GLOBE Estonia Learning Expedition 2022

Connections between the chemical composition and Munsel color of coastal soils in relation to the distance from the sea

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Abstract

In the course of our field work, the soil composition on the northern side of the Käsmu peninsula was investigated. The research area quickly transitioned from sandy beaches into pine forests with blueberry ground cover. The geography seemed to be mainly affected by the sea, except near the third site where glacial erratic boulders could be observed. A transect was drawn from the coast with three dig sites picked alongside it, although due to rocky terrain preventing the digging, the third site was slightly offset.

The sites were analysed using GLOBE pedosphere protocols. Ground temperature, cloud cover and local flora were measured. The soil was separated into layers and sampled. The composition of the samples was analysed and given its corresponding Munsell colour code. A correlation between the redness of the soil and its iron content was observed. Contrary to our hypothesis, samples from site 1 and 2 did not contain more strontium than site 3, but could be linked to changing salinity of the seawater in the study area.

Our findings correlated with existing soil maps with site 1 classified as sandy soil with some biomass, site 2 podzol and site 3 as gleyed podzol.

1. Research questions

There were a few key questions we wanted answered with our research. We wanted to see what is the correlation between the colour of the soil and its composition. We set a hypothesis that the redder the soil the more iron content it would have.

We also wanted to see the correlation between a site's distance from the sea and the soil's salinity. We hypothesised that the sites closer to the sea would have a larger strontium concentration and in turn more salt traces from seaspray.

We were not quite sure how well documented the area's geology and soil classification is so we wanted to see if our findings line up with existing soil maps. We set a hypothesis that existing maps are accurate.

2. Research sites

Our research area was on the northern side of the Käsmu peninsula (Figure 1 and 2). We drew a transect from the shoreline and picked 3 dig sites along it. We failed to dig the third site inline with the transect due to erratic boulders covering our access to the soil. We decided to offset the digsite east of the transect, where the boulder field thinned (Figure 3).

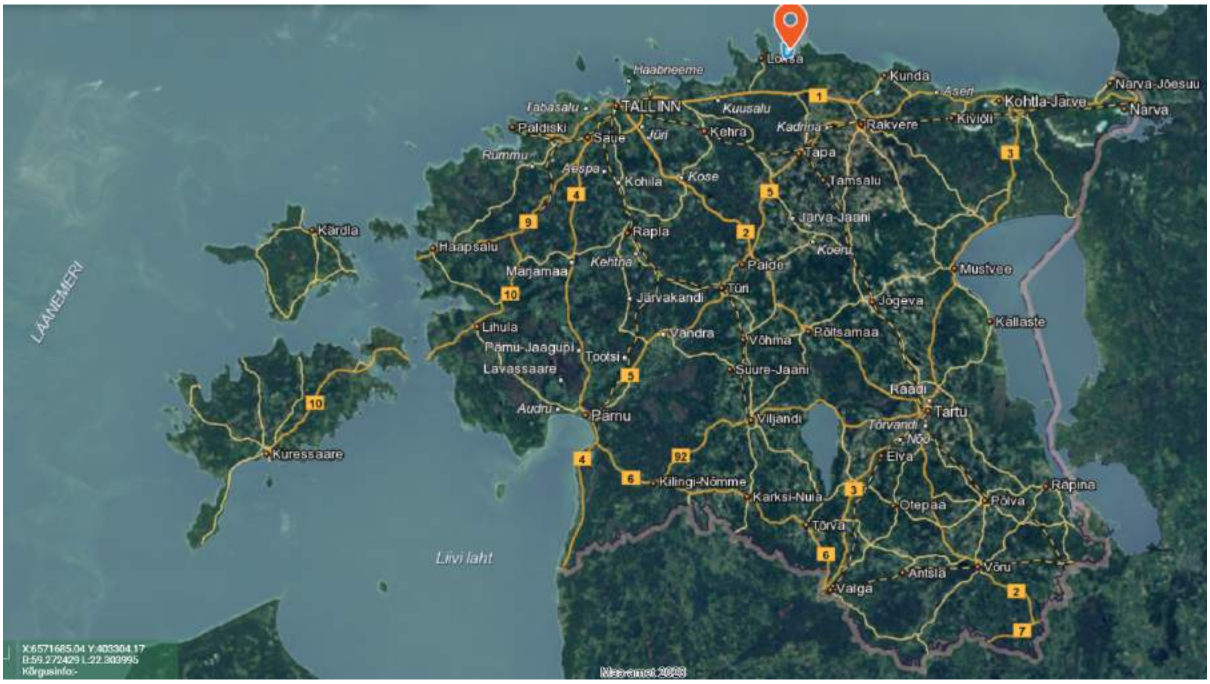

Figure 1. Location of Käsmu peninsula in Estonia. Source: Estonian Land Board (2023a)

Figure 2. Research area shown on map of north of Käsmu peninsula and a zoomed in area on LIDAR map showing elevation changes.

The first site was located on the sandy beach, a few meters from the sea (point 1 on Figure 3). We could observe some sparse ground cover. The second site was located roughly 40 metres from the sea (point 2 on Figure 3). The site was in a pine forest with blueberry and peat ground cover. The third site was located roughly 50 metres south and 50 metres east from the second site (point 3 on Figure 3). Plants surrounding the site looked quite similar to the second site

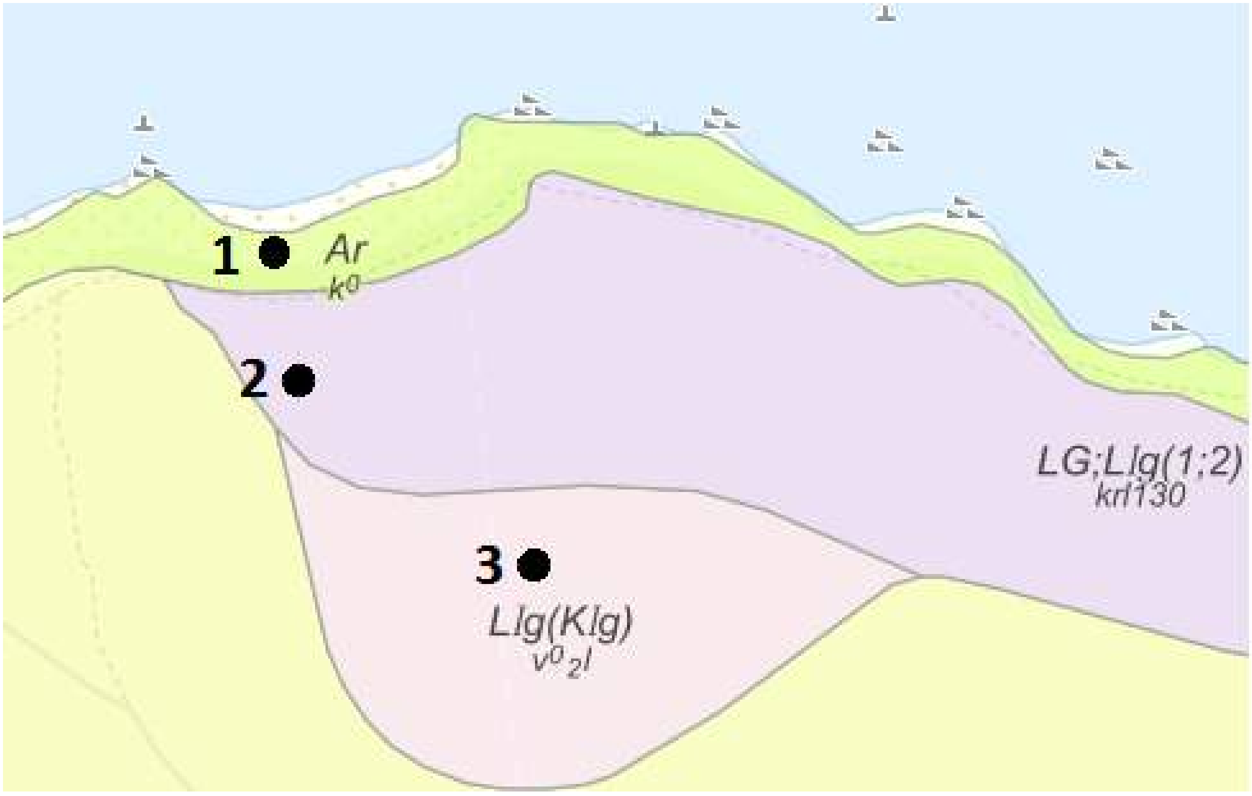

Figure 3. Location of research sites shown on Estonian Land Board's soil map. Abbreviations of soil types from Estonian Land Board's soil map explanation sheet:: Ar - salty primitive soil; LG - podzol; Llg - gleyed podzol. Source: Estonian Land Board (2023b); Estonian Land Board (2001)

3. Research methods

For the research we dug three excavations on the coast of Käsmu peninsula. Observations and fieldwork were conducted according to the GLOBE Soil Characterization Protocol. We measured the depth of each excavation and the different horizons in the soil with a measuring tape and marked the horizons with nails. Then we visually compared the grain sizes, colours and contents of different horizons and determined the soil classification. The determined classifications were compared to the classifications from the Estonian Land Board's soil map (Available at: https://xgis.maaamet.ee/xgis2/page/app/mullakaart). In addition, we measured the air temperature at each site and the soil temperature in 5 cm and 10 cm depth with thermometers. We visually measured the cloud coverage and took samples with a shovel from most of the horizons in each hole. Final thing we did on site was to describe each location and their vegetation. For location we wrote down the distance from the sea, a description of the surrounding and the coordinates of the hole. Vegetation was mostly determined on site by the students, except for the first site where plant species were identified with the help of "Eesti taimede kukeaabits" by Toomas Kukk (2009) and Google Lense.

Later we determined the colour of selected soil intervals according to the Munsell colour code using 2.The Globe Soil Color Book and the iron and strontium content of the soils using Bruker TRACER i5 handheld EDS-XRF instrument that uses x-rays to measure the chemical composition of a solid sample. Strontium was used as an indication of salinity as it is the 5-th most abundant cation in seawater and is typically not a major constituent in rocks (Major ion composition of seawater—Lenntech. (n.d.)).

4. Results

Research was conducted on August 3, 2022.

4.1 Site 1

The location of site 1 was near the coast, around 15 m from the sea. It was on the edge of the forest and was not located on a hill. The coordinates for the excavation were XY 6610155.70; 606812.37. The plant species on site were growing on sand (Rosa rugosa, Phragmites australis, Vicia sepium, Hieracium umbellatum, Melampyrum lineare, Honckenya peploides, Pinus sylvestris and Sphagnum). Cloud coverage at the time was about 40% and air temperature 19.9°C. Temperature from the depth of 5 cm was 22°C and from the depth of 10 cm 23°C.

Our excavation was 70 cm deep and we differentiated seven horizons. All seven horizons consisted of sand. We determined the soil type to be “sand with some biomass”. The Maa-amet soil map determined it to be “salty primitive soil”. The first layer was mostly sand and had no structure. Grain size was mostly uniform and the particles were about 1 mm in diameter. Second layer was visibly darker than the first layer and had a bigger grain size of about 1,5-2 mm in diameter. This layer was later identified as a storm layer. Third layer seemed to have the same kind of sand as the first layer, but was much darker in colour due to the biomass in it. Fourth layer had bigger grain size than the previous layer and resembled the storm layer that had been in the top layers. Fifth and sixth layer resembled the second and third layer. In the bottom of the hole was finer greyish sand.

Figure 4. Site 1 profile.

Figure 5. View to the sea

Figure 6. Vegetation.

	Depth range	Thickness of layer	Munsell colourcode Hue	Value	Chroma
Käsmu 1	0-33cm	33cm	10 YR	5	3
	33-36cm	3cm			
	36-38cm	2cm	10YR	4	2
	38-53cm	15cm	10YR	4	3
	53-55cm	2cm			
	55-58cm	3cm			
	58-70cm	12cm	10YR	5	3

Table 1. Data of excavation 1.

4.2 Site 2

The location of site 2 was near the coast, at the beginning of the forest, around 40 m from the sea, on the foot of the hill. The coordinates for the excavation were XY 6610128.37 ; 606820.64. The plant species on site were growing on a loose peat moss (Sphagnum) layer (*Vaccinium myrtillus, Vaccinium vitis-idaea, Pinus sylvestris*). Cloud coverage at the time was about 40% and air temperature 20.3°C. Temperature from the depth of 5 cm was 17°C and from the depth of 10 cm 17°C.

Our excavation was about 70 cm deep and we differentiated six horizons. We determined the soil type to be “podzol” and we were correct. According to Maa-amet’s soil map, the soil was classified as podzol. The first layer consisted of brown, extremely loose peat moss that had already started decomposing. Second layer was a darker brown colour and dry. It consisted of decomposed peat moss. Third layer was the eluviated horizon. It had a greyish colour and sand-like texture. Because of its colour we concluded that it might have less iron than the other horizons. Fourth layer mostly consisted of sand that was red in colour and had finer grains. Fifth layer was similar to the last layer, but was coarser. The bottom layer’s texture was harder than any from the last layers, but grain size was the same as in the fourth layer. The colour of this layer was grayer than the ones next to it.

Figure 7.Tree cover

Figure 8. Vegetation.

Figure 9. Site 2 profile.

			Munsell colourcode		
	Depth range	Thickness of layer	Hue	Value	Chroma
Käsmu 2	0-7cm	7cm			
	7-16cm	9cm	10YR	2	2
	16-20cm	4cm	10YR	6	2
	20-44cm	24cm	10YR	5	3
	44-53cm	9cm	10YR	4	4
	53 - 70cm	17cm	10YR	4	4

Table 2. Data of excavation 2.

4.3 Site 3

The location of site 3 was up from the coast and the hill, in the middle of the forest. Site 3 was around 150m from the sea. Because of big rocks in the soil, digging was complicated. We had to move further from the last two holes to find a place where digging would not be that difficult. The coordinates for the excavation were XY 6610073; 606835.45. The plant species on site were growing on a loose peat moss (Sphagnum) layer (*Vaccinium myrtillus, Pinus sylvestris*). Cloud coverage at the time was about 40% and air temperature 21.1°C. Temperature from the depth of 5 cm was 18°C and from the depth of 10 cm 17°C.

Our excavation was about 70 cm deep and we differentiated eight horizons. We determined the soil type to be “gleyed podzol with gravel”. According to Maa-amet’s soil map it was gleyed podzol. The first layer consisted of loose peat moss that had a brown colour and had started to decompose. Second layer had less loose peat moss than the first layer and consisted mostly of already decomposed material. It had a darker brown colour. Third layer was the start of an eluviated horizon. It consisted of grey sand. Fourth layer was the eluviated horizon. It consisted of white, very fine, loose sand. Fifth layer consisted of cemented red sand that had very fine grains. Sixth layer consisted mostly of gravel and roots. The grain sizes ranged from a few mm to 10 mm. Seventh layer consisted of two different kinds of soils. They were mixed with one another and pieces of the soil held its shape if lifted, but crumbled to sand as soon as they were moved around. The colour codes for these two different soils were 7,5YR 7/3 and 7,5YR 6/8. The bottom layer had a blocky consistency and consisted of gravel.

Figure 10. Site 3 profile.

Figure 11. Surroundings.

Figure 12. 7th layer

Figure 13. 7th layer when crumbled

			Munsell colourcode		
	Depth range	Thickness of layer	Hue	Value	Chroma
Käsmu 3	0-8cm	8cm			
	8-11cm	3cm			
	11-16cm	5cm	7,5 YR	4	2
	16-23cm	7cm	7,5 YR	4	4
	23-30cm	7cm	7,5YR	4	6
	30-40cm	10cm			
	40-47cm	7cm	7,5 YR	5	6
	47-70cm	23cm			

Table 3. Data of excavation 3.

5 Results and discussion of chemical composition

Results of iron and strontium concentration measurements expressed in weight percentage (wt%) with Munsell colour code values are listed in Table 4. Käsmu 1 was the site closest to the sea and Käsmu 3 was the farthest. The strontium concentration in the samples seems to increase with distance from the sea (Figure 14). As all the samples consisted mainly of sand that has originated from the sea, this trend could indicate changes in the salinity of the seawater during the time these soil layers were deposited or is connected to the minerals that are present in the sand. The coastline at Käsmu peninsula is made up of past shorelines of different Baltic sea stages.

Sample location and depth interval	**Element concentration as wt%**		**Munsell colour code**		
	Fe	**Sr**	**Hue**	**Value**	**Chroma**
Käsmu 1 0-33	**0,1896**	**0,0082**	10YR	5	3
Käsmu 1 36-38	**0,255**	**0,0138**	10YR	4	2
Käsmu 1 38-55	**0,2346**	**0,0118**	10YR	4	3
Käsmu 1 58-70	**0,3773**	**0,0122**	10YR	5	3
Käsmu 2 16-20	**0,1616**	**0,0127**	10YR	6	2
Käsmu 2 20-44	**0,1923**	**0,0063**	10YR	5	3
Käsmu 2 44-53	**0,2548**	**0,0148**	10YR	4	4
Käsmu 2 53-70	**0,2273**	**0,008**	10YR	4	4
Käsmu 3 11-16	**0,2873**	**0,0111**	7,5YR	4	2
Käsmu 3 16-23	**0,3045**	**0,0158**	7,5YR	4	4
Käsmu 3 23-30	**0,574**	**0,0135**	7,5YR	4	6
Käsmu 3 40-47	**0,8107**	**0,0167**	7,5YR	5	6

Table 4. Munsell colorcode values with iron and strontium concentration of the sampled material

The higher areas on the coastline correspond to older sea levels and the shoreline records the times of Litorina and Limnea sea. The Litorina sea was initially saltier and the seawater salinity decreased with time, and with it also the Strontium concentration (Läänemere arengulugu | loodusveeb. (n.d.)). As higher Strontium concentrations were measured from site 3 that was the furthest from the sea but also with the highest elevation, the observed trend could be connected to the changing salinity of the water over the course of the formation of the shoreline. The observed differences in Strontium concentrations could also just be due to changes in the types of minerals that were in the soil samples.

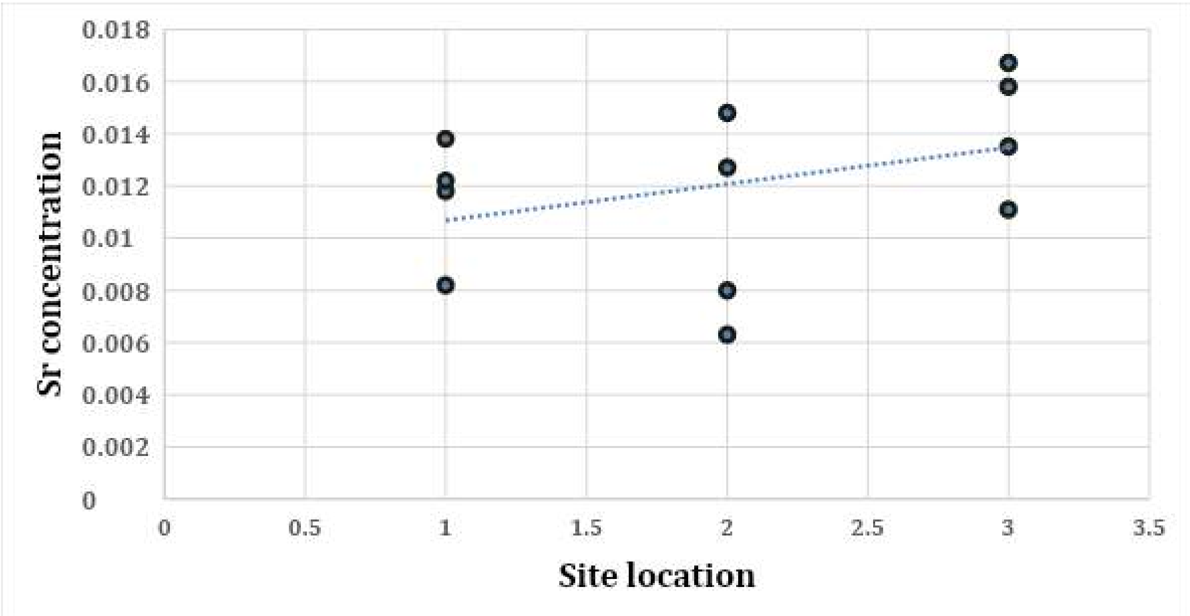

Figure 14. Correlation between strontium concentration in soil samples and the distance from the seashore. Site 1 is near the shore and site 3 is the furthest away.

From Figure 15 it can be seen that the concentration of iron in samples with Hue value of 7,5 were higher than in samples with Hue value 10 in the YR colour code.

Samples with Hue 7,5YR also show higher iron concentration with increasing Value and Chroma numbers as seen from Figures 16 and 17.

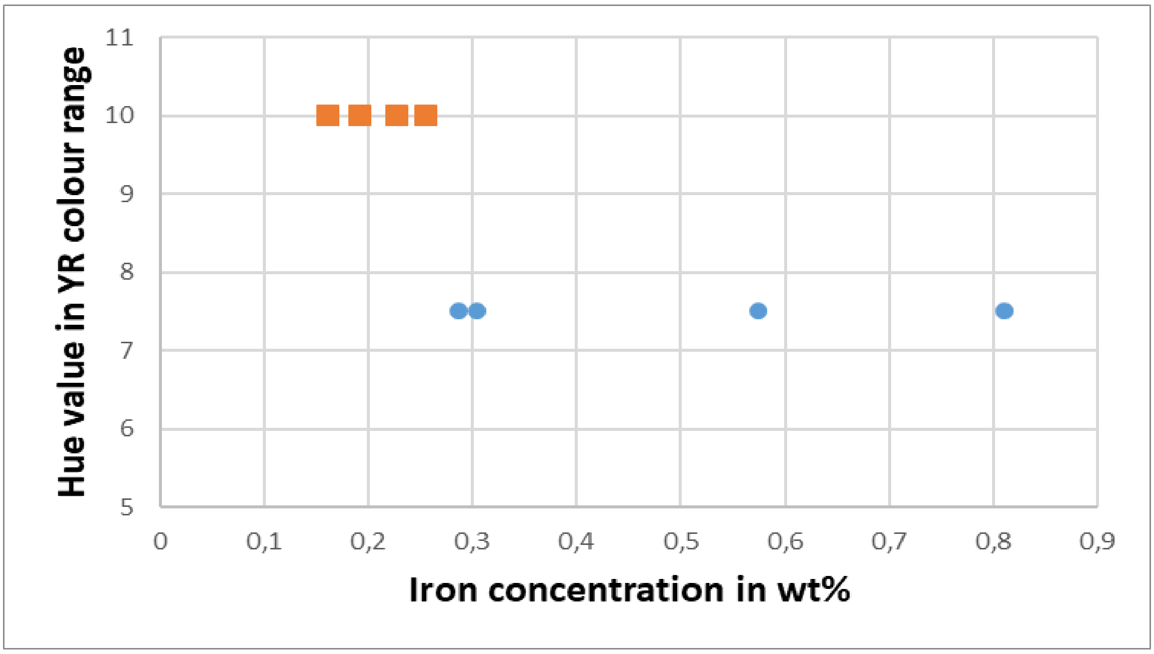

Figure 15. Correlation between Hue value in YR colour range of the Munsell colour code and iron concentration in the soil samples

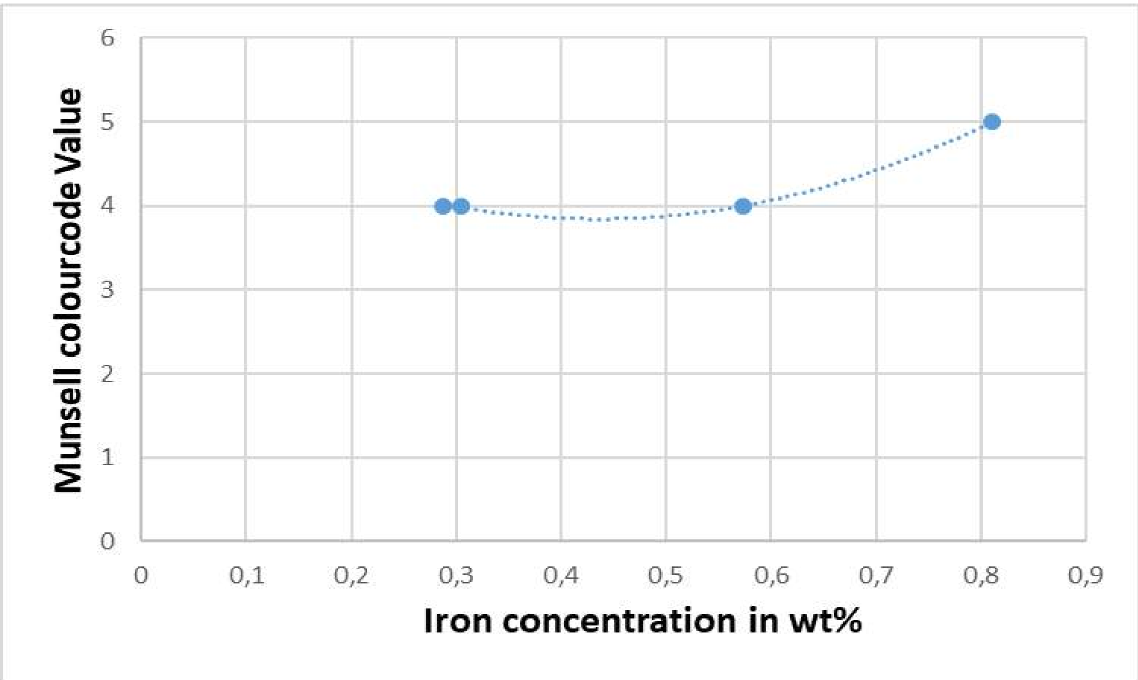

Figure 16. Correlation of Munsell colour code Value and iron concentration in samples with 7,5YR Hue values.

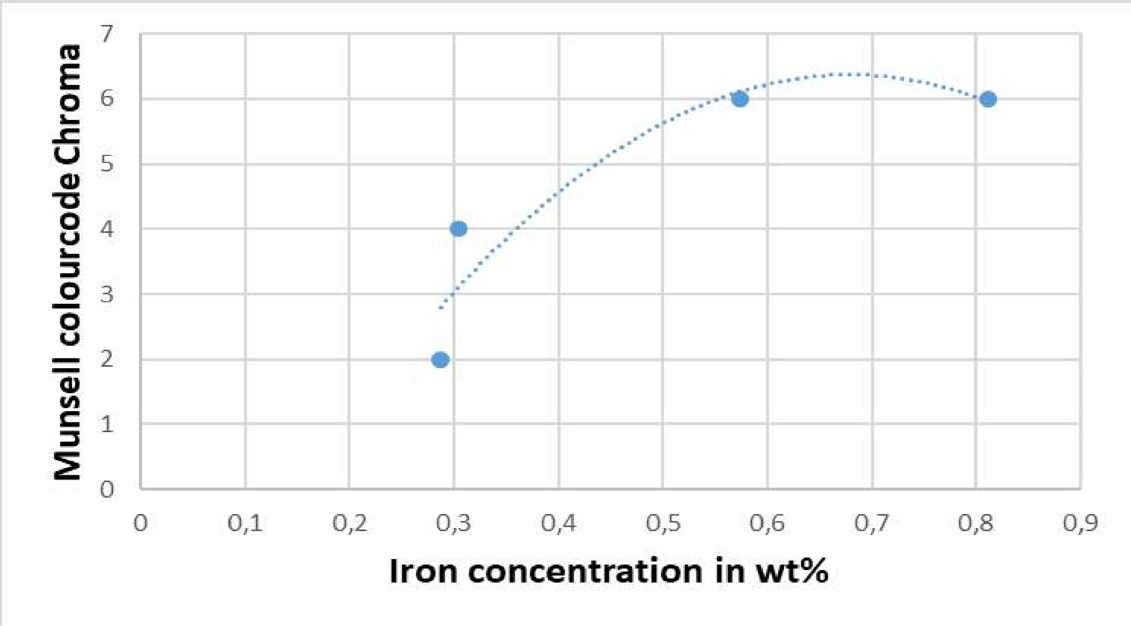

Figure 17. Correlation of Munsell colour code Chroma and iron concentration in samples with 7,5YR Hue values.

However, samples with Hue 10YR show a different pattern that varies with site location. In the case of site Käsmu 1, there is no trend between Chroma and iron concentration (Figure 19) and in the case of Value numbers, the lowest and highest iron concentration samples both have a Value of 5, so there is no clear correlation (Figure 18). In the case of location Käsmu 2, there is a positive trend between Chroma and iron concentration (Figure 19) but a negative trend between iron concentration and Value numbers. Although the Value and Chroma values of samples with 7,5YR Hue values both showed a positive correlation, the assigning of Value and Chroma values to the soil samples was very difficult due to the grainy nature of the soils. Especially for site 1 where the soil consisted of sand grains with different colours and it was hard to assign these numbers. So even though there seems to be some correlation for 7,5YR Hue values and conflicting results for 10YR Hue values it could simply be from mislabeling as the difference of one point in either scale (Value and Chroma) can be very subjective. This was also observed during assigning of the Munsell colour codes of the soil samples when the Hue values assigned by different group members were the same but for most of the soil samples the Value and Chroma values determined by different group members could differ by a value of 2.

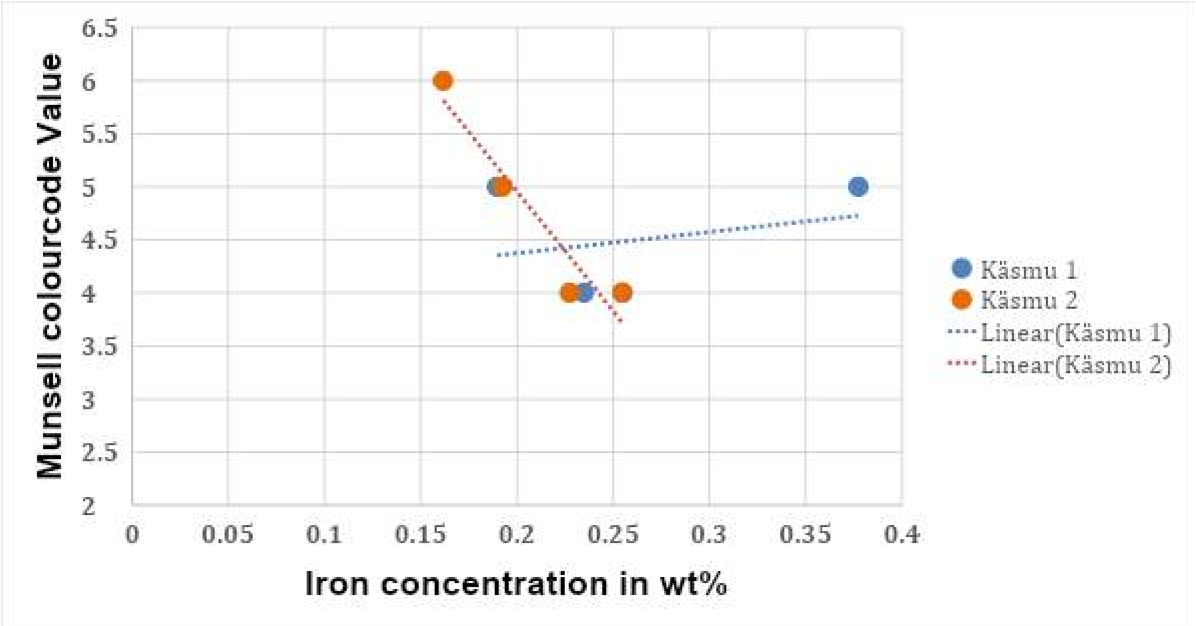

Figure 18. Correlation of Munsell colour code Value and iron concentration in samples with 10YR Hue values.

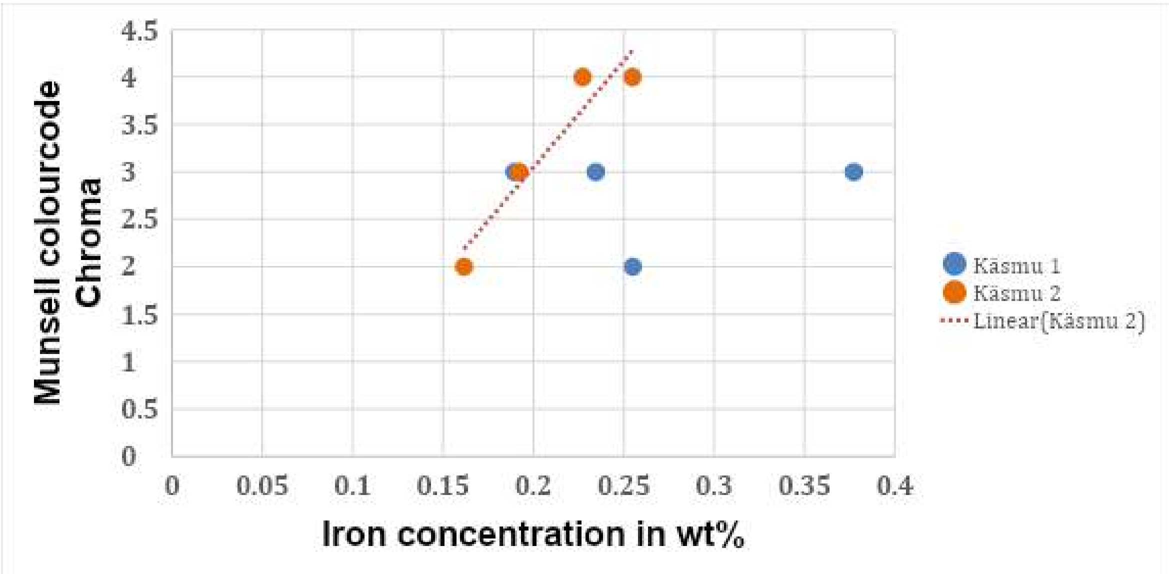

Figure 19. Correlation of Munsell colour code Chroma and iron concentration in samples with 10YR Hue values.

6. Conclusion

It was determined that there is a connection between the redness of the soil and its iron content. By using the Munsell colour code we observed that soils in the YR colour range with Hue values of 7,5YR had higher concentration of iron than soils with Hue values of 10YR. When comparing the 7,5YR and 10YR codes with the same Value and Chroma, our group members agreed that the 7,5YR colours were more red.

The hypothesis that the sites closer to the sea would have a larger strontium concentration did not hold true and an opposite trend was observed. This could be due to changes in the composition of the minerals in the soil samples or it could show the changes in the salinity of the seawater that formed those soils.

The classification of the soils in the excavation sites corresponded to the soil classification of the Estonian Land Board’s soil map and it could be said that for the study area the soil maps are accurate.

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