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 alases.

These peat soils are characterized by their high carbon content, which is maintained by cool, waterlogged conditions inhibiting decomposition – especially in the permafrost layer.

As the arctic climate warms permafrost thaw can be expected to expose soils rich in highly labile carbon to potential microbial activity.

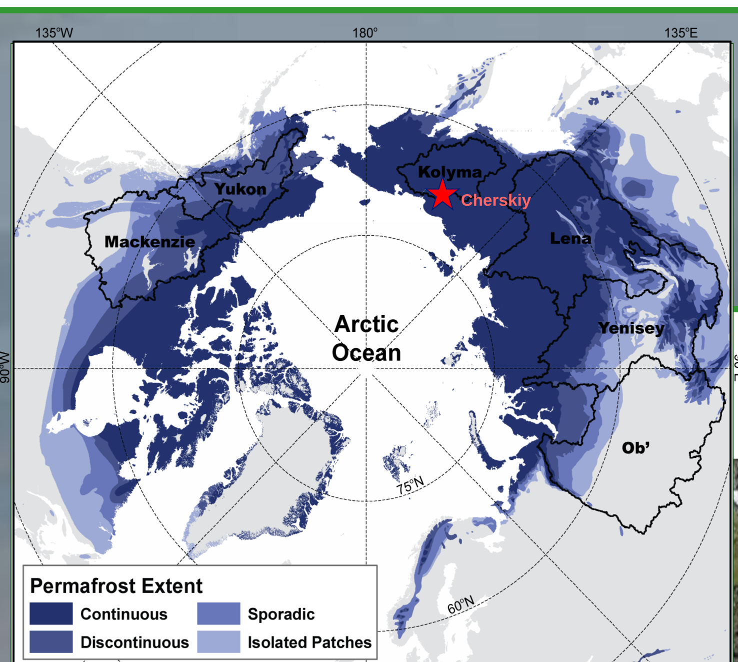
This could result in a loss of carbon stores due to microbial respiration or due to DOC export to aquatic systems. The latter having the potential to increase carbon availability to downstream ecosystems. Such export of terrestrial carbon to inland waters is a growing concern highlighted by Cole et al (2007) that is magnified by our study of peat permafrost (Frey & McClelland, 2009).

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:

Given the already low decomposition rates found in peat soils, will thawing result in a substantial loss of carbon from permafrost soils?

If so, is this the result of in-situ microbial activity or flushing of carbon into downstream ecosystems in the form of DOC?

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



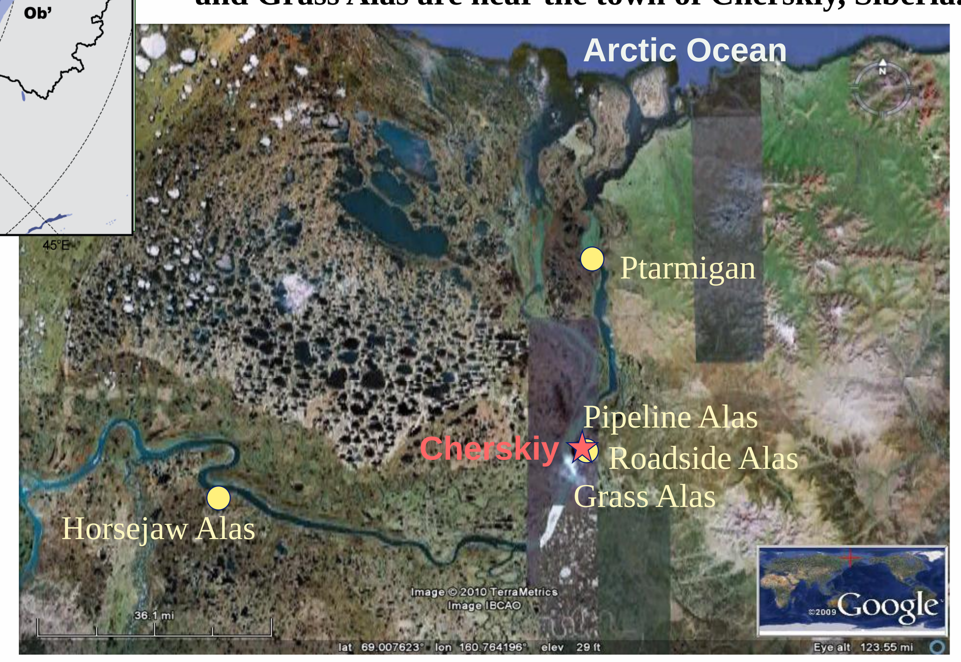


Figure 1: Locations of sample sites in the Kolyma river basin in eastern Siberia. Pipeline Alas, Roadside Alas, and Grass Alas are near the town of Cherskiy, Siberia.

At Each Site We:

Collected:	
Water samples from the lowest point without open water (Fig 2 shows pore water that was not sampled)	Soil samples from the active and permafrost layers in three locations forming a transect from the lowest point to the edge of peat cover (Fig 2 shows a permafrost soil core)
Analyzed:	
DOC in each water sample using a flourometer	Percent water and percent C content in each soil sample using loss on ignition (LOI) techniques
Measured C Lability by:	
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. Lability was defined as the amount of carbon respired over a 24 hour period

(Lability was measured as the amount of carbon respired over a 24 hour period)

Figure 2: Soil and water sampling

Permafrost Peat

Pore Water

Findings

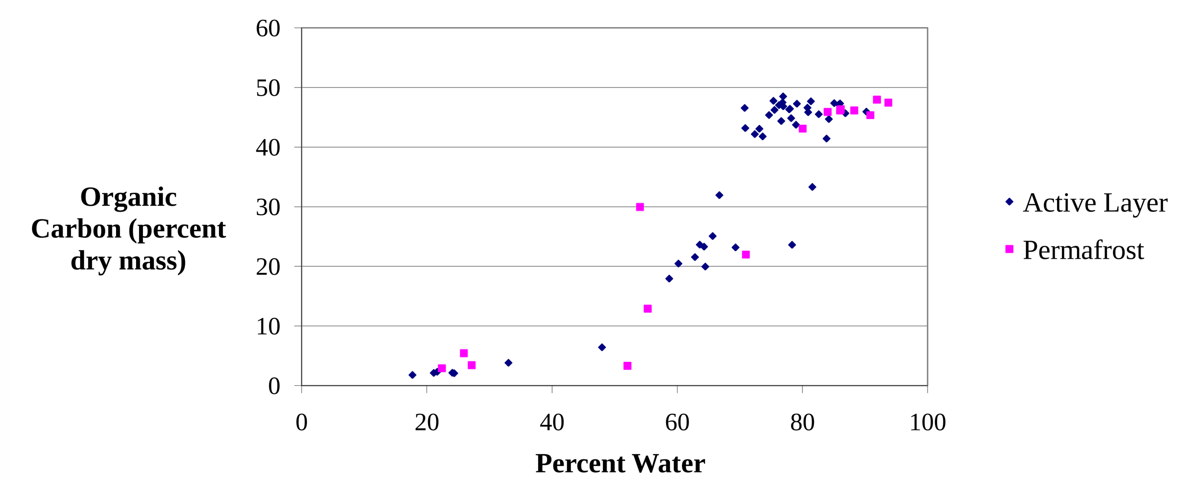
Overall, our data showed no significant difference between carbon content in frozen and active layers of peat soils.

This is most likely due to the high variability of carbon content among sites (Fig 3). Carbon content in soil samples ranged from a low of 2 percent in yedoma soils found below the peat layer at Horsejaw Alas, to a high around 47 percent in peat soils. Even when samples containing yedoma soils were excluded, the samples with the lowest carbon content contained 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 4).

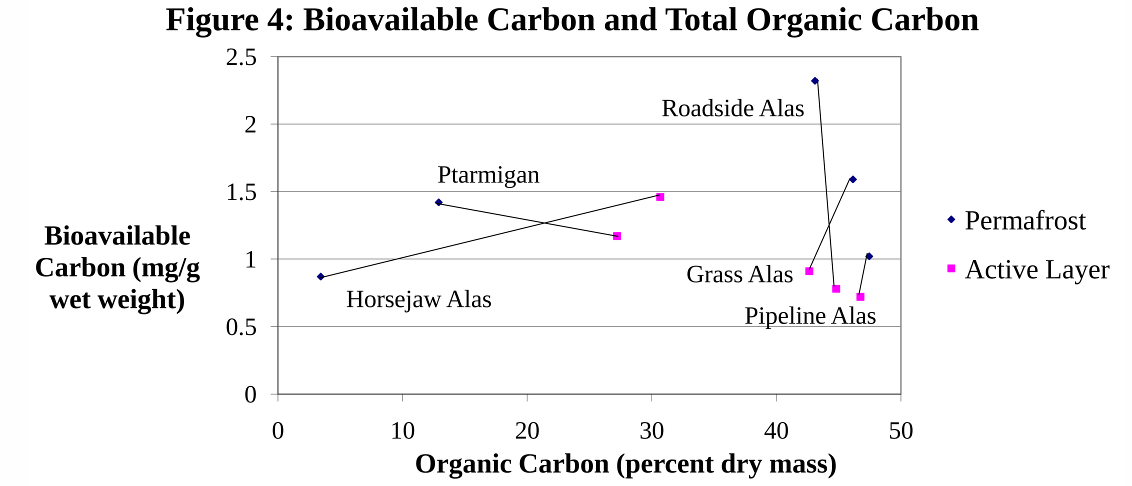
The site that did not show greater carbon content in the permafrost (Horsejaw Alas) had a very shallow layer of peat such that the permafrost sample contained yedoma soils. We were unable to obtain a sample of peat permafrost from this site.

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



We saw 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 4).

Figure 4: Bioavailable Carbon and Total Organic Carbon



We found high variability in the DOC cocentration of pore waters among peatland sites (Fig 5). All peatland pore waters had significantly higher DOC concentrations and carbon lability than downstream ecosystems in the Kolyma watershed (Fig 6).

Figure 5: Bioavailable DOC (mg C/L)

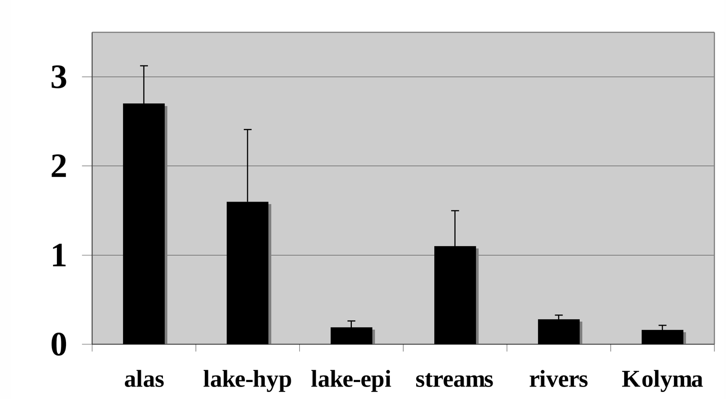
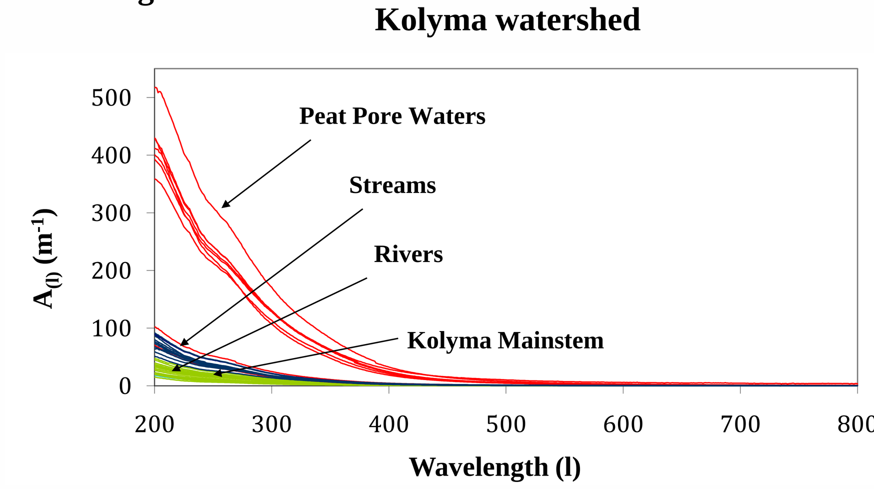


Figure 6: UV/Visible absorbance values for waters of the Kolyma watershed



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 thaw could result in the exposure of new, 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 peatlands themselves or downstream.

Previous research has shown that hydrology may be one of the most important factors controlling carbon storage in peat ecosystems (Limpens et al 2008). The close correlation between water content and carbon content 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 shallowness of the peat layer at Horsejaw 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 pore water 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 thaw result in drainage and loss or increased saturation and formation of peat soils?

How will this impact downstream ecosystems?

Figure 7: Two sample site locations

Pipeline Alas

Horesejaw Alas

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