How multiple-use forestry goals impact forest cover in southern Sweden

A quantitative study of forest change in Fulltofta estate between 1997–2023

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How multiple-use forestry goals impact forest cover in southern Sweden. A quantitative study of forest change in Fulltofta estate between 1997–2023

Hur mångbruk påverkar skogen i södra Sverige. En kvantitativ studie av förändring i skogssammansättning i Fulltofta mellan 1997–2023

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Abstract

Noble broadleaf forests in Sweden occupy only a fraction of the area they covered historically. In part, they have been replaced by planted even-aged Norway spruce forests. Today, climate change poses increasing risks to Norway spruce forests in southern Sweden. In Fulltofta estate in Skåne, a conversion of spruce to broadleaf stands was noted by Brunet (2007) who studied the land-use history of Fulltofta between 1772–2004 and gave management suggestions to restore parts of the historical noble broadleaf forest in the area.

This study aims to investigate whether the conversion of spruce to broadleaf stands observed by Brunet (2007) in Fulltofta has continued. The change in tree species composition as well as the area occupied by different forest types in Fulltofta is quantified using data extracted from two forest management plans (1997 and 2023). The area of old stands and their tree species composition is also quantified to gain further insight into the impact of the forest management on forest biodiversity.

The hypothesis is that Norway spruce has decreased in Fulltofta while broadleaves have increased between 1997–2023. The main findings confirm the hypothesis, showing that both the standing volume of Norway spruce and the area of Norway spruce-dominated stands have decreased, mainly in favor of broadleaves. Additionally, this study finds that the area of old stands in Fulltofta has increased. However, the results show that the management suggestions given by Brunet have only been partially fulfilled.

The study concludes that climate change adaptation is one of the main drivers of the decrease in spruce in Fulltofta, and that the identified reduction in the area of spruce forests is faster in Fulltofta than the rest of Skåne. In addition, multiple-use forestry in Fulltofta has made the landscape more diverse and potentially improved habitat availability for at least some species dependent on broadleaf forests.

Keywords: Desprucification, Forest history, *Picea abies*, *Fagus sylvatica*, *Quercus spp,* Sustainable forestry, GIS

Table of Contents

List of tables

List of figures

1. Introduction

1.1 Temperate broadleaf forests in southern Sweden

The temperate broadleaf forests of Europe are severely impacted by anthropogenic activity and are among the most fragmented forests in the world (Hannah & Carr 1995; Wade et al. 2003). In Sweden, temperate broadleaf forests are present in the southernmost parts of the country, within the natural range of characteristic broadleaf tree species such as European beech (*Fagus sylvatica*; hereafter beech), pedunculate oak (*Quercus robur*) and sessile oak (*Quercus petraea*; hereafter oak, along with *Q. robur*). Beech and oak are two of the six noble broadleaves, categorized as such by Swedish law in the Noble Broadleaf Act (SFS (1984:119) n.d.) along with elm (*Ulmus spp.*), European ash (*Fraxinus excelsior*), wild cherry (*Prunus avium*), lime (*Tilia spp.*), and maple (*Acer spp.*). The noble broadleaves are trees native to Sweden which possess high cultural, ecological and economic value. The law defines a noble broadleaf forest as “a forest of at least half a hectare, consisting of no less than 70 percent broadleaves and no less than 50 percent noble broadleaves” (SFS (1984:119) n.d.). In Sweden, noble broadleaf forest is the forest type with the highest share of red-listed species. Many of these species are also dependent on old forests, possessing a varied age class distribution with associated variation in dead wood size categories and states of decay (SLU Artdatabanken 2020). The southernmost Swedish county of Skåne is the county with the largest share of noble broadleaf forest area in the country (Brunet & Berlin 2005). Today, beech, oak- and mixed oak forest cover only a fragment of the area they once occupied in Skåne (SLU Artdatabanken 2020). Humans have used these forests for firewood, building material, fodder for cattle; or modified them through cattle grazing and other agricultural activities. Since the 19th century, reforestation has increased the forested area in Skåne, but with Norway spruce (*Picea abies*; hereafter spruce) instead of temperate broadleaf species (Brunet & Berlin 2005).

1.2 Spruce in southern Sweden

In Sweden, spruce naturally occurs in the boreal and boreonemoral zones where it is the most common tree species along with Scots pine (*Pinus sylvestris*) (Skogsdata 2024). Spruce is also present in the nemoral zone which includes the regions of Skåne, Blekinge and Halland (Skogsstyrelsen 2020). However, the forests in the nemoral zone have historically been dominated by temperate broadleaf trees. In the 19th century, the growing

demand for timber following the industrial revolution led to the large-scale planting of spruce in southern Sweden, including Skåne (Lindbladh et al. 2014; Skogsstyrelsen 2020). Today, spruce forests cover 33 percent of the productive forest area in Skåne, while noble broadleaf forests cover 18 percent (Skogsdata 2024).

The dominant silvicultural system for spruce in Sweden is even-aged rotation forestry where stands are clearcut at an age of 60–100 years (Felton et al. 2010; Skogskunskap 2024). The legal lowest felling age for conifer-dominated stands in Skåne varies between 45–90 years depending on the site index (SKSFS 2011:7 n.d.). Swedish spruce forestry yields high timber volumes and is economically important to private forest owners as well as companies, but it is also facing increasing and interrelated challenges from pests and climate change-related extreme weather events (Subramanian et al. 2016).

Spruce bark beetle (*Ips typographus*) outbreaks are threatening spruce forests, which are rendered more susceptible to bark beetle attacks when stressed by drought (Öhrn 2024). Infection rates by *Heterobasidion* species, fungi that cause root rot, will also likely increase as winters become milder (Subramanian et al. 2016). Spruce is the tree species most severely affected by root rot damage, which leads to economic losses of billions of Swedish kronor (SEK) in the forest industry annually (Witzell et al. 2017). Thawing of the soil due to increased average winter temperatures is also projected to lead to more damage by wind felling, especially in spruce (Keskitalo et al. 2016). With increasing temperatures, the range of the southern Swedish temperate broadleaves will move northward while the optimal zone for spruce will retreat to higher latitudes (Keskitalo et al. 2016).

1.3 Fulltofta estate

Fulltofta is a 2077-hectare estate located in central Skåne, to the east of lake Ringsjön (Figure 1). It is owned by the foundation Stiftelsen Skånska Landskap, which was created in 2004 to “protect, conserve, restore and develop natural and cultural values as well as promoting outdoor recreation” in Fulltofta, and a number of smaller estates spread across Skåne (Region Skåne 2025). More than 50 red-listed forest-associated species have been found in Fulltofta, and it is an important area for saproxylic insects connected to oak (Brunet & Berlin 2005). This makes it a priority area for conservation and restoration of forest ecological values.

Considering the risks associated with relying on spruce forestry in a changing climate, and the need to restore habitat for red-listed species associated with noble broadleaf forests (Löf et al. 2008), this study investigates Fulltofta estate, where a conversion of spruce forest to

broadleaf forest was noted in a study by Brunet (2007). This study will ideally shed light on how multiple-use forestry goals influence the landscape and the effects this has on forest biodiversity.

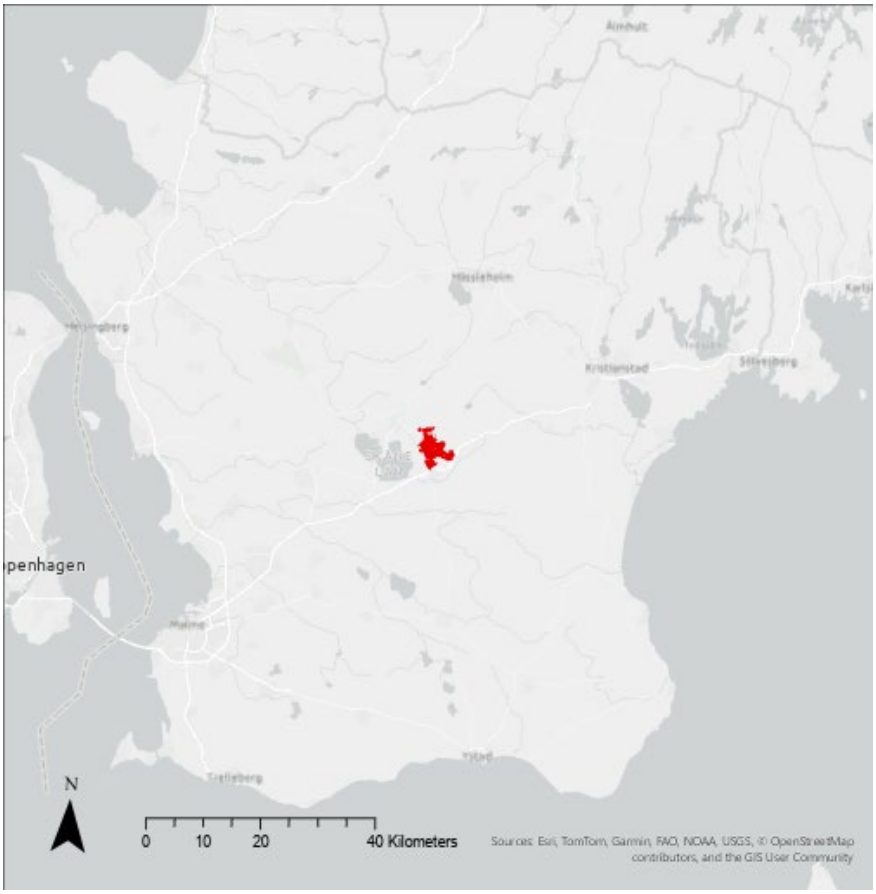

Figure 1 *Map of Skåne, showing the location of Fulltofta estate in red.*

1.4 Aim of the study

In the report *Fulltoftas skogar* (Forests of Fulltofta), Jörg Brunet (2007) describes how the landscape of the forest estate Fulltofta, Skåne, has changed from 1772 until 2004. Brunet notes that many spruce stands in Fulltofta were being converted to broadleaf stands at the time of his report.

This study aims to investigate whether the conversion of spruce to broadleaf stands observed by Brunet (2007) in Fulltofta has continued. The hypothesis is that spruce has decreased in Fulltofta while broadleaves have increased between 1997–2023. This will be tested by investigating the change in the volume per tree species and area of different forest types; using data extracted from the 1997 and the 2023 forest management plans for Fulltofta estate. Ideally, the results will show quantitatively which tree

species have increased and decreased, as well as show spatially where in the estate the different forest types have remained or been converted to other forest types.

Brunet (2007) divides Fulltofta into different areas and gives management suggestions for each area with the aim of restoring parts of the historical noble broadleaf forest to improve conditions for associated taxa (see ch. 2.2.1). An additional aim of this study is to investigate how recent changes in the tree species composition and areas of forest types in Fulltofta overlap with Brunet's management suggestions. To further investigate how the conditions for forest biodiversity have changed during the period studied, the area of old stands (above 80 years and 120 years of age) in different forest types of dominant tree species was also calculated and compared between 1997 and 2023. To contextualize and explain the results interviews were done with former and current forest managers in Fulltofta.

2. Materials and methods

2.1 Land-use in Fulltofta

Skåne is heavily influenced by human land-use. Historically, the land around human settlements was divided into the infields with hay meadows and crop fields closest to the settlements, and the outlands, further away (Berglund et al. 2014). The outlands were used for cattle grazing, and the infields were fenced off from the outlands to keep the cattle out.

Fulltofta was historically divided into outlands, which had almost no noble broadleaves in the 1700s; and infields, which had been forested with oak and beech since the 1700s and before. Between 1870–1920, large scale planting of spruce on the former outlands and infields in Fulltofta changed the landscape drastically and replaced many of the formerly noble broadleaf forests found at that time (Brunet 2007). Today, the historical infields and outlands are both forested. The main tree species found in Fulltofta are spruce, oak, beech, birch (*Betula pendula* and *B. pubescens*), hybrid larch (*Larix decidua x kaempferi*; non-native), European larch (*L. decidua*; non-native) and alder (*Alnus spp.*). There are also small amounts of Scots pine (*Pinus sylvestris*) and broadleaves such as aspen (*Populus tremula*), small-leaved lime (*Tilia cordata*) and maple (*Acer spp*.) (pcSKOG 2023).

Today, Stiftelsen Skånska Landskap describes their management of the forest in Fulltofta as multiple-use forestry. They have four goals which should be considered at landscape level, although several goals are often also present at stand level. Their forest management strategy (Bernö 2022) details the four goals: recreation and public health; promotion and conservation of biodiversity; production and economy; and climate change adaptation and mitigation. The measures taken include extending the rotation length of certain stands for enhanced recreational value; biodiversity and carbon storage; managing some stands of the forest with continuous cover forestry and planting of species mixtures for recreational and conservation purposes; and managing many areas with common rotation forestry for production (Bernö 2022). The income that Stiftelsen Skånska Landskap obtains from the forest, funds the maintenance of hiking paths, roads, parking lots, and other facilities for recreationists in the area (Anders Rosell, personal communication).

2.2 Delimitations

In this study, the parts of Fulltofta which are owned by Stiftelsen Skånska Landskap (and consequently included in their forest management plan of 2023) will be studied (Figure 2). The forest management plan from 1997 includes for the most part the same areas, making for easy comparison of tree species volumes and area. A minor change in the land area in the forest management plans has occurred however, with a few hectares of land added in 2023, most of which is classified as pasture in the forest management plan.

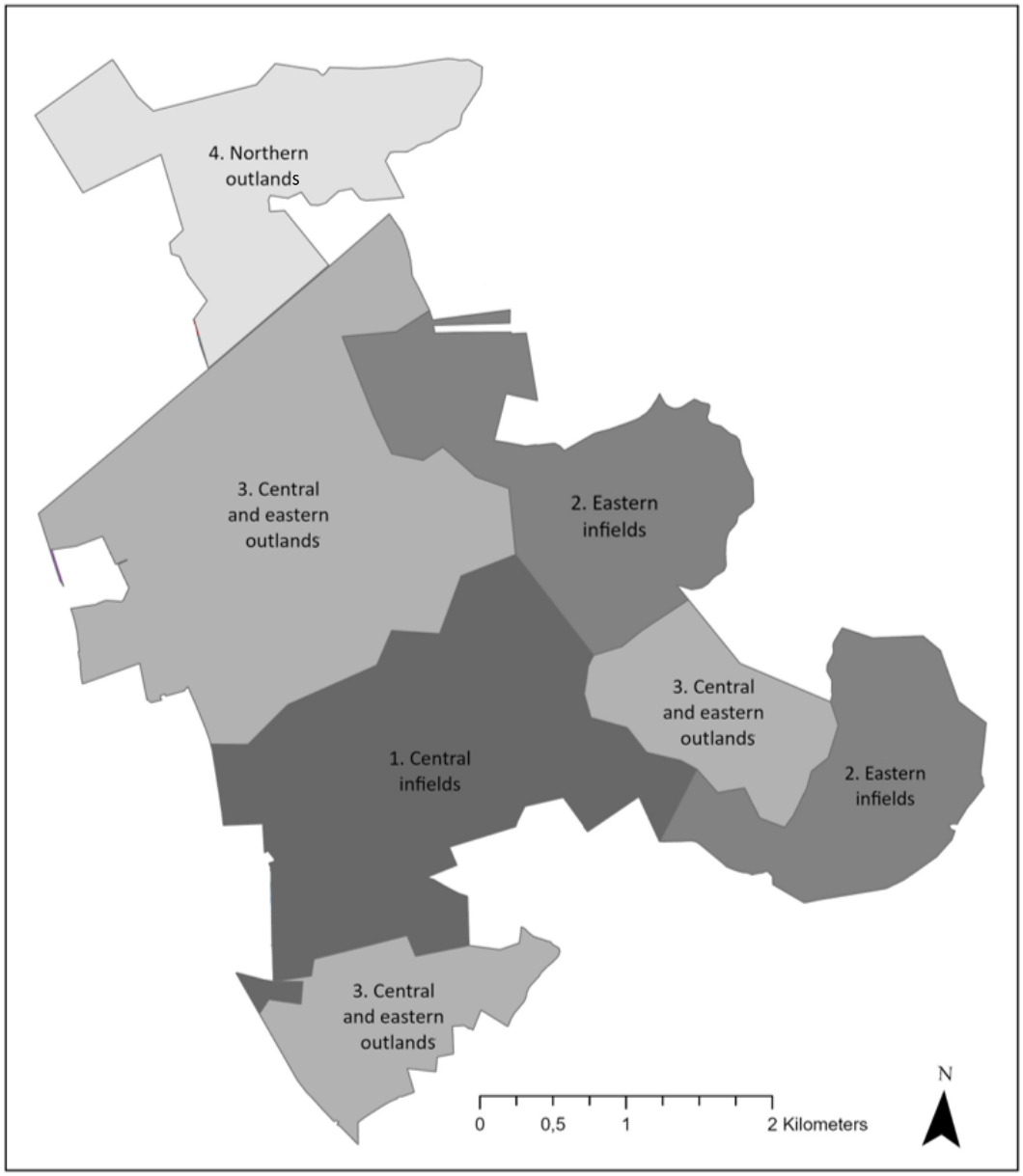

Figure 2 *Map of the area in Fulltofta owned by Stiftelsen Skånska Landskap, divided into historical infields (1. Central infields and 2. Eastern infields) and outlands (3. Central and eastern outlands and 4. Northern outlands).*

Brunet's report Fulltoftas skogar (2007) investigated the same area as this study, but excluding the former northern outlands (area no. 4, Figure 2). In his study, an area of former infields and outlands to the west was also included. However, it was in the ownership of O.D. Krook and Stiftelsen Fritidsområden (Brunet 2007) and does not appear in Stiftelsen Skånska Landskap's forest management plan. It has therefore been excluded from this study.

Brunet (2007) made suggestions for management for three areas in Fulltofta to improve nature conservation values. They are shown in figure 2 and detailed below.

1. Former central infields in Fulltofta: Brunet noted that beech had increased since the 1700s and no further increase was needed. The spruce forest should be converted to stands of other broadleaf species. Oak was one of the species he mentioned that was formerly important here and that should therefore be promoted.

2. Former eastern infields in Fulltofta: This was the area where Brunet identified the greatest need of restoration. The beech forests were fragmented and their area heavily reduced. They should be connected once more by converting spruce stands to beech stands.

3. Former central and eastern outlands in Fulltofta: In this area there was less of a need for restoration and it can be used for future conifer forestry if Stiftelsen Skånska Landskap desires to do so.

2.3 Data sources and analysis

Two forest management plans were used to compare the changes in forest cover, species composition and age classes over 26 years in Fulltofta estate. One plan was from 1997, and the other was from 2010 but updated in 2023 (hereafter referred to as 2023).

With the aim of visualizing and quantifying the change in tree species composition between 1997 and 2023, each forest stand in the management plan was categorized into forest types by the dominant tree species (≥ 70% of basal area in the stand), or as a mixed stand if no tree species was dominant. The 70% threshold follows the definition for mixed forest used by the Swedish forest agency (Skogsstyrelsen 2025).

The mixed stands were further categorized into conifer-dominated mixtures (when spruce, pine and larch ≥ 70% of basal area), broadleaf-

dominated mixtures (when beech, oak, birch and other broadleaves ≥ 70%), or as broadleaf-conifer mixtures (neither group is dominant). All land that was not classified as forested (skogsmark) in the forest management plan, was grouped as “Non-forested land”. This category included roads, powerlines, wetland, bodies of water, pastures, and “unspecified” land (pcSKOG 2023). Excel was used to calculate the area (ha), and the proportion of the total land area of Fulltofta (%) covered by each forest type. ArcGIS Pro was used to visualize the categories by stand in Fulltofta 1997 and 2023. The Python code for visualizations of land cover in ArcGIS Pro was generated using ChatGPT and manually controlled for anomalies (see Appendix 1 for the full code).

To evaluate the net change in the relative percentage of tree species between 1997 and 2023, the standing volume per species in m^3sk was calculated in Excel. To assess the net change of old stands, the area covered by stands ≥ 80 years old as well as the area of stands ≥ 120 years old was calculated in Excel. Excel was also used to calculate the stands ≥ 80 years per species as a percentage of the total area covered by that species. Maps were made in ArcGIS Pro showing the spatial distribution of stands ≥ 80 years.

Brunet (2007) divided Fulltofta into four different sections and gave management suggestions for each section. In order to compare Brunet’s management suggestions with the changes seen in the forest cover between 1997 and 2023, maps were made in ArcGIS Pro that divided Fulltofta into the sections that Brunet used. The maps were made using maps from his report of historical outlands and infields, along with his written descriptions of the extent of the areas, and with verbal input from Brunet himself.

Two semi-structured interviews were conducted to contextualize and explain the results. I interviewed Anders Ekstrand (in charge of the forest management in Fulltofta 1995–circa 2005) and Anders Rosell (involved in the forest management of Fulltofta since 2005, currently responsible for forestry and forest conservation) to obtain information about the management in Fulltofta. The information provided from these interviews has been used in the introduction and the discussion.

3. Results

3.1 Land cover change between 1997 and 2023 in Fulltofta

Spruce-dominated stands have decreased from 1015 ha in 1997 (Table 1, Figure 3) to 642 ha in 2023, a 37% decrease (Table 1, Figure 4) (side-by-side-comparison in Figure 5).

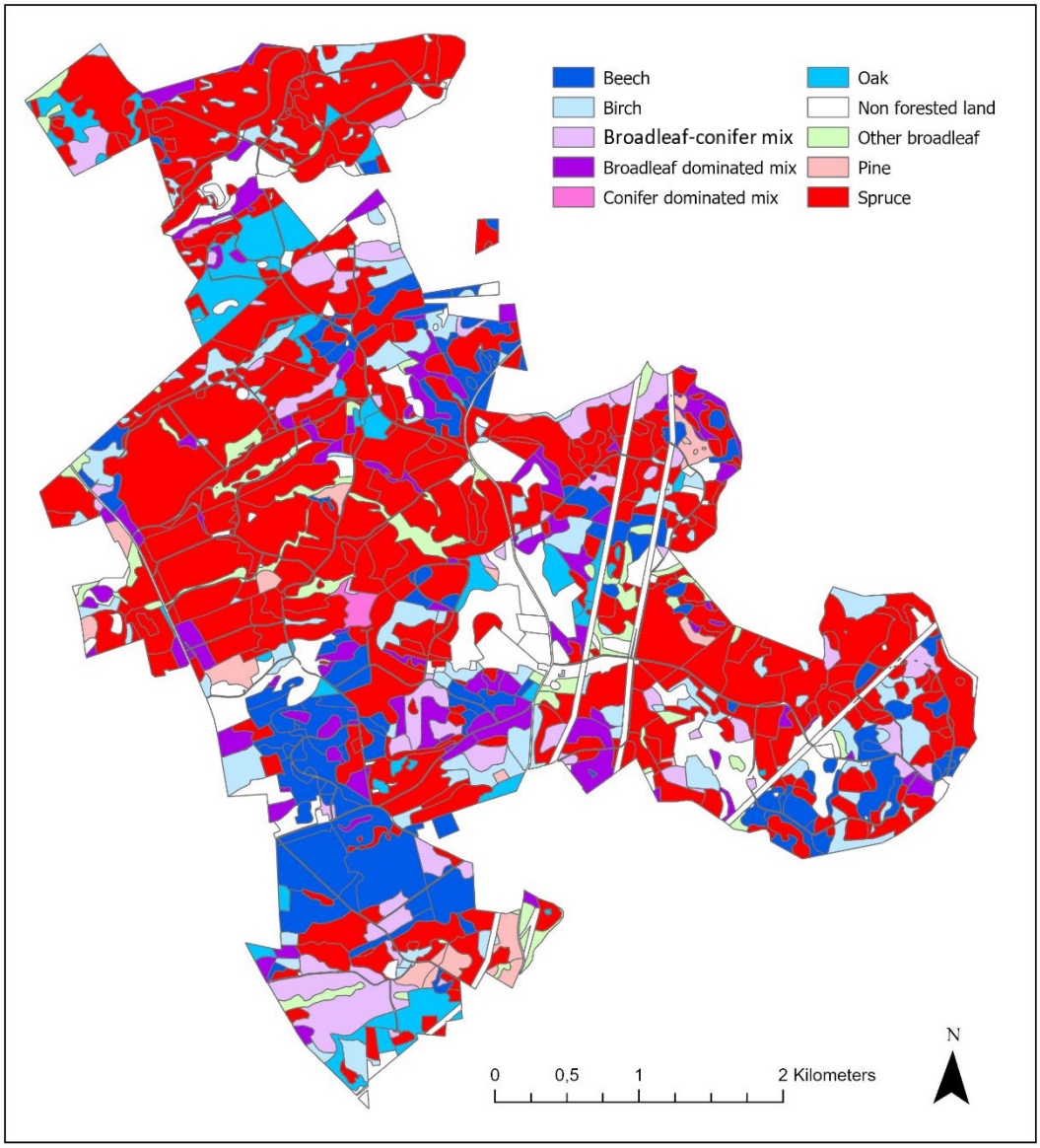

Figure 3 *Forest cover in Fulltofta in the year 1997. Stands are colored according to the forest type, defined either by the dominant species, type of mixture, or by the absence of forest.*

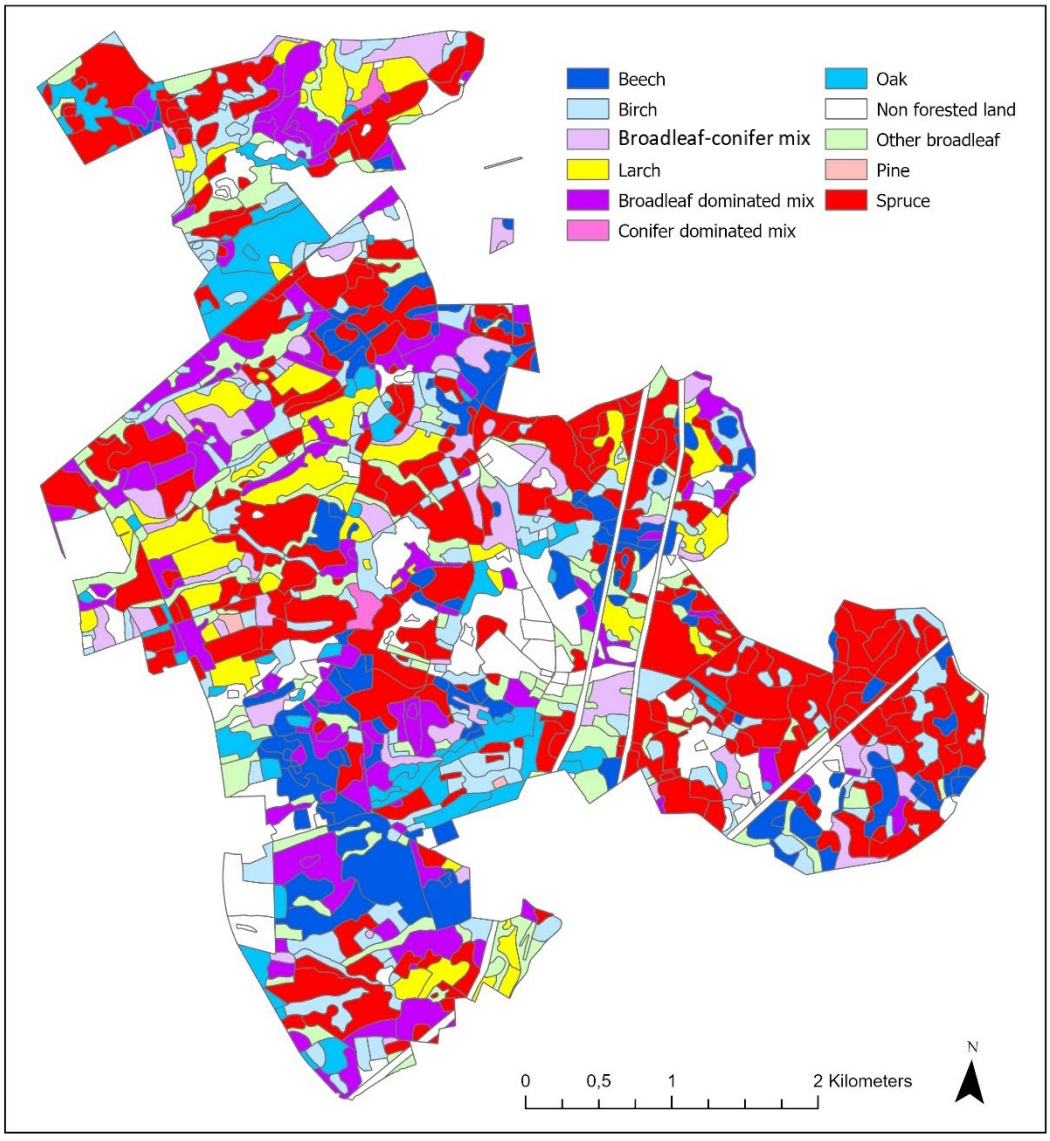

Figure 4 *Forest cover in Fulltofta in the year 2023. Stands are colored according to the forest type, defined either by the dominant species, type of mixture, or by the absence of forest.*

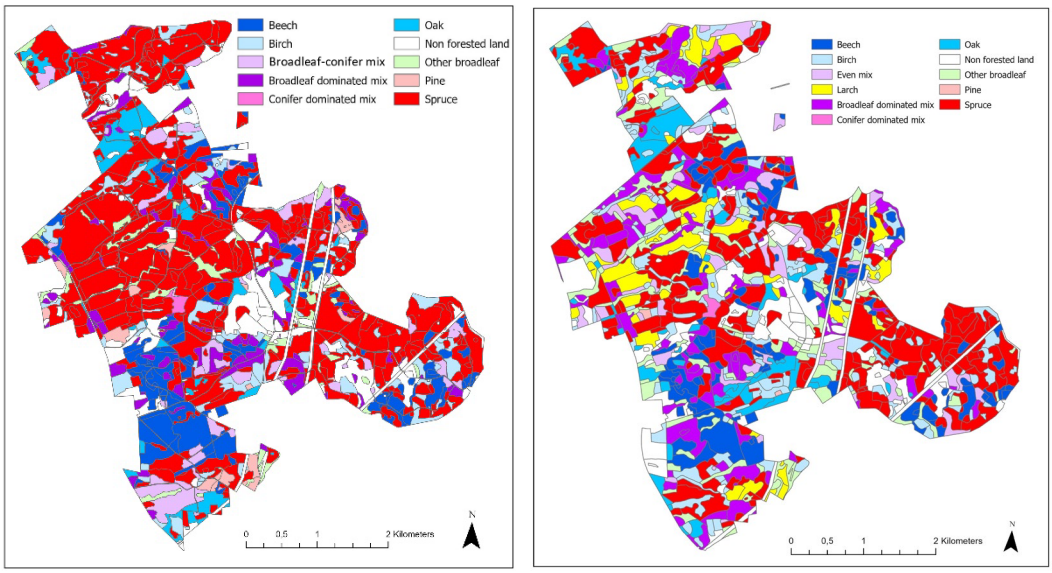

Figure 5 *Side-by-side comparison of forest cover in 1997 (left) and 2023 (right).*

Beech-dominated stands have decreased in area from 235 ha to 201 ha (13% and 11% of total forested land, respectively), whereas oak-dominated stands have increased from 94 ha to 123 ha (5% and 7%) between 1997 and 2023 (Table 1). Consequently, the area of noble broadleaves as a group have remained relatively static.

The area of mixed stands has increased, from 257 ha (14%) to 349 (19%), mostly due to an increase in broadleaf-dominated mixtures. Most of the mixed stands in Fulltofta in 2023 are dominated by broadleaves, or have an even ratio between broadleaves and conifers, as seen both in 1997 and 2023 (Table 1).

Larch was not present in the forest management plan from 1997. In 2023, 142 hectares were comprised of larch stands, equating with 8% of the forest cover (Table 1).

Table 1 *Area of the forest types (dominant species or mixture) in Fulltofta in 1997 and in 2023, sorted by the highest to lowest of the area in 2023. Forest types that have decreased in area during the period studied are highlighted in yellow.*

	1997		2023	
Forest type	Area, ha	Percent of forested land, %	Area, ha	Percent of forested land, %
Spruce	1015	55%	642	35%
Broadleaf-dominated mixture	127	7%	226	12%
Birch	143	8%	217	12%
Beech	235	13%	201	11%
Other broadleaf	62	3%	179	10%
Larch	0	0%	142	8%
Oak	94	5%	123	7%
Broadleaf-conifer mixture	125	7%	116	6%
Conifer-dominated mixture	5	0.3%	7	0.4%
Pine	36	2%	2	0.1%
Total forested land	1842		1855	

3.2 Land cover in 2023 on former spruce stands in Fulltofta

The stands that were dominated by spruce in 1997 are today primarily dominated by spruce, larch, oak or birch, or have become broadleaf-conifer mixtures or broadleaf mixtures (Figure 6).

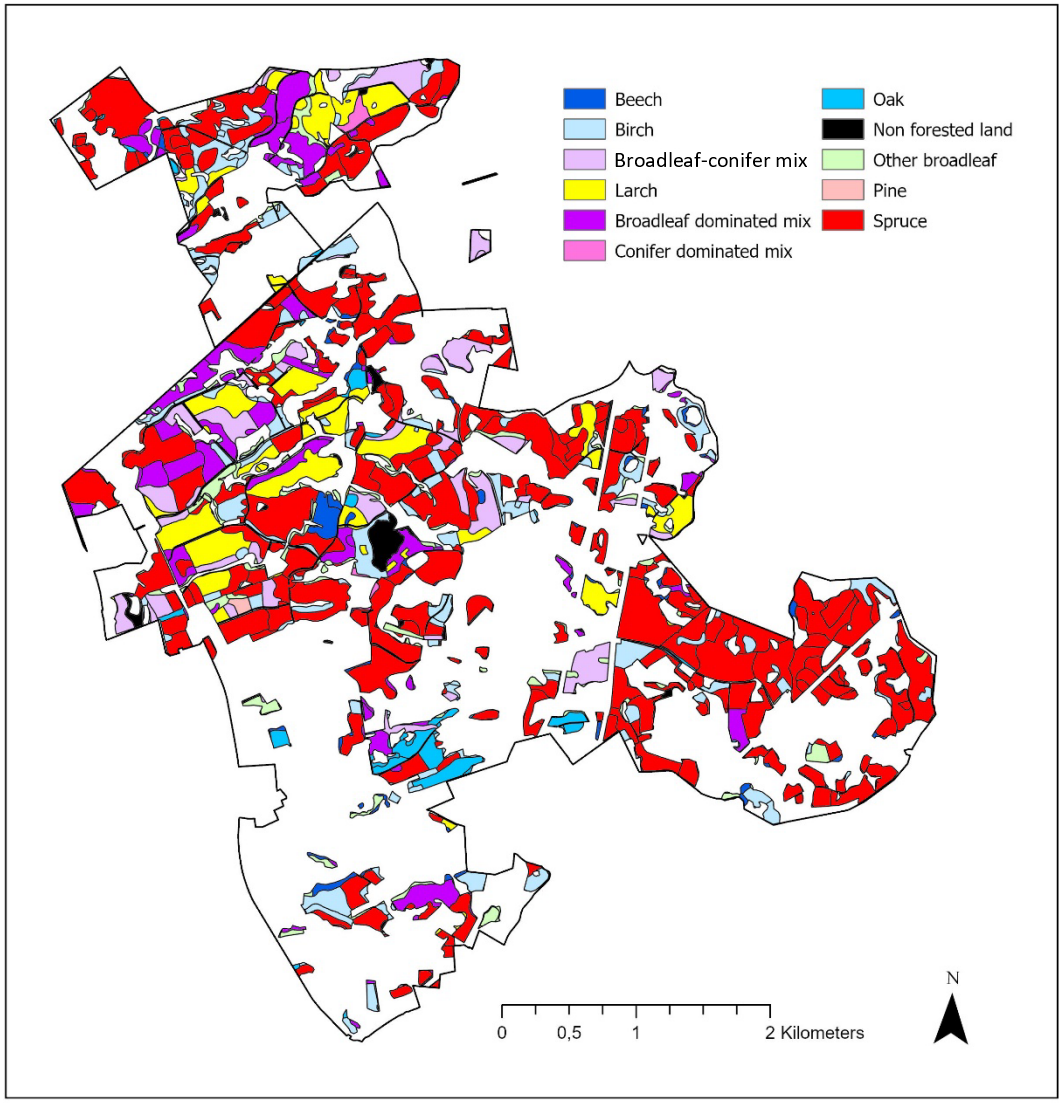

Figure 6 *Land cover of spruce stands in 1997 as represented by their tree species composition in 2023. Land which was not spruce-dominated in 1997 is shown in white.*

The following section shows each of the areas in Fulltofta established by Brunet (2007) and how the spruce forest in each section has transformed between 1997 and 2023; using the visualization of current forest types on former spruce stands as seen in Figure 6. Area number 4, “Northern

outlands" (Figure 2) has been excluded from further comparison since it was not a part of Brunet's (2007) study.

3.2.1 Former infields in central Fulltofta

Some of the former infield areas of central Fulltofta that were dominated by spruce in 1997 were still spruce-dominated in 2023, while other areas have been converted, mainly to oak, birch, other broadleaves, or mixtures (Figure 7).

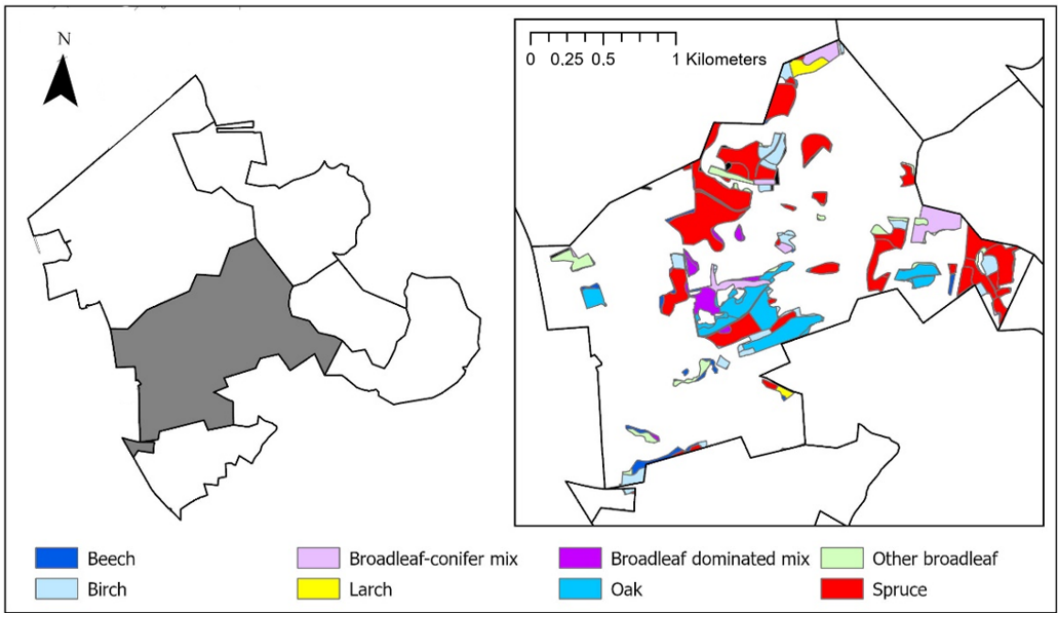

Figure 7 *Map of Fulltofta divided into sections (left), with the former infields in central Fulltofta shown in grey. A close-up of the former infields of central Fulltofta are shown in the right-hand insert. The stands which were spruce-dominated in 1997 are shown with the color of the forest type that occurs in 2023.*

3.2.2 Former infields in east Fulltofta

Much of the area dominated by spruce in 1997 on former infields in the east of Fulltofta, was still spruce-dominated in 2023 (Figure 8). Some of the spruce has been replaced by larch, birch and broadleaf-conifer mixtures. Small areas have been converted to beech and non-forested land.

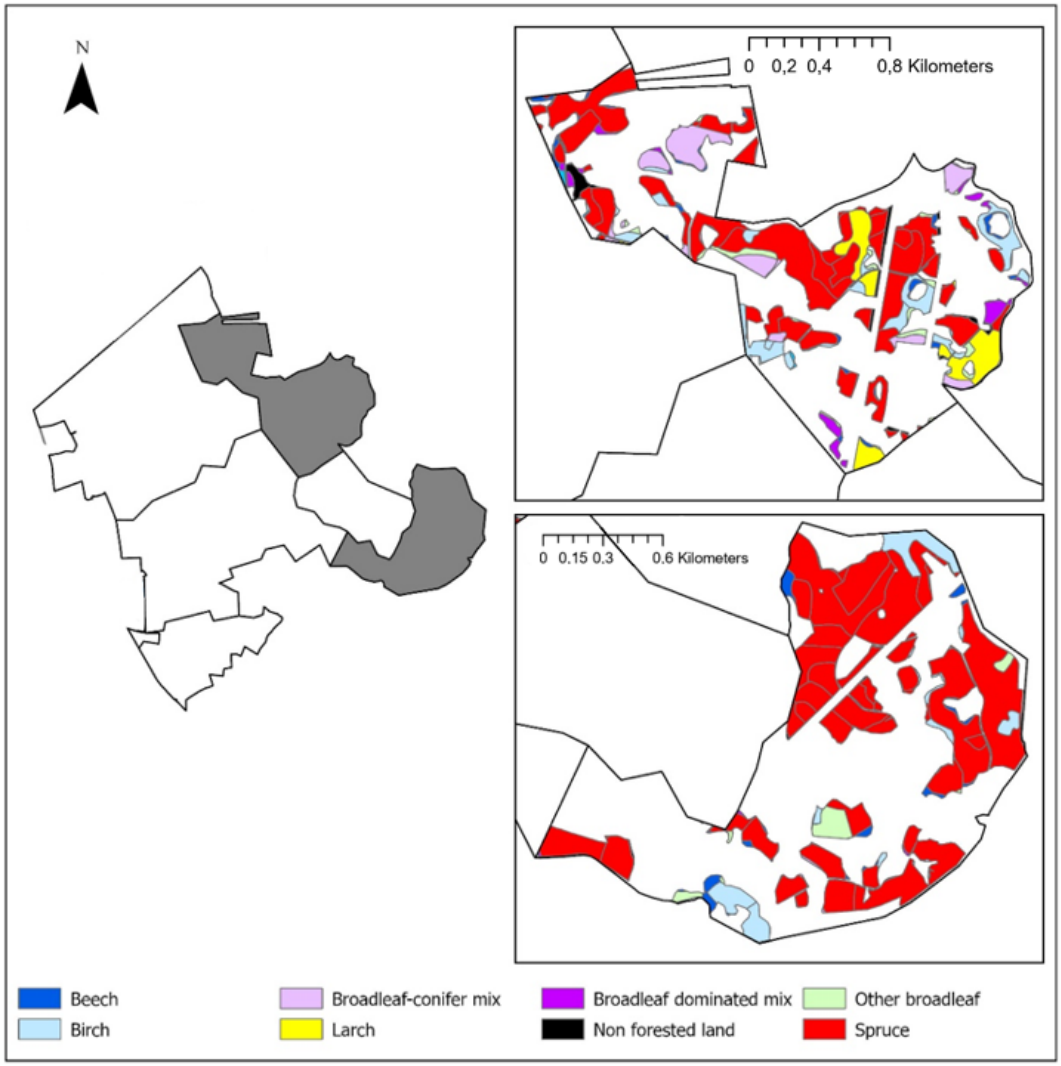

Figure 8 *Map of Fulltofta divided into sections (left), with the former infields in east Fulltofta shown in grey. The former infields of east Fulltofta are shown in the maps to the right. The stands which were spruce-dominated in 1997 are shown with the color of forest type that is there in 2023.*

3.2.3 Former outlands in central and east Fulltofta

Some of the area dominated by spruce in 1997 on the former outlands in central and east Fulltofta is still spruce-dominated in 2023 (Figure 9). Much of the spruce has been converted to larch or broadleaf-conifer mixtures and broadleaf mixtures, as well as birch.

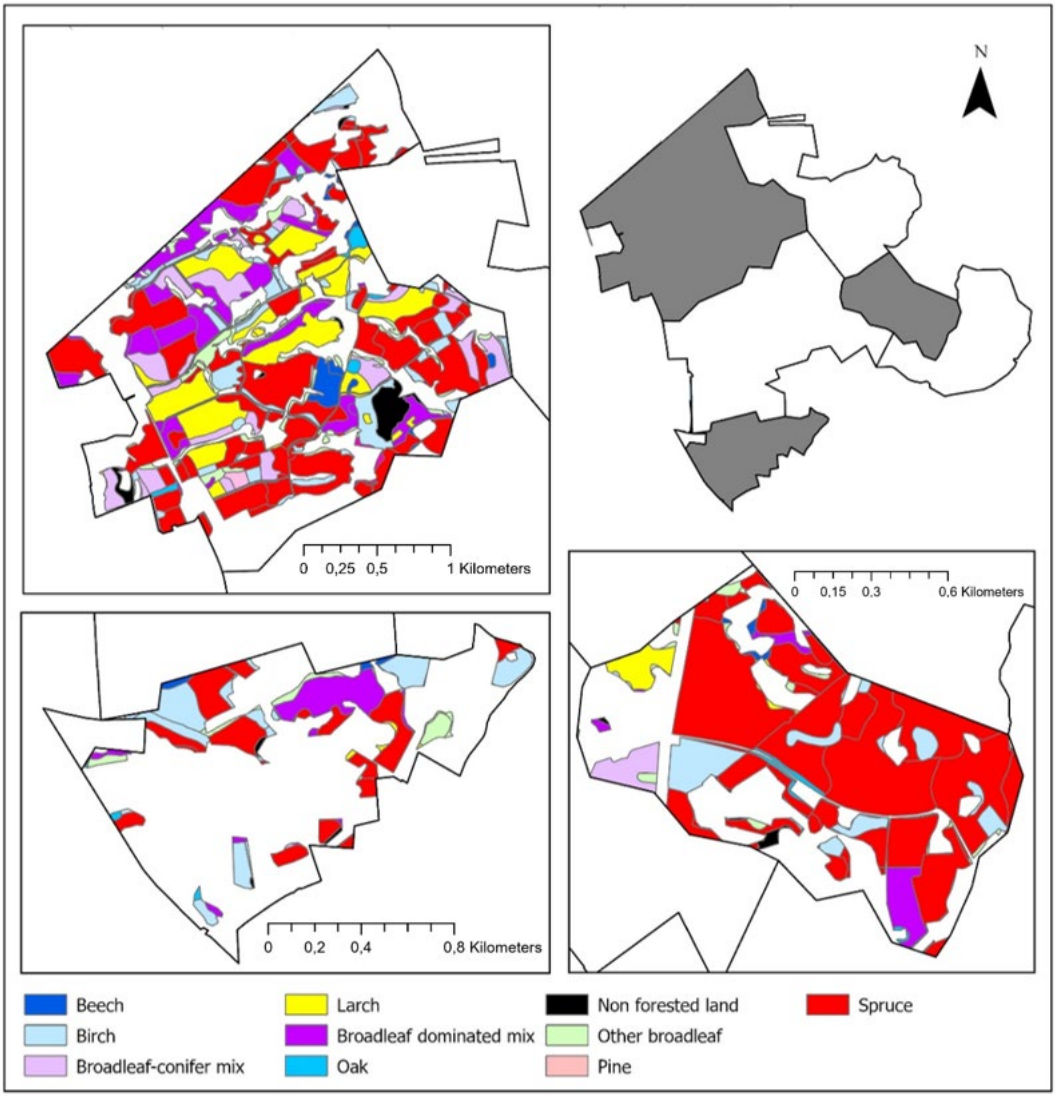

Figure 9 *Map of Fulltofta divided into sections (top right), with the former outlands in central and east Fulltofta shown in grey. The former outlands in central and east Fulltofta are shown in the callouts. The stands which were spruce-dominated in 1997 are shown with the color of forest type that is there in 2023.*

3.3 Volume per tree species in Fulltofta

The volume (m^3sk) of spruce has decreased between 1997 and 2023, from 74% to 45% of the total standing volume (Figure 10).

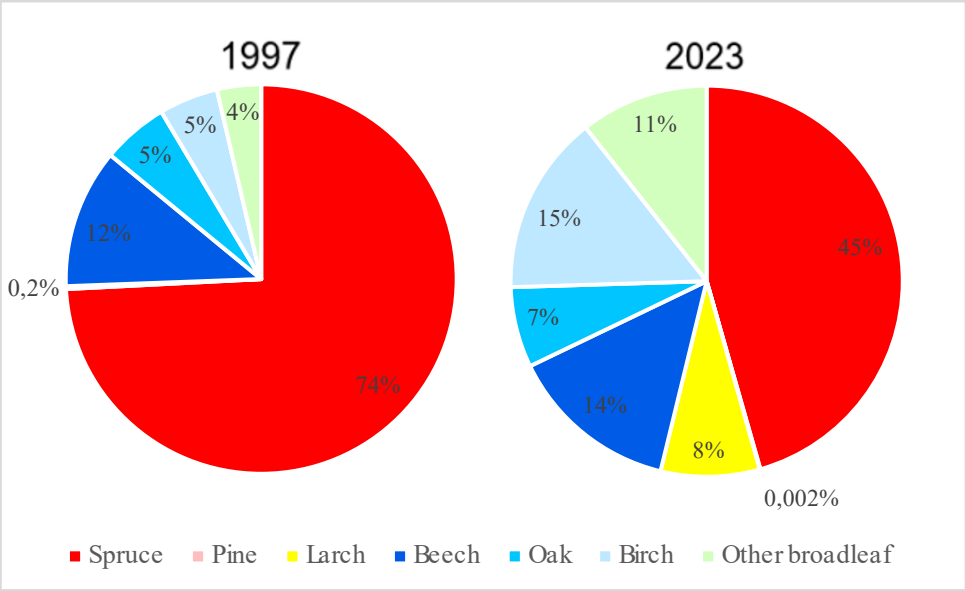

Figure 10 *Tree species proportion of volume in Fulltofta in 1997 and 2023 as organized by individual species and "other broadleaf" trees. "Other broadleaves" include aspen (Populus tremula), alder (Alnus spp.) and other broadleaf species not specified in the forest management plans of 1997 and 2023.*

Spruce has decreased from 229,052 m^3sk in 1997 to 167,247 m^3sk in 2023, a reduction of 61,805 m^3sk or 27%. During the same period, pine has decreased from 714 m^3sk to 220 m^3sk, whereas larch has increased from 0 m^3sk to 29,856 m^3sk (Table 2).

The broadleaf to conifer volume ratio has increased from 26/74 to 47/53 in the time period studied. All of the broadleaves studied have increased in volume: Beech from 35,730 m^3sk to 51,605 m^3sk; oak from 16,918 to 24,456 m^3sk; birch from 15,098 m^3sk to 54,613 m^3sk; and other broadleaves from 11,259 m^3sk to 38,888 m^3sk. The total standing volume in Fulltofta has increased by 58,123 m^3sk during the years studied (Table 2).

Table 2 *Standing volume per tree species in m^3sk and as a proportion of total volume in 1997 and 2023 in Fulltofta, sorted by highest to lowest volume in 2023. Tree species that have decreased in standing volume are highlighted in yellow.*

	1997		2023	
Tree species	Volume, m^3sk	Proportion, %	Volume, m^3sk	Proportion, %
Spruce	229,052	74%	167,247	45%
Birch	15,098	5%	54,613	15%
Beech	35,730	12%	51,605	14%
Other broadleaf	11,259	4%	38,888	11%
Larch	0	0%	29,865	8%
Oak	16,918	5%	24,456	7%
Pine	714	0,2%	220	0,06%
Total	308,771		366,894	

3.4 Old stands in Fulltofta

3.4.1 Stands ≥ 80 years

The area of stands that were ≥ 80 years of age has more than doubled from 189 ha (9% of Fulltofta's total area) to 401 ha (19% of the total area) between 1997 and 2023 (Table 3). The share of ≥ 80-year-old beech stands has increased during the time period considered: 62% of the beech forest was ≥ 80 years old in 2023 compared to only 37% in 1997 (Table 4). An increase in the share of forest ≥ 80 years can also be seen in broadleaf-dominated mixtures (from 21% to 39%) and in broadleaf-conifer mixtures (from 1.3% to 17%). The area of oak-dominated stands ≥ 80 years has increased since 1997, but as a share of total oak-dominated area they have decreased.

Table 3 *The area of stands ≥ 80 years in Fulltofta in 1997 and 2023 in hectares.*

Forest type	Area (ha) 1997	Area (ha) 2023
Beech	87	125
Broadleaf-dominated mixture	26	87
Oak	66	77
Other broadleaf	0.0	61
Spruce	0.7	20
Broadleaf-conifer mixture	1.6	20
Birch	7	12
Total	189	401
Percent of Fulltofta area	9%	19%

Table 4 *Stands ≥ 80 year old in Fulltofta in 1997 and 2023 as a percentage of the total area of that forest type in the same year.*

Forest type	1997	2023
Beech	37%	62%
Broadleaf-dominated mixture	21%	39%
Oak	70%	63%
Other broadleaf	0%	34%
Spruce	0.1%	3%
Broadleaf-conifer mixture	1.3%	17%
Birch	5%	5%

The stands ≥ 80 years are spread across Fulltofta in 2023 in a similar pattern as in 1997 (Figure 11. See Appendix 2 for full-size maps).

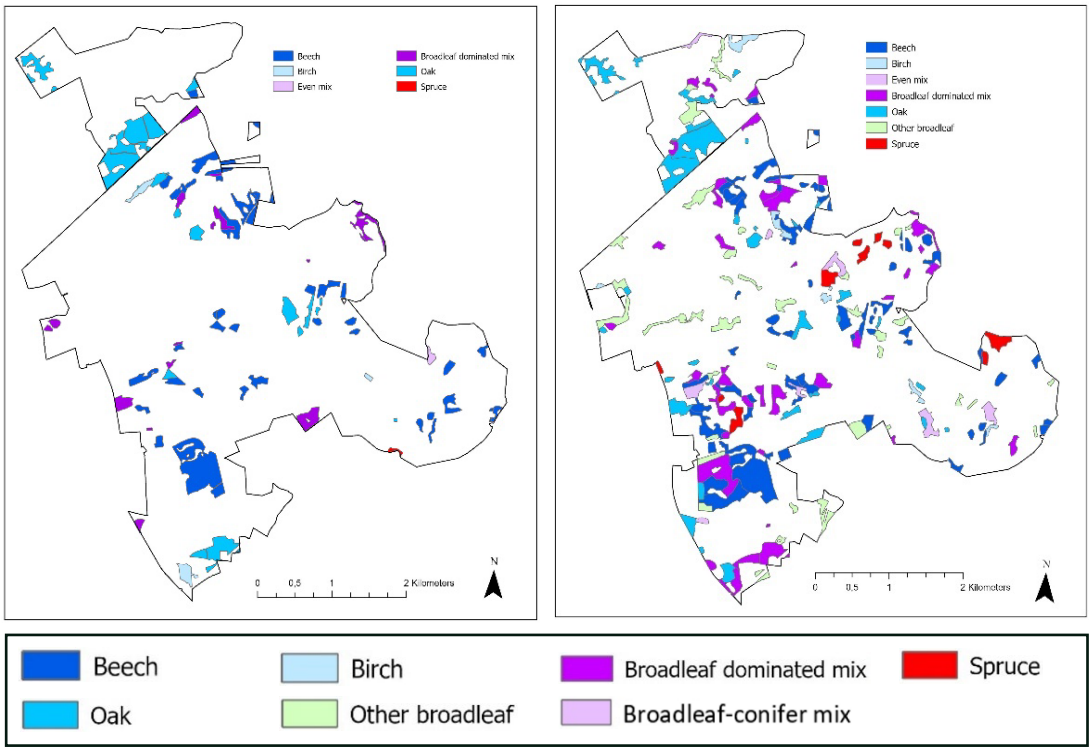

Figure 11 *Stands ≥ 80 years old in 1997 (left) and 2023 (right) in Fulltofta.*

3.4.2 Stands ≥ 120 years

From 1997 to 2023, the area of stands 120 years or older has increased from 55 ha to 134 ha. None of the ≥ 120 old forest types have decreased in area and the noble broadleaves oak and beech have the highest area today (Table 5). The oldest stand in Fulltofta in 1997 was 200 years old. In 2023, the oldest stand was 229 years old.

Table 5 *The area of stands ≥ 120 years in Fulltofta in 1997 and 2023 in hectares.*

Forest type ≥ 120	Area(ha) 1997	Area(ha) 2023
Beech	51	70
Oak	0.2	41
Broadleaf-dominated mixture	4	14
Broadleaf-conifer mixture	0	5
Other broadleaf	0	4
Total	55	134

4. Discussion

The main purpose of this study was to investigate whether the conversion from spruce forest to broadleaf forest observed in Fulltofta by Brunet (2007) has continued, to exemplify how multiple-use forestry can influence the landscape and investigate the possible effects this has on forest biodiversity. Additionally, the study investigated how the tree species composition has changed between 1997 and 2023. The hypothesis was that spruce had decreased in Fulltofta while broadleaves had increased between 1997–2023. The main findings confirm the hypothesis, showing that both the standing volume of spruce and the area of spruce-dominated stands have decreased, mainly in favor of broadleaves. However, spruce remains the most common species in Fulltofta, both in terms of standing volume and area.

The results show that the conversion of spruce stands to other forest types in Fulltofta has made the landscape into a more heterogenous mosaic of forest types, with more mixtures and more broadleaf stands. The species mixtures are almost exclusively either broadleaf-dominated or broadleaf-conifer mixtures, while conifer-dominated mixtures comprise less than half a percent of the total forested land in Fulltofta.

The changes seen in the noble broadleaves as a group are not as dramatic as the change in spruce, but they have increased nonetheless. Oak has become a dominant species in more stands and has increased in standing volume during the period studied. Beech is a dominant species in fewer stands in 2023 than in 1997 but has increased in standing volume. This could indicate that beech is more dispersed in the landscape, likely as a part of the stands of broadleaf-dominated mixtures, which have also increased in total area.

An additional aim of this study was to see whether the changes between 1997–2023 would overlap with Brunet's (2007) management suggestions aimed at nature conservation based on the land-use history. Brunet's suggestions were to convert spruce to broadleaf stands on the former infields of Fulltofta (area 1 and 2, Figure 2), whereas cultivation of conifers should be concentrated to the former outlands (area 3, Figure 2) if Stiftelsen Skånska Landskap wished to continue using spruce and other conifers in their forestry. The results of this study show that spruce on the former outlands has mainly been converted to larch stands, species mixtures, birch stands, or remained spruce. In the former infields in central Fulltofta, a few spruce stands have been converted to oak. The former infields in east Fulltofta, where Brunet identified the greatest need for restoration of beech forest on spruce stands, have seen a change from spruce to birch, but no

spruce stands have been converted to beech. In other words, the general trend in Fulltofta is in line with Brunet's suggestions, but the most important parts have not been fulfilled. This should be viewed in the context of the forest management strategy of the owner of the property, Stiftelsen Skånska Landskap, which apart from biodiversity goals, also includes recreation, climate change adaptation and production goals.

Put simply, the reality of multiple-use forestry in Fulltofta only partially overlaps with Brunet's (2007) management suggestions for improving conditions for biodiversity through restoration of noble broadleaf stands. On the other hand, the time period studied (26 years) is short in the time scales of southern Swedish spruce forestry, for which the lowest legal age for final felling is 45–90 years (SKSFS 2011:7 n.d.). It is also important to note that today, beech, pine, birch and oak are the main species planted in Fulltofta, while only very small amounts of spruce are planted (Andes Rosell, personal communication). It is therefore likely that the trend of decreasing spruce will continue in favor of broadleaves and pine, and this will become more apparent only when more of today's spruce stands have been harvested.

Stiftelsen Skånska Landskap explicitly wants to move away from reliance on spruce, as it is not seen as a tree species fit for a changing climate (Bernö 2022; Anders Rosell, personal communication). In other words, climate change adaptation is one of the main drivers behind the decrease in spruce in Fulltofta. Rosell adds that a reduction of volume production is expected, but the risk of relying on spruce is seen as greater than the potential benefits.

The increase in mixed stands between 1997 and 2023 can be explained in part by a wish to spread risks. Species mixtures are mentioned in the forest management strategy as a tool for risk mitigation (Bernö 2022), and the Swedish Forest Agency suggests that one way to increase the resilience of the forest is increasing the amount of conifer-broadleaf species mixtures (Eriksson et al. 2016). Studies have shown spruce-pine and spruce-birch mixtures to be more resilient to storm damage than pure spruce stands (Felton et al. 2016). Spruces in species mixtures also run a reduced risk of being attacked by spruce bark beetles compared to spruce trees in monocultures. Importantly, the characteristics of the tree species influence the resilience of the species mixture, and therefore the effects of the mixed stands in Fulltofta can only been properly evaluated by further studies investigating the tree species composition of the mixed stands. An additional effect of the increase in area covered by mixtures could be higher species diversity in many taxa at the stand level, as a heterogenous stand creates more niches for different taxa to inhabit (Felton et al. 2016).

The changes in Fulltofta can be compared to the changes seen in the wider landscape. According to the official statistics of the annual Swedish National Forest Inventory (Riksskogstaxeringen), between the year 1995 and 2023, spruce decreased in the southern region of Götaland from 50% to 45% of the growing stock (Skogsdata 2000, 2024). During the same period, modest increases were seen in the growing stock of larch, beech and oak. The trend hence mirrors the trend in Fulltofta, although in Fulltofta, the decrease of spruce has been more dramatic.

In terms of productive forest land, the area of spruce forest in Skåne decreased by 20% between 1999–2023 (Skogsdata 2000, 2024). In Fulltofta, the area of spruce stands decreased by 37% between 1997–2023. In other words, the decrease in the area of spruce forest is faster in Fulltofta than in the rest of Skåne. The multiple-use forestry goals of Stiftelsen Skånska Landskap, and specifically, their active consideration of climate change adaptation requirements, may have helped to accelerate their transition from spruce to broadleaf forest relative Skåne's forest management trajectory in general during this time period.

According to official statistics from the Swedish National Forest Inventory, the area of forests 80 years or older has had a net increase in the boreonemoral and nemoral regions of Sweden during the period 1997–2023. The area of forests older than 120 years has also seen a net increase during the same period (Skogsdata 2024). These trends mirror the increase in forests older than 80 years and 120 years in Fulltofta. Furthermore, the majority of the stands older than 80 and 120 years in Fulltofta were broadleaf-dominated, and the increase of the area of these stands is a likely indication of improving habitat conditions for taxa dependent on old broadleaf trees.

The increase in the area of old forests and the increased area of mixed stands goes hand in hand with Stiftelsen Skånska Landskap's management goals of encouraging recreation and public health; and promoting and conserving biodiversity. Old broadleaf stands are seen as an element that increases the recreational value of the forest (Bernö 2022), and species mixtures may have the same effect, although other factors such as structural heterogeneity may be more important in determining people's perception of the forest (Edwards et al. 2012).

Broadleaf stands, species mixtures and stands above 80 years and 120 years is an example of forest types that have become rare in the Swedish landscape due to conversion to agricultural land and planted even-aged conifer production forests (Naturvårdsverket 2022; Skogsdata 2024). The increase of these forest types in Fulltofta should benefit associated species, if appropriate management regimes are applied. Especially the increase of

noble broadleaf stands over 120 years old is likely to improve conditions for red-listed species, although even older trees and high amounts of dead wood are needed to approach the species diversity found in an old-growth forest (Brunet et al. 2010).

Very few stands of larch have been planted in Fulltofta since 2012 (Anders Rosell, personal communication). The increase in larch-dominated stands seen between 1997 and 2023 can therefore be expected to have reached its peak. It is unlikely to be planted more in the future and will likely decrease in the long term, as it is not conducive to the management goal of fostering “the typical Scanian landscape”, as stated in the Forest management strategy of Stiftelsen Skånska Landskap (Bernö 2022). Stiftelsen have also made the decision to avoid using exotic species, such as hybrid larch and European larch (Anders Rosell, personal communication). Most of the larch is concentrated to the former outlands of Fulltofta, where Brunet suggested that conversion to broadleaves was less important than on the former infields. According to Rosell, in the management there is an awareness of the land-use history in Fulltofta, and of the outland/infield system, which could be a reason why so much larch was planted on the former outlands where forest continuity presumably is less important from an ecological point of view. According to Rosell, one of the reasons why larch was planted was due to its fast growth, a limitation in the availability of birch seedlings, as well as the expected increase in understory light provided by larch’s deciduous nature; relative to the evergreen spruce.

The planting of larch in Fulltofta started before 1997, contrary to the results of the standing volume calculations of this study which indicate that there was no larch at that time. According to Anders Ekstrand, forest manager in Fulltofta between 1995–2005, the quantity of larch in 1997 was quite low (Anders Ekstrand, personal communication). It can be inferred that there was too little larch in 1997 for it to be given its own tree species category in the forest management plan. This shows the limitations of relying on forest management plans as a tool for determining species distribution. The forest management plan is a tool for management, and estimates of basal area per species are just that—estimates. However, a management plan can give information on trends in the landscape, and the results clearly show one possible expression of multiple-use forestry in a southern Swedish context.

The implications for biodiversity are not only dependent on the tree species present, but also on the management system applied. Stiftelsen Skånska Landskap manages some of the beech forest with a traditional shelterwood system. Additionally, they have increased the area managed

with continuous cover forestry methods in Fulltofta during the time period studied (Anders Rosell, personal communication; Anders Ekstrand, personal communication). The extent and exact nature of the silvicultural methods used in Fulltofta are beyond the scope of this study, and would need to be known in order to make an assessment of the ecosystem services the forest provides. However, traditional shelterwood management has been found to provide insufficient conditions for many species of conservation concern compared to selectively harvested beech forests and old-growth beech forest (Brunet et al. 2010). This is much due to the low amount of dead wood and lack of tree related microhabitats found on old trees, as well as the homogenizing effect of the shelterwood canopy on light conditions (Brunet et al. 2010). These factors need to be understood along with the tree species composition and age distribution to properly assess conditions for red-listed species in Fulltofta.

The findings in this study parallel an increasing awareness of the problems with spruce in southern Sweden and an increasing understanding of the importance of restoring temperate broadleaf forests (Löf et al. 2008; SLU Artdatabanken 2020). Previous studies about Fulltofta estate have looked at the forest history, land use and tree species composition going back as far as 2000 years, and up until 2007 (Brunet 2007; Lindbladh et al. 2007). This study has continued investigating the tree species composition until 2023, with the added context of multiple-use forestry and how current trends in forestry in Sweden can be seen mirrored in Fulltofta.

5. Conclusions

This study has found that through multiple-use forestry management, Stiftelsen Skånska Landskap have reduced their reliance on spruce and made the forest in Fulltofta more diverse. Spruce has declined in favor of species mixtures, broadleaf stands, and larch stands; likely with many positive implications for the goals the forest management of Stiftelsen Skånska Landskap. The decrease of spruce in Fulltofta has been faster than in the rest of Skåne, which points to the potential of multiple-use forestry goals to diversify the forest and improve habitat for broadleaf-dependent species. The decline in spruce is likely to continue in the future due spruce being negatively affected by climate change-related events.

Although the results of this study show that the changes seen in Fulltofta only partially overlap with Brunet's (2007) management suggestions for improving conditions for biodiversity through restoration of noble broadleaf stands, the increase in old noble broadleaf stands have most likely improved conditions for red-listed species dependent on old stands. Furthermore, the increase in tree species mixtures and broadleaf stands may improve the conditions for broadleaf-dependent species and forest biodiversity in general. However, it is unlikely that the conditions for biodiversity in Fulltofta today are as good as in an old-growth forest.

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References

Berglund, B.E., Kitagawa, J., Lagerås, P., Nakamura, K., Sasaki, N. & Yasuda, Y. (2014). Traditional Farming Landscapes for Sustainable Living in Scandinavia and Japan: Global Revival Through the Satoyama Initiative. *AMBIO*, 43, 559–578. https://doi.org/10.1007/s13280-014-0499-6

Bernö, H. (2022). *Skogsbruksstrategi*. Stiftelsen Skånska Landskap. https://media.fabriq-cms.se/skanskalandskap/255bc624-bd8b-4932-b14d-27a1b7391d9d/Skogsbruksstrategi-Stiftelsen-Sk%C3%A5nska-Landskap-2022.pdf

Brunet, J. (2007). *Fulltoftas skogar: Förändringar i utbredning och sammansättning under perioden 1772 - 2004*. (33). Southern Swedish Forest Research Centre. https://www.slu.se/globalassets/ew/org/inst/ssv/press/arbetsrapporter/33_arbetsrapport-33_fulltofta.pdf

Brunet, J. & Berlin, G. (2005). *Skånes skogar – historia, mångfald och skydd*. (Skåne i utveckling 2005:12). Länsstyrelsen i Skåne län. https://www.lansstyrelsen.se/download/18.68fbc90d193243b379e48a40/1732527365132/Sk%C3%A5nes%20skogar%20-%20historia,%20m%C3%A5ngfald%20och%20skydd.pdf

Brunet, J., Fritz, Ö. & Richnau, G. (2010). Biodiversity in European beech forests - a review with recommendations for sustainable forest management. *Ecological bulletins*, 53, 77–94

Edwards, D.M., Jay, M., Jensen, F.S., Lucas, B., Marzano, M., Montagné, C., Peace, A. & Weiss, G. (2012). Public Preferences Across Europe for Different Forest Stand Types as Sites for Recreation. *Ecology and Society*, 17 (1). https://doi.org/10.5751/ES-04520-170127

Eriksson, H., Bergqvist, J., Hazell, P., Isacsson, G., Lomander, A. & Black-Samulesson, S. (2016). *Effekter av klimatförändringar på skogen och behov av anpassning i skogsbruket.* (2016:2). Skogsstyrelsen. https://shop.skogsstyrelsen.se/shop/9098/art63/48637063-1d24e7-klimatet_webb_ny.pdf

Felton, A., Lindbladh, M., Brunet, J. & Fritz, Ö. (2010). Replacing coniferous monocultures with mixed-species production stands: An assessment of the potential benefits for forest biodiversity in northern Europe. *Forest Ecology and Management*, 260 (6), 939–947. https://doi.org/10.1016/j.foreco.2010.06.011

Felton, A., Nilsson, U., Sonesson, J., Felton, A.M., Roberge, J.-M., Ranius, T., Ahlström, M., Bergh, J., Björkman, C., Boberg, J., Drössler, L., Fahlvik, N., Gong, P., Holmström, E., Keskitalo, E.C.H., Klapwijk, M.J., Laudon, H., Lundmark, T., Niklasson, M., Nordin, A., Pettersson, M., Stenlid, J., Sténs, A. & Wallertz, K. (2016). Replacing monocultures with mixed-species

stands: Ecosystem service implications of two production forest alternatives in Sweden. *Ambio*, 45 (2), 124–139. https://doi.org/10.1007/s13280-015-0749-2

Hannah, L. & Carr, J.L. (1995). Human disturbance and natural habitat: a biome level analysis of a global data set. *Biodiversity and Conservation*, 4 (2), 128–155. https://doi.org/10.1007/BF00137781

Keskitalo, E.C.H., Bergh, J., Felton, A., Bjoerkman, C., Berlin, M., Axelsson, P., Ring, E., Agren, A., Roberge, J.-M., Klapwijk, M.J. & Boberg, J. (2016). Adaptation to climate change in Swedish forestry. *Forests*, 7 (2). https://doi.org/10.3390/f7020028

Lindbladh, M., Axelsson, A.-L., Hultberg, T., Brunet, J. & Felton, A. (2014). From broadleaves to spruce – the borealization of southern Sweden. *Scandinavian Journal of Forest Research*, 29 (7), 686–696. https://doi.org/10.1080/02827581.2014.960893

Lindbladh, M., Brunet, J., Hannon, G., Niklasson, M., Eliasson, P., Eriksson, G. & Ekstrand, A. (2007). Forest History as a Basis for Ecosystem Restoration—A Multidisciplinary Case Study in a South Swedish Temperate Landscape. *Restoration Ecology*, 15 (2), 284–295. https://doi.org/10.1111/j.1526-100X.2007.00211.x

Löf, M., Madsen, P. & Stanturf, J., A. (2008). Restoration of broadleaved forests in southern Sweden - Some thoughts about a new management concept. *Svensk Botanisk Tidskrift*, 102 (1), 43–51

Naturvårdsverket (2022). *Ett rikt växt- och djurliv*. (7071). Naturvårdsverket. https://www.naturvardsverket.se/4acbf3/globalassets/media/publikationer-pdf/7000/978-91-620-7071-7.pdf

Öhrn, P. (2024). Carbon castles vs. beetle-fungus armies. *Diss. Sveriges Lantbruksuniversitet*, (2024:35). https://doi.org/10.54612/a.7oclpl1aad

pcSKOG (2023). Skogsbruksplan: Skånska Landskap Fulltofta. [internal document: unpublished]

Region Skåne (2025). *Stiftelsen Skånska Landskap*. *Region Skåne*. https://utveckling.skane.se/regional-utveckling/verksamhetsomraden/natur-och-rekreation/stiftelsen-skanska-landskap/ [2025-05-14]

SFS (1984:119) (n.d.). *Ädellövskogslag*. Jordbruksdepartementet. https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/adellovskogslag-1984119_sfs-1984-119/ [2025-05-07]

Skogsdata (2000). Aktuella uppgifter om de svenska skogarna från Riksskogstaxeringen. Department of forest resource management, SLU, Umeå. https://www.slu.se/globalassets/ew/org/centrb/rt/dokument/skogsdata/skogsdata2000_webb.pdf

Skogsdata (2024). Aktuella uppgifter om de svenska skogarna från Riksskogstaxeringen. Department of forest resource management, SLU,

Umeå.
https://www.slu.se/globalassets/ew/org/centrb/rt/dokument/skogsdata/skogsdata_2024_web.pdf

Skogskunskap (2024). *Gran (Picea abies)*. https://www.skogskunskap.se/skota-barrskog/foryngra/valj-tradslag-i-barrskogen/gran-picea-abies/ [2025-05-13]

Skogsstyrelsen (2020). *Forest management in Sweden - Current practice and historical background*. (4). Skogsstyrelsen.
https://www.skogsstyrelsen.se/globalassets/om-oss/rapporter/rapporter-20222021202020192018/rapport-2020-4-forest-management-in-sweden.pdf [2025-05-16]

Skogsstyrelsen (2025). *Blandskog*. https://www.skogsstyrelsen.se/bruka-skog/olika-satt-att-skota-din-skog/att-skota-blandskog/ [2025-05-10]

SKSFS 2011:7 (n.d.). *Skogsstyrelsens föreskrifter och allmänna råd till Skogsvårdslagen*. Skogsstyrelsen.
https://www.skogsstyrelsen.se/globalassets/lag-och-tillsyn/foreskrifter-efter-amne/skogsvard/sksfs-2011-7-skogsstyrelsens-foreskrifter-och-allmanna-rad-till-skogsvardslagen-.pdf

SLU Artdatabanken (2020). *Tillstånd och trender för arter och deras livsmiljöer – rödlistade arter i Sverige 2020*. (SLU Artdatabanken rapporterar, 24).
https://www.slu.se/globalassets/ew/subw/artd/6-publikationer/32.-tillstand-och-trender-2020/tillstand-trender.pdf [2025-05-12]

Subramanian, N., Bergh, J., Johansson, U., Nilsson, U. & Sallnäs, O. (2016). Adaptation of Forest Management Regimes in Southern Sweden to Increased Risks Associated with Climate Change. *Forests*, 7 (1), 8.
https://doi.org/10.3390/f7010008

Wade, T.G., Riitters, K.H., Wickham, J.D. & Jones, K.B. (2003). Distribution and Causes of Global Forest Fragmentation. *Conservation Ecology*, 7 (2).
https://doi.org/10.5751/es-00530-070207

Witzell, J., Berglund, M., Bergquist, J., Bernhold, A., Björklund, N., Granström, A., Åberg, A.G., Hanson, L., Hansson, P., Hellqvist, C., Lindelöw, Å., Långström, B., Nordlander, G., Peterson, M., Rönnberg, J. & Wallertz, K. (2017). *Skador på skog*. (Skogsskötselserien, 1). Skogsstyrelsen.
https://www.skogsstyrelsen.se/globalassets/mer-om-skog/skogsskotselserien/skogsskotselserien-12-skador-pa-skog-del-1-skogsskador-i-skogens-olika-utvecklingsstadier.pdf [2025-05-13]

Appendix 1 – Python code used for visualizations of forest types in ArcGIS Pro

Python code used for visualizations of forest types in 1997 in ArcGIS Pro:

Number=:

```
tree_type(!GRAN!, !TALL!, !BOK!, !EK!, !BJORK!, !OV_LOV!,
!AGOTEXT!)
```

Code block:

```
def tree_type(gran, tall, bok, ek, bjork, ov_lov, agotext):
    # AGOTEXT-based land class overrides
    if agotext in (
        "Bete",
        "In\"ga In\"goback",
        "Grustag Stenbr",
        "Kraftledning",
        "Tvrig mark",
        "V\"g samt Upplag",
        "Vatten Sj\"",
        "Myr-  K\"rr-  Mo"
    ):
        return "OtherLand"

    # Species dominance (>= 70)
    if gran >= 70:
        return "Spruce"
    elif tall >= 70:
        return "Pine"
    elif bok >= 70:
        return "Beech"
    elif ek >= 70:
        return "Oak"
    elif bjork >= 70:
        return "Birch"
    elif ov_lov >= 70:
        return "OtherLeaf"

    # Mixed forest classification
    total_conifer = gran + tall
    total_broadleaf = bok + ek + bjork + ov_lov
    max_species = max(gran, tall, bok, ek, bjork, ov_lov)

    if max_species < 70:
        if total_conifer > total_broadleaf and total_conifer >=
70:
            return "MixedConifer"
        elif total_broadleaf > total_conifer and total_broadleaf
>= 70:
            return "MixedBroadleaf"
        else:
            return "EvenMix"

    return "Other"
```

Python code used for visualizations of forest types in 2023 in ArcGIS Pro:

Number=:

```
tree_type(!GRAN!, !TALL!, !L_V!, !BOK!, !EK!, !BJ_RK!, !ASP!,
!AL!, !L_RK!, !AGONAMN!)
```

Code block:

```
def tree_type(gran, tall, l_v, bok, ek, bj_rk, asp, al, l_rk,
agonamn):
    # Land type overrides - all mapped to OtherLand
    if agonamn in ("Myr", "Inägomark", "Vatten", "Övrig
landarea"):
        return "OtherLand"

    # Dominant species (≥ 70%)
    if gran >= 70:
        return "Spruce"
    elif tall >= 70:
        return "Pine"
    elif l_v >= 70 or asp >= 70 or al >= 70:
        return "OtherLeaf"
    elif bok >= 70:
        return "Beech"
    elif ek >= 70:
        return "Oak"
    elif bj_rk >= 70:
        return "Birch"
    elif l_rk >= 70:
        return "Larch"

    # Mixed classification (applies when no dominant species)
    total_conifer = gran + tall + l_rk
    total_broadleaf = l_v + bok + ek + bj_rk + asp + al
    max_species = max(gran, tall, l_v, bok, ek, bj_rk, asp, al,
l_rk)

    if max_species < 70:
        if total_broadleaf >= 70 and total_broadleaf >
total_conifer:
            return "MixedBroadleaf"
        elif total_conifer >= 70 and total_conifer >
total_broadleaf:
            return "MixedConifer"
        else:
            return "EvenMix"

    return "Other"
```

Appendix 2 – Maps of stands older than 80 years

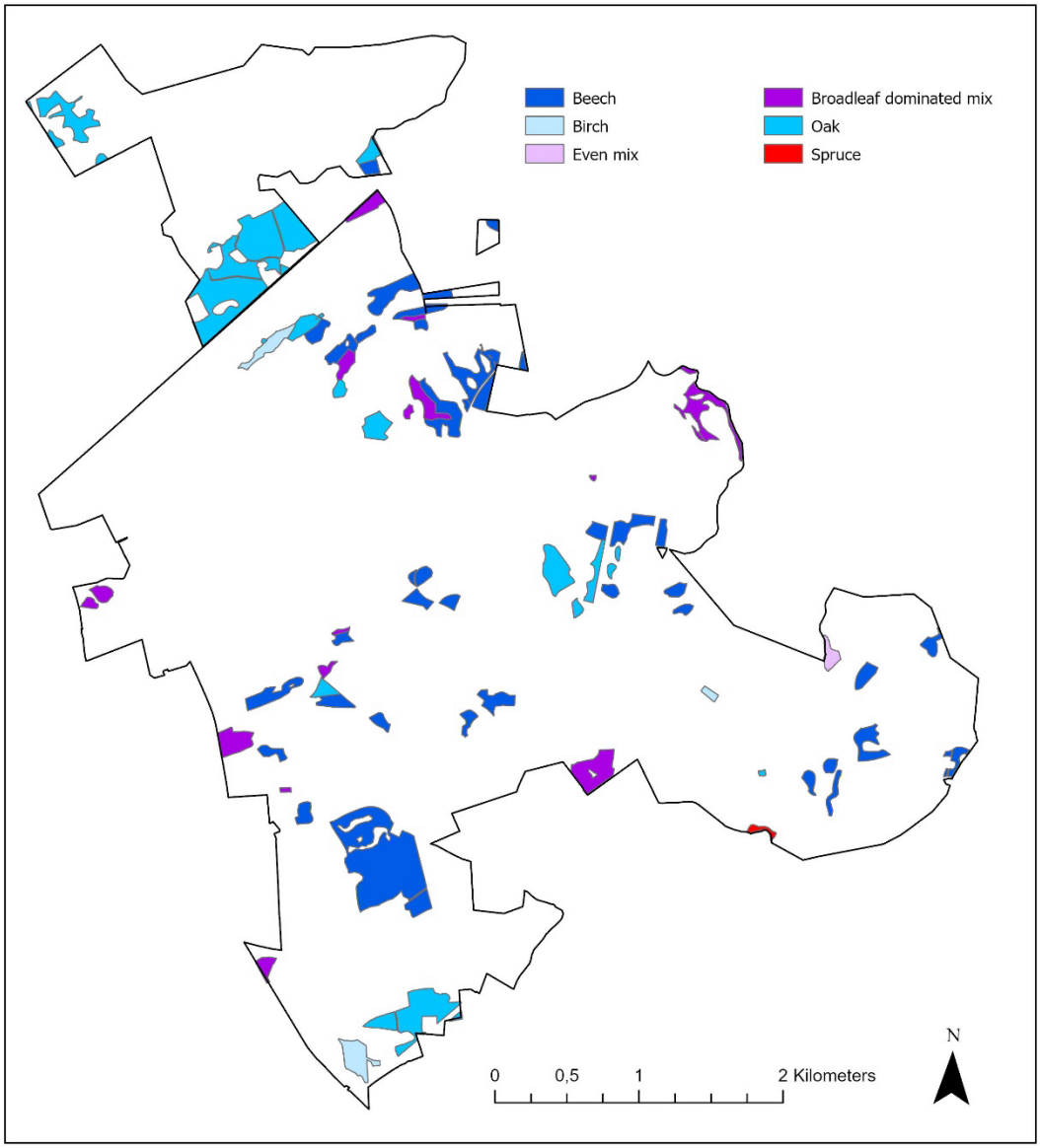

Figure 12 *Stands 80 years or older in 1997 by dominant species in Fulltofta.*

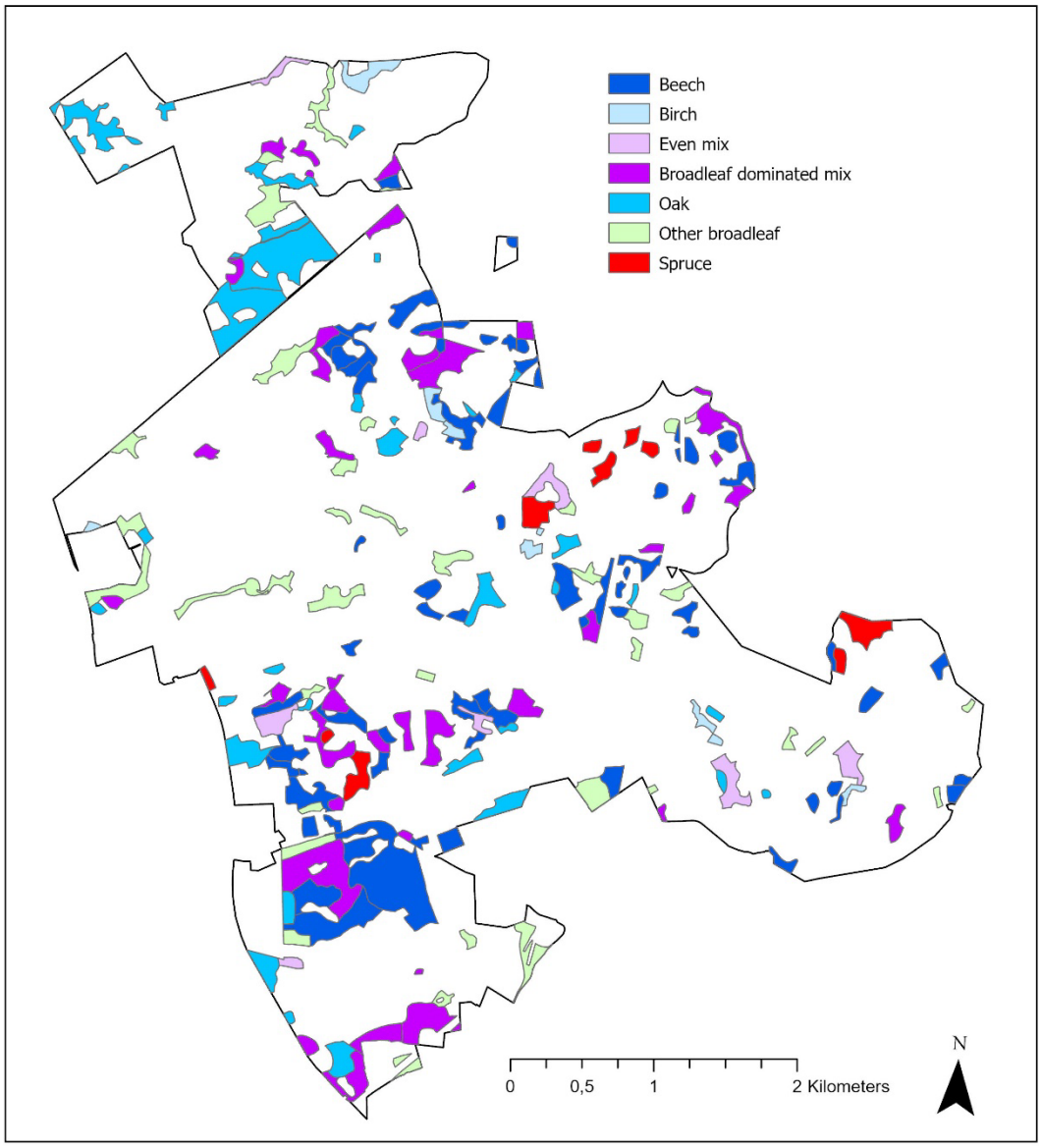

Figure 13 *Stands 80 years or older in 2023 by dominant species in Fulltofta.*

Publishing and archiving

☒ YES, I, Ella Brink, have read and agree to the agreement for publication and the personal data processing that takes place in connection with this.