GLOBAL SYMPOSIUM ON SOIL ORGANIC CARBON, Rome, Italy, 21-23 March 2017

Re-wetting drained peatlands can potentially reduce large greenhouse gas emissions

Hongxing He[1], Åsa Kasimir[1]*

[1]Department of Earth Sciences, University of Gothenburg, Gothenburg, Sweden; E-mail: hongxing.he@gu.se

Abstract

Drained peatlands are hot spots for GHG emissions, which could be mitigated by rewetting and land use change. We performed an ecological analysis of rewetting drained fertile peatlands in a hemiboreal climate by different land use strategies over 80 years. Vegetation, soil processes and total GHG emissions were modeled using the CoupModel for four scenarios: 1) business as usual – Norway spruce with average groundwater level of -40 cm; 2) willow with groundwater at -20 cm; 3) reed canary grass with groundwater at -10 cm; and 4) a fully rewetted wetland. The predictions were based on previous model calibrations with a number of high resolution datasets consisting of water, heat, carbon and nitrogen cycling. The modelled long term spruce biomass was validated by measured onsite tree ring data. Scenario 1 resulted in a total soil emission (including stored peat depletion CO_2 + N_2O + CH_4) of 13.8 Mg CO_2eq ha^{-1} yr^{-1}, and compared with this the scenarios 2, 3 and 4 reduced emissions by 25%, 44% and 7%, respectively. Draining also increases vegetation growth but not as steep change as the GHG emissions increase. We conclude that raising the water table for fertile drained peat soils could significantly reduce GHG emissions. This needs to be considered for land use planning and policy-making.

Keywords: Norway Spruce, Willow, Reed Canary Grass, Wetland, Ground water level, CO_2, CH_4, N_2O

Introduction, scope and main objectives

The land-use sector 'Agriculture Forestry and Other Land Use (AFOLU)' contributes 24% of annual anthropogenic greenhouse gas (GHG) emissions. Of these, one quarter comes from drained peatlands, mainly in the boreal and tropical regions. The Swedish National Inventory Reporting to the UN climate convention (UNFCCC) shows drained peatlands to have emissions about 10 Tg CO_2eq yr^{-1}, almost as high as the road traffic, 17 Tg CO_2eq yr^{-1}.

Several factors have been found to influence the size of the emissions, including the groundwater level, land use intensity, climate zones, and soil fertility. In general, nutrient rich fens with deep groundwater level are larger GHG sources than ombrotrophic bogs with shallow groundwater level, while intensive land use in tropical and/or temperate regions have much higher emissions than extensive land use in boreal regions. For policy introduction it is a need to show potential of emission reductions and other ecosystem gains for a number of rewetting options. Since soil wetness is known as a decisive factor for GHG emissions, from a local management perspective re-wetting drained fertile peatlands is thus a promising mitigation strategy. The central questions were: 1) what is the best possible land use of drained peatlands? and 2) which vegetation type and soil wetness are preferable for low GHG emissions?

Methodology

We used the CoupModel for analyzing four land use scenarios associated with rewetting fertile drained peatland in hemiboreal climate. Four scenarios were developed, from moderately drained (i.e. groundwater level at around 1) -40 cm, 2) -20 cm, 3) -10 cm into 4) wet soil (i.e. a water level in the soil surface, 0 cm). Since willow and reed canary grass are known to cope wetter conditions better than spruce these were selected as vegetation for scenario 2 and 3 respectively.

The data used for model forcing, parameterization, calibration and validation was obtained from the Skogaryd research catchment (http://gvc.gu.se/english/research/skogaryd), located in the southwest of Sweden (58°23′ N, 12°09′ E), which now has a managed Norway spruce (*Picea abies*) forest 66 years of age. The site has drained fertile peat soil earlier used for agriculture from 1870s until 1951. The ecosystem model CoupModel (available at www.coupmodel.com) was used to simulate the scenarios. First the model was calibrated using high resolution datasets (2007-2009) consisting of net radiation, soil surface heat flow, soil temperature, soil water content, groundwater level, net ecosystem exchange and N_2O emissions (He et al., 2016a). Modelled long term (1951-2011) spruce biomass prediction was validated by measured onsite tree ring data. The calibrated spruce scenario was used as a base for generating the other scenario simulations (He et al., 2016b). Parameters describing the willow, reed canary grass and wetland characteristics and management regimes are not calibrated against real measured data on this site but are compiled from previous CoupModel applications made elsewhere. For scenario comparison the simulation period was 80 years for all scenarios, which includes a full forest rotation period. Model sensitivities were conducted by varying the groundwater level by ±20 cm, ±10 cm and ±5cm for scenario 1, 2 and 3 respectively.

Results

Over 80 years the simulated annual average aboveground biomass production was for spruce, willow, reed canary grass and wetland: 10.4, 10.0, 11.7 and 4.0 respectively, expressed as Mg CO_2 ha^{-1} yr^{-1} (Fig. 1). The results show the peat to disappear for the first three drained land use options by 11.5, 4.7, 1.1 Mg CO_2 ha^{-1} yr^{-1}, but accumulate by 1.2 Mg CO_2 ha^{-1} yr^{-1} for the wetland scenario (Fig. 1). Simulated N_2O emissions were 2.5, 1.0, 0.2 and 0 also expressed as Mg CO_2 ha^{-1} yr^{-1} for the four scenarios. For CH_4 emissions the spruce scenario had a soil uptake of 0.2 Mg CO_2 ha^{-1} yr^{-1} while the willow, reed canary grass and wetland scenarios emitted methane in the size of 4.6, 6.4 and 14.1 expressed as Mg CO_2 ha^{-1} yr^{-1} respectively (Fig. 2). The total soil GHG emissions for these four scenarios were: 13.8, 10.3, 7.7 and 12.9 Mg CO_2 ha^{-1} yr^{-1}. The results show that when groundwater level is deep CO_2 dominates the emission, and when wet CH_4 (Fig. 2). The relationship between N_2O and the groundwater level is not as clear as for the other gases but for the wetter scenarios N_2O emission was overall low. When adding all three GHG's together the tendency of higher emissions by deeper groundwater level prevails, however high emissions was found for the scenario 4 when the water level was in the soil surface, since this resulted in high CH_4 emissions (Fig. 2).

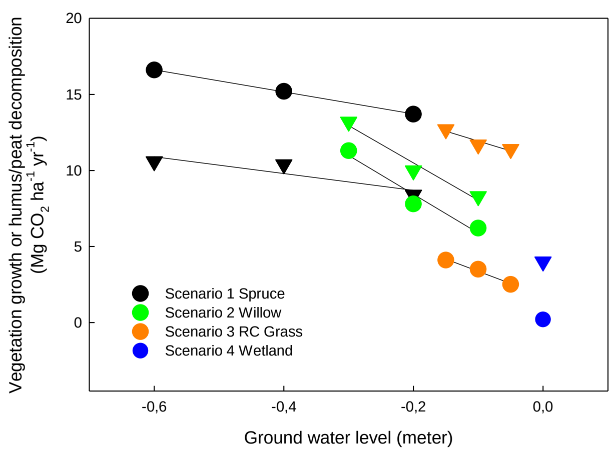

Fig. 1: Sensitivity of mean aboveground biomass growth and peat decomposition to the groundwater level. (▼) Vegetation growth and (●) peat decomposition. Vegetation for the scenarios are; 1) spruce, 2) willow, 3) reed canary grass and 4) wetland mosses.

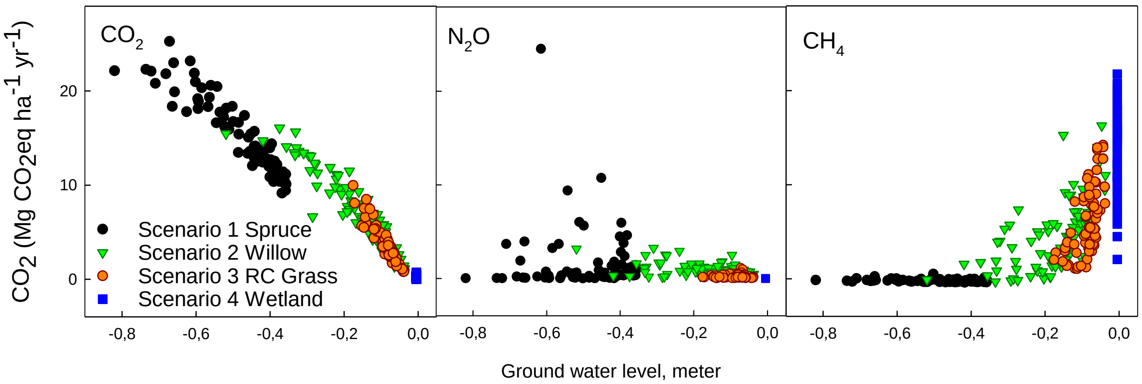

Fig. 2: Annual mean soil flux of CO_2 due to peat decomposition, N_2O and CH_4 for the four scenarios with 1) spruce, 2) willow, 3) reed canary grass and 4) wetland mosses, related to annual mean groundwater level over 80 years.

Discussion

While most of the biomass produced over a century is recycled into CO_2 the peat soil emissions adds GHG into the atmosphere which is distinctive from producing biomass on a mineral soil. Here we found the soil emissions of the scenario with water at -10 cm and reed canary grass to have the least GHG emissions, followed by willow, wetland, and where the spruce forest scenario was the worst with largest soil emissions. If also including the vegetation growth for a full GHG balance scenarios 2, 3 and 4 resulted in losses of 6.7, 7.0 and 7.2 Mg CO_2eq ha^{-1} yr^{-1} over the 80 years while the losses for the scenario 1 with spruce was lower, 5.5 Mg CO_2eq ha^{-1} yr^{-1} due to not including the final clear cut. After the harvest roots left in the soil will decay with a half-life of 19 years and of the harvested timber we assume 40% used as high quality timber and the rest (60%) as paper or fuel wood, which according to by IPCC guidelines have half-life of ‘Harvested Wood Products’ 30 years and 2 years respectively. Then it takes only ten more years after spruce harvest for this scenario to show a double loss, 10.9 Mg CO_2eq ha^{-1} yr^{-1}. The harvested willow and reed canary grass are all assumed to be incinerated for bioenergy purpose thus the carbon is released back to atmosphere quickly. It is also possible to consider avoidance of GHG by replacement of products otherwise causing high emissions, like concrete and fossil fuel use. However in a world where we want to avoid further warming we conclude biomass production on peat soils to be harmful for the atmosphere. We must keep the soil carbon in the ground, where peat soils are especially vulnerable for decomposition due to draining. How to best avoid GHG emissions needs more studies, including other plants and management options.

Conclusions

Compared to a business as usual spruce production on drained peat soil our examples show wetter conditions to mitigate soil emissions. Rewetting the drained peat soils need policy introduction and land use planning for actions reducing GHG emissions.

References

He, H., Jansson, P.-E., Svensson, M., Meyer, A., Klemedtsson, L., and Kasimir, Å.: Factors controlling Nitrous Oxide emission from a spruce forest ecosystem on drained organic soil, derived using the CoupModel, Ecological Modelling, 321, 46-63, doi:org/10.1016/j.ecolmodel.2015.10.030, 2016a.

He, H., Jansson, P.-E., Svensson, M., Björklund, J., Tarvainen, L., Klemedtsson, L., and Kasimir, Å.: Forests on drained agricultural peatland are potentially large sources of greenhouse gases – insights from a full rotation period simulation, Biogeosciences, 13, 2305-2318, doi:10.5194/bg-13-2305-2016, 2016b.