Master's thesis

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Grasslands in Trondheim; Land-use, plant species richness and soil characteristics

Master's thesis in Supervisor: Gunnar Austrheim
Co supervisors: Tanja Kofod Petersen, Dag-Inge Øien
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Abstract

Semi-natural grasslands are important for biodiversity, but land use changes is causing a decline in biodiversity at a global level. Urbanization and intensification of agriculture has been found to be major contributors to this decline. As cities increase in both size and population, inclusion of urban ecosystems in conservation efforts will become more important. In this study we examined: (1) current land-use of 1605 polygons within the landcover classes “home field grazing” and “open firm ground” which were expected to include most of the grassland habitats within a delimited area of Trondheim municipality. (2) Land-use, vascular plant richness, soil nutrient status, carbon content and other habitat characteristics from a subset of 31 grassland polygons. Linear models were used to assess the relationship between species richness, land-use type and soil characteristics. A NMDS ordination analysis was used to assess the relationship between species composition and land use. We found that grasslands in Trondheim are dominated by recreational or public space (outdoor sports facilities, cemeteries and churchyards and public parks and gardens) which are strongly modified and species poor. Only a limited area could be classified as semi-natural grasslands. No relationship was found between species richness, land use and soil nutrient levels in the subset of 31 grasslands representing four different grassland habitats: semi-natural grasslands, grasslands with tall grasses and weeds, late successional grassland, and grasslands with home field grazing. However, the ordination analysis revealed a relationship between the species composition and current land-use. The results of this study imply that land-use management can promote desired species composition, and that inclusion of species composition in conservation efforts can help promote endangered habitat types, such as semi-natural grasslands.

Keywords: Urban ecosystems, land use, species richness, soil characteristics

Sammendrag

Seminaturlige grasmarker er viktige for biologisk mangfold, men endringer i arealbruk har gitt en nedgang i biologisk mangfold på globalt nivå. Urbanisering og intensivering av landbruket har vist seg å være viktige bidragsytere til denne nedgangen. Etter hvert som byene øker i både størrelse og befolkning, blir inkludering av urbane økosystemer i bevaringsarbeidet viktigere. I denne studien undersøkte vi: (1) nåværende arealbruk av 1605 polygoner innenfor arealtypene "innmarksbeite" og "åpen fastmark" som var forventet å inkludere de fleste av grasmarkene innenfor et avgrenset område av Trondheim kommune. (2) Jordbruk, artsrikdom av karplanter, næringsinnhold i jord, karboninnhold og andre habitategenskaper fra en undergruppe bestående av 31 grasmarkspolygoner. Lineære modeller ble brukt til å vurdere sammenhengen mellom artsrikdom, arealbruk og jordegenskaper. En NMDS-ordinasjonsanalyse ble brukt til å vurdere sammenhengen mellom artssammensetning og arealbruk. Vi fant at gressletter i Trondheim domineres av rekreasjons- eller offentlig plass (utendørs idrettsanlegg, kirkegårder og offentlige parker og hager) som er sterkt modifisert og artsfattige. Bare et begrenset område kan klassifiseres som seminaturlige grasmarker. Det ble ikke funnet noen sammenheng mellom artsrikdom, arealbruk og jordnæringsnivåer i undergruppen av 31 grasmarkspolygoner som representerte fire forskjellige grasmarkstyper: seminaturlige grasmarker, gressområder med høye gress og ugress, sen suksessive grasmarker og innmarksbeite. Ordinasjonsanalysen viste imidlertid et forhold mellom artssammensetningen og nåværende arealbruk. Resultatene av denne studien antyder at bevissthet rundt arealbruk kan fremme ønsket artssammensetning, og at inkludering av artssammensetning i bevaringsarbeid kan bidra til å fremme truede naturtyper, slik som seminaturlige grasmarker.

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1. Introduction:

Both the urban population and urban land cover is predicted to increase in the coming decades (Seto, Fragkias, Güneralp, & Reilly, 2011; United Nations, 2018). This increase will put further stress on already vulnerable ecosystems and will demand an increase in resources from the surrounding areas. Loss of biodiversity in urban areas has been reported as one of the consequences of these changes (Hansen et al., 2005; Luck, 2007). The global IPBES report published in May 2019 stated that land-use has as much effect on biodiversity as global climate change (Díaz et al., 2019). The report highlights the urgency of including urban areas in the conservation efforts to mitigate the damaging effects of the urban sprawl. On a global scale, cities have been shown to harbour high levels of biodiversity (Aronson et al., 2014) showing that cities can indeed make a difference in conservation efforts (Beninde, Veith, & Hochkirch, 2015).

1.1 Assessment schemes and management

There are many assessments and management schemes to protect and restore the biodiversity at both global (Silva et al., 2008) regional and local levels (Langedal & Nøst, 2013). The United Nations' (UN) Sustainable Development Goals and the Convention for Biodiversity's Aichi targets are UN initiatives that are well known and respected (CBD, 2014; United Nations, 2015). One of the major contributors to these schemes is the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). IPBES aims to strengthen science-policy interface to promote a sustainable development with a focus on protection of the biodiversity and environmental (Díaz et al., 2019). Regional initiatives such as the European commission's LIFE and the United Kingdom's National Ecosystem Assessment (NEA, 2011) assess current status and propose management schemes. In Norway, the *Nature Diversity Act* dictates and limits interference in nature (Naturmangfoldloven, 2009). There are also several national management tools, such as the *Norwegian Red List for Species*, *the Red List for Ecosystems and Habitat Types*, and *the Alien Species List*, to describe and explain the status of the Norwegian ecosystems (Artsdatabanken, 2015, 2018a, 2018b). Trondheim municipality has a management scheme aimed at sustainable development towards 2020 (Langedal & Nøst, 2013). Several studies have been conducted to assess the current state of biodiversity in the municipality's cultural landscapes (Øien, 2010a, 2010b, 2013). These studies have also included management schemes, and follow-ups representing an important contribution to the municipality's efforts to halt biodiversity loss (Langedal & Nøst, 2013).

1.2 Semi-natural grasslands

The semi-natural grasslands in Europe have been shaped through centuries of low-intensity management practices, such as grazing and mowing (Aalberg Haugen et al., 2019). Today, agricultural intensification, land use change and urbanization threaten this habitat type (Fischer, von der Lippe, & Kowarik, 2013). About 60% of cultivated land in Norway is used intensively to maximize biomass production. Ploughing, fertilization and the use of ley species is a result of this (Aalberg Haugen et al., 2019). The intensive management of the infield is in contrast with the management of the outlaying grassland. These areas have traditionally played a vital role in for the farms as grazing areas and for haymaking, but their usage has declined throughout the 20th century (Aalberg Haugen et al., 2019). A result of the decline in traditional land-use is the decline of the habitat type (Hovstad, Johansen L., Arnesen, Svalheim, & Velle, 2018). The 2018 red list for nature types listed Semi-natural meadow as vulnerable and hay meadows as critically endangered (Artsdatabanken, 2018b). While the abandonment of traditional agricultural practices is well documented, there is little knowledge of how urbanization affects these habitats and their biodiversity (Aalberg Haugen et al., 2019).

Semi-natural grasslands are naturally species rich in plants and form the foundation of a species rich fauna (Aalberg Haugen et al., 2019). The habitat is dominated by grass and herbs species, with little tree and shrub cover. The species richness of the grasslands depends on the regional species pool in combination with abiotic and climatic conditions and management regimes (Bonari et al., 2017; Gazol et al., 2012; Kielland-Lund, 1992; Moen, Norderhaug, & Skogen, 1993). In addition to the endangered nature types, about 24% of the endangered species on different trophic levels in Norway are associated with grasslands, highlighting another reason to conserve these areas.

Areas managed with mowing and grazing display slightly different characteristics from each other. Mowed grasslands have a more homogeneous species composition, are normally dominated by grass species, while grazed areas have a more heterogeneous species composition and are normally dominated by herbs (Norderhaug & Isdal, 1999). Grazing alters small-scale conditions, the removal of biomass creates new establishment opportunities and manure gives variation in nutrient availability (Gazol et al., 2012; Moen et al., 1993). Traditional mowing included the removal of biomass, thus the removal of nutrient resulting in low nutrient levels.

In addition to management practices, the abiotic and climatic conditions can affect the species composition in semi-natural grasslands (Moen et al., 1993). Low nutrient levels and harsh

climatic conditions promote stress tolerating plants, higher nutrient levels and less disturbed areas promote competitors, while high intense disturbance promote ruderals (Grime, 2006). All these conditions can be met in semi-natural grasslands and in urban ecosystems. Indicator species can be used to determine key biotic and abiotic conditions in an area. These species have a narrow niche for specific environmental factors, their presence is therefore an indication of conditions being met (Rolstad, Gjerde, Gundersen, & Sætersdal, 2002). Indicator species for nutrient poor, low intensively managed grasslands include harebell (*Campanula rotundifolia*) and common bent (*Agrostis capillaris*) Indicator species for semi-natural grasslands in succession include fireweed (*Epilobium angustifolium*) and meadowsweet (*Filipendula ulmaria*) for high nutrient areas and grey alder (*Alnus incana*) for low nutrient areas (Kielland-Lund, 1992; Moen et al., 1993).

1.3 Urban ecosystems, conservation and ecosystem services

Several studies have pointed out the potential for using urban habitats in the conservation of biodiversity, and how urban ecology studies can provide guidelines for urban planning (Klaus, 2013; NEA, 2011; Seto, Güneralp, & Hutyra, 2012; Zerbe, Maurer, Schmitz, & Sukopp, 2003). Though urban ecology is recognised today as a separate field, the theories and models used to explain the dynamics are mostly borrowed from classic ecology (Breuste, Niemelä, & Snep, 2008). The island biogeography theory and the species-area relationship are both regarded as suitable to describe and predict the dynamics of the fragmented and heterogenous nature of the urban ecosystems (Crawley & Harral, 2001; Wilson & MacArthur, 1967). In addition, metapopulation theory and beta-diversity have both been proposed to explain the dispersal patterns and variation of species composition (Breuste et al., 2008; Hanski & Gilpin, 2008).

Not only can urban conservation help mitigate the negative effects of urbanization, it can also be an important contribution to the wellbeing of the urban population through the services and goods provided by the local environment (Fischer et al., 2013). In its holistic framework, IPBES describes how ‘Nature’s benefit to humans’ is an anthropocentric way of considering and quantifying the goods and services provided to humans by nature (Díaz et al., 2019). These goods will in this paper be referred to as simply ‘ecosystem services’ (Costanza et al., 1997; Díaz et al., 2019). The term can be applied to a wide range of services but is often described through the four main categories; provisioning (e.g. food production), regulating (e.g. water regulation), cultural (e.g. recreational services) and supporting services (e.g. photosynthesis).

Traditionally, conservation aims to achieve a natural state for the local flora and fauna, with the aim to conserve an area to a standard without human impact. Cities cannot achieve this, as the ecosystem is shaped by the kind, intensity and frequency of anthropogenic disturbance (Breuste et al., 2008; Kowarik, 2011). This disturbance results in different abiotic conditions within a city compared with the surrounding area (Breuste et al., 2008). High proportion of sealed land cover, little vegetation, and tall structures result for example in a higher average temperature and different wind conditions within a city compared to the surrounding areas (Bolund & Hunhammar, 1999). Urban conservation efforts should consider this balance; that the urban ecosystems are not natural, nor completely artificial, which will be reflected in the species composition and ecosystem function (Klaus, 2013).

Consideration of ecosystem management on all levels of city planning and inclusion of green infrastructure are good ways to mitigate the damaging effects of urbanization on biodiversity (Beninde et al., 2015; Hostetler, Allen, & Meurk, 2011). This is in accordance with the island biogeography theory and becomes more relevant in places where the scarce availability of land makes increase of patch size difficult (Beninde et al., 2015; Breuste et al., 2008). Through connected areas or as steppingstones, a corridor can give wildlife the opportunity to live in and disperse throughout communities in which they otherwise would not be able to thrive In addition, biodiversity-friendly management, such as low intensity and heterogenous management, could be a good alternative in places where there is no option to extend the current areas (Beninde et al., 2015).

Human activity might facilitate the introduction of new species (Polce et al., 2011). Climatic changes might also make it more difficult for the native species to continue living there. This can provide further opportunities for alien species to occupy areas inhabitable for the local species (Polce et al., 2011). On a global scale Polce et al. (2011) found that anthropogenic disturbance was a significant explanatory variable for increased presence and cover of alien species. In a global study by Aronson et al. (2014) it was found that cities on median contained 28% exotic plants. Though some alien species are introduced unwittingly, many are introduced purposely (Janhäll, 2015). The ecosystem services provided by green areas are the main reason for including them in the city planning (Janhäll, 2015).

1.4 Urban ecosystems

The combination of manmade construction and natural habitat results in the mosaic composition of the urban ecosystem (Fischer et al., 2013). The green spaces within urban areas vary in both function and species composition. Formal green spaces, often with high anthropogenic disturbance, include parks, playgrounds and sports facilities. Informal green spaces might appear less modified by humans, but the anthropogenic disturbance may still be a determining factor for the species composition. This type includes areas such as indigenous vegetation types, derelict industrial sites, overgrown gardens, and ruderal sites (Breuste et al., 2008; Fischer et al., 2013).

Urban grasslands include both areas with high and low intensity management. High intensity includes areas such as parks, playgrounds and sports fields (Breuste et al., 2008; Klaus, 2013) which can be characterized by disturbance such as regular mowing (Klaus, 2013). The intensively managed areas are often species poor, with a few dominating species, and a high proportion of introduced species (Breuste et al., 2008; Hostetler et al., 2011; Klaus, 2013). The introduced species may provide fewer benefits to the local environment, which results in a lower ecological value for the habitat (Klaus, 2013). Urban grasslands also include areas with less intensive management. These areas tend to reflect the local species pool but can also have the characteristics of high disturbance, for example few dominating species (Klaus, 2013).

1.5 Aims and hypotheses

In this study, we aim to (1) identify grassland habitats within central parts of Trondheim, their different land uses and main environmental characteristics, (2) assess vascular plant richness and soil nutrient status for a subgroup of grasslands classified as *home field grazing*. (3) examine to which extent land-use and nutrient levels can explain species richness and species composition of vascular plants in semi-natural grasslands within Trondheim and its outskirts.

We hypothesize that that urban grasslands will be dominated by habitats with high anthropogenic disturbance such as parks and recreational space (1); that low nutrient levels will be correlated with a high species richness (2); that low degree of anthropogenic disturbance will be correlated with a high species richness (3); that there will be a correlation between species composition and land-use (4a) and low intense regimes will promote typical grassland species (4b).

2. Methods:

2.1 Study sites:

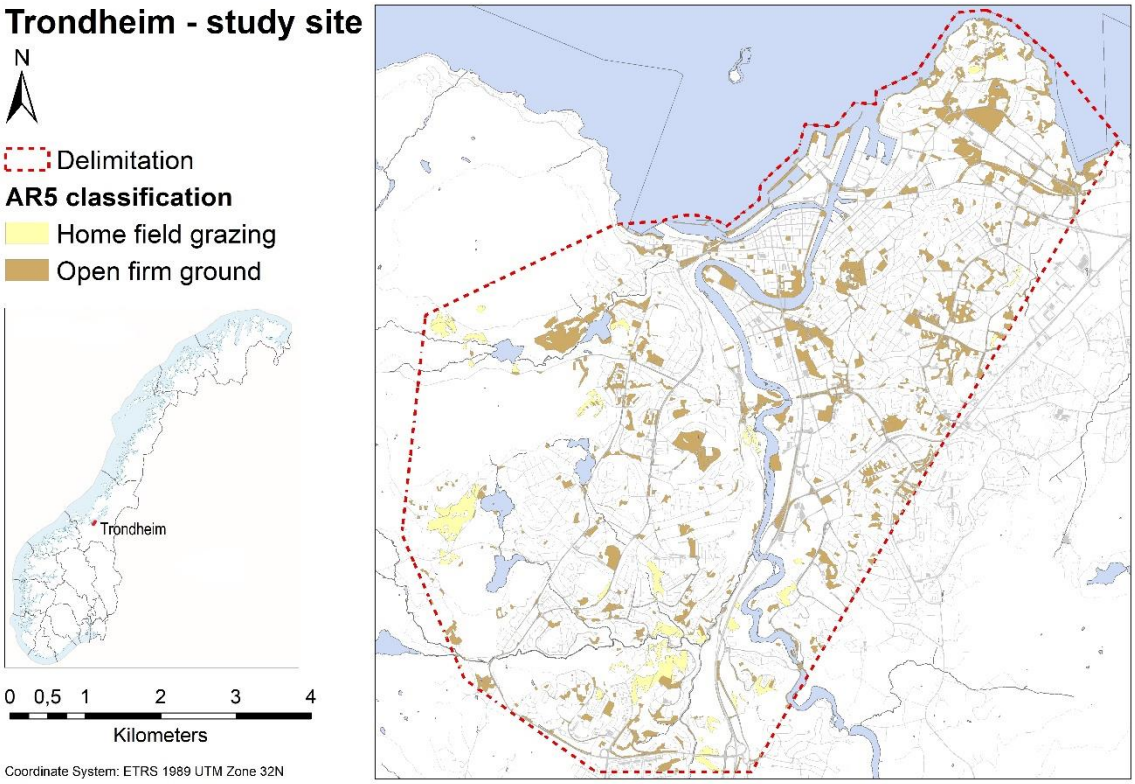

Figure 1: Map of the study sites in Trondheim municipality. The delimitation marks the border for selected urban area.

The study was performed in Trondheim municipality in Trøndelag county, Norway (63°26′24″N 10°24′0″E). Trondheim is the third largest city in Norway, with a population of about 200 000 (SSB, 2019). Distance to wilderness is relatively short and is therefore an integrated part of the city-experience. The primary focus of the study is on urban ecology, so a polygon of the urban part of Trondheim municipality was created. The polygon has a dual purpose: To restrict the study within the urban part of Trondheim, but at the same time reflect the broad array of the grassland habitat types found within the municipality. The relatively close proximity to the Norwegian Sea give Trondheim a slightly oceanic climate, and most of the study area is within the southern boreal zone, with the upper parts in Bymarka reaching the middle boreal zone (Lyngstad, Øien & Arnesen, 2002; Moen et al., 1993). The Area resource Map (AR5) provided by the municipality was used as a basis for identifying grassland sites within the polygon. The AR5 map is a national map standard designed for use at a scale of 1:5 000. It describes the land-use, tree species, forest quality and basic conditions (NIBIO, 2018).

The map shows area status, not necessarily current usage. Grassland is a broad habitat category mainly found within the land cover type *Home Field Grazing* (HFG), but also *Open Firm Ground* (OFG). A total of 66 areas classified as HFG and 1600 areas classified as OFG was included in this study. HFG is defined by AR5 as areas which can to be used for grazing but are not harvested mechanically (NIBIO, 2018). OFG is defined as areas neither classified as cultivated soil, forest, built-up areas, nor transport areas (NIBIO, 2018). It includes a wide range of habitat types for example semi-natural grasslands, edge zones and asphalted areas.

2.2 Land-use history

The land-use history of Trondheim is well documented (Blom, Danielsen, Mykland, Stugu & Supphellen, 1997). Previous studies combined with historical data gives a good basis. Trondheim's urban, military and agricultural history have shaped the green areas within the city centre and on the outskirts of the city. There are areas where traditional management has been maintained or recommenced (e.g. Lian and Lavollen) (Øien, 2013). Previous military settings have been converted to parks and recreational spaces (e.g. Festningen), and in some areas the agricultural practices have been intensified. Some areas also show fewer signs of human disturbance, either because they have been kept in their natural state or because previous management has ceased, and they now are in a later successional state.

2.3 Soil samples

The soil samples were taken and analysed in collaboration with the Norwegian University of Life Sciences (NMBU) in the lab at MINA, J.nr.357-2018. Soil samples were collected using an auger of 2 cm width. For each plot, three replicas were taken at mid-elevation level and each replica contained the soil from two augers. The samples were taken at 20 cm depth. After collection, the soil samples were dried at 50°C for 48 hours and then sieved at 2 mm. Total carbon (C%) and nitrogen (N%) content was determined by dry combustion (Leco CHN-1000; Leco Corporation, Sollentuna, Sweden) (Nelson & Sommers, 1982) and the Dumas method (Bremmer & Mulvaney, 1982) respectively. The phosphate content in the AL-extract (P-AL) was determined colorimetrically according to the molybdenum blue method (Crouch & Malmstadt, 1967).

2.4 Survey of vascular plant species

A trained botanist surveyed the areas and noted all observed vascular plant species based on a structured walk through the area (se appendix A). Time spent on each site was approximately one to two hours, depending on the size of each polygon. For areas with multiple habitat types, only the habitat types relevant for this study was surveyed. Patches of forest inside grasslands and edge zones were excluded. From the complete species list, a sublist of grassland species was compiled (appendix B). This list consisted of species only considered to be strict grassland species in line with "Håndbok for feltregisterering" and Lid & Lid flora (Lid & Lid, 2014; Moen et al., 1993) to exclude weeds, ley species as well as species associated with forests and other habitats.

2.5 Site survey of HFG (land use)

The assignment of a land-use category for HFG was done through a field survey. A standardized form was used to describe the current land-use for the area (appendix C). This form was filled out for all areas classified as HFG within in the study site. The form looked at current land use, the degree of succession and state of area. The form was used to classify the areas according to land-use, and categories are listed below (table 1).

2.6 Area classification of OFG

Areas classified as OFG was primarily evaluated using aerial photographs. When it was not possible to determine current land-use form aerial photographs, the areas were visited in the field. The categories were made to reflect the variation of land use, a total of 10 categories (table 1). The classification is based on previous assessments of urban ecosystem services, both local and international (Lyngstad et al., 2002; NEA, 2011).

Table 1: Land-use categories, based on the AR5 and UK NEA (2011).

Land-use category	Description
Semi-natural grasslands	High levels of species richness, intermediate nutrient levels, not in use/ extensively used
Tall grasses and weeds	Overgrown with tall grasses and "weeds"
Late succession	Invaded and dominated by trees and shrubs
Home field grazing	In use for grazing. Nutrient rich, maintained, intensively used
Edge zone	Primary purpose is separation of elements, for example between roads or between roads and buildings.
Outdoor sports facilities	Primary use of area is for organized sports.
Cemeteries and churchyards	Primary use is cemeteries and churchyards, can contain areas similar to the "Public parks and gardens" category.
Public parks and gardens	Primary use of area is recreational for the general public. Can include playgrounds etc.
Incidental open greenspace	Open green area with no apparent usage, can be intensively or extensively maintained.
Asphalt, gravel & rocks	Little to no vegetation. Can be of natural reasons or due to human disturbance.

2.7 Statistical/data analysis:

We performed a spatial assessment of the current use of available green space with an urban subset of the city of Trondheim. Maps were constructed using ArcGIS 10 (ESRI, 2012), using national standard AR5-resource map provided by Trondheim municipality (NIBO, 2018). "Analysis tools" and the function *cut* in ArcGIS was used to construct separate layers containing only the delimitated area and the areas classified as HFG and OFG within this site. An area-wide GIS-based analysis was performed to calculate area of each land-use category using the *summary* function.

We applied linear regression, analysis of variance (ANOVA) to assess whether nutrient levels (quantitative; Nitrogen %, Phosphorus), carbon (%) and land-use (categorical, four levels) could explain species richness, and Non-metric Multidimensional Scaling (NMDS) to assess differences species composition of vascular plants in semi-natural grasslands. Because the study was heterogenous with sites spanning a broad range of different habitats, NMDS was used to reveal the main gradients in vascular plant communities.

Data preparation and statistical analyses were performed in R, version 3.5.2. Outliers of analysed soil samples were identified using the *boxplot.stats()$out* function from the package "grDevices", and then removed (R Core Team, 2018). For the response variables, both soil samples and species richness were ln-transformed prior to analyses to avoid heteroscedasticity.

The functions *lm(), aov()* and *TukeyHSD()* from the package "stats" was used for the linear mode, ANOVA and the post hoc Tukey test, respectively (R Core Team, 2018). For the linear model, analysis was performed both with total species richness and species richness/area. The NMDS-ordination analysis was performed to test for the correlation between plant species composition and land-use, the function *metaMDS* from the package "vegan" was used (Oksanen et al., 2016). The number of reduced dimensions were four, and Bray-Curtis dissimilarity were used to calculate the dissimilarity distance matrix.

3. Results

3.1 Land use

The study site (figure 2) covers 55 km^2 of land (17% of the land area in Trondheim municipality). Within this delimitation the polygons of HFG and OFG cover 5,5 km^2 combined, meaning that they comprise of 10% of total land area with 2% and 8% to HFG and OFG respectively. Of the combined HFG and OFG land cover, 2,6 km^2 was in this study classified as recreational or public space (*outdoor sports facilities*, *cemeteries and churchyards* and *public parks and gardens*), this amounts to 5% of total land area within the delimitation. While 0,5 km^2 (<1%) was classified as *semi-natural grasslands* or *home field grazing*.

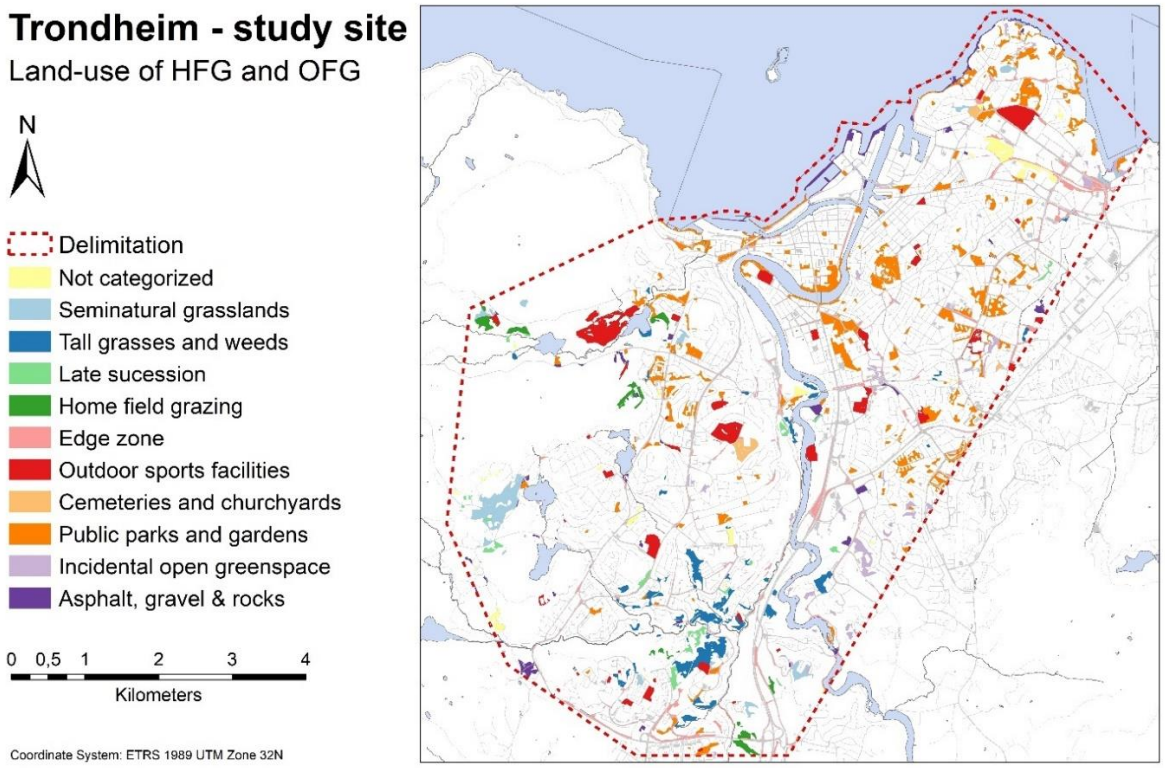

Figure 2: Land-use categories within the categories Home field grazing (HFG) and Open firm ground (OFG) in the study area

3.1.1 OFG

1569 polygons were classified as OFG within the study site, of these, 30 were not categorised. Some sites were under construction and difficult to access, or on private property. The remaining 1539 were categorized according to current land-use (figure 3a, table 2). In numbers, the majority of the polygons were categorized as *edge zone*, but with a median size of 230 m^2 this category constitutes only 16% of the total land area of OFG (figure 3a, table 2). The biggest proportion of land area were *public parks and gardens*, constituting 304 sites and covering 38% of OFG area (figure 3a, table 2).

3.1.2 HFG

Of 66 evaluated polygons, 60 fall within the definition of HFG provided by AR5. Of these, 17 are in use as grazing areas (*homefield grazing*), and 12 were evaluates as *semi-natural grasslands*, which constitutes 19% and 32% of the total area of HFG respectively (see figure 3b, table 2). A combination of the two classifications *late succession* and *Tall grasses and weeds*, constitutes 32 areas and 47% of the area of the 60 polygons. 6 polygons classified to HFG were evaluated, based on current usage, to not be within the definition given for HFG. These areas include *outdoor sports facilities*, *public parks and gardens*, and *asphalt, gravel and rocks*.

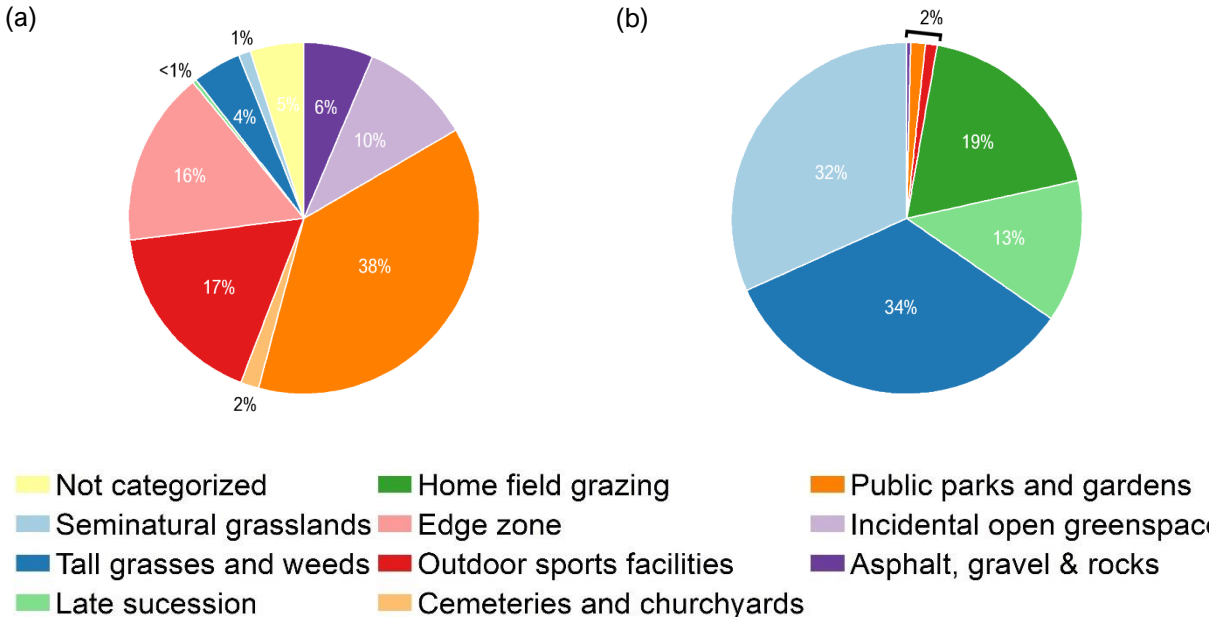

Figure 3: Percentage of each land-use categories of areas classified as OFG (a) and HFG (b).

Table 2: Number and percent area of polygons for 10 land-use categories within AR5 classes Home field grazing (HFG) and Open firm ground (OFG).

	Open firm ground		**Home field grazing**	
Land-use category	*Number of polygons :*	*Percentage of area:*	*Number of polygons:*	*Percentage of area:*
Not categorized	30	5%	-	-
Semi-natural grasslands	7	1 %	12	32 %
Tall grasses and weeds	41	4 %	17	34 %
Late succession	9	<1%	14	13 %
Home field grazing	-	-	17	19 %
Edge zone	855	16 %	-	-
Outdoor sports facilities	56	17 %	1	1 %
Cemeteries and churchyards	5	2 %	-	-
Public parks and gardens	304	38 %	4	1 %
Incidental open greenspace	115	10 %	-	-
Asphalt, gravel, rocks	147	6 %	1	<1 %
Total	1569	100%	66	100%

3.2 Species richness in HFG sites

Species richness was recorded for 34 of 66 HFG sites. In the surveyed sites, 191 vascular plant species were recorded. Species lists are provided in Appendix A. Of these, 96 species were classified as grassland species. The species richness varied greatly within each land-use type, but not significantly between them (figure 4a, table 3, ANOVA). When divided by area, the species richness of *semi-natural grassland* was nearly significantly higher than that of *tall grasses and weeds* (figure 5.b, table 3, ANOVA, t-value = 2.525, df = 3, P = 0.0783).

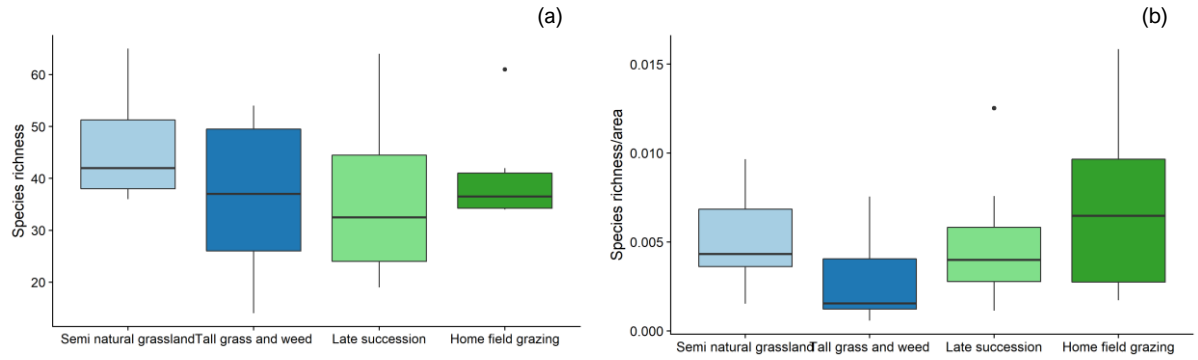

Figure 4: Species richness (a) and species richness/area (b) for each land-use category in HFG.

Table 3: Results from post hoc Tukey test on differences in species richness/area between habitats.

	Species richness				**Species richness/area**			
	Estimate	*Std. Error*	*t value*	*Pr(>|t|)*	*Estimate*	*Std. Error*	*t value*	*Pr(>|t|)*
Tall grasses and weed - Semi natural grassland	-0.307	0.200	-1.531	0.432	-0.81557	0.397	-2.054	0.1928
Late succession - Semi natural grassland	-0.302	0.213	-1.414	0.500	-0.08776	0.423	-0.208	0.9967
Home field grazing - Semi natural grassland	-0.123	0.228	-0.540	0.948	0.18723	0.452	0.414	0.9754
Late succession - Tall grasses and weed	0.005	0.183	0.029	1.000	0.72781	0.364	2.002	0.2111
Home field grazing - Tall grasses and weed	0.184	0.200	0.917	0.795	1.00280	0.397	2.525	0.0783 .
Home field grazing - Late succession	0.179	0.213	0.837	0.835	0.27499	0.423	0.651	0.9138

3.3 Soil samples:

After removal of 10 outliers (C: n=3, N: n=2, P-AL: n=5), 31 sites were included in the soil characteristics analyses. There was great variation within each land-use category, especially within *Semi-natural grasslands* and *Home field grazing* (figure 5). For land-use and nitrogen content there was a significant difference between the categories *home field grazing* and *tall grasses and weeds* (figure 5b, table 4, ANOVA, t-value = 3.208, df = 3, P = 0.0183). There was no significant linear relationship between species richness and soil characteristics for any of the soil characteristics studied (table 4).

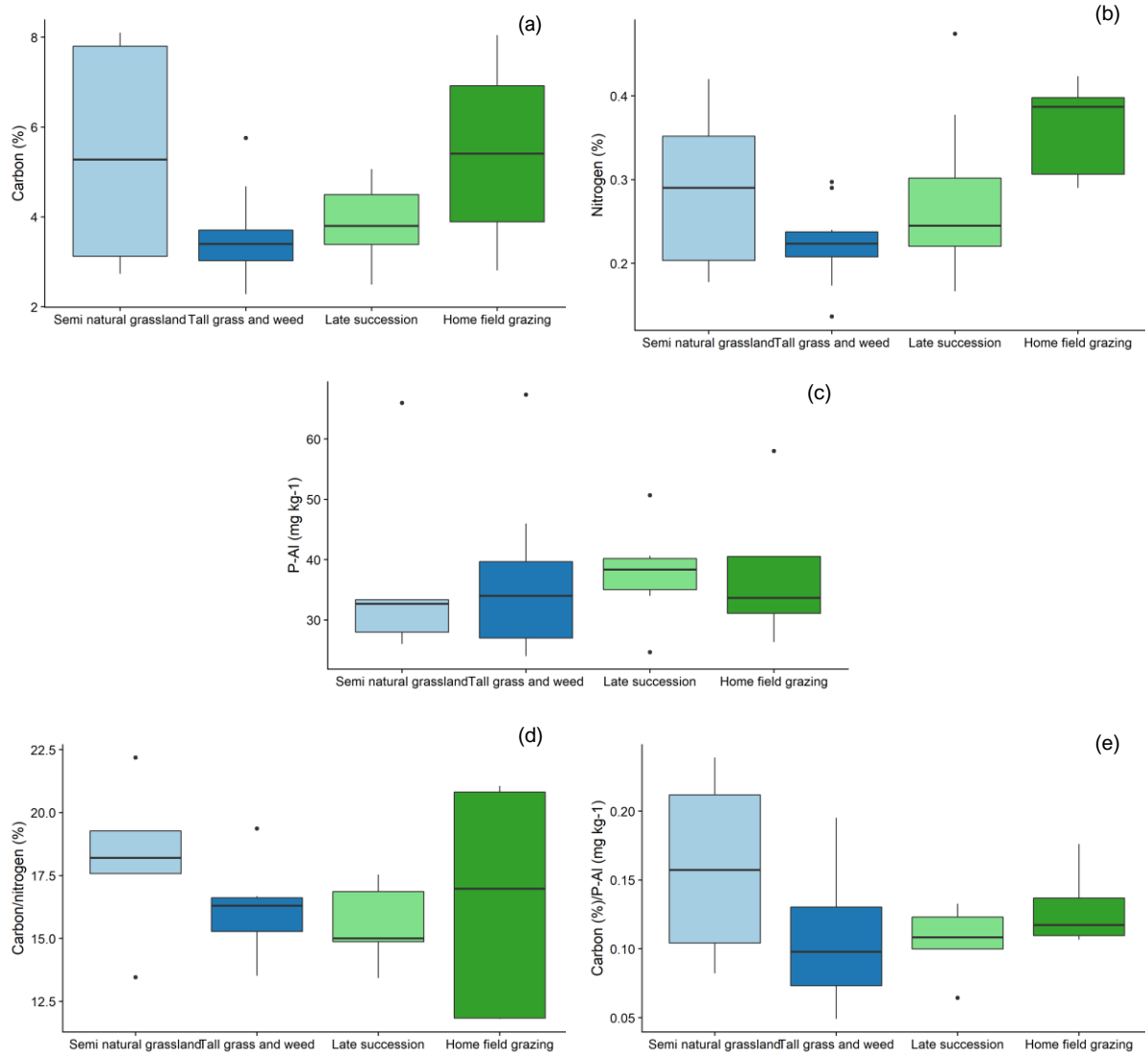

Figure 5: Soil nutrient levels for each land-use type. (a) is total carbon content (%), (b) is total nitrogen content (%), (c) is plant available phosphorus (P-Al (mg kg^{-1})). (d) and (e) is the share of carbon to nitrogen and share of carbon to plant available phosphorus respectively.

Table 4: Results from post hoc Tukey test on differences in total nitrogen content (%) between habitats.

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
Tall grasses and weed - Semi natural grassland	-0.22702	0.15300	-1.484	0.4598
Late succession - Semi natural grassland	-0.03719	0.15925	-0.234	0.9953
Home field grazing - Semi natural grassland	0.26383	0.17667	1.493	0.4543
Late succession - Tall grasses and weed	0.18983	0.13250	1.433	0.4897
Home field grazing - Tall grasses and weed	0.49084	0.15300	3.208	**0.0183**
Home field grazing - Late succession	0.30101	0.15925	1.890	0.2566

Table 5: Results from linear models on how soil characteristics affect species richness.

	Species richness													
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	3.28	2.69 – 3.86	<0.001	25993	3.05 – 4.37	<0.001	1.91	-0.05 – 3.87	0.068	1.58	-1.07 – 4.24	0.254	3.46	2.52 – 4.41	<0.001
C (%)	0.21	-0.20 – 0.61	0.321												
N (%)				0.09	-0.39 – 0.57	0.706									
P (P-Al)							0.46	-0.09 – 1.01	0.111						
C/N										0.72	-0.23 – 1.67	0.151			
C/P													-0.03	-0.45 – 0.39	0.882
Observations	29			28			26			27			25		
R^2 / R^2 adjusted	0.036 / 0.001			0.006 / -0.033			0.102 / 0.065			0.081 / 0.044			0.001 / -0.042		

Table 6: Results from linear models on how soil characteristics affect species richness for species richness/area.

	Species richness/area														
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	-6.42	-7.70 – -5.14	<0.001	-4.95	-6.35 – -3.55	<0.001	-5.43	-9.89 – -0.98	0.025	-6.00	-12.00 – 0.01	0.062	-4.09	-6.03 – -2.15	<0.001
C (%)	0.48	-0.40 – 1.37	0.292												
N (%)				0.57	-0.45 – 1.59	0.282									
P (P-Al)							-0.08	-1.33 – 1.16	0.896						
C/N										0.10	-2.05 – 2.25	0.929			
C/P													0.77	-0.10 – 1.64	0.097
Observations	29			28			26			27			25		
R^2 / R^2 adjusted	0.041 / 0.005			0.044 / 0.008			0.001 / -0.041			0.000 / -0.040			0.115 / 0.077		

3.4 Species composition

3.4.1 All species

The NMDS of all recorded species (n= 191) resulted in a 4-axis optimal solution, with final stress 0.086. The coordinates from the NMDS ordination were significantly different for three of the land-use types. Both *Tall grasses and weeds* (2) and *Late succession* (3) were significantly different from *Home field grazing* (4) (figure 6, table 7). Result of post hoc Tukey comparison of differences between land-use types for axis 2, 3 and 4 are given in appendix D. The ordination plot of the species revealed some clustering according to land-use type, though most species are clustered around origin (see figure 7). The species located on the left side of the plot were mostly grassland species, such as thread rush (*Juncus filiformis*) and devil's-bit (*Succisa pratensis*) while the species located on the right were mostly forest species including herb-Paris (*Paris quadrifolia)* and Scandinavian small-reed (*Calamagrostis purpurea*).

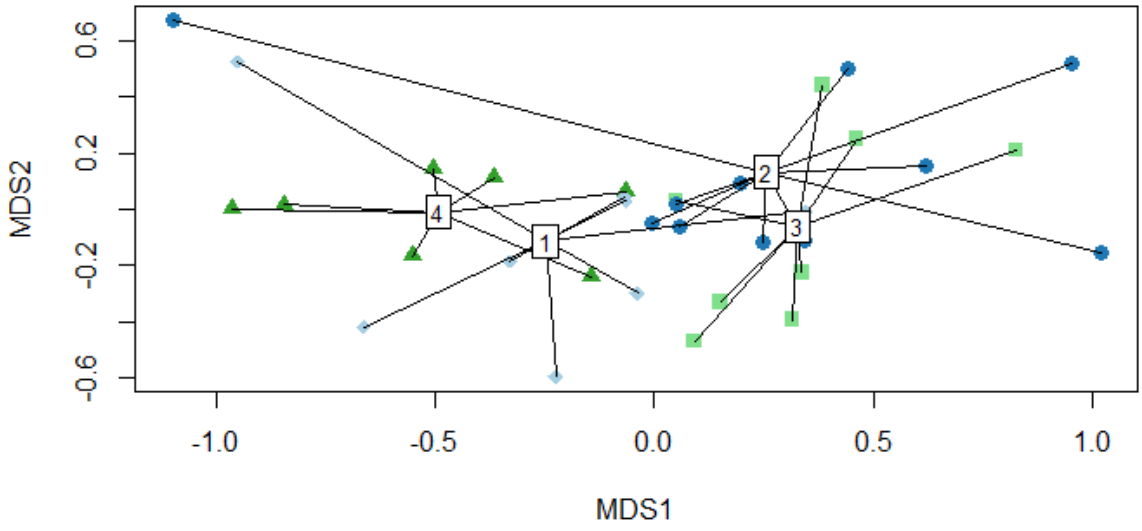

Figure 6: Ordination plot of 34 grassland sites classified into 4 different habitats (cf. Table 1) along non-metric multidimensional scaling (NMDS) axes 1 (MDS1) and 2 (MDS2). The number at the centre of each cluster describes its land-use type as follows: 1: Semi-natural grassland, *2:* Tall grasses and weeds, *3:* Late succession, *4:* Home field grazing.

Table 7: Post hoc Tukey comparison of differences between land-use types, based on ordination score along axis 1 (MDS1) (se figure 6).

	Difference	Lower	Upper	P adjuted
Tall grasses and weed - Semi natural grassland	0,505	-0,034	1,045	0,073
Late succession - Semi natural grassland	0,576	-0,005	1,156	0,053
Home field grazing - Semi natural grassland	-0,243	-0,844	0,358	0,693
Late succession - Tall grasses and weed	0,070	-0,469	0,610	0,984
Home field grazing - Tall grasses and weed	-0,748	-1,309	-0,187	**0,006**
Home field grazing - Late succession	-0,818	-1,419	-0,218	**0,004**

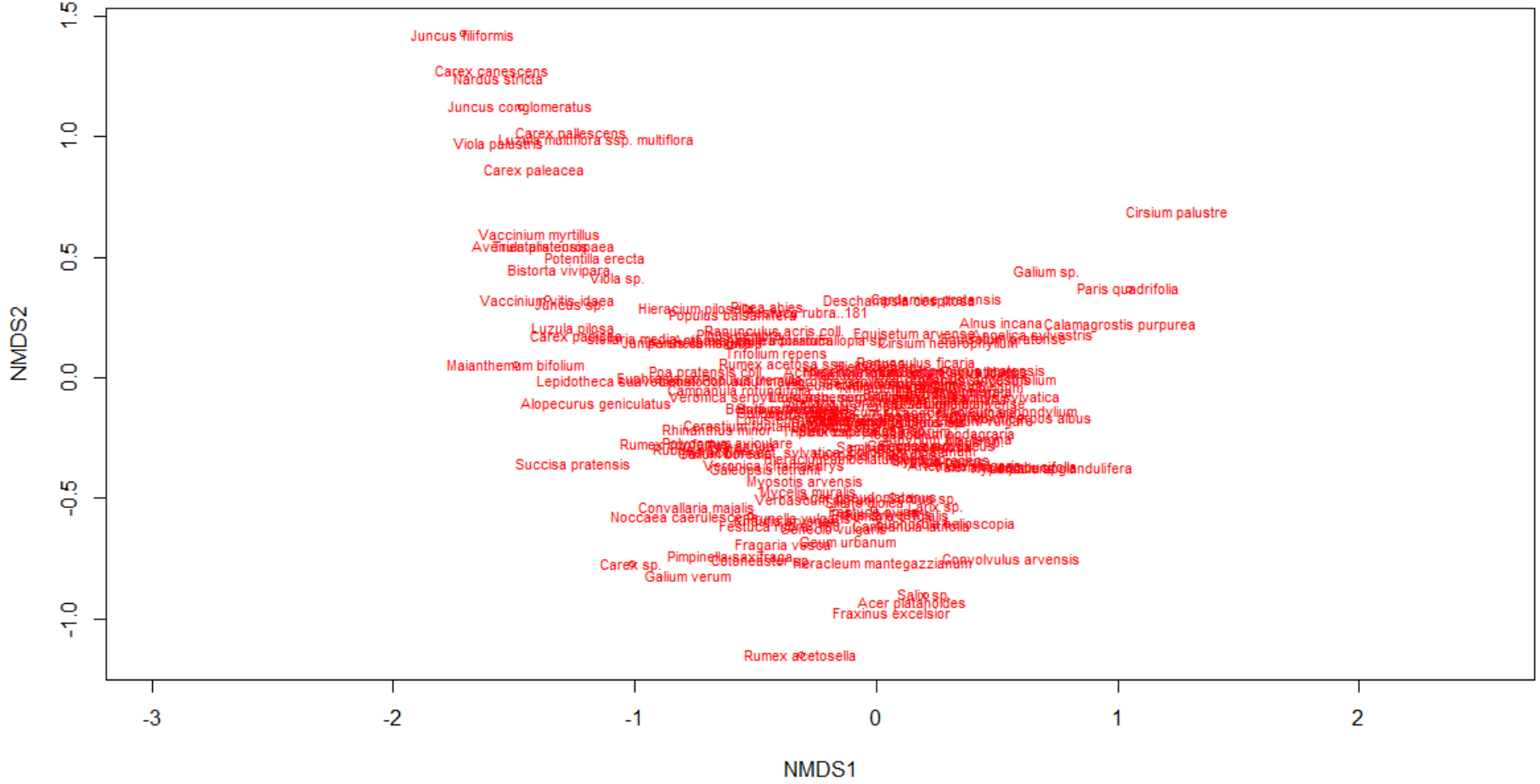

Figure 7: Ordination plot of vascular plant species along non-metric multidimensional scaling (NMDS) axes 1 (MDS1) and 2 (MDS2). See appendix B for species lists.

3.4.2 Grassland species:

The NMDS of the strict grassland species (n=96) resulted in a 4-axis optimal solution, with final stress 0.092. As with the NMDS analysis for all recorded species, the coordinates from the grassland species analysis were significantly different for three of the land-use types. Both *Tall grasses and weeds* (2) and *Late succession* (3) were significantly different from *Home field grazing* (4) (figure 8, table 8). Result of post hoc Tukey comparison of differences between land-use types for axis 2, 3 and 4 are given in appendix D. The ordination plot of the species revealed some clustering according to land-use type, though most species are clustered around origin (figure 9). The species located on the left (negative) side of the plot are mostly smaller stress tolerant species while the species located on the right (positive side) are mostly tall and fast-growing species (competitors).

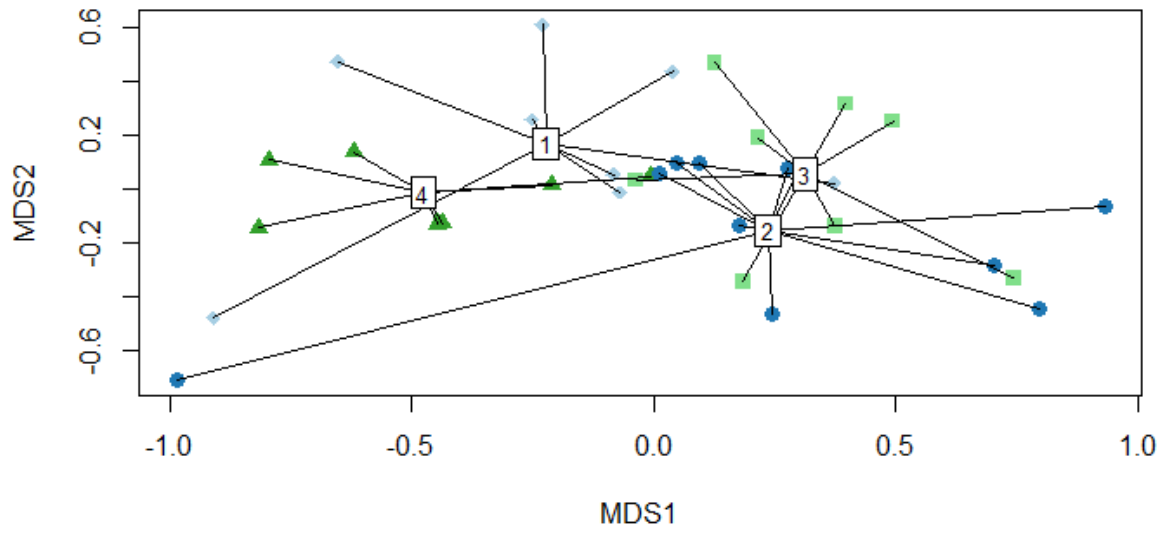

Figure 8: Ordination plot of 34 grassland sites classified into 4 different habitats (cf. Table 1) along non-metric multidimensional scaling (NMDS) axes 1 (MDS1) and 2 (MDS2). The number at the centre of each cluster describes its land-use type as follows: 1: Semi-natural grassland, *2:* Tall grasses and weeds, *3:* Late succession, *4:* Home field grazing.

Table 8: Post hoc Tukey comparison of differences between land-use types based on ordination score along axis 1 (MDS1) (se figure 8).

	difference	**Lower**	**Upper**	**P adj**
Tall grasses and weed - Semi natural grassland	0,459	-0,041	0,959	0,081
Late succession - Semi natural grassland	0,536	-0,002	1,073	0,051
Home field grazing - Semi natural grassland	-0,253	-0,810	0,304	0,610
Late succession - Tall grasses and weed	0,077	-0,423	0,577	0,975
Home field grazing - Tall grasses and weed	-0,712	-1,232	-0,192	**0,004**
Home field grazing - Late succession	-0,788	-1,345	-0,232	**0,003**

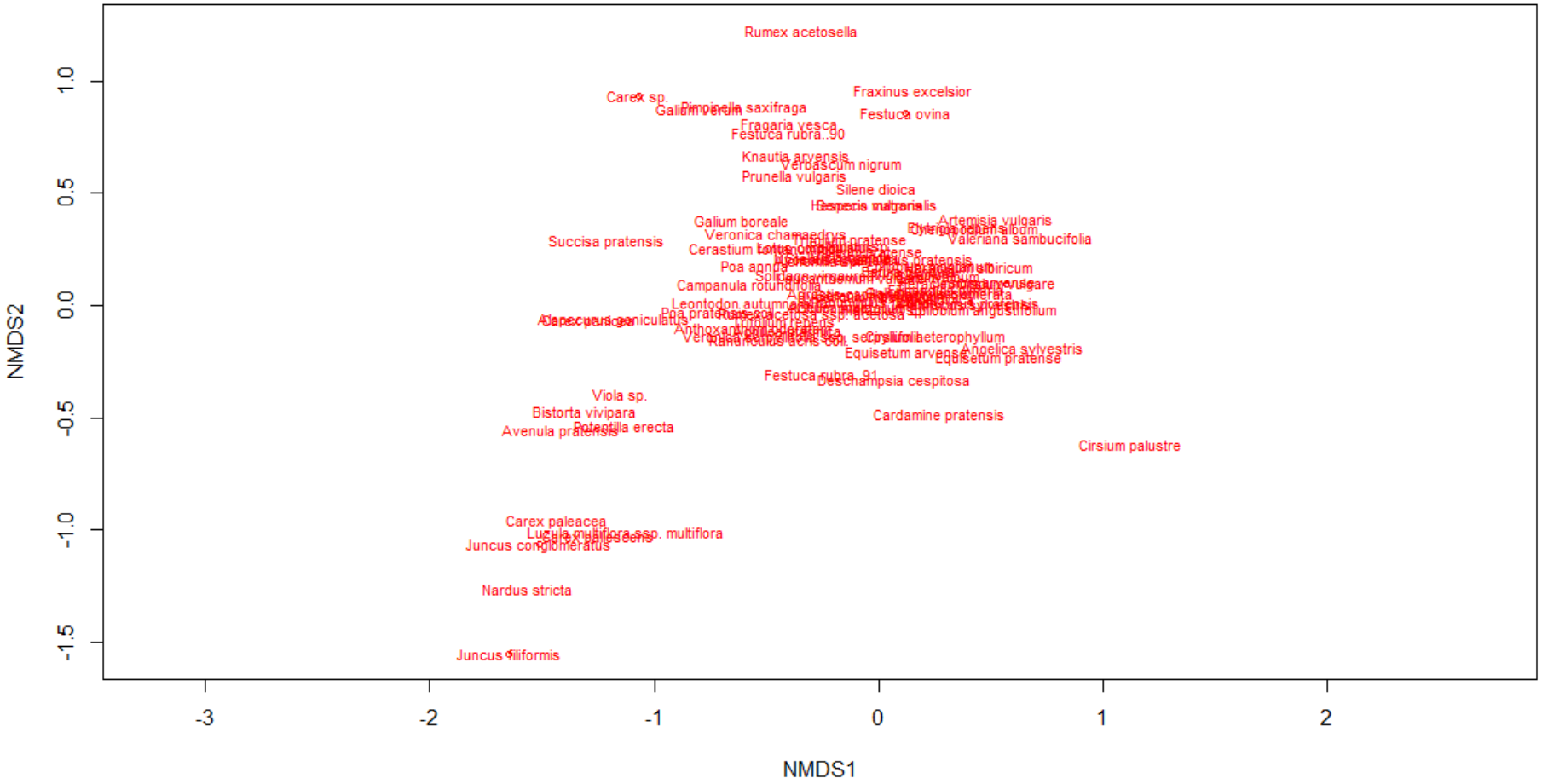

Figure 9: Ordination plot of grassland plant species along non-metric multidimensional scaling (NMDS) axes 1 (MDS1) and 2 (MDS2). See appendix B for species lists.

4. Discussion

Grasslands are important habitats for biodiversity, but land-use change such as urbanization is a great threat (IPBES; Lindborg & Eriksson, 2004). This study examined grassland habitats within a delimitated area of Trondheim municipality, their land use and main habitat characteristics. In addition, a subset of 31 grassland sites were examined for vascular plant diversity and soil nutrients to explore how land use and soil affected grassland plant diversity.

4.1 Current land-use of OFG and HFG

1539 polygons classified as open firm ground (OFG) were classified according to land-use in the study. In area, the biggest land-use group was *Public parks and gardens* which constituted 38% of OFG-area within the delimitation. Public parks traditionally serve a lower ecological value than semi-natural grasslands due to its high rates of disturbance and alien species (Klaus, 2013). In recent years, it has become an increasing focus to increase the ecological value of public parks and to promote native species (Often, 2011; Øien, 2013). Aronson et al. (2014) found that the majority of species found in urban areas are local, but that the urban species pool only constitutes about 25 % of the local species pool. The second largest land-use category was -*outdoor sport facilities*. Many of these areas displayed similar ecological characteristics as *public parks and gardens*, with high rate of disturbance and alien species. As polygons were classified according to use, this category also included artificial turf, which, due to its artificial land cover, has a negligible ecological value. *Public parks and gardens* and *outdoor sport facilities* both provide important ecosystem services to the urban population. In addition to their biological value and supporting services these sites provide both recreational and cultural services. “Marinen”, a park in the city centre, and “Sverresborg Folk Museum” are two examples of this. “Sverresborg Folk Museum” has also included traditional management in its areas, resulting in sites with semi-natural grassland characteristics.

The most numerous land-use type was *edge zone*, though it only constituted 16% of area of OFG-polygons. This land-use category represents a potentially important function as steppingstones between habitats, as many of these areas were roadside, and patches separating roads. This is supported by Beninde et al. (2015), who found that patch area and corridors had a positive effect on biodiversity. *Edge* zones also provide important regulatory ecosystem services to the local population. Vegetation alongside roads have been found to reduce air

pollution, and open vegetation has been found to help rainwater drainage (Bolund & Hunhammar, 1999).

The other main group of study sites included in this study were sites categorized as *home field grazing* (HFG). In land cover, only 19% of area was used for grazing, the management regime the category's name might suggest. It is important to point out that unlike the classification defined in this study, AR5 classifies according to soil status, not usage. 32% of land area was classified as *semi-natural grasslands*. Combined, these two categories represent the desired habitat types to promote diversity (Bonari et al., 2017). Semi-natural grasslands, both grazed and mowed are species rich with a distinct species composition, with potential cascading effects on invertebrates and higher trophic levels, which directly or indirectly are depending on the plant community (Bonari et al., 2017). These sites include sites where traditional management have been continued at low intensity in recent history, areas that have been restored, and areas that have been abandoned, yet still maintain its semi-natural characteristics (Artsdatabanken, 2018b). The habitat type is considered endangered in its own right, and multiple species of special interest were observed at these habitat types, including the red listed species mother of thyme (*Thymus praecox arcticus*) and field gentian (*Gentianella campestris*) (Artsdatabanken, 2015).

The land-use categories *Late Succession* and *Tall grasses and weeds* were dominated by weeds, successional shrubs and forest species and with few strict semi-natural grassland species. In the interest of preserving the semi-natural grassland (an early successional stage), late successional stages promote different species composition and different ecosystem services. *Tall grasses and weeds* were often dominated by pioneer species such as rosebay fireweed (*Epilobium angustifolium*), European raspberry (*Rubus idaeus*) and meadowsweet (*Filipendula ulmaria*), indicating high nutrient levels and intensive previous land-use (Moen et al., 1993). Though these species indicate high nitrogen content, the soil samples showed lower nitrogen levels. This can be due to the nitrogen being fixated in the above ground biomass (Kleinebecker et al., 2018).

4.2 Species richness and species composition

Species richness was recorded for 34 sites classified as HFG. The species richness varied within each land-use category, but not significantly between them. In contrast, it was expected form our hypothesis that the low-intensity use and less disturbed areas would have higher species

richness: that *semi-natural grasslands* and *home field grazing* would have higher species richness due to their management regimes. The management intensity was not included as a factor in the analysis, which could account for some of the variation within each land-use category. An example is the variation within *homefield grazing*. (Klaus, 2013) looked at how management regimes (fertilization, mowing, grazing) and intensity affected the seedbanks in temperate grasslands. The study found that intensive mowing and fertilization decreased species richness while intensive grazing increased species richness.

A linear model was used to explain the relationship between species richness and soil nutrient levels. None of the nutrient levels tested had a linear relationship with species richness. Both total species richness and species richness/area was tested, but neither gave any significant results, rejecting our hypothesis that lower nutrient levels results in higher species richness. This is not consistent with literature, as Cornwell and Grubb (2003) assessed the regional species richness patterns in central Europe. They found that grassland species richness peaked on nutrient-poor soils. Especially high levels of soil nitrogen has been found to have a negative impact on species richness. Stevens et al. (2010) investigated how nitrogen deposition affected species richness in grasslands. They found that species richness decreased with increased nitrogen deposition. A reason for why the total nutrient value might not be a good indicator was expressed by Kleinebecker et al. (2018). They explored the explanatory power of different indicators of nutrient value in explaining species richness in agricultural grasslands and found direct measurements of soil nutrient was less effective at predict plant species richness. This was in part attributed to the effects of the temporal variability on plant productivity (Kleinebecker et al., 2018).

According to our hypothesis, soil nutrient levels were expected to vary between land-use types. However, total nitrogen in *Home field grazing* and *tall grasses and weeds* were the only two groups that were different. *Home field grazing* had high levels of nitrogen while *tall grasses and weeds* had low levels of nitrogen. The high nitrogen content in *Home field grazing* could be due to artificial fertilization, or fertilization from the grazing animals. The low nitrogen content in *tall grasses and weeds* (the land-use type had both low variance and low content) could be due to fixation in above ground biomass (Kleinebecker et al., 2018). These sites were often dominated by species such as rosebay fireweed and European raspberry that would indicate a higher nitrogen content.

The NMDS showed that the species composition of both *Tall grasses and weeds* and *Late succession* were different from that of *Home field grazing.* Both *Tall grasses and weeds* and *Late succession* had many typical competitor-species such as rosebay fireweed while *semi-natural grassland* and *home field grazing* showed a more similar species composition with a high proportion of strict grassland species. This is in line with the findings of Bonari et al. (2017), who looked at the effect of management practices on species richness and species composition. They found that species composition was affected by mowing, grazing and mixed management. The study concluded that management regimes that resembles the historic regimes would best promote the local species composition.

From the ordination plot for all observed species, we see that the species that thrive in open areas clustered together on the left side and typical forest species clustered on the right side. For the ordination plot for the strict grassland species, the distribution of species reflected a nutrient gradient, with the species adaptable to low nutrient levels on the right and species that grow fast and tall are on the right. These ordination plots indicate that a focus on land-use and desired species composition can affect the compositional gradient, which is in accordance with our hypothesis.

4.3 Methodological considerations

Field data was recorded during the summer of 2018, this summer precipitation was low and temperatures were high (Grinde, Heiberg, & Mamen, 2018). These climatic conditions could have had an effect on productivity and soil composition (Kleinebecker et al., 2018). Management intensity was not measured quantitively for this study. Estimations of shrub cover were performed during field survey (see appendix A), but it was not included as a factor in the analysis. Management intensity has been found to have an effect on species richness, so future studies could include land-use intensity to better show the relationship between soil nutrient levels and species richness. As total nutrient levels have been found to be less effective in predicting species richness, future studies could include other indicators for nutrient levels (Kleinebecker et al., 2018).

4.4 Management implications

The urban species pool has been found to hold a low share of the local species pool (Aronson et al., 2014). In Trondheim, the urban grasslands were primarily parks and recreational spaces, contributing less in promotion of local species due to its intensive management regime. Though these areas provide important cultural ecosystem services, management effort could include more local species and have less intensive management regimes, to improve the regulating and supporting services. Inclusion of parks in management efforts has also been suggested in relation to protection against the spread of invasive species. Hostetler et al. (2011) highlighted the importance of including surrounding areas of protected sites, arguing that policies should target both new and established areas to ensure this.

The presence of both endangered nature types and endangered species in the urban setting exemplifies the need to include urban areas in conservation and the importance of proper management, such as low intensity grazing or mowing, of these sites (Bonari et al., 2017; Hansson & Fogelfors, 2000). The ordination analysis showed that land-use has an effect on the species composition, which indicates that management of land-use can promote the desired species. A focus on management promoting grassland species should therefore be a priority in conservation efforts.

5. Conclusion

Trondheim has large areas dominated by grasslands providing important ecosystem services to its population. However, this study showed that grassland areas consisted of primarily of parks and recreational spaces, and thus the ecosystem services provided were primarily cultural and recreational. Contradictory to our hypotheses, no linear relationships were found between soil nutrient levels and species richness. However, species composition was significantly different for three of the land-use types, indicating that management of land-use can promote wanted species composition.

6. Acknowledgements

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Appendix A: Vascular plants species observed for 34 localities in Trondheim

Observed vascular plants for 34 localities in Trondheim. Locality ID is in accordance with msid in the AR5 map provided by the municipality. Abundance is evaluated on a scale from 1(rare) to 3(dominant).

Part 1:

Scientific name	Norwegian name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Pteridophytes													
Athyrium filix-femina	Skogburkne		2					2		2		2	
Equisetum arvense	Åkersnelle							2					
Equisetum pratense	Engsnelle												
Equisetum sylvaticum	Skogsnelle	2	3	2		2		2	2	2			
Gymnocarpium dryopteris	Fugletelg												
Gymnosperms													
Juniperus communis	Einer											2	
Larix sp.	Lerk					1			1		1		
Picea abies	Gran			2						2			
Pinus cembra	Sembrafuru									2	1		
Pinus sylvestris	Furu					1					2		
Trees, shrubs and dwarf shrubs													
Acer platanoides	Spisslønn					2					2		
Acer pseudoplatanus	Platanlønn				2			2		2	2	2	
Alnus incana	Gråor	2		2				2	2	2			
Alnus sp.	Or												
Betula pendula	Hengebjørk								2				
Betula pubescens	Dunbjørk			2	2	2			2		2	2	2
Calluna vulgaris	Røsslyng											2	
Corylus avellana	Hassel												

Scientific name	Norwegian name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Cotoneaster sp.	Mispel										1	2	
Fallopia sp.	Slirekne												
Fraxinus excelsior	Ask					1					2		
Hippophae rhamnoides	Tindved											3	
Lonicera xylosteum	Leddved										2		
Malus sp.	Eple												
Populus balsamifera	Balsampoppel							2					
Populus tremula	Osp							2	2				2
Prunus padus	Hegg	2				2		2	2		2		
Ribes sp.	Rips										2		
Rosa rugosa	Rynkerose									1			
Rosa sp.	Nyperose	2						2	2		2	3	2
Salix caprea coll.	Selje	2		2	2	2	2	2	2	1	2	2	2
Salix sp.	Vier												
Sambucus racemosa	Raudhyll					1		2		2	2		
Sorbus aucuparia	Rogn				2	2	2	2			3	2	2
Sorbus sp.	Asal										1		
Spirea sp.	Spirea									2			
Symphoricarpos albus	Snøbær									2			
Ulmus glabra	Alm												
Vaccinium myrtillus	Blåbær											2	
Vaccinium uliginosum	Blokkebær												
Vaccinium vitis-idaea	Tyttebær											2	
Herbs													
Cardamine amara	Bekkekarse							2					
Heracleum sp.	Bjørnekjeks			3					3	2		2	
Campanula rotundifolia	Blåklokke			1			1		1		3	3	2
Succisa pratensis	Blåknapp											2	
Prunella vulgaris	Blåkoll												

Scientific name	Norwegian name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Rubus idaeus	Bringebær		2			2		2	2	2	2	2	
Artemisia vulgaris	Burot					1		2					
Hesperis matronalis	Dagfiol											2	
Galeopsis sp.	Då		2			1							2
Geum rivale	Enghumleblom	2						2					
Rhinanthus sp.	Engkall												
Cardamine pratensis	Engkarse						2						
Ranunculus acris coll.	Engsoleie	2	2	2			2		2				
Rumex acetosa ssp. *acetosa*	Engsyre	2	2	2	2		2	2	2	1	2		2
Viola sp.	Fiol												
Hypericum maculatum	Firkantperikum							2	2			2	2
Lysimachia vulgaris	Fredløs												
Vicia cracca	Fuglevikke	2		2		1	2	2		1	2	2	
Leontodon autumnalis	Følblom	1		2	2		1	2	2	1	2	2	2
Epilobium angustifolium	Geitrams			3	3	2		2	2	3	2		3
Pimpinella saxifraga	Gjeldkarve										3	3	3
Vicia sepium	Gjerdevikke	2		2		2	1	2	2	2	2		2
Stellaria graminea	Grasstjerneblom	2	2	2			1	2	2			2	2
Plantago major	Groblad	2	2		2			2		1			
Galeopsis speciosa	Guldå							1					
Solidago virgaurea	Gullris							2				1	2
Galium verum	Gulmaure										3	3	
Lathyrus pratensis	Gulskolm	2	2	2	2	2		2	2	2	2	2	2
Bistorta vivipara	Harerug											2	
Tussilago farfara	Hestehov	2		2	2	2		2	2		2		
Anthriscus sylvestris	Hundekjeks	2	2	3	3	3	2	3	3	3	2		2
Rumex longifolius	Høymole	2	2		2	2	2	2		2	2		
Hieracium pilosella	Hårsvæve												
Fumaria offcialis	Jordrøyk							1					

Scientific name	Norwegian name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Antennaria dioica	Kattefot											2	
Heracleum mantegazzianum	Kjempebjørnekjeks										3		
Impatiens glandulifera	Kjempespringfrø							3		2			
Geum urbanum	Kratthumleblom		2			1		1			2	2	
Epilobium montanum	Krattmjølke		2		2	1		2	2				
Rumex confertus	Krushøymol												
Ranunculus repens	Krypsoleie		2	2	2	1	2	2	2				
Galeopsis tetrahit	Kvassdå							1					
Cirsium heterophyllum	Kvitbladtistel	2		2			2	2	2	2			
Trifolium repens	Kvitkløver	2		2	2	1	2			2		3	
Galium boreale	Kvitmaure								1			2	3
Anemone nemorosa	Kvitveis												
Heracleum sphondylium	Kystbjørnekjeks												
Veronica officinalis	Legeveronika												
Convallaria majalis	Liljekonvall											2	2
Spergula arvensis	Linbendel												
Lupinus sp.	Lupin			3				2	1	2			
Taraxacum sp.	Løvetann	2	2	2	2	2	2	2	2	1	2	2	2
Maianthemum bifolium	Maiblom												
Alchemilla sp.	Marikåpe	2	2	2	2	1	2	2	2	2	3	3	2
Fragaria vesca	Markjordbær										2	2	
Galium sp.	Maure												
Chenopodium album	Meldestokk							1					
Filipendula ulmaria	Mjødurt	2	2	2	2	2		2	2	1		2	
Epilobium sp.	Mjølke sp.											2	
Viola palustris	Myrfiol												
Cirsium palustre	Myrtistel									1			
Verbascum nigrum	Mørkkongslys												2
Thymus praecox ssp. Articus	Norsk timian											2	

Scientific name	Norwegian name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Achillea ptarmica	Nyseryllik	2		2			1	2	2	1			2
Hypericum sp.	Perikum												
Leucanthemum vulgare	Prestekrage	1		1	1		1						2
Tanacetum vulgare	Reinfann										3		
Achillea millefolium	Ryllik	2	2	2	2		2	2	2	2	2	3	2
Silene dioica	Rød jonsokblom						1	2					
Trifolium pratense	Rødkløver	2	2	2		1	2		2	2	2	3	3
Knautia arvensis	Rødknapp										2	2	2
Heracleum sibiricum	Sibirbjørnekjeks												2
Hieracium umbellatum	Skjermsvæve			2							2	2	
Viola riviniana	Skogfiol												
Trifolium medium	Skogkløver											2	
Mycelis muralis	Skogsalat											2	
Trientalis europaea	Skogstjerne												
Geranium sylvaticum	Skogstorkenebb	2	2		2		2	2	2	1		2	2
Stachys sylvatica	Skogsvinerot							2					
Hieracium sect. *sylvatica*	Skogsvæver												3
Chamaepericlymenum suecicum	Skrubbær												
Aegopodium podagraria	Skvallerkål			2		2	2	2	2	2	2		2
Angelica sylvestris	Sløkje			2				2	2	1			
Rhinanthus minor	Småengkall										2		2
Rumex acetosella	Småsyre										2		
Veronica serpyllifolia ssp. *serpyllifolia*	Snauveronika				2		2						
Impatiens noli-tangere	Springfrø												
Campanula latifolia	Storklokke												
Melampyrum pratense	Stormarimjelle												
Galium album	Stormaure								2	1			
Urtica dioica	Stornesle		2		3	2	2	2	2	2	2		

Scientific name	Norwegian name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Listera ovata	Stortviblad												
Convolvulus arvensis	Strandvindel					2							
Galium uliginosum	Sumpmaure			2					2	2			
Hieracium sp.	Svæve						1	2					
Rubus saxatilis	Teiebær											2	
Potentilla erecta	Tepperot								1			2	
Lotus corniculatus	Tiriltunge											2	
Lepidotheca suaveolens	Tunbalderbrå												
Veronica chamaedrys	Tveskjeggveronika						2	2				2	
Tripleurospermum indorum	Ugrasbalderbrå	2			2			1					
Cerastium fontanum coll.	Vanlig arve	2			2								
Persicaria amphibia	Vass-slirekne							2					
stellaria media	Vassarve						2						
Cirsium vulgare	Vegtistel												
Valeriana sambucifolia	Vendelrot					2		2	2	2			
Linum catharticum	Vill-lin											2	
Ranunculus ficaria	Vårkål	2								1			
Potentilla tabernaemontani	Vårmure											1	
Noccaea caerulescens	Vårpengeurt										1	2	
Euphrasia sp.	Øyentrøst			2						1		3	
Brassica rapa ssp. campestris	Åkerkål							1					
Myosotis arvensis	Åkerminneblom				2	1							
Senecio vulgaris	Åkersvineblom				2	1		2				2	
Cirsium arvense	Åkertistel		2	2		3		3	3	3			
Euphorbia helioscopia	Åkervortemjølk							1					
Graminoids													
Agrostis capillaris	Engkvein	3	2	3	2	2	3	2	2	2	3	3	2
Alopecurus geniculatus	Knereverumpe												
Alopecurus pratensis	Engreverumpe										3		

Scientific name	Norwegian name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Anthoxanthum odoratum	Gulaks			2			3		1		2	3	3
Avenella flexuosa	Smyle			2							2	2	
Avenula pratensis	Enghavre											2	
Calamagrostis purpurea	Skogrørkvein									2			
Carex canescens	Gråstarr												
Carex echinata	Stjernestarr												
Carex flacca	Blåstarr											2	
Carex leporina	Harestarr												
Carex nigra ssp. *nigra*	Slåttestarr											2	
Carex paleacea	Havstarr												
Carex pallescens	Bleikstarr												
Carex panicea	Kornstarr											2	
Carex sp.	Starr											2	
Dactylis glomerata	Hundegras	3	2	3	3	3		3	3	3	3	3	3
Deschampsia cespitosa	Sølvbunke	3	3	2	2	2	3	2	2	2			
Elytrigia repens	Kveke					3		3	2	2	2		
Festuca ovina	Sauesvingel												
Festuca rubra	Raudsvingel										2	2	
Festuca rubra	Rødsvingel			2					2				2
Juncus conglomeratus	Knappsiv												
Juncus filiformis	Trådsiv												
Juncus sp.	Siv												
Luzula multiflora ssp. *multiflora*	Engfrytle												
Luzula pilosa	Hårfrytle											2	
Nardus stricta	Finnskjegg												
Paris quadrifolia	Firblad												
Phleum pratense	Timotei	3	2	2	2	2	3		2	2	3		2
Poa annua	Tunrapp		2		2						2		
Poa pratensis coll.	Engrapp		2		2		3		1		2	2	

Scientific name	Norwegian name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Polygonum aviculare	Tungras				2			1					
Scirpus sylvaticus	Skogsivaks	2				2							
	Number of species:	**35**	**28**	**41**	**34**	**41**	**34**	**64**	**50**	**49**	**54**	**65**	**37**

Part 2:

Scientific name	Norwegian name	8436	9017a	9017b	1072	6732	2964	6927	25599	9917	20932	22874
Pteridophytes												
Athyrium filix-femina	Skogburkne				2		2					
Equisetum arvense	Åkersnelle					2			2	2		
Equisetum pratense	Engsnelle						2					
Equisetum sylvaticum	Skogsnelle	3				2	2	2				
Gymnocarpium dryopteris	Fugletelg										1	
Gymnosperms												
Juniperus communis	Einer					2						
Larix sp.	Lerk				1		2					
Picea abies	Gran	2								2		
Pinus cembra	Sembrafuru									1		
Pinus sylvestris	Furu		2			2						
Trees, shrubs and dwarf shrubs												
Acer platanoides	Spisslønn				2							
Acer pseudoplatanus	Platanlønn				3		2			2		
Alnus incana	Gråor		2	2	1	3	3					
Alnus sp.	Or	2						1				
Betula pendula	Hengebjørk											
Betula pubescens	Dunbjørk	2	2		2	2		1	2	2	2	
Calluna vulgaris	Røsslyng											
Corylus avellana	Hassel				2							
Cotoneaster sp.	Mispel		2									
Fallopia sp.	Slirekne					3			1			
Fraxinus excelsior	Ask				2							
Hippophae rhamnoides	Tindved											
Lonicera xylosteum	Leddved											

Scientific name	Norwegian name	8436	9017a	9017b	1072	6732	2964	6927	25599	9917	20932	22874
Malus sp.	Eple				1							
Populus balsamifera	Balsampoppel											
Populus tremula	Osp		2				2	2	2	2	2	2
Prunus padus	Hegg		2		2		2	1				
Ribes sp.	Rips						2					
Rosa rugosa	Rynkerose											
Rosa sp.	Nyperose	2			1		2	2		2		
Salix caprea coll.	Selje	2	2		2	2	2	2	2	2	2	
Salix sp.	Vier				2							
Sambucus racemosa	Raudhyll							2		2		
Sorbus aucuparia	Rogn						2	3	2	2	2	2
Sorbus sp.	Asal						2					
Spirea sp.	Spirea											
Symphoricarpos albus	Snøbær											
Ulmus glabra	Alm						2					
Vaccinium myrtillus	Blåbær											
Vaccinium uliginosum	Blokkebær											
Vaccinium vitis-idaea	Tyttebær											
Herbs												
Cardamine amara	Bekkekarse											
Heracleum sp.	Bjørnekjeks		3		3							
Campanula rotundifolia	Blåklokke				1		2	1	1	2	1	1
Succisa pratensis	Blåknapp										2	
Prunella vulgaris	Blåkoll				2					2		
Rubus idaeus	Bringebær	3			2	2	3	2		2		
Artemisia vulgaris	Burot	2				2						
Hesperis matronalis	Dagfiol				2			1				
Galeopsis sp.	Då			2	2							
Geum rivale	Enghumleblom								2			

Scientific name	Norwegian name	8436	9017a	9017b	1072	6732	2964	6927	25599	9917	20932	22874
Rhinanthus sp.	Engkall							1				
Cardamine pratensis	Engkarse											
Ranunculus acris coll.	Engsoleie	2		2	2	2		2	3	3	3	3
Rumex acetosa ssp. *acetosa*	Engsyre							2	2	2		2
Viola sp.	Fiol								1	2		
Hypericum maculatum	Firkantperikum				1		1		2			
Lysimachia vulgaris	Fredløs		2									
Vicia cracca	Fuglevikke		2			2		1	2			
Leontodon autumnalis	Følblom				1			1	2	3	2	3
Epilobium angustifolium	Geitrams		2	3	2	3	3	2		1		
Pimpinella saxifraga	Gjeldkarve											
Vicia sepium	Gjerdevikke	2	2		1		2	2	1	2		
Stellaria graminea	Grasstjerneblom	2	2		2			2	2	2		2
Plantago major	Groblad				2			2		2		
Galeopsis speciosa	Guldå											
Solidago virgaurea	Gullris						1	1	2	1	1	
Galium verum	Gulmaure										1	
Lathyrus pratensis	Gulskolm	2	3	2	2	3	2	2	2	2		
Bistorta vivipara	Harerug								1	1	2	
Tussilago farfara	Hestehov	2	2	2	2	2	2	2		2		
Anthriscus sylvestris	Hundekjeks	3	2	2	3	2	3	3	2			
Rumex longifolius	Høymole			2	2				3		2	
Hieracium pilosella	Hårsvæve		2									
Fumaria offcialis	Jordrøyk		2									
Antennaria dioica	Kattefot											
Heracleum mantegazzianum	Kjempebjørnekjeks											
Impatiens glandulifera	Kjempespringfrø											
Geum urbanum	Kratthumleblom				2							
Epilobium montanum	Krattmjølke											

Scientific name	Norwegian name	8436	9017a	9017b	1072	6732	2964	6927	25599	9917	20932	22874
Rumex confertus	Krushøymol									2		
Ranunculus repens	Krypsoleie				2	2			3	3	2	
Galeopsis tetrahit	Kvassdå									2		
Cirsium heterophyllum	Kvitbladtistel	2					2	2	1	2	1	
Trifolium repens	Kvitkløver		2	2	1	2		2	2	2	2	2
Galium boreale	Kvitmaure							1		1	1	
Anemone nemorosa	Kvitveis											
Heracleum sphondylium	Kystbjørnekjeks			2	3	2						
Veronica officinalis	Legeveronika											
Convallaria majalis	Liljekonvall											
Spergula arvensis	Linbendel										2	
Lupinus sp.	Lupin	2					2	1		1		
Taraxacum sp.	Løvetann		2	2	2	2	2	2		2		2
Maianthemum bifolium	Maiblom										1	
Alchemilla sp.	Marikåpe		3	2	2	2	2	2	3	3	2	3
Fragaria vesca	Markjordbær		1									
Galium sp.	Maure						2	1				
Chenopodium album	Meldestokk											
Filipendula ulmaria	Mjødurt	1	2				2	1		2		
Epilobium sp.	Mjølke sp.	2	2		2	2	2		2	2	2	
Viola palustris	Myrfiol										2	
Cirsium palustre	Myrtistel											
Verbascum nigrum	Mørkkongslys				1							
Thymus praecox ssp. Articus	Norsk timian											
Achillea ptarmica	Nyseryllik		1			2		2	2	2	2	2
Hypericum sp.	Perikum	1										
Leucanthemum vulgare	Prestekrage		1		1	1	1	1		1	1	
Tanacetum vulgare	Reinfann		2	2	1							
Achillea millefolium	Ryllik	2	2		3		3	2	3	3	2	2

Scientific name	Norwegian name	8436	9017a	9017b	1072	6732	2964	6927	25599	9917	20932	22874
Silene dioica	Rød jonsokblom		2		2					1		
Trifolium pratense	Rødkløver	1	2		1	2	1	2				2
Knautia arvensis	Rødknapp	1			1		1			2		
Heracleum sibiricum	Sibirbjørnekjeks	3					2	2				
Hieracium umbellatum	Skjermsvæve	2						2		2		
Viola riviniana	Skogfiol											
Trifolium medium	Skogkløver											
Mycelis muralis	Skogsalat						2					
Trientalis europaea	Skogstjerne								1		2	
Geranium sylvaticum	Skogstorkenebb	2					2	1		2		
Stachys sylvatica	Skogsvinerot				2		2					
Hieracium sect. *sylvatica*	Skogsvæver											
Chamaepericlymenum suecicum	Skrubbær											
Aegopodium podagraria	Skvallerkål	3	3		2		2	2		2		
Angelica sylvestris	Sløkje	2					2	2				
Rhinanthus minor	Småengkall		2						2	2	2	2
Rumex acetosella	Småsyre											
Veronica serpyllifolia ssp. *serpyllifolia*	Snauveronika											
Impatiens noli-tangere	Springfrø											
Campanula latifolia	Storklokke			2	2			1				
Melampyrum pratense	Stormarimjelle											
Galium album	Stormaure											
Urtica dioica	Stornesle	2		2	3			1		2		
Listera ovata	Stortviblad		1									
Convolvulus arvensis	Strandvindel											
Galium uliginosum	Sumpmaure											
Hieracium sp.	Sveve		2		1	2	2		1		2	
Rubus saxatilis	Teiebær						2			2	2	

Scientific name	Norwegian name	8436	9017a	9017b	1072	6732	2964	6927	25599	9917	20932	22874
Potentilla erecta	Tepperot						1				2	
Lotus corniculatus	Tiriltunge	2				2		1			2	
Lepidotheca suaveolens	Tunbalderbrå								1	2	2	
Veronica chamaedrys	Tveskjeggveronika											
Tripleurospermum indorum	Ugrasbalderbrå											
Cerastium fontanum coll.	Vanlig arve		2							2		2
Persicaria amphibia	Vass-slirekne											
stellaria media	Vassarve										2	
Cirsium vulgare	Vegtistel						1					
Valeriana sambucifolia	Vendelrot	2	2				2					
Linum catharticum	Vill-lin											
Ranunculus ficaria	Vårkål											
Potentilla tabernaemontani	Vårmure											
Noccaea caerulescens	Vårpengeurt				1							2
Euphrasia sp.	Øyentrøst									2	3	2
Brassica rapa ssp. campestris	Åkerkål											
Myosotis arvensis	Åkerminneblom									2		
Senecio vulgaris	Åkersvineblom											
Cirsium arvense	Åkertistel	3	3	3	3	3	3	3				
Euphorbia helioscopia	Åkervortemjølk											
Graminoids												
Agrostis capillaris	Engkvein	2	2	2	2	2	3	2	3	3	3	3
Alopecurus geniculatus	Knereverumpe									2	2	
Alopecurus pratensis	Engreverumpe	2	3	2		2	2	3		2		
Anthoxanthum odoratum	Gulaks	1						2	2	2		2
Avenella flexuosa	Smyle		2			2	2				2	
Avenula pratensis	Enghavre											
Calamagrostis purpurea	Skogrørkvein											
Carex canescens	Gråstarr											

Scientific name	Norwegian name	8436	9017a	9017b	1072	6732	2964	6927	25599	9917	20932	22874
Carex echinata	Stjernestarr											
Carex flacca	Blåstarr											
Carex leporina	Harestarr											
Carex nigra ssp. *nigra*	Slåttestarr											
Carex paleacea	Havstarr									1		
Carex pallescens	Bleikstarr							1				
Carex panicea	Kornstarr											
Carex sp.	Starr											
Dactylis glomerata	Hundegras	3	3		3	2	3	3	3			
Deschampsia cespitosa	Sølvbunke					2	3	2	3		2	
Elytrigia repens	Kveke	2		2	2	2	2	2				
Festuca ovina	Sauesvingel		2									
Festuca rubra	Raudsvingel					2						
Festuca rubra	Rødsvingel						2			2		
Juncus conglomeratus	Knappsiv											
Juncus filiformis	Trådsiv											
Juncus sp.	Siv									2	2	
Luzula multiflora ssp. *multiflora*	Engfrytle											
Luzula pilosa	Hårfrytle									1		
Nardus stricta	Finnskjegg											
Paris quadrifolia	Firblad											
Phleum pratense	Timotei	1	3		2	2		2				2
Poa annua	Tunrapp								1	2	2	
Poa pratensis coll.	Engrapp		2						2	2	2	
Polygonum aviculare	Tungras										2	
Scirpus sylvaticus	Skogsivaks											
	Number of species:	**37**	**44**	**19**	**55**	**36**	**53**	**54**	**38**	**61**	**42**	**20**

Part 3:

Scientific name	Norwegian name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Pteridophytes												
Athyrium filix-femina	Skogburkne				1	2						
Equisetum arvense	Åkersnelle				2	2	2		2			
Equisetum pratense	Engsnelle				2	2			2			
Equisetum sylvaticum	Skogsnelle						2		2	2		
Gymnocarpium dryopteris	Fugletelg											
Gymnosperms												
Juniperus communis	Einer	2										
Larix sp.	Lerk											
Picea abies	Gran	2	2						1			
Pinus cembra	Sembrafuru		2									
Pinus sylvestris	Furu											
Trees, shrubs and dwarf shrubs												
Acer platanoides	Spisslønn											
Acer pseudoplatanus	Platanlønn				2							
Alnus incana	Gråor			3	3	2	3	3	3	2		3
Alnus sp.	Or											
Betula pendula	Hengebjørk											
Betula pubescens	Dunbjørk	2	2						2			
Calluna vulgaris	Røsslyng		2									
Corylus avellana	Hassel											
Cotoneaster sp.	Mispel											
Fallopia sp.	Slirekne											
Fraxinus excelsior	Ask											
Hippophae rhamnoides	Tindved											
Lonicera xylosteum	Leddved											

Scientific name	Norwegian name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Malus sp.	Eple											
Populus balsamifera	Balsampoppel	2										
Populus tremula	Osp		2									
Prunus padus	Hegg			1	1	1						
Ribes sp.	Rips									1		
Rosa rugosa	Rynkerose											
Rosa sp.	Nyperose				1	3						2
Salix caprea coll.	Selje			1	2				2			
Salix sp.	Vier											
Sambucus racemosa	Raudhyll				1	1			2			
Sorbus aucuparia	Rogn		2	1	2	1						
Sorbus sp.	Asal											
Spirea sp.	Spirea											
Symphoricarpos albus	Snøbær											
Ulmus glabra	Alm											
Vaccinium myrtillus	Blåbær	2	2									
Vaccinium uliginosum	Blokkebær		2									
Vaccinium vitis-idaea	Tyttebær		2									
Herbs												
Cardamine amara	Bekkekarse											
Heracleum sp.	Bjørnekjeks				3		2	1		1	2	
Campanula rotundifolia	Blåklokke	2	2		1							1
Succisa pratensis	Blåknapp											
Prunella vulgaris	Blåkoll											
Rubus idaeus	Bringebær			3		3	3	3		3		
Artemisia vulgaris	Burot											
Hesperis matronalis	Dagfiol											2
Galeopsis sp.	Då								1			
Geum rivale	Enghumleblom											

Scientific name	Norwegian name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Rhinanthus sp.	Engkall											
Cardamine pratensis	Engkarse			2								
Ranunculus acris coll.	Engsoleie	3	2				2		2			
Rumex acetosa ssp. *acetosa*	Engsyre		2		1		2		2			
Viola sp.	Fiol	2										
Hypericum maculatum	Firkantperikum						2		2	2		
Lysimachia vulgaris	Fredløs											
Vicia cracca	Fuglevikke				2				2			
Leontodon autumnalis	Følblom	3	2						2			
Epilobium angustifolium	Geitrams			2	2	3	3	3			2	3
Pimpinella saxifraga	Gjeldkarve											
Vicia sepium	Gjerdevikke				2	1	2		2			2
Stellaria graminea	Grasstjerneblom								2	1		2
Plantago major	Groblad	2					2					
Galeopsis speciosa	Guldå											
Solidago virgaurea	Gullris											1
Galium verum	Gulmaure											
Lathyrus pratensis	Gulskolm			1	2				2	2	2	
Bistorta vivipara	Harerug	3	2									
Tussilago farfara	Hestehov			3	2				2	2		
Anthriscus sylvestris	Hundekjeks			3	3	2	2	2	3	3	3	3
Rumex longifolius	Høymole					1			2			
Hieracium pilosella	Hårsvæve	2										
Fumaria offcialis	Jordrøyk											
Antennaria dioica	Kattefot											
Heracleum mantegazzianum	Kjempebjørnekjeks			1								
Impatiens glandulifera	Kjempespringfrø										2	
Geum urbanum	Kratthumleblom											
Epilobium montanum	Krattmjølke											

Scientific name	Norwegian name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Rumex confertus	Krushøymol											
Ranunculus repens	Krypsoleie								2		2	
Galeopsis tetrahit	Kvassdå											
Cirsium heterophyllum	Kvitbladtistel			1	1		1	2	2	2	2	2
Trifolium repens	Kvitkløver	3	2				2		2			
Galium boreale	Kvitmaure											
Anemone nemorosa	Kvitveis		2									
Heracleum sphondylium	Kystbjørnekjeks			3								
Veronica officinalis	Legeveronika		2									
Convallaria majalis	Liljekonvall											
Spergula arvensis	Linbendel											
Lupinus sp.	Lupin											
Taraxacum sp.	Løvetann	2		2	2				2			
Maianthemum bifolium	Maiblom											
Alchemilla sp.	Marikåpe	2			1				2			
Fragaria vesca	Markjordbær				1							
Galium sp.	Maure				2		1	2				1
Chenopodium album	Meldestokk											
Filipendula ulmaria	Mjødurt						1	3	2		3	
Epilobium sp.	Mjølke sp.			1								1
Viola palustris	Myrfiol	3	3									
Cirsium palustre	Myrtistel							2				
Verbascum nigrum	Mørkkongslys											
Thymus praecox ssp. Articus	Norsk timian											
Achillea ptarmica	Nyseryllik	2	2		2				2			1
Hypericum sp.	Perikum											
Leucanthemum vulgare	Prestekrage				1				1			1
Tanacetum vulgare	Reinfann						1	2	2			
Achillea millefolium	Ryllik	2	2	3	2		2		2	2		3

Scientific name	Norwegian name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Silene dioica	Rød jonsokblom											
Trifolium pratense	Rødkløver				2				2			
Knautia arvensis	Rødknapp											
Heracleum sibiricum	Sibirbjørnekjeks											3
Hieracium umbellatum	Skjermsvæve											1
Viola riviniana	Skogfiol		3									
Trifolium medium	Skogkløver											
Mycelis muralis	Skogsalat											
Trientalis europaea	Skogstjerne	2										
Geranium sylvaticum	Skogstorkenebb				1		1	1		2		
Stachys sylvatica	Skogsvinerot			1			1					2
Hieracium sect. *sylvatica*	Skogsvæver											
Chamaepericlymenum suecicum	Skrubbær		2									
Aegopodium podagraria	Skvallerkål				3						3	3
Angelica sylvestris	Sløkje			2	1		1	2		2	2	2
Rhinanthus minor	Småengkall								2			
Rumex acetosella	Småsyre											
Veronica serpyllifolia ssp. *serpyllifolia*	Snauveronika											
Impatiens noli-tangere	Springfrø			2								
Campanula latifolia	Storklokke											
Melampyrum pratense	Stormarimjelle		2									
Galium album	Stormaure											
Urtica dioica	Stornesle	2		3		2		2	2			
Listera ovata	Stortviblad											
Convolvulus arvensis	Strandvindel											
Galium uliginosum	Sumpmaure											
Hieracium sp.	Sveve				2				2	3		
Rubus saxatilis	Teiebær											

Scientific name	Norwegian name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Potentilla erecta	Tepperot	3	3									
Lotus corniculatus	Tiriltunge								2			
Lepidotheca suaveolens	Tunbalderbrå											
Veronica chamaedrys	Tveskjeggveronika											
Tripleurospermum indorum	Ugrasbalderbrå											
Cerastium fontanum coll.	Vanlig arve											
Persicaria amphibia	Vass-slirekne											
stellaria media	Vassarve											
Cirsium vulgare	Vegtistel											
Valeriana sambucifolia	Vendelrot										2	
Linum catharticum	Vill-lin											
Ranunculus ficaria	Vårkål											
Potentilla tabernaemontani	Vårmure											
Noccaea caerulescens	Vårpengeurt											
Euphrasia sp.	Øyentrøst	2							1			
Brassica rapa ssp. campestris	Åkerkål											
Myosotis arvensis	Åkerminneblom											
Senecio vulgaris	Åkersvineblom											
Cirsium arvense	Åkertistel			3	3	3			3			2
Euphorbia helioscopia	Åkervortemjølk											
Graminoids												
Agrostis capillaris	Engkvein	3			2	1	2		2	3		2
Alopecurus geniculatus	Knereverumpe											
Alopecurus pratensis	Engreverumpe			2	2	2	2		2	2	2	3
Anthoxanthum odoratum	Gulaks	2	3		2					3		
Avenella flexuosa	Smyle	3	3									
Avenula pratensis	Enghavre		3									
Calamagrostis purpurea	Skogrørkvein						2				2	
Carex canescens	Gråstarr	2	2									

Scientific name	Norwegian name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Carex echinata	Stjernestarr	2										
Carex flacca	Blåstarr											
Carex leporina	Harestarr	2										
Carex nigra ssp. *nigra*	Slåttestarr											
Carex paleacea	Havstarr		2									
Carex pallescens	Bleikstarr	2	2									
Carex panicea	Kornstarr	2										
Carex sp.	Starr											
Dactylis glomerata	Hundegras			3	3	3	3	3		2	3	2
Deschampsia cespitosa	Sølvbunke	2	3	2	2	2	3	3	2	3		2
Elytrigia repens	Kveke								3			
Festuca ovina	Sauesvingel											
Festuca rubra	Raudsvingel											
Festuca rubra	Rødsvingel	2	2	2	2							
Juncus conglomeratus	Knappsiv	2										
Juncus filiformis	Trådsiv		2									
Juncus sp.	Siv	2										
Luzula multiflora ssp. *multiflora*	Engfrytle		2						1			
Luzula pilosa	Hårfrytle		2									
Nardus stricta	Finnskjegg	3	2									
Paris quadrifolia	Firblad			1								
Phleum pratense	Timotei								2	2		
Poa annua	Tunrapp											
Poa pratensis coll.	Engrapp	2	2									
Polygonum aviculare	Tungras											
Scirpus sylvaticus	Skogsivaks											
	Number of species:	**36**	**37**	**26**	**39**	**19**	**26**	**15**	**43**	**21**	**14**	**25**

Appendix B: Vascular grassland species observed for 34 localities in Trondheim

Observed vascular plants, subcategory grassland species, for 34 localities in Trondheim. Locality ID is in accordance with msid in AR5 map provided by the municipality. Abundance is evaluated on a scale from 1(rare) to 3(dominant).

Part 1:

Scientific name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Equisetum arvense							2					
Equisetum pratense												
Betula pendula								2				
Fraxinus excelsior					1					2		
Ulmus glabra												
Heracleum sp.			3					3	2		2	
Campanula rotundifolia			1			1		1		3	3	2
Succisa pratensis											2	
Prunella vulgaris												
Artemisia vulgaris					1		2					
Hesperis matronalis											2	
Geum rivale	2						2					
Cardamine pratensis						2						
Ranunculus acris coll.	2	2	2			2		2				
Rumex acetosa ssp. acetosa	2	2	2	2		2	2	2	1	2		2
Viola sp.												
Hypericum maculatum							2	2			2	2
Lysimachia vulgaris												
Vicia cracca	2		2		1	2	2		1	2	2	
Leontodon autumnalis	1		2	2		1	2	2	1	2	2	2
Epilobium angustifolium			3	3	2		2	2	3	2		3
Pimpinella saxifraga										3	3	3

Scientific name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Vicia sepium	2		2		2	1	2	2	2	2		2
Stellaria graminea	2	2	2			1	2	2			2	2
Solidago virgaurea							2				1	2
Galium verum										3	3	
Lathyrus pratensis	2	2	2	2	2		2	2	2	2	2	2
Bistorta vivipara											2	
Anthriscus sylvestris	2	2	3	3	3	2	3	3	3	2		2
Antennaria dioica											2	
Epilobium montanum		2		2	1		2	2				
Cirsium heterophyllum	2		2			2	2	2	2			
Trifolium repens	2		2	2	1	2			2		3	
Galium boreale								1			2	3
Veronica officinalis												
Alchemilla sp.	2	2	2	2	1	2	2	2	2	3	3	2
Fragaria vesca										2	2	
Chenopodium album							1					
Filipendula ulmaria	2	2	2	2	2		2	2	1		2	
Epilobium sp.											2	
Cirsium palustre									1			
Verbascum nigrum												2
Achillea ptarmica	2		2			1	2	2	1			2
Leucanthemum vulgare	1		1	1		1						2
Achillea millefolium	2	2	2	2		2	2	2	2	2	3	2
Silene dioica						1	2					
Trifolium pratense	2	2	2		1	2		2	2	2	3	3
Knautia arvensis										2	2	2
Heracleum sibiricum												2
Geranium sylvaticum	2	2		2		2	2	2	1		2	2
Angelica sylvestris			2				2	2	1			

Scientific name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Rumex acetosella										2		
Veronica serpyllifolia ssp. serpyllifolia				2		2						
Melampyrum pratense												
Galium album								2	1			
Urtica dioica		2		3	2	2	2	2	2	2		
Listera ovata												
Galium uliginosum			2					2	2			
Hieracium sp.						1	2					
Potentilla erecta								1			2	
Lotus corniculatus											2	
Veronica chamaedrys						2	2				2	
Cerastium fontanum coll.	2			2								
Cirsium vulgare												
Valeriana sambucifolia					2		2	2	2			
Linum catharticum											2	
Ranunculus ficaria	2								1			
Myosotis arvensis				2	1							
Senecio vulgaris				2	1		2				2	
Cirsium arvense		2	2		3		3	3	3			
Agrostis capillaris	3	2	3	2	2	3	2	2	2	3	3	2
Alopecurus geniculatus												
Alopecurus pratensis										3		
Anthoxanthum odoratum			2			3		1		2	3	3
Avenula pratensis											2	
Carex echinata												
Carex flacca											2	
Carex leporina												
Carex nigra ssp. nigra											2	
Carex paleacea												

Scientific name	5561	4698	17309	13548	17675	26729	27536	27629	5261	16320	21514	13534
Carex pallescens												
Carex panicea											2	
Carex sp.											2	
Dactylis glomerata	3	2	3	3	3		3	3	3	3	3	3
Deschampsia cespitosa	3	3	2	2	2	3	2	2	2			
Elytrigia repens					3		3	2	2	2		
Festuca ovina												
Festuca rubra										2	2	
Festuca rubra			2					2				2
Juncus conglomeratus												
Juncus filiformis												
Luzula multiflora ssp. multiflora												
Nardus stricta												
Phleum pratense	3	2	2	2	2	3		2	2	3		2
Poa annua		2		2						2		
Poa pratensis coll.		2		2		3		1		2	2	
Number of species:	**24**	**19**	**28**	**23**	**22**	**27**	**33**	**36**	**29**	**27**	**39**	**26**

Part 2:

Scientific name	8436	90171	90172	1072	6732	2964	6927	25599	9917	20932	22874
Equisetum arvense					2			2	2		
Equisetum pratense						2					
Betula pendula											
Fraxinus excelsior				2							
Ulmus glabra						2					
Heracleum sp.		3		3							
Campanula rotundifolia				1		2	1	1	2	1	1
Succisa pratensis										2	
Prunella vulgaris				2					2		
Artemisia vulgaris	2				2						
Hesperis matronalis				2			1				
Geum rivale								2			
Cardamine pratensis											
Ranunculus acris coll.	2		2	2	2		2	3	3	3	3
Rumex acetosa ssp. acetosa							2	2	2		2
Viola sp.								1	2		
Hypericum maculatum				1		1		2			
Lysimachia vulgaris		2									
Vicia cracca		2			2		1	2			
Leontodon autumnalis				1			1	2	3	2	3
Epilobium angustifolium		2	3	2	3	3	2		1		
Pimpinella saxifraga											
Vicia sepium	2	2		1		2	2	1	2		
Stellaria graminea	2	2		2			2	2	2		2
Solidago virgaurea						1	1	2	1	1	
Galium verum										1	
Lathyrus pratensis	2	3	2	2	3	2	2	2	2		

Scientific name	8436	90171	90172	1072	6732	2964	6927	25599	9917	20932	22874
Bistorta vivipara								1	1	2	
Anthriscus sylvestris	3	2	2	3	2	3	3	2			
Antennaria dioica											
Epilobium montanum											
Cirsium heterophyllum	2					2	2	1	2	1	
Trifolium repens		2	2	1	2		2	2	2	2	2
Galium boreale							1		1	1	
Veronica officinalis											
Alchemilla sp.		3	2	2	2	2	2	3	3	2	3
Fragaria vesca		1									
Chenopodium album											
Filipendula ulmaria	1	2				2	1		2		
Epilobium sp.	2	2		2	2	2		2	2	2	
Cirsium palustre											
Verbascum nigrum				1							
Achillea ptarmica		1			2		2	2	2	2	2
Leucanthemum vulgare		1		1	1	1	1		1	1	
Achillea millefolium	2	2		3		3	2	3	3	2	2
Silene dioica		2		2					1		
Trifolium pratense	1	2		1	2	1	2				2
Knautia arvensis	1			1		1			2		
Heracleum sibiricum	3					2	2				
Geranium sylvaticum	2					2	1		2		
Angelica sylvestris	2					2	2				
Rumex acetosella											
Veronica serpyllifolia ssp. serpyllifolia											
Melampyrum pratense											
Galium album											
Urtica dioica	2		2	3			1		2		

Scientific name	8436	90171	90172	1072	6732	2964	6927	25599	9917	20932	22874
Listera ovata		1									
Galium uliginosum											
Hieracium sp.		2		1	2	2		1		2	
Potentilla erecta						1				2	
Lotus corniculatus	2				2		1			2	
Veronica chamaedrys											
Cerastium fontanum coll.		2							2		2
Cirsium vulgare						1					
Valeriana sambucifolia	2	2				2					
Linum catharticum											
Ranunculus ficaria											
Myosotis arvensis									2		
Senecio vulgaris											
Cirsium arvense	3	3	3	3	3	3	3				
Agrostis capillaris	2	2	2	2	2	3	2	3	3	3	3
Alopecurus geniculatus									2	2	
Alopecurus pratensis	2	3	2		2	2	3		2		
Anthoxanthum odoratum	1						2	2	2		2
Avenula pratensis											
Carex echinata											
Carex flacca											
Carex leporina											
Carex nigra ssp. nigra											
Carex paleacea									1		
Carex pallescens							1				
Carex panicea											
Carex sp.											
Dactylis glomerata	3	3		3	2	3	3	3			
Deschampsia cespitosa					2	3	2	3		2	

Scientific name	8436	90171	90172	1072	6732	2964	6927	25599	9917	20932	22874
Elytrigia repens	2		2	2	2	2	2				
Festuca ovina		2									
Festuca rubra					2						
Festuca rubra						2			2		
Juncus conglomeratus											
Juncus filiformis											
Luzula multiflora ssp. multiflora											
Nardus stricta											
Phleum pratense	1	3		2	2		2				2
Poa annua								1	2	2	
Poa pratensis coll.		2						2	2	2	
Number of species:	**25**	**29**	**11**	**29**	**23**	**31**	**35**	**28**	**36**	**23**	**14**

Part 3:

Scientific name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Equisetum arvense				2	2	2		2			
Equisetum pratense				2	2			2			
Betula pendula											
Fraxinus excelsior											
Ulmus glabra											
Heracleum sp.				3		2	1		1	2	
Campanula rotundifolia	2	2		1							1
Succisa pratensis											
Prunella vulgaris											
Artemisia vulgaris											
Hesperis matronalis											2
Geum rivale											
Cardamine pratensis			2								
Ranunculus acris coll.	3	2				2		2			
Rumex acetosa ssp. acetosa		2		1		2		2			
Viola sp.	2										
Hypericum maculatum						2		2	2		
Lysimachia vulgaris											
Vicia cracca				2				2			
Leontodon autumnalis	3	2						2			
Epilobium angustifolium			2	2	3	3	3			2	3
Pimpinella saxifraga											
Vicia sepium				2	1	2		2			2
Stellaria graminea								2	1		2
Solidago virgaurea											1
Galium verum											
Lathyrus pratensis			1	2				2	2	2	

Scientific name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Bistorta vivipara	3	2									
Anthriscus sylvestris			3	3	2	2	2	3	3	3	3
Antennaria dioica											
Epilobium montanum											
Cirsium heterophyllum			1	1		1	2	2	2	2	2
Trifolium repens	3	2				2		2			
Galium boreale											
Veronica officinalis		2									
Alchemilla sp.	2			1				2			
Fragaria vesca				1							
Chenopodium album											
Filipendula ulmaria						1	3	2		3	
Epilobium sp.			1								1
Cirsium palustre							2				
Verbascum nigrum											
Achillea ptarmica	2	2		2				2			1
Leucanthemum vulgare				1				1			1
Achillea millefolium	2	2	3	2		2		2	2		3
Silene dioica											
Trifolium pratense				2				2			
Knautia arvensis											
Heracleum sibiricum											3
Geranium sylvaticum				1		1	1		2		
Angelica sylvestris			2	1		1	2		2	2	2
Rumex acetosella											
Veronica serpyllifolia ssp. serpyllifolia											
Melampyrum pratense		2									
Galium album											
Urtica dioica	2		3		2		2	2			

Scientific name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Listera ovata											
Galium uliginosum											
Hieracium sp.				2				2	3		
Potentilla erecta	3	3									
Lotus corniculatus								2			
Veronica chamaedrys											
Cerastium fontanum coll.											
Cirsium vulgare											
Valeriana sambucifolia										2	
Linum catharticum											
Ranunculus ficaria											
Myosotis arvensis											
Senecio vulgaris											
Cirsium arvense			3	3	3			3			2
Agrostis capillaris	3			2	1	2		2	3		2
Alopecurus geniculatus											
Alopecurus pratensis			2	2	2	2		2	2	2	3
Anthoxanthum odoratum	2	3		2					3		
Avenula pratensis		3									
Carex echinata	2										
Carex flacca											
Carex leporina	2										
Carex nigra ssp. nigra											
Carex paleacea		2									
Carex pallescens	2	2									
Carex panicea	2										
Carex sp.											
Dactylis glomerata			3	3	3	3	3		2	3	2
Deschampsia cespitosa	2	3	2	2	2	3	3	2	3		2

Scientific name	28140	25458	28422	17374	11755	3761	15407	22485	28321	7978	8452
Elytrigia repens								3			
Festuca ovina											
Festuca rubra											
Festuca rubra	2	2	2	2							
Juncus conglomeratus	2										
Juncus filiformis		2									
Luzula multiflora ssp. multiflora		2						1			
Nardus stricta	3	2									
Phleum pratense								2	2		
Poa annua											
Poa pratensis coll.	2	2									
Number of species:	**22**	**21**	**14**	**27**	**11**	**18**	**11**	**29**	**16**	**10**	**19**

Appendix C: Field survey

Form used to describe the current land-use and status for sites classifies as HFG.

Date_____ Plot ID_____

1. Biodiversity

Table 1: Observed red listed species

Species name	Coordinates

Table 2: Observed alien species

Species name	Coordinates

2. Environmental conditions

soil alkalinity: [ ] Not evaluated [ ] Alkaline [ ] Intermediate [ ] Acidic

Nutritional value: [ ] Not evaluated [ ] Nutrient rich [ ] Intermediate [ ] Nutrient poor

Soil humidity: [ ] Extreme dry [ ] dry [ ] intermediate [ ] moist [ ] wet [] heterogeneous

Notes:

1

Date_____ Plot ID_____

3. Management

Management intensity: [ ] not in use [ ] extensively [ ] moderate [ ] moderate intensive [ ] intensive

Management regime: [ ] Ploughing [ ] grazing [ ]mowing [ ]fertilizing [ ] pesticides [ ] burning [ ] manual clearing

Reforestation: [ ] in use [ ] <10 % trees and shrubs [ ] 10-30% trees and shrubs [ ] >30% trees and shrubs

Notes:

Appendix D: Results from linear model

Result of Post hoc Tukey comparison of differences for carbon (C%), phosphorus (P-Al), carbon/nitrogen and carbon/phosphorus.

Table 1: Post hoc Tukey comparison of differences in total carbon content (%) between land-use types.

	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	-0,349	-0,847	0,148	0,241
Late succession - Semi natural grassland	-0,260	-0,801	0,280	0,556
Home field grazing - Semi natural grassland	0,031	-0,527	0,590	0,999
Late succession - Tall grasses and weed	0,089	-0,357	0,535	0,946
Home field grazing - Tall grasses and weed	0,381	-0,088	0,849	0,141
Home field grazing - Late succession	0,292	-0,222	0,805	0,167

Table 2: Post hoc Tukey comparison of differences in available phosphorus (P-Al) between land-use types.

	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	-0,001	-0,459	0,457	1,000
Late succession - Semi natural grassland	0,055	-0,460	0,569	0,991
Home field grazing - Semi natural grassland	0,036	-0,533	0,606	0,998
Late succession - Tall grasses and weed	0,056	-0,375	0,487	0,984
Home field grazing - Tall grasses and weed	0,038	-0,458	0,533	0,997
Home field grazing - Late succession	-0,018	-0,566	0,530	1,000

Table 3: Post hoc Tukey comparison of differences in carbon/nitrogen share between land-use types.

	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	-0,109	-0,353	0,135	0,611
Late succession - Semi natural grassland	-0,140	-0,401	0,121	0,465
Home field grazing - Semi natural grassland	-0,114	-0,396	0,168	0,680
Late succession - Tall grasses and weed	-0,031	-0,250	0,189	0,980
Home field grazing - Tall grasses and weed	-0,005	-0,249	0,239	1,000
Home field grazing - Late succession	0,025	-0,236	0,286	0,993

Table 3: Post hoc Tukey comparison of differences in carbon/phosphorus share between land-use types.

	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	-0,382	-1,012	0,249	0,355
Late succession - Semi natural grassland	-0,336	-1,032	0,361	0,548
Home field grazing - Semi natural grassland	-0,136	-0,900	0,627	0,959
Late succession - Tall grasses and weed	0,046	-0,502	0,594	0,995
Home field grazing - Tall grasses and weed	0,246	-0,385	0,876	0,702
Home field grazing - Late succession	0,199	-0,497	0,896	0,855

Appendix E: NMDS Ordination results

All species:

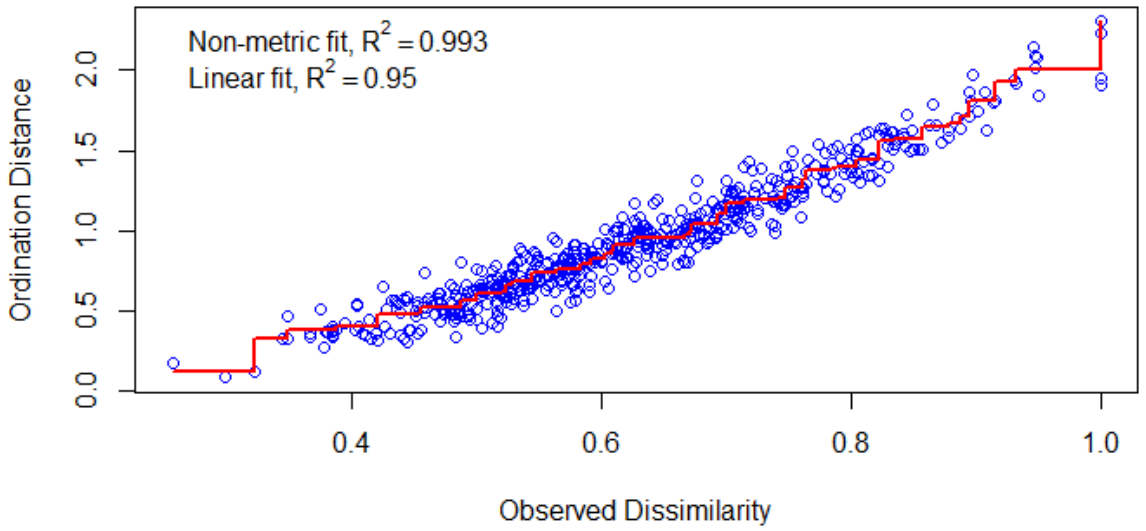


Figure: Stressplot of NMDS for all species.

Post hoc Tukey along axis 2, 3 and 4:

Table 1: Post hoc Tukey comparison of differences between land-use types based on ordination score along axis 2 (MDS2) (se figure 6).

	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	0,246	-0,128	0,621	0,299
Late succession - Semi natural grassland	0,053	-0,350	0,456	0,984
Home field grazing - Semi natural grassland	0,104	-0,314	0,521	0,906
Late succession - Tall grasses and weed	-0,193	-0,568	0,181	0,507
Home field grazing - Tall grasses and weed	-0,143	-0,533	0,247	0,753
Home field grazing - Late succession	0,051	-0,367	0,468	0,987

Table 2: Post hoc Tukey comparison of differences between land-use types based on ordination score along axis 3.

	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	-0,077	-0,430	0,277	0,935
Late succession - Semi natural grassland	0,006	-0,374	0,387	1,000
Home field grazing - Semi natural grassland	0,132	-0,262	0,526	0,800
Late succession - Tall grasses and weed	0,083	-0,271	0,436	0,919
Home field grazing - Tall grasses and weed	0,208	-0,159	0,576	0,427
Home field grazing - Late succession	0,126	-0,268	0,519	0,821

Table 3: Post hoc Tukey comparison of differences between land-use types based on ordination score along axis 4.

	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	0,095	-0,199	0,388	0,817
Late succession - Semi natural grassland	0,171	-0,145	0,487	0,467
Home field grazing - Semi natural grassland	0,313	-0,015	0,640	0,065
Late succession - Tall grasses and weed	0,076	-0,217	0,370	0,894
Home field grazing - Tall grasses and weed	0,218	-0,088	0,523	0,234
Home field grazing - Late succession	0,142	-0,185	0,469	0,645

Grassland species:

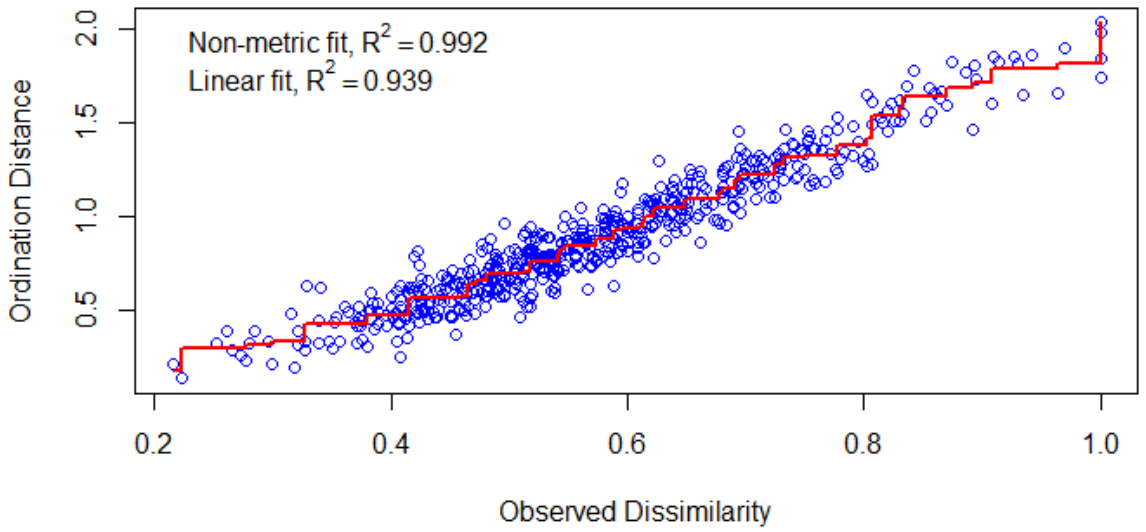


Figure: Stress plot of NMDS for grass species.

Post hoc Tukey along axis 2, 3 and 4:

Table 4: Post hoc Tukey comparison of differences between land-use types based on ordination score along axis 2 (MDS1) (se figure 6).

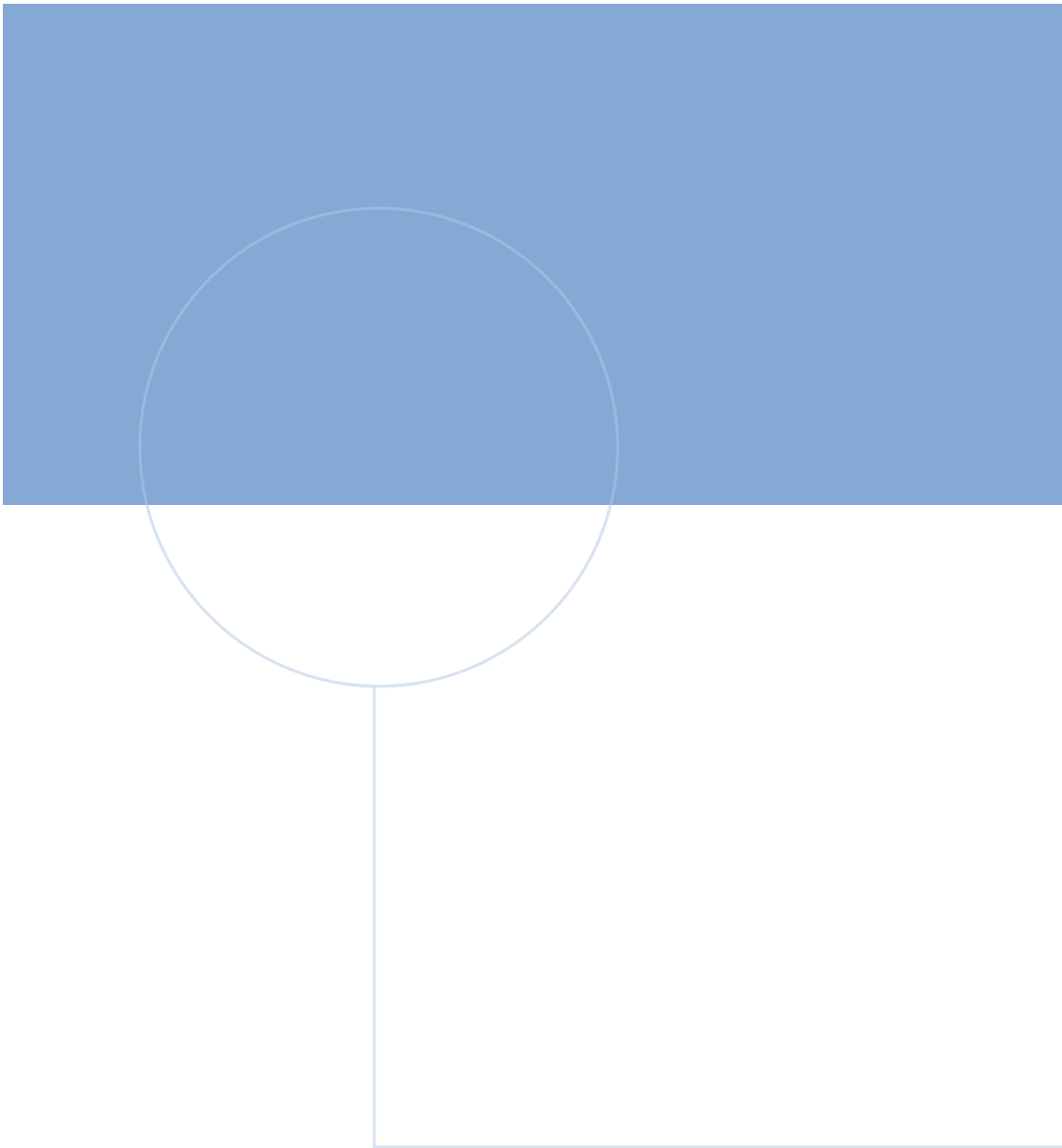
	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	-0,324	-0,678	0,031	0,083
Late succession - Semi natural grassland	-0,114	-0,496	0,267	0,848
Home field grazing - Semi natural grassland	-0,184	-0,578	0,211	0,592
Late succession - Tall grasses and weed	0,210	-0,145	0,564	0,390
Home field grazing - Tall grasses and weed	0,140	-0,229	0,509	0,732
Home field grazing - Late succession	-0,070	-0,464	0,325	0,963

Table 5: Post hoc Tukey comparison of differences between land-use types based on ordination score along axis 3 (MDS1) (se figure 6).

	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	-0,082	-0,436	0,273	0,922
Late succession - Semi natural grassland	-0,031	-0,412	0,350	0,996
Home field grazing - Semi natural grassland	0,017	-0,378	0,411	0,999
Late succession - Tall grasses and weed	0,051	-0,304	0,405	0,980
Home field grazing - Tall grasses and weed	0,099	-0,270	0,467	0,886
Home field grazing - Late succession	0,048	-0,347	0,443	0,987

Table 6: Post hoc Tukey comparison of differences between land-use types based on ordination score along axis 4.

	difference	lower	upper	P adj
Tall grasses and weed - Semi natural grassland	0,009	-0,299	0,318	1,000
Late succession - Semi natural grassland	0,057	-0,275	0,388	0,966
Home field grazing - Semi natural grassland	0,148	-0,195	0,492	0,647
Late succession - Tall grasses and weed	0,047	-0,261	0,356	0,975
Home field grazing - Tall grasses and weed	0,139	-0,182	0,460	0,644
Home field grazing - Late succession	0,092	-0,252	0,435	0,886



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