DEPARTMENT OF BIOLOGICAL AND
ENVIRONMENTAL SCIENCES

THE INFLUENCE OF TUNDRA VEGETATION ON SOIL TEMPERATURES

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Degree project for Bachelor of Science with a major in Biology
BIO603 Biologi: Examensarbete 30 hp
First cycle
Semester/year: Spring/Summer 2022
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Frontpage photo taken by Maria Pavolotskaia

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ABSTRACT

The arctic has experienced more rapid global warming and is more sensitive to temperature changes compared with the rest of the world. We can already see how vegetation distributed across the arctic tundra has changed in composition, height, and abundance. It's not only that climate can change the vegetation; it has also been shown that the vegetation can have an impact on the climate and global warming through buffering effects on soil temperatures. This study aimed to investigate what influence alpine vegetation has on tundra soil temperatures by comparing the temperature difference between the vegetation canopy (representing the air temperature) and the soil and ground in places with different amounts and types of vegetation during the summer and winter season. 64 plots were installed on the tundra around Latnjajaure field station in northern Sweden with microclimate loggers to measure temperatures. A vegetation survey was performed at every plot to document vegetation cover and the types of species present. The coverage of shrubs in the plot was significantly related to soil temperatures in the summer, whereby a higher coverage of shrubs led to lower soil temperatures, but the same effect was not seen in surface temperatures. The abundance of moss in the plot had a significant effect in the winter season; more moss correlated with higher soil and ground temperatures compared to air temperatures. The amount of bare soil also showed significance where more bare soil correlated with lower soil temperatures. This study supports the claim that alpine vegetation significantly influences the soil temperatures on the tundra. It's also suggested that tundra vegetation could lower soil temperatures, offsetting the effects of increasing temperatures on the tundra and thereby influence the speed of permafrost thaw and greenhouse gas emissions.

SAMMANFATTNING

Arktis har en extra snabb global uppvärmning och är mer känslig för temperaturförändringar jämfört med resten av världen. Vi kan redan se att vegetationen utspridd över den arktiska tundran har ändrats i komposition, höjd och rikedom. Det är inte bara klimatet som har en påverkan på vegetationen, det har också visats att vegetationen i sin tur kan påverka klimatet och den globala uppvärmningen genom buffring av jordtemperaturen. Den här studien syftar till att undersöka inflytandet av alpin vegetation på tundrans jordtemperaturer genom att jämföra temperaturskillnaden mellan växternas takkrona (som representerar lufttemperaturen) med jordytan och i jorden, på platser med olika mängder och typer av vegetation under sommar- och vintersäsong. 64 stationer installerades på tundran runt Latnjajaure fältstation i norra Sverige med mikroklimatloggare för att mäta temperaturer. Vid varje station utfördes också en vegetationskartläggning för att dokumentera vegetationstäcket och vilka arter som fanns på platsen. Täckhetsgraden av buskar i stationen visade sig ha en signifikant effekt på jordtemperaturen på sommaren: en högre täckgrad gav lägre jordtemperaturer men samma effekt kunde inte ses på jordytans temperatur. Mängden mossa i stationen hade en signifikant effekt under vintersäsongen: mer mossa korrelerande med högre jord- och yttemperaturer jämfört med lufttemperaturer. Mängden bar jordyta visade också signifikans: mer bar jordyta gav lägre jordtemperaturer än lufttemperaturer. Denna studie stödjer påståendet att alpin vegetation har en signifikant påverkan på tundrans jordtemperatur och föreslår att tundravegetation kan sänka jordtemperaturen. Det förslås också att vegetation på tundran kan ha motverkande effekter på de ökande temperaturerna och därmed påverka smältningshastigheten av permafrosten och utsläppen av växthusgaser.

1. Introduction

Tundra

The tundra around the arctic circle is distinguished by long, snowy winters, abundant ice sheets and glaciers, and permanently frozen soils known as permafrost (Begon, 2021). The amount of sunshine also defines the arctic climate with long summer days and little or absent sunlight during winter days. The snow and ice have a high albedo (reflectance of solar radiation) and a low thermal conductivity (heat loss or transfer) (Symon et al., 2005). The tundra has a signature flora of mosses, lichen covers, grass, shrubs, and small dwarf trees. The coldest areas of the arctic tundra have little to no vegetational growth (Begon, 2021). Put these conditions together in different combinations and you get a great quantity of diverse microclimates. Microclimates are important when trying to better understand the arctic environment and its conditions. Temperatures at the landscape scale can differ substantially from temperatures at smaller scales within the landscape, sometimes by 20 °C (Bramer et al., 2018). Thus, focusing on microclimates in ecology studies instead of macroclimates gives a more authentic description of that specific area and the temperature that organisms in that area are actually experiencing. Every microclimate has a unique environment with different variables affecting the climate in that specific location, both biotic and abiotic. Abiotic factors are things like cliffs or mountain slopes casting shadows, sunlight, speed of the wind, and precipitation. Biotic things can also affect the climate, for example the presence of vegetation. Evapotranspiration from plants cools down the air temperature underneath the canopy (Gupta et al., 2018) and a vegetational canopy can also create a shadow underneath buffering the ground from the heat (Kántor et al., 2016). Vegetation creates a very dynamic environment due to the constant changes with growth or withering. These things are missed when using a macroclimate perspective, making the microclimate perspective the most realistic and useful when predicting responses to climate change (Zellweger et al., 2020).

Climate change

Global warming is up to four times higher in the Arctic compared to the average global temperatures (Rantanen et al., 2022). From the mid-1800s to the 1900s the average temperature on earth rose 1.1°C and has since passed 1,5°C. This global warming is a result of increasing greenhouse gas emissions due to human activity. Climate change has multiple consequences and affects all regions on earth but changes in the arctic are especially rapid (Change, 2021). Areas with snow and ice are sensitive to increases in temperature which could amplify the already rapid climate change in the area. Rising temperatures in the past 80 years have resulted in a higher number of mild winter days with positive and negative feedback processes both taking place at the same time. Positive feedbacks include snow and ice-albedo feedback and permafrost feedback. Negative feedbacks include less intense thermohaline circulation which heats the arctic and vegetation-carbon dioxide feedback enhancing vegetational growth which could in turn reduce the albedo on the tundra. These feedback loops combined with other factors are the reason behind polar amplification, i.e. that the temperatures in the Arctic are rising more rapidly than in other locations on earth (Symon et al., 2005). The polar amplification influences the arctic vegetation in several ways, causing longer growing seasons and shrubbing (expansion of shrubs) (Post et al., 2009). Experiments with warming treatments have shown a change in the composition and the abundance of plant species. The richness, diversity, and even distribution have been reduced because of higher temperatures (Walker et al., 2006). There has also been an increase in the overall height of the tundra plant communities because of the immigration of taller plant species, and not the loss of shorter ones (Bjorkman et al., 2018). This increase in taller vegetation happens at the expense of other plants like bryophytes and lichen covers (Scharn et al., 2021).

The effect of vegetation on soil temperatures

This focus on microclimates is not only giving us a better representation of the actual conditions in the environment but also allows us to see the impact of the vegetation more clearly. Vegetational canopies, mosses, and lichens can buffer the effects of global warming and the rising temperatures in the arctic areas. More shrubs and taller vegetation in the Arctic create denser canopies during the growing season, which blocks out the solar radiation and lowers the soil temperature (Von Oppen et al., Manuscript in review at Global Change Biology). Plant communities in the forest understory (plants under the canopy) are changing in composition towards species with an affinity to warm climates. The rate of the change does not depend on the changes in the overall climate in that region, but it depends on the changes in the microclimate under the canopy (Zellweger et al., 2020). Within plant groups, deciduous shrubs are among the most responsive to temperature changes. Several studies with experimental warming have shown an increase in deciduous shrub growth (Blok, Sass-Klaassen, et al., 2011). It has been suggested that the increase could be due to the loss of the underlying permafrost (Molau, 2010). The increase in plant height could lead to reduced albedo, higher energy uptake, and increased temperatures. Increased vegetation mass could also lead to more carbon storage and decreased carbon loss (Bjorkman et al., 2018).

The effects of increased shrub expansion on the arctic soils are not yet fully established. During winter periods the taller plants enables thicker snow covers with insulating effects, thus increasing soil temperatures (Von Oppen et al., Manuscript in review at Global Change Biology). Snow holding ability of the shrub increases linearly with the density and height of the shrubs until reaching a threshold. For 26 years, there was an increase (79%-92%) of biomass in the tundra landscape of Latnjajaure, Sweden. The large increase was mostly because of the spread of shrubs (Molau 2012). The taller and closer shrubs collect snow that has extra insulating properties compared to other “normal” snow covers because of bonds created in metamorphism due to strong temperature gradients (Sturm et al., 2001). Metamorphism is the process where fallen snow crystals are transformed, changing size and shape, after reaching the ground. An additional effect of shrubbing is that canopies holding snow slows down the winds closest to the ground surface, leading to less snow being carried away by the wind, thus building up the snow cover even more (Molau, 2010).

Mosses are another type of vegetation that affects the microclimate in the Arctic. They have been shown to have high control of water and energy in the tundra ecosystem (McFadden et al., 2003). Evaporation from the tundra soil lowers the soil temperature since the heat energy is transferred from the soil to the vaporizing water; if there is less evaporation because of dry soil or canopy shading it will be the opposite effect (Boike et al., 2008). A big ratio of evaporation originates from the mosses rather than from the vascular plants (McFadden et al., 2003), even as much as 50-58% of evapotranspiration from the tundra soil is thought to evaporate from mosses (Boike et al., 2008). Moss has a small thermal conductivity which insulates the soil, thus further lowering the temperature. This happens the most when holding less moisture and more air (Blok, Heijmans, et al., 2011). The moss layer has an impact on other properties of the soil beside the temperature such as the thawing and to some extent the soil moisture (Gornall et al., 2007). The moisture of the soil impacts the plant communities, as high moisture seems to be a joint factor in increasing height (Bjorkman et al., 2018). Moss and lichen abundance and diversity have been shown to decrease with warm temperatures treatments (Walker et al., 2006).

Consequences of changes in soil temperature

Changes in soil temperature on the tundra can have serious consequences. It can affect the decomposition of organic matter, movement of carbon, and energy transfer (Gornall et al., 2007). In the permafrost, there are large storages of carbon originating from decomposed animals and plants, over 1000 billion tons in the upper layer of 3 meters. Increased soil temperatures and thawing permafrost could lead to further microbial activity and decomposition, emitting more greenhouse gasses (carbon dioxide and methane) and progressing climate change (Begon, 2021).

Aim and hypothesis

This study aims to improve the understanding of what effect alpine vegetation has on the tundra soil and possible future changes in soil temperatures. Temperature and vegetation data was used from plots across an elevational and temperature gradient at Latnjajaure, Sweden to examine the relationship between soil temperature and vegetation. Both summer and winter soil temperatures were examined separately. The study focuses on microclimates and includes several predictors: average vegetation height, the abundance of shrubs, the abundance of mosses, amount of bare soil and elevation. It was hypothesized that plots with taller plants would have higher soil temperatures compared to air temperatures in summer and winter, because of low albedo and thick snow covers.

Currently many studies regarding the influence of vegetations on soil temperature have had a focus on temperate forests and trees. There is a shortage of this kind of research on the tundra, and the studies that exist have not included winter temperatures. This thesis aims to fill this gap by focusing on the effects in the tundra, and including both summer and winter temperatures, making this study unique.

2. Method

Site description

The area of study was the Latnjajaure field station (LFS) in Kiruna municipality in the furthest north of Sweden. The field station was founded in 1965 near lake Latnjajaure in the valley Latnjavagge. The valley is a result of peri glaciation, or thawing of snow, a process that has a big impact on tundra landscapes (figure 1).

Figure 1, Picture of Latnjajaure lake and the valley where the plots were set up. *Latnjajaure* [Photogragh]. (2013). Collected 28 of August 2022 from https://commons.wikimedia.org/w/index.php?curid=28304561

The landscape is made up of tundra and mountainous environments, the floor of the valley is 950m above sea level (ASL) and the mountain peaks are at 1400m ASL (Scharn et al., 2021). It previously had permafrost which has disappeared from the area of this study in the last 20 years (Molau, 2010). The growing season in Latnjajaure lasts from May-August, the vegetation affects the composition of the soil, as does pH and moisture level, resulting in different types of soil in different areas. The average temperature over a year is -1,7 °C. The mean temperature of the coldest winter month, February, is -9,7 °C and the mean temperature of the warmest summer month, July, is 8,6°C (increasing by 0,3°C per decade) (Scharn et al., 2021).

Experimental setup

At the end of June in 2020, 64 microclimate plots were set up over an area of 15 km^2 on the tundra landscape at the Latnjajaure field station. TOMST TMS-4 microclimate loggers were placed in every plot to measure and record the moisture and temperature of the air, soil surface. All TMS loggers were put out in the field between the 26th of June and the 1st of July.

Protocol for setting up plots:

Before the field season started a random stratification was performed to generate locations for the plots. To ensure a spread of plots with diverse microclimates, plot locations were stratified based on 3 different levels of greenness and 5 levels of elevation (160m in each level). When the randomly generated plot location was deemed unsafe to access, didn’t meet the requirements (e.g., if it was in water or an area disturbed by humans), or when placing the TMS logger in the soil was not possible the plot was discarded and a randomly generated alternate location was used instead. Before a change of location, the setup was tried again 50cm away from the original position and if unsuccessful the procedure was repeated at 100, 150 and 200 cm in all cardinal directions. When the team arrived at the right coordinates a metal tent peg was used to mark the center, 10cm from the tent peg a TMS logger was placed in the true north direction (see figure 2).

Figure 2. A picture of a plot with the tent peg marking the center and a TMS logger 10cm from the tent peg. Image by Katrín Björnsdóttir, 2022.

The TMS loggers measure and record temperatures in 10-minute intervals at 3 different levels; 8cm into the soil (T1), 0 cm above the ground (T2), and 15 cm above the ground (T3) (see figure 3). The canopy layer represents the overall air temperature as the plots didn’t have any plants exceeding the 15 cm limit where the T3 measurements were taken.

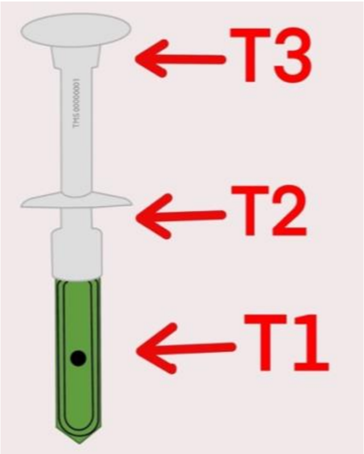

Figure 3. An illustration of a TMS logger with the 3 temperature measurement points marked out. By Edith Aspelin.

A vegetation survey was performed at all plots, documenting the different species and assessing their percentage abundance as well as the amount of bare soil. The assessments were made at a 15cm, 50cm, and 200cm in a circular radius from the tent peg. The data included in this paper was from the 50cm radius (see figure 4).

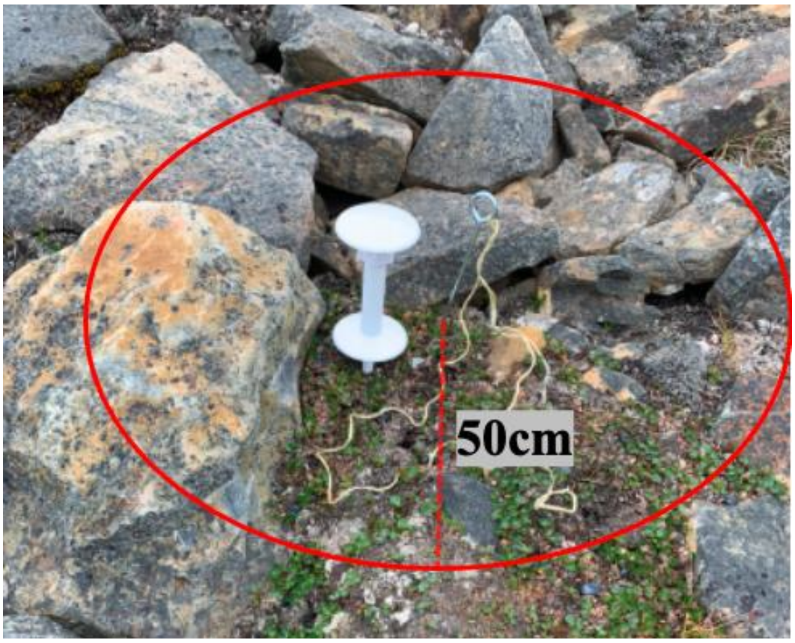

Figure 4. An illustration of the 50cm radius around the tent peg where the vegetation survey was performed. Photo by Edith Aspelin, 2022.

The aim was to look at the influence of vegetation on the temperature and the vegetation from the 200cm radius was unlikely to influence the recorded temperature and the 15cm radius could fail to include influencing factors. The temperature data from the TMS loggers were used to calculate the temperature difference between T3 and T1 as well as the temperature difference between T3 and T2, to see if the vegetation growing between the soil and the canopy influenced the temperature. The method origins from a protocol for setting up plots and vegetation surveys at Disco Island, in Greenland 2019 (unpublished).

Statistical analysis

I selected the dates for the temperature measurements that were to be included from the TMS logger and removed all measurements outside of this timeframe. The selected date range was from the end of June 2020, when the TMS loggers were placed in the field, to the end of August 2020 for the summer period and the beginning of December 2020 to the end of February 2021 for the winter period. Further, I extracted the average temperature for all the plots for both summer and winter and used that data to calculate ΔT (T1-T2 & T1-T3) for all plots and got the mean ΔT. Next, I categorized the species from the vegetation survey into functional groups (e.g., moss, shrubs) to calculate summed abundance of these groups. I then did my statistical analysis using R software platform version 4.2.1. I did a Pearson correlation test to check for relationships between the predictor variables to make sure that they weren't too highly correlated with each other. Then I did a multiple linear regression in R, with the level for significance being 0,05 to determine the effect of the predictor variables on the response variable and the direction of the relationships. I did the multiple linear regression two times to include the ΔT for the winter and summer season separately.

The response variable was the temperature difference (ΔT) for:
A) the canopy temperature minus the soil temperature (T3-T1) and
B) the canopy temperature minus the ground temperature (T3-T2).
The predictor variables were the average vegetation height, the abundance of shrubs, the abundance of moss, the amount of bare soil and elevation. Elevation was included to control for the fact that the data was collected from an elevational gradient.

3. Results

The *Pearson correlation test* showed that all correlations were less than 0,39 meaning there was no strong linear relationship between the variables which could make determining the effect of each predictor difficult.

To test and assess the strength of the relationship between the ΔT (for both T3-T1 and T3-T2) and the predictor variables, the MRA model was used. Table 1 has a summary of the results. The results from the multiple regression analysis performed on the summer data (table 1) showed that shrub cover predicted the ΔT for T3-T1 where more shrubs led to relatively cooler soil temperatures, but shrub cover was not significant for ΔT for T3-T2 (figure 5). Elevation had a significant effect on ΔT for T3-T1 but not for T3-T2, plots with higher elevations had warmer soils than air temperatures. The average community height, moss and amount of bare soil showed no significant effect. The results from the multiple regression analysis (table 1) performed on the winter data showed that moss had a significant effect on the ΔT for both T3-T1 and T3-T2, more moss in the plot led to relatively warmer soil temperatures (figure 5). Amount of bare soil was also significant for ΔT for T3-T1 and T3-T2, more bare soil in the plot led to lower soil temperatures than air temperatures. The average community height, shrub cover and elevation had no significant effect.

Table 1. Summary of statistics for the predictor variables relationship and effect on the temperature difference between canopy and soil, and canopy and ground. The model was a multiple regression analysis. Results of the MRA are given (P-value & Estimate). ***Bold*** *parameters indicate significance (p<0.05).*

Season	***ΔT***	***Predictors***	***P-Value***	***Estimate***
Summer	Canopy (T3) – Soil (T1)	Community height	0,191	7,310
		Shrub cover	**0,010**	**0,019**
		Elevation	**0,036**	**-0,002**
		Moss	0,073	0,008
		Bare soil	0,499	-0,011
	Canopy (T3) – Ground (T2)	Community height	0,571	-1,398
		Shrub cover	0,452	0,002
		Elevation	0,465	-0,000
		Moss	0,166	0,003
		Bare soil	0,478	-0,005

Winter	Canopy (T3) – Soil (T1)	Community height	0,150	-16,760
		Shrub cover	0,959	-0,001
		Elevation	0,112	0,004
		Moss	**0,003**	**-0,029**
		Bare soil	**0,005**	**0,104**
	Canopy (T3) – Ground (T2)	Community height	0,537	-6,712
		Shrub cover	0,751	0,004
		Elevation	0,146	0,003
		Moss	**0,007**	**-0,024**
		Bare soil	**0,040**	**0,069**

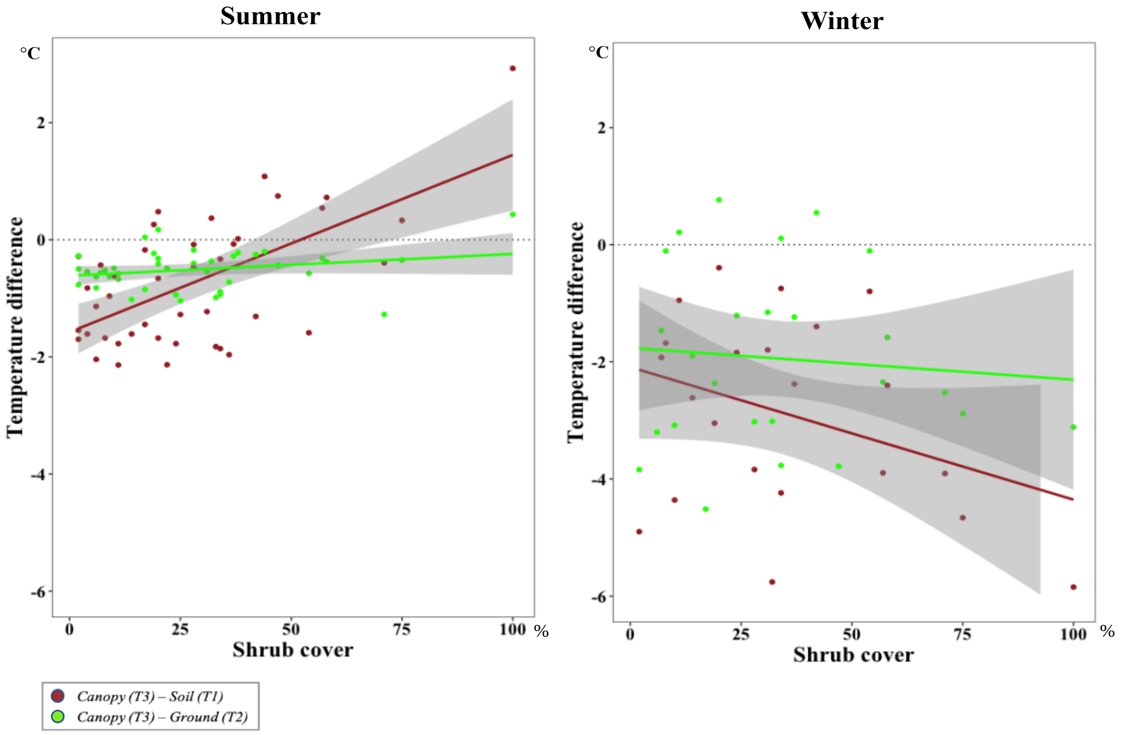

Figure 5. Relationship between the shrub cover and summer (a) and winter (b) temperature. The dotted line represents a shift, under the line the soil/ground temperature is higher than the air temperature and above the line, the air temperature is higher than the soil/ground. The thicker semitransparent grey line represents the standard error.

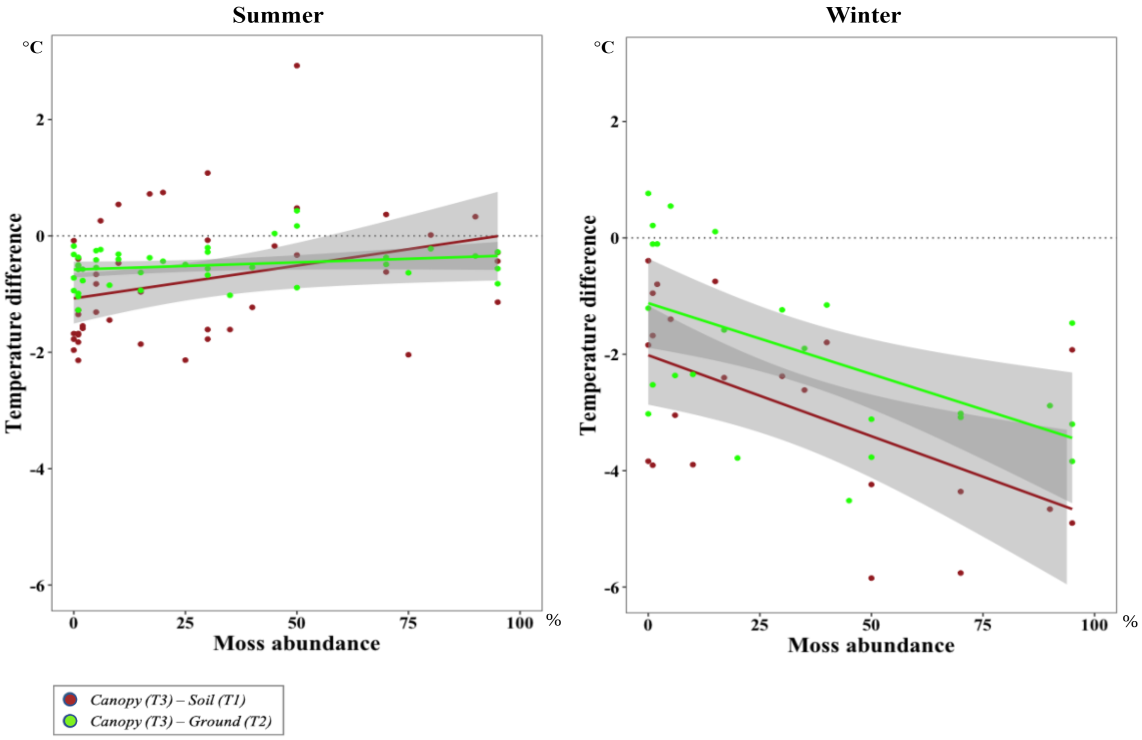

Figure 6. Relationship between moss abundance and summer (a) and winter (b) temperature. The dotted line represents a shift, under the line the soil/ground temperature is higher than the air temperature and above the line, the air temperature is higher than the soil/ground. The thicker semitransparent grey line represents the standard error.

4. Discussion

The result from my study suggests that vegetation influences soil temperatures in both summer and winter seasons. Shrub cover seems to have an influence on the summer soil temperature, higher shrub coverage led to soil temperatures that were lower than the air temperatures. This finding supports previous theories that shrubs are shadowing the ground and soil, obstructing the heating from solar radiation (Blok, Sass-Klaassen, et al., 2011) and (Von Oppen et al., Manuscript in review at Global Change Biology) among others. The same reasoning will lead one to expect the ground to be cooled similarly if the shrubs cool down the soil by casting a shadow on the ground. This has however not been shown (see figure 5), a result also found in a similar study (Von Oppen et al., Manuscript in review at Global Change Biology). A possible explanation for this irregularity could be the that shrubs have a lower albedo than the ground, since most shrubs have leaves that are darker than the soil surface which often is covered with lichens and moss. The heat absorbed could be reflected of the leaves heating up the air around the shrub affecting the T3 and T2 measurement, though this has not been found previously. Adding the overall ambient air temperature of the area as a parameter could bring further clarity. Snow covers early in the summer season could influence the temperature difference if the snow cover is in between the measurement points (see figure 7). However, I don’t believe this to have a big impact because of the short amount of time that would occur. Another issue with snow covers in early summer could be that the soil stays frozen a short time after the snow has melted away at a time when ground has already been warmed up by the sun. However, the soil temperature measurer is only 8 cm deep into the soil, and it shouldn’t take that long for the soil to thaw to that level.

Figure 7. A picture of Latnjajaure showing the irregular snow melt. Image by Edge lab field group, 2020.

The fact that neither shrub coverage (during winter) nor the average height of the plant community (winter or summer) affected the temperature difference contradicts other studies (Molau, 2010) and is contrary to my expectations and hypothesis. These results also differ from earlier research, about winter soil temperatures rising due to increased plant height and snow insulation (Von Oppen et al., Manuscript in review at Global Change Biology) (Sturm et al., 2001). However, my results for bare soil in the winter suggests that soils in plots with more vegetation are warmer. The significance of moss during the winter shows that mosses likely influence the conductivity and heat flux of the tundra soil, more moss in the plot correlated with higher soil temperature than the air temperature. This is consistent with previously published results and suggests that moss has a buffering effect, making the soil temperature less extreme than the air temperature. However, the moss showed no significant effect in the summer (see figure 6). A paper from 2011 regarding the cooling capacity of mosses on the Siberian tundra in the summer showed that the removal of the green moss layer increased evaporation but also distribution of heat flux down into the ground. They concluded that the heat loss due to increased evaporation was smaller than the increased input of heat, caused by the loss of green moss insulation. In other words, the effect of the removal of moss was increased temperatures. (Blok, Heijmans, et al., 2011). The mean temperature in Latnjajaure increases from -9,7 °C to 8,6°C in the summer (Scharn et al., 2021). Higher temperatures induce the melting of glaciers and snow making the tundra and moss wet (see figure 8). A higher level of moisture can reduce the impact of mosses since the thermal conductivity is stronger when holding less moisture (Blok, Heijmans, et al., 2011). This could be a possible explanation as to why the results from this paper differ from other studies.

Figure 8. A picture of wet moss on the tundra. Image by Edge lab field group, 2020.

For this reason, it would have been useful to add soil moisture as a predictor variable in this paper. Also, since high moisture seems have an influence on the increasing plant height of the vegetation (Bjorkman et al., 2018). Furthermore, it could also be that some character of the soil such as the moisture level (or composition) affects the distribution of heat. Considering this it would have been useful to include snow cover reports to get a fuller picture of soil moisture relationships. Unfortunately, it wasn't possible because there were not enough plots with recorded soil moistures.

Ultimately my results suggest that even though the vegetation on the tundra is limited due to frozen soils and tough growing environments its effects on soil temperature are non-negligible. This study has a unique perspective on tundra soil temperatures through its inclusion of data from both summer and winter temperatures and it implies that microclimate is influenced by the level of vegetation cover, the abundance of mosses and shrubs. With the warming of the Arctic being as rapid as it is, changes in the tundra plant community will likely keep happening.

My results indicate that moss heats up the soil in the winter, and warming treatments have shown a reduction in moss (Walker et al., 2006). My results also indicate that shrub cover has a cooling effect on soil temperatures during the summer, and previous research have shown that shrubs will increase with warmer temperatures (Post et al., 2009). This might predict that the increased shrubbing and loss of mosses could have cooling effects on the soil temperatures. For the tundra soil this could mean less thawing of the permafrost, which again, is of great importance since it can influence the speed of microbial activity and decomposition and the release of the large quantities of greenhouse gases that are frozen stuck in the upper layer of 3 meters. Any thawing could lead to more emissions of carbon dioxide and methane and escalate climate change by increasing global warming. The question is what size the impact of the vegetation would have compared to the overall increasing temperatures due to polar amplification? Further, the rate of the shrubbing and loss of moss is of significance, taking into consideration that warmer temperatures may lead to more precipitation and melting of snow/ice changing the soil moisture conditions which might also affect the change of vegetation. Regardless, even if shrubbing and a loss of moss could not stop the heating of the tundra soil and thawing of the permafrost, it might mean it will happen at a slower pace. To confirm this hypothesis more data and research is needed.

Conclusion:

The central hypothesis of this paper was that plots with taller vegetation would have warmer soils than air temperatures, neither the vegetation height nor the shrub coverage supported this. However, this study suggests that the percentage of vegetation cover, amount of moss, and shrubs influence the soil temperature difference and the microclimate on the tundra during both winter and summer. My study suggests that mosses (shown to decrease in warming treatments) had warming effects on winter soil temperatures and that shrubs (shown to increase with warmer temperatures) had a cooling effect on the summer soil temperatures. For the tundra this could mean reduced soil temperatures, slowing down the thawing of the permafrost and lessening greenhouse gas emissions.

5. Acknowledgments

I want to thank my supervisor, Anne Bjorkman, who supported me, gave me constructive feedback, and inspired me throughout my writing. I am so grateful that I was given the opportunity to accompany the EDGE group on a fieldwork trip to Svalbard and to be able to experience fieldwork as a biologist. I had an amazing learning experience working with skilled and enthusiastic professionals. Thank you to Wilhelm Osterman, Ellinor Delin, Mikael Helander, Maria Pavolotskaia, Mariela Johansson Vingård and Helena Sundell for making long days in the field fun and memorable. I would also like to extend my special thanks to my friend Maria Pavolotskaia, another bachelor's student who also wrote her thesis on a similar subject at the same time. I am very appreciative of all the help with my data in R and the general support and company.

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