EFFECTS OF FERTILIZERS ON THE SPECIES COMPOSITION OF BRYOPHYTES IN GRAZED PASTURES IN ROGALAND, NORWAY

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Cover photo

A curious herd of sheep at Reianes in Rennesøy municipality, paying close attention to the aspiring bryologist. Photo taken by Maria Lima.

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ABSTRACT

This study has aimed at looking at how the species composition of bryophyte communities in grazed pastures is affected by fertilizers.

Bryophyte species were collected from 25 different sites in Rogaland in Norway, of which 10 sites were unfertilized; 6 were fertilized with artificial fertilizer; 3 were fertilized with manure; and 6 were fertilized with both artificial fertilizer and manure. Bryophytes were collected from two types of substrates, namely from rocks and from soil. After additional data was collected, and all bryophyte species were identified, statistical analyses were performed using ordinations. Detrended correspondence analyses (DCA) and canonical correspondence analyses (CCA) were used.

The results showed that fertilizers do have an effect on the species composition of bryophytes. The two main factors that affect the species composition of bryophytes are: (1) the fertilizing – are the pastures fertilized or unfertilized; and (2) the substrate – are the bryophytes growing on rock or on soil? Although it was clear that fertilizers did have an effect, it remains unclear which type of fertilizer has the biggest effect on the species composition.

CONTENTS

1. INTRODUCTION

1.1 The status of bryophytes in Norway

Norway is one of the most species rich countries in Europe in terms of bryophytes, with 1071 registered species, of which 791 are mosses, 278 are liverworts and 2 are hornworts (Hassel et al., 2010). According to *The 2010 Norwegian Red List for Species*, 43 of the 225 bryophyte species found were connected to either semi-natural grassland or arable land (Kålås et al., 2010). This makes these two habitats the second most important habitats for red listed bryophytes in Norway, coming second only to bryophytes found on bedrocks and screes. Other studies from Hordaland (Jordal and Gaarder, 2009) and Rogaland (Norderhaug et al., 2007) have shown that out of all the species recorded in *The 2006 Norwegian Red List for Species*, 35% were linked to cultural landscapes, more than 25% were threatened due to overgrowth and about 20% were threatened due to an intensification of land-use and agriculture (Kålås et al., 2006). These observations indicate how important cultural landscapes are for Norwegian red listed bryophytes.

1.2 Bryophytes and cultural landscapes

'Cultural landscape' is an umbrella term that describes landscapes that have been continuously influenced and managed by humans over time, and it encompasses several different habitat types. Such habitat types may include pastures, coastal heathlands, hay meadows, cultivated fields and summer farms (Alm et al., 1999). Cultural landscapes can be characterized by how humans have managed them, e.g. through farming, forestry and settlements, and by the geographical placement of the landscape, e.g. in forests, mountains and coastal areas (Daugstad and Jones, 1998). In this thesis I will study pastures as a habitat type, more specifically pastures that are grazed by cattle or sheep and that are regularly fertilized with manure, artificial fertilizer or both of these.

Bryophytes found in arable and cultivated land are often specialist species that have adapted to regular disturbances such as ploughing, animal tracking and grazing, as well as to periodically dry conditions (Porley, 2008). Arable bryophytes often exhibit compressed life cycles, an adaptation that makes them able to survive in soils with a higher degree of disturbance, such as you would find in a pasture. They often reproduce asexually through vegetative propagules, such as gemmae, bulbils or tubers, or they reproduce sexually through the production of spores. Vegetative propagules and spores buried in the ground form what is called a diaspore bank, which allows the bryophytes to survive when conditions are less favourable above ground. It is unknown how long propagules and spores can remain viable in the diaspore bank, but they seem to be able to survive over longer periods of time if conditions are favourable (Porley, 2008). Disturbances such as ploughing or animal tracking can activate the diaspore bank.

Hardly any studies of bryophytes have been conducted in Norwegian cultural landscapes, and for most of the bryophyte species found the existing knowledge of occurrence is based on 100 years old information (Hassel, 2004). The Norwegian agricultural system has changed over many hundred years, going from a system with little or minor interferences with natural processes, where people were growing food and cereals on a small scale, to a machinery-intensive and heavily fertilized system. The tendency seems to be a gradual shift from a heterogeneous cultural landscape to a more homogeneous cultural landscape. The decline in mixed farming and the intensive use of fertilizers and chemicals, lead to changes in the farming and management regimes (Alm et al., 1999). Such interactions between humans and land-use have been more closely studied in countries such as Great Britain, Ireland and Austria (Preston et al., 2010, Zechmeister et al., 2003, Zechmeister et al., 2002), where they have found significant correlations between land-use intensity, structural diversity and species richness at both the habitat and the landscape scale (Zechmeister and Moser, 2001).

1.3 Bryophytes and fertilizers

A fertilizer can in the broadest sense be defined as something that provides a given area with more nutrients than it would otherwise have. Areas can be fertilized directly as a result of human activity, or indirectly by the addition of nutrients from precipitation or from the bedrock, like with acid rain or by erosion (Begon et al., 2006). In this thesis the focus will be on bryophytes living and growing in actively fertilized pastures where the use of fertilizers is a part of the farming practice, and I will compare this with bryophytes growing in unfertilized pastures.

Due to their lack of roots, bryophytes obtain nutrients differently than vascular plants. This happens through processes called 'wet deposition' and 'dry deposition' (Vanderpoorten and Goffinet, 2009). These are processes in which the bryophytes receive nutrients and minerals dissolved in rainwater and aerosols (wet deposition), as well as through dust and gases such as oxides of nitrogen and ammonia (dry deposition). Other factors that may impact the ability of bryophytes to obtain nutrients are their morphological differences. Acrocarpous bryophytes (species that have a stiff and erect growth form) have little or no rhizoids, and will therefore rely more on nutrient uptake by wet deposition. Pleurocarpous bryophytes (species with a creeping growth form) may instead develop runners covered in tiny rhizoids that can collect nutrients from the substrate (Vanderpoorten and Goffinet, 2009).

Nutrient uptake in bryophytes is closely linked to, and very much dependent on, the presence of water. The uptake of nutrients also takes place over the entire surface of the bryophyte, unlike with vascular plants, where the nutrient uptake predominantly takes place through the roots and stems (Glime, 2007). The nutrient requirements of bryophytes do not seem to differ that much from those of vascular plants, except perhaps in the amount of each nutrient needed (Vanderpoorten and Goffinet, 2009). The cycling of nutrients is very efficient in bryophytes compared to that in vascular plants, and the nutrient requirements of bryophytes can therefore be said to be very low in comparison (Vanderpoorten and Goffinet, 2009). Also, bryophytes have the ability to accumulate large concentrations of nutrients and chemicals, an ability that makes them valuable as biomonitors of ecosystem health (Flatberg et al., 1991, Fremstad and Eilertsen, 1994, Goffinet and Shaw, 2009).

The use of fertilizers will generally have a negative effect on bryophytes living with other plants in terms of growth, and by extension, survival (Glime, 2007). This is not necessarily because the bryophytes will die as a direct cause of being fertilized, but because other competitive plants will have an advantage over the bryophytes in terms of growth. In most artificial fertilizers used in agriculture there is an especially high content of nitrogen, phosphorus and potassium (Felleskjøpet, 2012), which all promote a rapid growth of grasses, hay and crops. The use of fertilizers will promote the growth of nitrophilous vascular plants, which in turn will outgrow the slower growing bryophytes and eventually shade them out (Glime, 2007). Such is a likely scenario where bryophytes and vascular plants grow together, like they would in a pasture or field, or any other natural habitat.

Fertilizers also affect the soil in which the bryophytes grow, and can alter the pH level. Heavy use of fertilizers, and especially acidic fertilizers like animal manure, can cause the pH level of the soil to drop to such an extent that it becomes unfavourable for bryophytes. This might lead to a loss of species diversity as studies have shown that high concentrations of nitrogen can be detrimental to the bryophyte community (Glime, 2007). The contrast between manure and artificial fertilizer is something that will be investigated in this project, as well as the contrast between bryophytes growing on soil and on rocks. Since most artificial fertilizers come in the form of pellets, it is reasonable to believe that bryophytes growing on rocks are less affected by artificial fertilizers, since the pellets will simply fall off the rocks when scattered across the pasture. This might in turn lead to there being more bryophyte species on rocks in artificially fertilized pastures than on rocks in pastures fertilized with manure. Conversely we might find that there are fewer species of bryophytes on rocks and in the soil of pastures fertilized with manure, as the acidic manure will wash these away. For this project I will therefore look at both rocks and soil as a substrate, and there will be a comparison of how the species composition varies between these two substrates.

1.4 Aims

This project aims to gain knowledge about the effects of fertilizers on the bryophyte composition in pastures, and aims to investigate how the species composition varies between differently fertilized pastures. Four types of pastures will be studied: (1) unfertilized pastures; (2) pastures fertilized with manure; (3) pastures fertilized with artificial fertilizer; and (4) pastures fertilized with both manure and artificial fertilizer. I will also look at how the species composition on rocks and on soil varies from each other, and how this varies for the different fertilizer treatments.

2. MATERIALS AND METHODS

2.1 Site selection

A total of 25 sites in municipalities Rennesøy, Sandnes and Gjesdal in Rogaland were chosen for this study (Figures 1-5). Suitable sites were found with the help from the County Governor of Rogaland, and sites were selected on the basis of vegetation, bedrock and surficial deposits. Sites with a neutral to slightly basic soil, and areas with intermediately rich vegetation, were preferred. More detailed site descriptions can be found in Table A1 in the Appendix. Within the three municipalities, six main areas were chosen: Bø and Reianes in Rennesøy; Kjosavik and Auglend in Sandnes; and Ytre Lima and Kluge in Gjesdal. Maps of surficial deposits (Anon., 2014b) showed that the soil was slightly different between these six areas, but these differences were assumed to have minor influences on the species composition. From the surficial deposit maps I found that Bø consisted of both weathered rock and exposed mountain, whereas Reianes consisted of only exposed mountain. Kjosavik consisted of mainly moraine, whereas Auglend consisted of both moraine and mire. Both Ytre Lima and Kluge consisted of moraine and glacial river deposits. Bedrock maps also showed that Rennesøy was slightly richer than Gjesdal and Sandnes (Anon., 2014a).

To compare the species composition of bryophytes between pastures with different fertilizer treatments, four types of pastures were studied: (1) unfertilized pastures; (2) pastures fertilized with manure; (3) pastures fertilized with artificial fertilizer; and (4) pastures fertilized with both manure and artificial fertilizer. The distribution of fertilizer treatments across sites can be found in Table 1.

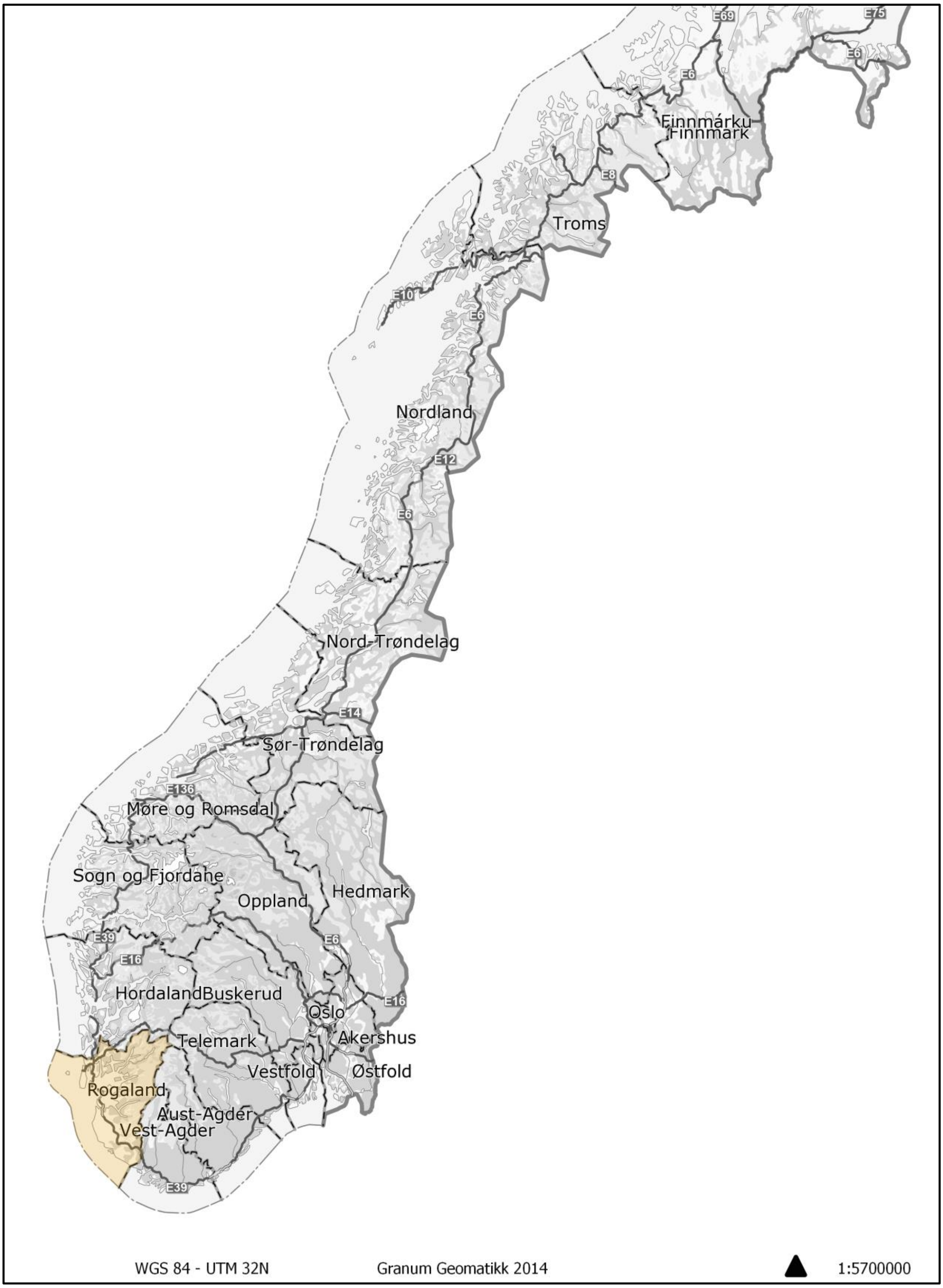

Figure 1: Map of Norway, with the county Rogaland highlighted in orange. Map made by Niels Torger Granum.

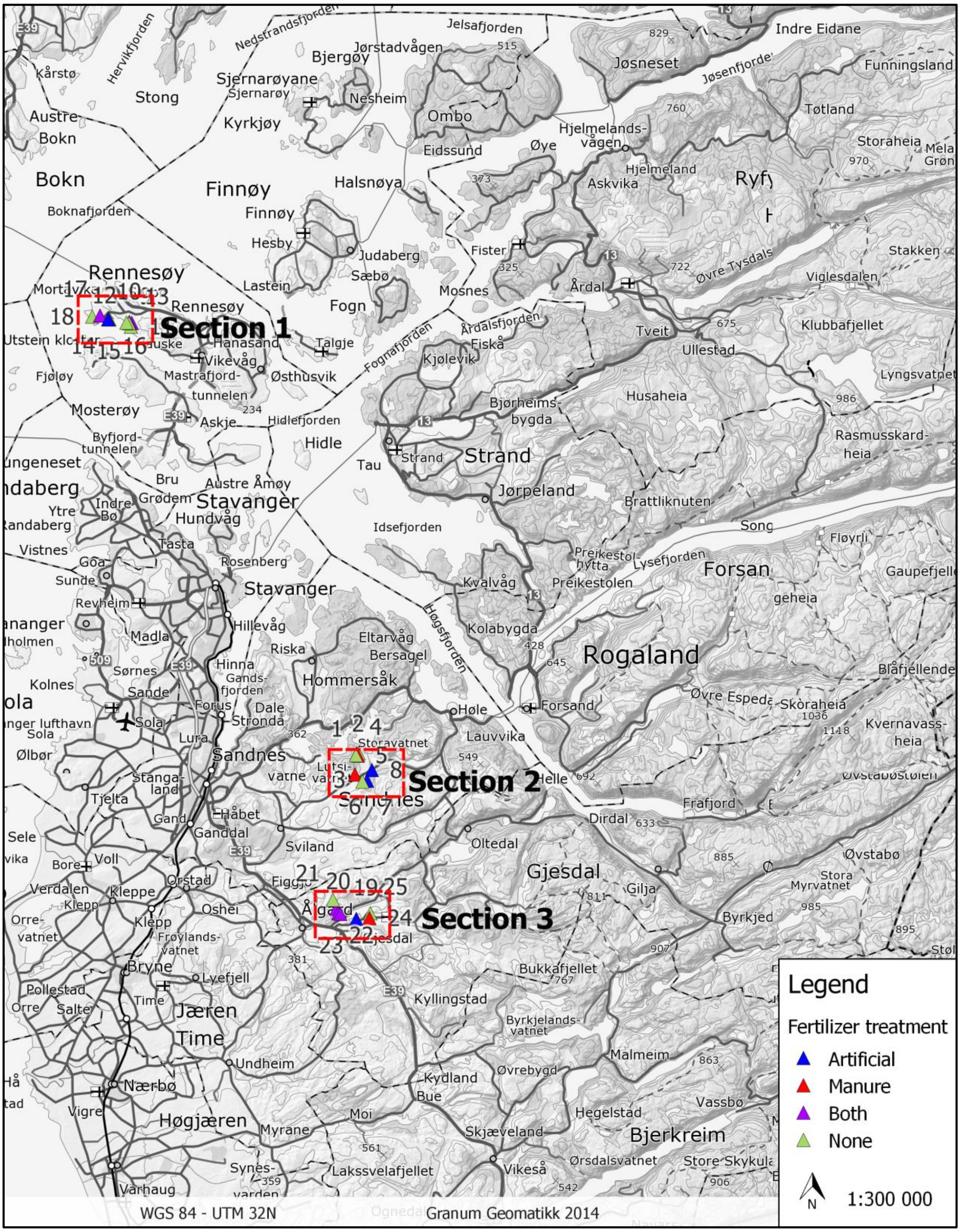

Figure 2: Study areas in Rogaland, Norway. Section 1 is in Rennesøy municipality, Section 2 is in Sandnes municipality and Section 3 is in Gjesdal municipality. The coloured triangles represent each site and their according fertilizer treatment. Map made by Niels Torger Granum.

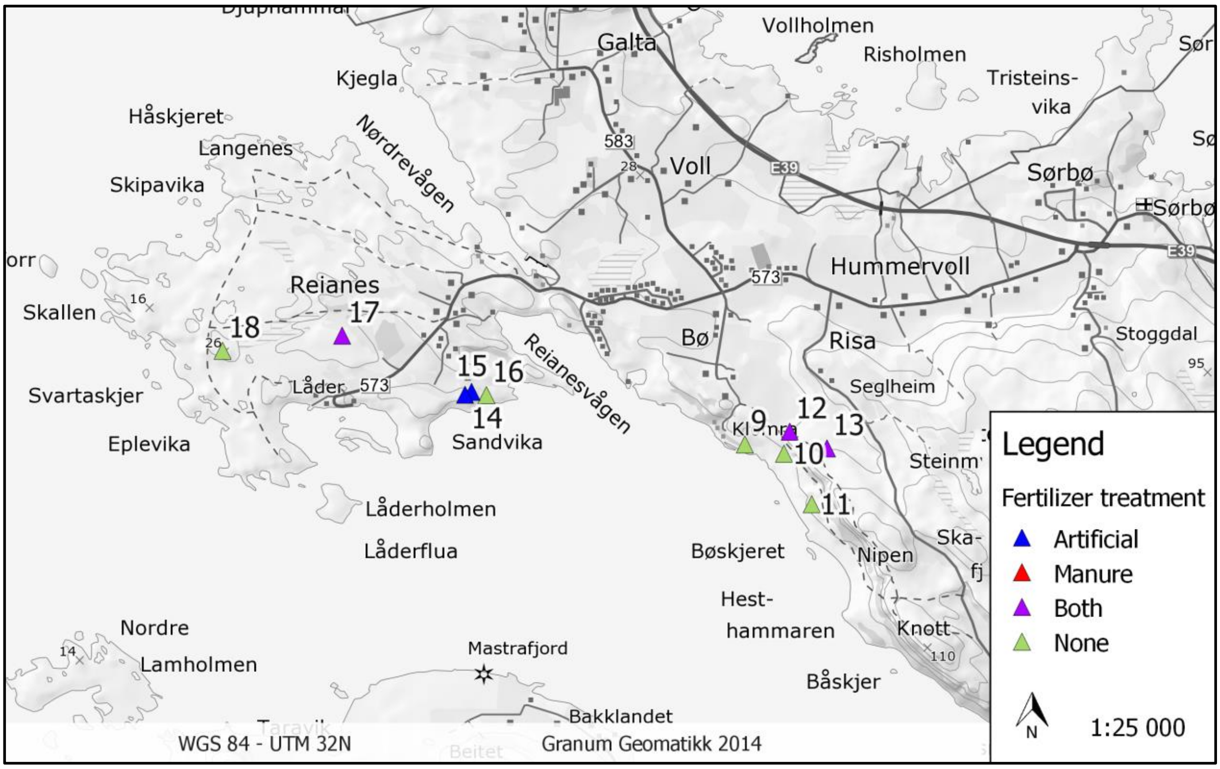

Figure 3: Sites in Rennesøy municipality. The coloured triangles represent each site and their according fertilizer treatment. Map made by Niels Torger Granum.

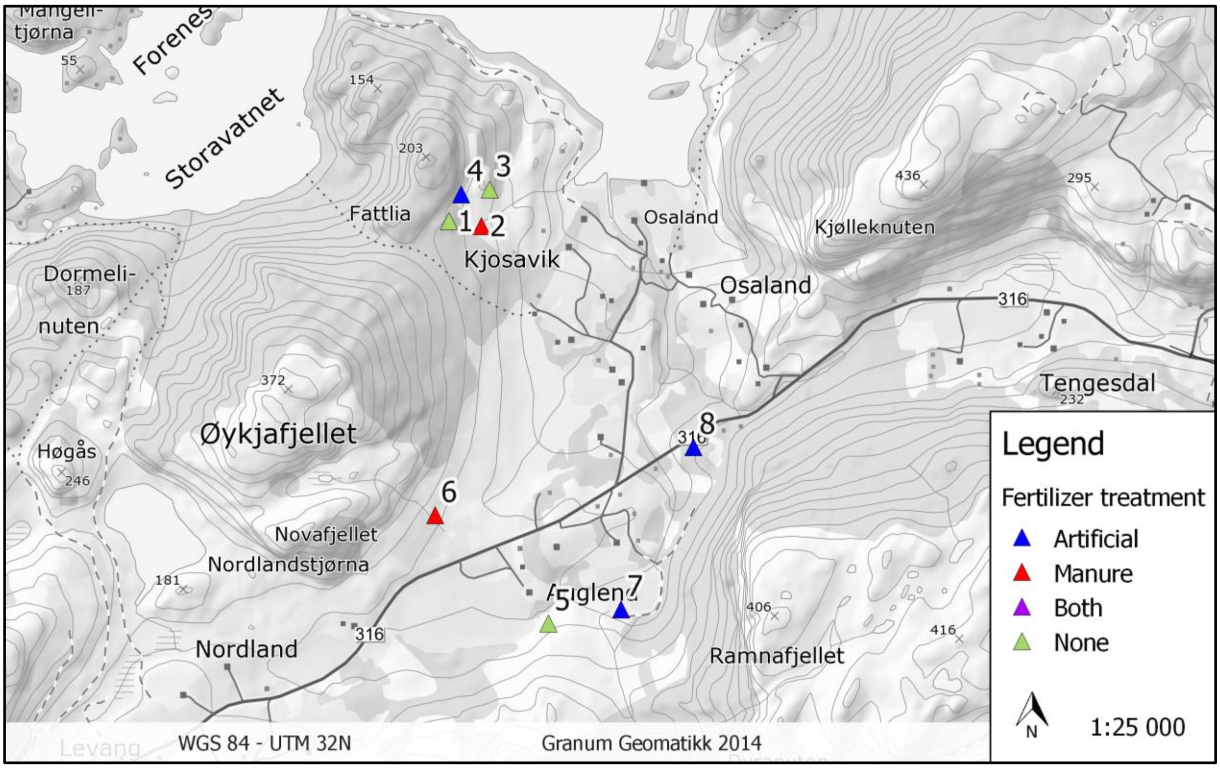

Figure 4: Sites in Sandnes municipality. The coloured triangles represent each site and their according fertilizer treatment. Map made by Niels Torger Granum.

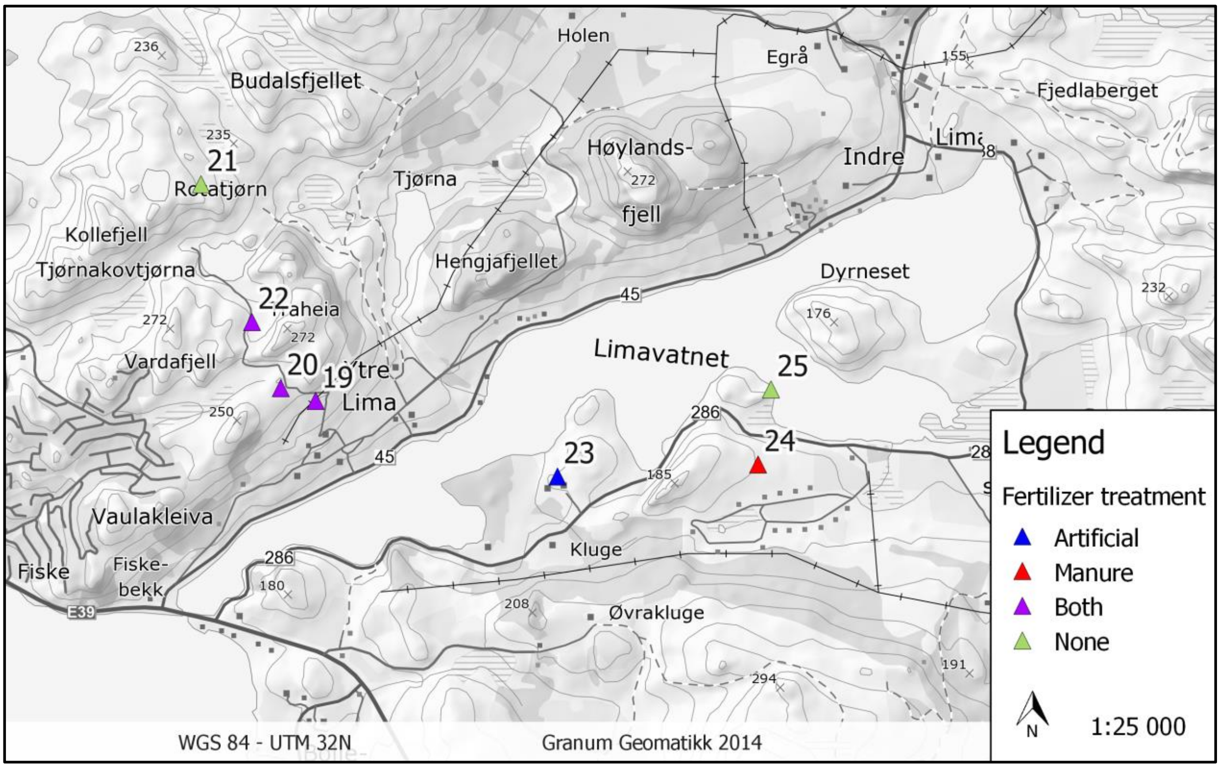

Figure 5: Sites in Gjesdal municipality. The coloured triangles represent each site and their according fertilizer treatment. Map made by Niels Torger Granum.

2.2 Fieldwork

Fieldwork was done over a three-week period in August 2013, from 8th August to 27th August. Before fieldwork started, all farmers were asked about how they managed their pastures, and they were also asked about fertilizing regimes and the fertilizer types used.

The fieldwork consisted of analysing quadrat plots to register species and taking soil samples beside each quadrat plot, as well as doing an assessment of vegetation coverage within each quadrat plot. Notes were taken on the general state of each site. This included registering which other plants were growing in the area, the moisture conditions, the amount of animal droppings in each site and the amount of animal tracks (Table A1, Appendix). As the size of the pastures varied from site to site, an attempt was made to use roughly the same amount of pasture for each site. That is to say, even if the pasture was very large, only a certain size of the pasture was used to have as equal pasture sizes as possible for this project. This was done by visual estimate, and the investigated sites might therefore show some variation in size, ranging from approximately 10 000 m^2 to 15 000 m^2 (Anon., 2014c).

Quadrat plots were analysed both on soil and on rock, and a total of ten quadrat plots were analysed at each site, five on soil and five on rock. The only exceptions for this were in sites 14 and 15, where quadrat plots were only done on the soil, as these sites did not contain any rocks. This sums up to 240 quadrat plots in total, with 125 of them being on soil and 115 of them being on rocks (Table 1). A metallic frame of 50×50 cm was used to delineate the quadrat plots. Before distributing the quadrats, an assessment of each site was done. I tried to use randomization when placing the quadrats, at the same time as I tried to capture the variations within each site. For each quadrat plot, all species of bryophytes were registered and samples were taken of all the bryophyte species for identification in the laboratory. For the quadrat plots on rocks the coverage of rock was also included, and for the quadrat plots on soil the coverage of bare soil was included. The coverage of any dead material and animal droppings were noted for both quadrat plots on rocks and quadrat plots on soil (Table A2, Appendix). The abundance of each species was registered on a scale from 1 to 3, where 1 was rare (<2%) and 3 was dominant, and the quadrat was divided into four equal sections to easier measure the presence/absence of species within the quadrat plot. In addition, GPS coordinates (GARMIN Oregon 450) as well as the inclination and aspect of the plots (SILVA Ranger Type 15 compass) were noted for each quadrat plot (Table A3, Appendix). Soil samples were taken just outside each quadrat plot, using a small gardening shovel. These samples were stored in a freezer the same day as collected.

Table 1: Overview of all 240 quadrat plots across the 25 sites, and their locations, fertilizer treatments and substrates. 125 of the quadrat plots were done on soil, and 115 were done on rocks. Out of all the 25 sites investigated, 3 of them were fertilized with manure; 6 were fertilized with artificial fertilizer; 6 were fertilized with both manure and artificial fertilizer; and 10 were unfertilized.

Plot	Municipality, area	Fertilizer treatment	Substrate
01.01 – 01.05	Sandnes, Kjosavik	None	Soil
01.06 – 01.10	Sandnes, Kjosavik	None	Rock
02.01 – 02.05	Sandnes, Kjosavik	Manure	Soil
02.06 – 02.10	Sandnes, Kjosavik	Manure	Rock
03.01 – 03.05	Sandnes, Kjosavik	None	Rock
03.06 – 03.10	Sandnes, Kjosavik	None	Soil

04.01 – 04.05	Sandnes, Kjosavik	Artificial	Soil
04.06 – 04.10	Sandnes, Kjosavik	Artificial	Rock
05.01 – 05.05	Sandnes, Auglend	None	Soil
05.06 – 05.10	Sandnes, Auglend	None	Rock
06.01 – 06.05	Sandnes, Auglend	Manure	Soil
06.06 – 06.10	Sandnes, Auglend	Manure	Rock
07.01 – 07.05	Sandnes, Auglend	Artificial	Soil
07.06 – 07.10	Sandnes, Auglend	Artificial	Rock
08.01 – 08.05	Sandnes, Auglend	Artificial	Soil
08.06 – 08.10	Sandnes, Auglend	Artificial	Rock
09.01 – 09.05	Rennesøy, Bø	None	Soil
09.06 – 09.10	Rennesøy, Bø	None	Rock
10.01 – 10.05	Rennesøy, Bø	None	Soil
10.06 – 10.10	Rennesøy, Bø	None	Rock
11.01 – 11.05	Rennesøy, Bø	None	Soil
11.06 – 11.10	Rennesøy, Bø	None	Rock
12.01 – 12.05	Rennesøy, Bø	Both	Soil
12.06 – 12.10	Rennesøy, Bø	Both	Rock
13.01 – 13.05	Rennesøy, Bø	Both	Soil
13.06 – 13.10	Rennesøy, Bø	Both	Rock
14.01 – 14.05	Rennesøy, Reianes	Artificial	Soil
15.01 – 15.05	Rennesøy, Reianes	Artificial	Soil
16.01 – 16.05	Rennesøy, Reianes	None	Soil
16.06 – 16.10	Rennesøy, Reianes	None	Rock
17.01 – 17.05	Rennesøy, Reianes	Both	Soil
17.06 – 17.10	Rennesøy, Reianes	Both	Rock
18.01 – 18.05	Rennesøy, Reianes	None	Soil
18.06 – 18.10	Rennesøy, Reianes	None	Rock
19.01 – 19.05	Gjesdal, Ytre Lima	Both	Soil
19.06 – 19.10	Gjesdal, Ytre Lima	Both	Rock
20.01 – 20.05	Gjesdal, Ytre Lima	Both	Soil
20.06 – 20.10	Gjesdal, Ytre Lima	Both	Rock
21.01 – 21.05	Gjesdal, Ytre Lima	None	Soil
21.06 – 21.10	Gjesdal, Ytre Lima	None	Rock
22.01 – 22.05	Gjesdal, Ytre Lima	Both	Soil
22.06 – 22.10	Gjesdal, Ytre Lima	Both	Rock
23.01 – 23.05	Gjesdal, Kluge	Artificial	Soil
23.06 – 23.10	Gjesdal, Kluge	Artificial	Rock
24.01 – 24.05	Gjesdal, Kluge	Manure	Soil
24.06 – 24.10	Gjesdal, Kluge	Manure	Rock
25.01 – 25.05	Gjesdal, Kluge	None	Soil
25.06 – 25.10	Gjesdal, Kluge	None	Rock

2.3 Laboratory work

All bryophyte species collected were dried and identified in the laboratory, using a stereo microscope (ZEISS West Germany 475022) and a light compound microscope (Leitz WETZLAR Germany D 68507). Species identification started in October 2013, and finished in February 2014. The bryophyte samples were studied both in dry and wet condition to better observe different character traits. Floras and keys used to identify bryophytes include those of Smith (2004), Watson (1981), Frey et al. (2006), Damsholt (2002), Atherton et al. (2010) and the two volumes of *Nationalnyckeln* (Hallingbäck et al., 2006, Hallingbäck et al., 2008). I followed the nomenclature provided by Artsdatabanken (*Artsnavnebasen*, 2011) for bryophytes, and the nomenclature provided by Lid and Lid (2005) for the vascular plants identified in the field (Table A1, Appendix).

Soil samples were collected for every quadrat plot done on soil, resulting in a total of 125 soil samples. All soil samples were sieved using a GEONOR 2 mm steel sieve to remove most of the vascular plants and fibres. After sieving, the samples were stored in small plastic freezer bags and returned to the freezer again. The pH value was measured for all 125 soil samples. Since pH is a measurement of the acidity or alkalinity of a solution, the pH values may say something about how much the fertilizers are influencing the soil. Before measuring the pH values, the samples were weighed and added water. Soil and water were mixed in a 1:5 ratio, that is to say 10 g of soil was used for each sample along with 50 mL of osmosis water. The soil and the osmosis water were then mixed in a plastic bottle, and put in a shaking machine (Stuart Orbital Shaker SSL1) for six hours, and then left to settle overnight. The pH was measured from the clear water layer at the top of the soil sample the following day using a pH meter (JENWAY 3510 pH Meter). The results of the pH measurements can be found in Table 3 in Results.

2.4 Statistical analyses

The data was processed in the program R using multivariate statistics. Ordination analyses were done on the data using detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA). The confidence level for all statistical analyses was set to p<0.05.

DCA is a multivariate method that combines the concept of reciprocal averaging (RA) with detrending in place of orthogonalization, followed by standardization to unit within-sample variance (Hill and Gauch, 1980). This method provides both an interpretable species ordination as well as a sample ordination, and the arch effect is avoided. CCA is a multivariate method used to explain the relationships between species and their environment (Borcard et al., 2011). The method extracts synthetic environmental gradients from ecological data sets, where the gradients visualize and describe the differential habitat preferences of the studied taxa. The method therefore provides opportunities for statistical testing and estimation of the effects of environmental variables and other explanatory variables on biological communities, even if the effects are hidden by other large sources of variation (ter Braak and Verdonschot, 1995).

The gradient length of the species data was checked using the 'decorana' function in the 'vegan' library in R, with downweighting of rare species. This yielded an axis length of about 2.53, which is right on the borderline between using a linear and a unimodal approach to further analyse the data. But since the axis length was just over 2.5, a unimodal approach was taken. Also, an additional species named *no_sp* was added to the species data, to represent the plots where no bryophyte species were found. A plot was then made using correspondence analysis (CA), but this showed a clear arch effect, so a DCA was used instead.

A series of ANOVA tests were then performed on the environmental variables, to assess how important the different variables are for the entire data set. The data set was then split in two, in order to look at the data for 'Rock' and 'Soil' separately. ANOVA tests were performed on the site scores for 'Rock' and the site scores for 'Soil', and plots were made for site and species scores for both 'Rock' and 'Soil'.

A list of all the R code used for the statistical analyses can be found in Figure A4 in the Appendix.

3. Results

3.1 Results of species identification

A total number of 61 species of bryophytes were found, of which 52 were mosses and 9 were liverworts (Table 2). Out of the 61 species, 31 were only found on rock; 18 were only found on soil; and 12 species were found on both substrates (Table 2). None of the species found were listed in *The 2010 Norwegian Red List for Species* (Kålås et al., 2010).

Table 2: List of all bryophyte species found, and on what kind of substrate they were found. R = rock, S = soil and R, S = rock and soil. Species listed under 'Bryophyta' are mosses, and species listed under 'Marchantiophyta' are liverworts.

BRYOPHYTA		**BRYOPHYTA**	
Scientific name	**Substrate**	**Scientific name**	**Substrate**
Andreaea rothii	R	*Polytrichum juniperinum*	R
Andreaea rupestris	R	*Polytrichum piliferum*	R
Brachythecium populeum	R	*Pseudoscleropodium purum*	R, S
Brachythecium reflexum	S	*Racomitrium aciculare*	R
Brachythecium rutabulum	S	*Racomitrium affine*	R
Brachythecium salebrosum	S	*Racomitrium aquaticum*	R
Bryum alpinum	R	*Racomitrium fasciculare*	R
Bryum capillare	R	*Racomitrium heterostichum*	R
Calliergonella cuspidata	S	*Racomitrium lanuginosum*	R, S
Campylopus atrovirens	R	*Racomitrium sudeticum*	R
Campylopus flexuosus	R, S	*Rhizomnium punctatum*	S
Ceratodon purpureus	R	*Rhytidiadelphus loreus*	R
Cynodontium polycarpon	R	*Rhytidiadelphus squarrosus*	R, S
Dicranum fuscescens	R	*Sanionia uncinata*	R, S
Dicranum scoparium	R, S	*Schistidium crassipilum*	R
Eurhynchium pulchellum	S	*Sphagnum compactum*	S
Grimmia montana	R	*Sphagnum inundatum*	S
Grimmia pulvinata	R	*Sphagnum tenellum*	S
Grimmia trichophylla	R	*Tortella tortuosa*	R
Hedwigia ciliata	R	*Ulota crispa*	R
Hedwigia stellata	R	**MARCHANTIOPHYTA**	
Hylocomium splendens	R, S	**Scientific name**	**Substrate**
Hypnum cupressiforme	R, S	*Barbilophozia attenuata*	R, S
Hypnum jutlandicum	R	*Cephalozia bicuspidata*	S
Hypnum lacunosum	R	*Diplophyllum albicans*	S
Kindbergia praelonga	S	*Lophozia ventricosa*	R, S
Orthotrichum rupestre	R	*Nardia compressa*	S
Plagiomnium elatum	S	*Odontoschisma sphagni*	S
Plagiomnium ellipticum	S	*Ptilidium ciliare*	R
Pleurozium schreberi	R, S	*Scapania nemorea*	S
Pohlia nutans	R	*Tritomaria exsectiformis*	S
Polytrichastrum formosum	R, S		

3.2 Results of pH measurements

The lowest mean pH value was found at site 5 (pH=1.87±0.18), and the highest mean pH value was found at site 16 (pH=5.08±0.24) (Table 3). Both sites were unfertilized. Site 5 was a very moist site, with a lot of wetland vegetation and with faeces from both cattle and sheep scattered across the area (Table A1, Appendix). This might explain the low mean pH value. Site 16 had both moist and dry areas, and contained a lot of rocks (Table A1, Appendix). This site was in Rennesøy municipality, which has more base-rich soils (Anon., 2014b), and that may be the reason for the higher mean pH value.

Table 3: This table shows the mean pH value and the standard deviation for each site. The pH values for each plot can be found in Table A4 in the Appendix.

Site	Fertilizer	Mean pH	Site	Fertilizer	Mean pH
1	None	2.30 ± 0.75	14	Artificial	3.71 ± 0.12
2	Manure	2.16 ± 0.17	15	Artificial	3.66 ± 0.24
3	None	2.11 ± 0.15	16	None	5.08 ± 0.24
4	Artificial	2.21 ± 0.11	17	Both	4.44 ± 0.37
5	None	1.87 ± 0.18	18	None	3.93 ± 0.28
6	Manure	3.01 ± 0.29	19	Both	3.76 ± 0.12
7	Artificial	3.37 ± 0.13	20	Both	4.04 ± 0.22
8	Artificial	3.31 ± 0.23	21	None	4.80 ± 0.57
9	None	3.12 ± 0.34	22	Both	4.15 ± 0.09
10	None	3.43 ± 0.25	23	Artificial	3.56 ± 0.52
11	None	4.51 ± 0.39	24	Manure	3.82 ± 0.09
12	Both	4.61 ± 0.42	25	None	3.66 ± 0.11
13	Both	3.94 ± 0.10			

The mean pH for each fertilizer treatment was also calculated. The lowest mean pH was found in pastures fertilized with manure (pH=3.00±0.73), and the highest mean pH was found in pastures fertilized with both manure and artificial fertilizers (pH=4.16±0.38) (Table 4). An ANOVA test was done to see if the mean pH values for the different fertilizer types were different from each other. The mean pH values were significantly different for the different fertilizer types (F=8.43 and Pr(>F)=$3.92*10^{-5}$), and they explained 17.29% of the variation.

Table 4: This table shows the mean pH value and the standard deviation for the pastures of each fertilizer treatment. By the term 'Both' is meant the use of both manure and artificial fertilizer as a treatment.

Unfertilized	Artificial	Manure	Both
3.48 ± 1.14	3.30 ± 0.57	3.00 ± 0.73	4.16 ± 0.38

3.3 Results of statistical analyses for the entire data set

3.3.1 Canonical correspondence analysis (CCA)

When checking the axis length of the species data using the 'decorana' function in the 'vegan' library in R (with downweighting of rare species), the axis length was found to be about 2.53. This is right on the borderline between using a linear and a unimodal approach for analysing the data further. But since the axis length was just over 2.50, a unimodal approach was taken and a correspondence analysis was performed.

The correspondence analysis performed on the data set gave a clear arch effect (Figure 6), which is a common problem when using correspondence analysis. To rectify this problem, a detrended correspondence analysis was used instead to plot the site scores and species scores of the data.

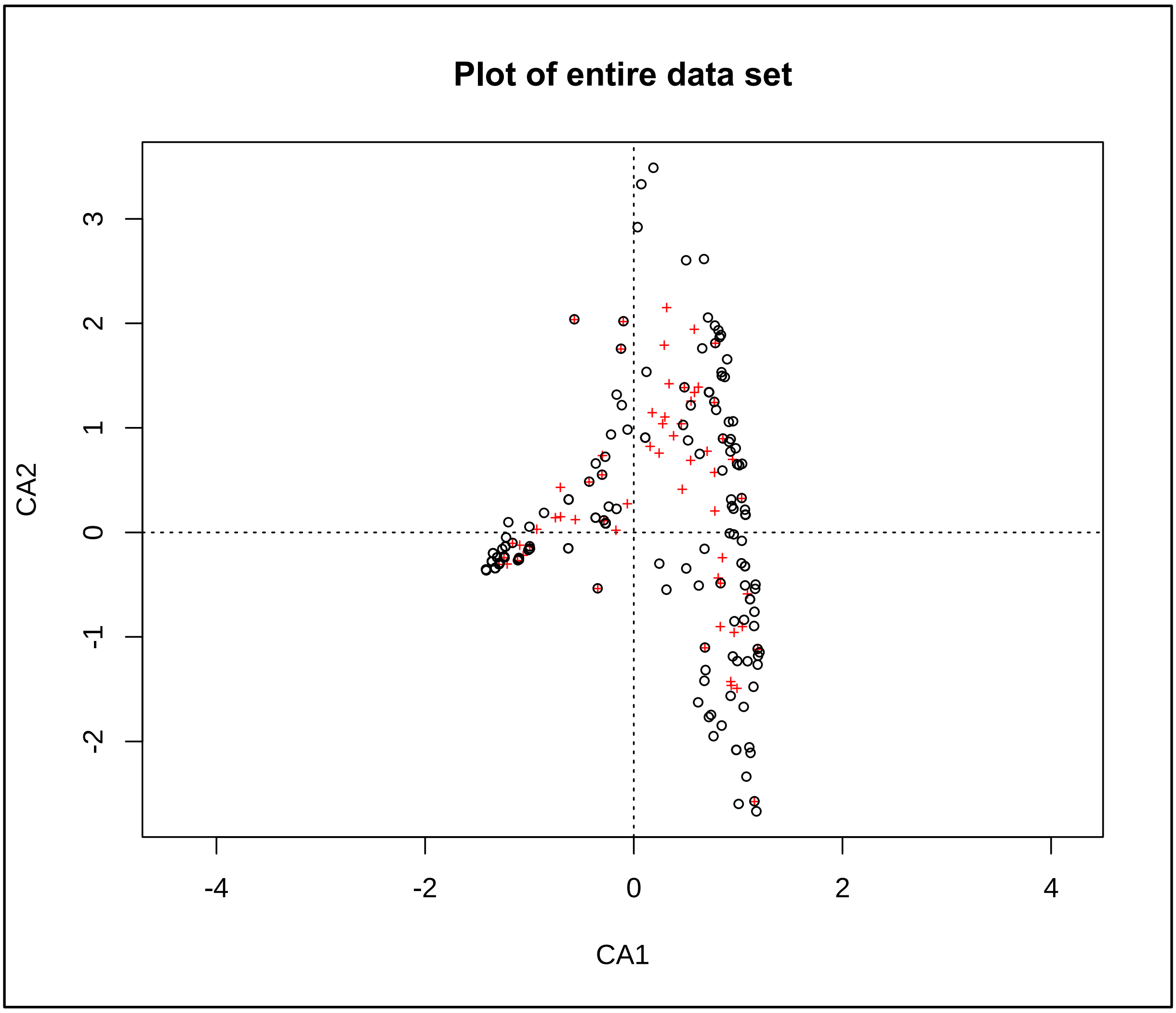

Figure 6: Correspondence analysis of entire data set, showing a clear arch effect. The circles represent the site scores and the crosses represent the species scores.

3.3.2 Detrended correspondence analysis (DCA)

From the detrended correspondence analysis performed on the data (Figure 7) we can see that species found on typically dry substrates are gathered in the left part of the diagram (such as *Campylopus atrovirens*, *Andreaea rothii* and *Hedwigia stellata*), and that species found on typically moister substrates are gathered in the right part of the diagram (such as *Brachythecium rutabulum*, *Hylocomium splendens* and *Rhytidiadelphus squarrosus*). The first axis is the most important (Eigenvalue=0.63), and represents a gradient of substrate moisture, with dryer substrates to the left and moister substrates to the right. The second axis is much less clear (Eigenvalue=0.24), but seems to be a combination of air humidity or shading and a weak pH gradient. For pH, the gradient seems to go from higher pH at the bottom to lower pH at the top. This observation matches the species distribution in Figure 7b to some degree, except for the species *Tortella tortuosa* and *Schistidium crassipilum*. These are both calcicoles that prefer substrates with a higher pH, yet they are found high up in the ordination plot (Figure 7b). Both species were found in Rennesøy, which has rich bedrock and surficial deposits (Anon., 2014a, Anon., 2014b), so a possible explanation for this can be that another factor than pH (e.g. light or air humidity) is stronger, and that this is why these two species are found so high up in the ordination plot. For shading, the gradient seems to go from high sun exposure at the bottom, to lower sun exposure at the top. This is somewhat reflected in species like *Bryum alpinum* and *Polytrichum juniperinum*, which often grow in unshaded, exposed areas. For air humidity, the gradient seems to go from lower air humidity at the bottom to higher air humidity at the top. This is somewhat reflected in species like *Campylopus atrovirens* and *Hypnum jutlandicum*, which often grow in moister, oceanic areas.

To try to explain the variation in the species composition, a series of ANOVA tests were performed for the variables 'pH'; 'Site'; 'Rock'; and 'Fertilizers'. These all explained a significant part (*p* value less than 0.05) of the variation in species composition when tested as the only explanatory variable (Table 5). The pH values were only tested for the 'Soil' data.

Table 5: ANOVA tests based on CCA of the whole data set using only the variables listed as explanatory variables. For R code see Figure A4 in the Appendix.

	Df	Chisq	Residual Chisq	F	Pr(>F)
pH	1	0.04	1.62	3.61	0.01 *
Site	24	0.52	2.87	1.62	0.005 **
Rock	1	0.50	2.89	41.77	0.005 **
Fertilizers	3	0.10	3.30	2.42	0.005 **

Furthermore, an ANOVA test was performed for the different fertilizer treatments, including the variables listed in Table 5. All fertilizer treatments were significant, with a *p* value of less than 0.05 when testing their marginal effects (Table 6).

Table 6: ANOVA test based on CCA of the whole data set testing the marginal effects after including all the other variables ('pH', 'Site', 'Rock', 'Fertilizers' (all treatments: Manure, Artificial, Both and Unfertilized)). By the term 'Both' is meant that both manure and artificial fertilizers were used as a treatment. For R code see Figure A4 in the Appendix.

	Df	Chisq	F	N.Perm	Pr(>F)
Rock	1	0.51	43.04	199	0.005 **
Manure	1	0.04	3.47	199	0.005 **
Artificial	1	0.05	4.27	199	0.005 **
Both	1	0.04	4.04	199	0.005 **
Residual	235	2.78			

Because all the interaction terms between 'Rock' and the different fertilizer treatments were significant, further analyses were done separately for 'Rock' and 'Soil'.

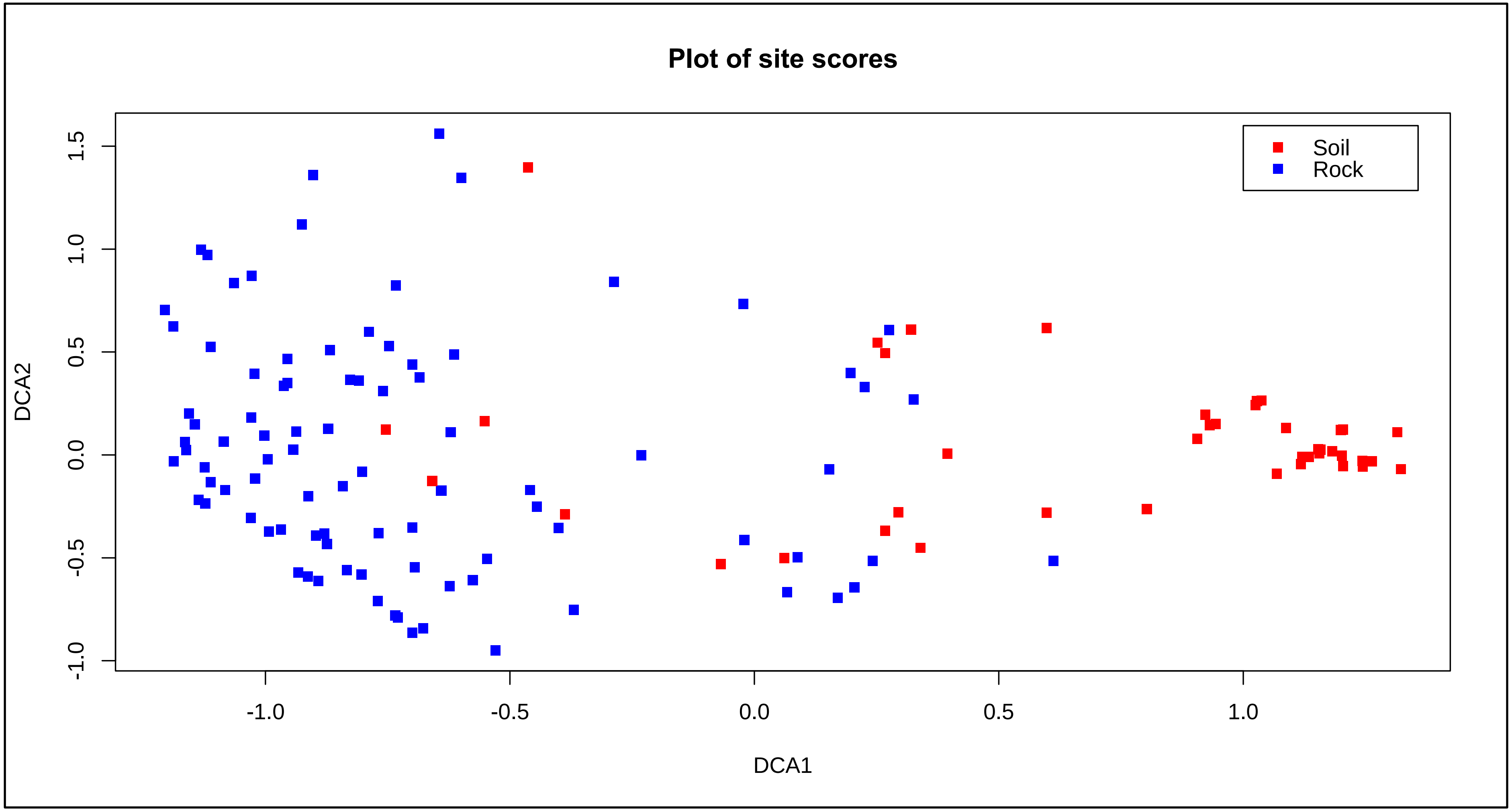

Figure 7a: Detrended correspondence analysis of site scores. Blue squares represent site scores for quadrat plots on rocks, whereas red squares represent site scores for quadrat plots on soil.

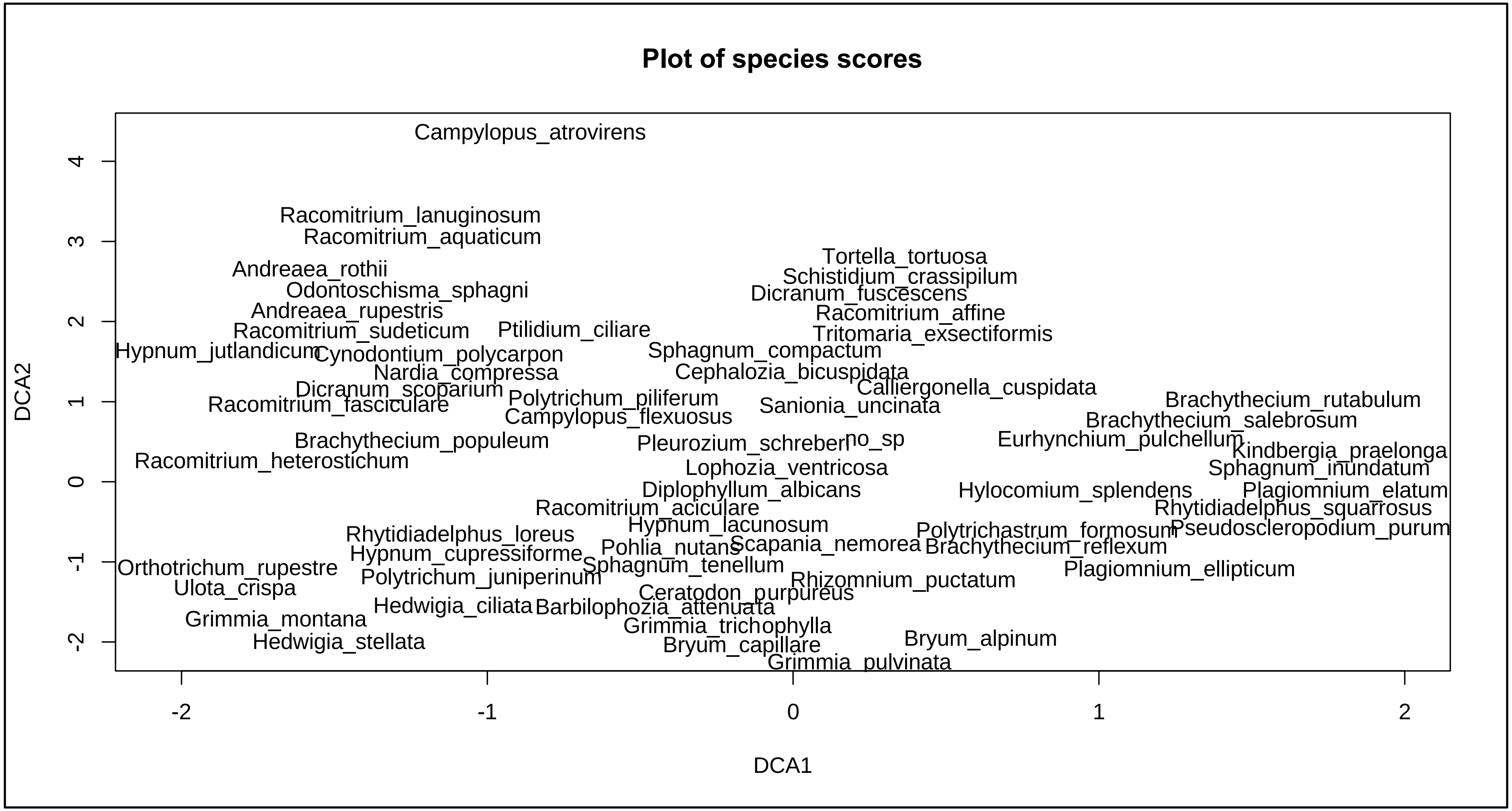

Figure 7b: Detrended correspondence analysis of species scores. The species are distributed as in Figure 7a, with species growing on dry substrates to the left and species growing on moister substrates to the right. Some of the species names have been moved slightly so that the text can be read properly. For the original version of this plot, see Figure A1 in the Appendix.

3.4 Results of statistical analyses for the data sets on 'Rock' and 'Soil'

For both 'Rock' species and 'Soil' species the main difference in the species composition that could be explained by the different fertilizer treatments was similar. This main difference was found between the unfertilized sites, which are the green squares to the left in the diagrams, and the fertilized sites, which are the red, blue and purple squares to the right in the diagrams (Figures 8 and 10). The first axis therefore represents a fertilizer gradient, going from 'Unfertilized' at the left side to 'Fertilized' at the right side. We can see that the unfertilized areas contain more of species such as *Tortella tortuosa* and *Schistidium crassipilum* than the fertilized sites (Figures 9 and 11). These two species are often connected to richer areas, and we can also find liverworts such as *Lophozia ventricosa* and *Ptilidium ciliare* in the unfertilized areas. The second axis represents a short moisture gradient, going from 'Dry' at the bottom to 'Moist' at the top. There are some clear differences in the species found on rocks and on soil. Typically, the species found on rocks are acrocarps, that is to say they have an erect growth form, and are quite stress tolerant. The species found on soil are typically pleurocarps with a creeping growth form, and these are often more moisture demanding than species growing on rocks. We can also find liverworts in the moister areas.

3.4.1 'Rock' data set

The effects of the different fertilizers on the species composition were checked for 'Rock' and 'Soil' separately. An ANOVA test of the data set for 'Rock' showed that the fertilizer variables explained about 6.18 % of the variation in the species composition ($F=2.43$, $p<0.05$) (Table 7). Eigenvalues for the first and second axis of the 'Rock' data set were 0.14 and 0.03, respectively.

Table 7: Results from the CCA of data set for 'Rock' using fertilizer as the explanatory variable.

	Df	Chisq	F	N.Perm	Pr(>F)
Fertilizer	3	0.18	2.43	199	0.005 **
Residual	111	2.86			

The species in Figure 9 follow the same pattern as in Figure 8, with species found in unfertilized pastures to the left and species found in fertilized pastures to the right. Species like *Grimmia trichophylla* and *Grimmia pulvinata* are gathered in the lower right corner, where the arrow for 'Artificial' is pointing in Figure 8. In the direction of the arrow for 'Manure' we find the species *Brachythecium populeum*, *Hypnum jutlandicum*, *Racomitrium affine*, *Ulota crispa* and *Polytrichastrum formosum*. The arrow for 'Both' is pointing up towards the right corner of the plot in Figure 8, where we can find species like *Bryum alpinum* and *Orthotrichum rupestre*. In Figure 9 there is a higher number of species found on the left side of the plot.

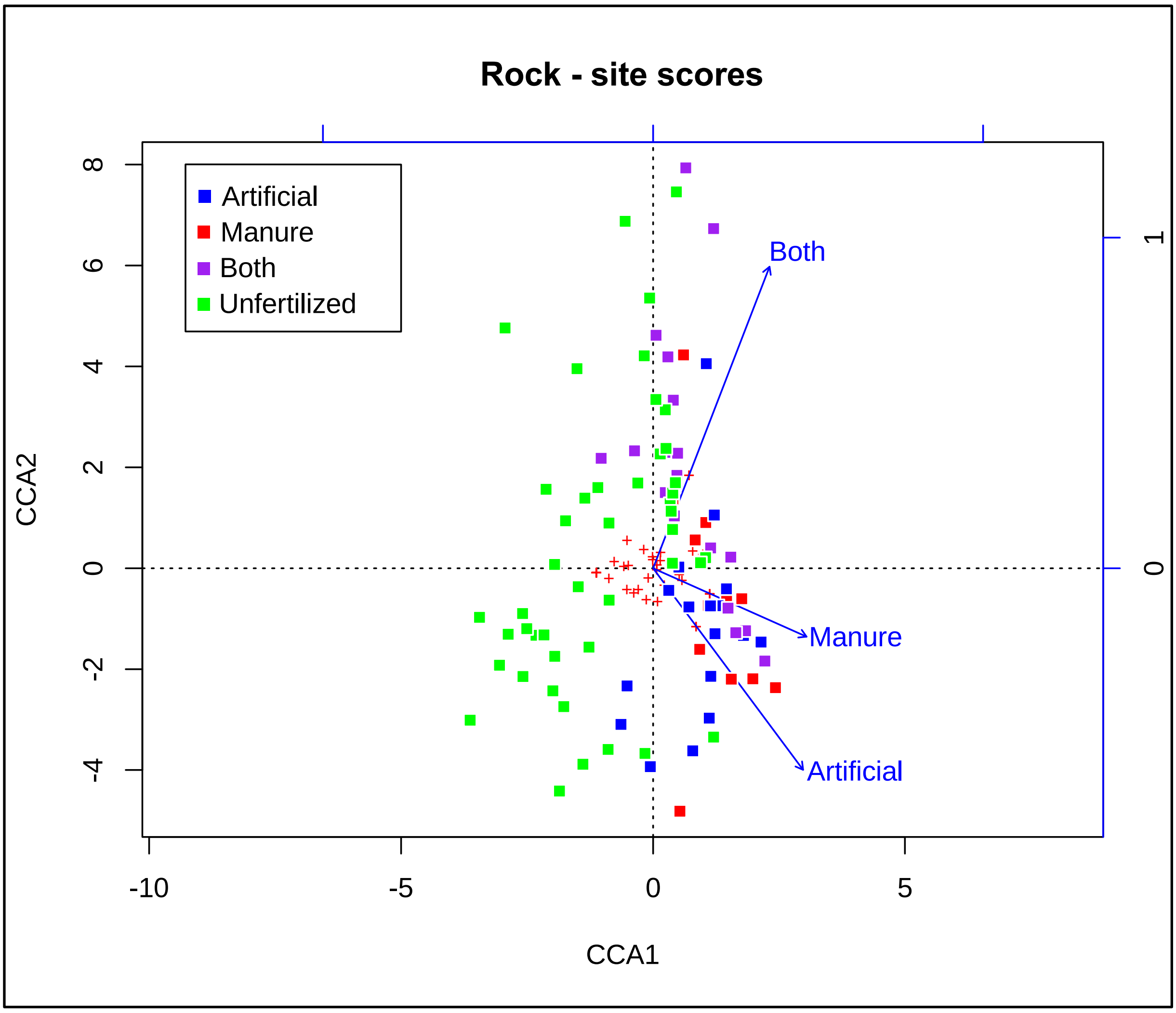

Figure 8: Canonical correspondence analysis of site scores for rock. This plot shows the site scores for species on rock, in relation to fertilizer treatments.

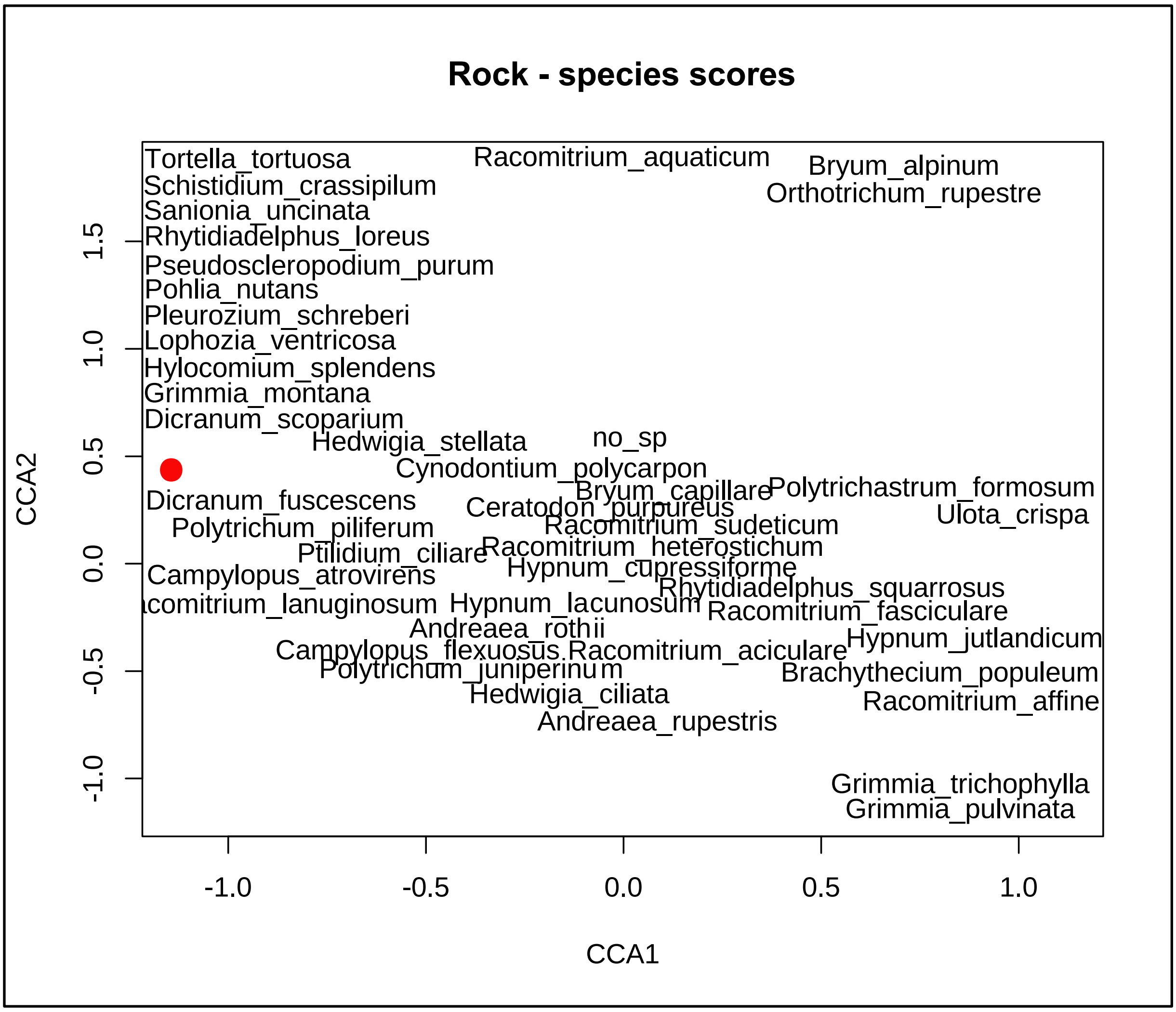

Figure 9: Canonical correspondence analysis of species scores for rock. This plot shows the species scores for species on rock. The red dot indicates a point where the species from *Tortella tortuosa* down to *Dicranum scoparium* (plus *Racomitrium aquaticum*) were clustered on top of each other. Some of the other species names have been moved slightly so that the text can be read properly. For the original version of this plot, see Figure A2 in the Appendix. The point *no_sp* was actually quite centred, but was covered by so much text that I moved it straight upwards into the free space.

3.4.2 'Soil' data set

An ANOVA test of the data set for 'Soil' showed that the fertilizer variables explained about 6.84 % of the variation in the species composition (F=2.96, $p<0.05$) (Table 8). Eigenvalues for the first and second axis of the 'Soil' data set were 0.11 and 0.02, respectively.

Table 8: Results from the CCA of data set for 'Soil' using fertilizer as the explanatory variable.

	Df	Chisq	F	N.Perm	Pr(>F)
Fertilizer	3	0.13	2.96	199	0.005 **
Residual	121	1.84			

The species in Figure 11 follow the same pattern as in Figure 10, with species found in unfertilized pastures to the left and species found in fertilized pastures to the right. The species *Brachythecium salebrosum* is placed in the bottom right corner, where the arrow for 'Manure' is pointing in Figure 10. Species like *Kindbergia praelonga* and *Brachythecium rutabulum* are found where the arrow for 'Artificial' is pointing. The arrow for 'Both' is pointing up towards the right corner in Figure 10, where we can find the species *Plagiomnium elatum*. Like in Figure 9, there is a higher number of species found on the left side of Figure 11.

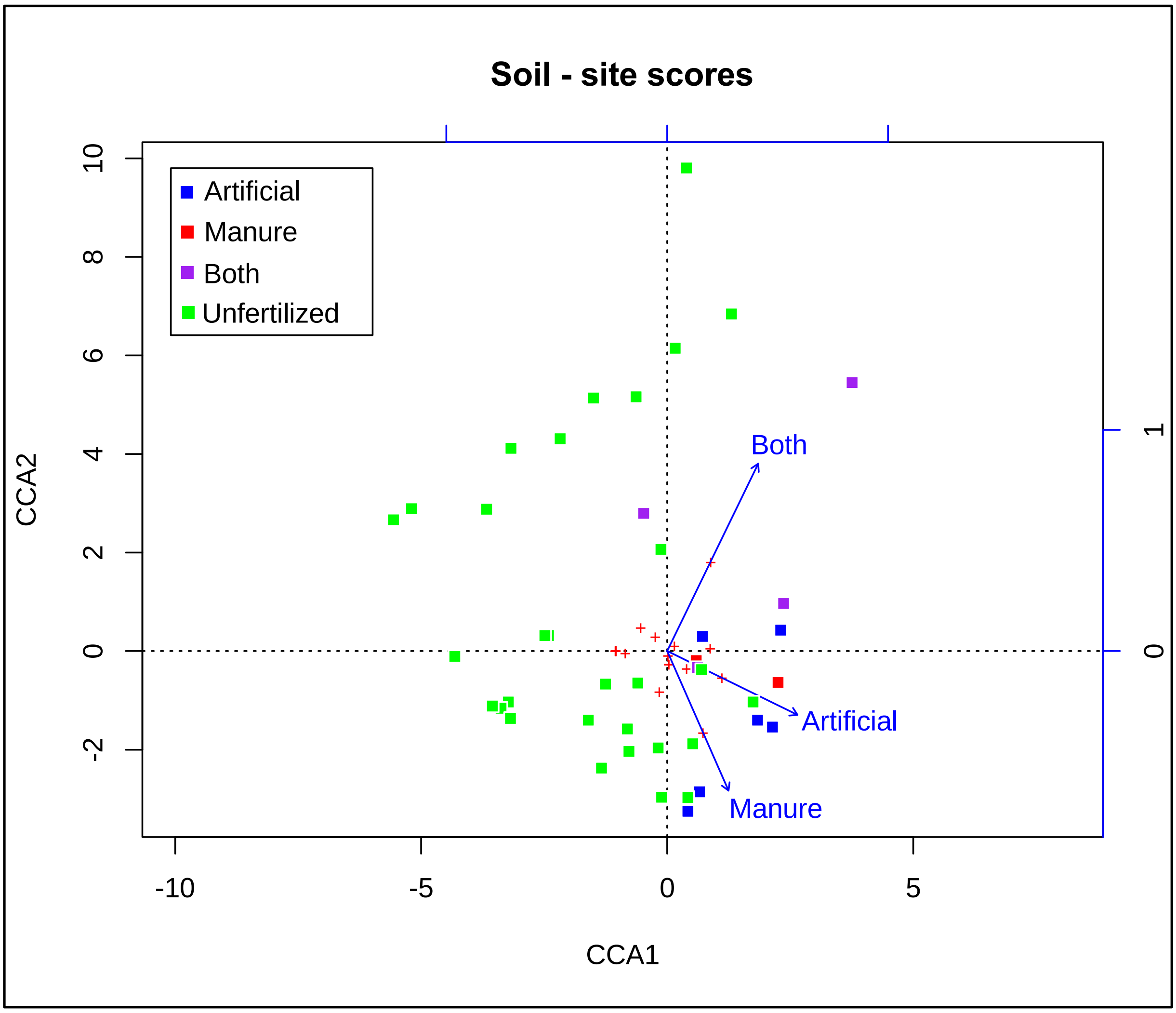

Figure 10: Canonical correspondence analysis of site scores for soil. This plot shows the site scores for species on soil, in relation to fertilizer treatments.

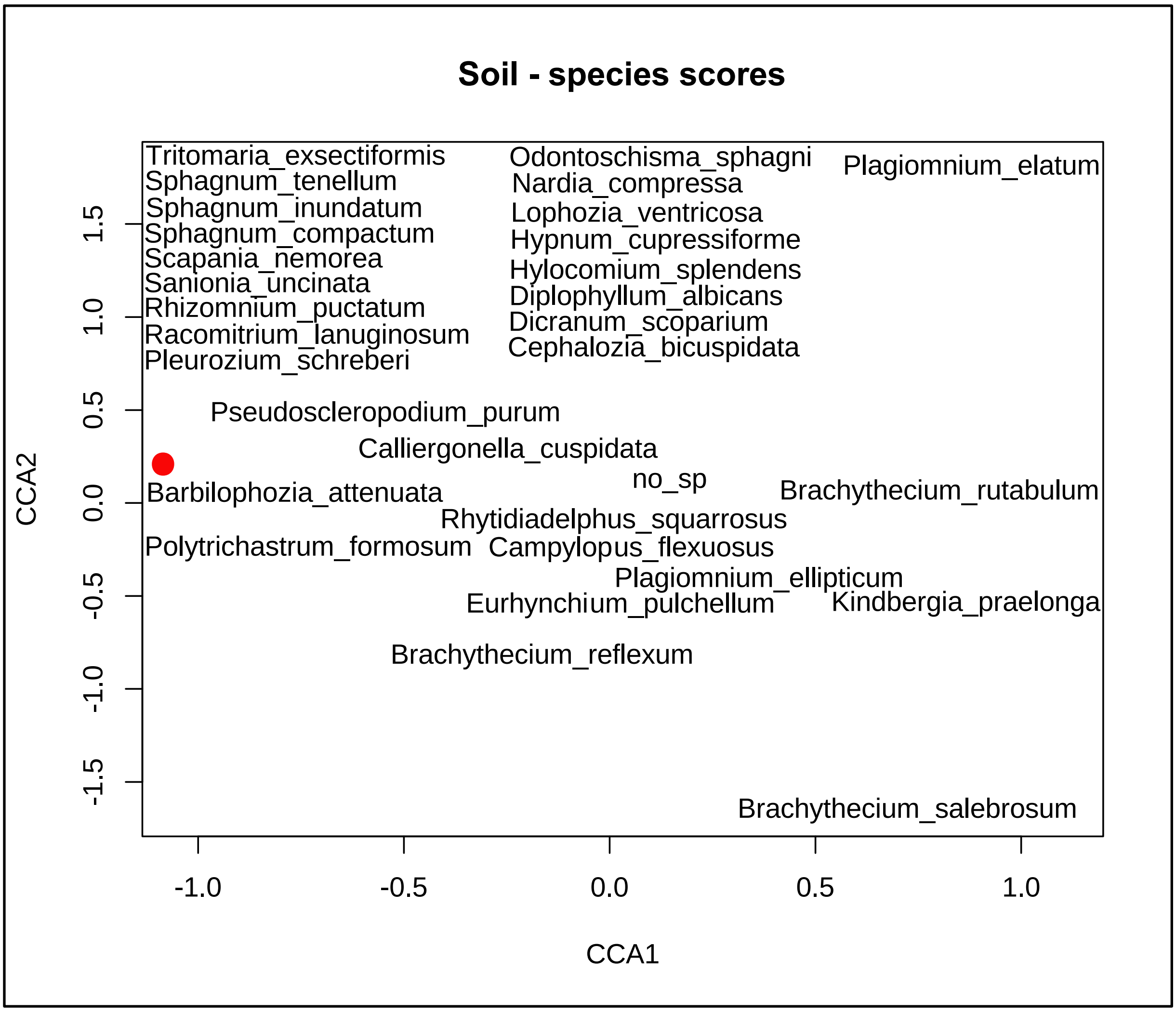

Figure 11: Canonical correspondence analysis of species scores for soil. This plot shows the species scores for species on soil. The red dot indicates a point where the species from *Tritomaria exsectiformis* to *Cephalozia bicuspidata* were clustered on top of each other. Some of the other species names have been moved slightly so that the text can be read properly. For the original version of this plot, see Figure A3 in the Appendix.

3.5 Summary of results

For the detrended correspondence analysis performed on the entire data set, the first axis was the most important, and represented a substrate moisture gradient going from dryer substrates on the left to moister substrates on the right (Figure 7a). The second axis was less clear, but seemed to be a combination of air humidity or shading and a weak pH gradient (Figure 7b).

For the canonical correspondence analyses performed on the data sets for 'Rock' and 'Soil', the first axis was the most important, and represented a fertilizer gradient going from ‘Unfertilized’ to ‘Fertilized’. The second axis represented a short moisture gradient, going from ‘Dry’ at the bottom to ‘Moist’ at the top (Figures 8 and 10). In summary, we saw that there was a higher number of species in the unfertilized pastures, and that this was true for both ‘Rock’ and ‘Soil’ species (Figures 9 and 11).

4. DISCUSSION

4.1 Summary of results

About half of all the species recorded were growing only on rock, and the other half was found growing either only on soil or on both soil and rock (Table 2, Results). The ordination (Figure 7, Results) confirmed this separation of species growing on rock and soil along a moisture gradient on the first axis. The second axis was less clear and seemed to partly reflect air humidity or shading, but also a weak pH gradient. When analysed separately, both the species on soil and the species on rock spread along a gradient influenced by nitrogen, which reflected either an unfertilized or fertilized condition. The second axis was a short moisture gradient for both cases.

4.2 Discussion of results

4.2.1 Ordinations

The assumption of the second axis in Figure 7 being a complex gradient was based on information about the ecology of the different species (Atherton et al., 2010, Frey et al., 2006, Hallingbäck et al., 2006, Hallingbäck et al., 2008, Heegaard, 1997, Porley, 2008, Smith, 2004, Watson, 1981), as well as the reports by Hill *et al.* (1999) and Hill *et al.* (2007). From the latter report I looked at the tables explaining different environmental variables, with examples of species found along these gradients of environmental variables. I specifically looked at the gradients for light, pH, moisture and nitrogen, and found that for Figure 7, the second axis seemed to be a combination of light, air humidity and a weak pH gradient. As mentioned in Results, this combination of gradients does not necessarily fit all the species in the ordination plot, as was the case with the species *Tortella tortuosa* and *Schistidium crassipilum*, which were placed high up in the ordination plot, when they 'should' have been placed further down according to the pH gradient. This mismatch of placement was also the case for the species *Andreaea rothii* and *Andreaea rupestris*, which are typically found on dry substrates (Heegaard, 1997).

For Figures 8-11 the axes were somewhat easier to interpret, as the gradients suited the species a bit better than in Figure 7. The first axis for both 'Rock' and 'Soil' was interpreted as a fertilizer gradient going from 'Unfertilized' to 'Fertilized'. The second axis for both 'Rock' and 'Soil' was interpreted as a short moisture gradient going from

‘Dry’ at the bottom to ‘Moist’ at the top. These gradients were reflected in the species found on the two substrates. More liverworts were found on ‘Soil’ than on ‘Rock’, and liverworts as well as species of *Sphagnum* spp. were found on the unfertilized side of the plot, in the moister areas. More species typically connected to richer habitats were found on ‘Rock’ than on ‘Soil’, and species such as *Tortella tortuosa* and *Schistidium crassipilum* were found on the unfertilized side of the plot, in the intermediately moist areas.

4.2.2 Unfertilized vs. fertilized

The results showed that there were two main factors affecting the species composition of bryophytes: (1) whether the bryophytes were growing in an unfertilized or fertilized pasture; and (2) whether they were growing on rock or on soil. It was quite clear from the results that the use of fertilizers did have an effect on the species composition of bryophytes, and that there were more bryophytes found in the unfertilized sites than in the fertilized sites. However, it is not possible to say which fertilizer treatment had the biggest effect of the species composition. A previous study done on bryophytes has shown that fertilizing does not necessarily inhibit growth. In an experiment by Salemaa *et al.* (2008), the growth responses of the three species *Hylocomium splendens*, *Pleurozium schreberi* and *Dicranum polysetum* were studied when exposed to different concentrations of nitrogen. They found that the growth increased gradually up to a maximum, and that it decreased at higher nitrogen supply levels. *Dicranum* showed the highest tolerance towards high nitrogen concentrations, followed by *Pleurozium* and then *Hylocomium*. This experiment showed that these bryophytes were able to use nitrogen for growth, given that they also had the right amount of light, moisture and temperature. The effects of fertilizers, and nitrogen in particular, on vegetation have been more closely studied in terms of airborne nitrogen and pollution (e.g. studies by Bobbink et al. (1998) and Flatberg et al. (1991)). A study from 1994 (Fremstad and Eilertsen) showed that the moss *Racomitrium lanuginosum* was an eligible biomonitor for nitrogen pollution. This study also pointed out how the influence of nitrogen affects the balance between *Racomitrium lanuginosum* and vascular plants, and especially how it leads to the growth of graminoids, which in turn will outgrow and shade out the moss layer.

4.2.3 Rock vs. soil

The fact that most species were found only on rock may suggest that growing conditions are more favourable on rocks than on soil, and that rock-growing species are less affected by fertilizers than soil-growing species. In addition to the effects of fertilizers, the two substrates undergo different types of disturbance, and provide different growth conditions for the bryophytes. It is plausible that bryophytes growing on rocks will be much less affected by competition than bryophytes growing on soil. Many rock-growing bryophytes are stress-tolerant due to their ability to survive desiccation and 'hibernate' (Bates, 2009). Rocks as substrates also provide for many microhabitats with varying degrees of moisture and light-exposure. The high number of species found on rocks correlates with the occurrence of many acrocarps with a certain desiccation tolerance, such as species of *Grimmia pulvinata* and *Hedwigia stellata*. But due to the relatively moist macroclimate of the study areas, moisture-demanding species such as *Campylopus atrovirens* and *Hypnum jutlandicum* were also found. These were probably found here due to the relatively moist macroclimate of the study area. The species that occur only on soil tend to be more moisture-demanding pleurocarps, as well as species of *Sphagnum* spp. and liverworts. Bryophytes growing on soil will be much more affected by competition from other species, and particularly from vascular plants, than will species growing on rocks. Nitrophilous grasses grow faster than bryophytes, and can shade out the bryophytes and dominate the substrate. This means that the soil-growing bryophytes are not necessarily disturbed by fertilizing directly, but that they suffer the consequences of this because fertilizing favours the growth of vascular plants (Glime, 2007). In addition there is also the aspect of the grazing, and the impact of the animals. Since the animals are grazing on the pasture, it is most likely here that the main disturbances of the substrate will occur. That is to say that the soil-growing species are more likely to be disturbed by animal tracking than the rock-growing species. The species found on both rock and soil are called 'generalists', and are typically pleurocarps with broad ecological niches such as the species *Sanionia uncinata*, *Hypnum cupressiforme* and *Racomitrium lanuginosum*.

4.3 Further work

If any further work were to be done in this field of study, I would aim to rectify some of the problems I came across during fieldwork and laboratory work, and do a more thorough investigation of the sites beforehand. I found that the surficial deposits of the six main areas I studied were different, and maybe to such a large degree that the results of pH values were not entirely comparable. A more thorough look at surficial deposit maps of Norway should therefore have been done to ensure that the selected study sites were as similar as possible.

Also, in conversation with the different farmers I found that the fertilizing regimes and fertilizers used were not exactly the same either, again making it more difficult to compare the results. The amounts of fertilizers used, as well as the type of fertilizers used, will probably influence which species can be found there, and also differ for the two substrates. There are for example several different types of artificial fertilizers available on the market, and they all contain different amounts of nitrogen, sodium, phosphorus and potassium (Felleskjøpet, 2012).

Another aspect of this study is of course the grazing aspect. It would be interesting to look closer at how grazing and animal tracking influence the species richness and species composition of bryophytes (e.g. work by Gornall et al. (2009)). It is plausible to think that animal tracking from larger animals such as cattle and horses can disturb the substrate, and create areas of bare soil for bryophytes to occupy. The amounts of animals grazing at any one point will also matter, as well as which types of animals that are grazing (i.e. larger animals will cause more damage to the substrate than smaller animals) (Staaland et al., 1998).

4.4 Conclusion

From the ordinations it is quite clear that fertilizers do have an effect on the species composition of bryophytes, both for species growing on rocks and species growing on soil. However, it is less evident which type of fertilizer has the largest impact on the species composition.

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6. APPENDIX

In the Appendix you can find figures and tables containing the raw data that I have collected during fieldwork. Such raw data includes site descriptions, the coverage of vascular plants and bryophytes for each of my plots, inclination and aspect data, and pH values for all my plots. Figures are listed first, and then tables.

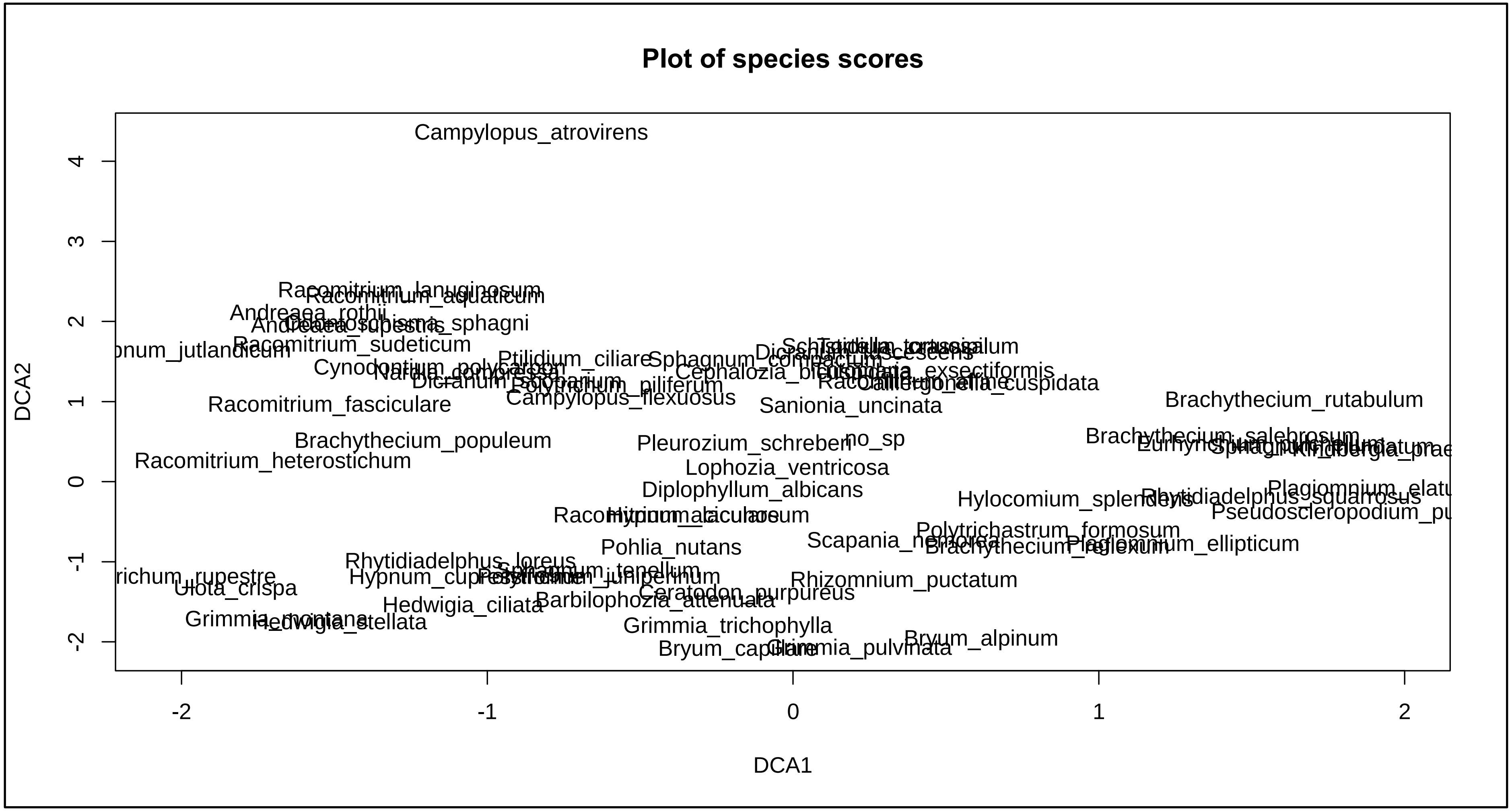

Figure A1: Original version of Figure 7b in Results.

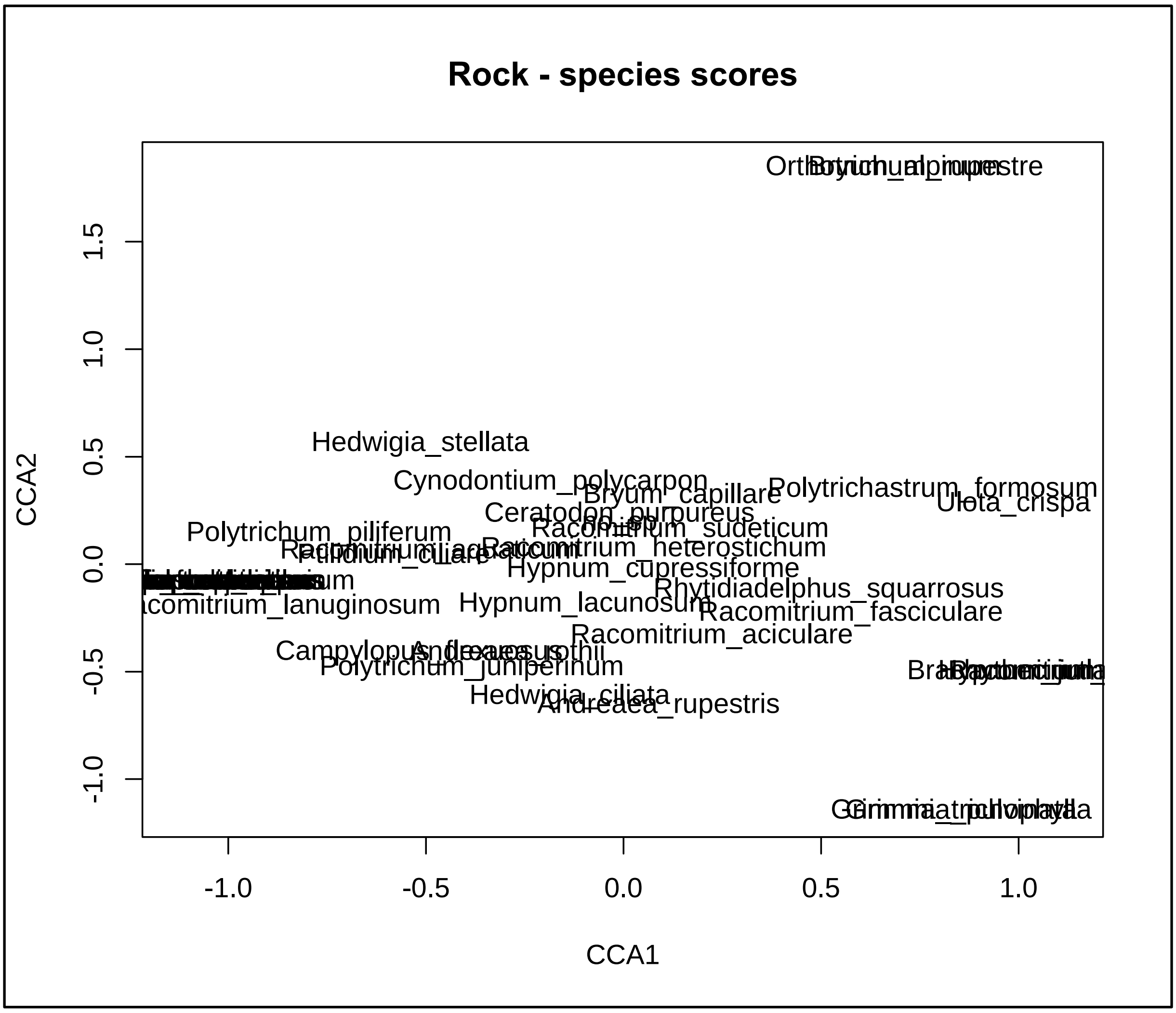

Figure A2: Original version of Figure 9 in Results.

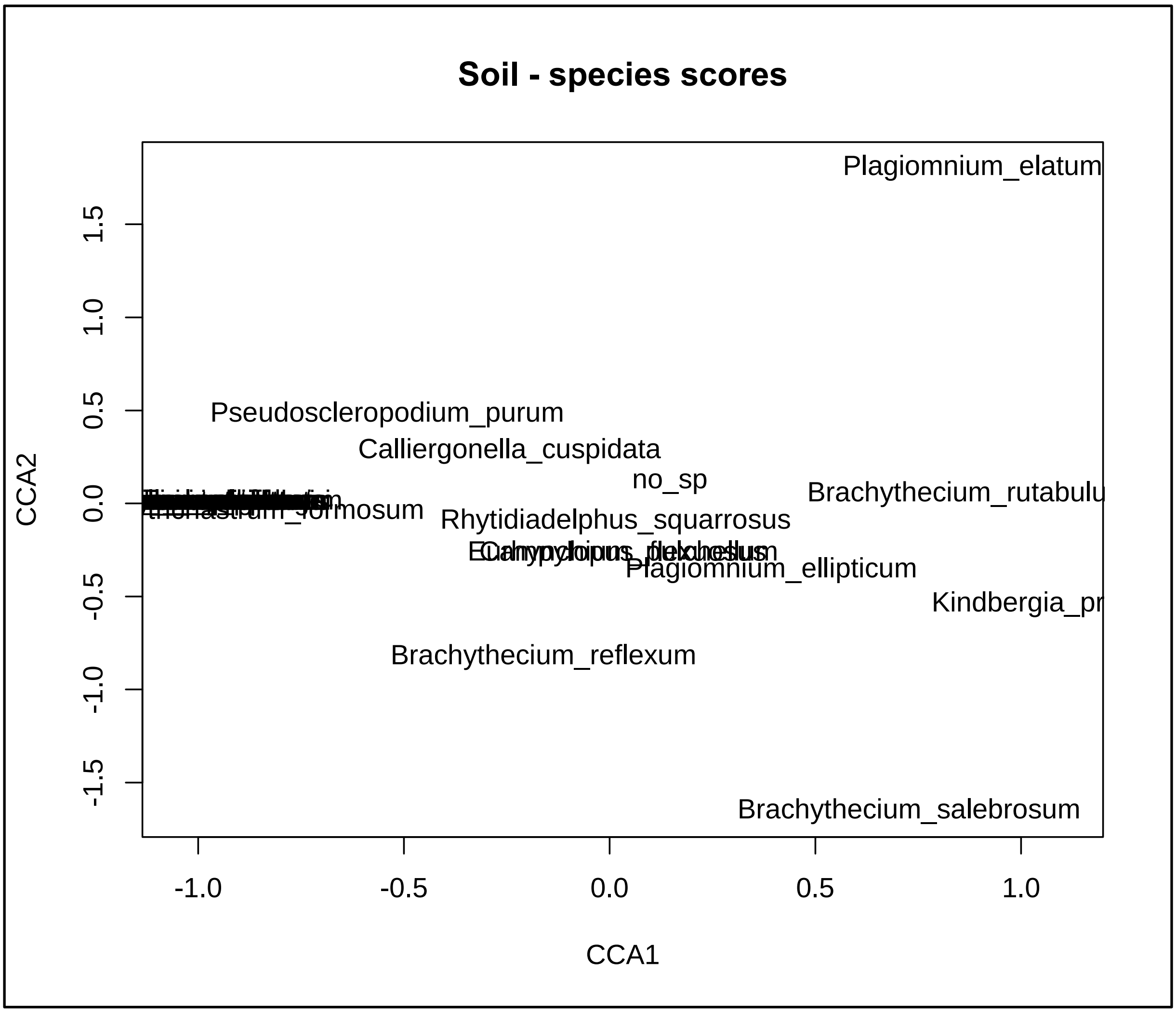

Figure A3: Original version of Figure 11 in Results.

```
###########################################################################################

#Importing the data
maria1.df<-read.table("clipboard",header=T)
summary(maria1.df)
names(maria1.df)
maria.df<-cbind(maria1.df,rep(1,1200))
colnames(maria.df)[65]<-"no_sp"
names(maria.df)

#Organizing the data for big quadrats and the smaller quadrats within each quadrat
art.df<-maria.df[,-c(1,2,3)]
rute<-maria.df[,2]
art.big<-art.df[rute==1,]
art.small<-art.df[rute==0,]

#Organizing the data for 'Rock' and 'Soil'
rock<-maria1.df[,3]
art.soil<-art.df[rock==0&rute==1,]
art.rock<-art.df[rock==1&rute==1,]
site<-maria1.df[,3]
rock.b<-rock[rute==1]

###########################################################################################

#Installing the 'vegan' library and the 'decorana' function, with downweighting of rare species
library(vegan)
decorana(downweight(art.big))

#Plot of data using CA
ca1<-cca(downweight(art.big))
plot(ca1)
title("Plot of entire data set")

#Plot of data using DCA
dca1<-decorana(downweight(art.big))
plot(dca1)
title("Plot of entire data set")

#Summary of DCA
s1<-summary(dca1)
site1<-s1[[4]]
sp1<-s1[[1]]
```

Figure A4a: R code used for statistical analyses.

```
#Plotting the site scores
plot(site1[,1],site1[,2],xlab="DCA1",ylab="DCA2",type="n")
points(site1[rock.b==1,1],site1[rock.b==1,2],pch=15,col="blue")
points(site1[rock.b==0,1],site1[rock.b==0,2],pch=15,col="red")
legend(1,1.6,pch=15,col=c("red","blue"),legend=c("Soil","Rock"))
title("Plot of site scores")
summary(site1[,1],site1[,2],xlab="DCA1",ylab="DCA2",type="n")

#Plotting the species scores
plot(sp1[,1],sp1[,2],xlab="DCA1",ylab="DCA2",type="n")
text(sp1[,1],sp1[,2],labels=colnames(art.big))
title("Plot of species scores")
summary(sp1[,1],sp1[,2],xlab="DCA1",ylab="DCA2",type="n")

############################################################################################

#Looking at environmental variables
env.df<-read.table("clipboard",header=T)
attach(env.df)

#pH
cca1<-cca(downweight(art.big)~pH.value,na.action=na.omit)
anova(cca1)

#Site
cca1<-cca(downweight(art.big)~factor(Site),na.action=na.omit)
anova(cca1)

#Rock
cca1<-cca(downweight(art.big)~Rock,na.action=na.omit)
anova(cca1)

#Fertilizers
cca1<-cca(downweight(art.big)~Manure+Artificial+Both+Unfertilized,na.action=na.omit)
anova(cca1)

#Do the terms add significance?
cca2<-cca(downweight(art.big)~Rock+Manure+Artificial+Both,na.action=na.omit)
anova(cca2,by="margin")

#Testing each interaction term
cca2<-cca(downweight(art.big)~Rock+Manure+Artificial+Both+Rock:Manure+Rock:Artificial+
      Rock:Both,na.action=na.omit)
anova(cca2,by="margin")
```

Figure A4b: R code used for statistical analyses.

```r
#####################################################################################################

#CCA Rock
s1<-summary(cca2)
site1<-s1[[2]]
sp1<-s1[[1]]

#Plotting CCA Rock for site scores
plot(cca2,main="Rock - site scores")
points(site1[Manure[Rock==1]==1,1],site1[Manure[Rock==1]==1,2],pch=15,col="red")
points(site1[Artificial[Rock==1]==1,1],site1[Artificial[Rock==1]==1,2],pch=15,col="blue")
points(site1[Both[Rock==1]==1,1],site1[Both[Rock==1]==1,2],pch=15,col="purple")
points(site1[Unfertilized[Rock==1]==1,1],site1[Unfertilized[Rock==1]==1,2],pch=15,col="green")
legend(-5,9,pch=15,col=c("blue","red","purple","green"),legend=c
	("Artificial","Manure","Both","Unfertilized"))

#Plotting CCA Rock for species scores
plot(sp1[,1],sp1[,2],xlab="CCA1",ylab="CCA2",type="n")
text(sp1[,1],sp1[,2],labels=rownames(sp1))
title("Rock - species scores")

#####################################################################################################

#CCA Soil
s1<-summary(cca3)
site1<-s1[[2]]
sp1<-s1[[1]]

#Plotting CCA Soil for site scores
plot(cca3,main="Soil - site scores")
points(site1[Manure[Rock==0]==1,1],site1[Manure[Rock==0]==1,2],pch=15,col="red")
points(site1[Artificial[Rock==0]==1,1],site1[Artificial[Rock==0]==1,2],pch=15,col="blue")
points(site1[Both[Rock==0]==1,1],site1[Both[Rock==0]==1,2],pch=15,col="purple")
points(site1[Unfertilized[Rock==0]==1,1],site1[Unfertilized[Rock==0]==1,2],pch=15,col="green")
legend(-5,9,pch=15,col=c("blue","red","purple","green"),legend=c
	("Artificial","Manure","Both","Unfertilized"))

#Plotting CCA Soil for species scores
plot(sp1[,1],sp1[,2],xlab="CCA1",ylab="CCA2",type="n")
text(sp1[,1],sp1[,2],labels=rownames(sp1))
title("Soil - species scores")

#####################################################################################################
```

Figure A4c: R code used for statistical analyses.

```
##########################################################################################

#Testing if there are significant differences between pH values of sites of different fertilizer treatments
ph.test<-read.table("clipboard",header=T)
fit.lm<-lm(ph.test[,2]~factor(ph.test[,1]))
anova(fit.lm)

##########################################################################################
```

Figure 4d: R code used for statistical analyses.

Table A1: Detailed descriptions of the sites, including information on which plants were growing in the area, the moisture conditions, the amount of animal droppings in each site and the amount of animal tracks, if any.

Municipality	Site	Fertilizer	Description
Sandnes	1	None	Unfertilized part of a bigger pasture. Quite a lot of *Juniperus* in the site, with both dry and moist areas. Surrounded by *Betula* forest. Tall grasses. Little animal faeces, which may indicate low grazing pressure.
	2	Manure	Rocks are acid-washed many places. Quite a lot of *Juniperus* in the pasture. *Betula* and *Picea* around. Also a lot of *Cirsium*, both one and two years old. Faeces scattered across the pasture, both from sheep and cattle. Proprietor says this area is not grazed as much as the others. Intermediately moist.
	3	None	Unfertilized area lying between two fertilized areas. Sward is more yellow in colour than fertilized areas. Some *Juniperus* around the area. Also saw *Campanula rotundifolia*, *Anthoxanthum odoratum*, *Leonthodon autumnalis* and *Rumex acetosella*. Fairly dry, the area is a hill. Little faeces in the area.
	4	Artificial	Artificial fertilizer used in this area. Surrounded by *Betula* forest. Also some *Juniperus* in the area, and one *Sorbus aucuparia*. The area is a hill reaching up to a mountain and a forest. There is also a lot of *Cirsium* in the pasture, and the sward is green. A lot of *Stellaria media*, intermitted with *Cerastium fontanum*. Neither very moist nor very dry, but more moist than dry.
	5	None	Mire-type vegetation, quite moist. Hill with mire below. Plots were taken from the hill. A lot of *Juniperus* in the hill, also some *Betula* and *Sorbus aucuparia*. Tufts of grass scattered around the area, found species of heather (*Erica tetralix* and *Calluna vulgaris*), as well as *Narthecium ossifragum*. Faeces from both sheep and cattle.
	6	Manure	On a hill. Surrounded by *Betula*, also some *Sorbus aucuparia* and *Juniperus*. Rocks are white as a result of fertilizing. In the pasture: *Achillea millefolium*, *Leonthodon autumnalis*, *Stellaria graminea*, *Cirsium* sp., *Plantago major*, *Campanula rotundifolia*, *Potentilla erecta*, *Rumex acetosella*, *Stellaria media*, *Juncus conglomeratus* and *Ranunculus*. Areas with grasses in tufts, otherwise short sward. Saw cow pats at regular intervals. Intermediately moist, not very moist on the hill.
	7	Artificial	Lots of rocks in the pasture. Both sheep and cattle graze here. Surrounded by *Betula* forest, and also some *Sorbus aucuparia*. Some *Juniperus* in the pasture. Also saw *Stellaria media*, *Cirsium* sp., *Leonthodon autumnalis*, *Ranunculus acris*, *Trifolium repens*, *Rumex acetosella*, *Campanula rotundifolia*, *Potentilla erecta* and *Juncus conglomeratus*. Intermediately moist. The area is a hill which flattens out towards a river. Faeces both from sheep and cattle in the pasture.
	8	Artificial	Lots of rocks in the pasture. Surrounded by *Betula*, *Juniperus*, *Quercus* and *Sorbus aucuparia* in the pasture. Lots of *Stellaria media* and tufts of grass. Also saw *Cirsium* and *Ranunculus acris*. Moist area.
Rennesøy	9	None	Area by the sea. Very little *Juniperus*, *Picea* and *Sorbus aucuparia* in the pasture. Some *Corylus* by the fence. Very short sward, more yellow than the other areas. Faeces scattered across the pasture. Surrounded by rock fence, but with gaps so livestock can walk freely between the pastures. Rocks in the pasture, might be rich bedrock. Looks like compressed slate. Could the area be affected by its proximity to the sea? Lots of rain this day.
	10	None	Area by the sea. Was fertilized three to four years ago. *Sorbus aucuparia*, *Juniperus*, *Betula* and *Corylus* in the pasture. Sward

			slightly taller here than in site 9. Quite a lot of rocks in the pasture. Faeces from both sheep and cattle in the pasture. Also saw *Prunella vulgaris*, *Potentilla erecta*, *Calluna vulgaris*, *Leonthodon autumnalis*, *Ranunculus acris*, *Juncus conglomeratus*, *Campanula rotundifolia*, *Nardus stricta* and *Viola palustris*. Area also used as hiking/recreational area.
	11	None	Long area lying between a mountain on the one side and the sea on the other side. Sheep and cattle graze here, faeces scattered across the area. Never been fertilized before. Some *Sorbus aucuparia* and *Juniperus* in the pasture, and a forest along the mountain containing *Corylus*, plus a tree I did not recognise. Rocks in the pasture. Also saw some *Cirsium* sp., *Potentilla erecta*, *Nardus stricta*, *Achillea millefolium* and *Anthoxanthum odoratum*. Area also used as hiking/recreational area.
	12	Both	Short sward, quite a lot of *Stellaria media*. Surrounded by stone fence, but with gaps so the animals can walk freely between the pastures. Some *Cirsium* sp., also some *Sorbus aucuparia* and *Corylus* by the fence. Few rocks in the pasture. Sheep faeces scattered across the pasture. Area also used as hiking/recreational area.
	13	Both	Very short sward, some *Cirsium* sp. and *Stellaria media* in the pasture, few rocks. Faeces scattered across the pasture. Lots of *Achillea millefolium* and *Trifolium repens*. Uneven terrain with lots of bumps, and there seems to be more bryophytes on these than on the ground. Area also used as hiking/recreational area.
	14	Artificial	Very few trees, some *Sorbus aucuparia* by the fence. Area is surrounded by stone fence, but with gaps to allow animals to walk freely among the pastures. No rocks in the pasture, only on the part that was not fertilized. Faeces scattered across pasture. Only sheep graze. Relatively dry. A lot of *Leonthodon autumnalis*, little *Stellaria media*. Green sward with both short and tall grass.
	15	Artificial	Relatively dry, but with moist areas. Lots of *Leonthodon autumnalis*, very little *Stellaria media*. Faeces scattered across the pasture, only from sheep. No rocks except for a vertical cliff that was not studied. No trees except for some *Sorbus aucuparia* by the fence. Green grass.
	16	None	Unfertilized area, but was fertilized three years ago with artificial fertilizer. Both dry and moist areas, with tufts of grass. Yellowish green sward, quite a lot of rocks in the pasture. Grazed by sheep, faeces scattered across the pasture. Uneven terrain, lots of bumps. Also saw *Campanula rotundifolia*, *Juncus conglomeratus*, *Leonthodon autumnalis*, *Achillea millefolium*, *Viola palustris*, one *Juniperus* and some *Sorbus aucuparia* and *Betula* by the fence.
	17	Both	Short sward, green. Rocks in the pasture. Intermediately moist, with some wetter areas. Also saw *Stellaria media*, *Achillea millefolium*, *Lepidotheca suaveolens*, *Rumex* sp. (large leaves, no flowers), *Leonthodon autumnalis*, *Rumex acetosella*, *Capsella bursa-pastoris*, some *Cirsium* sp. and *Sorbus aucuparia* by the fence. Area is surrounded by stone fence, with gates opened and closed by the farmer.
	18	None	Bordering on the ocean. Lots of *Juniperus*, rocks protrude from the ground. Richer area, lots of shrubs and low plants. Lots of lichen on the rocks. Short to medium sward, yellowish-green. Quite a lot of wetter areas. Little faeces. Saw *Drosera rotundifolia*.
Gjesdal	19	Both	Tall sward, lots of rocks in the pasture. Grazed by sheep. Area surrounded by *Betula*, *Sorbus aucuparia* and *Corylus* by the

			fences. Yellowish-green colour. Also saw *Leonthodon autumnalis*, *Campanula rotundifolia*, *Cerastium fontanum*, *Cirsium* sp., *Silene* sp., *Rumex longifolius*, *Rumex acetosella* and *Populus tremula*. Little faeces.
	20	Both	Sward is short and very green. Lots of *Stellaria media*, *Lepidotheca suaveolens* and *Trifolium repens*. Faeces scattered across the pasture. Relatively dry area, and forms a slope to the south.
	21	None	Area on mountaintop. Very little faeces. Lots of tall grass, and a lot of *Juniperus* and *Betula* in the pasture. Quite dry. Some species of heather. Also *Narthecium ossifragum*, *Campanula rotundifolia*, *Potentilla erecta* and a species of *Eriophorum*. Very yellowish-green, some brown and a lot of dead matter as well.
	22	Both	Grazed by sheep, faeces scattered across the pasture. Lots of rocks. Stone fence surrounding the area, but with gaps to allow the animals to walk freely between areas. Very green, some *Juniperus* in the pasture. Intermediately moist, some *Cirsium* sp., *Lepidotheca suaveolens* and *Stellaria media*.
	23	Artificial	Only cattle graze, faeces scattered across the pasture. Some damage to the soil due to animal tracking. Some *Betula* and *Juniperus* in the pasture, and some rocks. Also saw *Ranunculus acris*, *Taraxacum* sp., *Capsella bursa-pastoris*, *Cerastium fontanum*, *Rumex longifolius*, *Rumex acetosa* and *Trifolium repens*. Both short and tall grass, area surrounded by forest on the northern side by the water.
	24	Manure	Grazed by sheep. Faeces scattered across the area, but not much. Some *Juniperus* in the pasture, and some rocks. Both tall and short grasses, yellowish-green of colour. Also saw *Leonthodon autumnalis*, *Anthoxanthum odoratum* and *Nardus stricta*.
	25	None	Very tall grass. Lots of dead heather and grass, and quite a lot of *Juniperus*. Lies by Limavatnet. Few rocks, almost no animal faeces. Grazed by sheep. Also saw *Calluna vulgaris*, *Erica tetralix*, *Molinia caerulea*, *Potentilla erecta*, *Campanula rotundifolia*, *Narthecium ossifragum* and *Succisa pratensis*.

Table A2: Coverage of bryophytes, vascular plants, lichens, rock, faeces, bare soil and dead material for each quadrat plot. By 'dead material' is meant any withered or dead bryophytes, vascular plants and lichens.

Plot	Municipality	Fertilizer	Substrate	Percentage of cover per quadrat plot								SUM
				Bryophytes	Herbs	Graminoids	Lichens	Rock	Faeces	Bare soil	Dead material	
01.01	Sandnes	None	Soil	40	10	50	0	0	0	0	0	100
01.02	Sandnes	None	Soil	40	30	30	0	0	0	0	0	100
01.03	Sandnes	None	Soil	50	10	40	0	0	0	0	0	100
01.04	Sandnes	None	Soil	30	20	50	0	0	0	0	0	100
01.05	Sandnes	None	Soil	50	<5	50	0	0	0	0	0	100
01.06	Sandnes	None	Rock	60	<5	5	5	30	0	0	0	100
01.07	Sandnes	None	Rock	45	0	0	15	40	0	0	0	100
01.08	Sandnes	None	Rock	30	0	0	5	65	0	0	0	100
01.09	Sandnes	None	Rock	60	0	0	10	30	0	0	0	100
01.10	Sandnes	None	Rock	25	0	0	10	65	0	0	0	100
02.01	Sandnes	Manure	Soil	<5	30	65	0	0	<5	0	0	95
02.02	Sandnes	Manure	Soil	<5	20	80	0	0	0	0	0	100
02.03	Sandnes	Manure	Soil	<5	45	55	0	0	0	0	0	100
02.04	Sandnes	Manure	Soil	40	20	40	0	0	0	0	0	100
02.05	Sandnes	Manure	Soil	<5	20	75	0	0	5	0	0	100
02.06	Sandnes	Manure	Rock	60	0	0	0	40	0	0	0	100
02.07	Sandnes	Manure	Rock	<5	0	0	0	100	0	0	0	100
02.08	Sandnes	Manure	Rock	20	0	0	0	80	0	0	0	100
02.09	Sandnes	Manure	Rock	15	0	10	5	70	0	0	0	100
02.10	Sandnes	Manure	Rock	40	<5	20	5	35	0	0	0	100
03.01	Sandnes	None	Rock	25	0	0	20	55	0	0	0	100
03.02	Sandnes	None	Rock	15	0	0	<5	85	0	0	0	100
03.03	Sandnes	None	Rock	10	0	0	40	50	0	0	0	100
03.04	Sandnes	None	Rock	5	0	0	20	75	0	0	0	100
03.05	Sandnes	None	Rock	10	0	0	60	30	0	0	0	100
03.06	Sandnes	None	Soil	20	10	70	0	0	0	0	0	100
03.07	Sandnes	None	Soil	40	10	50	0	0	0	0	0	100

03.08	Sandnes	None	Soil	50	20	30	0	0	0	0	0	100
03.09	Sandnes	None	Soil	40	20	40	0	0	0	0	0	100
03.10	Sandnes	None	Soil	40	5	55	0	0	0	0	0	100
04.01	Sandnes	Artificial	Soil	<5	80	20	0	0	0	0	0	100
04.02	Sandnes	Artificial	Soil	0	35	55	0	0	5	5	0	100
04.03	Sandnes	Artificial	Soil	40	20	40	0	0	0	0	0	100
04.04	Sandnes	Artificial	Soil	<5	20	80	0	0	<5	0	0	100
04.05	Sandnes	Artificial	Soil	10	10	80	0	0	0	0	0	100
04.06	Sandnes	Artificial	Rock	50	0	0	5	45	0	0	0	100
04.07	Sandnes	Artificial	Rock	20	0	0	20	60	0	0	0	100
04.08	Sandnes	Artificial	Rock	40	0	0	30	30	0	0	0	100
04.09	Sandnes	Artificial	Rock	30	0	10	25	60	0	0	0	125
04.10	Sandnes	Artificial	Rock	60	0	0	10	30	<5	0	0	100
05.01	Sandnes	None	Soil	5	10	60	0	0	25	0	0	100
05.02	Sandnes	None	Soil	60	15	25	0	0	0	0	0	100
05.03	Sandnes	None	Soil	50	20	30	0	0	0	0	0	100
05.04	Sandnes	None	Soil	10	10	35	0	0	0	45	0	100
05.05	Sandnes	None	Soil	60	20	20	0	0	0	0	0	100
05.06	Sandnes	None	Rock	<5	0	0	80	20	0	0	0	100
05.07	Sandnes	None	Rock	50	0	0	10	40	0	0	0	100
05.08	Sandnes	None	Rock	20	0	<5	10	70	0	0	0	100
05.09	Sandnes	None	Rock	50	20	10	10	10	0	0	0	100
05.10	Sandnes	None	Rock	<5	0	0	5	95	0	0	0	100
06.01	Sandnes	Manure	Soil	40	20	40	0	0	0	0	0	100
06.02	Sandnes	Manure	Soil	10	25	65	0	0	0	0	0	100
06.03	Sandnes	Manure	Soil	0	40	40	0	0	20	0	0	100
06.04	Sandnes	Manure	Soil	20	20	60	0	0	0	0	0	100
06.05	Sandnes	Manure	Soil	60	30	10	0	0	0	0	0	100
06.06	Sandnes	Manure	Rock	40	0	<5	<5	55	0	0	0	95
06.07	Sandnes	Manure	Rock	5	0	0	40	55	0	0	0	100
06.08	Sandnes	Manure	Rock	5	0	0	0	95	0	0	0	100
06.09	Sandnes	Manure	Rock	50	0	0	<5	50	0	0	0	100

06.10	Sandnes	Manure	Rock	15	0	0	5	80	0	0	0	100
07.01	Sandnes	Artificial	Soil	40	30	30	0	0	0	0	0	100
07.02	Sandnes	Artificial	Soil	15	40	45	0	0	0	0	0	100
07.03	Sandnes	Artificial	Soil	80	5	15	0	0	0	0	0	100
07.04	Sandnes	Artificial	Soil	15	40	20	0	0	5	20	0	100
07.05	Sandnes	Artificial	Soil	30	10	60	0	0	0	0	0	100
07.06	Sandnes	Artificial	Rock	10	0	0	40	50	0	0	0	100
07.07	Sandnes	Artificial	Rock	5	0	0	85	10	0	0	0	100
07.08	Sandnes	Artificial	Rock	15	0	0	50	35	0	0	0	100
07.09	Sandnes	Artificial	Rock	25	0	0	20	55	0	0	0	100
07.10	Sandnes	Artificial	Rock	40	0	10	5	45	0	0	0	100
08.01	Sandnes	Artificial	Soil	<5	50	50	0	0	0	0	0	100
08.02	Sandnes	Artificial	Soil	5	15	80	0	0	0	0	0	100
08.03	Sandnes	Artificial	Soil	80	10	10	0	0	0	0	0	100
08.04	Sandnes	Artificial	Soil	<5	5	95	0	0	0	0	0	100
08.05	Sandnes	Artificial	Soil	5	10	85	0	0	<5	0	0	100
08.06	Sandnes	Artificial	Rock	40	<5	5	45	10	0	0	0	100
08.07	Sandnes	Artificial	Rock	25	0	0	5	70	0	0	0	100
08.08	Sandnes	Artificial	Rock	<5	0	0	40	60	0	0	0	100
08.09	Sandnes	Artificial	Rock	90	0	0	<5	10	0	0	0	100
08.10	Sandnes	Artificial	Rock	20	0	0	10	70	0	0	0	100
09.01	Rennesøy	None	Soil	60	20	20	0	0	0	0	0	100
09.02	Rennesøy	None	Soil	10	20	70	0	0	<5	0	0	100
09.03	Rennesøy	None	Soil	15	40	45	0	0	0	0	0	100
09.04	Rennesøy	None	Soil	10	10	80	0	0	0	0	0	100
09.05	Rennesøy	None	Soil	60	<5	40	0	0	0	0	0	100
09.06	Rennesøy	None	Rock	10	<5	0	60	30	0	0	0	100
09.07	Rennesøy	None	Rock	10	5	5	60	20	0	0	0	100
09.08	Rennesøy	None	Rock	10	<5	10	20	60	0	0	0	100
09.09	Rennesøy	None	Rock	0	0	0	20	80	0	0	0	100
09.10	Rennesøy	None	Rock	25	<5	5	15	55	0	0	0	100
10.01	Rennesøy	None	Soil	5	15	80	0	0	<5	0	0	100

10.02	Rennesøy	None	Soil	15	25	60	0	0	0	0	0	100
10.03	Rennesøy	None	Soil	70	10	20	0	0	0	0	0	100
10.04	Rennesøy	None	Soil	15	5	80	0	0	0	0	0	100
10.05	Rennesøy	None	Soil	25	15	60	0	0	<5	0	0	100
10.06	Rennesøy	None	Rock	25	0	0	15	60	0	0	0	100
10.07	Rennesøy	None	Rock	5	0	5	80	10	0	0	0	100
10.08	Rennesøy	None	Rock	40	<5	15	10	35	0	0	0	100
10.09	Rennesøy	None	Rock	30	5	10	5	50	0	0	0	100
10.10	Rennesøy	None	Rock	20	5	10	20	45	0	0	0	100
11.01	Rennesøy	None	Soil	60	15	25	0	0	0	0	0	100
11.02	Rennesøy	None	Soil	15	20	60	0	0	5	0	0	100
11.03	Rennesøy	None	Soil	20	10	70	0	0	0	0	0	100
11.04	Rennesøy	None	Soil	15	20	65	0	0	0	0	0	100
11.05	Rennesøy	None	Soil	20	40	40	0	0	0	0	0	100
11.06	Rennesøy	None	Rock	40	0	<5	20	40	0	0	0	100
11.07	Rennesøy	None	Rock	20	0	0	<5	80	0	0	0	100
11.08	Rennesøy	None	Rock	25	<5	<5	5	65	0	0	0	95
11.09	Rennesøy	None	Rock	40	0	0	<5	60	0	0	0	100
11.10	Rennesøy	None	Rock	30	<5	0	15	55	0	0	0	100
12.01	Rennesøy	Both	Soil	0	50	50	0	0	<5	0	0	100
12.02	Rennesøy	Both	Soil	0	15	80	0	0	5	0	0	100
12.03	Rennesøy	Both	Soil	0	10	90	0	0	0	0	0	100
12.04	Rennesøy	Both	Soil	0	40	60	0	0	0	0	0	100
12.05	Rennesøy	Both	Soil	20	10	70	0	0	0	0	0	100
12.06	Rennesøy	Both	Rock	<5	0	0	50	50	0	0	0	100
12.07	Rennesøy	Both	Rock	15	0	20	10	55	<5	0	0	100
12.08	Rennesøy	Both	Rock	0	0	0	40	60	0	0	0	100
12.09	Rennesøy	Both	Rock	10	0	<5	80	10	0	0	0	100
12.10	Rennesøy	Both	Rock	0	0	0	60	40	0	0	0	100
13.01	Rennesøy	Both	Soil	20	20	60	0	0	0	0	0	100
13.02	Rennesøy	Both	Soil	10	40	35	0	0	15	0	0	100
13.03	Rennesøy	Both	Soil	60	10	30	0	0	0	0	0	100

13.04	Rennesøy	Both	Soil	5	20	75	0	0	0	0	0	100
13.05	Rennesøy	Both	Soil	30	15	55	0	0	0	0	0	100
13.06	Rennesøy	Both	Rock	25	<5	10	25	40	<5	0	0	100
13.07	Rennesøy	Both	Rock	0	0	0	95	5	0	0	0	100
13.08	Rennesøy	Both	Rock	0	0	0	5	95	0	0	0	100
13.09	Rennesøy	Both	Rock	5	0	<5	40	55	0	0	0	100
13.10	Rennesøy	Both	Rock	10	0	0	40	50	0	0	0	100
14.01	Rennesøy	Artificial	Soil	5	20	75	0	0	<5	0	0	100
14.02	Rennesøy	Artificial	Soil	<5	50	50	0	0	<5	0	0	100
14.03	Rennesøy	Artificial	Soil	0	35	60	0	0	5	0	0	100
14.04	Rennesøy	Artificial	Soil	5	20	75	0	0	<5	0	0	100
14.05	Rennesøy	Artificial	Soil	<5	40	55	0	0	<5	0	0	95
15.01	Rennesøy	Artificial	Soil	0	20	80	0	0	0	0	0	100
15.02	Rennesøy	Artificial	Soil	5	15	80	0	0	0	0	0	100
15.03	Rennesøy	Artificial	Soil	0	15	80	0	0	5	0	0	100
15.04	Rennesøy	Artificial	Soil	0	15	85	0	0	0	0	0	100
15.05	Rennesøy	Artificial	Soil	10	20	70	0	0	0	0	0	100
16.01	Rennesøy	None	Soil	<5	5	95	0	0	0	0	0	100
16.02	Rennesøy	None	Soil	<5	50	45	<5	0	0	0	0	95
16.03	Rennesøy	None	Soil	5	15	80	0	0	0	0	0	100
16.04	Rennesøy	None	Soil	10	40	50	<5	0	0	0	0	100
16.05	Rennesøy	None	Soil	30	15	55	0	0	0	0	0	100
16.06	Rennesøy	None	Rock	20	<5	<5	20	55	0	0	0	95
16.07	Rennesøy	None	Rock	35	<5	5	55	5	0	0	0	100
16.08	Rennesøy	None	Rock	<5	0	0	95	5	0	0	0	100
16.09	Rennesøy	None	Rock	60	5	<5	10	25	0	0	0	100
16.10	Rennesøy	None	Rock	0	0	0	90	10	0	0	0	100
17.01	Rennesøy	Both	Soil	<5	40	60	0	0	0	0	0	100
17.02	Rennesøy	Both	Soil	0	10	90	0	0	<5	0	0	100
17.03	Rennesøy	Both	Soil	0	10	90	0	0	<5	0	0	100
17.04	Rennesøy	Both	Soil	<5	60	40	0	0	0	0	0	100
17.05	Rennesøy	Both	Soil	0	30	70	0	0	<5	0	0	100

17.06	Rennesøy	Both	Rock	15	<5	<5	5	80	0	0	0	100
17.07	Rennesøy	Both	Rock	50	5	15	30	<5	0	0	0	100
17.08	Rennesøy	Both	Rock	0	0	0	10	90	0	0	0	100
17.09	Rennesøy	Both	Rock	20	0	0	10	70	0	0	0	100
17.10	Rennesøy	Both	Rock	5	0	0	10	85	0	0	0	100
18.01	Rennesøy	None	Soil	40	20	40	0	0	0	0	0	100
18.02	Rennesøy	None	Soil	20	20	60	0	0	0	0	0	100
18.03	Rennesøy	None	Soil	60	20	20	0	0	0	0	0	100
18.04	Rennesøy	None	Soil	20	20	55	0	0	0	5	0	100
18.05	Rennesøy	None	Soil	10	20	70	0	0	0	0	0	100
18.06	Rennesøy	None	Rock	15	<5	<5	40	40	0	0	0	95
18.07	Rennesøy	None	Rock	60	<5	<5	<5	30	<5	0	0	90
18.08	Rennesøy	None	Rock	0	0	0	90	10	0	0	0	100
18.09	Rennesøy	None	Rock	40	0	0	10	50	0	0	0	100
18.10	Rennesøy	None	Rock	<5	0	0	95	5	0	0	0	100
19.01	Gjesdal	Both	Soil	5	10	85	0	0	0	0	0	100
19.02	Gjesdal	Both	Soil	10	5	85	0	0	0	0	0	100
19.03	Gjesdal	Both	Soil	0	5	95	0	0	0	0	0	100
19.04	Gjesdal	Both	Soil	0	5	95	0	0	0	0	0	100
19.05	Gjesdal	Both	Soil	20	10	60	0	0	0	10	0	100
19.06	Gjesdal	Both	Rock	30	0	0	<5	70	0	0	0	100
19.07	Gjesdal	Both	Rock	10	0	0	85	5	0	0	0	100
19.08	Gjesdal	Both	Rock	<5	0	0	80	20	0	0	0	100
19.09	Gjesdal	Both	Rock	5	0	0	80	15	0	0	0	100
19.10	Gjesdal	Both	Rock	40	0	<5	55	<5	0	0	0	95
20.01	Gjesdal	Both	Soil	<5	45	50	0	0	<5	0	0	95
20.02	Gjesdal	Both	Soil	0	10	90	0	0	0	0	0	100
20.03	Gjesdal	Both	Soil	15	15	70	<5	0	0	0	0	100
20.04	Gjesdal	Both	Soil	5	10	85	0	0	0	0	0	100
20.05	Gjesdal	Both	Soil	20	10	70	0	0	0	0	0	100
20.06	Gjesdal	Both	Rock	0	0	0	50	50	0	0	0	100
20.07	Gjesdal	Both	Rock	50	0	0	45	5	0	0	0	100

20.08	Gjesdal	Both	Rock	0	0	0	30	70	0	0	0	100
20.09	Gjesdal	Both	Rock	<5	0	0	95	5	0	0	0	100
20.10	Gjesdal	Both	Rock	5	0	0	80	15	0	0	0	100
21.01	Gjesdal	None	Soil	0	10	70	0	0	0	0	20	100
21.02	Gjesdal	None	Soil	15	15	50	0	0	0	0	20	100
21.03	Gjesdal	None	Soil	10	20	60	0	0	0	0	10	100
21.04	Gjesdal	None	Soil	60	10	30	0	0	0	0	0	100
21.05	Gjesdal	None	Soil	<5	5	95	0	0	0	0	0	100
21.06	Gjesdal	None	Rock	0	0	0	95	5	0	0	0	100
21.07	Gjesdal	None	Rock	20	0	0	60	20	0	0	0	100
21.08	Gjesdal	None	Rock	0	0	0	85	15	<5	0	0	100
21.09	Gjesdal	None	Rock	<5	0	0	40	60	0	0	0	100
21.10	Gjesdal	None	Rock	15	0	<5	5	75	<5	0	0	95
22.01	Gjesdal	Both	Soil	<5	15	85	<5	0	0	0	0	100
22.02	Gjesdal	Both	Soil	40	15	45	0	0	0	0	0	100
22.03	Gjesdal	Both	Soil	0	50	50	0	0	0	0	0	100
22.04	Gjesdal	Both	Soil	0	40	60	0	0	0	0	0	100
22.05	Gjesdal	Both	Soil	35	10	55	0	0	0	0	0	100
22.06	Gjesdal	Both	Rock	30	0	0	30	40	0	0	0	100
22.07	Gjesdal	Both	Rock	0	0	0	70	30	0	0	0	100
22.08	Gjesdal	Both	Rock	5	0	0	75	20	0	0	0	100
22.09	Gjesdal	Both	Rock	5	0	0	75	20	0	0	0	100
22.10	Gjesdal	Both	Rock	0	0	0	40	60	0	0	0	100
23.01	Gjesdal	Artificial	Soil	5	40	50	0	0	0	5	0	100
23.02	Gjesdal	Artificial	Soil	0	10	50	0	0	0	40	0	100
23.03	Gjesdal	Artificial	Soil	<5	25	75	0	0	0	0	0	100
23.04	Gjesdal	Artificial	Soil	20	20	60	0	0	0	0	0	100
23.05	Gjesdal	Artificial	Soil	0	10	90	0	0	0	0	0	100
23.06	Gjesdal	Artificial	Rock	30	0	0	15	55	0	0	0	100
23.07	Gjesdal	Artificial	Rock	5	0	0	85	10	0	0	0	100
23.08	Gjesdal	Artificial	Rock	50	0	0	10	40	0	0	0	100
23.09	Gjesdal	Artificial	Rock	20	15	0	10	55	0	0	0	100

23.10	Gjesdal	Artificial	Rock	50	0	0	30	20	0	0	0	100
24.01	Gjesdal	Manure	Soil	60	5	35	0	0	0	0	0	100
24.02	Gjesdal	Manure	Soil	85	<5	15	0	0	<5	0	0	100
24.03	Gjesdal	Manure	Soil	15	15	70	0	0	<5	0	0	100
24.04	Gjesdal	Manure	Soil	30	15	55	0	0	0	0	0	100
24.05	Gjesdal	Manure	Soil	30	40	30	0	0	0	0	0	100
24.06	Gjesdal	Manure	Rock	20	0	0	50	30	<5	0	0	100
24.07	Gjesdal	Manure	Rock	15	0	0	10	75	0	0	0	100
24.08	Gjesdal	Manure	Rock	15	0	<5	80	<5	0	0	0	95
24.09	Gjesdal	Manure	Rock	15	0	0	65	20	0	0	0	100
24.10	Gjesdal	Manure	Rock	15	0	0	40	45	0	0	0	100
25.01	Gjesdal	None	Soil	10	<5	40	0	0	0	0	50	100
25.02	Gjesdal	None	Soil	5	5	80	0	0	0	0	10	100
25.03	Gjesdal	None	Soil	80	0	20	0	0	0	0	0	100
25.04	Gjesdal	None	Soil	0	15	85	0	0	0	0	0	100
25.05	Gjesdal	None	Soil	10	5	85	0	0	0	0	0	100
25.06	Gjesdal	None	Rock	0	0	0	95	5	0	0	0	100
25.07	Gjesdal	None	Rock	40	0	0	40	20	0	0	0	100
25.08	Gjesdal	None	Rock	25	0	0	10	65	0	0	0	100
25.09	Gjesdal	None	Rock	10	0	0	70	20	0	0	0	100
25.10	Gjesdal	None	Rock	10	0	0	40	50	0	0	0	100

Table A3: GPS coordinates, aspect and inclination for each plot.

Plot	Municipality	Fertilizer	Substrate	Date	Grid	Position	Aspect	Inclination
01.01	Sandnes	None	Soil	2013-08-08	UTM-UPS. WGS 84	32 V 0321387 6529537	60	10
01.02	Sandnes	None	Soil	2013-08-08	UTM-UPS. WGS 84	32 V 0321391 6529543	60	15
01.03	Sandnes	None	Soil	2013-08-08	UTM-UPS. WGS 84	32 V 0321382 6529570	50	20
01.04	Sandnes	None	Soil	2013-08-09	UTM-UPS. WGS 84	32 V 0321370 6529558	65	15
01.05	Sandnes	None	Soil	2013-08-09	UTM-UPS. WGS 84	32 V 0321355 6529558	80	10
01.06	Sandnes	None	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321350 6529559	295	20
01.07	Sandnes	None	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321362 6529555	105	30
01.08	Sandnes	None	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321376 6529551	105	20
01.09	Sandnes	None	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321381 6529545	35	10
01.10	Sandnes	None	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321365 6529565	120	20
02.01	Sandnes	Manure	Soil	2013-08-09	UTM-UPS. WGS 84	32 V 0321527 6529513	35	5
02.02	Sandnes	Manure	Soil	2013-08-09	UTM-UPS. WGS 84	32 V 0321514 6529508	80	10
02.03	Sandnes	Manure	Soil	2013-08-09	UTM-UPS. WGS 84	32 V 0321520 6529496	50	5
02.04	Sandnes	Manure	Soil	2013-08-09	UTM-UPS. WGS 84	32 V 0321543 6529479	290	15
02.05	Sandnes	Manure	Soil	2013-08-09	UTM-UPS. WGS 84	32 V 0321560 6529482	10	5
02.06	Sandnes	Manure	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321570 6529483	360	35
02.07	Sandnes	Manure	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321548 6529497	195	20
02.08	Sandnes	Manure	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321542 6529524	15	45
02.09	Sandnes	Manure	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321561 6529549	115	20
02.10	Sandnes	Manure	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321569 6529537	330	5
03.01	Sandnes	None	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321564 6529672	350	10
03.02	Sandnes	None	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321563 6529668	120	60
03.03	Sandnes	None	Rock	2013-08-09	UTM-UPS. WGS 84	32 V 0321567 6529661	400	30
03.04	Sandnes	None	Rock	2013-08-10	UTM-UPS. WGS 84	32 V 0321566 6529646	50	30
03.05	Sandnes	None	Rock	2013-08-10	UTM-UPS. WGS 84	32 V 0321559 6529648	270	20
03.06	Sandnes	None	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321555 6529647	115	40
03.07	Sandnes	None	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321555 6529655	130	20
03.08	Sandnes	None	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321557 6529659	80	30
03.09	Sandnes	None	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321572 6529665	45	20
03.10	Sandnes	None	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321573 6529654	80	30

04.01	Sandnes	Artificial	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321439 6529654	60	15
04.02	Sandnes	Artificial	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321443 6529644	100	10
04.03	Sandnes	Artificial	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321443 6529627	110	20
04.04	Sandnes	Artificial	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321416 6529607	115	20
04.05	Sandnes	Artificial	Soil	2013-08-10	UTM-UPS. WGS 84	32 V 0321406 6529626	155	10
04.06	Sandnes	Artificial	Rock	2013-08-10	UTM-UPS. WGS 84	32 V 0321402 6529616	350	20
04.07	Sandnes	Artificial	Rock	2013-08-10	UTM-UPS. WGS 84	32 V 0321415 6529607	170	5
04.08	Sandnes	Artificial	Rock	2013-08-10	UTM-UPS. WGS 84	32 V 0321424 6529619	165	20
04.09	Sandnes	Artificial	Rock	2013-08-10	UTM-UPS. WGS 84	32 V 0321436 6529627	170	25
04.10	Sandnes	Artificial	Rock	2013-08-10	UTM-UPS. WGS 84	32 V 0321436 6529653	5	30
05.01	Sandnes	None	Soil	2013-08-12	UTM-UPS. WGS 84	32 V 0321819 6527793	340	10
05.02	Sandnes	None	Soil	2013-08-12	UTM-UPS. WGS 84	32 V 0321826 6527798	360	5
05.03	Sandnes	None	Soil	2013-08-12	UTM-UPS. WGS 84	32 V 0321836 6527797	380	10
05.04	Sandnes	None	Soil	2013-08-12	UTM-UPS. WGS 84	32 V 0321850 6527794	390	15
05.05	Sandnes	None	Soil	2013-08-12	UTM-UPS. WGS 84	32 V 0321873 6527807	360	10
05.06	Sandnes	None	Rock	2013-08-12	UTM-UPS. WGS 84	32 V 0321856 6527813		
05.07	Sandnes	None	Rock	2013-08-12	UTM-UPS. WGS 84	32 V 0321836 6527811	90	5
05.08	Sandnes	None	Rock	2013-08-12	UTM-UPS. WGS 84	32 V 0321828 6527799	270	30
05.09	Sandnes	None	Rock	2013-08-12	UTM-UPS. WGS 84	32 V 0321829 6527791	200	10
05.10	Sandnes	None	Rock	2013-08-12	UTM-UPS. WGS 84	32 V 0321814 6527794	150	20
06.01	Sandnes	Manure	Soil	2013-08-13	UTM-UPS. WGS 84	32 V 0321334 6528258	130	10
06.02	Sandnes	Manure	Soil	2013-08-13	UTM-UPS. WGS 84	32 V 0321310 6528301	150	10
06.03	Sandnes	Manure	Soil	2013-08-13	UTM-UPS. WGS 84	32 V 0321297 6528333	225	5
06.04	Sandnes	Manure	Soil	2013-08-13	UTM-UPS. WGS 84	32 V 0321302 6528378	135	20
06.05	Sandnes	Manure	Soil	2013-08-13	UTM-UPS. WGS 84	32 V 0321299 6528407	110	25
06.06	Sandnes	Manure	Rock	2013-08-13	UTM-UPS. WGS 84	32 V 0321281 6528400	110	10
06.07	Sandnes	Manure	Rock	2013-08-13	UTM-UPS. WGS 84	32 V 0321263 6528386	300	30
06.08	Sandnes	Manure	Rock	2013-08-13	UTM-UPS. WGS 84	32 V 0321259 6528360	100	20
06.09	Sandnes	Manure	Rock	2013-08-13	UTM-UPS. WGS 84	32 V 0321279 6528330	310	40
06.10	Sandnes	Manure	Rock	2013-08-13	UTM-UPS. WGS 84	32 V 0321320 6528267	260	20
07.01	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322135 6527851	355	5
07.02	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322112 6527813	10	10

07.03	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322122 6527798	360	5
07.04	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322092 6527789	395	15
07.05	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322065 6527773	370	20
07.06	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322073 6527767	400	5
07.07	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322061 6527790	40	30
07.08	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322086 6527796	100	20
07.09	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322114 6527792	150	0
07.10	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322138 6527854	240	5
08.01	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322454 6528565	340	20
08.02	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322490 6528573	380	20
08.03	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322505 6528567	365	20
08.04	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322528 6528529	240	0
08.05	Sandnes	Artificial	Soil	2013-08-14	UTM-UPS. WGS 84	32 V 0322505 6528514	180	0
08.06	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322498 6528521	90	15
08.07	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322496 6528547	305	20
08.08	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322487 6528551	330	30
08.09	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322457 6528562	160	10
08.10	Sandnes	Artificial	Rock	2013-08-14	UTM-UPS. WGS 84	32 V 0322434 6528553	15	5
09.01	Rennesøy	None	Soil	2013-08-16	UTM-UPS. WGS 84	32 V 0306236 6558091	85	5
09.02	Rennesøy	None	Soil	2013-08-16	UTM-UPS. WGS 84	32 V 0306237 6558106	140	15
09.03	Rennesøy	None	Soil	2013-08-16	UTM-UPS. WGS 84	32 V 0306207 6558123	360	0
09.04	Rennesøy	None	Soil	2013-08-16	UTM-UPS. WGS 84	32 V 0306185 6558149	200	30
09.05	Rennesøy	None	Soil	2013-08-16	UTM-UPS. WGS 84	32 V 0306157 6558168	205	0
09.06	Rennesøy	None	Rock	2013-08-16	UTM-UPS. WGS 84	32 V 0306156 6558155	220	5
09.07	Rennesøy	None	Rock	2013-08-16	UTM-UPS. WGS 84	32 V 0306169 6558147	190	5
09.08	Rennesøy	None	Rock	2013-08-16	UTM-UPS. WGS 84	32 V 0306187 6558132	240	50
09.09	Rennesøy	None	Rock	2013-08-16	UTM-UPS. WGS 84	32 V 0306218 6558091	200	35
09.10	Rennesøy	None	Rock	2013-08-16	UTM-UPS. WGS 84	32 V 0306250 6558095	290	20
10.01	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306395 6558066	195	5
10.02	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306390 6558026	225	5
10.03	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306400 6557991	270	10
10.04	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306469 6557946	5	5

10.05	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306489 6557887	380	5
10.06	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306487 6557896	40	20
10.07	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306467 6557937		
10.08	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306440 6557979	400	15
10.09	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306423 6558050	240	20
10.10	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306402 6558055	250	60
11.01	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306514 6557847	360	10
11.02	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306552 6557804	195	5
11.03	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306583 6557790	260	5
11.04	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306596 6557772	30	10
11.05	Rennesøy	None	Soil	2013-08-17	UTM-UPS. WGS 84	32 V 0306630 6557733	300	5
11.06	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306591 6557767	30	20
11.07	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306587 6557783	75	5
11.08	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306554 6557796	105	20
11.09	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306527 6557824	90	30
11.10	Rennesøy	None	Rock	2013-08-17	UTM-UPS. WGS 84	32 V 0306510 6557856	310	10
12.01	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306418 6558161	25	10
12.02	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306437 6558171	280	5
12.03	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306501 6558168	70	5
12.04	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306490 6558132	250	5
12.05	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306478 6558087	50	0
12.06	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306449 6558104	335	20
12.07	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306436 6558134	5	30
12.08	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306480 6558178	320	15
12.09	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306495 6558097	105	15
12.10	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306525 6558122	305	10
13.01	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306581 6558088	240	20
13.02	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306599 6558044	240	5
13.03	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306569 6558014	30	15
13.04	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306625 6557970	365	5
13.05	Rennesøy	Both	Soil	2013-08-18	UTM-UPS. WGS 84	32 V 0306614 6557930	5	5
13.06	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306611 6557941	375	20

13.07	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306601 6557955	165	10
13.08	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306669 6557961	180	20
13.09	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306594 6558003	395	25
13.10	Rennesøy	Both	Rock	2013-08-18	UTM-UPS. WGS 84	32 V 0306622 6558044	325	10
14.01	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305013 6558321	80	15
14.02	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305020 6558327	90	0
14.03	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305038 6558323	75	10
14.04	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305051 6558311	385	5
14.05	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305028 6558299	400	5
15.01	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305040 6558334	60	10
15.02	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305018 6558360	225	5
15.03	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305043 6558364	30	10
15.04	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305078 6558375	15	0
15.05	Rennesøy	Artificial	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305066 6558330	65	5
16.01	Rennesøy	None	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305104 6558320	220	10
16.02	Rennesøy	None	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305122 6558326	160	20
16.03	Rennesøy	None	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305129 6558339	385	0
16.04	Rennesøy	None	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305157 6558335	80	0
16.05	Rennesøy	None	Soil	2013-08-19	UTM-UPS. WGS 84	32 V 0305169 6558327	400	30
16.06	Rennesøy	None	Rock	2013-08-19	UTM-UPS. WGS 84	32 V 0305180 6558310	70	15
16.07	Rennesøy	None	Rock	2013-08-19	UTM-UPS. WGS 84	32 V 0305172 6558304	150	10
16.08	Rennesøy	None	Rock	2013-08-19	UTM-UPS. WGS 84	32 V 0305151 6558293	100	15
16.09	Rennesøy	None	Rock	2013-08-19	UTM-UPS. WGS 84	32 V 0305133 6558309	50	15
16.10	Rennesøy	None	Rock	2013-08-19	UTM-UPS. WGS 84	32 V 0305107 6558318	110	10
17.01	Rennesøy	Both	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0304479 6558577	10	5
17.02	Rennesøy	Both	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0304461 6558564	10	5
17.03	Rennesøy	Both	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0304407 6558537	205	5
17.04	Rennesøy	Both	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0304434 6558518	40	0
17.05	Rennesøy	Both	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0304514 6558505	340	0
17.06	Rennesøy	Both	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0304549 6558507	275	10
17.07	Rennesøy	Both	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0304536 6558544	220	20
17.08	Rennesøy	Both	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0304489 6558572	320	10

17.09	Rennesøy	Both	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0304450 6558575	400	25
17.10	Rennesøy	Both	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0304390 6558590	15	15
18.01	Rennesøy	None	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0303961 6558511	300	5
18.02	Rennesøy	None	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0303946 6558526	70	10
18.03	Rennesøy	None	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0303947 6558555	80	10
18.04	Rennesøy	None	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0303910 6558553	30	5
18.05	Rennesøy	None	Soil	2013-08-21	UTM-UPS. WGS 84	32 V 0303890 6558559	210	15
18.06	Rennesøy	None	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0303909 6558557	395	15
18.07	Rennesøy	None	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0303932 6558560	20	10
18.08	Rennesøy	None	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0303998 6558530	55	20
18.09	Rennesøy	None	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0303978 6558507	40	30
18.10	Rennesøy	None	Rock	2013-08-21	UTM-UPS. WGS 84	32 V 0304010 6558501	50	0
19.01	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320369 6519053	160	10
19.02	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320348 6519043	150	10
19.03	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320319 6519028	155	20
19.04	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320284 6519045	145	20
19.05	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320299 6519041	140	15
19.06	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320292 6519053	280	5
19.07	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320300 6519070	185	5
19.08	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320311 6519072	195	15
19.09	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320343 6519068	230	30
19.10	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320374 6519077	180	15
20.01	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320218 6519108	100	0
20.02	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320197 6519085	10	0
20.03	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320208 6519055	130	10
20.04	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320232 6519023	160	20
20.05	Gjesdal	Both	Soil	2013-08-23	UTM-UPS. WGS 84	32 V 0320245 6519035	150	20
20.06	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320251 6519049	70	25
20.07	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320258 6519073	30	25
20.08	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320240 6519078	350	30
20.09	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320219 6519079	290	5
20.10	Gjesdal	Both	Rock	2013-08-23	UTM-UPS. WGS 84	32 V 0320189 6519078	40	5

21.01	Gjesdal	None	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0319872 6519990	40	10
21.02	Gjesdal	None	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0319905 6519973	50	5
21.03	Gjesdal	None	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0319920 6519975	15	0
21.04	Gjesdal	None	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0319906 6519951	255	0
21.05	Gjesdal	None	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0319922 6519932	310	5
21.06	Gjesdal	None	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0319901 6519938	70	20
21.07	Gjesdal	None	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0319896 6519963	30	5
21.08	Gjesdal	None	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0319892 6519980	15	20
21.09	Gjesdal	None	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0319895 6519994	330	10
21.10	Gjesdal	None	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0319922 6519982	95	10
22.01	Gjesdal	Both	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0320093 6519394	120	5
22.02	Gjesdal	Both	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0320083 6519356	85	10
22.03	Gjesdal	Both	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0320080 6519328	30	5
22.04	Gjesdal	Both	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0320109 6519298	10	10
22.05	Gjesdal	Both	Soil	2013-08-25	UTM-UPS. WGS 84	32 V 0320131 6519321	350	10
22.06	Gjesdal	Both	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0320137 6519336	25	30
22.07	Gjesdal	Both	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0320121 6519361	390	10
22.08	Gjesdal	Both	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0320104 6519386	305	10
22.09	Gjesdal	Both	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0320093 6519364	145	5
22.10	Gjesdal	Both	Rock	2013-08-25	UTM-UPS. WGS 84	32 V 0320078 6519316	160	25
23.01	Gjesdal	Artificial	Soil	2013-08-26	UTM-UPS. WGS 84	32 V 0321416 6518726	5	5
23.02	Gjesdal	Artificial	Soil	2013-08-26	UTM-UPS. WGS 84	32 V 0321474 6518731	300	15
23.03	Gjesdal	Artificial	Soil	2013-08-26	UTM-UPS. WGS 84	32 V 0321545 6518724	120	5
23.04	Gjesdal	Artificial	Soil	2013-08-26	UTM-UPS. WGS 84	32 V 0321627 6518746	125	10
23.05	Gjesdal	Artificial	Soil	2013-08-26	UTM-UPS. WGS 84	32 V 0321672 6518765	145	10
23.06	Gjesdal	Artificial	Rock	2013-08-26	UTM-UPS. WGS 84	32 V 0321693 6518802	90	5
23.07	Gjesdal	Artificial	Rock	2013-08-26	UTM-UPS. WGS 84	32 V 0321641 6518804	200	20
23.08	Gjesdal	Artificial	Rock	2013-08-26	UTM-UPS. WGS 84	32 V 0321540 6518756	180	10
23.09	Gjesdal	Artificial	Rock	2013-08-26	UTM-UPS. WGS 84	32 V 0321514 6518704	390	5
23.10	Gjesdal	Artificial	Rock	2013-08-26	UTM-UPS. WGS 84	32 V 0321422 6518715	320	15
24.01	Gjesdal	Manure	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322285 6518779	90	0
24.02	Gjesdal	Manure	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322253 6518772	60	5

24.03	Gjesdal	Manure	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322206 6518770	75	10
24.04	Gjesdal	Manure	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322159 6518763	90	5
24.05	Gjesdal	Manure	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322126 6518815	90	5
24.06	Gjesdal	Manure	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322120 6518799	50	20
24.07	Gjesdal	Manure	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322148 6518762	80	30
24.08	Gjesdal	Manure	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322188 6518749	100	20
24.09	Gjesdal	Manure	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322254 6518752	10	30
24.10	Gjesdal	Manure	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322275 6518760	390	20
25.01	Gjesdal	None	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322341 6519103	50	0
25.02	Gjesdal	None	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322329 6519107	380	0
25.03	Gjesdal	None	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322303 6519124	10	0
25.04	Gjesdal	None	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322275 6519132	65	5
25.05	Gjesdal	None	Soil	2013-08-27	UTM-UPS. WGS 84	32 V 0322249 6519174	240	0
25.06	Gjesdal	None	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322264 6519158	220	5
25.07	Gjesdal	None	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322281 6519134	220	0
25.08	Gjesdal	None	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322288 6519121	400	25
25.09	Gjesdal	None	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322308 6519100	5	15
25.10	Gjesdal	None	Rock	2013-08-27	UTM-UPS. WGS 84	32 V 0322349 6519106	10	15

Table A4: pH values for each site. The lowest value was found to be 1.60 and the highest value was found to be 5.60.

Plot	pH	Plot	pH	Plot	pH	Plot	pH	Plot	pH
01.01	3.45	06.01	3.00	11.01	5.00	16.01	5.30	21.01	5.60
01.02	2.45	06.02	3.00	11.02	4.85	16.02	5.35	21.02	5.15
01.03	2.35	06.03	2.55	11.03	4.30	16.03	5.00	21.03	4.55
01.04	1.60	06.04	3.20	11.04	4.30	16.04	4.95	21.04	4.55
01.05	1.65	06.05	3.30	11.05	4.10	16.05	4.80	21.05	4.15
02.01	2.25	07.01	3.55	12.01	5.15	17.01	5.05	22.01	4.00
02.02	2.40	07.02	3.25	12.02	4.95	17.02	4.50	22.02	4.15
02.03	1.95	07.03	3.25	12.03	4.50	17.03	4.25	22.03	4.20
02.04	2.05	07.04	3.40	12.04	4.20	17.04	4.10	22.04	4.15
02.05	2.15	07.05	3.40	12.05	4.25	17.05	4.30	22.05	4.25
03.06	2.35	08.01	3.65	13.01	3.95	18.01	4.40	23.01	2.70
03.07	1.95	08.02	3.25	13.02	4.10	18.02	4.00	23.02	3.60
03.08	2.05	08.03	3.35	13.03	3.90	18.03	3.75	23.03	3.95
03.09	2.05	08.04	3.00	13.04	3.85	18.04	3.75	23.04	3.55
03.10	2.15	08.05	3.30	13.05	3.90	18.05	3.75	23.05	4.00
04.01	2.25	09.01	2.55	14.01	3.85	19.01	3.85	24.01	3.85
04.02	2.30	09.02	3.20	14.02	3.80	19.02	3.85	24.02	3.80
04.03	2.15	09.03	3.25	14.03	3.70	19.03	3.60	24.03	3.95
04.04	2.05	09.04	3.15	14.04	3.55	19.04	3.85	24.04	3.80
04.05	2.30	09.05	3.45	14.05	3.65	19.05	3.65	24.05	3.70
05.01	1.60	10.01	3.05	15.01	3.30	20.01	3.75	25.01	3.80
05.02	2.05	10.02	3.55	15.02	3.55	20.02	4.30	25.02	3.75
05.03	1.80	10.03	3.50	15.03	3.90	20.03	4.05	25.03	3.60
05.04	1.95	10.04	3.70	15.04	3.80	20.04	4.20	25.04	3.55
05.05	1.95	10.05	3.35	15.05	3.75	20.05	3.90	25.05	3.60