this project was to determine the climate impact of continued peatland forestry vs peatland restoration which are the two primary management strategies currently debated among the Swedish governmental agencies and policy makers.

The project was carried out at two historically drained nutrient-poor peatland forests (Trollberget and Hälsingfors) located in the vicinity of Vindeln, Västerbotten. In Nov 2020, a ~10 ha area within the Trollberget site was rewetted with an additional ~1.5 ha still remaining as a drained control. Altogether, this project combined plot-level carbon dioxide (CO2) and methane (CH4) flux measurements using manual chambers at the Trollberget site with ecosystem-scale GHG measurements using the eddy covariance technique at Hälsingfors as well as complementary data on tree production, vegetation cover and soil properties.

An analysis of the so far collected data suggests that the annual GHG balance from soil-atmosphere CO2 and CH4 exchanges (incl. net CO2 uptake by trees and respiration losses during the night and non-growing season months) for the two drained peatland forest sites may vary from sink to source depending on annual tree growth. Furthermore, the GHG balance at the drained sites was dominated by the net CO2 exchange although CH4 emissions contribute about 30% when accounting for the ~30 times greater warming potential of CH4 relative to CO2.

The preliminary data from the first growing season following rewetting suggests only limited changes in CO2 and CH4 fluxes which remain still more similar to the drained conditions than to those in the nearby natural Degerö mire. However, the effects of rewetting may increase over the coming years in relation to changes in vegetation development and soil biogeochemistry. Continued monitoring for another two years (2021/22) is therefore planned in order to gain a more robust understanding of the initial rewetting effects on the climate impact of drained peatland forests in boreal Sweden.

Overall, the combination of datasets from drained, rewetted and natural conditions allowed for a unique comparison of the GHG balances within the same area. The main conclusions from this study are that i) nutrient-poor drained peatland forests in boreal Sweden do not act as major GHG sources and ii) rewetting has limited effects on the GHG balance during the initial year. The insights from this project thus provide the various Swedish forest stakeholders more science-based evidence to support sustainable and climate-responsible forest management decisions.

Resultat

The overall project aim was to investigate how rewetting affects the GHG balance of drained peatland forests in boreal Sweden. To achieve this, I conducted GHG flux measurements along 4 transects established perpendicular to the main drainage ditch at 3 different distances from the ditch (i.e. 5, 25 and 50 m) as well as inside of the main drainage ditch. These data were further complemented by various supporting biotic/abiotic measurements to monitor their change following rewetting and to elucidate the driving variables of the fluxes. The results presented in this report primarily focus on the drained peatland forest sites as data from the rewetting area is still limited (May-Aug 2021).

Daytime net CO2 exchange (i.e. NEE) was negative indicating CO2 uptake during the growing season months at the drained peatland forest for all three ditch distances (Appendix Fig. 1a-c). No significant ditch distance effect was found on the transect CO2 fluxes but the 25 m location showed overall the greatest net CO2 uptake. This was a result of both slightly higher gross primary production (i.e. GPP) of the ground vegetation and slightly lower soil heterotrophic respiration (i.e. Rh) compared to the 5 and 50 m ditch distances. The initial effect of rewetting (i.e. <1 year after blocking the ditches) indicates that the net CO2 uptake has increased slightly at all 3 ditch distances (Appendix Fig. 1d) but further measurements are needed to make more robust assessments.

The methane (CH4) emissions measured along transects at the drained peatland forest site were generally low (<5 mg C m-2 h-1) (Appendix Fig. 2a) likely due to the existence of a sufficient aerobic peat layer where CH4 oxidation into CO2 can take place. The one time sampling campaign for nitrous oxide (N2O) showed very low emissions and even some small uptake fluxes (Appendix Fig. 2b) which was expected given the high soil C:N ratio (~45). Overall, the CH4 and N2O emissions were slightly higher at the 25 m ditch distance, however, this difference was not statistically significant. During the first growing season months following rewetting, CH4 emissions had not yet changed considerably (Appendix Fig. 2c).

The GHG flux data from the main drainage ditch for the drained peatland forest site have been separated into vascular- and moss-dominated sections. The vascular plant plots showed significantly higher net CO2 uptake (Appendix Fig. 3a) likely due to a dense cover of Carex rostrada with high biomass values. In comparison, there was no significant difference between the vascular- and moss plots when it comes to the ditch CH4 flux (Appendix Fig. 3b) which is partly due to the very large variability in the moss-dominated (mostly Sphagnum) sections. After rewetting, the net CO2 uptake was significantly reduced in the filled ditch where plant production has not yet recovered (Appendix Fig. 3c). Meanwhile, CH4 emissions from the filled ditch were also significantly lower.

The total GHG balance based on daytime measured NEE as well as CH4 emissions expressed as CO2 equivalents indicated a net GHG sink for both the drained and recently rewetted sites (Appendix Fig. 4). The generally similar GHG balances for the two sites suggest that rewetting has so far had a limited effect on the GHG fluxes. Moreover, the GHG balances were driven primarily by NEE (~70%) although CH4 emissions also played an important role when considering its 30 times larger warming potential. Compared to the natural peatland, both the drained as well as the rewetted sites exhibit far smaller net GHG uptake.

It is noteworthy, however, that the annual GHG balance requires also the accounting for the CO2 uptake via tree biomass production (~20-120 g C m-2 yr-1 at the drained sites; near-zero following rewetting) and GHG losses occurring during the night and non-growing season months. Preliminary data from the continuous ecosystem-scale GHG flux measurements at the drained Hälsingfors peatland forest indicate a sink of ~100 g C m-2 yr-1 in 2020, whereas empirical modeling of the plot-scale data at Trollberget suggests a weak source of ~10 g C m-2 yr-1 during 2019-2020. This difference

in annual budgets is mainly related to a denser tree cover at the Hälsingfors site and shows the importance of tree CO2 uptake in determining the GHG sink-source strength.
Less than one year following rewetting, the observed changes in GHG fluxes are minor and still more similar to the drained conditions than to those in the nearby natural Degerö mire. However, the effects of rewetting on the GHG dynamics are expected to further increase over the coming years and a follow up project has been launched to continue the monitoring at the rewetting site. Overall, the main conclusions from the currently available data are that i) nutrient-poor drained peatland forests in boreal Sweden do not act as major GHG sources and ii) rewetting has limited effects on the GHG balance during the initial year.

Målbeskrivning

Overall, the project followed the proposed activity- and time plan which means that the primary goals of the project have been or will be achieved in the near future.

The most important deviations were caused by the decision from Länsstyrelsen Västerbotten to postpone the ditch-blocking activities until Nov 2020. This means that I was not able to collect any rewetting data within the duration of this project (end date: Apr 2021). However, I will continue exploring the initial restoration effects during 2021/22 thanks to additional funding from Formas for which the current project from Skogssällsskapet was an important stepping-stone.

In addition, there was also a delay with starting the collection of ecosystem-scale eddy covariance GHG flux data at the second drained peatland forest site (Hälsingfors) due to persistent technical problems. These issues were finally resolved in Mar 2020 and good quality data is available starting from then. These data are currently processed by a PhD student in a parallel project and will be made available as reference for further comparison with results from this rewetting project.

Finally, some delays to data analysis and dissemination activities were caused by me taking parental leave between Jul 2018 and Aug 2019 for a total of 10 months. However, the work on the first publication focusing on the GHG balance of drained peatland forests has now started with an anticipated submission by the end of this year. The second publication on rewetting effects will occur during my subsequent Formas project period (2023) due to the postponed ditch-blocking activities.

Kommunikation och nyttiggörande av resultat

1) I presented my work at:
• The European Geosciences Union (EGU) conference that attracts >10 000 scientists from across the world. “Soil-atmosphere CO2 and CH4 fluxes in a nutrient-poor drained peatland forest in boreal Sweden” (Apr 2020)
• The Annual Krycklan Symposium which is well attended by the Swedish forest stakeholders. “How does rewetting affect the greenhouse gas balance of a drained peatland forest in boreal Sweden?” (Sep 2020)
2) Popular science ”Forskarintervju” published on the Skogssällskapet website (Oct 2020) and in the magazine Skogsvärden (2020-4). ”Ny forskning ska visa hur skog på torvmark kan göra bäst klimatnytta” (text: L. Mölder)

3) I was a member of the Advisory board for a recent report by Skogsstyrelsen on options for mitigating the climate impact of drained peatland forests “Klimatpåverkan från dikad torvtäckt skogsmark – nuläge och möjliga åtgärder” (Apr 2021)
4) I have been in close contact with representatives from Länsstyrelsen VB, Skogsstyrelsen and Holmen Skog informing them about the project and disseminating the results in multiple meetings. I am also leading a new collaboration between SLU and Holmen Skog with the goal to establish additional research sites in rewetted peatland forests within Västerbotten.
5) This project has also lead to a collaboration with Finnish colleague Prof. Annalea Lohila who is leading the project “Finland – carbon-neutral Fenland”. Within this project we will share knowledge and discuss the ongoing restoration projects in Sweden and Finland, synthesize the existing data and apply it in joint modelling studies
6) I am currently involved in planning a demonstration area with boardwalks, signs and a visiting platform which will be established by Skogsstyrelsen and Länsstyrelsen VB at the rewetting area during 2021/22. I will use this demo-area for site excursions with stakeholders, members of the public as well as students.
7) Data collected within this project has also been used in several synthesis studies:
a. Virkkala et al. (2021) Statistical upscaling of ecosystem CO2 fluxes across the terrestrial tundra and boreal domain: Regional patterns and uncertainties. Global Change Biology 27: 4040-4059
b. Järveoja et al. (2020) Bimodal diel pattern in peatland ecosystem respiration rebuts uniform temperature response. Nature Communications 11: 4255
c. Virkkala et al. The ABCflux database: Arctic-Boreal CO2 flux observations and ancillary information aggregated to monthly time steps across terrestrial ecosystems. Earth System Science Data (in review)
d. Lembrechts et al. Global maps of soil temperature. Invited submission to Global Change Biology (in review)
8) Main supervisor for MSc thesis projects based on data from the Trollberget site:
• M. Casselgård “Effects of 100 years of drainage on peat properties” (SLU; Mar 2020)
• R. Onstenk “The effect of rewetting peatland forest on the emission of CH4 and CO2 in Northern Sweden” (Wageningen University; ongoing)