„Breaking the Ice“

Christopher Poeplau

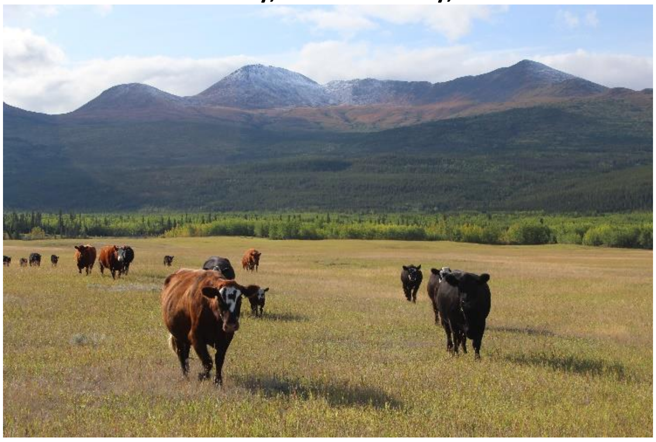
- **Effects of land use change on soil carbon dynamics in subarctic soils were recorded**
- **The interaction with the occurrence of permafrost under forest was the main focus**
- **Greater carbon losses when forest soils were permanently frozen prior to change**
- **Microbial carbon use efficiency improved with agricultural use**

Background, objective and approach

Advancing climate change is shifting potential agricultural land northward. This can potentially lead to increased land use changes in the vast subarctic and arctic areas of the world. When ecosystems are naturally taken under agricultural use, this can lead to a sharp decline in soil carbon stocks, which in turn fuels climate change. This could be even more true for permafrost soils, those soils that are permanently frozen under natural vegetation, because land-use change could lead to an acceleration of the thaw process.

With this main hypothesis, the DFG-funded project "Breaking the Ice" was started in January 2019. In addition to the general change of carbon stocks after land use change, different pathways and processes of the potential changes should also be elucidated. Among other things, microbial physiology played a key role in this project.

Pasture in the Ibex Valley, Yukon Territory, Kanada



The Canadian Yukon Territory was chosen as the study area because i) various permafrost zones can be found there in a relatively small area and easily accessible, ii) agriculture has been practiced since the Gold Rush (early 19th century), iii) the cultivated soils were comparable due to their location on the river, and iv) contacts with Canadian farmers could be established without difficulty.

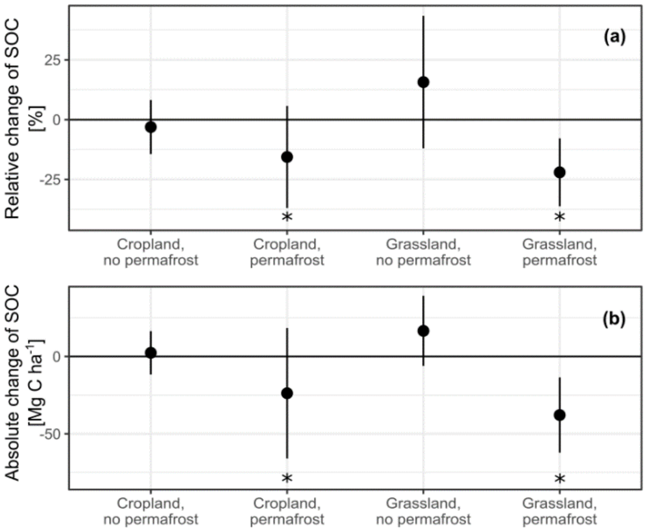
Agriculture in the Yukon Territory to date has tended to be small-scale, mostly organic, and focused on the local market. A total of 18 farms were visited, and in a paired approach, the adjacent forest and agricultural plots (cropland, grassland, or both) were each sampled, if possible to a depth of 80 cm. In addition, soil temperature sensors and green tea bags were used at 10 and 50 cm depth to measure litter decomposition rates. Both were removed again after 2 years. Finally, some key data on the management of the sampled area were requested via a questionnaire.

Frozen loam soil

The soil samples taken were already prepared on site and analyzed for stone content and bulk density. Carbon and nitrogen contents were then analyzed at the Thünen Institute, and phosphorus, texture and cation exchange capacity were analyzed on composite samples. The pH value was also determined. Finally, in addition to fractionation of organic matter, microbial C-use efficiency was determined using short-term incubations with isotopically labeled water (^{18}O). In this method, microbial growth is determined by the incorporation of the oxygen tracer into the DNA of the microorganisms.

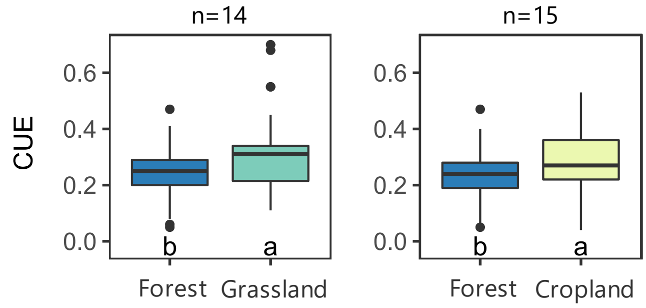
Key results of the project

On average, land use change from forest to cropland or grassland resulted in soil warming of 2.1 °C. In the case of permafrost soils, this led to an increased dew process and also drainage of the soils. In fact, permafrost was not detected in the upper meter of the soil in any case under cropland or grassland use, while this was the case in 11 of 18 forest sites. This change in microclimate and hydrology strongly affected soil carbon dynamics: Significant decreases in soil carbon stocks were found only when permafrost-influenced forest soils were converted to agricultural soils.



Relative and absolute change in soil organic carbon stocks at 0-80 cm soil depth after deforestation and establishment of cropland or grassland. were converted.

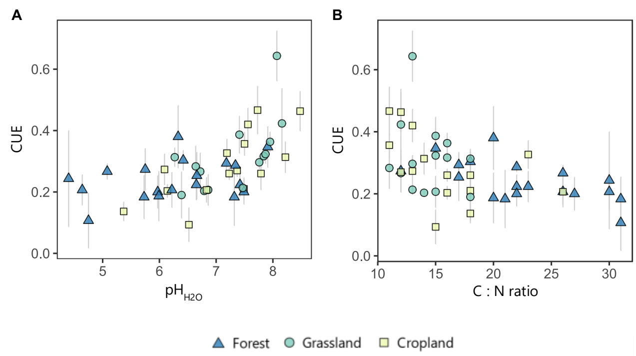
As expected, the greatest losses were found in the labile particulate carbon fraction. Interestingly, however, there was always an absolute increase in the more stable mineral-associated carbon fraction after land-use change. This can possibly be explained by the increase in microbial C use efficiency: After conversion to grassland or cropland, there was a 26% and 30% increase in this metabolic indicator, respectively, which may have favored the increased formation of dead microbial biomass and thus mineral-associated carbon. This could partly explain the positive trends in carbon stocks after deforestation of permafrost-free soils.



Microbial Carbon Use Efficiency (CUE) before and after deforestation.

It was also investigated by which factors the change in C use efficiency was favored. Here, the C:N ratio of the organic matter and the pH of the soil were of particular importance.

Changes of these factors after deforestation can be expected by the use nitrogen effect was, since microorganisms need this for biosynthesis and subarctic forests are often very nutrient-limited.



Microbial Carbon Use Efficiency (CUE) as a function of soil pH and the C:N ratio.

Summary and outlook

The project was able to give a first impression of the influence subarctic land use changes can have on soil carbon stocks and which processes can contribute to these dynamics. In the zone of discontinuous permafrost, it is of utmost importance to avoid deforestation of permafrost soils for a sustainable and climate-smart establishment of agriculture. Increased microbial growth may also have positive effects on soil carbon stocks on permafrost-free soils.

Further information

Contact

[1] Thünen Institute of Climate-Smart Agriculture
Christopher.poeplau@thuenen.de
www.thuenen.de/ak

Laufzeit

1.2019-3.2022

Projekt-ID

1987

Key publications

Peplau et al. (2022)
Subarctic soil carbon losses after deforestation for agriculture depend on permafrost abundance, Global Change Biology

Schroeder et al. (2022)
Deforestation for agriculture increases microbial carbon use efficiency in subarctic soils. *Biology and Fertility of Soils*.

Funded by

DFG Deutsche Forschungsgemeinschaft

DOI:10.3220/PB1668502011000