GLOBE Regional Learning Expedition

Exploring the Suur Taevaskoda sandstone outcrop

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ABSTRACT

Soil plays a vital role in our global ecosystems. Soils influence our daily lives in numerous, often overlooked ways, and their significance deserves greater attention. We can gather information from a multitude of different sources: from books, soil maps, specialists and geographic info systems. A more effective way to acquire knowledge is through direct fieldwork and data collection. This report is the result of that determination.

The fieldwork for this report was conducted during the GLOBE Estonia Learning Expedition of 2024 at Suur Taevaskoda, Estonia. We had the help of a junior researcher in geology Eelika Kiil and geography teacher Vaike Rootsmaa. To test our hypotheses, we constructed four boreholes and examined a nearby outcrop. We worked according to GLOBE soil protocols, helping us characterize different soil types, horizons, textures, and measure the soil temperature and pH.

We discovered that human impact on the soil horizons in the form of walking or trampling is noticeable, but menial. Furthermore, we confirmed that pine needles have a considerable impact on the soil's pH, but the overall vegetation and tree shadows did not change the soil temperature considerably during our fieldwork.

Keywords: soil horizons; borehole; vegetation; trampling; human impact

1. Research Questions and Hypothesis

The pedosphere is the thin outermost layer of the Earth that is composed of soils. These soils consist of three main components: minerals, organic matter and pores which can contain water or air. Soil formation is a very long process that is influenced by many factors like climate, organisms, relief, parent rock and time. The soil itself has a lot of important properties, including providing an environment for plants to grow and soil organisms to live in, storing and filtering water and affecting Earth's climate. It is the foundation for agriculture and construction, but it is also greatly influenced by erosion, including the impact of humans, which can greatly influence its properties. The importance of soil in our everyday lives is already well-known, but the more we learn about it, the clearer we begin to understand the importance of soil in our global ecosystem and how humanity can both destroy and improve it.

In Estonia, large-scale soil mapping began back in 1954, and the first maps were for agricultural enterprises. Today, these maps have evolved to be the basis of detailed spatial analysis from geology, urban development, reclamation planning, agricultural improvements and countless more. Therefore, it is crucial to improve our soil maps by collecting additional information.

The data for this report was collected during the GLOBE Estonia Learning Expedition 2024 at Taevaskoja, Estonia, mainly on 13 August. More precisely, it was collected on the Suur Taevaskoda sandstone outcrop, both on top of the outcrop and right next to a river near the foot. The exact locations are pointed out on the map from the Republic of Estonia Land Board (Figure 1). Locations 1, 2, 4, and 5 were boreholes, while the 3rd was a small outcrop caused by erosion. We also knew the outcrop was located on the Devonian sandstones from 359-419 million years ago, and that we are dealing with a tourist location. Furthermore, we aimed to analyze the soil below and above the outcrop. Knowing that below is a clearing and above there is a pine forest, we started thinking of research questions and set our hypotheses.

Figure 1. Map showing the exact research locations at Suur Taevaskoja, Estonia (ELB, 2024).

Considering the area's popularity with tourists, we aimed to assess any visible human impact on the soil. Due to the significant differences in vegetation between our two primary research points, we were particularly interested in comparing the soil's pH and temperature at each location. As we had very little time to do the tests and research the locations beforehand, thus having little knowledge overall, we compiled three simple research questions that we could easily check.

Our research questions were:

1. What kind of human impact can we see on the soil horizons?
2. Is there a difference in soil pH at the Suur Taevaskoda clearing and upper forest?
3. How does the different vegetation affect the soil, mainly the temperature?

Following our research questions, we set our hypotheses:

1. The top horizons of soil will be more compressed at the areas where human impact is bigger.

2. Because of the acetic pine tree needles, the pH will be lower in the forest on top of the outcrop.
3. The temperature will be higher on the clearing because of the lack of trees and shadows.

2. Materials and Methods

Our fieldwork was conducted on 13 August 2024 at Suur Taevaskoda. During the fieldwork, we made four boreholes and examined an outcrop (for the exact locations see Figure 1). The soil parameters were measured in two groups: sites 1-3 on the clearing, and sites 4-5 in the upper forest. We followed the instructions from GLOBE soil protocols. To study the effects of tourism, we drilled boreholes in pairs— one in undisturbed natural ground and the other in an area showing clear signs of trampling.

The activities conducted during the fieldwork are as follows:

1. Making boreholes - we used a soil drill with a 20 cm tip to make the boreholes. We avoided larger excavations to preserve the natural beauty of the sandstone outcrop. The soil was placed on plastic to make examining and returning the soil easier. The location was recorded using Google Maps and photographs of north, south, east, west, the sky and the borehole site ground.

2. Temperature - while we were drilling, we set up our analogue soil thermometers and measured the air temperature. We measured the soil temperature at the depth of 5 cm and 10 cm below the surface.

3. Identifying soil layers - We used nails to separate the different layers, and a tape measure to get the approximate thickness of the layers and the overall depth. Next, we used the Munsell Books of Colour to identify the colors of the layers. It had rained the day before so no extra water was needed.

4. Observing soil parameters - we determined the texture, clay content, and a very approximate moisture content of the soil.

5. Testing the pH - we used a universal indicator, universal pH scale and distilled water to determine the approximate pH of the soil.

6. Testing for carbonates - we expected no carbonates, because of the location, pH and the parent rock, but we tested the soil with vinegar when we saw some small gravel and granules. We saw no reaction.

7. Identifying plant and tree species - we used the internet and the help of Flora Incognita to determine the dominant plant and tree life.

8. Cleanup and returning the soil - after our research, we returned the soil to its place and cleaned our equipment.

This process was repeated in both the main groups. Due to the lack of equipment and time, we did not take any samples.

Activities after fieldwork:

1. Further plant and tree life identification - we used the help of identification handbooks, instructors and the internet to improve our findings.

2. Compiling all the info - we compiled all our findings from the protocol papers onto our Google Drive and tidied everything up, making it easily readable.

3. We used the Republic of Estonia Land Board (ELB) to determine the soil type at our fieldwork coordinates. Using the ELB charts, the clearing was AG, a type of gley soil, and on the upper forest LkI;L(k)I, a type of podzol and a mix of podzol and humus. (Approximate areas in Figure 2).

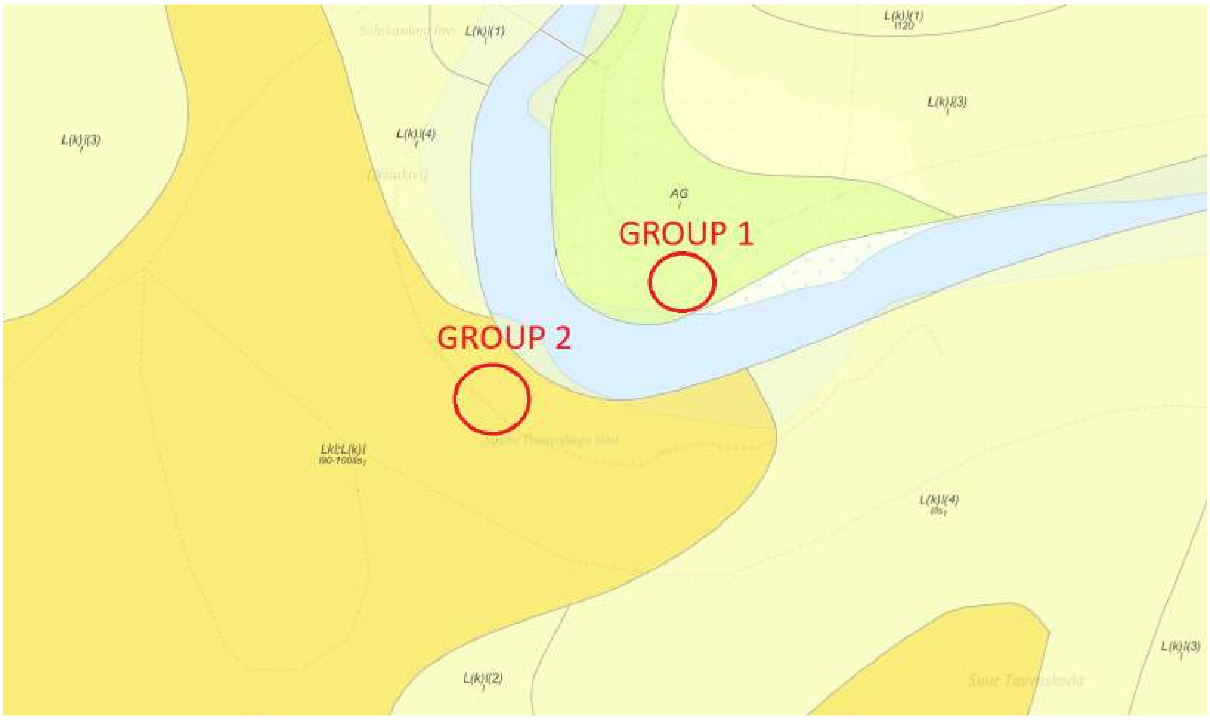


Figure 2. Approximate fieldwork locations on the ELB soil type map (ELB, 2024).

3. Data Summary and Analysis

We named our fieldwork sites after easily recognisable names, which distinguished them very shortly. We also did our work in two main sites, which we can simplify to group 1, the clearing, and group 2, the upper forest. (Refer to Figure 3) Accordingly, the first site was named “Grass” (“Rohi”), the second “Sand” (“Liiv”) and the third “Outcrop” (“Paljand”). The fourth was named “Natural” (“Looduslik”) and the fifth “Road” (“Rada”).

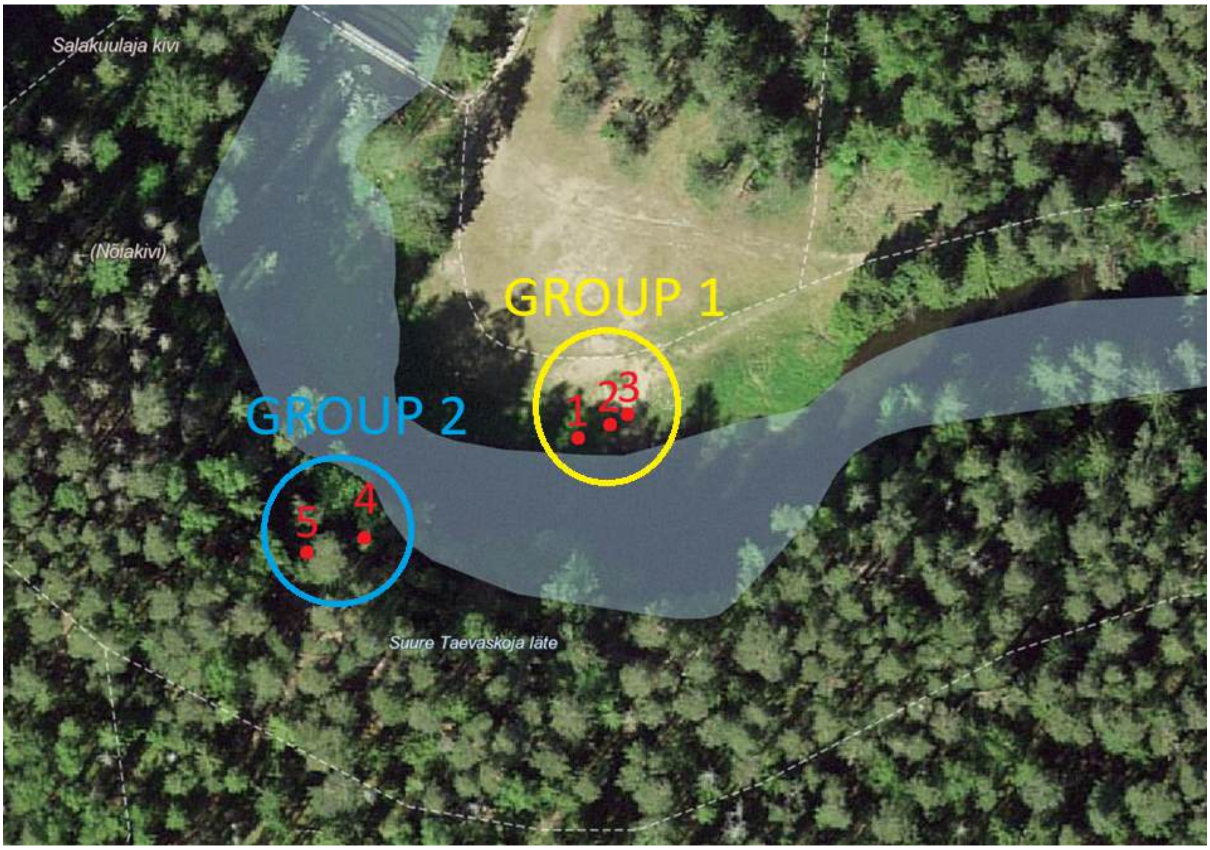


Figure 3. Fieldwork sites and their grouping (ELB, 2024).

GROUP 1

Grass

The first site (N 58.107781, E 27.050277) was located on the clearing in a grassy area with little to no visible trampling. It was about 5 meters from the river and around 2 meters away from a mowed and walked area. It was surrounded by different poacae and carex, some more notable species were the common bracken (Pteridium aquilinum), common nettle (Urtica dioica), and ground elder *(Aegopodium podagraria)*. It was around 37,5 meters above sea level (using ELB).

Figure 4. The Grass site view north

Figure 5. The Grass site before the borehole

Each of the layers was sandy and quite a dark brown color, as seen in Table 1. The first horizon was around 20 cm, the second around 35 cm and the third was over 30 cm thick. In total, we drilled in the ground about 85 cm. Because of the sandy loam texture and plant life, we were unable to determine whether the top layer was just sandy loam, humus or a mix of the two.

Soil horizon	Thickness (cm)	Texture	Munsell Soil Colour	
1 OA[1]	20	sandy loam, (humus)	10YR 2/2	
2 C1	35	sandy	7.5YR 4/6	
3 C2	30+	sandy	7.5YR 5/6	

Table 1. Grass site horizon thickness, texture and color

Sand

The second site (N 58.107804, E 27.050338) was located on the clearing in a visibly trampled and sandy area. It was close to the Grass site, around 10 steps or 7-8 meters. It was around 9 meters from the river. The spot was mostly sandy with a bit of grass. There were no notable plant species close, but we can refer to the main species at the Grass site that was quite near. It was around 37,5 meters above sea level (using ELB).

[1] This refers to the genetic composition of the soil horizon, see references for used site.

Figure 6. Sand site borehole and surrounding ground

Figure 7. Sand site view north

At this site, the horizons were quite similar - both were sandy loam and even on the picture it is hard to tell the color difference. This time the horizons did not change much, the first horizon was 20 cm thick and the next continued for over 55 cm, as seen in Table 2. In total we drilled in the ground for about 75 cm.

Soil horizon	Thickness (cm)	Texture	Munsell Soil Colour	
1 C1	20	sandy loam	7.5YR 6/6	
2 C2	55+	sandy loam	7.5YR 4/6	

Table 2. Sand site horizon thickness, texture and color

Outcrop

The third site (N 58.107812, E 27.050395) was located on the clearing at a natural outcrop. It was located about 2 meters from the Sand site and around 10 meters from the river. The vegetation was similar to the Sand site with some grass, but no notable species. During our research, there was visible erosion in the form of two kids digging with their hands right next to us. It was again around 37,5 meters above sea level (ELB) and on a small 10° incline relative to the river.

Figure 7. View of the outcrop

Figure 8. View of the surrounding area of the outcrop and erosion, which is also contributed by humans

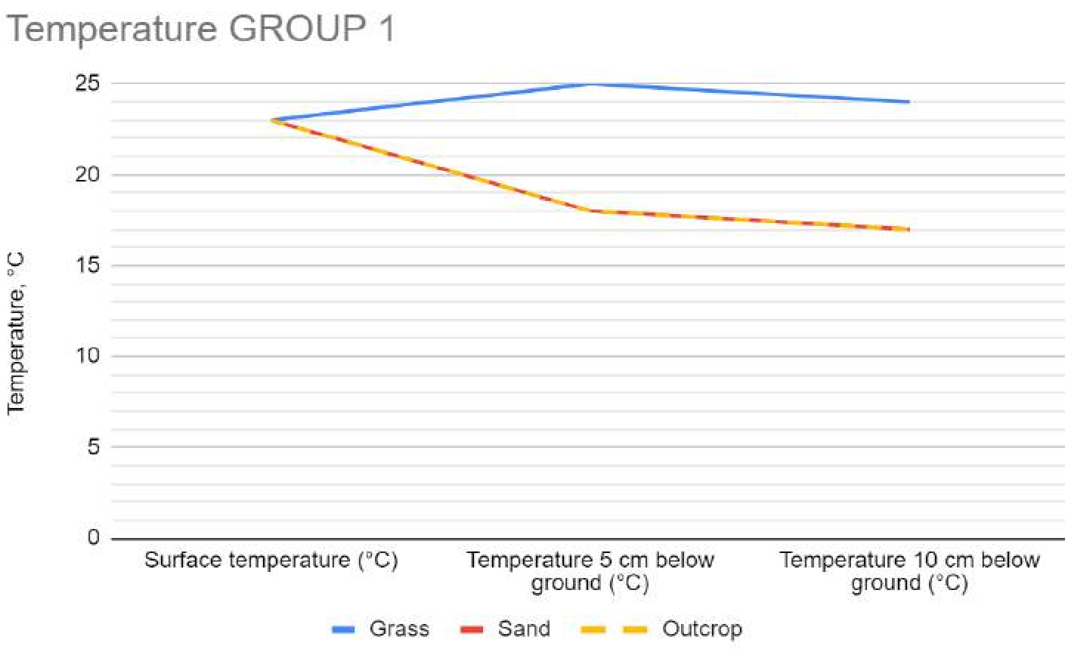
At this site we had a lot of visible horizons, six in total. The top layer was sandy loam and the next five were sandy. The top three layers were rather thin and the next three were all over 20 cm thick, the exact measurements can be seen in Table 3. They were all of similar colors.

Soil horizon	Thickness (cm)	Texture	Munsell Soil Colour	
1 OC	3	sandy loam	7.5YR 4/2	
2 C1	10	sandy	7.5YR 6/2	
3 C2	5	sandy	7.5YR 6/4	
4 C3	29	sandy	7.5YR 5/2	
5 C4	22	sandy	7.5YR 7/4	
6 C5	20+	sandy	7.5YR 2/2	

Table 3. Outcrop site horizon thickness, texture and color

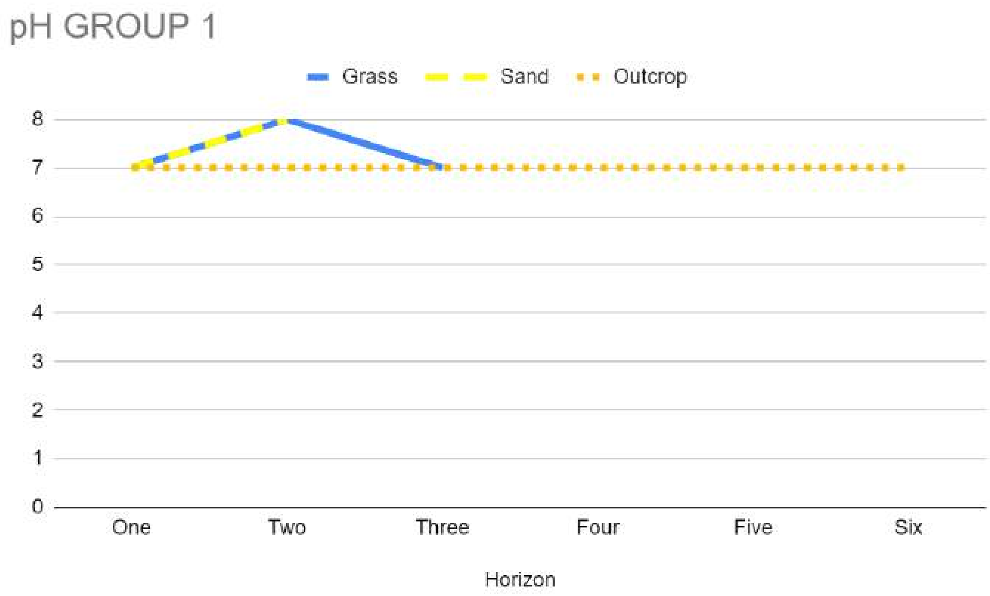
GROUP 1 temperature, pH and compiled graph

The surface temperature was consistently 23°C. At the Grass site, the temperature at 5 cm and 10 cm in the ground was 7°C higher than at the Sand and Outcrop sites, as seen in Graph 1.



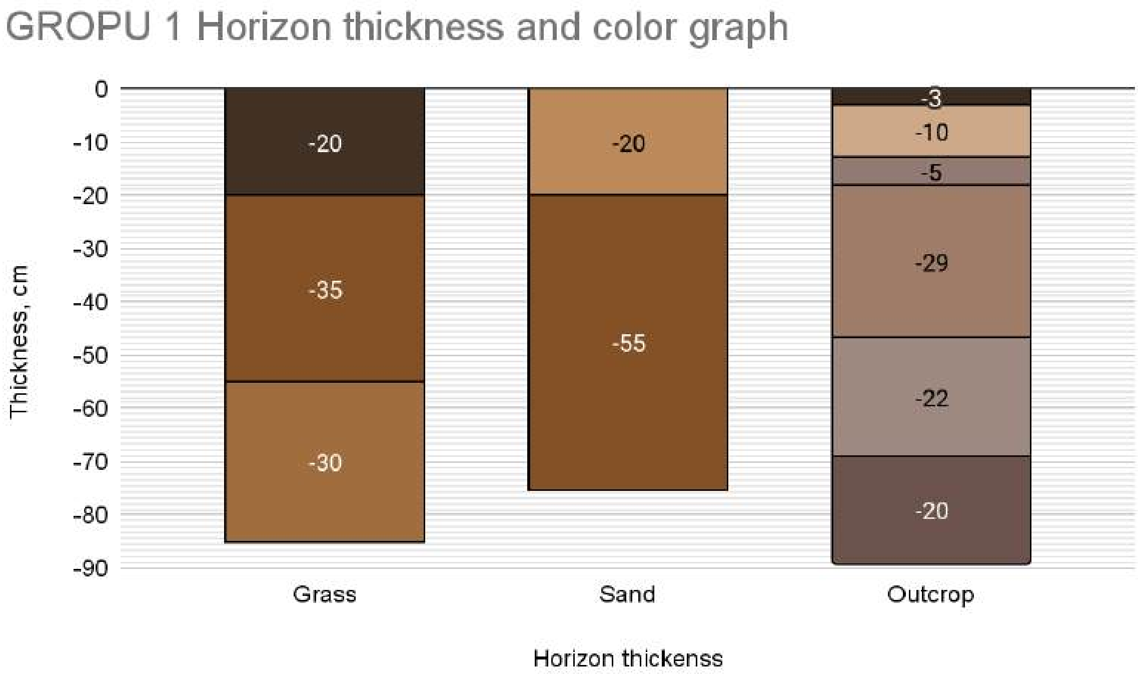
Graph 1. Temperature of GROUP 1

There was little variation in the pH. It was mostly 7, with two horizons testing at pH 8. While testing for carbonates there was some small gravel, but testing it with vinegar gave no reaction. Therefore, we can conclude that there were not many or any carbonates. Later info from our supervisor Eelika Kiil confirmed it because on the Devonian sandstone layer, there should not be carbonates in the soil. For more precise info about the pH refer to Graph 2.



Graph 2. pH at GROUP 1 sites

For an overview of the different horizons, their thicknesses and color see graph 3.



Graph 3. GROUP 1 sites horizon breakdown by approximate thickness and color

GROUP 2

Natural

The fourth site (N 58.107618, E 27.049633) was located on top of the Suur Taevaskoja outcrop in a pine forest. The borehole was made behind a fence around 3 meters from a road nearby at the point where the ground was still flat but quite close to the edge of the outcrop. The main species of plant life are as follows: Baltic pines *(Pinus sylvestris)*, ferns *(Dryopteris)*, raspberries *(Rubus idaeus)*, *Rubus nessensis*, buckthorns *(Frangula alnus)*, rowan *(Sorbus aucuparia)*, lingonberry *(Vaccinium vitis-idaea)*, lily of the valley *(Convallaria majalis)*, European blueberry *(Vaccinium myrtillus)*, European spruce *(Picea abies)*. It was around 67 meters above sea level (using ELB).

Figure 9. Natural site ground view before borehole

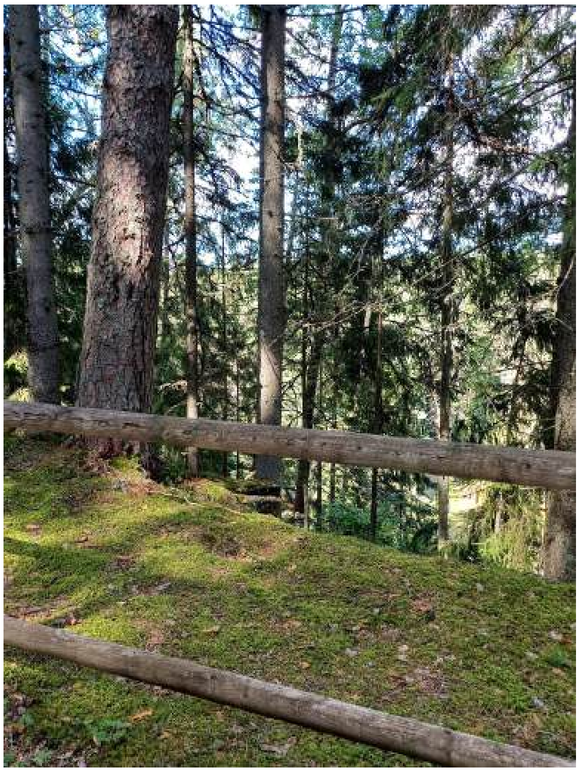


Figure 10. View north behind the fence at the Natural site

The Natural site finally gave us a different breakdown from the 3 sites in GROUP 1. Here the ground was covered in a 3 cm thick layer of still decomposing organic matter, also known as duff. All of the following layers were sandy. The second layer was around 10 cm, the third 5 cm and the fourth over 29 cm thick. The last layer also gave a bit of variation in the color as it was visibly more orange than the rest. For a more detailed overview see Table 4.

Soil horizon	Thickness (cm)	Texture	Munsell Soil Colour	
1 O	3	Organic (duff)		
2 A	10	sandy	10YR 5/3	
3 C1	5	sandy	10YR 8/2	
4 C2	29+	sandy	7.5YR 4/6	

Table 4. Natural site horizon thickness, texture and color

Road

The fifth site (N 58.107584, E 27.049476) was located near the fourth site, but around half a meter from the road in a more trampled area. As the two locations were so close, the plant life did not change. It was around 68 meters above sea level (using ELB).

Figure 11. The Road site view before the borehole

Figure 12. The Road site view south

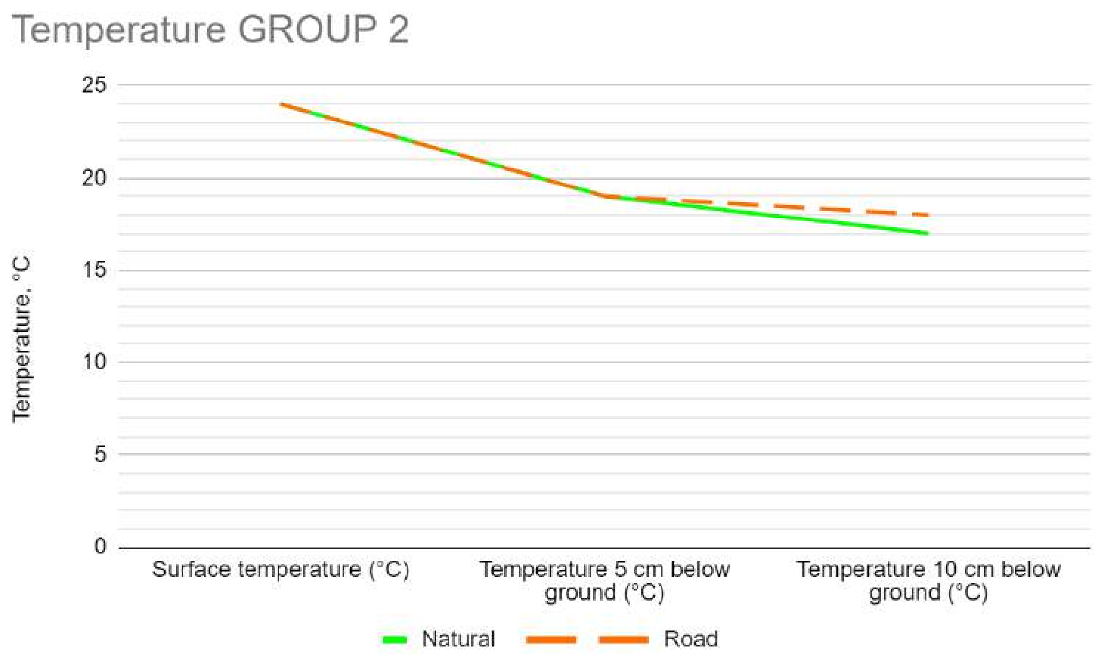
The Road site was very similar to the Natural site. Here the ground was also covered in a 3 cm layer of duff and the next layers were almost as thick as on the previous site. The colors did differ slightly. The third horizon was a bit darker and the fourth a bit brighter compared to the Natural site. To see the full breakdown refer to table 5.

Soil horizon	Thickness (cm)	Texture	Munsell Soil Colour	
1 O	3	Organic (duff)		
2 C1	10	sandy	10YR 4/4	
3 C2	5	sandy	7.5YR 6/2	
4 C3	29+	sandy	7.5YR 5/8	

Table 5. Road site horizon thickness, texture and color

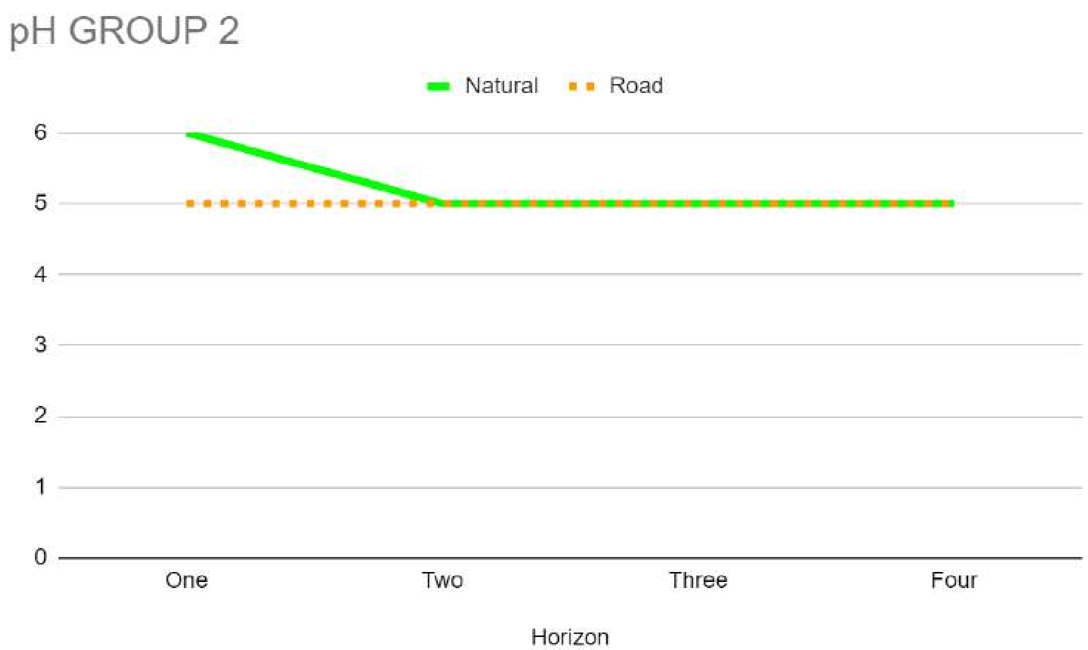
GROUP 2 temperature, pH and compiled graph

Again the surface temperatures were matching - both were 24°C. The in-ground temperatures were similar as well. At the depth of 5 cm they were 19°C, and at the depth of 10 cm they differed by 1 degree – on the Natural site it was 17°C and on the road site 18°C. This can be seen on Graph 4.



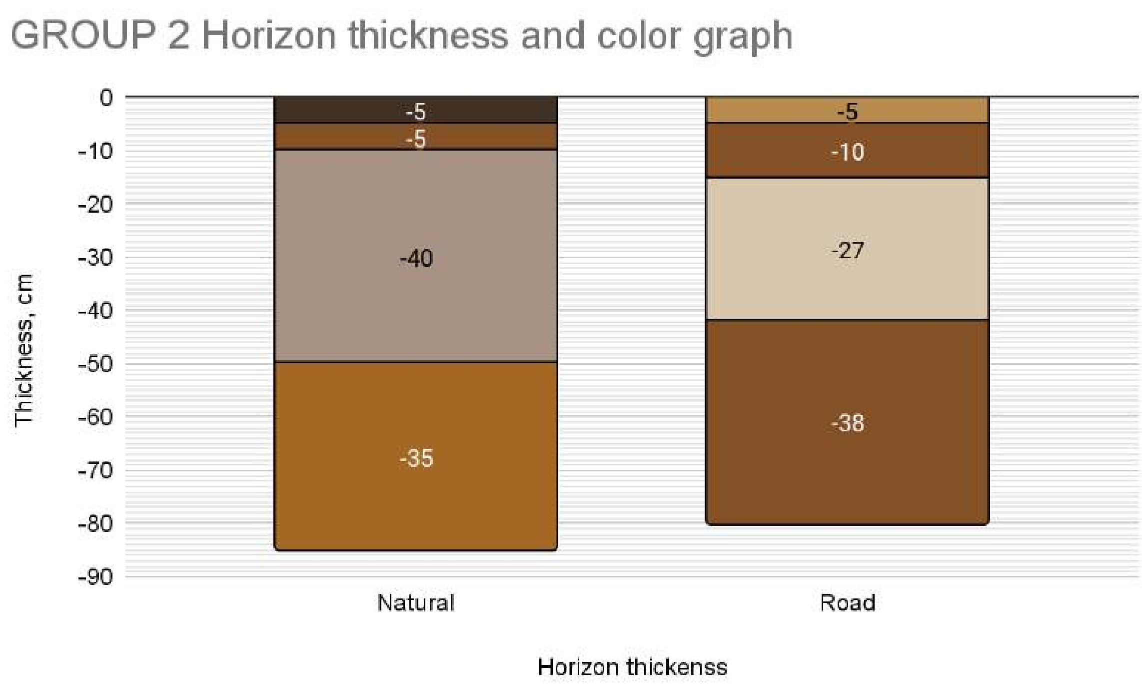
Graph 4. Temperature graph of GROUP 2

Next up was the pH. Overall it was pH 5, with the exemption of the first horizon of the Natural site where it was pH 6. We concluded that this acidity is probably caused by the pine needles, which have acidic properties. For a visible overview see Graph 5.



Graph 5. pH at GROUP 2 sites

For a compiled overview of the horizons, their colors and thicknesses, look at Graph 6.



Graph 6. GROUP 2 sites horizon breakdown by approximate thickness and color

4. Results, Conclusions and Discussions

When studying soils, it is crucial to remember that they can be greatly affected by human or geological factors, such as erosion, parent rock and groundwaters. All these factors played a role in our research. For example, our temperature measurements were likely affected by not only the plant life but also the rainfall the day before, the river next to GROUP 1 and the elevation differences. The constant sandy texture was directly correlated to the parent rock - sandstone - and the two different groups had considerably different plants and trees, or the lack of them.

However, during our fieldwork, we could confirm our hypothesis that the ground in the forest was indeed more acidic. Due to the fact that sand should be close to the pH of 7, we concluded that the main contributors to that acidity were the pine needles, which contain multiple organic acids (refer to Reference 4, for an abstract study of pine needles in China). This information was provided by our supervisor Eelika Kiil and can be confirmed by many sources, including an in-depth page about pine oil and its production (Reference 5).

Our other hypotheses were not so clear. In trampled areas (Sand and Road sites), the topsoil horizon appeared thinner and less integrated with the second horizon. However, the difference was marginal. And our hypothesis that the temperature at GROUP 1 would be lower was not confirmed by our tests. The difference was small, but the higher temperatures were recorded at GROUP 2. As stated before, it can be caused by the rainfall the day before. It can also be affected by the one-hour time gap between the measurements or the river next to GROUP 1 sites.

Overall, the research successfully addressed our primary objectives, and all goals were achieved. Some of our hypotheses were correct, yet some did not find confirmation. But we do have many points to improve on. We measured the moisture content of the soil but only on a scale of wet/ damp/ dry and it was not very conclusive. If we had more time, we could take some samples with us to test the moisture more precisely. This could furthermore help to determine the effect of precipitation, elevation and nearby bodies of water, letting us compare the data with NASA satellites and help them improve even more.

Our team could also have split up to get a wider range of measurements for temperature during the short 4-hour expedition.

At the expedition, there were multiple other groups, but we were the only solely pedosphere group. There were some measurements made by other teams, but the locations differed a lot. If more groups focused on the soil, our research would have greater accuracy and overall quality. By discussing and comparing findings, the data could be significantly improved.

Still, the soil maps in Estonia have excellent quality and high accuracy. Of course, there is always room for improvement, but our research is just for that. With these soil maps, there are countless possibilities from using them for city planning to plant life preservation and agricultural land evaluation. With the contribution of small and big research teams, the quality only grows and brings forth the possibility of automation. Using satellites, planes and drones, we can improve the total quantity of accurate information we can get. This data greatly contributes to a better understanding of the effects of climate, water, relief, vegetation and soil. This also includes things such as human influence and pollution, which can help us preserve or even improve our environment. As these possibilities improve, we can gather real-time data and act faster than ever before, be it to stop the death of a marshland or prevent a crisis wherever it is needed the most.

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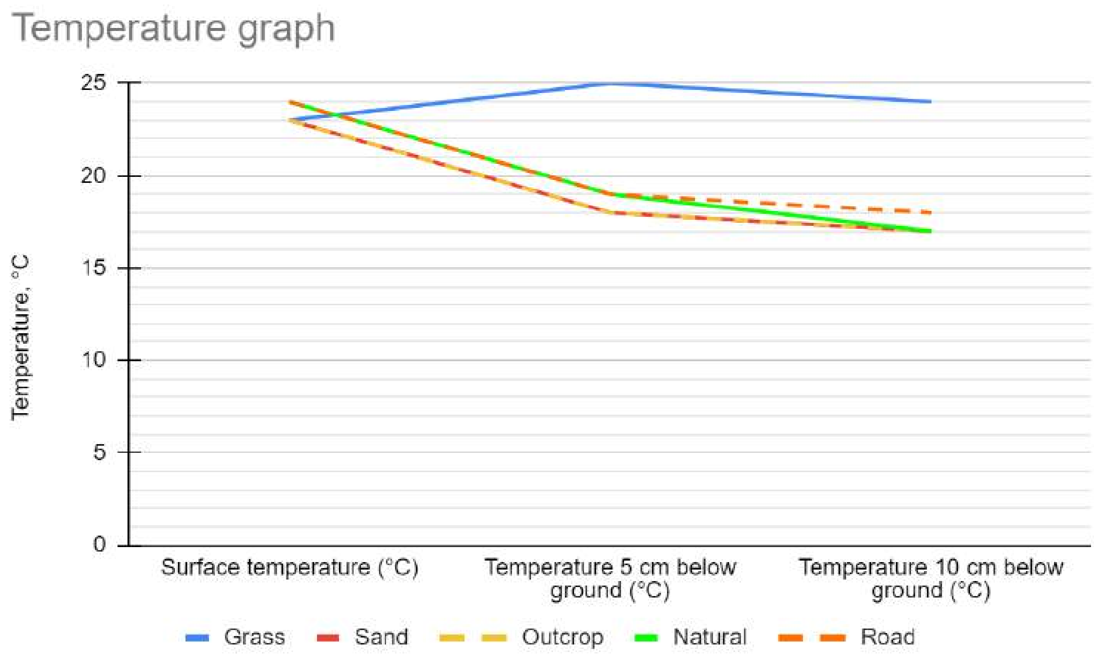
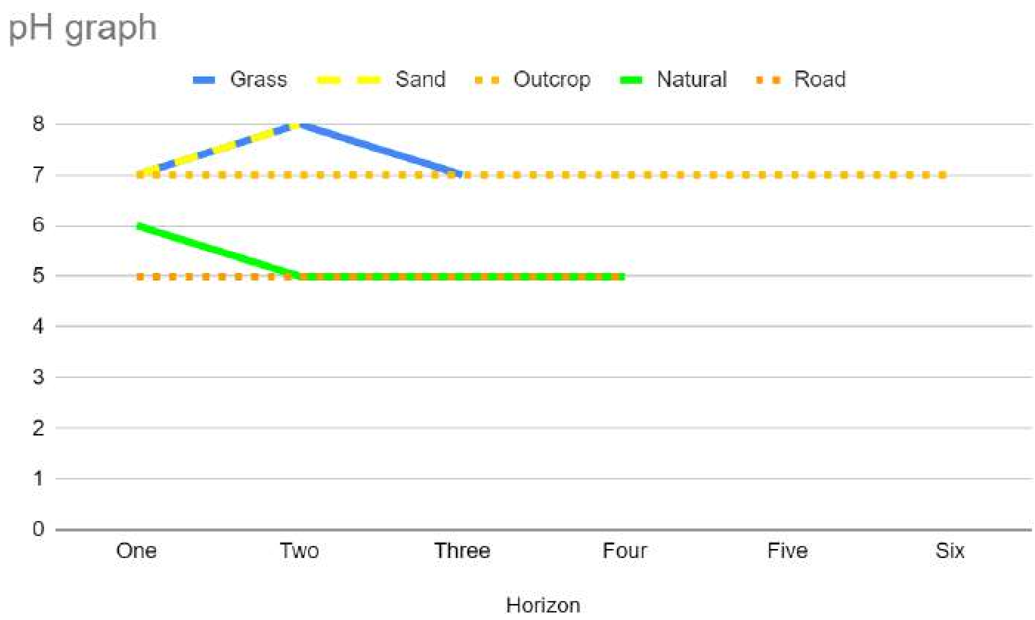
7. All the figures and pictures are the compiled work of Silver Oja, Vaike Rootsmaa and Andre Ületoa

APPENDIX

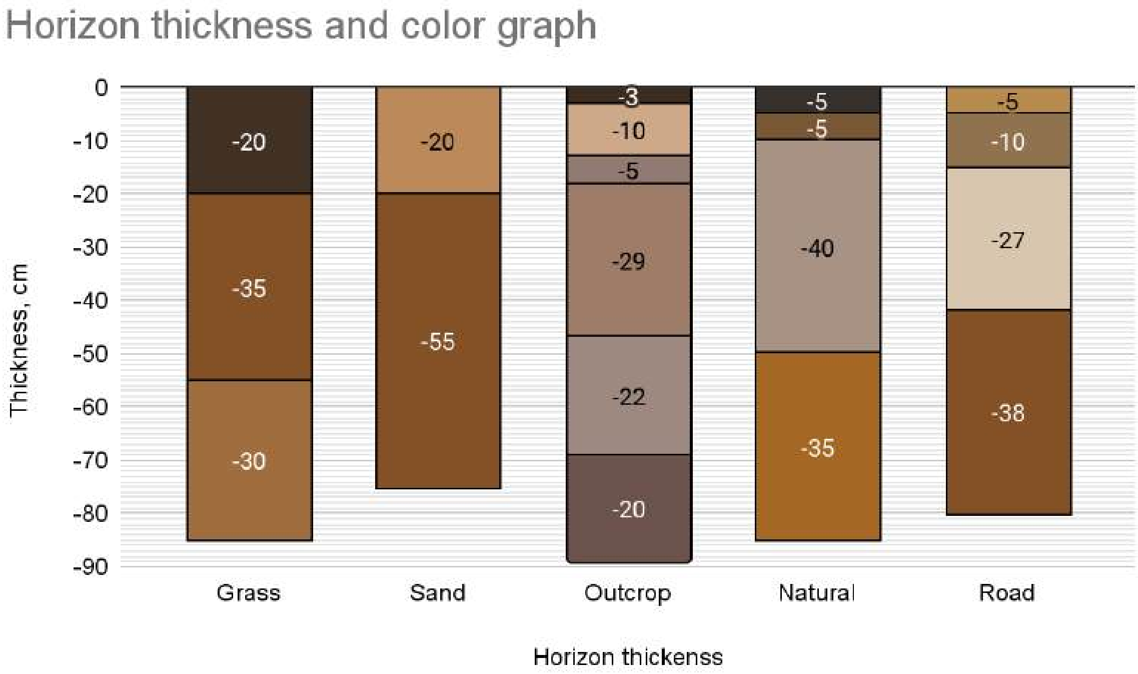
Five Site Compiled Graphs



Graph 7. Temperature of each site



Graph 8. pH of each site



Graph 9. Horizon thickness and color of each site

Reference Photographs of Suur Taevaskoda

Figure 13. View of the Suur Taevaskoda sandstone outcrop

Figure 14. A better overview of the Road site's road