Remapping Oslo: 40 years of vegetation change in Holmenkollen, Grefsen and Grorud

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Master of Science Thesis
Biology: Ecology and Evolution
Department of Biosciences and the Natural History Museum

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Abstract

Introduction and goals: The world's population is now passing 8 billion, and urbanisation is one of the main threats to biodiversity globally. Oslo, the capital of Norway, has densified considerably within the city zone during the last decades. The landscape effects on biodiversity of urbanisation in Oslo, however, is not well known. The aim of this master thesis is therefore to:

1) Map and quantify the vegetation changes from 1980s to 2021,
2) Interpret and discuss the ecological impact of the registered changes, and
3) Increase the understanding of the process of urbanization with respect to vegetation changes and nature management.

Material and methods: To achieve the aim, detailed vegetation maps (1:10 000) from Oslo, published in the early 1980s, were digitized and remapped in 2021. The three selected vegetation maps from Oslo, represent an east-west gradient, covering the map sheets of Grorud, Grefsen and Holmenkollen. The protected rangeland forest surrounding Oslo (Oslomarka) was excluded. The remapping was done in-situ with aerial photos, with QGIS in a field-computer with GPS. Land cover transformations and area statistics were estimated using QGIS, whereas analyses on ecological impacts were measured using landscape ecology metrics from FRAGSTATS.

Results: Within the re-mapped parts of Oslo, between 1980 and 2021, large areas with vegetation types were lost to urbanisation. Cultivated land, bilberry spruce forests, abandoned species rich meadows and low herb spruce forest decreased most in terms of area. In terms of percentage reduction, moist meadow, weeds, cultivated land and abandoned species rich meadows were most reduced. For the landscape metrics, many index values were reduced from 1980 to 2021. For the class indices, the values show clear directions. The total area of each class (CA) and the mean patch area (AREA_MN) decrease, whereas the mean of Euclidean nearest-neighbor distance (ENN_MN) increases. Housing, apartment buildings, golf courses, industrial areas and business and office premises are the urban types that has expanded most in terms of area.

Discussion: The loss of cultivated land is probably of minor importance for biodiversity conservation, except when there is a trajectory towards rewilding, which is positive in terms of management. Most other losses of vegetation types will influence the capability of sustainable management of biodiversity. Noticeable, the other vegetation types have smaller and fewer polygons, which is lowering the connectivity and increasing the fragmentation.

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Introduction

The proportion of the global population living in urban areas is increasing. Although the global population growth rate is predicted to decrease (United Nations, 2019), an increased proportion is predicted to live in urban areas in the future. The trend of urbanization is not new. In 1950, 30 % of the global population lived in urban areas. By 2018, the global population living in urban areas reached 55 % and is expected to increase to 68 % by 2050 (United Nations, 2019). This might lead to an increase in human pressure on nature surrounding cities, as well as the nature remaining within the cities. In Norway, the urban population percentage is higher than the global average. In 2021, 82 % of the population in Norway were residing in urban areas (SSB, 2021).

The world is not only facing a climate crisis (Al-Ghussain, 2019; Pörtner and Roberts, 2022), but a biodiversity crisis as well (Butchart et al., 2010). Of all human activity, urbanization is one of the greatest threats to biodiversity (Czech et al., 2000; McDonald et al., 2020; Pimm and Raven, 2000; Sala et al., 2000), and habitat loss is one of the key reasons for species extinction (Halley et al., 2013). Different species have different habitat requirements. When a patch of vegetation is lost, several species might lose their habitat. This is true even if the vegetation is not lost to e.g., urbanization and human development, but could also follow from a change in vegetation character, e.g., by forest regrowth or wildfire. However, overall, human activity has a large-scale impact on the earth's areas and 75 % of earth's land areas have been degraded by human impact (IPBES 2018). Vegetation plays an important role in regulating the cycles of the biosphere and affects both water cycles, climate, biodiversity and soil (Biondi et al., 2004; Bonan, 2016). Vegetation is important for soil protection as it binds soil and helps prevent soil loss and runoff (Liu et al., 2018). Vegetation in many locations is suffering from water shortage and drought (Binns et al., 2001; Kelley et al., 2015). Water shortage is a global problem as billions of people lack adequate access to clean water (Mekonnen and Hoekstra, 2016) and the World Economic Forum considers the water crisis to be one of the largest risks the world is facing (World Economic Forum, 2015).

To combat nature-loss, action needs to be taken on a global scale. “Leaders pledge for nature” is a commitment endorsed by more than 90 world leaders, including the former prime minister of Norway, Erna Solberg. The aim of the pledge is to reverse biodiversity loss by 2030. To achieve this goal, it is necessary to protect existing nature and to restore already damaged nature. This was acknowledged by the UN, who declared 2021-2030 to be the decade of ecosystem restoration (“UN Decade on Restoration,” n.d.). Ecosystem restoration is thus widely acknowledged as an important contribution to combating nature loss. According to IPBES (2019), one million species are at present in danger of becoming extinct, and loss of habitat is one of the most important reasons for species loss (Halley et al., 2013; Pimm and Askins, 1995).

Knowledge-based land management is invaluable if the loss of nature is to be limited. Knowledge-based land management is dependent on knowledge both of what needs management to persist and where this is. Therefore, we need to know the condition and distribution of different types of vegetation. This makes mapping of vegetation types defined by plant species an important tool in nature management and city planning (Pedrotti, 2013).

Vegetation type and nature type maps.

Vegetation maps show a generalized picture of the composition and distribution of vegetation in a given area at the time of mapping (Bryn, 2006). Variation in nature is often categorized according to species composition, environmental gradients, and climatic/geological factors (Halvorsen et al., 2020). The variation is infinite in time and space, making it impossible to give an accurate representation of all variations on a single map. Variation in nature is for the most part continuous with no sharp borders (Goodall, 1963; Morgan et al., 2010). Dividing continuous variation into classes is a type of ecological generalization necessary in vegetation mapping (Bryn et al., 2020). Species respond differently to growing conditions such as bioclimatic zones, temperature, soil pH, precipitation, disturbances and other factors. Some species are often found together, and the vegetation types represent more or less stable entities (Bryn, 2006). A vegetation type can be described as a characteristic group of species found together in places with similar conditions (Rekdal and Larsson, 2005).
Vegetation maps are a useful tool in environmental and urban management as well as for various research purposes (De Cáceres and Wiser, 2012).

The main applications fall within five categories (Bryn et al., 2020):

- describing nature
- documentation of variation in nature: presence and distribution of vegetation and nature types
- management: basis for decision making on land use change, conservation or development
- research: ground truth in modeling, red list assessments
- monitoring changes in nature

Several classification systems for vegetation mapping have been developed. Such systems are often hierarchical, dividing vegetation into classes at different levels (Cherrill and McClean, 1999). In Norway, the vegetation mapping system by Fremstad (1998) is one system used for detailed mapping at scales between 1:5 000 and 1: 20 000. A system by Rekdal and Larson (2005) is an option for survey mapping on scales between 1:20 000 and 1: 50 000.

There are long traditions for vegetation mapping in Norway (Bryn, 2006), but in the last decade there has been a shift in focus from mapping of vegetation types to mapping of nature types (European Environment Agency. and Museum national d'Histoire naturelle (MNHN)., 2014). Whereas vegetation type maps focus on the differences in vegetation, nature type maps take into consideration the variation in vegetation and animal species (Halvorsen et al., 2009). Before 2015, DN Håndbok 13 was the most used mapping system. In 2015 Natur i Norge (NiN) became the norm for publicly funded mapping of nature types in Norway (Meld. St. 14 (2015–2016), 2015). Species composition changes along environmental gradients, making environmental variation an important aspect of the NiN system (Halvorsen et al., 2009).

Remapping

If vegetation maps are to be of use in planning and management, they must be up to date. Vegetation changes due to climate change and altered land use (Bryn, 2008; Moen et al., 2006; Rutherford et al., 2008) means vegetation maps are valid only for a limited time period, and will at some point be outdated. One method of updating maps is remapping, where the same area is mapped anew. Remapping not only makes the maps up to date, but it also enables comparisons between the old and new maps and makes it possible to investigate changes in the composition of species or nature types (Käyhkö and Skånes, 2006; Lundberg, 2011). Thus, remapping is a tool to track changes in vegetation and nature types over time.

City planning

As cities grow, the need for management and planning increases, is biodiversity is to be preserved. In general, city planning strives to balance different needs such as commercial, residential and recreational needs, all requiring areas. In this context, it is vital to balance the needs of today with those of the future. This might imply protecting green areas at the expense of short-term benefits such as economic gain or transport efficiency. Not all green areas are equal though; a park with only short-cropped grass, like a lawn, has little ecological value (Gaston et al., 2005; Threlfall et al., 2017, 2016), but may still be an important recreational spot for the residents of the city (Bolund and Hunhammar, 1999; Hartig et al., 2014). A remnant spot of woodland may look less attractive and to a lesser degree have value to local residents for recreation, but may function as habitat for more species. Green areas, whether they are public or private, have the potential to support or increase biodiversity if planned and managed correctly (Shwartz et al., 2013). For instance, one way to improve the diversity of wild flowers in lawns is simply to let the grass grow longer and increase the time between mowing (Shwartz et al., 2013).

Landscape metrics.

Boundaries arise between adjacent patches in spatially heterogeneous landscapes (Cadenasso et al., 2003). In the transition, zone conditions will often differ from the interior of the landscape patch (Ries et al., 2004), e.g. light, moisture and wind (Fagan et al., 1999; Ries et al., 2004). The changes that occur from the interior towards the fringes is termed the edge effects (Perlman and Milder, 2005).The edge might support a higher abundance of species and a species composition that differs from the interior (Honnay et al., 2002; Watkins et al., 2003). Species specializing in interior habitat might struggle if interior habitat diminishes. When the landscape is fragmented, edge habitat increases, and connectivity decreases for species specializing in interior habitat. Connectivity and edge effects are important in an urban setting because the contrast between e.g., a green patch and its surrounding urban fabric is high, and traversing the urban fabric may represent a serious risk to many species. Due to ongoing urban development, many habitat patches inside an urban area end up as smaller, disconnected fragments. Fragmentation and connectivity affects dispersal, migration and gene flow (McCallum and Dobson, 2002). Corridors between vegetation patches might contribute to mitigate the effects of habitat loss and fragmentation and facilitate the exchange of individuals in otherwise isolated patches (Aars and Ims, 1999; Gregory et al., 2014).

Oslo

According to Snorre Sturlason, Oslo was founded in 1050 by Harald Hardråde (Hødnebø and Magerøy (ed.) 1982)), but archaeological findings suggest that Oslo was founded even earlier (Nedkvitne and Norseng, 2000). The city has been growing and expanding for about 1000 years, but there is still nature within and surrounding Oslo. An increasing population and expanding city increase the pressure on surrounding areas. Housing as well as schools, grocery stores, sports arenas and infrastructure is necessary. All of this might affect both the nature outside or inside the city limits, and bit by bit, nature is lost. The city-ecological program for Oslo municipality states "increased building density should not impact green areas" (my translation:(Oslo kommune, 2011)). To assess whether this is the case, mapping the extent of nature changes over time, i.e., remapping is necessary.

Aims

In this study, remapping was used as a tool to map and quantify vegetation changes over the last 40 years in the study area. To understand the impact of urbanization on the distribution and extent of terrestrial nature in a growing capital within the Nordic Region, Oslo (Norway) was chosen as the study site.

Representing the traditional East-End to West-End socioeconomic gradient of Oslo (St.meld. nr. 31 (2006-2007), 2006), I have remapped three detailed vegetation maps from the early 1980s (Kummen and Larsson, 1984, 1981a, 1981b). The purpose of this master thesis is to:

1) Map and quantify the vegetation changes from 1980s to 2020.
2) Interpret and discuss the ecological impacts of the registered changes.
3) Increase the understanding of the process of urbanization with respect to vegetation changes and nature management.

Material and methods

Study site

The study area is located in Oslo, southeast Norway. Oslo is the capital of Norway and the largest city in the country. In 2021 there were 697 010 residents, an increase of 65 % from 454 819 in 1980 (SSB, 2022). Oslo municipality is, from geographical, developmental and management perspectives, divided into two zones: 1) the city zone where new buildings and infrastructure is developing and, 2) the administratively protected, forested rangeland surrounding the city (Oslomarka) (Markaloven, 2009). Within the city zone, small pockets of forest, parks and fields provide habitat to red-list species and vegetation types with high biodiversity.

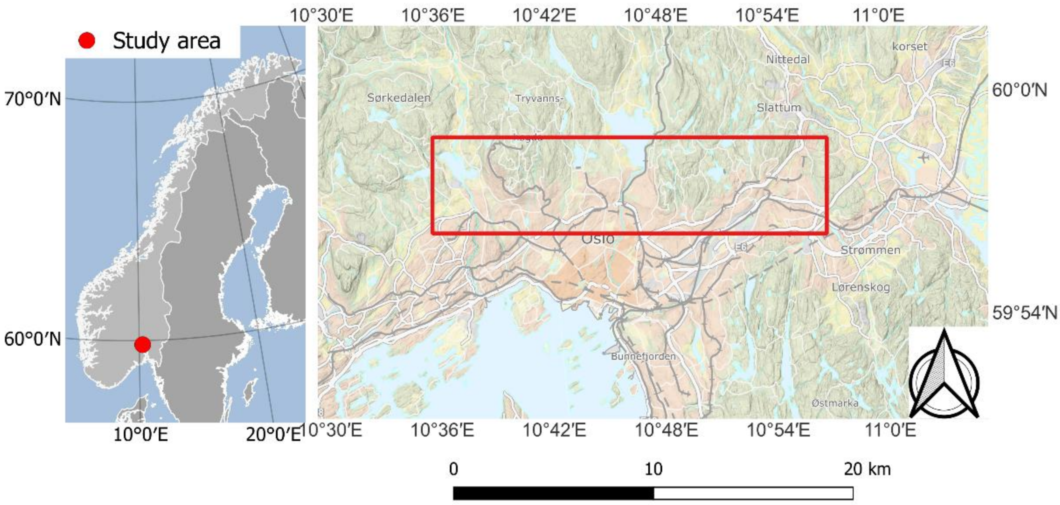

Figure 1: An overview map of Scandinavia (left) with highlighted location of study area in red circle. Detailed study area is highlighted in the red rectangle on a map of the Oslo municipality (right). Maps obtained from Geonorge. EPSG:25832 - ETRS89 / UTM zone 32N.

Oslo is located in the boreonemoral vegetation zone. The zone is characterized by temperate deciduous trees in sunny slopes while spruce, pines, birch and other more cold-tolerant trees dominate elsewhere (Moen, 1998). Oslo is located by the Oslofjord, but the terrain rises to 700 m above sea level (a.s.l.) in Oslomarka. Inside the study area, (Figure 1), the elevation ranges from about 100 m. a.s.l. to 500 m. During the last glacial maximum, the sea level was about 220 m above the present sea level (Moen et al., 1998). The total area covered by the three maps is 89 386 200 m^2.

Material

Vegetation maps

This study is based on remapping of three vegetation type-maps (Kummen and Larsson, 1984, 1981a, 1981b) published by Oslo Helseråd in the 1980s (hereafter referred to as "original"). The maps were produced at a scale of 1:10 000 and cover Holmenkollen, Grefsen and Grorud. The fieldwork was conducted by Jordregisterinstituttet, in 1979 for the Grefsen and Holmenkollen maps, and in 1981 for the Grorud map. The maps were printed in 1981 and 1984 respectively. The mapping at that time was field-based and analogue, conducted with aerial photos and 3D equipment.

The vegetation type system

The vegetation type system used in 1980 is hierarchical and consists of three levels (Hesjedal, 1973). There are eight major groups (*hovedgrupper*) that are based on ecological entities like forest, swamp, heathland, mountains etc. The major groups are further divided into 26 minor groups (*enkeltgrupper*), based on plant sociology and trophic levels. The minor groups are divided into vegetation types (*vegetasjonstyper*). There are 79 vegetation types in the type system, a number well suited to mapping at a scale of 10:000 according to Hesjedal (1973). In the three maps included in this thesis, all eight major groups and 46 vegetation types were used. Alongside the maps (within the map legend), there are brief descriptions of the major and minor groups and vegetation types, including information about common species, soil, moisture and physiognomy that characterizes the different vegetation types (Appendix 1).
In the original maps, there are one urban group. As this thesis is aiming to quantify loss of nature in the urban setting (Aim 1) and find the reasons for this loss (Aim 3), it was necessary to distinguish between different urban types.
Therefore, I added four minor urban groups and divided these into 31 urban types (Table 1). It was necessary to add two new vegetation types as well, as they were found during remapping in areas that had been restored or replaced with a vegetation type. The vegetation types were allotment garden (*parsellhager*) and yellow flag iris swamp (*sverdliljesump*).

Table 1: List of vegetation types or urban types added to the system.

Major group	**Minor group**	**Vegetation type / urban type**	
Urban	U1: Public institutions	U1_a	Kindergarten
		U1_b	Playground
		U1_c	School
		U1_d	University
		U1_e	Health premises
		U1_f	Cultural buildings
		U1_g	Graveyard
		U1_h	Religious buildings
		U1_i	Embassy
		U1_j	Armed forces
		U1_k	Recycle station
	U2: Housing	U2_a	Housing (villas/townhouses)
		U2_b	Apartment buildings
	U3: Business	U3_a	Industrial area
		U3_b	Business and office premises
		U3_c	Camping ground
	U4: Infrastructure	U4_a	Public transport
		U4_b	Road
		U4_c	Public parking
		U4_d	Power line corridor
		U4_e	Construction site
		U4_f	Quarry
	U5: Sports or outdoor activities	U5_a	Sports facilities
		U5_b	Sports stadium
		U5_c	Alpine slopes
		U5_d	Ski stadium
		U5_e	Beach
		U5_f	Sports field (gravel / artificial grass)
		U5_g	Golf course
		U5_h	Activity farm
		U5_i	Paddock
Vegetation	W: Swamp, often with sedges.	W3	Yellow flag iris swamp
	X: Other	PA	Allotment garden

Aerial photos

Orthophoto images were accessed from "*Norge i bilder*" (www.norgeibilder.no). Newer photos were from 2020 and 2019. The older photos were from 1956 and 1980. To compare the network of roads in the 1980s and today, orthophotos from 1971 and 1984 obtained from Oslo municipality were utilized. A complete list of orthophotos used are found in Table 2.

Table 2: Ortophoto images used.

Oslo municipality 2019	Date: Image date: 2019-04-13 Datum: EPSG:25832 - ETRS89 UTM zone 32N Resolution: 0.05 m. Coverage number: CO-12184
Oslo municipality 2020.	Date: Image date: 2020-03-31 Datum: EPSG:25832 - ETRS89 / UTM zone 32N Resolution: 0.08 m. Coverage number: TT-14465
Oslo municipality 1956	Date: Image date: 1956 Datum: EPSG:25832 - ETRS89 / UTM zone 32N Resolution: 0.20 m.
Oslo municipality 1980	Date: Image date: 1980 Datum: EPSG:25832 - ETRS89 / UTM zone 32N Resolution: 0.20 m.
Oslo municipality 1971	Date: Image date: 1971 Datum: UTM Zone 32N Resolution: 0.25 m.
Oslo municipality 1984	Date: Image date: 1984 Datum: UTM Zone 32N Resolution: 0.25 m.

Set-up in QGIS

The original maps existed in digital format (shapefiles) at NIBIO. The shapefiles were uploaded to a Windows field-PC and set up in QGIS version 3.20 (QGIS Development team, 2021). The setup in QGIS included the vegetation maps, orthophotos and raster maps. The vegetation types are delineated as polygons, each vegetation type is shown in a corresponding color (Figure 2). Two copies of the historical vegetation maps were used, one was kept intact, and one was subjected to the editing process during remapping.

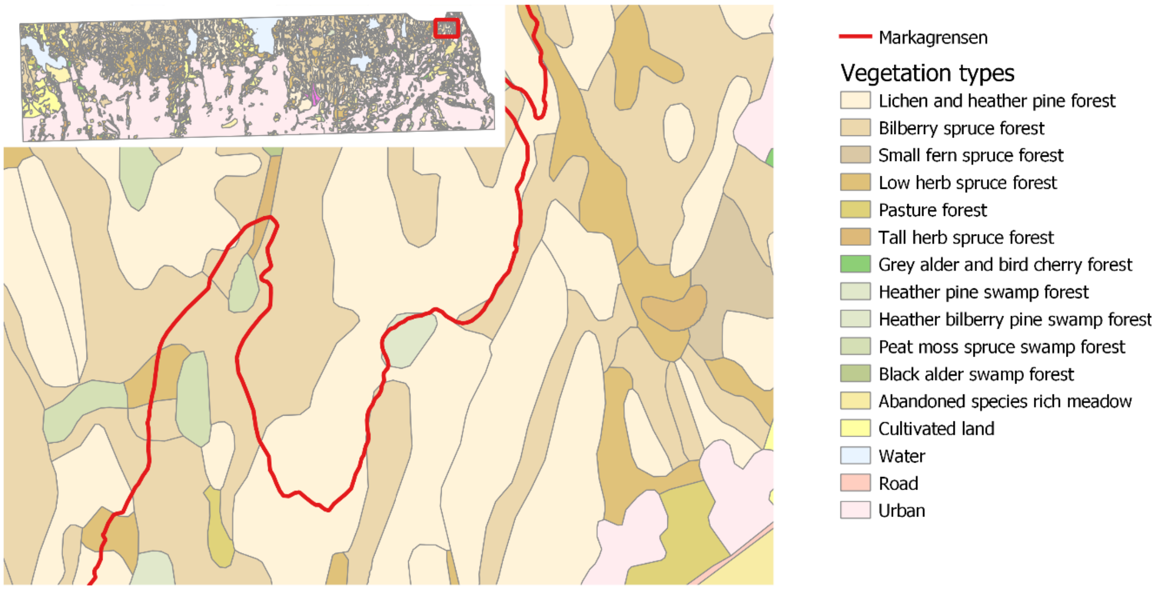

Figure 2: Homogeneous vegetation is delineated to form polygons. A full description of the vegetation types can be found in Appendix 1. The figure shows a detail of the Grorud vegetation map and is meant as an example to illustrate the delineation and color system of the map. The example is from the 1980 map and shows an area located north in Grorud.

Methods

Field remapping with QGIS

The remapping fieldwork took place in July and August 2021. A digital copy of the map from 1980 was used as a starting point, and changes were digitized directly on this vector map. For each polygon, a decision had to be made. If no changes had taken place, the polygon was left intact. In cases where changes had occurred the polygon was assigned a new vegetation or urban type from the category list (Table 1 and Appendix 1). Sometimes only parts of an area were changed. In those cases, the polygon's geometry was adjusted to represent the reality observed in the field by splitting, stretching, or reducing its boundaries, and the new polygon(s) was assigned an appropriate vegetation or urban type. Polygons were split and merged as needed to create new boundaries between various vegetation and urban types. Orthophotos were used in the background to make delineation easier. The opacity of the maps was adjusted to better show boundaries in the orthophotos.

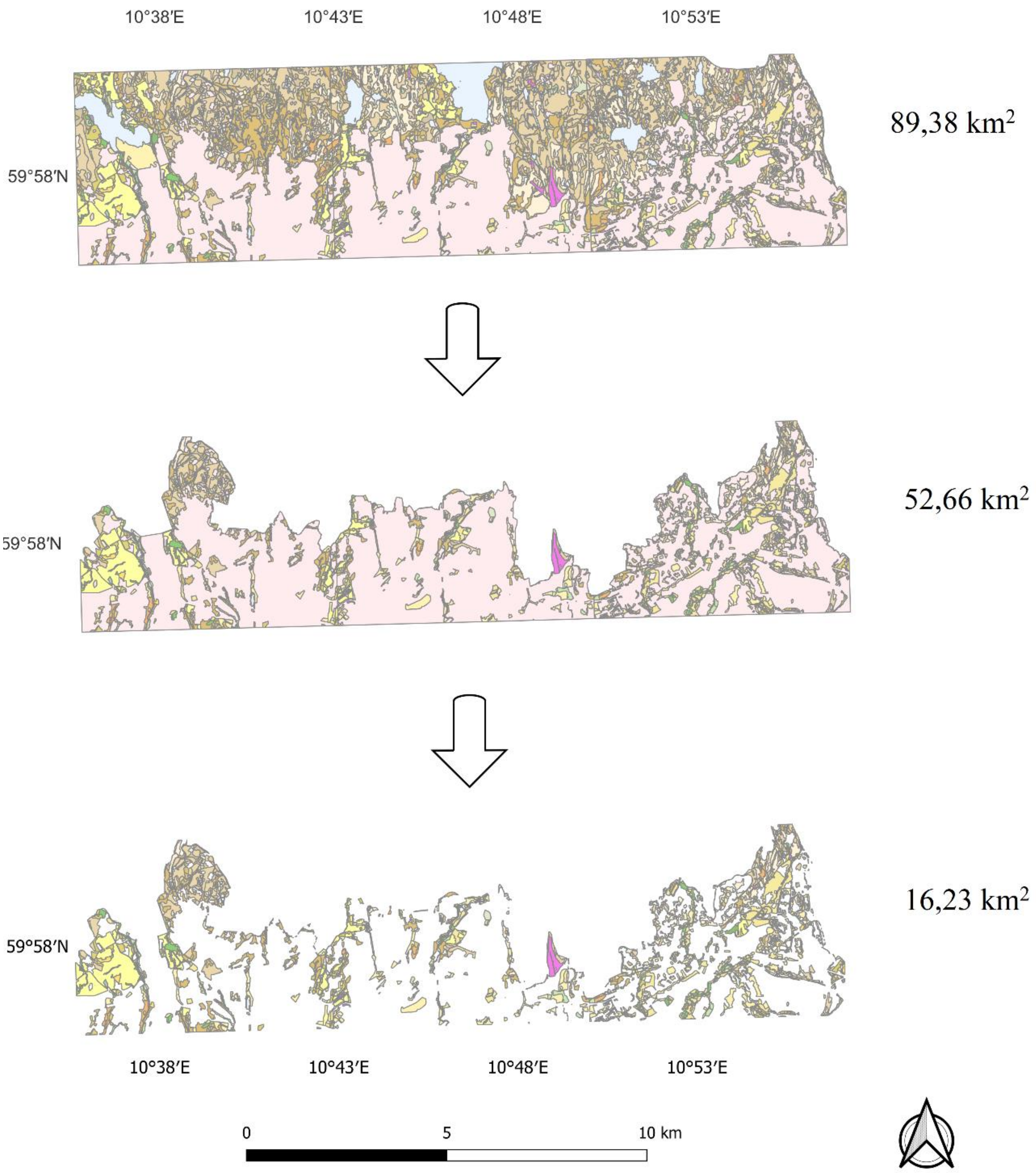

Figure 3: Filtering of the historical maps (top) consisted of excluding the protected rangeland zone (Oslomarka) north of Oslo (middle) and the urban classes(bottom). Map obtained from Geonorge.

Map preparations and filtering

The three historical maps cover 89,38 km2 (top of Figure 3). The maps covered part of the city zone, but the northernmost edges also covered Nordmarka (Figure 3). It is forbidden to establish new infrastructure within the forested rangeland zone Oslomarka (Markaloven, 2009, §5). Building activity was strictly limited even before the law came into place. For this reason, the remapping was only conducted within the city zone where almost all changes have taken place. The part of the city zone covered by the map is 52,66 km2 (middle of Figure 3). By removing urban areas, 16,23 km2 remains (bottom of Figure 3).

A few roads were missing from the 1980's map, although they existed at the time. To avoid detecting false changes orthophotos from 1971 and 1984 were utilized. If a road was visible on the 1971 and/or 1984 orthophotos but missing in the 1980's map, it was added to the original map before analysis.

Quality control and preparations for analyses

The remapping from 2021 was quality controlled by a second person with 20 years of experience with vegetation mapping, focusing on difficult areas where the vegetation classification and polygon delineation was uncertain. This was done during a week in September 2021. Secondly, technical errors (node errors etc.) were corrected using the topology checker function in QGIS. The remapped areas were split into three areas, mirroring the three original vegetation maps, Grorud, Grefsen and Holmenkollen. The maps were further split into seven boroughs to enable analysis on administrative levels. The boroughs were: Nordre Aker, Vestre Aker, Sagene, Alna, Grorud, Bjerke and Stovner. The maps did not cover all boroughs fully, so only the four maps with a coverage above 50 % were chosen for further analysis. These were Nordre Aker, Vestre Aker, Grorud and Stovner. An index for the vegetation types was created to enable rasterization, and all the maps were rasterized with a raster cell size of 1×1 meter.

Map analyses

All GIS-analyses were conducted with QGIS version 3.20 (QGIS Development team, 2021). The forest rangeland areas outside "markagrensa" (Oslomarka) were excluded using the "clip" function. Area statistics were extracted from all maps, as well as for the three separate map sheets (Grorud, Grefsen, Holmenkollen) and the four remaining boroughs. Data management and analysis were done in Microsoft Excel, QGIS and R Statistical Software (v4.1.2; R Core Team 2021). FRAGSTATS, a spatial pattern analysis program (McGarigal and Marks, 1995), was used to calculate landscape metrics. The metrics will provide quantitative values for a variety of differences between periods, as well as differences between map sheets / boroughs. We selected four metrics for landscape level analysis, and seven for class level analysis, as shown in Table 3 (read more about the metrics here:

FRAGSTATS: spatial pattern analysis program for quantifying landscape structure (McGarigal and Marks, 1995)).

Table 3: Indices used to describe the vegetation maps and the changes from 1980s to 2021

Landscape level:	Number of patches (NP) Mean of patch area (AREA_MN) Contagion (CONTAG) Patch richness (PR)
Class level:	Total class area (CA) Number of patches (NP) Mean of patch area (AREA_MN) Percentage of landscape (PLAND) Mean of Euclidean nearest-neighbor distance (ENN_MN) Standard deviation of Euclidean nearest-neighbor distance (ENN_SD) Coefficient of variation of Euclidean nearest-neighbor distance (ENN_CV)

All metric analyses were performed using R Statistical Software (v4.1.2; R Core Team 2021).

Red Listed vegetation types

The Norwegian red list for nature types (NBIC, 2018) describes 123 red listed nature types, of which 74 are listed as threatened. To quantify the extent of loss of red listed nature types, those equivalent to the vegetation types in the type system used in this project (Table 4) were identified (Table 9). Data about the loss of threatened nature types might help answer Aim 2.

Red List of Threatened Species

To examine whether species on the Red List (NBIC, 2021) may have been lost in the study area due to habitat changes, Red List data were downloaded from the Species Map Service by The Norwegian Biodiversity Information Centre (NBIC) (downloaded 08.04.2022). The dataset includes vascular plants, mosses, lichen and fungi, in four Red List categories: Vulnerable (VU), Endangered (EN), Critically Endangered (CR) and Regionally Extinct (RE). To extract the observations within the study area (city zone) the “clip” function in QGIS was used, with the Red List dataset as the input layer while a vector layer of the study area was used as the clipping layer. This rendered a new dataset with 839 observations, all located within the study area. An overlay analysis was performed, and observations in urban areas in the 1980s map were excluded, leaving 364 observations in vegetated areas recorded in 1980. The number of observations was further reduced to 267 by removing all observations with a coordinate uncertainty above 100 m. To find observations located in polygons that had undergone changes, an overlay analysis was performed. Data about the loss of threatened species might give a better understanding of the ecological impact of vegetation changes (Aim 2).

Zoning plans

To better understand the urbanization process and area management (Aim 3), zoning plans for Oslo municipality were used. The zoning plans are available from the municipality's website (Planinnsyn). To work with the zoning plans in QGIS, WMS were obtained from NIBIO. The zoning plan was uploaded as a WMS-layer in QGIS and visually compared to the 2021-map. Where future regulation differed from present day use, information on area and vegetation type affected were extracted from the 2021-map.

There were some exceptions.

An area regulated to e.g., housing was treated as such even if building limits were in place. Even if an area is regulated to housing, it might not be allowed to erect buildings covering the entire plot. Typically, an area within the polygon is set aside for buildings. Figure 4 shows the different boundaries. Parks connected to apartment buildings were not marked for the same reason. The parks are part of the housing area but would not be lost as a vegetation type.

Figure 4: A polygon regulated for housing (yellow) with a thin dotted, red line showing the building limit. It is not allowed to erect buildings outside this area even though the entire polygon is regulated to housing.

Results

Area statistics

A total of 66 vegetation or urban types were found in the study area during remapping in 2021. This includes original vegetation types and new vegetation and urban types added to the 2021 category list. A total of 4 893 570 m^2 were recorded as changed, from vegetation to urban or to another vegetation type. This represents approximately 30 % of the total area of 16 232 388 m^2 (Figure 5).

Figure 5: Dark color represents changed areas. White represents areas that have not undergone change or areas that were urban in 1980. Urban areas were not remapped. The red line delimit the study area. The jagged line to the north represent "markagrensa".

Table 4: Area statistics showing the area cover for each vegetation type in different years and the area lost/gained in m^2.

Code	English name	Norwegian name	Area 2021	Area 1980	Difference
A2	Lichen and heather pine forest	Lav- og lyngrik furuskog	1 048 737	1 280 680	-231 943
B2	Bilberry spruce forest	Blåbærgranskog	1 504 188	2 499 045	-994 857
B3	Small fern spruce forest	Småbregnegranskog	73 699	105 202	-31 503
B4	Large fern spruce forest	Storbregnegranskog	27 450	58 314	-30 864
Beit	Pasture forest	Beitemark	87 947	122 002	-34 055
C1	Lime-rich pine forest	Kalkfuruskog	253 393	265 281	-11 888
C2	Low herb spruce forest	Lågurtgranskog	1 341 711	2 033 545	-691 834
C3	Pasture forest	Vanlig hagemarkskog	748 749	964 529	-215 780
C4	Tall herb spruce forest	Høgstaudegranskog	107 866	150 722	-42 856
Dyrk	Cultivated land	Dyrket mark	923 292	2 031 805	-1 108 513
E1	Elm and linden forest	Alm-lindeskog	195 161	149 531	45 630
E2	Grey alder and ash forest	Gråor-askeskog	333 323	268 872	64 451
E3	Grey alder and bird cherry forest	Gråor-heggeskog	843 512	684 924	158 588
E4	Broadleaved pasture woodland	Varmekjær hagemarkskog	61 114	129 345	-68 231
G1	Heather pine swamp forest	Røsslyng·furumyrskog	33 333	40 553	-7 220
G2	Heather bilberry pine swamp forest	Bærlyng-furumyrskog	10 210	13 067	-2 857
G3	Peat moss spruce swamp forest	Torvmose-gransumpskog	11 767	16 289	-4 522

G4	Reed grass willow swamp forest	Skogrørkvein·viersumpskog	6 702	6 702	0
G6	Black alder swamp forest	Svartorsumpskog	2 170	4 295	-2 125
G7	Rich beach swamp forest	Rik strandsumpskog	17 364	21 576	-4 212
H2	Species poor bog	Fattigmyr	9 809	17 546	-7 737
IK	Not mapped	IK	10 095	10 095	0
K	Parks and green areas	Parkområder og grøntanlegg	2 285 424	2 238 238	47 186
PA	Allotment garden	Parsellhage	59 082	0	59 082
PL	Tree plantation on arable field	Plantefelt på Innmark	11 663	0	11 663
Q2	Bloody cranesbill vegetation	Blodstorkenebbeng	4 726	4 726	0
R3	Abandoned species poor meadow	Fattig ødeeng	25 795	0	25 795
R4	Abandoned species rich meadow	Rik ødeeng	726 076	1 557 365	-831 289
R5	Weeds	Ugrassamfunn	358 914	917 500	-558 586
S2	Moist meadow	Fukteng	6 503	17 406	-10 903
U1_a	Kindergarten	Barnehage	73 422	0	73 422
U1_b	Playground	Lekeplass	4 142	0	4 142
U1_c	School	Skole	108 146	0	108 146
U1_d	University	Universiteter og høgskoler	85 046	0	85 046
U1_e	Health premises	Helserelaterte bygg/områder	87 165	0	87 165
U1_f	Cultural buildings	Kulturbygg	8 565	0	8 565
U1_g	Graveyard	Gravplass	169 229	0	169 229
U1_h	Religious buildings	Religiøse bygg	12 204	0	12 204
U1_i	Embassy	Ambassade	41 373	0	41 373
U1_j	Armed forces	Forsvaret	27 220	0	27 220
U1_k	Recycle station	Gjenbruksstasjon	19 663	0	19 663
U2_a	Housing (villas/townhouses)	Bolig / enebolig / rekkehus	1 793 390	0	1 793 390
U2_b	Apartment buildings	Blokker	466 714	0	466 714
U3_a	Industrial area	Industriområde (containerlagring / bygg / parkering)	323 713	0	323 713
U3_b	Business and office premises	Forretnings- og kontorarealer	289 520	0	289 520
U4_a	Public transport	Kollektivtransport	11 142	0	11 142
U4_c	Public parking	Offentlig parkeringsplass	10 285	0	10 285
U4_d	Power line corridor	Kraftgater	23 561	0	23 561
U4_e	Construction site	Anleggsområde	123 416	0	123 416
U4_f	Quarry	Steinbrudd / grustak	88 135	0	88 135
U5_a	Sports facilities	Idrettsanlegg	94 627	0	94 627
U5_b	Sports stadion	Idrettsstadion	13 057	0	13 057
U5_f	Sports field (gravel / artificial grass)	Idrettsbane (grus / kunstgress)	135 803	0	135 803
U5_g	Golf course	Golfbaner	353 045	0	353 045
U5_h	Activity farm	Aktivitetsgaard	39 822	0	39 822
U5_i	Paddock	Paddock (hestehage / grus)	18 071	0	18 071

Ur	Talus slope	Ur	10 169	10 169	0
V3	Stonecrops vegetation	Bergknappsamfunn	20 253	20 772	-519
Vann	Water	Vann	199 845	196 157	3 688
Vei	Road	Vei	250 242	164 480	85 762
W2	Rich sedge swamp	Rikstarrsump	4 239	5 616	-1 377
W3	Yellow flag iris swamp	Sverdliljesump	773	0	773
X	Common reed swamp	Takrørsump	3 987	0	3 987

Table 5:.28,11 % of the vegetated area of 1980 has been lost due to urbanization. This means 91,36 % of the registered changes in are due to urbanization.

	Nature (km^2)	**Urban (km^2)**
1980	16,0	0
2021	11,5	4,5
Vegetation lost		28,11 %
Percentage of change due to urbanization		91,36 %

The majority of the changes registered between 1980 and 2021 are due to urbanization. 4,5 km^2, corresponding to 28,11 % of the vegetated area of 1980, converted from a vegetation type to an urban type. This is 91,36 % of the total change in type is due to urbanization.

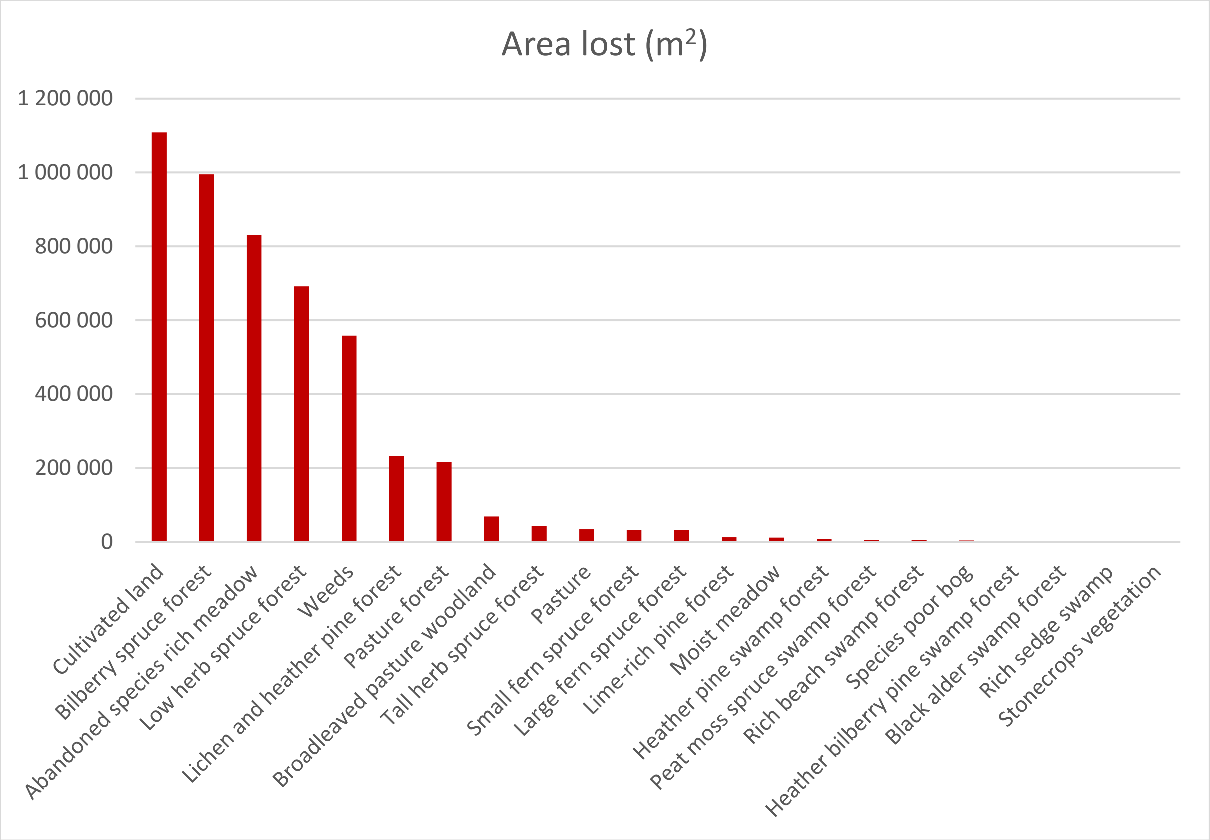

Figure 6: Area lost (m²) per vegetation type.

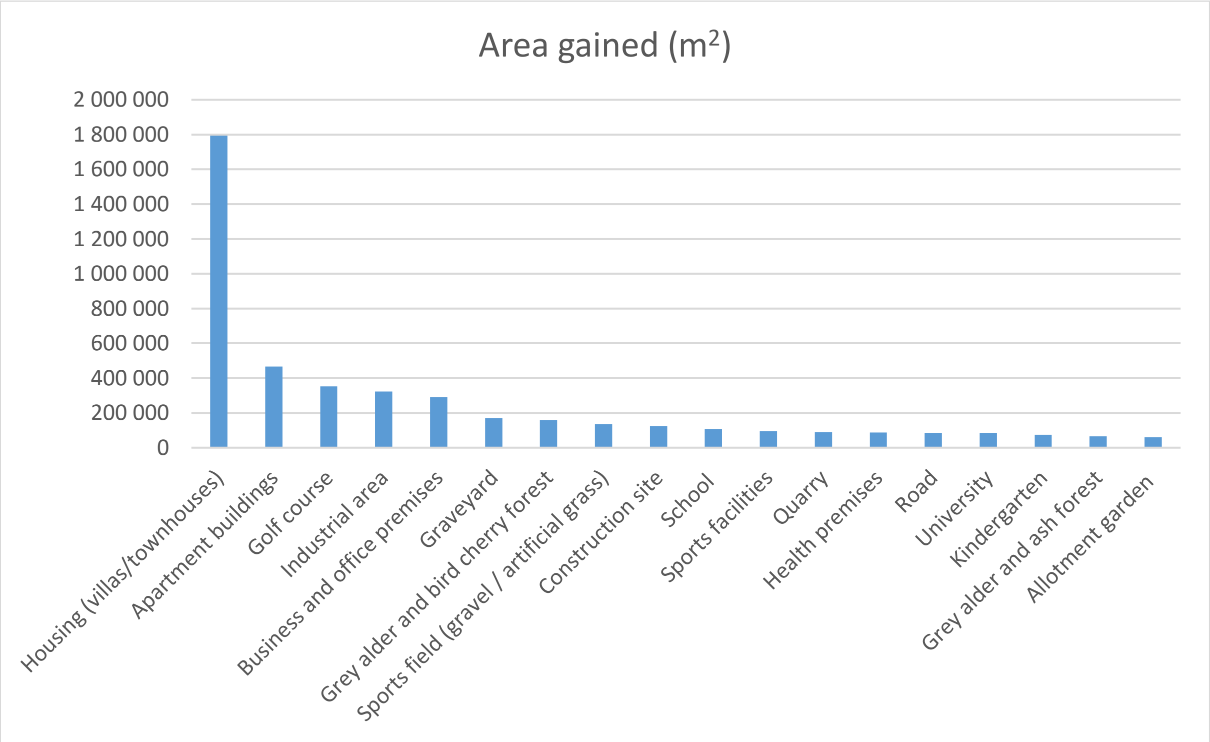

Figure 7: Area gained (m²) per vegetation or urban type, only shown for types with a gain above 50 000 (m²).

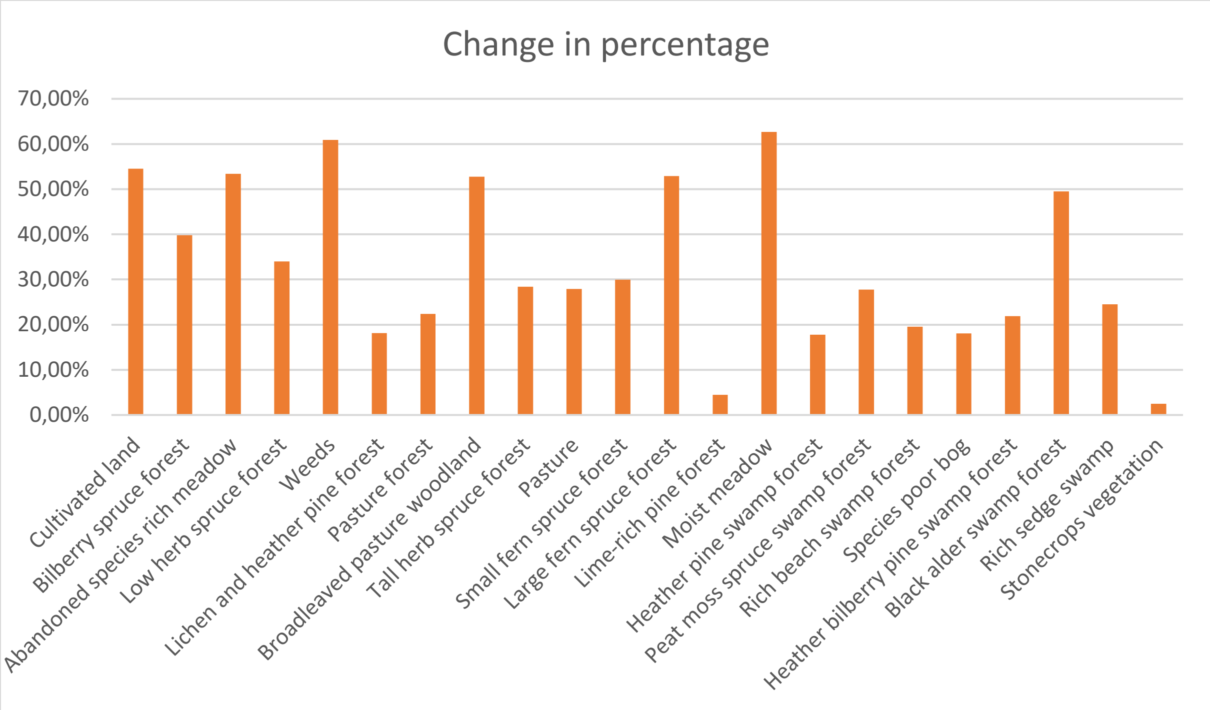

Figure 8: Area lost per vegetation type shown as percentage of total area for that specific vegetation type. Six vegetation types have been reduced by more than 50 % of the area in 1980.

The vegetation type with the greatest loss was cultivated land (Figure 6), with 1 108 513 m^2, corresponding to 54 % of its total area in 1980 (Figure 8). Abandoned species rich meadow suffered the third greatest loss of all vegetation types (Figure 6). Abandoned cultivated land converted to grassland is named "Abandoned species rich meadow" in this type system. For this vegetation type 53 % (830 000 m^2) (Figure 8) lost since 1980. The decrease of all types of cultivated land has contributed to a total vegetation-type loss of 23% between 1980 and 2021. (Figure 9). Figure 10 shows formerly cultivated land has turned into a golf course.

Of the forest types bilberry spruce forest was reduced by 39 % (990 000 m^2), while the more species rich low herb spruce forest was reduced by 34% (700 000 m^2) (Figure 8).
In total, 1 793 390 m^2 covered by vegetation types was converted to housing, specifically villas or townhouses, while 466 714 m^2 were lost to apartment buildings (Figure 7). In 2021, housing occupied 2 260 104 m^2, corresponding to 14 % of the total area and almost half of the changed area. Figure 11 shows an example of vegetation changes due to the building of houses in Voksenkollen.

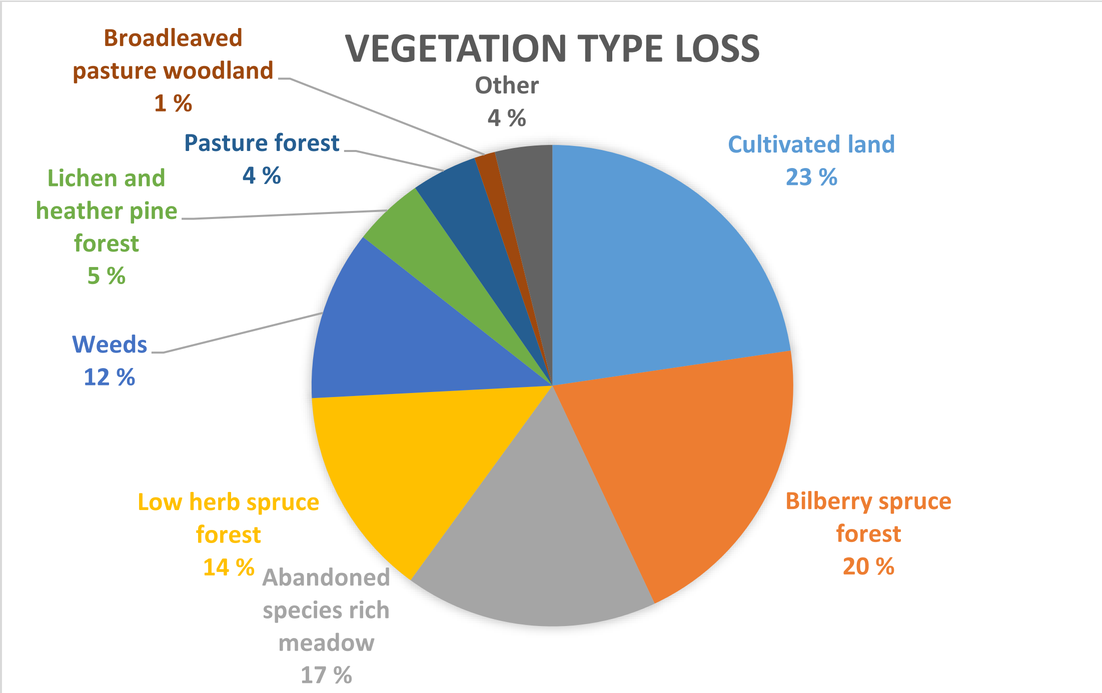

Figure 9: Precentral contribution to the total loss by the different vegetation types. The vegetation types with a loss below 50 000 m² is generalized into one group called "Other".

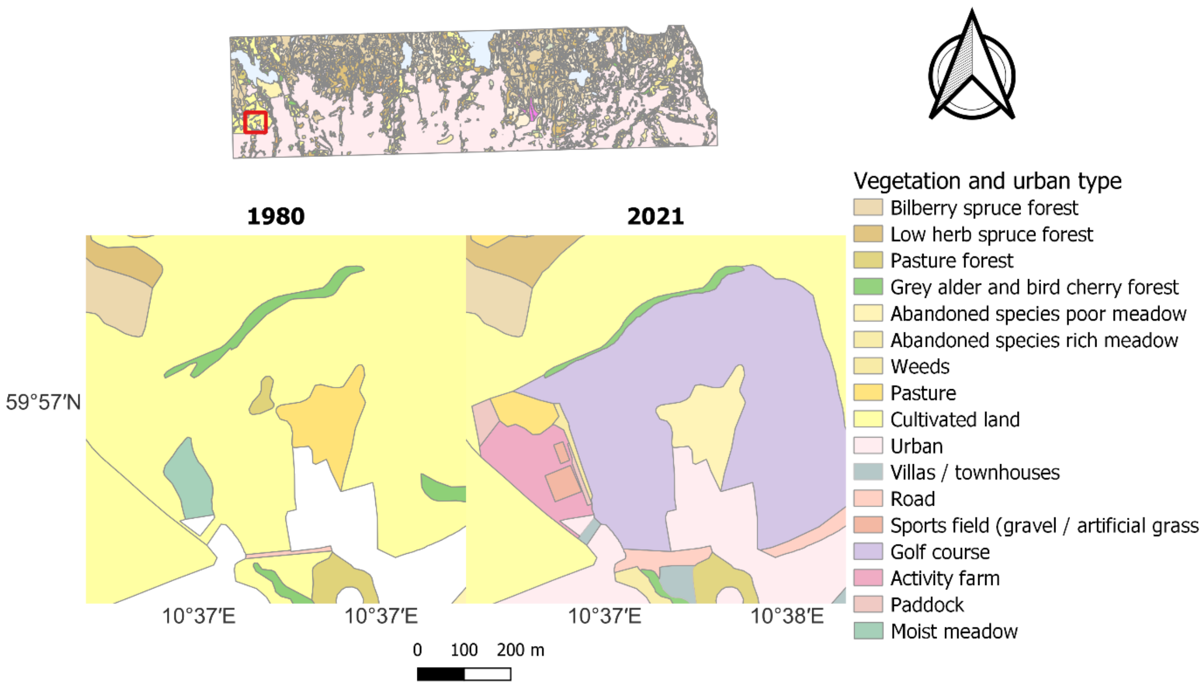

Figure 10: The golf course at Grini is built on formerly cultivated land. Grini is located in the eastern part of Bærum, far west on the map. One polygon of moist meadow (light green) disappeared along with cultivated land to make way for stables (as indicated by Activity farm, shown in pink)).

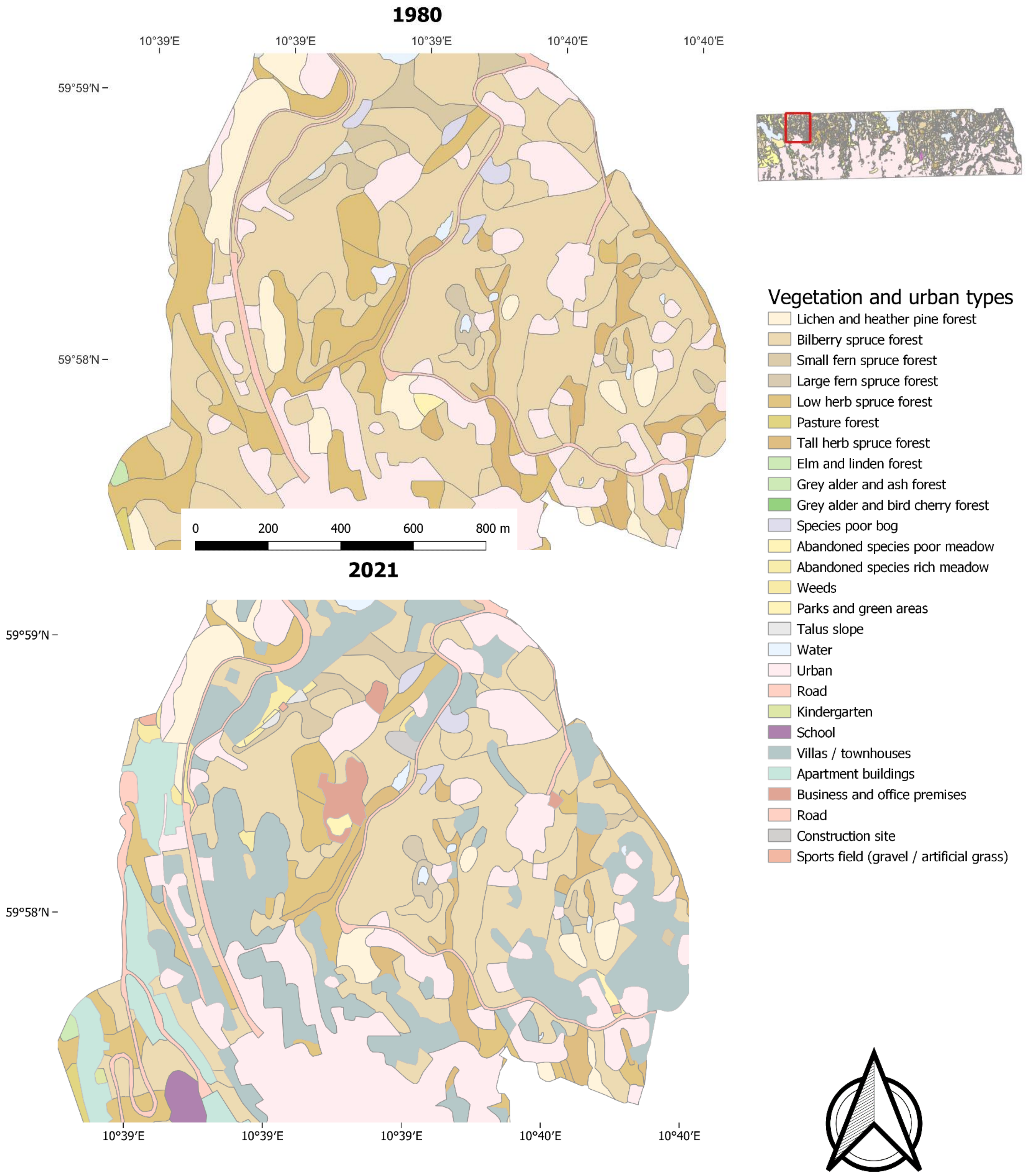

Figure 11: Voksenkollen is located in the northwest of the map, bordering Oslomarka. A popular area for families to settle down, apartment buildings and villas / townhouses increased at the expense of bilberry spruce forest and low herb spruce forest.

Map analysis

Four landscape indices from FRAGSTATS are provided in Table 6. Five class indices are shown in Table 7 and Table 8. The remaining two class indices can be found in Appendix 1. The number of polygons increased by 697, while the mean size of each polygon decreased by 0,84 ha (8 400 m^2) (Table 6). On average, the patch area decreased, being most pronounced for abandoned species rich meadow. On the other end of the spectrum, cultivated land had the largest increase in mean patch size. Parks and green areas had one of the largest increases in number of patches, though the mean size of each patch decreased (Table 7). On average, the mean Euclidian distance increased with rich sedge swamp as the most extreme case. The mean Euclidian distance decreased in some vegetation types; this was most pronounced for moist meadow (Table 8).

Table 6: Fragstats landscape indices for the entire study area. NP: Number of patches, PR: patch richness. AREA_MN: mean patch area (ha), CONTAG: contagion index,

Year	NP	PR	AREA_MN	CONTAG
1980	1613	32	0,98	56,77
2021	1777	39	0,67	56,52

Table 7: Fragstats class indices for the entire study area. CA: total area for each class (ha), NP: number of patches, AREA_MN: mean patch area (ha).

	CA		NP		AREA_MN	
Vegetation or urban type	**1980**	**2021**	**1980**	**2021**	**1980**	**2021**
Lichen and heather pine forest	127,99	105,13	197	202	0,65	0,52
Bilberry spruce forest	249,77	150,34	181	164	1,38	0,92
Small fern spruce forest	10,51	7,37	11	9	0,96	0,82
Large fern spruce forest	5,83	2,74	14	11	0,42	0,25
Lime-rich pine forest	26,51	25,32	22	22	1,20	1,15
Low herb spruce forest	204,12	134,34	235	210	0,87	0,64
Pasture forest	96,39	74,85	115	150	0,84	0,50
Tall herb spruce forest	15,06	10,78	27	23	0,56	0,47
Elm and linden forest	14,95	19,51	22	27	0,68	0,72
Grey alder and ash forest	26,87	33,50	33	37	0,81	0,91
Grey alder and bird cherry forest	68,45	84,31	83	89	0,82	0,95
Broadleaved pasture woodland	12,93	6,11	17	14	0,76	0,44
Heather pine swamp forest	4,05	3,33	2	2	2,03	1,67
Heather bilberry pine swamp forest	1,31	1,02	5	4	0,26	0,25
Peat moss spruce swamp forest	1,63	1,17	7	5	0,23	0,23
Reed grass willow swamp forest	0,67	0,67	1	1	0,67	0,67

Black alder swamp forest	0,43	0,22	2	1	0,21	0,22
Rich beach swamp forest	2,15	1,73	1	1	2,15	1,73
Species poor bog	1,75	1,44	5	4	0,35	0,36
Stonecrops vegetation	2,08	2,03	5	5	0,42	0,41
Bloody cranesbill vegetation	0,47	0,47	1	1	0,47	0,47
Abandoned species poor meadow		2,58		2		1,29
Abandoned species rich meadow	155,66	72,17	136	131	1,14	0,55
Weeds	91,70	35,87	69	115	1,33	0,31
Moist meadow	1,74	0,65	4	3	0,43	0,22
Rich sedge swamp	0,56	0,42	3	2	0,19	0,21
Yellow flag iris swamp		0,08		1		0,08
Common reed swamp		0,40		1		0,40
Cultivated land	203,06	92,27	56	11	3,63	8,39
Pasture forest	12,19	8,79	12	10	1,02	0,88
Tree plantation on arable field		1,17		2		0,58
Parks and green areas	223,70	228,42	163	239	1,37	0,96
Allotment garden		5,91		4		1,48
Golf course		35,28		2		17,64
Water	19,60	19,97	146	148	0,13	0,13

Table 8: Fragstats indices for the entire area on class level. ENN_MN: Mean of Euclidean nearest-neighbor distance (m), PLAND: percentage of landscape.

	ENN_MN		**PLAND**	
Vegetation type	**1980**	**1980**	**2021**	**2021**
Lichen and heather pine forest	44,33	8,06	8,87	47,45
Bilberry spruce forest	57,28	15,75	12,60	65,79
Small fern spruce forest	892,25	0,65	0,61	1114,24
Large fern spruce forest	655,39	0,38	0,23	660,26
Lime-rich pine forest	158,92	1,64	2,09	287,36
Low herb spruce forest	87,11	12,92	11,30	85,02
Pasture forest	133,72	6,05	6,28	110,87
Tall herb spruce forest	179,03	0,96	0,90	167,12
Elm and linden forest	493,24	0,94	1,63	490,65
Grey alder and ash forest	234,37	1,70	2,87	282,85
Grey alder and bird cherry forest	132,76	4,33	7,13	123,75
Broadleaved pasture woodland	1053,18	0,83	0,51	1236,88
Heather pine swamp forest	6685,07	0,26	0,27	6693,08
Heather bilberry pine swamp forest	2745,08	0,08	0,09	3545,56
Peat moss spruce swamp forest	503,18	0,10	0,09	372,95
Reed grass willow swamp forest	0,00	0,04	0,06	0,00
Black alder swamp forest	7878,03	0,03	0,02	0,00

Rich beach swamp forest	0,00	0,14	0,15	0,00
Species poor bog	143,72	0,12	0,08	132,57
Stonecrops vegetation	116,29	0,13	0,17	116,29
Bloody cranesbill vegetation	0,00	0,03	0,04	0,00
Abandoned species poor meadow			0,21	3135,66
Abandoned species rich meadow	117,76	9,81	6,07	126,50
Weeds	188,51	5,80	2,99	187,99
Moist meadow	4524,74	0,11	0,06	1242,13
Rich sedge swamp	6686,48	0,03	0,03	17426,21
Yellow flag iris swamp			0,01	0,00
Common reed swamp			0,03	0,00
Cultivated land	101,28	12,85	7,74	43,93
Pasture forest	417,11	0,77	0,74	1244,90
Tree plantation on arable field			0,10	5256,41
Parks and green areas	84,54	14,13	19,28	83,39
Allotment garden			0,51	3532,17
Graveyard				2210,03
Golf course				15988,74
Water	109,63			108,61

The indices calculated for the 1980 map used a raster map of the vegetated area of 1980: 16 km^2. The indices calculated for the 2021 map used a raster map of the vegetated area of 2021: 11,5 km^2.

Red Listed vegetation types

Red listed nature types (NBIC, 2018) were compared to the types used in this project. Five types were found to be comparable (Table 9), based on types defined by Nature in Norway (NiN: see supplementary in Halvorsen et al. 2020).

Table 9: Red-listed nature types comparable to types in the classification system used in this project.

Red-Listed nature type (2018): **Lime-rich mire and swamp forest with broadleaf deciduous tree dominance.** (*Rik svartorsumpskog*)	
Swamp forest dominated by black alder. Dominated by deciduous species	
Red list category	Vulnerable (VU).
Type in NiN-system:	V2-3 Intermediately lime-rich mire forest lawn V2-4 Intermediately lime-rich mire forest hummock V2-5 Lime-rich swamp forest lawn V2-6 Lime-rich swamp forest hummock With: 1AR-A-E. No species group dominates, broadleaf deciduous trees are the only species group with cover > 25%

Vegetation type (1980 / 2021)	G6 Black alder swamp forest (*Svartorsumpskog*)
Area lost:	2 125 m². (49, 48 %)
Red-Listed nature type (2018): **Lime-rich forest with forbs and conifer dominance.** (*Kalk- og lågurt furuskog*)	
Lime-rich to somewhat lime-rich forest on dry soils. For the most part dominated by pine, but spruce might dominate on the moister soils. Open, species rich forest.	
Red list category	Vulnerable (VU)
Type in NiN-system:	T4-6 Intermediately lime-rich submesic to subxeric forest T4-7 Moderately lime-rich submesic to subxeric forest T4-8 Strongly lime-rich submesic to subxeric forest T4-10 Intermediately lime-rich subxeric forest T4-11 Moderately lime-rich subxeric forest T4-12 Strongly lime-rich subxeric forest T4-14 Intermediately lime-rich xeric forest T4-15 Moderately lime-rich xeric forest T4-16 Strongly lime-rich xeric forest T4-19 Strongly lime-rich submesic tall-herb forest T4-20 Strongly lime-rich subxeric tall-herb forest With: 1AR-A-B. No species group dominates, coniferous trees are the only species group with cover > 25%
Vegetation type (1980 / 2021)	C1 Lime-rich pine forest (*Kalkfuruskog*)
Area lost:	11 888 m². (4, 48 %)
Red-Listed nature type (2018): **Lime-rich deciduous woodland.** (*Kalkedelløvskog*)	
This type is drier than "*Frisk rik edelløvskog*". Deciduous trees dominate, especially lime trees.	
Red list category	Endangered (EN)
Type in NiN-system:	*T4-8 Strongly lime-rich submesic to subxeric forest* *T4-12 Strongly lime-rich subxeric forest* With: 1AR-A-E. No species group dominates, broadleaf deciduous trees are the only species group with cover > 25%
Vegetation type (1980 / 2021)	E1 Elm linden forest (*Alm-lindeskog*) fits the description with the exception of elm. Elm is a characteristic, but not necessary, species in elm linden forest. Elm is not mentioned in the description of Lime-rich deciduous woodland.
Area gained:	45 630 m². (30, 52 %)
Red-Listed nature type (2018): **Lime-rich deciduous submesic woodland.** (*Frisk, rik edelløvskog*)	
Deciduous woodland on lime-rich, moist soil. Elm, hazel and lime trees are the most common tree species. Located in relatively steep, south and/or west facing terrain.	
Red list category	Near threatened (NT
Type in NiN-system:	T4-3 Moderately lime-rich submesic forest T4-4 Strongly lime-rich submesic forest With: 1AR-A-E. No species group dominates, broadleaf deciduous trees are the only species group with cover > 25%
Vegetation type (1980 / 2021)	E1 Elm linden forest (*Alm-lindeskog*) fits the description. E2 Grey alder ash forest (*Gråor-askeskog*) might not be rich enough.
Area gained:	45 630 m². (30, 52 %)
Red-Listed nature type (2018): **Strongly lime-rich tall-herb spruce forest.**	

(*Høgstaudegranskog*)	
Lush and highly productive forest, often in the lowlands.	
Red list category	Near threatened (NT).
Type in NiN-system:	*T4-18 Strongly lime-rich tall-herb forest* With: *1AR-A-B. No species group dominates, coniferous trees are the only species group with cover > 25%*
Vegetation type (1980 / 2021)	C4 Tall-herb spruce forest (*Høgstaudegranskog*)
Area lost:	42 856 m². 28, 43 % loss.
Red-Listed nature type (2018): **Lime-rich open shallow-soil ground in the boreonemoral zone.** (*Åpen grunnlendt kalkrik mark i boreonemoral sone*)	
Natura	
Red list category	Endangered (EN)
Type in NiN-system:	T2-7 Strongly lime-rich open subxeric shallow-soil ground T2-8 Strongly lime-rich open xeric shallow-soil ground
Vegetation type (1980 / 2021)	Q2 Bloody cranesbill vegetation (*Bodstorknebbeng)*
Area lost:	0 m². 0 % loss.

Of the five vegetation, two described the same vegetation type. Elm linden forest fits the description of two nature-types: Lime-rich deciduous submesic woodland and Lime-rich deciduous woodland. Elm linden forest increased by 45 630 m^2. The remaining three types decreased. In total, 56 869 m^2 of Red-Listed nature types were lost.

Red list of Threatened Species

The earliest observations in The Norwegian Biodiversity Information Centre are from 1700. The earliest observation included after filtering of observations was from 1985, the newest from 2022.

Table 10: Number of observations of Red Listed species in polygons that have undergone changes.

	Number	**Species**	**Latin name**	**Red list category**
Observations in polygons that were urban in 2021, but not in 1980:	5	Ash	*Fraxinus excelsior*	EN
	1	Carpet bugle	*Ajuga reptans*	EN
	1	White willow	*Salix alba*	CR
	1	Yew	*Taxus baccata*	VU
	1	Short-fruited Willowherb	*Epilobium obscurum*	VU

Observations in changed polygons:	19	Ash	*Fraxinus excelsior*	EN
	9	Elm	*Ulmus glabra*	EN
	2	Purple-stemmed cat's tail	*Phleum phleoides*	VU
	3	Carpet bugle	*Ajuga reptans*	EN
	12		*Granulobasidium vellereum*	VU
	1		*Cortinarius puellaris*	VU
	1	White willow	*Salix alba*	CR
	3	Dropwort	*Filipendula vulgaris*	VU
	1	Cowslip	*Primula veris*	VU
	1	Spring speedwell	*Veronica verna*	VU
Vulnerable	22			
Endangered	37			
Critically endangered	2			
Regionally extinct	0			
Observations in total:	**61**			

61 observations of red listed species were located in polygons that changed between 1980 and 2021 (Table 10). Nine of the observations were from polygons that had changed from a vegetation type to an urban type. The rest were located in polygons that were classified as a different vegetation type in 2021 compared to 1980.

Zoning plans

An overview of the areas regulated to different use than the current vegetation or urban type is presented in Table 11, while Table 12 shows future land use and the areas regulated to the different urban types.

Table 11: Area of existing vegetation types regulated to different land use.

Vegetation or urban type	Area (m^2)	Percentage of type on 2021-map
Elm and linden forest	1 792	1 %
Construction site	2 108	2 %
Stonecrops vegetation	136	1 %
Bloody cranesbill vegetation	3 220	68 %
Bilberry spruce forest	309 281	21 %
Species poor bog	3 024	21 %
Recycle station	19 663	100 %
Grey alder and ash forest	20 413	6 %

Grey alder and bird cherry forest	136 916	16 %
Tall herb spruce forest	23 240	22 %
Lichen and heather pine forest	115 498	11 %
Low herb spruce forest	109 754	8 %
Public parking	1 662	16 %
Paddock	4 165	23 %
Parks and green areas	27 914	1 %
Allotment garden	49 981	85 %
Abandoned species rich meadow	117 215	16 %
Small fern spruce forest	27 060	37 %
Quarry	4 571	5 %
Peat moss spruce swamp forest	941	8 %
Weeds	29 808	8 %
Pasture forest	65 207	9 %
Broadleaf pasture woodland	8 124	13 %

Table 12: Area regulated to the different categories.

Regulated to	Area (m^2)
Kindergarten	12 761
Housing	295 073
Prison	30 514
Business premises	14 697
Graveyard	284 149
Health and social institution	107 477
Sports facilities	9 596
Private institution	198 499
School	35 528
Town square	902
Road	69 570
Housing / kindergarten / public benefit	2 810
Housing / business / public	2 183
City centre oriented objectives	140
Industry	17 797

In total, 1 081 695 m^2 of existing vegetation and urban types are regulated for different uses as identified in the land use plans (Table 12). Housing is the category with the largest area planned, followed by graveyards as a close second (Table 12). The zonal plan uses the term “private institution”. In this case, it refers to hotels / conference centers. Bilberry spruce forest was the vegetation type with the greatest planned loss, partly due to the large total area of the type (Table 11). In some cases, an area was regulated to different uses, like housing and offices in the same building. These cases were treated as a separate category and not included in housing or offices.

Discussion

Urbanization is one of the largest threats to species diversity due to habitat loss and fragmentation (Czech et al., 2000; McDonald et al., 2020; Pimm and Raven, 2000; Sala et al., 2000). Yet, many species have adapted, and some species thrive in the city. For instance, several species of birds have higher population density and growth rate in cities than surrounding areas (Faeth et al., 2011). To minimize the negative consequences and enhance the positive impact urbanization and cities have on biodiversity and conservation, is an important aspect of planning for the future as we face growing urbanization, loss of biodiversity and the climate crisis (Al-Ghussain, 2019; IPBES, 2019)

Vegetation change

Within the remapped parts of Oslo, between 1980 and 2021, large areas with vegetation types were lost to urbanisation. Cultivated land, bilberry spruce forests, abandoned species rich meadows and low herb spruce forest decreased most in terms of area (Figure 6). In terms of percentage reduction, moist meadow, weeds, cultivated land and abandoned species rich meadows took the lead (Figure 8).

The general trend of nature loss in a rapidly growing city is not in itself surprising. Oslo, as many other fast-developing cities, has prioritized urban development higher than the conservation of nature within the city zone. In Oslo, 30 % of the study area changed to a different vegetation or urban type, meaning 70 % remained unchanged. Studies show a similar pattern in other cities: for example, 62 % of the study area remained unchanged in Rome (Italy) over a period from 1954 to 2001 (Frondoni et al., 2011). The study of Rome covers a period of 47 years compared to the 40 years covered by this study, yet it seems Oslo is doing slightly better with regard to preserving nature in urban areas. The tendency of urbanization is seen in cities as diverse as Rome, Beijing, Manila, Istanbul and others (Çakir et al., 2008; Frondoni et al., 2011; Murakami et al., 2005; Wu et al., 2006). Within the municipality of Beijing, urban land cover increased by 50 % from 1986 to 2001 (Wu et al., 2006), while in the United States urban land cover increased by 34 % between 1982 and 1997 (Alig et al., 2004). In Kolkata, formerly called Calcutta (India), urban areas increased from 19 % in 1991 to 56 % in 2018 (Mandal et al., 2019). In Oslo on the other hand, the increase in urban land cover was 28,11 %. This is similar to what was found in Barcelona, where urban land cover increased by 27,7 % between 1993 and 2000 (Catalán et al., 2008). This contrast suggests that, despite the process of urbanization being prominent in Oslo, the degree of nature loss due to urbanization is lower than or equal to other cities with comparable studies.

Urbanization impacts nature and vegetation within and surrounding cities, but all vegetation types will probably not be equally impacted. In the study area of Oslo (hereafter referred to as Oslo, despite not covering the entire city or municipality), cultivated land was the vegetation type with the greatest loss of area (Table 4). The mean patch size increased by almost five hectares, while the number of polygons decreased, opposite of what was registered for most vegetation types. The increase in mean patch size was due to the loss of mainly small patches, while large patches were slightly reduced or remained intact. In Oslo, 54 % of the cultivated land disappeared from 1980 to 2021 (Figure 8). Loss of agricultural land is a global challenge (FAO, 2017), the causes varies from soil delegation, erosion, abandonment and urbanization (Jie et al., 2002; Radwan et al., 2019). Urbanization is a major cause for loss of cultivated land, as reported in many studies. For example, in the city of Rome (Italy) (Frondoni et al., 2011), urbanization was the most important factor that explained the loss and fragmentation of agricultural land, while the increase in urban areas in Beijing and the USA occurred at the expense of agricultural land (Alig et al., 2004; Wu et al., 2006). In Rome, 31 % of cultivated land decreased, yet it was still the largest land cover type in the municipality. More than half of the total loss was cropland in Barcelona between 1993 and 2000. Yet, the 54 % loss registered in Oslo is equal to or surpasses losses seen elsewhere.
Some vegetation types are more prone to change than others, or at higher risk of removal. Cultivated land seems to be one such type, as shown by the high levels of area loss in Oslo and other cities. Despite the importance of cultivated land for food production, sustainability and national security, the suitability of cultivated land for building purposes (large, flat areas with soils instead of bedrock) might explain why it seems to be a disproportionate loss of the type (Saizen et al., 2006; Yokohari et al., 2000). In addition, in developing cities with high property prices, farmers can earn much more from selling their property or turning them into golf courses, than what they can from farming.

The conversion of agricultural land to urban areas was the main reason for urban spread in Rome and Barcelona, but the condensation of the urban core was also a major contributor. While condensation might reduce the spread of urban areas into surrounding nature areas, it also negatively affects the habitats and biodiversity inside the city (Carbó-Ramírez and Zuria, 2011). Former refuges or corridors might be reduced or lost. In Rome, 80 % of agricultural areas, wetland and deciduous scrubs changed from 1954 to 2021, while woodlands and plantations in much higher degree remained the same (Frondoni et al., 2011). This is in contrast to Oslo, where forest types were some of the vegetation types with the greatest losses, especially bilberry spruce forest and low herb spruce forest (Table 4). This might reflect the fact that Oslo has large forests surrounding the city, and even within the city, many of the vegetation types that in 1980 covered the largest area were forest types.

As fallow or extensively managed grassland are valuable ecosystems, providing food and habitat to a range of species (Bengtsson et al., 2019; Diekmann et al., 2019), the decrease is a concern (Schils et al., 2022). More than half the area of abandoned species rich meadow, 53 %, were lost in the study area (Table 4). It was the vegetation type with the third greatest loss, only surpassed by cultivated land and bilberry spruce forest. Oslo, there has been an intensified attention on the decline of insects (Oslo kommune, 2022a), leading to a higher focus on green roofs and other artificial ecosystem structures with some ecosystem services (Plan- og bygningsetaten, 2022). However, maintaining the species rich meadows could be a more sustainable alternative, and can be used in addition to the artificial ecosystems which are getting more popular on larger buildings in Oslo (Alexander et al., 2016; Plan- og bygningsetaten, 2022). The loss of fallow land is seen in many urban areas, and the loss seems to be severe in many cases. Fallow land in Kolkata saw a serious decrease from 1991 to 2018, mostly due to urbanization. A study from the Demeer Valley (Belgium) showed the same tendencies, though the grasslands in this study were more intensively cultivated.

The results show a decrease in mean polygon size for a majority of vegetation types (Figure 6), and a 10 % increase in the number of polygons (Table 6). The number of polygons increase while on average they decrease in size. This is a sign of fragmentation as an effect of urbanization, seen in many other cities as well. For example, between 1954 and 1980, the number of patches in Rome (Italy) increased with 76 %, and between 1980 and 2001 it increased with 29 %. At the same time, the mean size of each patch decreased. A study of urbanization and fragmentation in Istanbul (Turkey) found the same effect. The most noticeable exception in Oslo was parks, with an increase of 76 polygons, which is the vegetation type with the largest number of polygons (Table 7). In contrast to other vegetation types, parks are considered an important component of cities and the preservation and creation is often promoted (Engström and Gren, 2017), but then mainly for recreational purposes.

Wetlands are important ecosystems and provide many ecosystem services such as carbon storage (Gorham, 1991), flood prevention (Vázquez-González et al., 2019; Zedler, 2003) and habitat for a wide range of species (Rusin, 2016; Swengel and Swengel, 2010). The loss of wetlands is substantial throughout the world and through history (Asselen et al., 2013), and Norway is no exception (Magnussen et al., 2018). In June 2021, the Norwegian government published a "Nature Strategy for Wetlands" (my translation: (Klima- og miljødepartementet, 2021), which suggests several migiating measures to reduce the loss of wetlands, and state that the most common cause of wetland loss is building activities. This study shows that across the remapped area in Oslo, the area covered by moist meadow decreased by more than 62 %, and species poor bog decreased by 44 % compared to 1980. All the other swamp forest types lost on average 22 % of their former area (Table 4 - types G1-G7). Wetlands and peatland forest were estimated to make up almost 13 % of Norway's total area in 2018 (Bryn et al., 2018). A report shows that 100 km^2 of different wetland types were lost due to building purposes between 1990 and 2019 in Norway (Miljødirektoratet, 2022).

Much of the waterways were kept intact and some restoration had taken place. Most notably the yellow flag iris swamp on the Grorud map-sheet. A pond is a relatively small feature in the landscape, but has important ecological functions like habitat for amphibians (Cushman, 2006) and aquatic insects (Gledhill et al., 2008) as well as the esthetic value for humans (Ngiam et al., 2017). The restoration shows a willingness by the municipality to restore important habitats.

Finally, it needs to be stated clearly that it is challenging to compare studies conducted in different cities, because the investigated time-period often varies, different methods for mapping land cover change has been implemented, the outsets in terms of nature in each city are different, the city structures and development varies, and the size of the areas defined within the city borders vary. In general, however, the results indicate that Oslo has lost less nature to urbanization than many other developing cities, with the exception of cultivated land.

Ecological impacts

To improve our understanding of the ecological impacts related to nature loss within Oslo, in a 40-year urbanization perspective, the analyses have leaned on metrics developed within landscape ecology (Farina, 2022). For the landscape metrics, mean patch area and contagion index values were reduced from 1980 to 2021, while patch richness and number of patches increased (Table 6). For the class indices (Table 7 and Table 8), the values show clear directions. For example, the total area of each class (CA) and the mean patch area (AREA_MN) decreased, whereas the mean of Euclidean nearest-neighbor distance (ENN_MN) increased.

Landscape changes, caused by urbanization from 1980-2021 (see discussion in next subchapter), has led to an increase in the number of vegetation type polygons, but a decrease in the size of each patch (Table 6). Several small polygons rather than a few larger ones indicate a more fragmented landscape. On the other hand, an increase in the number of polygons may not always be an advantage for biodiversity conservation. Few large polygons might be better for biodiversity than many small polygons, if the total area remains the same (Diamond, 1975). For a long time, the so-called SLOSS-debate (SLOSS: Single Large or Several Small) was a theme causing a lot of controversy in nature conservation (Fahrig, 2020; Quinn and Harrison, 1988; Simberloff and Abele, 1982). Although the controversy never ended up with a clear conclusion, it is fair to summarize that both options have advantages and disadvantages, with respect to sustainable biodiversity conservation (Soulé and Simberloff, 1986; Tjørve, 2010). A single large patch will in general have a larger core area, and a smaller area influenced by edge effects (Ries et al., 2004; Willis, 1984). For species sensitive to influence from surrounding areas, e.g. noise or pollutants from traffic, larger polygons will be advantageous. However, several small patches have been forwarded as important when it is an advantage to “spread the risk” (Den Boer, 1968). Such issues can be exemplified by species with sub-populations severely affected by diseases, or for species depending on meta-population dynamics (Hanski, 1998). In such situations, several small patches may in fact be advantageous for the conservation of specific species and sub-populations. It may also be that several small patches, being scattered over a larger landscape, may incorporate for example more abiotic variation in topography, climate, soil nutrients and water availability. This could prevent devastating effects of extreme disturbance- or stress events, such as the summer drought in south Norway 2018 (Gangstø Skaland et al., 2019). In the case from Oslo, however, the data reflect a transition from several larger polygons to fewer smaller polygons, combined with a net loss of area for most of the vegetation types (Table 4). In brief, this means that the spatiotemporal distribution of the vegetation types within Oslo developed in a negative way for biodiversity conservation, in both respects. There are a few exceptions, for example, gray alder and bird cherry forest and elm and parks and green areas, but these do not reflect undisturbed vegetation or high-value types (see discussion on red-listed vegetation types further down).

The carrying capacity with respect to biodiversity is lower in smaller patches, for both species and individuals (MacArthur and Wilson, 1967; Uroy et al., 2019). Larger patches are often more spatially heterogeneous and support a greater variety in habitats. The Island biogeography theory states that small islands hold fewer species than larger islands, and the species on small islands have an increased risk of extinction (MacArthur and Wilson, 1967). Patches of vegetation types in urban areas are islands of habitats surrounded by a “sea” of asphalt and other urban structures. In addition, the Island biogeography theory pinpoints that the degree of isolation is important for immigration and extinction at the islands. According to the theory (Levey et al., 2005; MacArthur and Wilson, 1967), longer distances between islands increases the extinction risk, reduces the immigration flux, and therefore reduces the in-situ biodiversity. This is linked to the dispersal rates of the potential species pool within a larger landscape, but generally, fewer species will be able to reach patches far away. The adverse effect of small patch size and isolation might be further enhanced by dispersal challenges, something that could lead to inbreeding depression in small species populations (Keller and Waller, 2002). Increased distance between patches might favor long distance dispersers. As the distance between patches of the same class increased even as mean patch size decreased, the carrying capacity is assumed to decrease and extinction risk increase. The extinction risk, however, will probably vary amongst different species groups (e.g. amphibians versus bryophytes) with varying functional traits, and even vary within similar groups and genus. For example, for amphibians such as salamanders, increased distances between available patches will inhibit the necessary meta-population dynamics to maintain local populations in a long-term perspective (Cushman, 2006; Gibbs, 1998; Orloff, 2011). Some populations might survive for some years as sink-populations (Furrer and Pasinelli, 2016; Pulliam, 1988), but the extinction debt will sooner or later catch up with the species and reduce the local distributions (Tilman et al., 1994). On the other hand, cosmopolitan bryophytes with wide ecological niches will most likely hardly be affected locally by the size or degree of isolation of patches in Oslo.

The results show a decrease in mean polygon size for a majority of vegetation types (Table 7). Cultivated land was an exception. The mean polygon size of cultivated land increased by almost five hectares. Also, for most vegetation types, the number of patches / polygons decreased from 1980 to 2021 (Table 7). The most noticeable exception was parks, with an increase of 76 polygons. Cultivated land had a massive decrease in number of polygons, and this was the vegetation type with the greatest loss of area. A few large fields remained intact or slightly reduced, whereas small patches were lost. This contributed to the increase in mean polygon size in cultivated land. A loss of cultivated land was seen throughout the map, 55 % of the total area of cultivated land disappeared from 1980 to 2021. The loss of cultivated land, however, was buffered by the stability registered in the western part of the map sheet of Holmenkollen. That map extends into the neighboring municipality Bærum (west of Oslo), where most of the cultivated lands still in agricultural use is located. The loss of cultivated land within Oslo is therefore greater than the overall results reflect at first glance. The areas covered by the map sheet of Grorud and Grefsen lost 100 % and 90 % cultivated land, respectively. This trend was seen on the scale of boroughs as well; all four boroughs lost more than 90 % of the cultivated land. Two boroughs, Grorud and Stovner, lost 100 %. Almost all the remaining cultivated land was located in the area covered by the Holmenkollen map sheet. The loss of cultivated land is not so important for maintaining biodiversity, since monoculture, plowing, weed fighting (spraying with pesticides) and fertilization hardly improve the conditions for high biodiversity (Chamberlain et al., 2000; Krebs et al., 1999; Liu et al., 2013; Wretenberg et al., 2007). However, some of the cultivated land has through succession turned into vegetation types, and thus contribute to re-wilding of small patches (Bowen et al., 2007; Corlett, 2016; Jørgensen, 2015). Therefore, instead of turning cultivated land into urban structures or golf courses (Figure 10), these areas could be used for active restoration of ecosystems (Turley et al., 2020) or left for passive rewilding, if the goal is to maintain the biodiversity within Oslo municipality. If not, one could argue that maintaining the food production on these areas anyway is more important than to use such valuable soil-resources for urban purposes. According to the Food and Agriculture Organization (FAO) of the United Nations the global food production needs to increase (Food and Agriculture Organization of the United Nations, 2017), and Norway has very limited soil-resources (Lundekvam et al., 2003). In addition, the present and forthcoming climate change challenges amplify the need for local food production (IPCC, 2014) and maintaining biodiversity

(IPBES, 2019). In the face of these considerations, to stop or reverse the decrease of cultivated land in Oslo seems the best course of action.

Landscape connectivity and fragmentation are important spatiotemporal aspects of biodiversity conservation (Bierwagen, 2007; Farina, 2022; Framstad et al., 2018; McCallum and Dobson, 2002). Connectivity metrics reflect proxies for important ecological processes, such as genetic exchange amongst relatives, and is usually based on a neighbor distance metric between patches of similar classes (McGarigal and Marks, 1995). Fragmentation is a result of lowered connectivity, and thus includes the effect of fever patches (Aars and Ims, 1999; Gregory et al., 2014). Lime rich pine forest had the same number of polygons in both maps, but a loss of 11 888 m^2 (Table 3) means it was not among the vegetation types with the greatest loss. Yet it was one of the vegetation types with the greatest increase in nearest neighbor distance (Table 7). The largest change in nearest neighbor distance is seen in black alder swamp forest, from 7878 m in 1980 to 0 in 2021. The simple explanation for this is the rareness of the type. Only two polygons existed in 1980, and it was reduced to one in 2021. Nearest neighbor distance is linked to the number of polygons, and a reduction in the number of polygons might have a large impact on the distance. A smaller distance indicates higher connectivity, whereas larger distances are generally a consequence of fragmentation. If the number of patches is limited, the loss of one patch might have a large impact. If one patch were located far from the others, the removal of this patch would have a larger impact on the nearest neighbor index than a patch located closer to the other patches. The nearest neighbor index would decrease, something that could be interpreted as a good sign. Yet, the decrease would be the result of habitat loss, not habitat increase. This effect is reflected in the indices for moist meadow. More than 60 % of the moist meadow were lost, and the mean nearest neighbor distance between patches of this vegetation type decreased from 4524 m to 1242 m. When considering the other indices like number of patches and mean patch area, it is obvious that the reason is because much of this habitat has been lost. Loss of habitat could also have the opposite effect, an increase in the mean nearest neighbor distance. Therefore, when considering indices for use in biodiversity conservation issues, the context is important. Whether the mean distance increase or decrease indicates the location of the habitat loss relative to the remaining habitat. This shows the importance of discussing the effect of changes in one index in the context of changes within other indices; alone they might often give us limited information. Much more understanding can be gained from looking at them together.

Red Listed vegetation types

Red listing of endangered ecosystems, operationalized through the use of defined vegetation types, nature types or habitat types, is a central part of biodiversity conservation internationally (IUCN, 2017). In Norway as well, there is a recently up-dated red list (2018) for ecosystems and habitats (NBIC, 2018), which can be used to assess important landscape-biodiversity changes in Oslo from 1980-2021. The classification system used in the 1980-mapping for vegetation types, however, are not similar. Therefore, in this study, we have compared types that by definition encompasses similar ecological spaces (equal structure, similar species composition and the same ecological processes defining the unit). The most recent red list in Norway is based on Nature in Norway (NiN), defining the units of nature types on differences in ecological space along ecological gradients (Halvorsen et al., 2020). The main components defining the types in NiN, however, is equal as in the vegetation type system from the 1980s; species composition of photosynthesizing plants related to local gradients in for example soil nutrients (lime richness), soil water and water surplus (wetlands). It has therefore not been too challenging to compare the vegetation types with the recently red listed nature types.

In Oslo, almost half of the black alder swamp forest was lost from 1980-2021. It is a rare vegetation type which is the equivalent to Lime-rich mire and swamp forest with broadleaf deciduous tree dominance, which is a type considered vulnerable in the Norwegian Red List of nature types. It is also rare on the map; in 1980, there were only two polygons, but they were reduced to one polygon in 2021. The loss sustained by this one polygon is no more than 2 125 m² yet illustrate the fact that not only area, but also vegetation type is of importance when evaluating landscape changes in a biodiversity conservation setting. A similar loss of area from another and more abundant vegetation type, like bilberry spruce forest, would have little consequence. In general, red listed vegetation types are for the most part lime rich (NBIC, 2018). Nutrient poor vegetation types are more common, both in Oslo and in Norway (Bryn et al., 2018). Settlements have been developed along the coast and rivers throughout history (Diamond, 2002), on nutrient rich and arable land since the beginning of agriculture around 3700 BC in Norway (Berglund, 2011). As settlements grow into cities, the land turned into urban areas. The loss of nutrient rich vegetation types is therefore a natural consequence of urban development. The loss of cultivated land and abandoned species rich meadow is a reminder of this. Yet, the vegetation type with the second greatest loss in area, bilberry spruce forest, is not a nutrient rich vegetation type. It is abundant throughout the country (Bryn et al., 2018), and is still, despite a loss of almost 40 % in Oslo, the most abundant vegetation type in the 2021 map. Elm linden forest is the equivalent of two red listed nature types; Lime-rich deciduous submesic woodland and Lime-rich deciduous woodland. The area covered by elm linden forest increased by 30,5 % in Oslo, mostly by expanding already existing forests in a state of succession. This shows that re-wilding is potential way of increasing the area of rare and endangered vegetation types in Oslo.

Red List of Threatened Species

Within the biodiversity conservation community, there is high focus on red listed species (Mace et al., 2008; IUCN 2022). These are species with declining populations or reduced habitats (IUCN, 2022). Data extracted from The Species Map Service by The Norwegian Biodiversity Information Centre show a limited impact on the registered red list species. Only 61 observations are affected in one way or the other by the changes that occurred from 1980 to 2921. The earliest observations that meet the criteria are from 1985 and many were made at a much later date. It makes it impossible, with the method used in this study, to know whether the observations were made before or after the changes. Nine observations were made in polygons that changed from vegetation to urban. Still, it is hard to know if the specimen is lost or survived in the fringes of the polygon, without a proper re-mapping at the species level. A tree for example, is not necessarily felled even if a building is erected nearby. Often the orthophotos showed trees on the observation site, suggesting the tree(s) might still exist. Most of the observations were made in polygons that changed vegetation type, i.e., from cultivated land to weed or from pasture forest to a different kind of forest. While habitat is important and change of habitat might mean lower survival rates for several species, a change in habitat is not synonymous with extinction (Fierro-Calderón and Martin, 2019; Rymer et al., 2013). An individual ash or elm tree, two of the most common species in the Red List observations, might not be negatively affected by a change in vegetation type, even if the habitat itself is degraded. The main conclusion, however, is that there are too few spatially precise and old (before 1980) entries of red listed species from Oslo, to enable a reasonable analysis of the effects that landscape changes have had on red listed species in Oslo. We therefore recommend strengthening the mapping of red listed species in Oslo, so that future analyses can take advantage of a better data set.

Urbanization, vegetation change and nature management.

The trajectories from vegetation types to urban land cover types reflect the spatial prioritising that has taken place as a part of the city planning and development in Oslo the last 40 years. Housing, apartment buildings, golf courses, industrial areas and business and office premises has expanded most in terms of area (Figure 7).

Replacement of nature and zoning plans

The municipality authorities regularly present plans for the future development of Oslo, and areas are presently regulated for different purposes. Zoning plans show the intention for future development of the city, when it comes to e.g. biodiversity conservation, buildings and infrastructure expansion. Housing was the main reason behind vegetation type loss in the past (Table 12; first and second classes) and will probably be so in the future as well (Oslo kommune, 2015). The policy intentions however, has been and still is to maintain the biodiversity within the city (Oslo kommune, 2011). Yet, according to the results of the presented analyses from 1980 to 2021, a more realistic goal is probably to reduce the rate of biodiversity loss. The settlement pressure in Oslo has been and is very high (Oslo kommune, 2022b; SSB, 2022). The land demand for residential purposes is therefore unlikely to decrease, as there is still a surplus of people moving into Oslo, compared to the rate of housing expansion well (Oslo kommune, 2015; SSB, 2022). Looking at Figure 7, there is no doubt that housing was the urban type contributing most to vegetation loss. Much of the land cover changes caused by urbanization is due to an increase in housing; a trend that is seen elsewhere in the world as well. In Maryland (USA), 63 % of the urbanization between 1973 and 200 was due to an increase residential areas (Irwin and Bockstael, 2007), and in the country as a whole, the increase of housing near national parks is threatening the conservation value of these areas (Radeloff et al., 2010). Oslo municipality wants to plant 100 000 trees over the years to 2030 (Oslo kommune, 2021). Though commendable, one could argue that it would be more sustainable to prevent the felling of already existing trees.

The category that is predicted to consume second most nature in the future is graveyards; 284 149 m^2 (Table 12) is regulated as graveyards in the future. A large area surrounding Voksen church is regulated to graveyard, allowing the present graveyard to expand when the time comes. The surrounding area is a popular recreational area and includes species rich fields and deciduous forests facilitated for recreational activities like walking and frisbee golf. There are several large, old linden trees in the area, as well as a patch of elm linden forest, a red listed vegetation type. This forest is not regulated for graveyards, but for a road. The graveyard by Grefsen church is also set for expansion. Surprisingly, 100 % of the (new) recycle stations is going to disappear. The area has been regulated to graveyard. 85 % of the allotment gardens have been regulated to different use, and part is due to Grefsen graveyard. Bloody cranesbill vegetation is going to suffer a severe loss if the zoning plans are followed. This red listed vegetation type has not been diminished in the last 40 years (Table 4) but stands to lose 68 % of the area in the future. No cultivated land is regulated for different use in the future. Abandoned species rich meadow is formerly cultivated land that is left fallow and is one of the vegetation types with the highest loss in both m^2 and percentage. Grorud had large areas of abandoned species rich meadow. One of the reasons the loss of cultivated land was not more severe is because it was already fallow when the maps were made 40 years ago. Loss of cultivated land is a national problem, and the present government is trying to slow the loss (Prop. 200 S, 2020). When buildings are constructed or golf courses are made on cultivated land, the soil is removed and often it is impossible to reverse the process. While the loss of abandoned farmland is less of a problem than the loss of actively cultivated land, abandoned farmland has the potential to become cultivated land again.

Geographical differences

Few geographical gradients could be found with respect to vegetation changes or urbanization. The largest difference has already been mentioned; the difference in cultivated land between the Holmenkollen map-sheet and the two other map-sheets. No such difference was seen between the four different boroughs (Nordre Aker, Vestre Aker, Stovner and Grorud) (Appendix 5-8). Grorud was the borough with the least percentage change; 23 % (Appendix 7) compared to the 41 % reported in Nordre Aker (Appendix 6). Vestre Aker showed the largest increase in housing, 21 % of what was still vegetation in 1980 was converted to residential areas in 2021 (Appendix 5). Much of this increase found place at Voksenkollen (Figure 11). In contrast, the same number is 7,6 % in Stovner (Appendix 8). Looking at industry, Stovner stands out. At 6 %, Stovner is the only borough where more than 2 % of the vegetated area of 1980 became industrial areas in 2021 (Appendix 8). This gives the impression of an east-west gradient, where housing is favored in the west, while industry is favored in the east. However, the two eastern boroughs are at opposite ends looking at changes due to urbanization. In Grorud, 99 % of the area changes since 1980 was due to urbanization (Appendix 7), while it is 50 % for Stovner (Appendix 8). Stovner, Grorud and

Vestre Aker had similar urban to vegetation ratio in 1980, while Nordre Aker had much less vegetated areas (Appendix 5-8).

Differences between boroughs seem to follow no geographical pattern, and no clear conclusions can be drawn about east-west gradients in urbanization.

Possible errors and difficult decisions

Several decisions had to be made during the project that affected the outcome. Often the decisions were difficult to make, like the problem of which vegetation types should be considered as nature (see later paragraph). Vegetation mapping is subject to the individual mappers. In this study the maps of 1980 and 2021 were made by different mappers, this enhances surveyor bias. In some cases, urban structures present in 1980 were not digitized, something that caused a problem in 2021.

Efforts to avoid errors when remapping

It is desirable to avoid errors in vegetation mapping, but there are several pitfalls (Haga et al., 2021). Principally, there are two potential categories of errors in remapping (Kaur and Stoltzfus, 2017); 1) register a change in land cover when there was no change (false positive errors), 2) leave out real changes (false negative errors). Remapping an area where deciduous forest has given way to kindergartens is relatively straightforward, but it gets more complicated if the forest is still there. Inter-observer variability is common in vegetation mapping (Cherrill, 2016; Stevens et al., 2004) and in the case of remapping, it is impossible to fully calibrate new mappers 40 years after the first mapping. Different subjective decisions should not affect the outcome if the remapping results are to be perceived as reliable and reproducible. To avoid registering false positives, a conservative remapping approach was implemented. Most importantly, we used a copy of the original maps for change detection, instead of trying to make a completely new map (and then compare the new with the old). This is important, because map experiments have shown that both vegetation type assignment and delineation of polygons will vary strongly among mappers (Haga et al., 2021). Therefore, by method, we probably reduced the number of false positives in delineation. Secondly, we did not register a change from one vegetation type to a closely related type if there was doubt, for example from grey alder ash forest to grey alder bird cherry forest, unless we were certain that actual changes had taken place. This probably reduced the number of false positives in vegetation type assignment, but could in contrast lead to a limited number of false negatives. By remapping directly on copies of the old maps, the original polygons and assignments were kept intact where no change was detected, and inter-observer errors (caused by e.g. lack of calibration or subjective decisions) were therefore probably reduced to a minimum.

In the original map, the polygons were delineated based on several criteria. Vegetation type was the main criteria, dominant tree species a secondary factor. Dominant tree species were not a determining factor for delineation in 2021. For this reason, some polygons with the same vegetation type lie side by side. This increases the number of polygons in 2021. However, the number of adjacent polygons of the same type are few and of limited consequence for the analyses. The total number of polygons increases slightly, but the differences between the original and new maps remain the same. The differences in area, not the actual numbers, are the main component for the analyses in this project. The reason for not merging adjacent polygons is to preserve the original maps to the greatest possible degree. In addition, the FRAGSTATS indices were not affected by the adjacent polygons, since all indices were performed on raster maps.

Nature or not

During the analyses of land cover change, with respect to biodiversity conservation, it became necessary to distinguish between nature and non-nature. Easy at first glance, but it proved to be a challenge. In the original map from 1980, there was only one urban type. All other types were classified as vegetation. This raises a significant question; are all vegetation types defined by natural processes and important in a biodiversity conservation perspective? What about parks or cultivated land? Few would contest the claim that for example parks could be defined as a vegetation type, since it is covered by grasses and trees. But this does not parks functioning as natural or undisturbed ecosystems important for biodiversity conservation. In our opinion, there is not necessarily a sharp boundary between nature and non-nature; rather it is a gradual transition.

A decision had to be made. It was desirable to make as few changes as possible to the 1980 map, to protect the integrity of the map and make less room for errors. It was thus decided to treat every vegetation type from 1980 as nature. This includes parks and cultivated land. The case for parks could be argued either way, as nature or not. A short-cropped lawn is not a functioning ecosystem, and of little ecological value. Some invertebrates live in the soil

(Wolters, 2001) and some birds, like white wagtail and common starling feeds on invertebrates found in grassland (Bowler et al., 2019; Heldbjerg et al., 2019), but there are no nesting sites, no food for pollinating insects etc. Parks like these are mostly of recreational value. Yet, parks are diverse. Some parks contain flowerbeds, meadows or large trees. Large trees are keystone structures, providing food and habitat for many species (Tews et al., 2004). The amount of dead wood is positively correlated with tree size (Sirami et al., 2008) and dead and decaying wood are necessary for the life cycle of several species of beetles (Økland et al., 1996). Public concern over large, decaying trees might lead to tree felling. Removal of dead trees, logs or debris, are often based on concerns for public safety or aesthetic arguments, the impulse to tidy-up a “messy” nature (McDonnell, 2007).

Parks have the potential to preserve large trees and provide valuable habitat to many invertebrate and vertebrate species (Stagoll et al., 2012). The ecological value is much higher in parks that offer a variety of habitats. This variety might offer much needed food sources or nesting sites in an urban environment. A second argument could be made for the inclusion of parks in the category “nature”: restoration. Few would argue the fact that parks are closer to nature than, say, a parking lot or a building. If left fallow, the park would over time change character. New species would move in and the succession would lead to a change in species composition. Eventually nature would take over and the park transform into a meadow or on a later stage, a forest.

To classify cultivated land as nature is harder to argue for. The land is put under the plough, monoculture of crops is common, pesticides are usually used to mitigate negative impacts by insects and weeds, and quite often artificial fertilizer is used. As already mentioned, cultivated land has some ecological value, but by most definition, it is not a natural ecosystem. It was decided however, to include cultivated land in the nature category. Partly to stay true to the 1980 map, but the restoration and rewilding arguments are valid in this case too. Abandoned cultivated land turns into meadows, in many cases species rich. The loss of cultivated land is therefore not necessarily, from an ecological perspective, negative. Abandoned cultivated land in later succession stages is much more nature–like and, like parks, and will eventually turn into functioning ecosystems, given enough time.

Two new vegetation types were introduced in 2021; yellow flag iris swamp and allotment garden. Yellow flag iris swamp was included in nature without argument. Although the yellow flag iris swamp was a restored vegetation type, it is non-the-less made up by a species composition reflecting natural processes of wetlands (Halvorsen, 2016). Allotment gardens,

however, is a difficult case. Strongly cultivated, they might still consist of a greater variety of flowering plants, large trees and habitats for insects and birds than cultivated land.
Of the 31 urban types introduced in 2021, two were included as nature; golf course and graveyard. A golf course might not have less ecological value than a simple park without trees and flowers, but it is somewhat more cultivated. Yet, not as strongly cultivated as cultivated land, and with larger spatial heterogeneity in the degree of cultivation. In an attempt at consistency, golf courses were included as nature. The same goes for graveyards. Graveyards often have a high diversity of flowering plants and large trees. While not a functional ecosystem, they nonetheless provide food sources and suitable habitat for several species in urban areas.
The decision to include parks, graveyard, golf courses and allotment gardens in the nature category influences the percentage of change. Table 5 shows that 28,11 % of the original area were urbanized: the percentage would have been much higher had these types been included in urban areas.

While parks, cultivated land, allotment gardens, graveyards and golf courses were included in the nature category in this project, arguments could be made to exclude them. This approach would be equally valid, depending on what aspects were emphasized.

Conclusions

About 30 % of the areas registered as vegetated types changed to another vegetation or urban type in the study area in Oslo from 1980 to 2021. The majority of the changes were caused by urbanization; 28 % of the vegetated areas in 1980 were urban in 2021, though this percentage could have been higher depending on which categories that are defined as nature.

Future research into vegetation change and urbanization in Oslo could take different directions. One approach could be to investigate the plant species composition in changed areas, to quantify species loss or turnover.

Based on ecological theory, it is possible to draw conclusions about how fragmentation and habitat loss affects biodiversity. Yet, as this study focuses on vegetation type trajectories, not species turnover, the full ramifications are not known.

To investigate how the vegetation in the entire Oslo has changed during these 40 years, other vegetation maps could be utilized. To remap the entire city would give a much clearer idea of the extent of change in a growing city in general, for Oslo specifically.

Another approach could be to look deeper into the urbanization process and city plans of the past. To investigate what former city governments and councils envisioned and planned for when it came to urbanization and vegetation. Has the development in Oslo gone according to plan, or has nature been sacrificed in the name of progress?

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Appendix 1

Total study area

Table A 1: The vegetation system in Norwegian. Only vegetation types used in the project included.

Kode	**Beskrivelse av vegetasjonstypene**
A-serien er furuskoger på kalkfattig og vanligvis tørkesvak mark. De er dominert av lyng, moser og lav. Jorda er sterkt sur, surhetsgraden (pH) = 3,6-3,8	
A2	**Lav- og lyngrik furuskog:** En lysåpen furuskog, ofte iblanda osp, rogn og gran, på grunnlendte knauser og åsrygger. Skogen vokser seint og gir låg produksjon av trevirke. Jordlaget er tynt og flekker med bart fjell er vanlig i låglandet, men i åsterrenget finner vi en annen utforming med et ganske tjukt råhumuslag. Typiske arter: Krekling, røsslyng, lys og grå reinlav, islandslav og sigdmoser.
B-serien er artsfattige granskoger på middels næringsrik mark med godt jordekke. Lyng, bregner og moser dominerer i disse skyggefulle skogene. Jorda er oftest sur, pH under 4,5.	
B2	**Blåbærgranskog:** Dette er vår artsfattigste granskog og den vanligste typen i Oslomarka. Produksjonsevna for trevirke er middels til høy. Skogbotn er dekt av blåbærlyng og moser. På lysåpne steder er det mye smyle. Ellers er maiblom, skogstjerne, stri kråkefot, linnea og nikkevintergrønn faste innslag.
B3	**Småbregnegranskog:** Fuktig og kjølig granskog i baklier og mørke daler. Produksjonsevna for trevirke er høy. I liene er det sigevann som gir bedre næringsinnhold i jorda enn i forrige type. Vi finner de samme artene som i B2, men også mer næringskrevende arter som hvitveis, gaukesyre, engkvein, og bregner som fugletelt og hengeving.
B4	**Storbregnegranskog:** En høgproduktiv granskog som vi oftest finner på flat, litt vassjuk leirjordmark. Skogproduksjonen blir ofte redusert av vindfelling forårsaket av grunt rotnett på våt, elastisk jord. Skogbotn er dominert av bregner: Skogburkne, sauetelg, fugletelg, hengeving. Ellers finner vi skogsnelle, krypsoleie og store tovmosematter. Rike utforminger har høge stauder.
C-serien er barskoger på mark hvor det er god næringstilgang og rask stoffomsetning i jorda. Låge urter er et viktig innslag i skogbotn. Jorda er svakt sur til basisk, pH over 4,5.	
C1	**Kalkfuruskog:** Furuskog på kalkrik, men grunn jord med låg til middels produksjon av trevirke. Noen av de tørkesterke artene vi kjenner fra A2 spiller en stor rolle (røsslyng, sauesvingel, mjølbær, reinlav), men karakteristisk er den rike floraen av låge urter og kalk- og lyskrevende arter. Vi finner et buskskikt av berberis, rosearter, svartmispel, dvergmispel og einer, mens feltskiktet består av arter som liljekonvall, blodstorkenebb, knollmjødurt, kantkonvall, rødflagre, aksveronika, knoppurt, gjeldkarve og bakkemynte. Edle lauvtrær som alm, lind og hassel kan også finnes noen steder. Malmøya har gode eksempler på kalkfuruskog. Kalkfuruskogene er sjeldne vegetasjonstyper også i nordisk sammenheng. De er ømfintlige for sterk slitasje.
C2	**Lågurtgranskog:** Dette er en artsrik og høgproduktiv skogtype som vi finner på næringsrik jord overalt i Oslo. Den vanligste utformingen har et typisk barskoginventar med lyng og husmoser, men enkeltstående individer av skogfiol, jordbær, legeveronika, knollerteknapp og skogsveve indikerer rikere næringstilstand enn i B-skogene. En annen rikere og mer engpreget utforming, har arter som blåveis, lønn, kranskonvall, hassel, tysbast og krossved.
C3	**Vanlig hagemarkskog:** Rundt gårdstun og gammel dyrket mark finner vi en kulturpåvirka skogtype, beslekta med lågurtgranskogen, men som regel med lauvtredominans. Skogproduksjonen er normalt høg, unntatt på grunnlendte arealer. Vegetasjonen bærer preg av tidligere beite ved at den inneholder mange arter som tåler sterk beiting og tråkk.
C4	**Høgstaudegranskog:** Langs bekker og i dråg litt opp i åsene finner vi en frisk skogtype med høg produksjon av trevirke. Denne typen vokser bare der hvor det er friskt, næringsrikt sigevann i jorda. Høge stauder som turt, tyrihjelm, enghumleblom, vendelrot og mjødurt dominerer skogbotn. Under disse er det en rik flora av låge urter, bregner og kravfulle moser.

E-serien er lauvskogsamfunn dominert av ask, alm, lind og lønn (varmekjære og næringskrevende) eller av gråor (næringskrevende). Undervegetasjonen består for det meste av urter og gras, og ofte et frodig buskskikt. Jorda er alltid næringsrik.	
E1	**Alm-lindeskog:** Dette er en varmekjær skog med middels til høg produksjon av lauvtrær. Vi finner den ofte i bratte, solrike lier med kalkrik, god jord. I tillegg til alm og lind er det gjerne aks, lønn, villmorell og hassel. Vegetasjonsdekket i skogbotn inneholder en mangfoldig flora av krevende gras, urter og moser. Trollbær, tannrot, nesleklokke, krattfiol, sanikel og myske er noen av karakterartene. Hovedøya og Bygdøy har fine bestander av alm-lindeskog.
E2	**Gråor-askeskog:** I lune bekkedaler og lier på kalkrik, friskt fuktig jord finner vi en høgproduktiv, varmekjær lauvskog. Feltskiktet er meget frodig, med saftige, næringskrevende urter og et karakteristisk våraspekt med gullstjerne og vårkål som blomstrer før trærne får blad. Andre viktige arter: storklokke, nyresoleie, maigull, springfrø, skogsvinerot og firblad. Gråor-askeskog finnes bl.a. ved Voksen og langs Lysakerelva.
E3	**Gråor-heggeskog:** I bunnen av raviner og langs med bekker og elver der marka oversvømmes i flomperioder, ofte på frostutsatte steder, finner vi en høgproduktiv, hardfør gråorskog. Vegetasjonen er frodig med hegg og rips i busksjiktet og med strutseving, sneller, mjødurt og hvitveis som dominerer feltsjiktet.
E4	**Varmekjær hagemarkskog:** En økologisk parallell til C3 på steder der nærings- og klimaforhold er så gode at edelløvskogen er konkurransedyktig. Gjerne på gammel kulturmark. Her er mye lønn og bjørk, men også alm og ask. Botnvegetasjonen består av en blanding av gammel kulturvegetasjon, gjerne grasarter, og edellauvskogsarter. Gode eksempler finnes på Hovedøya.
G-serien er skogsamfunn på torvjord og sumpmark. På den næringsfattigste marka er det furuskog, på den middelsrike granskog, og på rik mark svartorskog eller gråseljekratt. Plantene er tilpasset et vått, surstoffattig rotmiljlø.	
G1	**Røsslyng furumyrskog:** Dette er sintvoksende, ofte forkrøpla furuskog på regnvannsmyr hvor nesten all næringstilførsel kommer fra nedbør. Torva er sur, pH under 3.5, og som regel dårlig omdanna. Vegetasjonen er en blanding av furuskogarter og myrarter, dominert av lyng som røsslyng, krekling, tranebær, kvitlyng og molte. I botn er det en matte av nøysomme torvmoser, ofte oppbygd i tuer med lav på toppen.
G2	**Bærlyng furumyrskog:** Denne myrskogen utvikles på torvmark der næringen ikke bare kommer med nedbøren (strøfall, jordvann). Som G1 har den dominans av lyng og torvmoser, men feltsjiktet er høgere og tettere. Her og der står der forkrøpla smågran. Skillearter mot G1: blåbær, gråstarr, duskull, trådsiv, blåtopp (på forstyrra mark) og vanlig bjørnemose.
G3	**Torvmose-gransumpskog:** Seintvoksende skog med dype, mørke kroner i forsenkninger og i kanten av myrer i granskogområdene. Undervegetasjonen består av urter, gras og starr med ei tett matte av torvmoser, særlig grantorvmose. Myrfiol, myrhatt, skogsnelle, småtveblad, skogrørkvein, stjernestarr og bregner forteller at næringsforholdene er bedre enn i furumyrskogene.
G4	**Skogrørkvein·viersumpskog:** Detter er nærmest et krattsamfunn som vi finner på torv ved bekker og tjern og på næringsrik, forsumpa mark i åstraktene. Vierarter, bjørk, gråor og gran dominerer i busk- og tresjiktet. I feltsjiktet er det skogrørkvein, sølvbunke, slirestarr, soleiehov og skogsnelle som dominerer. Ellers finner vi flere næringskrevende urter og moser.
G6	**Svartorsumpskog:** På tilsvarende lokaliteter som G4 vil vi i låglandet finne et svartordominerte samfunn, ofte ispedd litt gran og bjørk. Trærne står ofte på høge tuer. Myrmaure, myrkongle, gulldusk, gulstarr, bekkekarse, mannasøtgras, vassrørkvein og langstarr skiller samfunnet fra fattige sumpskoger. En rik utforming finnes bl.a. ved blåtjern.
G7	**Rik strandsumpskog:** Dette er en noe uensarta type vegetasjon som vi finner i kanten av næringsrike vann, ofte med dyrka mark innafor. Samfunnet har høg biologisk produksjon. Ofte er det tette, ugjennomtrengelige kratt med gråselje, svartvier, oreartene, bjørk, ørevier, trollhegg, istervier og pors. Under dominerer vassrørkvein sammen med skogsivaks, takrør, kattehale, mjødurt og sneller.
H-serien er treløse myrområder. Torva her er for fuktig til at det kan vokse skog. Det har tidligere vært større myrareal i Oslo, men mye har blitt grøfta og er nå vokst til med skog.	

H2	**Fattigmyr:** Jordvannspåvirka myr på flate områder eller rundt næringsfattige tjern. Torva er fattig på næringsstoffer og forholdsvis sur, pH 4-4,5. Vegetasjonen er vanligvis dominert av halvgras som bjønnskjegg, duskull, trådstarr, flaskestarr, gråstarr, frynsestarr og slåttestarr, samt andre nøysomme arter som bukkeblad, tepperot og kvitmyrak over ei tett matte av torvmoser.
Knaussamfunn har vi kalt ei gruppe vegetasjonstyper på skogløse knauser med tynt jordlag. Sommerstid vil det være sterk solinnstråling og ofte tørkestress. Vinterstid vil det også være ekstreme forhold med frost og vindslitasje. Vegetasjonen er frodigst tidlig på sommeren. Her vokser mange rosettplanter som har bladverket samla i en tett krans helt nede ved bakken og bladene er gjerne tykke og hårete. Knaussamfunnene er et særtrekk for vegetasjonen rundt indre Oslofjord.	
V3	**Bergknappsamfunn:** På de skrinneste knausene der vegetasjonen kan synes helt avsvidd i tørre somre, dominerer de tykkbladete bergknappene. Andre arter: stemorsblom, knavel, nyresildre, sølvmure, vårskrinneblom og tjæreblom. Er berggrunnen kalkrik, finner vi utforminger med bakkemynte, markmalurt og sandarve.
Q2	**Blodstorkenebbeng:** I overgangen mellom Q1 og skog, helst kalkfuruskog, finner vi et samfunn med arter som krever mer jord og bedre fuktighet: blodstorkenebb, bergmynte, nakkebær, prikkperikum, dragehode, krattsoleie og nikkesmelle. Her kan også være mye busker av mispel, berberis og roser.
Engsamfunn finner vi på mark med skikkelig jorddekke der det av en eller annen grunn ikke vokser skog. Mye av de kulturbetingede engene gror igjen med lauvskog når de ikke brukes lenger. Når skogartene har etablert seg, klassifiseres arealet som skog.	
R3	**Fattig ødeeng:** Dette er tidligere dyrka mark eller beitemark. Når arealene ikke lenger er i aktiv kultur, dannes halvnaturlig graseng. Typiske grasengarter: Engkvein, engrapp, rødsvingel, engsoleie, kvitkløver, fuglevikke, firkantperikum, prestekrage.
R4	**Rik ødeeng:** Tilsvarende eng på næringsrik mark. Her finner vi i tillegg engreverumpe, hundegras, markrapp, høymole, stormaure og hestehavre.
R5	**Ugrassamfunn:** På jordfyllinger og ellers på steder der jorda nylig har vært gravd opp, etablerer det seg en blanding av pionerarter og åkerugras. Vanlige arter er steinkløver, burot, åkertistel, svineblom og geitrams.
S2	**Fukteng** Dette er naturlig våte engsamfunn eller halvnaturlige enger på dårlig grøfta mark, men sølvbunke, mjødurt, myrtistel, knappsiv, sløke, sogsivaks, soleiehov og blåtopp.
Innsjøstrand kaller vi den åpne sumpvegetasjonen og vannplantesamfunnene som iblant brer seg fra stranda og utover i tjern, innsjøer og elver.	
W2	**Rikstarrsump:** Starrdominert sumpsamfinn i svært næringsrike vann. Ofte utenfor en sone med rik strandsumpskog (G7). Kjennes på krevende starr: kvasstarr, dronningstarr, kjempestarr, stautstarr og på forekomst av selsnepe, myrkongle, mjølkerot, sverdlilje, kjempesøtgras og brei dunkjevle.
X	**Takrørsump:** Sumpsamfunn som vanligvis er dominert av det høge graset takrør, men også noen få ganger av sjøsivaks eller kjempesøtgras. Arter ra starrsumpene finnes også her (f. eks brei dunkjevle). Andre: smal dunkjevle, strandrør, kjempepiggknopp, stautpiggknopp.

Table A 2: The vegetation system in English (my translation). Only vegetation types used in the project included.

Code	Description of vegetation types
A: Pine forest on lime poor, dry ground. Dominated by heather, mosses and lichen. Acid soil.	
A2	**Lichen and heather pine forest:** An open pine forest, often with aspen, rowan and spruce, on knolls and ridges, Slow-growing and low production forest. Shallow soil layer, with patches of bare rock are common in the lowlands, while the humus layer is thicker higher up the hillside. Typical species: crowberry, heather, reindeer cup lichen, shrubby cup lichen, Iceland lichen and fork mosses.
B: Species poor spruce forests on intermediate lime rich soils. Dark forest dominated by heather, ferns and mosses. Acid soil, pH below 4.5.	
B2	**Bilberry spruce forest:** A species poor spruce forest and the most common forest type in Oslomarka. Medium to high production. The forest floor is covered by bilberry and mosses. Wavy hair grass grows in open areas. Other common species are false lily of the valley, arctic starflower, stiff clubmoss, twinflower and one-sided shineleaf.
B3	**Small fern spruce forest:** Moist and cool spruce forest in dark valleys. High production forest. On the hillsides, the nutrient level is higher than in B2, due to seep water. Common species are the same as in B2, but we also find more nutrient demanding species as wood anemone, wood sorrel, browntop and ferns like oak fern and long beech fern.
B4	**Large fern spruce forest:** A highly productive spruce forest often found on flat, wet clay soils. Forest production is often reduced by windthrow due to shallow root systems on wet, elastic soil. The forest floor is dominated by ferns: lady fern, spreading wood fern, oak fern and long beech fern. Other common species are wood horsetail, creeping buttercup and sphagnum mosses. Tall herbs are common.
C: Coniferous forest on nutrient rich soils and fast nutrient cycles in the soil. Low herbs are common. The soil is weakly acid to basic. pH above 4.5.	
C1	**Lime-rich pine forest:** Pine forest on lime rich, but shallow soil with low to medium wood production. Some of the drought tolerant species from A2 is very common (heather, sheep fescue, bearberry and reindeer lichen), but more characteristic is the many nutrient and light demanding low herbs. Common shrubs are berberis, roses, cotoneaster, common cotoneaster and juniper. Other common species are lily of the valley, bloody cranesbill, dropwort, angular Solomon's seal, dark red helleborine, spiked speedwell, basketflower, burnet-saxifrage and basil thyme. Deciduous trees like elm, linden and hazel might be found.
C2	**Low herb spruce forest:** A species rich and highly productive forest found on nutrient rich soil many places in Oslo. The most common variation has species typical for spruce forests, mainly heather and mosses, but single individuals of wood violet, wild strawberry, heath speedwell, heath pea and wall hawkweed indicate a more nutrient rich forest than the forest of the B-type.
C3	**Pasture forest:** By farms and formerly cultivated land, a semi-natural forest type is found. It is similar to C2, but usually dominated by deciduous trees. Forest production is medium to high, except on shallow soils. The vegetation is dominated by species adapted to grazing.
C4	**Tall herb spruce forest:** By streams and on moist areas in the hillside is a highly productive forest to be found. This type is only found where nutrient rich water is seeping through the soil. Tall herbs like wolf's-bane, water avens, elder-leaved valerian and meadowsweet dominate the forest floor. Beneath, low herbs, ferns and mosses are found.
E: Deciduous forests dominated by ash, elm, linden, grey alder and maple trees. The understory is dominated by grasses, herbs and shrubs. The soil is always nutrient rich.	
E1	**Elm and linden forest:** Deciduous forests with a medium to high wood production. Often found on steep, sunlit slopes with nutrient rich soil. Elm, linden, ash and hazel dominates. The forest floor is dominated by a variety of demanding grasses, herbs and mosses. Baneberry, coral root, nettle-leaved bellflower, sanicle wood and sweet woodruff.
E2	**Grey alder and ash forest:** A more water demanding deciduous forest than E1. Nutrient demanding low herbs like yellow star-of-Bethlehem, pilewort flower before the trees sprout leaves in spring. Other important species are giant bellflower, goldilocks buttercup, golden-saxifrage, touch-me-not balsam, hedge woundwort and true lover's knot.
E3	**Grey alder and bird cherry forest:** At the bottom of ravines and by streams and rivers where the ground is often flooded, this highly productive forest found. More cold-tolerant than E1 and E2. Lush vegetation with bird cherry, flowering currant, ostrich fern, snake grass, meadowsweet and wood anemone.

E4	**Broadleaved pasture woodland:** An ecological parallel to C3 where the nutrient and climate allows deciduous forest. Often formerly cultivated land. Maple, birch, elm and ash are common trees.
G: Swamp forest. Nutrient poor soil is dominated by pine, intermediate soils are dominated by spruce forest and nutrient rich soils are dominated by black alder or grey sallow.	
G1	**Heather pine swamp forest:** Slow growing pine forest on ombrotrophic bogs. The peat is acidic, pH below 3.5. The vegetation consists of a combination of pine forest species and species usually found on bogs. The vegetation is dominated by heather, crowberry, cranberry, bog-rosemary and cloudberry. Less demanding sphagnum mosses, often with lichen, dominate the bottom layer.
G2	**Heather bilberry pine swamp forest:** Swamp forest on peat where more nutrients arrive by other means than precipitation. Dominated by heather and sphagnum mosses, but unlike G1, we also find bilberry, woollyfruit sedge, thread rush and hair mosses.
G3	**Peat moss spruce swamp forest:** A dark, slow growing forest found in indents and by the edge of bogs. Dominated by spruce. The understory is dominated by herbs, grasses, sedges and sphagnum mosses. Marsh violet, purple marshlocks, wood horsetail, heartleaf twayblade, star sedge and ferns indicate more nutrient in the soil than in the pine forests.
G4	**Reed grass willow swamp forest:** Dominated by shrubs. Found by streams, ponds and nutrient rich peatlands. Willows, birch, grey alder and spruce dominate. Beneath, the vegetation is dominated by tufted hair grass, sheathed sedge, marsh-marigold and wood horsetail.
G6	**Black alder swamp forest:** On similar locations as G4, but lower in the terrain, we can find a forest dominated by black alder. Marsh bedstraw, wild calla, tufted loosestrife, hedgehog grass, large bitter-cress, floating sweet-grass and purple small-reed separate G6 from more nutrient poor swamp forest types.
G7	**Rich beach swamp forest:** Found by nutrient rich ponds and lakes, often close to cultivated land. Highly productive. Grey willow, dark-leaved willow, alder, birch, eared willow, alder buckthorn and bog-myrtle create dense thickets.
H: Bog where no trees grow as the ground is to wet.	
H2	**Species poor bog:** Bog affected by soil water, found on flat surfaces or close to nutrient poor ponds and lakes. The peat is low on nutrients and moderately acidic, pH 4-4.5. The vegetation is dominated by deergrass, woollyfruit sedge, bottle sedge, black sedge, bogbean, tormentil and sphagnum mosses.
Shallow soil communities are vgetation types on tree-less areas with a shallow soil layer. Some types are affected by strong sun in the summer. During winter, winter and low temperatures creates a hostile environment.	
V3	**Stonecrops vegetation:** On knolls with only a thin layer of soil, the vegetation might dry out completely during summer. Dominated by drought tolerant stonecrops. Other species: wild pansy, meadow saxifrage, hoary cinquefoil and thale cress. Basil thyme, field wormwood and thyme-leaf sandwort are found on lime rich ground.
Q2	**Bloody cranesbill vegetation:** In the transition zone between Q1 and forest, mainly lime rich pine forest. The vegetation requires a deeper layer of soil and more moisture: bloody cranesbill, creamy strawberry, St. John's wort, dragonhead and. nottingham catchfly. Cotoneaster, berberis and roses might also grow here.
Meadows are found on treeless ground with a good soil layer.	
R3	**Abandoned species poor meadow:** Abandoned cultivated land or pasture. No longer in use it turns into a semi natural meadow. Typical species: common bent, bluegrass, red fescue, meadow buttercup, white clover, tufted vetch, spotted St. Johnswort and daisy.
R4	**Abandoned species rich meadow:** Same as R3, but on nutrient rich soil. In addition to the species of R3, meadow foxtail, orchard grass, rough meadow-grass, northern dock, hedge bedstraw and bulbous oat grass are common.
R5	**Weeds:** On areas where the soil has recently been disturbed, pioneer species and weeds establish themselves. Common mugwort, field thistle, ragworts and rosebay willowherb are common species.
S2	**Moist meadow:** Natural or semi natural wet or moist meadows., with meadowsweet, swamp thistle, compact rush, wild angelica, wood clubrush, marsh-marigold and purple moor-grass.
Swamp- or water plants by beaches, lakes, ponds and rivers.	
W2	**Rich sedge swamp:** Swamp dominated by sedges, in nutrient rich waters. Often close to G7. Demanding sedges dominate: acute sedge, hop sedge, greater pond sedge and lesser pond-sedge. Other species: cowbane, wild calla, milk-parsley, yellow flag iris, great manna grass and common bulrush.

X	**Common reed swamp:** Swamp, usually dominated by common reed, sometimes by lakeshore bulrush or great manna grass. Other species: great manna grass, reed canary grass and simplestem bur-reed.

Table A 3: Some vegettion types existed in the original map, but were not included in the description of the vegetation types.

Code	Norvegian name	English name
Beit	Beitemark	Pasture
Dyrk	Dyrket mark	Cultivated land
K	Parkområder og grøntanlegg	Parks and green areas
PL	Plantefelt på Innmark	Tree plantation on arable field
Vann	Vann	Water
Ur	Ur	Talus slope

Table A 4: ENN_SD: Standard deviation of Euclidean nearest-neighbor distance, ENN_CV: Coefficient of variation of Euclidean nearest-neighbor distance.

Vegetation type	ENN_SD		ENN_CV	
Lichen and heather pine forest	1980	2021	1980	2021
Bilberry spruce forest	98,06691	118,8538	221,2018	250,5026
Small fern spruce forest	135,2762	158,7234	236,1602	241,243
Large fern spruce forest	1447,618	1542,164	162,2444	138,4053
Lime-rich pine forest	741,4824	807,6674	113,1362	122,3256
Low herb spruce forest	237,9264	976,5159	149,713	339,8275
Pasture forest	142,5559	140,1678	163,649	164,867
Tall herb spruce forest	199,3919	143,4736	149,1109	129,4089
Elm and linden forest	465,769	485,4043	260,1643	290,4533
Grey alder and ash forest	527,1574	554,5235	106,8774	113,0181
Grey alder and bird cherry forest	608,1067	662,962	259,4676	234,388
Broadleaved pasture woodland	231,8132	203,6834	174,6136	164,5968
Heather pine swamp forest	2973,256	3291,412	282,3116	266,107
Heather bilberry pine swamp forest	0	0	0	0
Peat moss spruce swamp forest	2284,379	3983,755	83,21714	112,3589
Reed grass willow swamp forest	690,9973	736,8155	137,3263	197,5659
Black alder swamp forest	0	0	0	0
Rich beach swamp forest	0	0	0	0
Species poor bog	0	0	0	0
Stonecrops vegetation	61,33167	67,12753	42,67555	50,63717
Bloody cranesbill vegetation	55,88149	55,88149	48,05314	48,05314
Abandoned species poor meadow	0	0	0	0
Abandoned species rich meadow		0		0
Weeds	174,5171	196,5469	148,2025	155,374
Moist meadow	789,5569	236,6893	418,8303	125,9046
Rich sedge swamp	6791,534	2129,381	150,0979	171,4303

Yellow flag iris swamp	7034,336	0	105,2024	0
Common reed swamp		0		0
Cultivated land		0		0
Pasture forest	247,9947	62,55448	244,8717	142,4056
Tree plantation on arable field	493,2978	1639,135	118,2653	131,6683
Parks and green areas		0		0
Allotment garden	162,3384	146,3011	192,0277	175,4338
Graveyard		381,614		16,24541
Golf course		364,6551		112,3873
Water		346,3799		188,603

Appendix 2

Holmenkollen map-sheet

Table A 5: Area statistics showing the area cover for each vegetation type in different years and the area lost/gained in m2 for Holmenkollen map sheet.

Vegetation or urban type	Area 2021	Area 1980	Difference
Lichen and heather pine forest	102 074	175 529	-73 455
Bilberry spruce forest	793 752	1 464 882	-671 130
Small fern spruce forest	51 186	80 046	-28 860
Large fern spruce forest	22 808	31 517	-8 709
Pasture forest	22 454	92 877	-70 423
Lime-rich pine forest	147 552	134 288	13 264
Low herb spruce forest	686 712	1 147 618	-460 906
Pasture forest	275 216	489 388	-214 172
Tall herb spruce forest	102 823	142 124	-39 301
Cultivated land	892 936	1 629 251	-736 315
Elm and linden forest	85 210	65 085	20 125
Grey alder and ash forest	159 316	87 167	72 149
Grey alder and bird cherry forest	339 620	324 989	14 631
Broadleaved pasture woodland	4 383	10 356	-5 973
Reed grass willow swamp forest	6 702	6 702	0
Black alder swamp forest	2 170	2 170	0
Species poor bog	14 372	17 546	-3 174
Parks and green areas	378 615	344 076	34 539
Allotment garden	6 093	0	6 093
Abandoned species poor meadow	25 795	0	25 795
Abandoned species rich meadow	197 915	198 849	-934
Weeds	41 197	15 614	25 583
Moist meadow	0	10 903	-10 903
Kindergarten	21 093	0	21 093

School	39 694	0	39 694
University	55 159	0	55 159
Health premises	63 673	0	63 673
Graveyard	68 676	0	68 676
Embassy	41 373	0	41 373
Armed forces	2 961	0	2 961
Housing (villas/townhouses)	1 013 190	0	1 013 190
Apartment buildings	243 354	0	243 354
Industrial area	46 604	0	46 604
Business and office premises	61 084	0	61 084
Public transport	9 711	0	9 711
Public parking	1 349	0	1 349
Construction site	49 813	0	49 813
Sports facilities	48 773	0	48 773
Sports field (gravel / artificial grass)	24 095	0	24 095
Golf course	242 046	0	242 046
Activity farm	25 454	0	25 454
Paddock	4 556	0	4 556
Talus slope	10 169	10 169	0
Water	93 948	93 948	0
Road	149 794	102 493	47 301
Rich sedge swamp	1 270	2 647	-1 377

Table A 6: In the area covered by the Holmenkollen map sheet, 28,56 % of the vegetated area of 1980 has been lost due to urbanization. This means 82,00 % of the registered changes in are due to urbanization.

	Nature (km^2)	Urban (km^2)
1980	6,68	
2021	4,78	1,91
Vegetation lost		28,65 %
Percentage of change due to urbanization		82,00 %

Table A 7: Fragstats class indices for the Holmenkollen map sheet. CA: total area for each class (ha), NP: number of patches, AREA_MN: mean patch area (ha).

	CA		NP		AREA_MN	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	17,54	10,20	25	20	0,70	0,51
Bilberry spruce forest	146,40	79,33	52	60	2,82	1,32
Small fern spruce forest	8,00	5,12	8	6	1,00	0,85
Large fern spruce forest	3,15	2,28	5	5	0,63	0,46
Lime-rich pine forest	13,42	15,66	5	7	2,68	2,24
Low herb spruce forest	115,58	68,78	100	80	1,16	0,86
Pasture forest	48,91	28,02	43	40	1,14	0,70
Tall herb spruce forest	14,20	10,27	24	20	0,59	0,51
Elm and linden forest	6,50	8,52	10	12	0,65	0,71
Grey alder and ash forest	8,71	15,92	11	15	0,79	1,06
Grey alder and bird cherry forest	32,48	34,07	37	36	0,88	0,95
Broadleaved pasture woodland	1,03	0,44	1	1	1,03	0,44
Reed grass willow swamp forest	0,67	0,67	1	1	0,67	0,67
Black alder swamp forest	0,22	0,22	1	1	0,22	0,22
Species poor bog	1,75	1,44	5	4	0,35	0,36
Abandoned species poor meadow		2,58		2		1,29
Abandoned species rich meadow	19,88	19,95	18	40	1,10	0,50
Weeds	1,56	4,12	1	28	1,56	0,15
Moist meadow	1,09		1		1,09	
Rich sedge swamp	0,26	0,13	2	1	0,13	0,13
Cultivated land	162,83	89,71	28	11	5,82	8,16
Pasture forest	9,28	2,24	9	2	1,03	1,12
Parks and green areas	34,39	37,96		38		1,00
Allotment garden		0,61		1		0,61
Graveyard		6,86		2		3,43
Golf course		24,19		1		

Table A 8: ENN_MN: Mean of Euclidean nearest-neighbor distance (m), ENN_SD: Standard deviation of Euclidean nearest-neighbor distance, ENN_CV: Coefficient of variation of Euclidean nearest-neighbor distance for the Holemnkollen map sheet.

	ENN_MN		ENN_SD		ENN_CV	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	65,50	102,30	72,77	189,24	111,10	184,99
Bilberry spruce forest	35,44	47,19	75,79	142,73	213,86	302,48
Small fern spruce forest	86,45	135,45	88,14	72,56	101,96	53,57
Large fern spruce forest	1085,57	1098,97	974,77	971,69	89,79	88,42
Lime-rich pine forest	369,29	124,16	286,88	238,46	77,69	192,07
Low herb spruce forest	67,39	117,47	107,08	183,61	158,89	156,31
Pasture forest	91,65	110,08	148,20	167,67	161,69	152,32
Tall herb spruce forest	66,87	30,74	163,16	33,09	244,01	107,66
Elm and linden forest	793,48	568,49	632,81	697,16	79,75	122,63
Grey alder and ash forest	468,76	313,65	1158,85	835,97	247,22	266,53
Grey alder and bird cherry forest	206,41	175,94	270,47	248,89	131,04	141,46
Broadleaved pasture woodland	0,00	0,00	0,00	0,00	0,00	0,00
Reed grass willow swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Black alder swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Species poor bog	143,78	132,65	61,26	67,06	42,61	50,55
Abandoned species poor meadow		3135,66		0,00		0,00
Abandoned species rich meadow	230,99	125,54	252,34	192,20	109,24	153,09
Weeds	0,00	318,83	0,00	441,90	0,00	138,60
Moist meadow	0,00		0,00		0,00	
Rich sedge swamp	2625,20	0,00	0,00	0,00	0,00	0,00
Cultivated land	78,73	43,71	158,73	62,64	201,62	143,32
Pasture forest	406,78	312,87	440,92	0,00	108,39	0,00
Parks and green areas		194,02		225,46		116,20
Allotment garden		0,00		0,00		0,00
Graveyard		2827,71		0,00		0,00

Appendix 3

Grefsen map sheet

Table A 9: Area statistics showing the area cover for each vegetation type in different years and the area lost/gained in m2 for Grefsen map sheet

Vegetation type	Area 2021	Area 1980	Difference
Housing (villas/townhouses)	339 413	0	339 413
Apartment buildings	200 811	0	200 811
School	60 716	0	60 716
Sports field (gravel / artificial grass)	56 694	0	56 694
Construction site	48 784	0	48 784
Allotment garden	46 081	0	46 081
Sports facilities	33 658	0	33 658
Industrial area	32 669	0	32 669
Kindergarten	31 233	0	31 233
Grey alder and bird cherry forest	109 643	78 437	31 206
University	29 887	0	29 887
Graveyard	27 289	0	27 289
Recycle station	19 663	0	19 663
Pasture forest	12 587	0	12 587
Tree plantation on arable field	11 663	0	11 663
Health premises	9 956	0	9 956
Activity farm	6 636	0	6 636
Cultural buildings	6 341	0	6 341
Business and office premises	5 766	0	5 766
Road	4 801	498	4 303
Weeds	2 973	0	2 973
Public parking	2 553	0	2 553
Public transport	1 431	0	1 431
Playground	1 098	0	1 098
Small fern spruce forest	920	920	0
Broadleafed pasture woodland	2 865	2 865	0
Water	93 842	93 842	0
Elm and linden forest	70 151	72 373	-2 222
Grey alder and ash forest	87 438	92 602	-5 164
Broadleafed pasture woodland	25 814	33 034	-7 220
Lime-rich pine forest	70 141	81 021	-10 880
Large fern spruce forest	0	12 018	-12 018
Pasture forest	134 039	176 621	-42 582
Lichen and heather pine forest	60 054	105 856	-45 802
Bilberry spruce forest	97 009	202 550	-105 541
Low herb spruce forest	310 210	454 957	-144 747
Abandoned species rich meadow	127 686	306 069	-178 383

Parks and green areas	587 175	772 524	-185 349
Cultivated land	30 356	308 264	-277 908

Table A 10: In the area covered by the Grefsen map sheet, 31,81 % of the vegetated area of 1980 has been lost due to urbanization. This means 87,17 % of the registered changes in are due to urbanization.

	Nature (km^2)	**Urban (km^2)**
1980	2,8	
2021	1,91	0,89
Vegetation lost		31,81 %
Percentage of change due to urbanization		87,17 %

Table A 11: Fragstats class indices for the Grefsen map sheet. CA: total area for each class (ha), NP: number of patches, AREA_MN: mean patch area (ha).

	CA		NP		AREA_MN	
Vegetation type	**1 980**	**2 021**	**1980**	**2021**	**1980**	**2021**
Lichen and heather pine forest	11	6	20	23	0,53	0,26
Bilberry spruce forest	20	10	29	23	0,70	0,42
Small fern spruce forest	0	0	1	1	0,09	0,09
Large fern spruce forest	1		2		0,60	
Lime-rich pine forest	8	7	11	11	0,75	0,64
Low herb spruce forest	46	31	55	53	0,83	0,59
Pasture forest	19	14	22	26	0,85	0,55
Elm and linden forest	7	7	12	13	0,61	0,54
Grey alder and ash forest	9	9	12	11	0,77	0,79
Grey alder and bird cherry forest	8	11	21	23	0,37	0,48
Heather pine swamp forest	3	3	1	1	3,30	2,58
Heather bilberry pine swamp forest	0	0	1	1	0,29	0,29
Abandoned species rich meadow	31	12	35	26	0,88	0,48
Weeds	1	0	1	2	1,09	0,15
Cultivated land	31	3	24	3	1,29	1,03
Pasture forest	0	1	2	2	0,24	0,63
Tree plantation on arable field		1		2		0,58
Parks and green areas	78	59	52	63	1,49	0,94
Allotment garden		5		1		4,60
Graveyard		3		3		0,91
Water	9	9	111	111	0,08	

Table A 12: ENN_MN: Mean of Euclidean nearest-neighbor distance (m), ENN_SD: Standard deviation of Euclidean nearest-neighbor distance, ENN_CV: Coefficient of variation of Euclidean nearest-neighbor distance for the Grefsen map sheet.

	ENN_MN		ENN_SD		ENN_CV	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	121,99	127,27	257,48	255,64	211,06	200,87
Bilberry spruce forest	57,48	78,80	147,08	155,49	255,87	197,31
Small fern spruce forest	0,00	0,00	0,00	0,00	0,00	0,00
Large fern spruce forest	1048,98		0,00		0,00	
Lime-rich pine forest	465,60	461,34	1319,24	1320,37	283,34	286,20
Low herb spruce forest	107,38	55,78	185,93	101,51	173,15	181,97
Pasture forest	258,01	254,68	325,95	628,88	126,33	246,94
Elm and linden forest	279,44	391,98	397,86	508,57	142,38	129,74
Grey alder and ash forest	247,00	92,10	794,87	160,45	321,81	174,21
Grey alder and bird cherry forest	90,96	55,64	276,50	136,52	303,97	245,35
Heather pine swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Heather bilberry pine swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Abandoned species rich meadow	155,71	272,31	225,33	506,31	144,71	185,93
Weeds	0,00	5179,55	0,00	0,00	0,00	0,00
Cultivated land	11,93	147,88	20,82	252,67	174,54	170,86
Pasture forest	7,00	5059,48	0,00	0,00	0,00	0,00
Tree plantation on arable field		5256,30		0,00		0,00
Parks and green areas	66,72	80,10	103,95	123,22	155,80	153,85
Allotment garden		0,00		0,00		0,00
Graveyard		155,99		78,18		50,12
Water	57,88		192,07		331,85	

Appendix 4

Grorud map sheet

Table A 13: Area statistics showing the area cover for each vegetation type in different years and the area lost/gained in m2 for Grorud map sheet

	Area 2021	Area 1980	Difference
Abandoned species rich meadow	400 475	1 052 447	-651 972
Weeds	314 744	901 886	-587 142
Bilberry spruce forest	613 427	831 613	-218 186
Lichen and heather pine forest	886 609	999 295	-112 686
Cultivated land	0	94 290	-94 290
Low herb spruce forest	344 789	430 970	-86 181
Broadleaved pasture woodland	56 731	118 989	-62 258
Lime-rich pine forest	35 700	49 972	-14 272
Large fern spruce forest	4 642	14 779	-10 137
Peat moss spruce swamp forest	11 767	16 289	-4 522
Rich beach swamp forest	17 364	21 576	-4 212
Tall herb spruce forest	5 043	8 598	-3 555
Heather bilberry pine swamp forest	7 345	10 202	-2 857
Small fern spruce forest	21 593	24 236	-2 643
Grey alder and ash forest	86 569	89 103	-2 534
Black alder swamp forest	0	2 125	-2 125
Stonecrops vegetation	20 253	20 772	-519
Heather pine swamp forest	7 519	7 519	0
Bloody cranesbill vegetation	4 726	4 726	0
Moist meadow	6 503	6 503	0
Rich sedge swamp	2 969	2 969	0
Yellow flag iris swamp	773	0	773
Cultural buildings	2 224	0	2 224
Playground	3 044	0	3 044
Water	12 055	8 367	3 688
Common reed swamp	3 987	0	3 987
Public parking	6 383	0	6 383
Allotment garden	6 908	0	6 908
Activity farm	7 732	0	7 732
School	7 736	0	7 736
Sports facilities	12 196	0	12 196
Religious buildings	12 204	0	12 204
Paddock	13 515	0	13 515
Health premises	13 536	0	13 536
Kindergarten	21 096	0	21 096
Apartment buildings	22 549	0	22 549
Power line corridor	23 561	0	23 561

Pasture forest	52 906	29 125	23 781
Armed forces	24 259	0	24 259
Construction site	24 819	0	24 819
Elm and linden forest	39 800	12 073	27 727
Road	95 647	61 489	34 158
Pasture forest	339 494	298 520	40 974
Sports field (gravel / artificial grass)	55 014	0	55 014
Graveyard	73 264	0	73 264
Quarry	88 135	0	88 135
Golf course	110 999	0	110 999
Grey alder and bird cherry forest	394 249	281 498	112 751
Parks and green areas	1 319 634	1 121 638	197 996
Business and office premises	222 670	0	222 670
Industrial area	244 440	0	244 440
Housing (villas/townhouses)	440 787	0	440 787

Table A 14: In the area covered by the Grorud map sheet, 19,80 % of the vegetated area of 1980 has been lost due to urbanization. This means 68,64 % of the registered changes in are due to urbanization.

	Nature (km^2)	Urban (km^2)
1980	6,52	
2021	5,25	1,29
Vegetation lost		19,80 %
Percentage of change due to urbanization		68,64 %

Table A 15: Fragstats class indices for the Grorud map sheet. CA: total area for each class (ha), NP: number of patches, AREA_MN: mean patch area (ha).

	CA		NP		AREA_MN	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	99,89	88,94	145	151	0,69	0,59
Bilberry spruce forest	83,12	61,31	100	83	0,83	0,74
Small fern spruce forest	2,42	2,16	2	2	1,21	1,08
Large fern spruce forest	1,48	0,46	6	5	0,25	0,09
Lime-rich pine forest	4,99	3,57	9	9	0,55	0,40
Low herb spruce forest	43,08	34,46	77	78	0,56	0,44
Pasture forest	29,84	33,93	53	90	0,56	0,38
Tall herb spruce forest	0,86	0,50	3	3	0,29	0,17
Elm and linden forest	1,21	3,98	1	2	1,21	1,99
Grey alder and ash forest	8,91	8,84	10	11	0,89	0,80
Grey alder and bird cherry forest	28,13	39,41	25	30	1,13	1,31
Broadleaved pasture woodland	11,89	5,67	15	13	0,79	0,44
Heather pine swamp forest	0,75	0,75	1	1	0,75	0,75
Heather bilberry pine swamp forest	1,02	0,73	4	3	0,25	0,24
Peat moss spruce swamp forest	1,63	1,18	7	5	0,23	0,24
Black alder swamp forest	0,21		1		0,21	
Rich beach swamp forest	2,16	1,74	1	1	2,16	1,74
Stonecrops vegetation	2,08	2,03	5	5	0,42	0,41
Bloody cranesbill vegetation	0,47	0,47	1	1	0,47	0,47
Abandoned species rich meadow	105,19	40,02	87	68	1,21	0,59
Weeds	90,14	31,45	70,00	86,00	1,29	0,37
Moist meadow	0,65	0,65		3		0,22
Rich sedge swamp	0,30	0,30		1		0,30
Yellow flag iris swamp		0,08		1		0,08
Common reed swamp		0,40		1		0,40
Cultivated land	9,42					
Pasture forest	2,91	5,29		6		0,88
Parks and green areas	112,11	131,90		142		0,93
Allotment garden		0,69		2		0,35
Graveyard		7,32		1		7,32

Table A 16: ENN_MN: Mean of Euclidean nearest-neighbor distance (m), ENN_SD: Standard deviation of Euclidean nearest-neighbor distance, ENN_CV: Coefficient of variation of Euclidean nearest-neighbor distance for the Grorud map sheet.

	ENN_MN		ENN_SD		ENN_CV	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	32,70	31,10	48,10	55,14	147,12	177,30
Bilberry spruce forest	68,15	71,88	154,42	169,27	226,58	235,50
Small fern spruce forest	2484,88	2531,37	0,00	0,00	0,00	0,00
Large fern spruce forest	277,73	549,06	402,56	490,16	144,95	89,27
Lime-rich pine forest	147,90	530,36	253,17	1530,54	171,18	288,59
Low herb spruce forest	104,11	71,02	146,27	92,57	140,50	130,35
Pasture forest	124,48	98,12	154,55	110,63	124,16	112,76
Tall herb spruce forest	1075,83	1075,83	1075,48	1075,48	99,97	99,97
Elm and linden forest	0,00	883,86	0,00	0,00	0,00	0,00
Grey alder and ash forest	421,73	618,38	960,01	1106,43	227,64	178,92
Grey alder and bird cherry forest	109,11	143,82	155,28	190,24	142,32	132,28
Broadleaved pasture woodland	427,14	374,65	524,89	673,18	122,88	179,68
Heather pine swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Heather bilberry pine swamp forest	1918,22	1727,29	1548,96	1992,74	80,75	115,37
Peat moss spruce swamp forest	503,18	372,83	691,20	736,88	137,37	197,65
Black alder swamp forest	0,00		0,00		0,00	
Rich beach swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Stonecrops vegetation	116,23	116,23	55,75	55,75	47,96	47,96
Bloody cranesbill vegetation	0,00	0,00	0,00	0,00	0,00	0,00
Abandoned species rich meadow	74,90	95,34	103,35	117,36	137,99	123,09
Weeds	83,23	143,43	123,28	148,26	148,11	103,37
Moist meadow		1242,13		2129,38		171,43
Rich sedge swamp		0,00		0,00		0,00
Yellow flag iris swamp		0,00		0,00		0,00
Common reed swamp		0,00		0,00		0,00
Cultivated land						
Pasture forest		606,99		617,29		101,70
Parks and green areas		58,31		111,40		191,07
Allotment garden		317,97		0,00		0,00
Graveyard		0,00		0,00		0,00

Appendix 5

Vestre Aker borough

Table A 17: Area statistics showing the area cover for each vegetation type in different years and the area lost/gained in m2 for Vestre Aker borough.

	Area 2021	Area 1980	Difference
Lichen and heather pine forest	100 906	174 284	-73 378
Bilberry spruce forest	684 865	1 313 387	-628 522
Small fern spruce forest	51 186	80 033	-28 847
Large fern spruce forest	22 808	31 517	-8 709
Lime-rich pine forest	55	55	0
Low herb spruce forest	643 188	1 102 283	-459 096
Pasture forest	114 155	177 634	-63 479
Tall herb spruce forest	73 625	110 433	-36 808
Cultivated land	14 885	291 791	-276 906
Elm and linden forest	49 054	46 201	2 852
Grey alder and ash forest	109 792	64 997	44 795
Grey alder and bird cherry forest	217 948	178 346	39 602
Broadleaved pasture woodland	4 383	10 356	-5 973
Black alder swamp forest	2 158	2 158	0
Species poor bog	14 374	17 547	-3 174
Parks and green areas	303 633	299 108	4 525
Allotment garden	6 093	0	6 093
Abandoned species poor meadow	2 088	0	2 088
Abandoned species rich meadow	158 920	109 620	49 301
Weeds	26 037	0	26 037
Kindergarten	11 638	0	11 638
School	39 694	0	39 694
University	0	0	0
Health premises	4 431	0	4 431
Graveyard	68 676	0	68 676
Embassy	41 373	0	41 373
Armed forces	2 961	0	2 961
Housing (villas/townhouses)	891 120	0	891 120
Apartment buildings	207 140	0	207 140
Industrial area	1 451	0	1 451
Business and office premises	41 620	0	41 620
Public transport	5 885	0	5 885
Road	99 537	63 374	36 164
Construction site	48 540	0	48 540
Sports facilities	3 921	0	3 921
Sports field (gravel / artificial grass)	19 549	0	19 549

Talus slope	10169,135	10169,135	2E-05
Water	59408,343	59408,343	0
Rich sedge swamp	427,90603	1804,5001	-1376,594

Table A 18: In Vestre Aker borough, 36,07 % of the vegetated area of 1980 has been lost due to urbanization. This means 93,11 % of the registered changes in are due to urbanization.

	Nature (km^2)	**Urban (km^2)**
1980	4,16	
2021	2,60	1,50
Vegetation lost		36,07 %
Percentage of change due to urbanization		93,11 %

Table A 19: Fragstats class indices for the Vestre Aker borough. CA: total area for each class (ha), NP: number of patches, AREA_MN: mean patch area (ha).

	CA		NP		AREA_MN	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	17,42	10,09	24	18	0,73	0,56
Bilberry spruce forest	131,26	68,45	34	43	3,86	1,59
Small fern spruce forest	8,00	5,12	7	6	1,14	0,85
Large fern spruce forest	3,15	2,28	5	5	0,63	0,46
Lime-rich pine forest	0,01	0,01	3	3	0,00	0,00
Low herb spruce forest	110,16	64,29	97	77	1,14	0,83
Pasture forest	17,75	11,41	19	16	0,93	0,71
Tall herb spruce forest	11,03	7,35	19	17	0,58	0,43
Elm and linden forest	4,62	4,90	21	21	0,22	0,23
Grey alder and ash forest	6,49	10,97	12	14	0,54	0,78
Grey alder and bird cherry forest	17,82	21,78	18	18	0,99	1,21
Broadleaved pasture woodland	1,03	0,44	1	1	1,03	0,44
Black alder swamp forest	0,22	0,22	1	1	0,22	0,22
Species poor bog	1,75	1,44	5	4	0,35	0,36
Abandoned species poor meadow	0,00	0,21		1		0,21
Abandoned species rich meadow	10,96	15,89	15	32	0,73	0,50
Weeds		2,60		19		0,14
Rich sedge swamp	0,18	0,04	2	1	0,09	0,04
Cultivated land	29,17	1,49	13	1	2,24	1,49
Pasture	1,69		2		0,84	
Parks and green areas	29,89	30,35	18	23	1,66	1,32
Allotment garden		0,61		1		0,61
Graveyard		6,86		2		3,43
Water	5,94	5,94		23		

Table A 20: ENN_MN: Mean of Euclidean nearest neighbor distance (m), ENN_SD: Standard deviation of Euclidean nearest-neighbor distance, ENN_CV: Coefficient of variation of Euclidean nearest-neighbor distance for Vestre Aker borough.

	ENN_MN		ENN_SD		ENN_CV	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	74,94	118,49	73,56	196,56	98,17	165,88
Bilberry spruce forest	47,86	59,12	91,20	166,05	190,56	280,87
Small fern spruce forest	125,79	135,45	82,98	72,56	65,97	53,57
Large fern spruce forest	1085,65	1098,97	974,66	971,69	89,78	88,42
Lime-rich pine forest	381,84	381,84	288,92	288,92	75,66	75,66
Low herb spruce forest	57,31	88,35	77,32	122,36	134,91	138,49
Pasture forest	120,02	171,06	209,91	220,03	174,90	128,63
Tall herb spruce forest	81,66	33,59	181,80	35,17	222,64	104,73
Elm and linden forest	336,56	278,64	569,95	569,59	169,35	204,42
Grey alder and ash forest	141,37	93,03	409,84	268,66	289,90	288,78
Grey alder and bird cherry forest	381,19	284,06	302,64	301,08	79,39	105,99
Broadleaved pasture woodland	0,00	0,00	0,00	0,00	0,00	0,00
Black alder swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Species poor bog	143,78	132,65	61,26	67,06	42,61	50,55
Abandoned species poor meadow		0,00		0,00		0,00
Abandoned species rich meadow	167,35	141,77	247,60	208,11	147,95	146,80
Weeds		322,06		341,70		106,10
Rich sedge swamp	2626,11	0,00	0,00	0,00	0,00	0,00
Cultivated land	178,17	0,00	220,77	0,00	123,91	0,00
Pasture	1603,82		0,00		0,00	
Parks and green areas	332,96	213,10	377,24	163,92	113,30	76,92
Allotment garden		0,00		0,00		0,00
Graveyard		2826,76		0,00		0,00
Water						

Appendix 6

Nordre Aker borough

Table A 21: Area statistics showing the area cover for each vegetation type in different years and the area lost/gained in m2 for Nordre Aker borough

Vegetation type	Area 2021	Area 1980	Difference
Housing (villas/townhouses)	278 152	0	278 152
Apartment buildings	154 222	0	154 222
University	85 047	0	85 047
Health premises	69 198	0	69 198
School	60 717	0	60 717
Construction site	40 916	0	40 916
Allotment garden	46 081	0	46 081
Industrial area	32 670	0	32 670
Sports facilities	32 591	0	32 591
Grey alder and bird cherry forest	104 370	75 341	29 029
Sports field (gravel / artificial grass)	29 244	0	29 244
Kindergarten	28 522	0	28 522
Graveyard	27 289	0	27 289
Recycle station	19 663	0	19 663
Grey alder and ash forest	59 300	51 328	7 972
Elm and linden forest	58 373	48 466	9 907
Tree plantation on arable field	7 375	0	7 375
Cultural buildings	6 341	0	6 341
Business and office premises	4 335	0	4 335
Activity farm	4 139	0	4 139
Public transport	3 868	0	3 868
Public parking	2 064	0	2 064
Heather bilberry pine swamp forest	2 865	2 865	0
Water	72 903	72 903	0
Road	10 766	14 990	-4 223
Heather pine swamp forest	25 814	33 034	-7 221
Pasture forest	2 359	9 902	-7 543
Weeds	3 637	15 614	-11 977
Large fern spruce forest	0	11 986	-11 986
Lime-rich pine forest	75 765	91 402	-15 637
Lichen and heather pine forest	44 808	80 533	-35 725
Parks and green areas	351 535	411 610	-60 075
Pasture forest	145 223	204 051	-58 828
Bilberry spruce forest	50 624	143 908	-93 284
Low herb spruce forest	240 940	375 741	-134 801

Abandoned species rich meadow	134 189	321 000	-186 810
Cultivated land	32 001	377 638	-345 637

Table A 22: In Nordre Aker borough, 36,66 % of the vegetated area of 1980 has been lost due to urbanization. This means 88,96 % of the registered changes in are due to urbanization

	Nature (km^2)	**Urban (km^2)**
1980	2,35	
2021	1,50	0,86
Vegetation lost		36,66 %
Percentage of change due to urbanization		88,96 %

Table A 23: Fragstats class indices for the Nordre Aker borough. CA: total area for each class (ha), NP: number of patches, AREA_MN: mean patch area (ha).

	CA		NP		AREA_MN	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	8,05	4,48	10	9	0,81	0,50
Bilberry spruce forest	14,38	5,06	16	10	0,90	0,51
Large fern spruce forest	1,20		1		1,20	
Lime-rich pine forest	9,13	7,57	12	11	0,76	0,69
Low herb spruce forest	37,56	24,09	54	46	0,70	0,52
Pasture forest	20,39	14,52	29	28	0,70	0,52
Elm and linden forest	4,84	5,83	7	9	0,69	0,65
Grey alder and ash forest	5,13	5,93	12	11	0,43	0,54
Grey alder and bird cherry forest	7,52	10,43	19	21	0,40	0,50
Heather pine swamp forest	3,30	2,58	1	1	3,30	2,58
Heather bilberry pine swamp forest	0,29	0,29	1	1	0,29	0,29
Abandoned species rich meadow	32,07	13,00	35	27	0,92	0,48
Weeds	1,56	0,36	1	2	1,56	0,18
Cultivated land	37,74	3,20	35	3	1,08	1,07
Pasture forest	0,99	0,24	2	1	0,50	0,24
Tree plantation on arable field		0,74		1		0,74
Parks and green areas	41,13	35,13	42	69	0,98	0,51
Allotment garden		4,61		1		4,61
Graveyard		2,73		3		0,91
Water	7,29	7,29	75	75	0,10	0,10

Table A 24: ENN_MN: Mean of Euclidean nearest neighbor distance (m), ENN_SD: Standard deviation of Euclidean nearest-neighbor distance, ENN_CV: Coefficient of variation of Euclidean nearest-neighbor distance for Nordre Aker borough.

	ENN_MN		ENN_SD		ENN_CV	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	222,17	251,08	361,44	375,68	162,69	149,62
Bilberry spruce forest	92,96	165,88	192,54	209,85	207,14	126,51
Large fern spruce forest	0,00		0,00		0,00	
Lime-rich pine forest	49,04	57,96	52,77	52,61	107,60	90,78
Low herb spruce forest	100,38	75,18	185,67	154,31	184,98	205,25
Pasture forest	182,42	132,51	288,89	187,59	158,37	141,56
Elm and linden forest	483,94	546,14	613,55	634,73	126,78	116,22
Grey alder and ash forest	48,33	18,29	108,48	15,52	224,46	84,84
Grey alder and bird cherry forest	194,45	140,92	428,91	336,71	220,57	238,94
Heather pine swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Heather bilberry pine swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Abandoned species rich meadow	163,19	196,86	234,26	306,52	143,55	155,71
Weeds	0,00	488,74	0,00	0,00	0,00	0,00
Cultivated land	12,16	147,90	18,23	252,71	149,91	170,86
Pasture forest	7,00	0,00	0,00	0,00	0,00	0,00
Tree plantation on arable field		0,00		0,00		0,00
Parks and green areas	79,53	62,38	115,25	104,94	144,92	168,22
Allotment garden		0,00		0,00		0,00
Graveyard		155,55		78,17		50,25
Water	73,44	73,44	248,08	248,08	337,80	337,80

Appendix 7

Grorud borough

Table A 25: Area statistics showing the area cover for each vegetation type in different years and the area lost/gained in m2 for Grorud borough.

Vegetation type	Area 2021	Area 1980	Difference
Abandoned species rich meadow	99 469	203 107	-103 638
Activity farm	5 943	0	5 943
Apartment buildings	8 030	0	8 030
Bilberry spruce forest	363 567	505 788	-142 221
Black alder swamp forest	0	2 098	-2 098
Bloody cranesbill vegetation	4 726	4 726	0
Broadleaved pasture woodland	30 019	59 930	-29 911
Business and office premises	141 941	0	141 941
Common reed swamp	3 987	0	3 987
Construction site	4 337	0	4 337
Cultivated land	0	21 430	-21 430
Cultural buildings	1 268	0	1 268
Elm and linden forest	14 645	0	14 645
Grey alder and ash forest	21 574	22 907	-1 333
Grey alder and bird cherry forest	112 564	122 805	-10 240
Health premises	1 605	0	1 605
Heather bilberry pine swamp forest	2 695	5 552	-2 857
Heather pine swamp forest	7 519	7 519	0
Housing (villas/townhouses)	257 901	0	257 901
Industrial area	33 848	0	33 848
Kindergarten	7 099	0	7 099
Large fern spruce forest	3 310	12 654	-9 345
Lichen and heather pine forest	757 819	843 428	-85 609
Lime-rich pine forest	22 127	22 136	-9
Low herb spruce forest	194 210	235 869	-41 659
Paddock	6 897	0	6 897
Parks and green areas	269 532	287 070	-17 538
Pasture forest	3 930	0	3 930
Pasture forest	47 151	39 886	7 265
Peat moss spruce swamp forest	7 759	8 390	-631
Public parking	4 390	0	4 390
Quarry	88 038	0	88 038
Road	41 592	29 280	12 312
School	600	0	600
Small fern spruce forest	21 592	24 235	-2 643
Sports facilities	4 317	0	4 317

Sports field (gravel / artificial grass)	23 794	0	23 794
Stonecrops vegetation	20 231	20 660	-429
Tall herb spruce forest	5 023	8 579	-3 556
Water	8 028	8 028	0
Weeds	115 109	253 635	-138 526

Table A 26: In Grorud borough, 22,93 % of the vegetated area of 1980 has been lost due to urbanization. This means 38,70 % of the registered changes in are due to urbanization.

	Nature (km^2)	Urban (km^2)
1980	2,75	
2021	2,14	0,63
Vegetasjon lost		22,93 %
Percentage of change due to urbanization		38,70 %

Table A 27: Fragstats class indices for the Grorud borough. CA: total area for each class (ha), NP: number of patches, AREA_MN: mean patch area (ha).

	CA		NP		AREA_MN	
Vegetation types	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	84,30	75,74	88	94	0,96	0,81
Bilberry spruce forest	50,56	36,34	51	38	0,99	0,96
Small fern spruce forest	2,42	2,16	2	2	1,21	1,08
Large fern spruce forest	1,26	0,33	3	2	0,42	0,17
Lime-rich pine forest	2,21	2,21	2	1	1,11	2,21
Low herb spruce forest	23,57	19,41	35	30	0,67	0,65
Pasture forest	3,99	4,71	10	21	0,40	0,22
Tall herb spruce forest	0,86	0,50	3	3	0,29	0,17
Elm and linden forest		1,46		2		0,73
Grey alder and ash forest	2,29	2,16	4	4	0,57	0,54
Grey alder and bird cherry forest	12,27	11,25	7	8	1,75	1,41
Broadleaved pasture woodland	5,99	3,00	8	6	0,75	0,50
Heather pine swamp forest	0,75	0,75	1	1	0,75	0,75
Heather bilberry pine swamp forest	0,55	0,27	2	1	0,28	0,27
Peat moss spruce swamp forest	0,84	0,78	5	4	0,17	0,19
Black alder swamp forest	0,21		1		0,21	
Stonecrops vegetation	2,07	2,02	5	5	0,41	0,40
Bloody cranesbill vegetation	0,47	0,47	1	1	0,47	0,47
Abandoned species rich meadow	20,30	9,94	23	22	0,88	0,45
Weeds	25,35	11,51	26	31	0,97	0,37
Common reed swamp		0,40		1		0,40
Cultivated land	2,14		4		0,54	
Pasture forest		0,39		2		0,20
Parks and green areas	28,69	26,94	24	40	1,20	0,67
Water	0,80	0,80	3	3	0,27	0,27

Table A 28: ENN_MN: Mean of Euclidean nearest neighbor distance (m), ENN_SD: Standard deviation of Euclidean nearest-neighbor distance, ENN_CV: Coefficient of variation of Euclidean nearest-neighbor distance for Grorud borough.

	ENN_MN		ENN_SD		ENN_CV	
Vegetation types	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	32,28	26,96	39,38	31,32	121,98	116,18
Bilberry spruce forest	58,69	72,18	92,74	115,06	158,04	159,39
Small fern spruce forest	2484,58	2530,75	0,00	0,00	0,00	0,00
Large fern spruce forest	311,41	982,29	506,10	0,00	162,52	0,00
Lime-rich pine forest	655,15	0,00	0,00	0,00	0,00	0,00
Low herb spruce forest	131,04	110,20	179,11	90,49	136,69	82,12
Pasture forest	196,64	174,99	227,88	199,21	115,88	113,84
Tall herb spruce forest	1076,15	1076,15	1075,08	1075,08	99,90	99,90
Elm and linden forest		882,97	#N/A	0,00	#N/A	0,00
Grey alder and ash forest	105,57	105,57	32,96	32,96	31,22	31,22
Grey alder and bird cherry forest	786,62	647,83	906,18	802,23	115,20	123,83
Broadleaved pasture woodland	381,39	274,56	596,98	616,36	156,53	224,49
Heather pine swamp forest	0,00	0,00	0,00	0,00	0,00	0,00
Heather bilberry pine swamp forest	3260,00	0,00	0,00	0,00	0,00	0,00
Peat moss spruce swamp forest	104,43	44,14	135,55	16,36	129,81	37,07
Black alder swamp forest	0,00		0,00		0,00	
Stonecrops vegetation	116,37	116,37	55,82	55,82	47,97	47,97
Bloody cranesbill vegetation	0,00	0,00	0,00	0,00	0,00	0,00
Abandoned species rich meadow	138,89	194,13	175,01	223,65	126,00	115,21
Weeds	156,71	188,02	205,19	228,85	130,94	121,72
Common reed swamp		0,00		0,00		0,00
Cultivated land	933,06		1573,56		168,64	
Pasture forest		3863,74	#N/A	0,00		0,00
Parks and green areas	69,41	89,83	132,24	135,22	190,51	150,53
Water	1003,74	1003,74	530,68	530,68	52,87	52,87

Appendix 8

Stovner borough

Table A 29: Area statistics showing the area cover for each vegetation type in different years and the area lost/gained in m2 for Stovner borough.

Vegetation type	Area 2021	Area 1980	Difference
Abandoned species rich meadow	177 668	580 001	-402 334
Activity farm	1 789	0	1 789
Allotment garden	6 908	0	6 908
Apartment buildings	3 137	0	3 137
Bilberry spruce forest	228 088	298 464	-70 376
Broadleaved pasture woodland	12 448	39 797	-27 348
Business and office premises	71 945	0	71 945
Construction site	20 482	0	20 482
Cultivated land	0	70 911	-70 911
Elm and linden forest	25 155	0	25 155
Golf course	110 999	0	110 999
Graveyard	73 264	0	73 264
Grey alder and ash forest	6 808	4 930	1 879
Grey alder and bird cherry forest	108 861	39 787	69 074
Health premises	11 931	0	11 931
Heather bilberry pine swamp forest	4 639	4 639	0
Housing (villas/townhouses)	124 784	0	124 784
Industrial area	169 749	0	169 749
Kindergarten	8 880	0	8 880
Large fern spruce forest	1 290	2 075	-785
Lichen and heather pine forest	126 500	150 663	-24 163
Low herb spruce forest	63 916	74 001	-10 085
Moist meadow	2 124	2 124	0
Paddock	5 562	0	5 562
Parks and green areas	685 600	497 901	187 700
Pasture forest	193 694	169 182	24 512
Pasture forest	1 889	29 125	-27 236
Peat moss spruce swamp forest	3 975	7 853	-3 877
Playground	1 408	0	1 408
Power line corridor	3 381	0	3 381
Religious buildings	12 203	0	12 203
Rich beach swamp forest	9 018	12 371	-3 353
Rich sedge swamp	2 429	2 429	0
Road	34 640	26 590	8 050
School	6 314	0	6 314
Sports facilities	5 504	0	5 504

Sports field (gravel / artificial grass)	22 714	0	22 714
Stonecrops vegetation	21	111	-90
Water	71	71	0
Weeds	112 793	448 991	-336 199

Table A 30: In Stovner borough, 20,49 % of the vegetated area of 1980 has been lost due to urbanization. This means 51,43 % of the registered changes in are due to urbanization.

	Nature (km^2)	Urban (km^2)
1980	2,46	
2021	1,95	0,50
Vegetation lost		20,49 %
Percentage of change due to urbanization		51,43 %

Table A 31: Fragstats class indices for the Stovner borough. CA: total area for each class (ha), NP: number of patches, AREA_MN: mean patch area (ha).

	CA		**NP**		**AREA_NM**	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	15,05	12,64	58	50	0,26	0,25
Bilberry spruce forest	29,83	22,79	43	38	0,69	0,60
Large fern spruce forest	0,21	0,13	3	3	0,07	0,04
Low herb spruce forest	7,40	6,39	18	15	0,41	0,43
Pasture forest	16,91	19,36	39	47	0,43	0,41
Elm and linden forest		2,51		1		2,51
Grey alder and ash forest	0,49	0,68	1	2	0,49	0,34
Grey alder and bird cherry forest	3,98	10,88	13	15	0,31	0,73
Broadleaved pasture woodland	3,97	1,24	9	5	0,44	0,25
Heather bilberry pine swamp forest	0,46	0,46	2	2	0,23	0,23
Peat moss spruce swamp forest	0,78	0,40	2	1	0,39	0,40
Rich beach swamp forest	1,24	0,90	5	3	0,25	0,30
Stonecrops vegetation	0,01	0,00	2	1	0,01	0,00
Abandoned species rich meadow	57,97	17,76	46	37	1,26	0,48
Weeds	44,88	11,27	22	31	2,04	0,36
Moist meadow	0,21	0,21	1	1	0,21	0,21
Rich sedge swamp	0,24	0,24	1	1	0,24	0,24
Cultivated land	7,09		4		1,77	
Pasture forest	2,91	0,19	3	2	0,97	0,09
Parks and green areas	49,76	68,51	40	68	1,24	1,01
Allotment garden		0,69		2		0,35
Graveyard		7,32		1		7,32
Golf course		11,10		1		11,10
Water	0,01	0,01		2		

Table A 32: ENN_MN: Mean of Euclidean nearest neighbor distance (m), ENN_SD: Standard deviation of Euclidean nearest-neighbor distance, ENN_CV: Coefficient of variation of Euclidean nearest-neighbor distance for Stovner borough.

	ENN_MN		**ENN_SD**		**ENN_CV**	
Vegetation type	1980	2021	1980	2021	1980	2021
Lichen and heather pine forest	49,95	65,23	88,67	147,11	177,52	225,54
Bilberry spruce forest	54,63	40,23	84,20	49,08	154,13	121,99
Large fern spruce forest	244,71	260,72	381,06	408,81	155,72	156,80
Low herb spruce forest	188,69	131,70	228,43	243,67	121,06	185,02
Pasture forest	106,83	83,13	150,26	68,50	140,66	82,41
Elm and linden forest		0,00		0,00		0,00
Grey alder and ash forest	0,00	2921,39	0,00	0,00	0,00	0,00
Grey alder and bird cherry forest	35,56	131,02	54,74	187,54	153,95	143,14
Broadleaved pasture woodland	387,25	961,27	723,82	1121,52	186,91	116,67

Heather bilberry pine swamp forest	576,68	576,68	0,00	0,00	0,00	0,00
Peat moss spruce swamp forest	1501,60	0,00	0,00	0,00	0,00	0,00
Rich beach swamp forest	9,83	39,36	15,43	3,51	156,96	8,92
Stonecrops vegetation	347,51	0,00	0,00	0,00	0,00	0,00
Abandoned species rich meadow	55,52	86,88	63,84	113,92	115,00	131,12
Weeds	127,64	184,99	220,68	182,47	172,90	98,64
Moist meadow	0,00	0,00	0,00	0,00	0,00	0,00
Rich sedge swamp	0,00	0,00	0,00	0,00	0,00	0,00
Cultivated land	13,71		13,25		96,63	
Pasture forest	448,58	9,06	747,06	0,00	166,54	0,00
Parks and green areas	51,05	51,40	104,81	106,13	205,29	206,46
Allotment garden		318,71		0,00		0,00
Graveyard		0,00		0,00		0,00
Golf course		0,00		0,00		0,00
Water						