Changing land cover affects temperature and active layer in subarctic regions

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Abstract

The objective of this research project is to look at the relationship between land cover, permafrost and soil in the subarctic region of Fairbanks, Alaska. Permafrost acts as barrier, holding water near the surface, and in 1908 a section of black spruce forest was clear cut for agriculture purposes. This transformed the land cover from spruce to predominately birch trees and increased permafrost thaw. The thawing of permafrost in this area created huge mounds in the forest known as the “bicycle bumps”. Transect soil moisture samples were taken on October 31, 2021 at the permafrost location and November 1, 2021 at the thermokarst location. Snow depth, snow surface temperature, and soil temperatures 5cm and 10cm were also taken a both locations. The results showed a connection between land cover and snow depth, further gravimetric soil samples are needed for measurable soil moisture data.

Research Question

How has the clearing of black spruce affected the active layer in the thermokarst location?
Does the an increased active layer(permafrost layer that freezes and thaws each year) have an affect on soils moisture content and temperature?
Importance: Increased land clearing could lead to further permafrost degradation and, warmer active layer above the permafrost , possibly causing declining snowpack.

Introduction

Climate change and development have created unique challenges around the world. One such challenge is the thawing of permafrost found in arctic and subarctic regions. Permafrost is the subsurface layer of soil that remains frozen throughout the year. This frozen layer holds water at the surface creating the wetland habitat important to animals and humans. What changes are happening in soil characteristics, like soil moisture, temperature, composition, microbial activity and methane release? There are so many interesting and important studies surrounding what permafrost and permafrost thaw but exactly how these changes will affect the flora and fauna in the area are still largely uncertain.

In a study affiliated with the International Permafrost Association(Chen, 2021), scientists looked at snow depth, land cover type, surface temperatures, and slope in relation to the thermal state of permafrost around the Alaska Highways(paras. 1). The study shows correlation between the snow depth, snow cover, and snow properties as well as how these factors affect heat fluxes, ultimately thawing underlying permafrost(2021). In a like manner, I compared adjacent sites off of the UAF ski trail system. Site one is an undisturbed black spruce forest that currently has a permafrost layer. The second site, now referred to as “the bicycle bumps” was once a black spruce forest but was cut down in 1908 and is now a birch thermokarst area with bumpy topography. For my GLOBE project I compared the soil moisture, soil temperature, surface temperature, and snow depth of these two land cover areas to better understand the relationship between permafrost and soil.

Research Methods

GLOBE data was collected on the ancestral lands of the Dena people of the lower Tanana River. The two data collection locations were adjacent to one another, divided by a UAF hiking/ski trail. The transect site 50 meters the west of the trail has a birch forest landcover and large thermokarst mounds known as the "bicycle bumps.” 50 meters east of the trail is a black spruce forests with a thick moss surface land cover and underlying permafrost.

In both locations transect soil moisture protocol was used to compare soil moisture in different land cover areas. 50 meters was measured, moving away from the trail, and marked every 5 meters with 3 sample collected at 50m. A trowel and pickaxe was used to dig 5cm into the soil and saved one soil sample from each location in a plastic bag. Soil was kept cold until samples could be dried. Snow surface temperature, soil temperature, and snow depth were also collected that this time.

Note: The data between sites was collected a day apart 10/31/21 atmospheric temperature was 7°C and 11/01/21 at 0°C. There was no snowfall in-between sample dates. Samples dried for 42 hours at 90 degrees F.

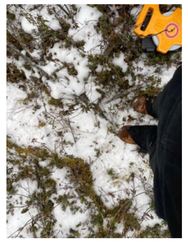

Figure 1. permafrost site Black spruce trees with thick moss layer

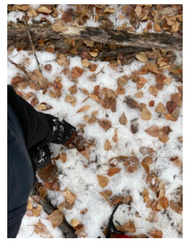

Figure 2. Thermokarst site Birch forest

Figure 3. Google earth image showing thermokarst transect site to the right and permafrost transect site to the left.

Results

After all soil samples were collected and dried in an oven for 42 hours at 90°F and then weighed a second time. The dry weights were then used to calculate the gravimetric soil moisture content. Figure 5. shows the soil moisture in both sites over a 50 meter profile location. The results in summary table 1 show that the standard deviation for permafrost gravimetric soil samples is at 17. 81 and 0.24 in the thermokarst location.

Summary Table 1.

Permafrost 10/31/21	GSM g/g	Soil Temp 5 cm (C)	Soil Temp 10 cm (C)	Snow Depth (cm)	Surface Temps (C)	Air temp (C)
Mean	28.85	-0.33	-0.67	8.89	0.47	7
Max	5.30	0	0	11	2	
Min	1.39	-1	-1	1.5	-1.2	
Standard deviation	17.81	0.58	0.58	3.01	1.12	

Thermokarst 11/01/21	GSM g/g	Soil Temp 5 cm (C)	Soil Temp 10 cm (C)	Snow Depth (cm)	Surface Temps (C)	Air temp (C)
Mean	0.35	0	-0.67	5.33	-0.05	0
Max	1.05	0	0	9	1.4	
Min	0.13	0	-1	4	-1.2	
Standard deviation	0.24	0	0.58	1.58	0.84	

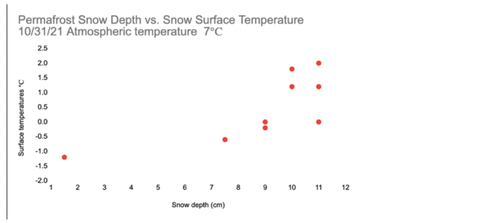

Figure 4. Permafrost snow depth vs. surface temperature

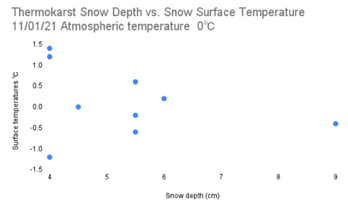

Figure 5. Thermokarst snow depth vs. surface temperature

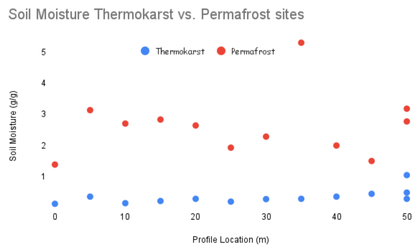

Figure 6. Soil moisture Thermokarst vs. Permafrost sites

Discussion

The results from the gravimetric soil moisture procedure in figure 6 show a significant increase in soil moisture content. This coincides with my hypothesis that soil moisture will be greater in permafrost site because of the frozen soil layer will hold water closer to the surface. Figures 2 and 3 show the relationship between land cover, snow depth and snow surface temperature. Both graphs show around the same surface temperature but snow depths are different, permafrost land cover type having a deeper snow depth. Deep snow acts as an insulator and is an important aspect of maintaining permafrost in a location. Land cover can also have an affect on surface temperature, snow depth and permafrost thaw. Clear cutting the black spruce opened up the area, allowing the soil to warm up and faster decomposition of organic matter. As the soil became warmer and more permafrost thawed the area changed from a swamp terrain, with thick moss and a water close to the surface to a birch forest with drier soil and less organic matter.

Limitations of the methods included: frozen ground at permafrost site, data was collected different days, and only one sample was taken every 5 meters instead of 2 samples every 5 meters. However, because data was collected at the very being of the snow pack season it can be useful for future comparisons.

Human error: did not dig deep enough in permafrost area because ground was frozen.

Experimental error: using plastic bags for soil collection. Bags sightly melted in the oven.

Conclusions

The results show that the permafrost site has higher soil moisture content and deeper snow depth than the thermokarst site. The results also show a connection between land cover and snow depth. Because snow depth and other snow properties affect permafrost thaw, further research in the area could be interesting.
Improvements to the methods include: sampling before the ground freezes, an in-depth land cover observation, and taking soil temperatures at the same location as the soil moisture in order to make clear comparisons.
Lastly, working with Christina Buffington MS., M.ED has been incredibly helpful. In the past, the idea of developing and completing a research project would have been incredibly intimidating. Having a mentor explain the process step by step made this experience attainable and fun.

Bibliography

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