Potential impacts of permafrost degradation on carbon storage of peat soils in the Kolyma River basin, East Siberia


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Permafrost and Peat

The Kolyma River basin in East Siberia is covered with numerous peat-filled, drained lake basins known as alas. These peat soils are characterized by their high carbon content, which is maintained by cool, waterlogged conditions inhibiting decomposition—especially in the peatland active layer. As the arctic climate warms permafrost there can be expected to expose soils rich in highly labile carbon to potential microbial activity.

This could result in a loss of carbon due to microbial respiration or due to DOC export to aquatic systems. The latter limiting the potential to increase carbon availability to downstream ecosystems. Such export of terrestrial carbon to inland waters is a timing concern highlighted by Cole et al. (2007) that is magnified by our study of peat permafrost (Fig 1).

Because of the possible feedbacks of these processes both on arctic ecosystems and to the global carbon budget, it is important to understand the following questions:

1) Given the above low decomposition rates found in peat soils, will warming result in a substantial loss of carbon from permafrost soils?

2) If so, how does the in situ microbial activity or flushing of carbon into downstream ecosystems in the form of DOC?

We addressed these questions by analyzing carbon content and labile in the active and permafrost layers of five peatlands in the Cherskiy, Russia (Fig 1).

Figure 1: Locations of sample sites in the Kolyma river basin in eastern Siberia. Pipeline Alas, Ptarmigan Alas, and Grass Alas are near the town of Cherskiy, Siberia.

Findings

Overall, our data showed no significant difference between carbon content in frozen and active layers of peat soils.

This is most likely due to the high variability of carbon content among sites (Fig 5). Carbon content in active layers ranged from a low of 2 percent in yedoma soils found below the peat layer at Heroski Alas to a high around 47 percent in peat soils. From when sample soils contained yedoma soils were excluded, the samples with the lowest carbon content comprised approximately 20 percent carbon.

When we compared permafrost and active layer samples taken from the same site, we found greater carbon content and higher lability in the permafrost than in the active layer within all but one of the individual sites (Fig 6).

The site that did not show greater carbon content in the permafrost (Heroski Alas) had a very shallow layer of peat such that the permafrost sample contained yedoma soils. We were unable to obtain a sample of permafrost soil from this site.

Figure 2: Soil and water sampling

Figure 3: Increasing Carbon Content with Increasing Water in Soil Samples

We found high variability in the DOC accumulation of peat waters among peatland sites (Fig 7). All peatland peat waters had significantly higher DOC concentrations and carbon lability than downstream ecosystems in the Kolyma watershed (Fig 8).

Figure 4: Reusable Carbon and Total Organic Carbon

We have a strong positive correlation between water content and carbon availability in soil samples regardless of whether they originated from permafrost or active layer samples (Fig 8).

Figure 5: Reusable DOC (mg C/L)

Figure 6: U/Visible absorbance values for waters of the Kolyma watershed

At Each Site We:

Water samples from the lowest point without open water (Fig 2 shows water at this point or samples not sampled). Organic Carbon (mg/L) and DOC in each water sample using a fluorometer Using the biological oxygen demand (BOD) in the pore water collected from each alas as a measure of the available C in each sample. Measuring the BOD of 1g of soil suspended in rain water. This resulted in a loss of carbon due to microbial respiration or due to DOC export to aquatic systems.

CO2 in each water sample using a fluorometer.

Using loss on ignition (LOI) techniques.

References


Conclusions

Our results suggest that the carbon found in the permafrost of peat soils tends to be more labile than carbon found in the active layer.

This means that permafrost could contribute to the resupply of highly labile pools of organic carbon to microbes. The high carbon content and lability of peatland pore waters compared to other aquatic ecosystems suggests that the carbon is quickly processed either in the peatland itself or downstream.

Previous research has shown that hydrology may be one of the most important factors controlling carbon storage in peat ecosystems (Liptrot et al. 2008). The close correlation between water content and carbon in peat soils in our data corroborates these findings.

Emerging Questions

What factors are responsible for the variability in carbon content in different peatlands?

What was responsible for the shredding of the peat layer at Heroski Alas?

Why did peat soils from Ptarmigan – the only site that was not an alas – show lower carbon content than most of the alas sites?

To what extent and in what ways do peatlands contribute to carbon availability in downstream ecosystems?

How much peat water export enters downstream ecosystems during each season? How quickly is carbon from this water decomposed?

What impact does this have on downstream ecosystems?

Given the close link between peat soil saturation and carbon content, how will changes in hydrology resulting from climate change impact carbon storage in peatlands?

Will permafrost soil result in drainage loss and increase saturation and formation of peat soils?

How will this impact downstream ecosystems?

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