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Variation in soil nutrient variables in relation to altitude and aspects in Sikilsdalen and Heimdalen of Southeast Norway

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This thesis is worth 60 study points

Abstract

The study investigates the variation in soil nutrients variables in an altitudinal gradient and aspect of Sikilsdalen and Heimdalen of Southeast Norway. The study was carried out with the data collected during the field work. The aim of the study was to analyse the variation in soil variables along altitude (1000 to 1575m) and from the slope with different aspect (north-facing slope/south-facing slope). Soil samples were taken in the homogeneous vegetation plots in every 25 meters of both mountains. Soil variables, volume weight, pH, Ca, Mg, K, P and Loi (organic carbon) were analyzed in a laboratory. The data was analysed by the MINI TAB program7.1. Pearson correlation, Regression, ANOVA and PCA analysis were done to examine the data from all perspective so that clear significant correlation and difference can be found along altitude and aspect. Pairwise comparisons were done by Tukey’s methods to find the significant mean difference with confidence intervals.

The method for soil analysis was followed by the standard soil analysis methods written by Krogstad, (1992). Soils of both northern (SF) and southern (NF) valley were acidic as pH was range from 4.1 to 5.3. Soil nutrients are correlated with each other but the significant correlation with altitude was showed only by P, Mg, Ca and Vw with different trends. In the southern slope (north-facing slopes) of both mountains, K, Mg, Ca, and Vw showed significant trends along altitude whereas in the northern slopes, P showed the significant difference with altitude in Sikilsdalen and none of the soil variables showed any significant difference with altitude in Heimdalen. The null hypothesis was rejected only for pH in both mountains. There is increasing tendency in pH with altitude in both valleys, but with different directions in Sikilsdalen and Heimdalen.

All the soil variables were found high in the middle part of both mountains. More variation was observed in northern aspect than the southern aspect due to more vegetation. Vw in both slopes increased with altitude and most other soil variables decreased with altitude. The effect of Loi was smaller in Heimdalen compared to Sikilsdalen.

Key words: Variation, altitude, correlation, aspects and soil variables, pH, Loi

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Foreword

My thesis entitled “Variation in soil nutrients variables in relation to altitude and aspect in Sikilsdalen and Heimdalen of Southeast Norway” has been completed with the supervision, help, support and motivation of different respected people.

Firstly, I owe my deepest gratitude to my Supervisor Dr. Philos Arvid Odland, who encourage and guided me through every step from initial to final submission. He has made available his support in and out of the University in no. of ways. I am also indebted to Associate Professor Live Semb Vestgarden and Associate Professor Stefanie Reinhard for being during initial field works and for guidance and support in soil sampling.

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<Bø i Telemark/15 May, 2017>

<Manju Sapkota>

1. Introduction

The soil is the outer crust layer of earth. Soil develops over a long period of time. Soil forming process and its related factors are dependent on different spatial and temporal scales, which define the nature and properties of soil (Burrough, 1983). The random variation in soil properties cannot be recognized by nature and scale of investigation (Ball and Williams, 1968). The systematic variability is gradual changes in soil properties which are the soil forming factors and depend on topography, lithology, climate, biological activity and age of soil of that particular region (Van Wambeke and Dudal, 1978).

Pedogenesis of soil is defined by lithology which is a principal factor in soil formation and genesis with the interaction of climate, parent material, relief, organism activity, time and topography of the area (Wilson et al., 2017). Conversion of forest to grassland results in the reduction of soil nutrients and organic carbon (Laurance et al., 1999). Soil genesis and its composition are influenced with the change in elevation and climate (Hutchins et al., 1976)

Soil properties change continuously with time and place (Heuvelink and Webster, 2001). Chemistry of soil in the high altitude can be explained with the study of the ionic chemistry of water sources (Sarin, et al., 1992). Soil properties are different with the difference in the type of vegetation and topographic aspect (Yimer, 2006). At the higher altitude, there is an increase in wetness and decrease in temperature which effects on soil development causing from podsolization to hydromorphism soil (Schawe et al., 2007). Podsolization is common in boreal zone where conifer and dwarf shrub plants play a vital role in developing this process (Stützer, 1999). Physical and chemical characteristics of soil in the alpine region on the top of boulders are poorly developed and acidic in nature resulting in low base saturation (Allen, 2005). Acid deposition on soil increases the rate of depletion of base cations from soil (Oulehle et al., 2007). Exchangeable base cations are directly linked with the type of vegetation in which concentration of cations are high along the lower the altitude where vegetation cover is high (Liptzin and Seastedt, 2009). There is always more organic matter in soil containing more residues from plants so the organic matter in the soil also determines the concentration of all nutrients absorbed by plants (Agbolla and Corey, 1973).

Phosphate remains in a store form in a soil for a long time and get penetrate into soil particles and release only after some surface activity is induced (Barrow, 1983). In general, there is an increase in organic matter with increasing altitude due to litter fall and low rate of decomposition in the summit forest (Wilcke et al., 2008; Tsui et al., 2004). Tusi et al., 2004 also explained that pH, available P, exchangeable cations like; Ca, Mg are significantly higher on the slope at 0-5 cm soil. It is said that the organic matter in soil gets decreases with the increase in pH (You et al., 1999).

1.1. Effect of Soil Properties on Slope, Altitude, and Aspect

Development of soil in different slope depends on the angle of slopes which affect the movement and accumulation of soil nutrients and ultimately bring the variation in soil nutrients and distribution of vegetation along the slope (Tsui et al., 2004). There is a change in soil properties in an altitude from 198 to 2865 m, where pH and base saturation decreases and OC increases in which precipitation and temperature have taken as main climatic factors (Dahlgren et al., 1997). Precipitation is the main climatic factor, which determines the organic matter in both north and south aspect and also has a positive relationship with altitude. Increased in mean annual precipitation along the altitude 60 to 1100 meters causes the decrease in soil pH, Ca, and Mg, whereas organic matter get increases (Rubinić et al., 2015).

High Infiltration rate, moisture content and moderate temperature in the north-facing slope results in an increase of OC (Boix-Fayos et al., 1998). Along aspect, lower level of phosphorus is due to increase in phosphorus fixation and lower deposition in the B-horizons (Yimer et al., 2006).

In Tropical Mountain, there is a change in soil properties along altitudinal gradient where soil organic matter increases along altitude but pH and nitrogen concentration decreased along the gradient (Wilcke et al., 2008). An increase in pH of soil also increased the dissolution of organic matter (You et al., 1999). Research carried out in deglaciated valley in Northern Sweden by Allen (2005) found that the soil is acidic and Calcium is higher than Magnesium followed by Potassium and Sodium. A study by Allen (2005) also gives the explanation that soils in the hard rock are formed by chemical weathering and provide the pedogenesis setting of that area.

1.2. Significance of the study

The study is limited to a previous botanical investigation of variation in plant distribution along North and South slopes in Sikilsdalen and Heimdalen. 5*5m plots were systematically distributed with 25 m elevation difference along predetermined lines from the valley bottom to the highest summits. The distribution of plants along these gradients can be assumed to be affected by soil variation in addition to chemical variables. This study gives the first primary data on physical and chemical properties of soil variables like; Volume weight (Vw), pH, Calcium (Ca), Magnesium (Mg), Potassium (K), Phosphorus (P), and Loss of Ignition (Loi) of two associated valleys; Sikilsdalen and Heimdalen. Study of soil chemistry can be helpful for the study of the ionic chemistry of water sources associated with two mountains.

1.3. Objectives

The main objectives of my study were;

- Was there significant difference in soil variables when we compare differences along gradients in altitude and aspect
- Was there significant difference between Sikilsdalen and Heimdalen

2. Materials and Methods

2.1. Study Area

The study was carried out in two valleys situated in the Southeast Norway; Sikilsdalen and Heimdalen. The details transect lines of both valleys can see in the figure 1.

Figure 1. Study area showing transect plots in Sikilsdalen (right) and Heimdalen (left)

2.1.1. Sikilsdalen

Sikilsdalen is a clear U-shaped valley with the main direction from east to west and constituted of Caledonian mountain chain. It is located in the eastern Jotunheimen central Southern Norway, at 61^0 28'N and $09^0$00' E. Valley ranges from an elevation 992 to 1778 m a.s.l. The 10 km long valley extends from the upper Sikilsdalen lakes (995 meters) to the west and east toward lower Sikilsdalen lakes (992 meters). In the east, there are two lakes drain her which is 5 km long (Nordhagen, 1943) as shown in Figure 2. The north-facing hillside has a smoother slope than the south-facing. According to Nordhagen (1943), the bedrock of the mountain consists of gneiss and quartzite rock. The rocks are said to be nutritious and provides good breeding for plant and crops, specifically to the vegetation on the northern hillside of Sikilsdalen. Most of the solid rock in Sikilsdalen has covered by moraine in different thicknesses, except in the steep slope which is rich in calcium and phosphate as a result of weathering of igneous rocks (Nordhagen, 1943).

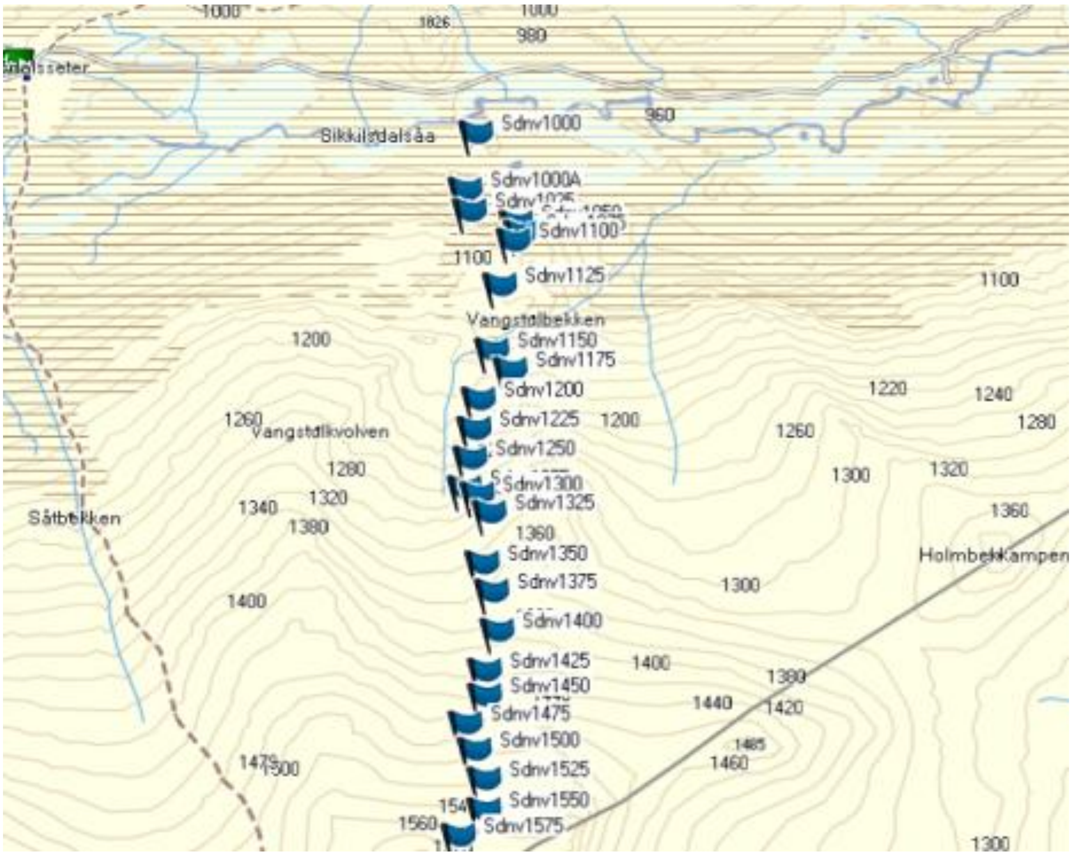

Figure 2. Plots in the north- facing slope of Sikilsdalen

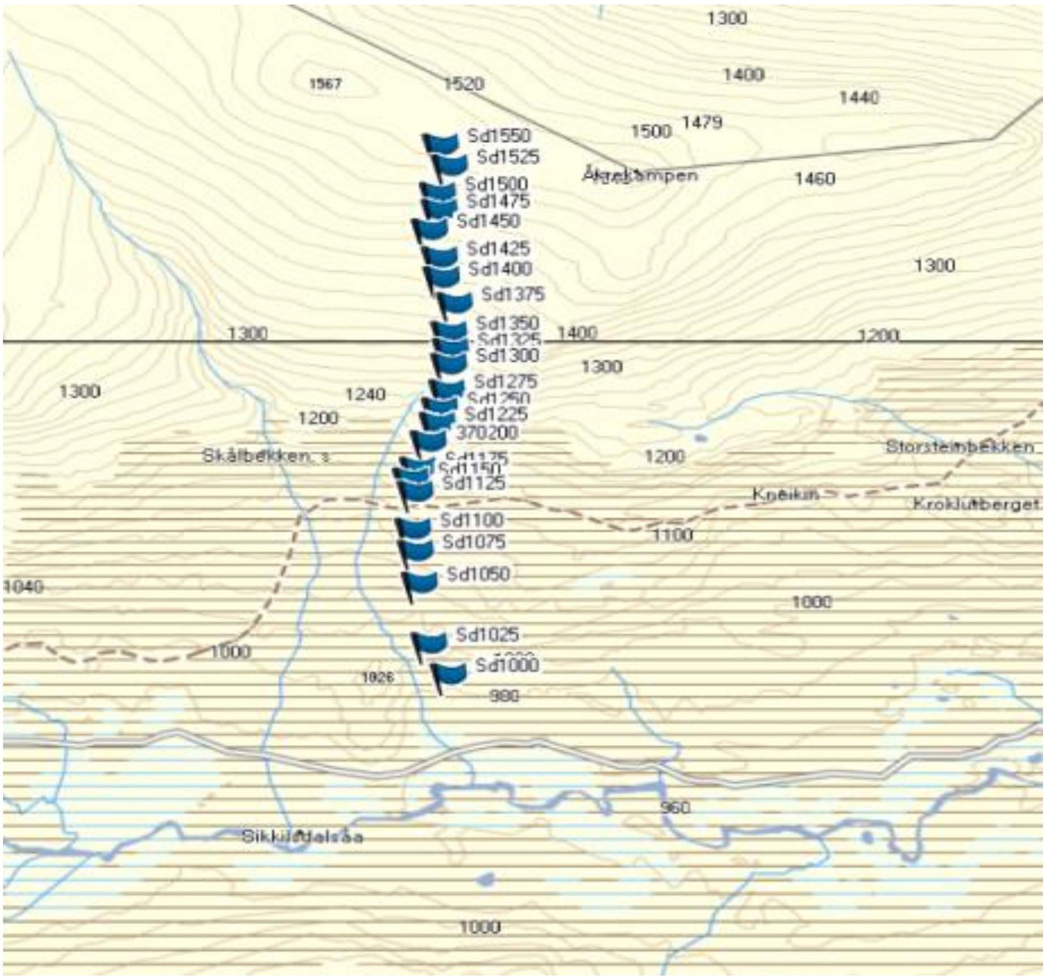

Figure 3. Plots in the south- facing slope of Sikilsdalen

According to Felde et al., (2012), Sikilsdalen is normally covered with snow so water availability and moisture content are high. The area receives a large amount of precipitation throughout the whole year and temperature is normally low. Nordhagen (1943) has set the tree line limits in Sikilsdalen at 1238 meters in the south-facing slope and 1175 meters on a north-facing slope of the mountain. The Low-alpine zone ends at 1450 meters in the south-facing and 1,350 meters in the north-facing slope. After the low-alpine pine zone, there is the middle-alpine zone which extends up to about 1800 meters. The high-alpine zone has not included in Sikilsdalen (Nordhagen, 1943).

In the study area, transect plots lie in the northern boreal zone, low alpine and between alpine zones. The boreal zone is dominated by birch and it extends from the valley floor to the tree line. In Low-alpine zone there are willow thickets and dwarf birch thickets in alternating sections (Nordhagen, 1943). The middle-alpine zone is characterized by graminoids, herbs, shrubs, and cryptogams. All bare mountains have characterized by dry areas with various lichens, and well-developed dry grass (Nordhagen, 1943).

A study from Felde et al., (2012) it is said that the area was used for horse, cow and sheep grazing but from the last few decades grazing activity of cow and goats have disappeared, sheep grazing has decreased and the area now used for horse grazing. From 2008 the grazing activity has increased by reindeer. Transects have little affected by human activity, and do not have large grazing damage but in the north-facing slope, there has more grazing damage by reindeer.

2.1.2. Heimdalen

It is also the U- shaped valley with the main direction west-east, situated in the east of Jotunheimen at 61 ° 26' N and E 09 ° 02' E. In the west there is the upper Heimdalen Lake at 1088 meters and lower Heimdalen Lake in the east at 1053 meters. The lower Heimdalen Lake is dammed up and drained in Hinøgla. The river Skjedøla flows into the lower Heimdalen Lake. Northern Heimdalen has the steady slope down towards the lower Heimdalen Lake. The south side of the mountain has a gentle slope (Høye, 2014).

The tree line for the south- facing slope is 1200 meters and on the north-facing slope, there is no dense forest (Østhagen and Egelie, 1978). The medium alpine zone starts at 1400 meters in the south-facing slope, and in the north-facing slope, it starts at 1300 meters. The medium-alpine zone is expected to go up to 1,800 meters (Østhagen and Egelie, 1978). In Heimdalen, transect plots are lies in northern boreal, low-alpine, and medium-alpine zone. The climatic condition is quite similar to Sikilsdalen Mountain (Høye, 2014).

Kloster and Hongve, (1978) studied on sediments of Øvre Heimdalen catchment, located on the downhill slope as shown in the Fig.5 and 6 results in the low organic matter and low primary production. The area is affected by the wind and heavy rain which results in leaching and eroding of soil materials into the lake (Grøterud and Kloster, 1978). The hillside in the south is affected by grazing animals. In the upper area, there is a herd of reindeer which constantly graze and walk around. In the lowlying areas, there are cows for grazing, but transect has not affected by grazing activities of the animal.

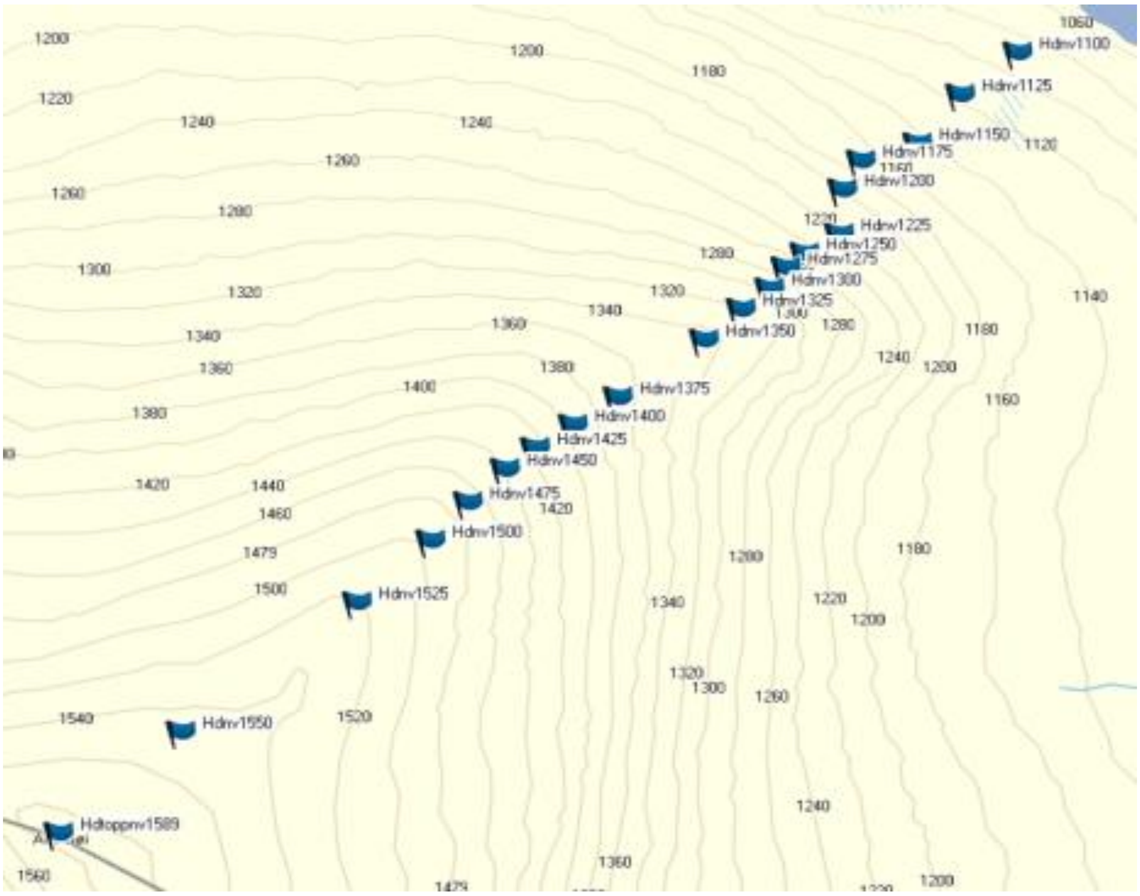

Figure 4. Plots in the north- facing slope of Heimdalen

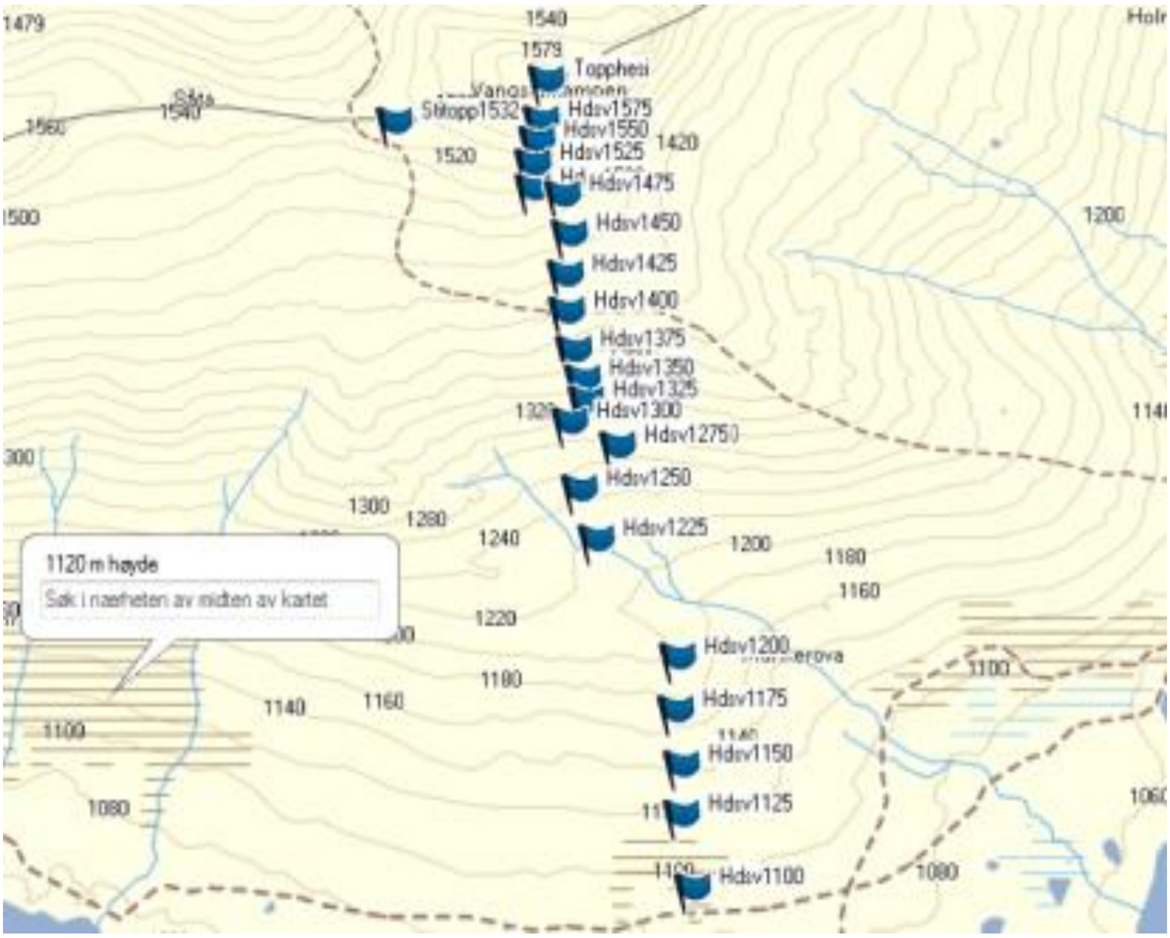

Figure 5. Plots in the South- facing slope of Heimdalen

2.2. Sampling

The fieldwork was conducted during the month of August 2014. The month was good to collect the soil sample despite some rain and windy at the top. Two valleys Sikilsdalen and Heimdalen were selected for collecting soil samples. Routes along four mountains were selected on the topographic map before the field survey and the plots were identified with the help of GPS along the transect lines. Soil samples were taken in every 25 meters in the same plots selected by (Høye, 2014). Soils were collected using steel soil core of 7cm diameter and 5 cm height. The top soil was collected from 4 cores which were mixed to form a single sample.

The study was done in two aspects of both mountains; south-facing slope and north-facing slope. North-facing slope is the southern slope and south-facing slope is the northern slope in both mountains. In Sikilsdalen, there was 23 samples side in south-facing slope (SDSV/SF) and 24 in the north-facing slope (SDNV/NF) excluding top. Similarly, in Heimdalen there were 20 and 19 sample sites in south-facing slope (HDSV) and north-facing slope (HDNV) respectively, excluding top. In SDNV, samples had collected from 1000 to 1575 m.a.s.l whereas in SDSV, from 1000 to 1550 m.a.s.l. Similarly, in HDNV, samples had collected from 1100 to 1550 m.a.s.l and in HDSV, from 1075 to 1575 m.a.s.l.

2. 3. Laboratory Methods

2. 3. 1 Drying: Soil samples were dried as soon as they arrived at the laboratory in a thin layer on brown paper on a tray at room temperature at 35 to 40^0c for one week. The drying soil was filter through a steel sieve with a 2mm mesh with the help of a porcelain pestle and large lumps of soils were broken and larger materials like stones were taken out before they pass through a sieve. Sifted soil was poured into a cardboard box and stored in a dry place. The sieve, mortar and collection receptacle was thoroughly clean after each operation.

2. 3. 2 Specific weight/ Volume weight: Specific weight is the weight of solid phase of soil i.e. mineral particles per unit volume. In most of the mineral soils, the soil particle density ranges from 2.6-2.7g/cm^3 (Hillel, 2003). The density of soil determines the different types of soils. In the lab, soil density is determined by mixing the soil thoroughly in its box by stirring it with the steel scoop. Then the scoop was filled carefully without exerting pressure on the wall of the box and it was exactly 5.22 ml of soil. The scoop with the soil was weighted and the result was recorded.

Calculation: Specific weight (Sw) = Weight of soil in gram/Volume of scoop

2.3.3 Loss of Ignition (Loi): 3 to 5g of soil is weighed into a previously weighed crucible and it dried for 6 hrs at 105^0c. The crucible with the sample is cooled in the desiccators for 30 mins and weighed was taken. The dry matter percentage can be calculations. For the loss of calculation the loss of ignition/ calcination, the crucible with dry soil is placed in the calcination oven for 3 hrs at 550^0c. The crucible with the sample is cooled in the desiccators for 30 mins and weighted was taken.

Soil organic matter can be calculated simply by Loss of Ignition method (Salehi et al., 2011; Koide et al., 2011) which is cheap, environmentally friendly and easy method for estimating carbon in soil.

Calculation formula gives by Krogstad, (1992)

% dry matter = m_3-m_1/m_2*100

% loss on Ignition = m_3- m_4/ m_3-m_1 * 100

m_1 = Wt. of crucible

m_2 = Wt. of soil before drying

m_3= Wt. of crucible with sample after drying

m_4= Wt. of crucible with sample after calcination

2. 3. 4 pH: 10 ml of soil was transferred to a graduated beaker with the help of a cylindrical measure. 25 ml of distilled water was added to the sample and closed it and shake by hand until soil gets well mixed with water, it was left for one day and next day the samples were shaken again for 15 minutes and test of pH started with calibrated pH meter with two buffer solution with pH 4.00 and 7.00. The electrode was inserted in the suspension with glass globe and the salt bridge stands over the soil sediments. Finally, the stable pH reading was noted from the instrument.

2. 3. 6 The methods for determining soluble Phosphorus, Potassium, Magnesium, and Calcium: This method has described by Egner et al., (1960). Nutrients were determined by extraction solution which contains the mixture of 0,1mol/l ammonium lactate, 0, 4 mol/l acetic acid and 3, 75 pH (Syversen and Borch, 2005).

400 g of soil is transferred to the extraction bottle and added 80 ml of Al- solution. The bottle was tight immediately and placed in the vibrator and after shaking process the suspension was filtered through a folded filter into 100 ml glass beaker.

Soluble phosphorus was determined by transferring 4 ml of soil extract to 50 ml plastic beaker and 10 ml of molybdate solution and 5 ml reduction solution was added. The beaker rotated slowly so that the reagent mixed with soil extract. After that solution turned into blue color depending on the phosphate concentration. The sample stood for 15 minutes after adding reagent and measured the intensity of the color with the help of spectrometer with the wavelength of 660 or 700 nm. The absorbance was read off for both the sample and for the reduction solutions with known concentration of phosphate.

Soluble potassium was determined by 5 ml of extracted soil and was transferred to a 15 ml plastic tube where 5 ml diluted cesium chloride was added. Potassium was measured by atomic absorption on a wavelength at 766.5, alternatively 769.9 nm in an acetylene/air flame.

Soluble magnesium and calcium were determined by 5 ml of extracted soil and was transferred to 15 ml plastic tube with 5 ml diluted strontium chloride solution. Magnesium and calcium were measured by atomic absorption at a wavelength of 285.2 or alternatively 202.6 for Mg and 423.1 nm for Ca, in acetylene – air flame in degrees of absorption or concentration for reference solutions.

2. 4. Statistical Analysis

All the data first entered in Excel and loaded in MINI TAB program 7.1. As soil variables, Volume weight (Vw), pH, Phosphorus (P), Potassium (K), Calcium (Ca) and Loss of Ignition (Loi) has taken as dependent variables. Pearson Correlation and Multiple Regression analysis were done from MINI TAB. The p-value was used to estimate the significances correlation and significant difference among different soil variables along altitude and aspects. Data used in the correlation and regression is not transformed. This analysis helps to understand how the typical value of dependent variables changed with independent variables like altitude and aspects.

All the data were Log10 transformed, normally distributed and the sample size is not equal as well as homogeneity can be seen in the variance, So, One –Way ANOVA test was performed to do the pairwise comparison of both mountains by Tukey's method that adjusts the confidence level for each individual interval. This test gives an assumption that statistically, significant difference might have existed in some of our groups. The null hypothesis (H_0) was set to analyze that there is no significant difference in the mean value of soil variables. All the decision was made based on the p- values. In the ANOVA analyses, only altitudes from 1100 to 1550m were used to have equal number of samples.

Principal Component Analysis (PCA) was performed on the soil variables of two mountains in both aspects as data were linearly related to each other. Eigenvalue was used to explain the amount of variation explained by the axis.

3. Results

3.1. Variation in soil variables along altitudinal gradient in Sikilsdalen

Sikilsdalen south facing slope (SDSV)

Pearson correlation analysis was carried out to analyze relationships between soil variables and altitude. It was found that Vw showed a strong negative significant relationship with K, Loi, Ca, Mg, and P **(P- values<0.05).** pH showed no correlation with any nutrients variables. P showed the significant correlation with K and Ca. There was a strong positive correlation among soil nutrients variables like; Mg, Ca, Loi, and K. When the nutrients variables were correlated with altitude, the only P showed strong but negative correlation with altitude. So it can be said that the only P showed the significant difference **(P- value<0.05)** along with an altitudinal gradient in the south facing slope of Sikilsdalen. All significant p-value are indicated in bold number in Table 1.

Table 1. Pearson correlations between the variables from SDSV, based on not transformed data.

	Altitude	Vw	pH	P	K	Mg	Ca
Vw	0,132						
	0,547						
pH	-0,015	0,303					
	0,946	0,160					
P	-0,507	-0,432	-0,356				
	0,014	**0,039**	0,095				
K	-0,262	-0,845	-0,221	0,561			
	0,228	**0,000**	0,310	**0,005**			
Mg	-0,322	-0,641	0,272	0,409	0,752		
	0,134	**0,001**	0,209	0,053	**0,000**		
Ca	-0,174	-0,721	0,191	0,430	0,853	0,898	
	0,428	**0,000**	0,381	**0,041**	**0,000**	**0,000**	
Loi	0,251	-0,831	-0,144	0,231	0,795	0,617	0,779
	0,247	**0,000**	0,511	0,289	**0,000**	**0,002**	**0,000**

Results from regression analysis found that Vw, pH, K, Mg, Ca and Loi did not show the significant difference in altitude**,** whereas P showed the significant difference in altitude **(p-value = 0.014)** (Annex I, Table II). The graph in Figure 6 showed the relationship between the soil variables and altitudinal gradient.

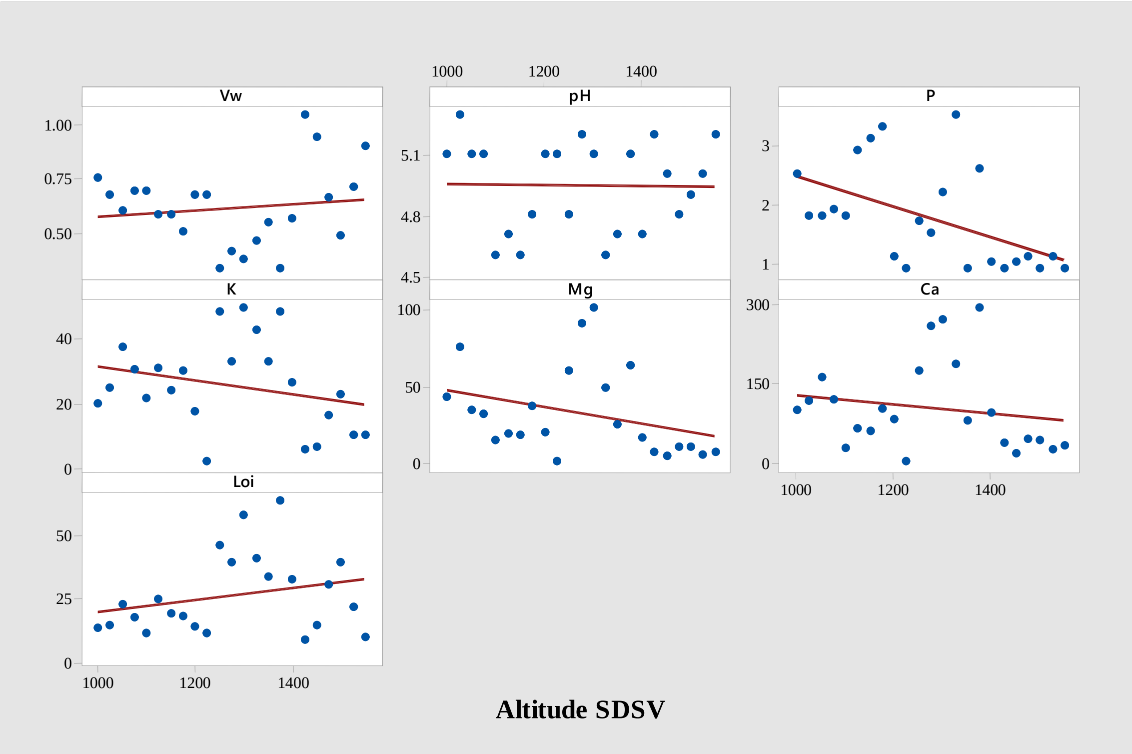

Figure 6. Regression analysis of soil variables along altitude in SDSV

Sikilsdalen north-facing slope (SDNV)

Pearson correlation analyses found that Vw has a strong but negative correlation with other soil variables except for pH. pH showed no correlation with any soil nutrients. There was a strong positive correlation in between P, K, Mg, Ca and Loi. When correlations were studied along altitude gradient, only Mg and P showed strong negative significant correlation with altitude (Table 2). From the regression analysis, it was found that only K, Mg and Ca showed the significant difference with altitude in north facing slope. The significant relationship can be seen in Figure 7 and for P-value refer (Annex I, Table II).

Table 2. Pearson correlations between the variables from SDNV, based on not transformed data. Sianificant correlations are indicated in bold numbers.

	Altitude	Vw	pH	P	K	Mg	Ca
Vw	0,093						
	0,674						
pH	-0,036	0,297					
	0,872	0,169					
P	-0,519	-0,440	-0,338				
	0,011	**0,036**	0,115				
K	-0,298	-0,800	-0,288	0,589			
	0,167	**0,000**	0,182	**0,003**			
Mg	-0,437	-0,678	0,090	0,571	0,864		
	0,037	**0,000**	0,682	**0,004**	**0,000**		
Ca	-0,254	-0,646	0,042	0,512	0,899	0,934	
	0,241	**0,001**	0,848	**0,012**	**0,000**	**0,000**	
Loi	0,247	-0,870	-0,248	0,248	0,736	0,572	0,645
	0,256	**0,000**	0,254	0,253	**0,000**	**0,004**	**0,001**

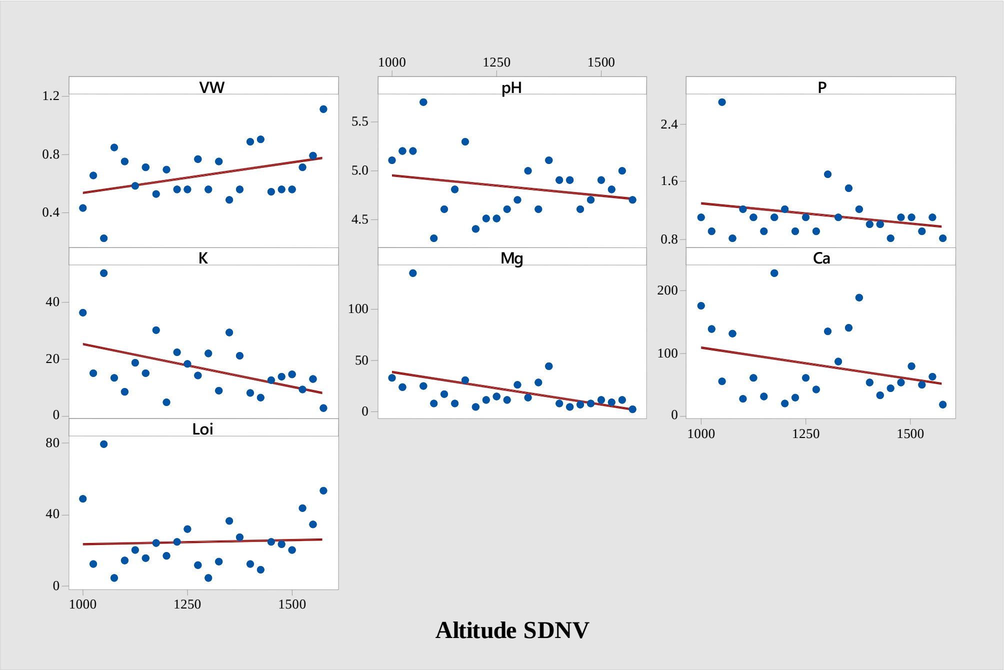

Figure 7. Regression analysis of soil variables along altitude in SDNV

3.2. Change in soil variables content in SDSV

Transformed data was used to analyzed the changing trend of each variable along different altitude in the south facing slope, volume weight of soil was found to be more in the elevation 1000m and less in the elevation 1250 (0.33 g/cm^3). pH lied between 4.6 and 5.3 along the whole altitude. Phosphorus was high in 1325m and decreased with increased elevation. It was found to be high between 1250m to 1375m (49.2 mg/100gm). Similarly, Magnesium was found to be high in between 1275 to 1375, maximum at 1300 (101mg/100gm) and very low at the 1525 (4.3 mg/100gm). Calcium was found to be higher in 1375 (291.5 mg/100gm) and low in 1525 (22.6 mg/100gm). K followed the same trend, maximum at the 1300 (49.2 mg/100gm) and decreased along increased altitude. Loi was found to be high in between 1250 to 1450 m. The highest value observed for Loi was 63.88 at 1375m and it decreased with increasing altitude. It was clearly visible from the Figure 8 that there was an increasing trend of soil variables up to the mid-altitude and started to decrease continuously from 1525m. In an altitude 1225m, all the values of soil variables were very low this was due to the steep slope and hard boulder rock was there where plant distribution and soil cover was very less.

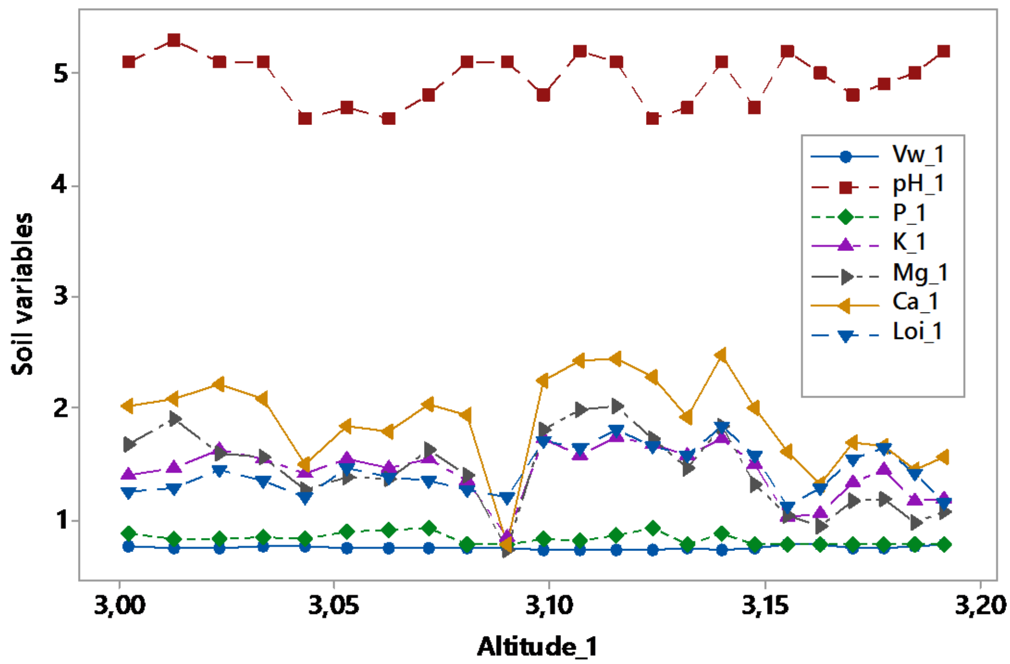

Figure 8. Soil data variation along the altitudinal gradient in SDSV (transformed data)

3.3. Change in soil variables content in SDNV

Volume weight is evenly distributed and found to be more in the mid-altitude; maximum Vw found was 0.90 mg/100gm. pH was in between 4.3 to 5 in the whole southern slope. Phosphorus values ranged from 1 to 1.7 over the whole elevation; with maximum value of 2.7 mg/100gm at 1050 m. Potassium was high in the mid-altitude (1050= 50.1 mg/100 gm) and gradually decreased from the mid-altitude towards the upper elevation. Magnesium was high at 1050 m (131.2 mg/100gm) and decreased gradually towards the higher altitude. Maximum value observed in Calcium was 131.2 mg/100gm at 1050 and gradually decreased with increasing altitude. There was not more difference Loi along the whole transect except in the uppermost region. The highest value was observed in 1050m which was 79.07 mg/100 gm.

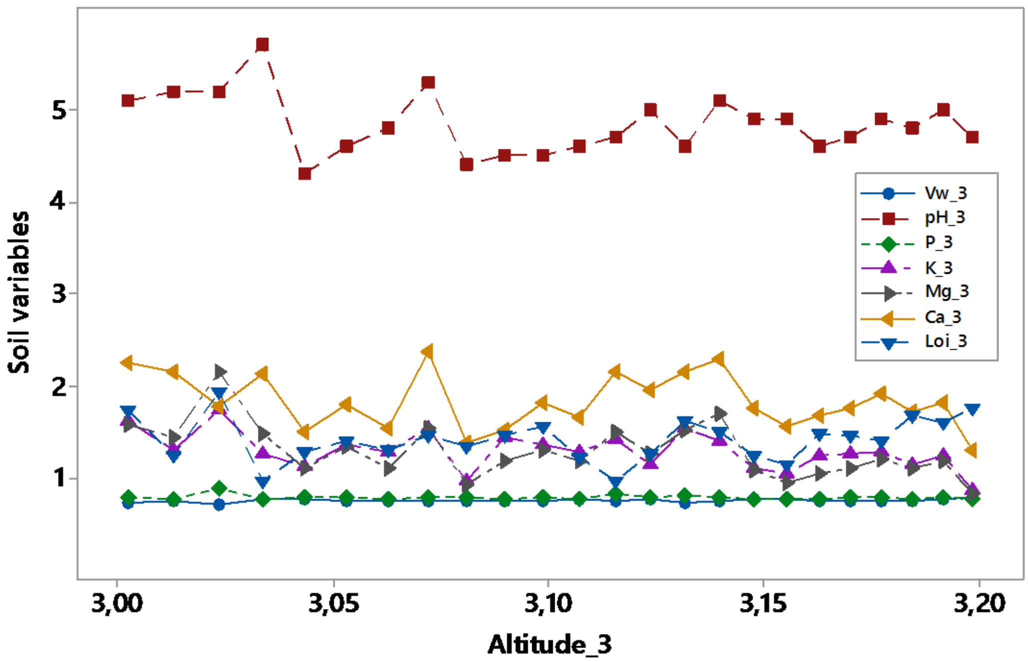

Figure 9. Soil data variation along the altitudinal gradient in SDNV (transformed data).

3.4. Variation in soil variables along altitudinal gradient in Heimdalen

Heimdalen north facing slope (HDNV)

The result from correlation analyses showed that there was a strong negative correlation between Vw and P, K, Mg, Ca as **p-value < 0.05.** There was a moderate positive correlation between P, K, and Mg. The strong positive correlation was found between K, Mg and Ca. The analyses along altitudinal gradient found that Vw showed positive significant moderate correlation and Ca showed negative significant moderate correlation. Other variables had no correlation with altitude (Table 3). Loi showed no correlation with altitude and other soil variables.

Regression analysis found that Vw, K, Mg, and Ca showed the significant difference with altitude **(p -value<0.05)** (Annex I, Table III). The graph in Figure 10 also showed the clear analysis among soil variables along the altitude.

Table 3. Pearson correlations between the variables from HDNV, based on not transformed data. Significant correlations are indicated in bold numbers.

	Altitude	Vw	pH	P	K	Mg	Ca
Vw	0,543 **0,016**						
pH	0,262 0,278	0,240 0,323					
P	-0,381 0,107	-0,505 **0,027**	-0,437 0,061				
K	-0,594 0,007	-0,774 **0,000**	-0,250 0,302	0,566 **0,011**			
Mg	-0,556 0,013	-0,802 **0,000**	0,036 0,882	0,562 **0,012**	0,824 **0,000**		
Ca	-0,474 **0,040**	-0,740 **0,000**	0,241 0,320	0,387 0,102	0,750 **0,000**	0,968 **0,000**	
Loi	-0,214 0,378	0,022 0,929	0,112 0,649	0,099 0,688	0,098 0,691	0,163 0,505	0,137 0,576

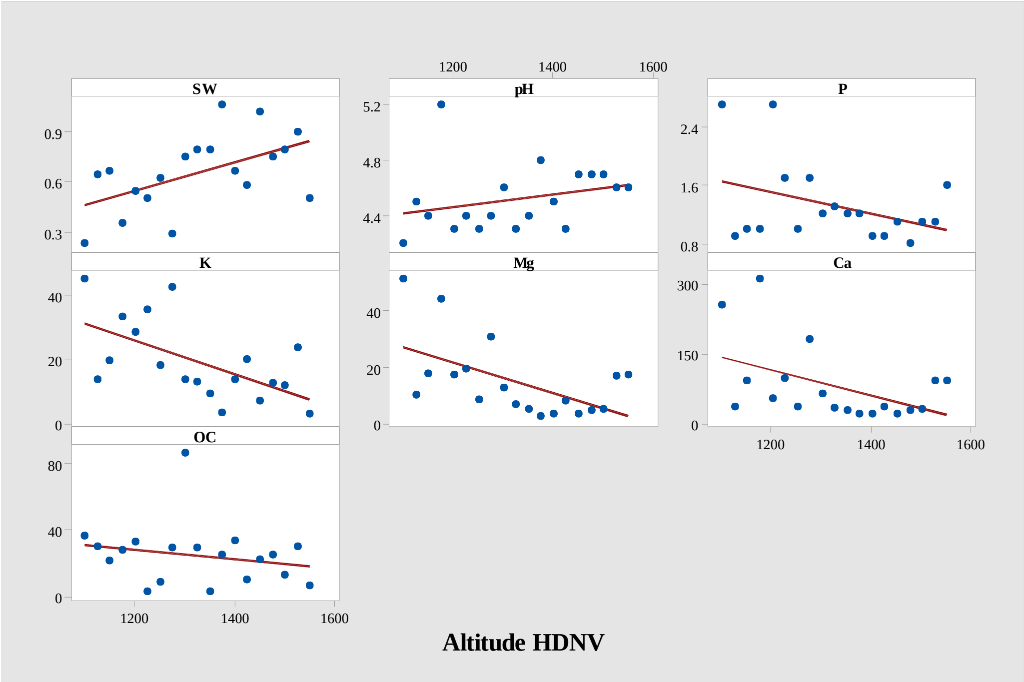

Figure 10. Regression analyses of soil variables along altitude in HDNV

Heimdalen south facing slope (HDSV)

In this northern slope of Heimdalen, Vw with P, pH with P, K with Mg and Mg with Ca showed the significant moderate correlation with each other. P showed the negative significant correlation with Vw and pH **as P- value (<0.05)**. In south facing slope only Vw among all other soil variables showed significant correlation with altitude as **p-value = 0.042** (Table 4). Regression analysis showed no any significant difference between soil variables and altitude (Figure 11 and Annex I, Table IV)

Table 4. Pearson correlations between the variables from HDSV, based on not transformed data. Significant correlations are indicated in bold numbers

	Altitude	Vw	pH	P	K	Mg	Ca
Vw	0,470						
	0,042						
pH	0,406	0,367					
	0,084	0,122					
P	- 0,229	-0,495	-0,620				
	0,345	**0,031**	**0,005**				
K	-0,438	-0,115	-0,088	-0,029			
	0,061	0,638	0,721	0,907			
Mg	-0,363	-0,169	0,217	0,071	0,550		
	0,127	0,488	0,372	0,774	**0,015**		
Ca	-0,204	-0,523	0,370	0,167	0,095	0,573	
	0,402	0,021	0,119	0,494	0,699	**0,010**	
Loi	-0,071	0,218	0,327	-0,353	-0,060	0,117	-0,122
	0,772	0,369	0,172	0,139	0,807	0,632	0.619

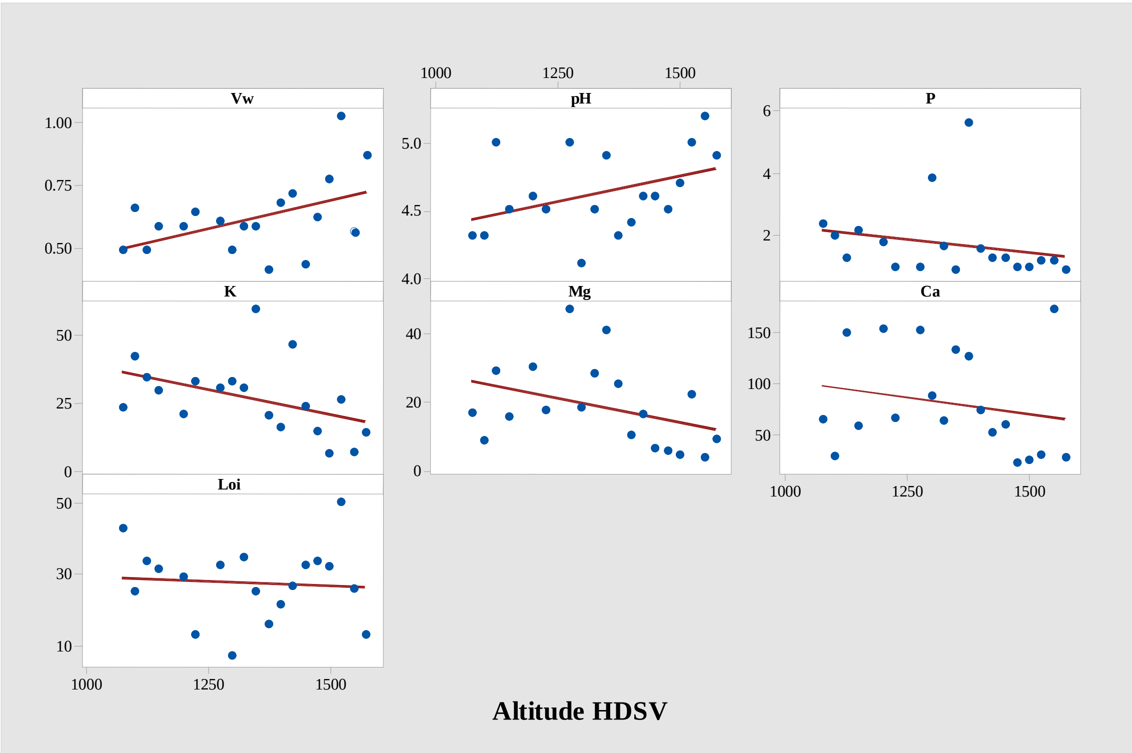

Figure 11. Regression analysis of soil variables along altitude in HDNV

3.5. Change in soil variables content in HDNV

Vw was same along the whole transect. pH was found in the range of 4.2 to 4.5. P was found in the range between 0.8 to 2.7 mg/100 gm and the highest value was observed in the lower altitude (1100m) but in an average distribution was found to be equal in all regions. K was found highest in the lower transect which was 45.2 (1100 m) and decreases along the upper transect, where the lowest value observed was 2.7mg/100gm at 1550 m. Mg showed the similar distribution where highest value observed was 51.1mg/100gm at 1100 m and lowest was 2.4mg/100gm at 1350 m from where the value decreased with altitude. Ca was high up to 1275m from 1100m where the highest value observed was 311.21mg/100gm in 1175 and gradually decreases with altitude. Loi was found to be high in between 1100 to 1350m where highest value observed was 86.48 mg/100gm at 1300 m. From the Figure 12, it showed the clear trend that all the soil variables were high on the lower altitude (1100m to 1275m).

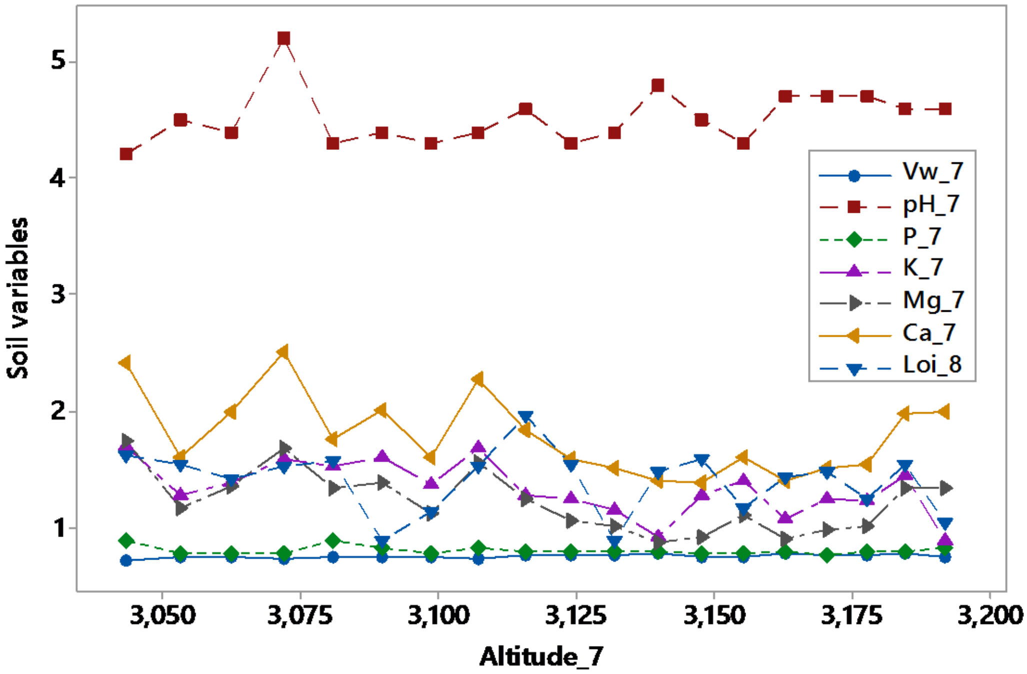

Figure 12. Soil data variation along the altitudinal gradient in HDNV (transformed data).

3.6. Change in Soil variables content along HDSV

Vw was almost same in lower altitude but in the upper altitude, the values were found to be slightly higher. pH was in the range between 4.1 to 5.2 along altitude. P was found high at the altitude 1300 to 1375m, where maximum value observed was 5.6 mg/100gm at 1375m, but there was not much change in the value along the whole transect. K was found to be less in lower and highest region but in middle region highest values observed was 59.3mg/100gm at 1350m and lowest was 5.8mg/100g at 1500m. A similar trend of change was found on all soil variables except Ca, where it was found slightly higher at 1550m (170.8 mg/100gm), and lower at 1575m (26.4mg/100gm). Loi was 42.82 mg/100gm which was the highest value observed at 1075m and decreased along with increasing altitude.

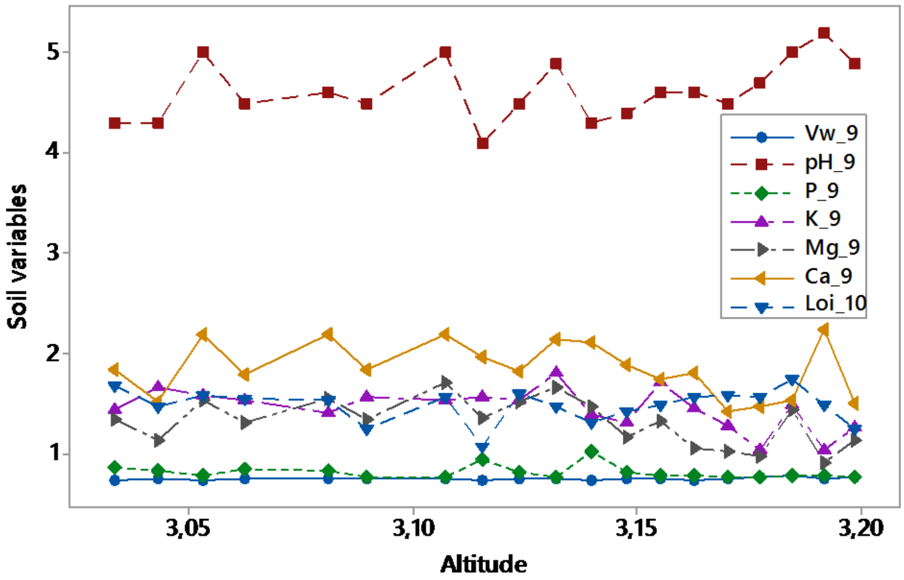

Figure 13. Soil data variation along the altitudinal gradient in HDSV (transformed data).

3.7. Pairwise comparison of change in means of soil variables in between two mountain by ANOVA Test

From the analysis, it was found that pH and K showed the significant mean difference and Null hypothesis (H_0) was rejected here as a **P value<0.05 (pH= 0.000 and K= 0.051)** (Table 5). Mean difference was seen only in the south facing slope of Sikilsdalen and Heimdalen. There was found no mean difference in any other soil variables on both aspects of two mountains (Table 5). Pairwise comparison graph of 4 factors (SS, SN, HN and HS) in Figure 14 also showed no any change in the interval and means of both south and north-facing slope in two mountains.

Table 5. Mean Analysis from ANOVA in tabulated form (1= SS, 2= SN, 3= HN, 4=HS)

Variables	Factor	N	Mean	St. Dev	95%CI	P-value
Vw	1	19	0,74806	0,01539	(0.74175; 0,75437)	0.731
	2	19	0,75234	0,00977	(0,74603; 0,75865)	
	3	19	0,75197	0,01724	(0,74566; 0,75828)	
	4	19	0,74927	0,01147	(0,74296; 0,75558)	
pH	1	19	4,9053	0,2198	(4,7888; 5,0217)	**0.000**
	2	19	4,7474	0,2547	(4,6310; 4,8638)	
	3	19	4,5211	0,2371	(4,4046; 4,6375)	
	4	19	4,6263	0,2997	(4,5099; 4,7427)	
P	1	19	0,8227	0,0577	(0,8006; 0,8448)	0.071
	2	19	0,78508	0,01489	(0,76296; 0,80721)	
	3	19	0,79935	0,03562	(0,77723; 0,82147)	
	4	19	0,8179	0,0673	(0,7958; 0,8400)	
K	1	19	1,4139	0,2580	(1,3153; 1,5126)	**0.051**
	2	19	1,2743	0,1591	(1,1756; 1,3730)	
	3	19	1,3295	0,2307	(1,2308; 1,4281)	
	4	19	1,4549	0,2028	(1,3563; 1,5536)	
Mg	1	19	1,3845	0,3691	(1,2591; 1,5098)	0.212
	2	19	1,2296	0,2063	(1,1043; 1,3550)	
	3	19	1,2183	0,2583	(1,0929; 1,3437)	
	4	19	1,3139	0,2347	(1,1885; 1,4393)	
Ca	1	19	1,8384	0,4349	(1,6839; 1,9929)	0.921
	2	19	1,8080	0,2753	(1,6535; 1,9625)	
	3	19	1,7844	0,3417	(1,6299; 1,9389)	
	4	19	1,8528	0,2736	(1,6983; 2,0073)	
Loi	1	19	1,4653	0,2220	(1,3677; 1,5630)	0.412
	2	19	1,3872	0.1780	(1,2896; 1,4848)	
	3	19	1,3988	0.2721	(1,3011; 1,4964)	
	4	19	1,4846	0,1650	(1,3870; 1,5822)	

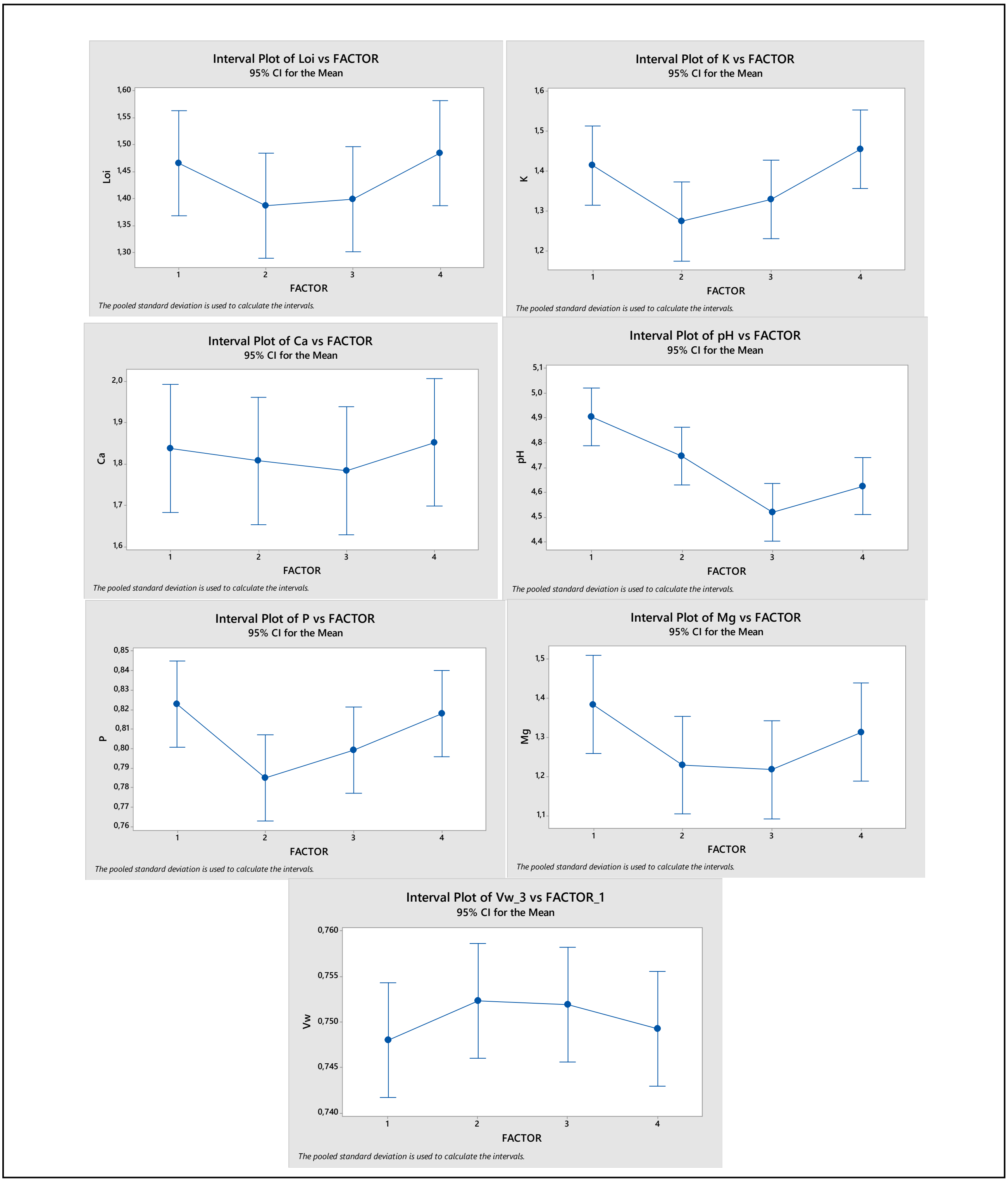

Figure 14. Pairwise mean comparison in both aspect of Sikilsdalen and Heimdalen by One- Way ANOVA test. In the above graph, 1= SS (south-facing slope of Sikilsdalen), 2= SN (north-facing slope of Sikildalne), 3= HN (north-facing slope of Heimdalen, 4=HS (south-facing slope of Heimdalen). CI is confidence interval.

3.8. Multivariate Statistical Analysis

PCA analysis was carried out and interpreted on the basis of obtained eigenvalue which explained the amount of variation by Axis. Axis 1 and Axis 2 had high eigenvalue; 7.5984 and 6.0096 respectively in the whole datasets. Other Axis 3 and 4 described less correlation among variables as eigenvalue was found to be very less, so it was not explained in the result. Axis 1 was best positively correlated to K in SS, Mg in SN, Loi in HN and Mg in HS. Axis 2 was best negatively correlated to altitude and pH in SS and SN respectively whereas in the case of Heimdalen, Axis 2 was best positively correlated to K in HN and best negatively correlated to Vw in HS (Table 6).

The result from a PCA analysis of data from the two transects in Sikilsdalen (Fig. 15) and Heimdalen (Fig. 16), found that the first component was correlated with altitude. Vw in both slopes increased with altitude and most other soil variables decreased with altitude. The effect of Loi was smaller in Heimdalen compared to Sikilsdalen

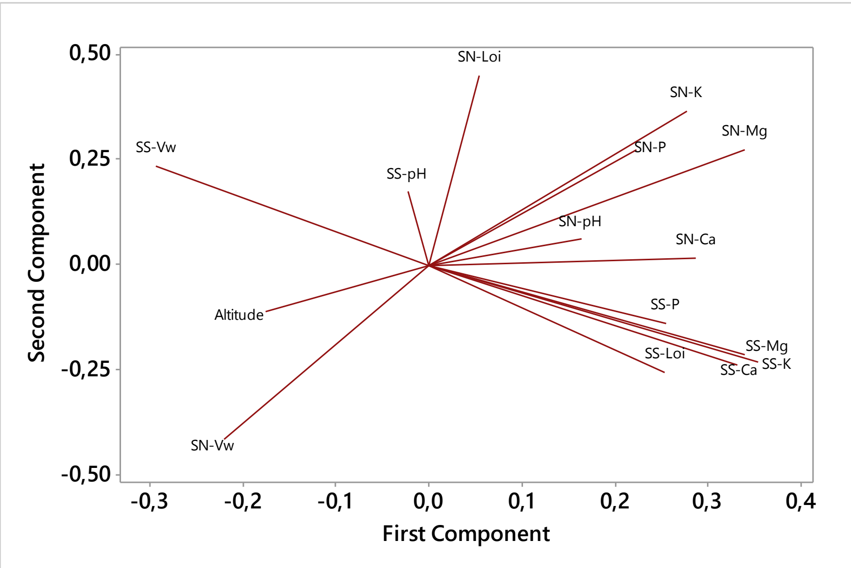

Figure 15. PCA ordination diagram of soil variables along the altitudinal gradient in Sikilsdalen, SS =south-facing slope, SN=north-facing slope. The direction of variation in most soil variables indicates an effect of aspect, with highest scores along Component 2 for the SN-plots.

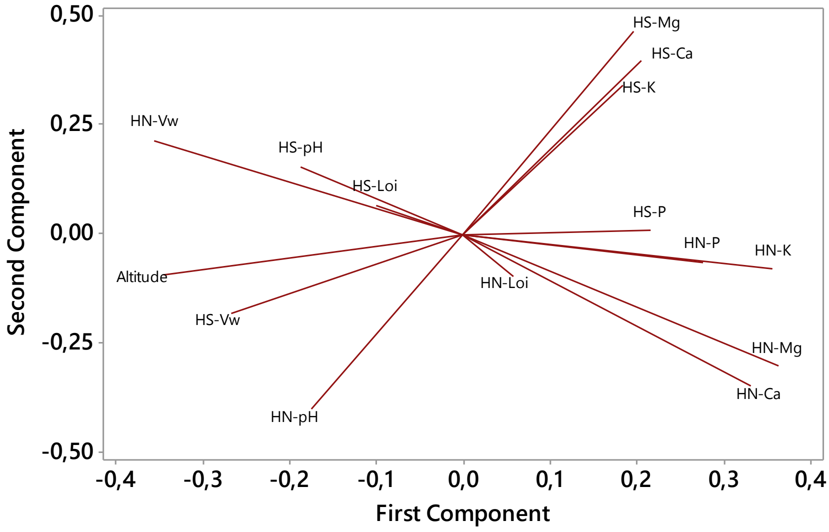

Figure 16.The result of a PCA analysis of soil variables along the altitudinal gradient in Heimdalen HS=south-facing slope, HN=north-facing slope. The direction of variation in most soil variables indicates also in this valley an effect of aspect, with highest scores along Component 2 for the HS-plots.

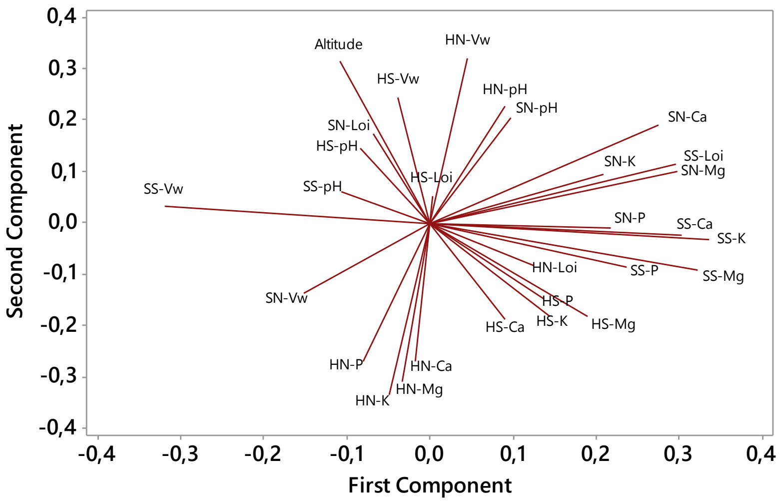

Figure 17. The result of a PCA analysis of soil variables along the altitudinal gradient in both Heimdalen and Sikilsdalen in both south-north slope The diagram also indicates a different direction of variation in P, K, Mg and Ca values between the HN and HS plots.

The result from a PCA analysis of data from the four two transects in both valleys is shown in Fig.17. The first component was best explained by high Vw values (in the SS slope) in the left part of the diagram and most other variables in the right part. Component 2 is correlated with increasing altitude toward the upper part of the diagram, and increasing P-values in the lower part. pH increased with altitude in both valleys, but with different directions in Sikilsdalen and Heimdalen. The tendency was the same also between the SN and SS plots.

Table 6. Correlation Matrix by PCA analysis

Site	Variables	PC1	PC2	PC3	PC4
	Altitude	-0,109	**-0,314**	0,060	-0,090
SS	Vw	-0,320	-0,033	-0,038	0,039
	pH	-0,107	-0,060	-0,137	-0,097
	P	0,237	0,085	0,053	0,325
	K	**0,336**	0,032	0,126	O,007
	Mg	0,323	0,092	0,078	-0,027
	Ca	0,303	0,024	0,159	-0,023
	Loi	0,297	-0,113	0,137	-0,124
SN	Vw	-0,151	0,136	0,270	0,092
	pH	0,097	**-0,205**	-0,027	0,356
	P	0,217	0,009	-0,026	-0,176
	K	0,209	-0,093	-0,372	-0,020
	Mg	**0,298**	-0,101	-0,243	-0,009
	Ca	0,275	-0,189	-0,174	0,093
	Loi	-0,069	-0,173	-0,259	-0,125
HN	Vw	0,045	-0,321	0,163	-0,147
	pH	0,091	-0,227	-0,259	0,357
	P	-0,080	0,269	-0,058	-0,126
	K	-0,048	**0,334**	-0,062	0,118
	Mg	-0,033	0,310	-0,238	0,250
	Ca	-0,018	0,268	-0,276	0,290
	Loi	**0,125**	0,083	0,205	0,294
HS	Vw	-0,038	**-0,245**	0,038	0,159
	pH	-0,084	-0,145	0,243	0,152
	P	0,137	0,149	-0,258	-0,295
	K	0,145	0,182	0,168	0,062
	Mg	**0,190**	0,183	0,167	-0,140
	Ca	0,091	0,188	0,117	-0,184
	Loi	0,003	-0,053	0,257	0,251

	PC1	PC2	PC3	PC4
Eigenvalue:	7, 5984	6, 0096	3, 1560	2.3955
Proportion:	0,262	0,207	0,109	0.083
Cumulative:	0,262	0,469	0,578	0.661

4. Discussion

4.1. Significant comparison between soil variables in two mountains

4.1.1. Soil nutrients variation along altitudinal gradient of Sikilsdalen

In both north and south facing slopes of Sikilsdalen, there is a significant correlation between volume weight and soil nutrients but in the negative direction. It can be assumed that that there is more sandy soil and then the fine soil which results in low minerals composition in soil. Since the specific surface of sand is no more than 1 or 2 m^2/g and types of soil is determined by the density of soil. P shows the significant difference with altitude in the south-facing slope while in the north-facing slope P and Mg showed the significant difference in altitude is due to weathering of igneous rocks which is rich in calcium and phosphate (Nordhagen, 1943). pH of the soil is in between 4.3 to 5.7 in a whole transects and do not show any significant correlation and difference along an altitudinal gradient. The results of lower pH in the study area support the statement given by Oulehle et al., (2007), that acidic nature of soil causes depletion exchangeable base cations. The acidification of soil is also due to deficiency of phosphorus and important bases in soil (Ndakidemi and Semoka, 2006). As the amount of all nutrients variability in particular soil is detected by the soil organic content (Agboola and Corey, 1973), high amount of organic carbon in mid-altitude (1375m) of the study area, results in high soil variables. Loi in the study area are significantly correlated with P, K, Mg, and Ca. At the higher altitude, there is less forest and dominated by grasses and dumpy plants which also strongly support the statement given by Liptzin and Seastedt (2009) that the exchangeable base cations; Ca, Mg, K are higher at the forest area. As the soil properties depend on the parent materials and topography of particular area (Sencindiver et al., 2015), lower values of soil variables at the altitude 1225 meters are due to the presence of hard rock and steep slope which results in the low amount of soil and ultimately the low nutrients variables.

4.1.2. Soil nutrients variation along altitudinal gradient in Heimdalen

In Heimdalen, all the variation in soil variables is greatly affected by erosion and leaching due to less vegetation, wind, and precipitation (Grøterud and Kloster, 1978). In the north-facing slope, all the soil variables are significantly positively correlated with each other except pH. Vw increases and Ca decreases with altitude. Vw, K, Mg, and Ca are significantly different along altitude in north-facing slope. Since Vw is negatively correlated with all soil variables except Ph and Loi, there is altitude in both slopes. Increasing in volume weight and decreasing in soil nutrients along altitudinal gradient also support the study carried out by Odland and Munkejord (2008) in Southern Norway. In Heimdalen, there is an increase in pH and decrease in Loi i.e. soil carbon which strongly supports the statement given by Cox and Whelan (2000) that pH decreases with the age of soil, so earlier developed soils are acidic in nature. Organic matter in low alpine is five times more than in the high alpine belt which shows the decreasing trend along increasing altitude explained by Stützer (1999) from the study in belt of Rondane Mountain of South Norway. In the south facing slope, Vw, P and pH have significant correlation and Ca, K and Mg are also significantly correlated with each other. None of the soil variables in south-facing slope show the significant difference in altitude. The values of soil variables are found more in higher altitude (1375m) in south-facing slope in compare to north- facing slope (1100m), as the tree line limits in south-facing slope is higher than the north-facing slope (Østhagen and Egelie, 1978). According to Young (1976); cited by Laurance et al., (1999), the acidity of the soil is the main factor to declining the phosphate in the soil when the pH of the soil is below 5.5. As the soil is acidic in the study area, we can say that there is also depletion of other soil variables along increasing altitude.

4.2. Comparison of soil nutrients variation in northern and southern slope.

Treeline of the northern slope is in the higher altitude than southern slope so the plant distribution is more on the northern slope than the southern slope. In the northern slope, there is more soil moisture, water content, moderate temperature, infiltration rate of soil is high and the area is shaded from direct sunlight, which ultimately provides the favorable condition to increase soil organic carbon (Boix-Fayos et al., 1998). There is no erosion and leaching activity in northern slope due to more plants cover.

In both slopes of two mountains, all the soil nutrients are decreasing along altitudinal gradient and volume weight is increasing. The northern slopes receive more snow because of this the water availability and moisture are high in the soil which helps to support trees and plants on the slopes. All the soil nutrients are high in the lower altitude in both mountain slopes, detected by the amount of soil organic matter which is also low in downhill slopes (Agboola and Corey, 1973).

Phosphorus shows the significant correlation and difference along altitude in the northern slope of Sikilsdalen which may be due to the reason that phosphate in the soil if remain for a long time, it penetrated into the soil particles and will recover slowly after the surface activity brings on (Barrow, 1983). The effect of Loi found smaller in Heimdalen compared to Sikilsdalen which may be due to more vegetation cover in Sikilsdalen. Deficiency of phosphorus and important bases in the soil explains the acidic condition of soil (Oulehle et al., 2007; Ndakidemi et al., 2006).

On the northern hillside of Sikilsdalen, the main rock is nutritious and provides good breeding to the vegetation which riches in calcium and phosphate as a result of weathering of igneous rocks (Nordhagen, 1943). Therefore aspect effect is less in both northern and southern slope of Sikilsdalen due to more vegetation. In the case of Heimdalen Vw increases along altitude in both slopes and due to no good vegetation cover none of the soil variables shows the significant difference in the altitude in the northern slope. There is the increasing tendency in pH with altitude in both valleys, but with different directions in Sikilsdalen and Heimdalen.

5. Conclusion

This is a primary study on the variation in soil variables along altitude and aspect of two mountains, situated in the Southeast Norway. Both mountains are very close to each other. The south-facing slope is the northern slope and north-facing slope is the southern slope of the mountain. The origin and structure of parent materials are seem to be same in both mountains. Volume weight, Phosphorus, Magnesium, and Calcium showed the significant correlation with altitude and these variables also showed significant difference in the altitude. All the soil variables are positively correlated to each other except pH. In Sikilsdalen, pH shows the positive correlation along altitude and in Heimdal, it shows the negative correlation along the altitude. In both north and south-facing slope of Sikilsdalen, pH shows the negative correlation with Loi. There is a decrease in soil carbon in both aspects of Heimdalen due to more erosion and leaching of soil materials. The effect of Loi is smaller in Heimdalen compared to Sikilsdalen. In both slopes of two mountains, all the soil nutrients are decreasing along altitudinal gradient and volume weight is increasing. In the southern slope, the direction of variation in most soil variables indicates the effect of aspect. Most of the soil variables show more significant difference along altitude in southern slope in compare to the northern slope. pH increased with altitude in both valleys, but with different directions in Sikilsdalen and Heimdalen. pH has no significant correlation with altitude and aspect but its acidic condition in soil has brought the variation along altitude. Organic Carbon (Loi) is also more explained on the basis of plant cover and soil pH. The pairwise comparison of all soil variables of both mountains brings the difference only in average pH which is due unequal distribution of plant cover.

There is not much difference in soil variables of both northern and southern slopes which have explained on the basis of plant cover and tree line limits that bring the variation on soil variables. The small variation in the soil variables is also due to closer sample plots. Mineral composition of parent rock and climate is assumed to be same on both slopes. Further research is required on the major climatic factors like; precipitation and temperature and geology of rocks along the parent's materials. It is also necessary to study the ionic chemistry of water sources associated with two mountains which give the physical and chemical characteristics of the soil of that particular areas.

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Annexs I

Table I. Regression analysis along altitude in Sikilsdalen South face (SDSV)

Altitude	Variables	Equation	R2	P- value
SDSV	Vw	Vw = 0.4308 + 0.000145*A	1.8	0.547
	pH	pH = 4.973 – 0.000020 * A	0.0	0.946
	P	P = 5.027 – 0.002565 *A	25.7	0.014
	K	K = 52.67 – 0.02131*A	6.8	0.228
	Mg	Mg = 101.9 – 0.05483 * A	10.4	0.134
	Ca	Ca = 212.5 – 0.0860 * A	3.0	0.428
	Loi	Loi = - 3.61 + 0.02323*A	6.3	0.247

Table II. Regression analysis along altitude in Sikilsdalen North face (SDNV)

Altitude	Variable	Equation	R2	P- value
SDNV	Vw	Vw = 0.1100 + 0.000423 *A	16.3	0.051
	pH	pH = 5.377 – 0.000419 * A	5.2	0.283
	P	P = 1.877 – 0.000577 * A	6.7	0.222
	K	K = 55.53 – 0.03013 * A	24.0	0.015
	Mg	Mg = 102.0 – 0.06352 * A	17.5	0.042
	Ca	Ca = 438.7 – 0.2627 * A	17.3	0.043
	Loi	Loi = 19.56+0.00427*A	0.2	0.840

Table III. Regression analysis along altitude in Heimdalen north-facing slope (HDNV)

Altitude	Variable	Equation	R2	P- value
HDNV	Vw	Vw= - 0.4904 + 0.000863*A	29.5	0.016
	Ph	pH = 3.935 + 0.000442 * A	6.9	0.278
	P	P = 3.302 - 0.001495 * A	14.5	0.107
	K	K= 89.11 - 0.05271 * A	35.3	0.007
	Mg	Mg = 86.26 - 0.05392 * A	30.9	0.013
	Ca	Ca = 448.5 - 0.2782 * A	22.5	0.040
	Loi	Loi = 62.14-0.02820*A	4.6	0.378

Table IV. Regression analysis along altitude in Heimdalen south face (HDSV)

Altitude	Variable	Equation	R2	P- value
HDSV	Vw	Vw = 0,0196 + 0,000446	22.1	0.042
	pH	pH = 3.598+0.000768 * A	16.5	0.084
	P	P = 3.982 – 0.001738 * A	5.3	0.345
	K	K= 75.91 – 0.03708 * A	19.2	0.061
	Mg	Mg = 56.46 – 0.02836 * A	13.1	0.127
	Ca	Ca = 166.2 – 0.06443 * A	4.2	0.402
	Loi	Loi = 33.80- 0.00476*A	0.5	0.772

Table V. Results summery of lab data of Sikilsdalen north-facing slope

Sikilsdalen north-facing slope (SDNV)								
No.	Altitude	Vw	pH	P	K	Mg	Ca	Loi
1	1000	0.43	5.1	1.1	36.1	32.7	176.1	48.57
2	1025	0.66	5.2	0.9	14.6	23.1	138	12.12
3	1050	0.21	5.2	2.7	50.1	135.6	545	79.07
4	1075	0.85	5.7	0.8	13	25.1	131.2	4.25
5	1100	0.75	4.3	1.2	8.2	7.8	26.4	14.28
6	1125	0.58	4.6	1.1	18.3	17.1	58.7	20.00
7	1150	0.71	4.8	0.9	14.5	7.8	29.8	15.27
8	1175	0.52	5.3	1.1	29.8	29.9	228.3	23.63
9	1200	0.69	4.4	1.2	4.4	3.5	18.8	16.76
10	1225	0.56	4.5	0.9	22.1	10.5	27.7	24.19
11	1250	0.56	4.5	1.1	17.8	14.7	59.3	31.61
12	1275	0.77	4.6	0.9	14	10.4	41.3	11.51
13	1300	0.56	4.7	1.7	21.9	26.2	134.5	4.37
14	1325	0.75	5	1.1	8.7	12.9	85.3	13.24
15	1350	0.48	4.6	1.5	29.2	28.5	139.8	36.25
16	1375	0.56	5.1	1.2	20.7	43.7	189.3	26.97
17	1400	0.89	4.9	1	7.9	7.4	52.3	12.22
18	1425	0.90	4.9	1	6	4	31.7	8.85
19	1450	0.54	4.6	0.8	12.3	6.2	43.2	24.68
20	1475	0.56	4.7	1.1	13.4	7.6	51.9	23.20
21	1500	0.56	4.9	1.1	14.4	10.8	78.2	19.76
22	1525	0.71	4.8	0.9	9	8	48	43.24
2	1550	0.79	5	1.1	12.8	10.5	61.3	34.37
24	1575	1.11	4.7	0.8	2.3	1.7	15.5	53.12

Table VI. Results summery of lab data of Sikilsdalen south-facing slope

Sikilsdalen south-facing slope (SDSV)								
No.	Altitude	Vw	pH	P	K	Mg	Ca	Loi
1	1000	0.75	5.1	2.5	19.8	42.3	98.8	13.16
2	1025	0.67	5.3	1.8	24.5	75	115.3	14.28
3	1050	0.60	5.1	1.8	37.1	34	160.8	22.50
4	1075	0.69	5.1	1.9	30.3	31.8	117.3	17.02
5	1100	0.69	4.6	1.8	21.3	13.8	26.7	11.11
6	1125	0.58	4.7	2.9	30.7	18.8	63.3	24.32
7	1150	0.58	4.6	3.1	23.9	17.8	56.9	18.92
8	1175	0.50	4.8	3.3	30	36.9	101.5	17.50
9	1200	0.67	5.1	1.1	17.1	19.7	81.6	13.33
10	1225	0.67	5.1	0.9	1.9	0.4	0.9	11.11
11	1250	0.33	4.8	1.7	48.1	59.9	173.7	45.71
12	1275	0.41	5.2	1.5	32.6	91	257.7	39.02
13	1300	0.37	5.1	2.2	49.2	101	270.6	58.14
14	1325	0.46	4.6	3.5	42.4	48.9	185.4	40.54
15	1350	0.54	4.7	0.9	32.5	24.4	78.9	33.33
16	1375	0.33	5.1	2.6	48.2	63.4	291.5	63.88
17	1400	0.56	4.7	1	26.2	15.9	93.6	32.50
18	1425	1.04	5.2	0.9	5.5	6	35.9	8.11
19	1450	0.94	5	1	6.5	3.8	16.1	14.28
20	1475	0.66	4.8	1.1	16.2	10	44.1	30.00
21	1500	0.48	4.9	0.9	22.5	10.1	39.8	38.88
22	1525	0.71	5	1.1	9.9	4.3	22.6	21.21
23	1550	0.90	5.2	0.9	10.1	6.6	31.8	9.30

Table VII. Results summery of lab data of Heimdalen north-facing slope

Heimdalen north-facing slope (HDNV)								
No.	Altitude	Vw	pH	P	K	Mg	Ca	Loi
1	1100	0.23	4.2	2.7	45.2	51.1	255.1	36.66
2	1125	0.64	4.5	0.9	13.8	9.8	35	30.30
3	1150	0.66	4.4	1	19.6	17.4	92.3	21.05
4	1175	0.35	5.2	1	33.2	43.8	311.2	28.12
5	1200	0.54	4.3	2.7	28.6	17.1	53.2	32.55
6	1225	0.50	4.4	1.7	35.4	19.4	96.2	2.77
7	1250	0.62	4.3	1	18.1	8.2	35.4	8.57
8	1275	0.29	4.4	1.7	42.6	30.5	179.8	29.03
9	1300	0.75	4.6	1.2	13.6	12.5	62.7	86.48
10	1325	0.79	4.3	1.3	12.8	6.6	33.1	29.26
11	1350	0.79	4.4	1.2	9	5.1	27.1	2.70
12	1375	1.06	4.8	1.2	3.4	2.4	20.3	25.00
13	1400	0.66	4.5	0.9	13.6	3.4	19.7	33.33
14	1425	0.58	4.3	0.9	19.8	7.8	34.8	9.67
15	1450	1.02	4.7	1.1	6.8	3.1	20.6	21.87
16	1475	0.75	4.7	0.8	12.7	4.7	27.8	25.00
17	1500	0.79	4.7	1.1	11.7	5.1	30.3	12.50
18	1525	0.90	4.6	1.1	23.5	16.5	90.5	29.73
19	1550	0.50	4.6	1.6	2.7	17	92.5	6.06

Table VIII. Result summary of lab data of Heimdalen south-facing slope

Heimdalen south- facing slope (HDSV)								
No.	Altitude	Vw	pH	P	K	Mg	Ca	Loi
1	1075	0.48	4.3	2.3	22.7	16.7	63.3	42.82
2	1100	0.66	4.3	1.9	41.5	8.5	27.7	25.00
3	1125	0.48	5	1.2	33.7	29	147.5	33.33
4	1150	0.58	4.5	2.1	29	15.4	57.5	31.25
5	1200	0.58	4.6	1.7	20.4	30.1	151.3	28.95
6	1225	0.64	4.5	0.9	32.4	17.4	64.5	12.50
7	1275	0.60	5	0.9	29.8	47.06	150.5	32.43
8	1300	0.48	4.1	3.8	32.4	18.2	87.2	6.66
9	1325	0.58	4.5	1.6	29.8	28.3	62.6	34.37
10	1350	0.58	4.9	0.8	59.3	40.8	131.6	25.00
11	1375	0.41	4.3	5.6	19.7	25	124.7	15.68
12	1400	0.67	4.4	1.5	15.4	9.8	72.2	21.21
13	1425	0.71	4.6	1.2	45.9	16.1	50.6	26.19
14	1450	0.43	4.6	1.2	23.4	6.2	58.5	32.43
15	1475	0.62	4.5	0.9	13.8	5.4	21.7	33.33
16	1500	0.77	4.7	0.9	5.8	4.3	24.4	31.81
17	1525	1.02	5	1.1	25.6	22.1	29.1	50.00
18	1550	0.56	5.2	1.1	6.1	3.3	170.8	25.71
19	1575	0.87	4.9	0.8	13.7	8.7	26.4	12.50