Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Biology

Elin Aksdal

Norway's Future Forest, warmer and greener?

A study on (1) the early recruitment of oak, red elderberry and spruce on post-harvested spruce plantations; (2) Visions, possible pathways and challenges to achieving more deciduous forest through interviews with the public sector.

Master's thesis in Natural Resources Management
Supervisor: Gunnar Austrheim, Department of Natural History
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Abstract

Due to climate change and drought seasons, spruce *Picea abies* have started to dry out and die. This happened in Moss municipality in 2018, and since then they've wanted to find other options than spruce, in particular deciduous forest mainly comprised of oak *Quercus robur*. Climate change and invasive species are two large threats for today's forests, and restoring forest types important for biodiversity and sustainability can help mitigate this. Through interviews with 5 governmental and 2 non-governmental actors, and extensive field work on 4 former spruce dominant recently clear-cut sites in Moss municipality, the goal of this thesis is to figure out what the primary goal for these forests are, and look at the recruitment and interactions between oak, spruce, and red elderberry *Sambucus racemosa*. The results show huge recruitment for all species across all sites, with significant height differences as well. No other significant interactions where found. Through the interviews it was found that most respondents find recreation and biodiversity more important for a deciduous forest, while production is possible but requires more resources and extensive work compared to spruce plantations. Respondents also believed that forests will change no matter what we do because of climate change. Red elderberry was not considered a big threat by most of them. Active management may be necessary if a quality forest is desired, no matter if it is planned as a production forest or simply a recreational forest. Involvement of socio-ecological concepts is important for studies like these, and adapting to a more sustainable management of forest is necessary if we want to adapt to climate change.

Keywords: Spruce *Picea Abies*; Oak *Quercus robeus*; Red elderberry *Sambucus racemosa*; Deciduous Forest; Norway, Governmental perspectives; Forest ecosystem management; Pathways; Desired States; Climate change; Invasive species.

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Abbreviations/Symbols

LAC	Limits of Acceptable Change
ES	Ecosystem services
SES	Socio-Ecological systems
IUCN	International Union for Conservation of Nature
UN	United Nations
NGO	Non-Governmental Organisation

1 INTRODUCTION

The earths land area is covered by 31% of forest, where about half of this is intact and more than one-third is primary forest with no visible human disturbances or affected ecological processes. Five countries manage over half the forest in the world, and two-thirds of the forest is found in ten countries. Deforestation and forest degradation is an ongoing problem due to land conversion and agricultural expansion. The world's forests contain a huge number of our terrestrial plants and animals, though a precise estimate is difficult to calculate. In 2019, 20 334 tree species were included in the IUCN Red List of threatened species, 8 056 of these were assessed as globally threatened (FAO & UNEP, 2020). Historically, temperate deciduous forest has been largely targeted for logging and agricultural purposes, with these purposes also being the main cause for the decrease of deciduous forest in the world. In Europe, these forests have been intensely used since the prehistoric days, having been used for many different things, only 1% of the original forest remains (Vasseur, 2012).

According to the UN's SDG 15 the agenda for 2030 is *"protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss"* (United nations, SDG 15). Biodiversity is important for many economic ventures, especially the activities related to agriculture, forestry, and fisheries (United nations, 2018). Biodiversity encapsulates the variety of life forms that exist on earth, and the natural patterns they occur in. Biodiversity and nature are declining at an unprecedented rate, and extinction for many life forms is a reality. One of the species currently on this track to extinction is the oak forest ecosystem (United nations blog, 2023).

Invasive species are one of the big reasons for biodiversity loss, as they out-compete the native species and create monocultures. The increase of invasive species is also significant and often because of trade and human trends, and this increase does not look to be slowing down (Díaz et al., 2019).

Climate change is another major driver for loss of habitats and biodiversity, and the rise in temperature has caused many problems for spruce plantations, such as more European spruce bark beetle *ips typographus* attacks and dryness (Økland et al. 2020). After what has been labelled "the summer of drought 2018", many spruce trees in Moss dried out and died, which has them considering other forest types. Therefore, it will be important to develop boreal and boreonemoral forest in the coming decades, to ensure global biodiversity. Study shows that an increase in forested areas can help with the mitigation of climate change (IPCC, 2019). As a part of the European commissions´ new forest strategy (European commission, 2021) to combat climate and environmental change, a plan has been set into motion to plant new trees and focus on restoration of for example deciduous forest.

1.1 Theory

The ecosystem could be defined as a delimited environment where animals, plants, and other organisms interact, in which humans are strongly connected too. The direct and indirect benefits we get from these interactions are then called “ecosystem services”. Decision-making and management decisions are more often than not, based on or impacted by different types of ecosystem services (ES). Forests benefit humans in a multitude of ways and new services and ways are still being discovered (UNECE, 2023).

The significance of societal and natural interactions has only grown stronger over the years, with researchers pointing out that we are crossing the sustainable threshold of what nature can manage before biodiversity loss and climate change get too much (Loft, et al 2016). For better management and perhaps better research when it comes to the natural sciences, we need a better understanding of how humans and nature interact, and we need to develop measures that can meet the challenges of a sustainable “earth-system” (Loft, et al 2016). Some have linked the concept of ES to the concept of “production-chains” as this can represent the “trickle down” of the ecosystem’s byproducts that humans then benefit from and ultimately result in human well-being (Loft, et al 2016). This concept, however, focus more on what benefits humans get from the ES, when we should also consider the demands for access to these ES, and the feedback loop that comes from human actions on ES (FIGURE 1.1).

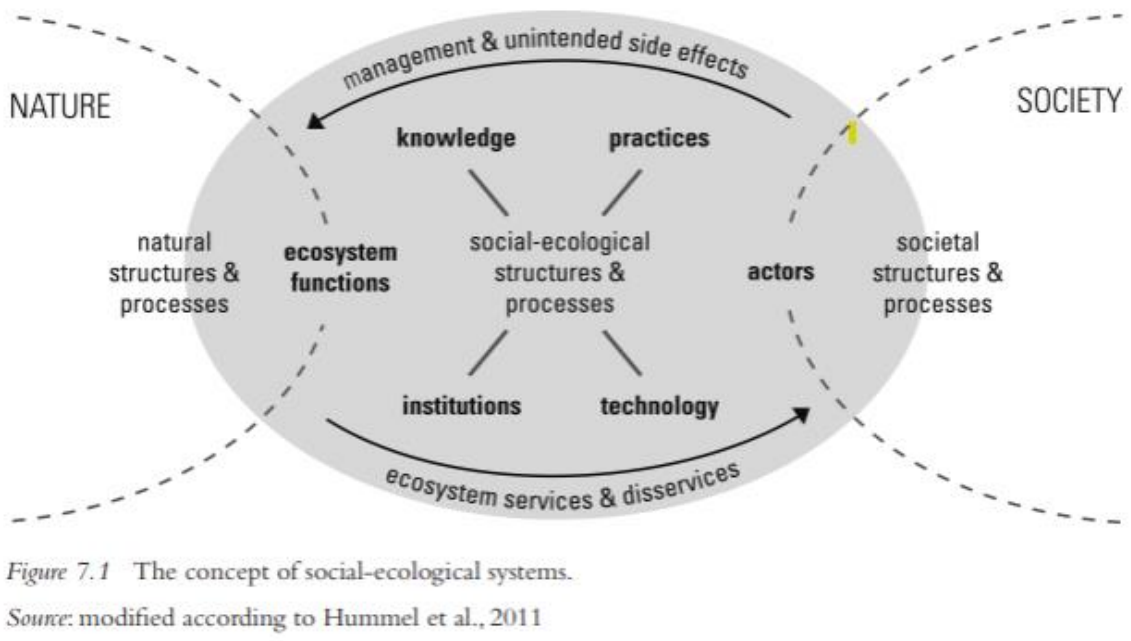

Figure 7.1 The concept of social-ecological systems.

Source: modified according to Hummel et al., 2011

Figure 1.1 *A socio-ecological services model, showing the feedback loop and structure between nature and society (Loft, L., et al 2016).*

The concept of a socio-ecological service (SES) framework is a complex system approach that allows for a deeper analysis on the interactions and linkages between nature and society and supports the integration of different kinds of knowledge (FIGURE 1.1). The core component of SES is the ecosystem functions and its actors. The ecosystem represents the capacity, natural processes, and structures that provide services. While the actors are then the direct and indirect drivers and beneficiaries of the ES. The actors also influence the SES through the act of management or the side effects thereof. Human-nature interactions will also vary between

cultures and contexts, this means that SES can change over time (Loft, L., et al 2016). A multidisciplinary study on the restoration of deciduous forest I believe needs such a view, as humans are so deeply integrated and involved with the forests here, and most forest in Norway is privately owned by the people. If we are aiming to restore oak/deciduous forests, it is not enough to simply do research and plant, we also need strategies, proper management, willingness, and consideration for what the locals want. We also need to consider how this will affect the ecosystem that already exists here.

According to research, the regeneration of temperate deciduous forest not only depends on the past activities or disturbances on a particular site, but also on the dynamics of the site's ecosystem. What the composition of the regenerated forest will look like depends on abiotic and biotic factors that can influence seeds, the presence and impacts of founder species, biodiversity level, and dispersal patterns. Restoration of temperate deciduous forest has been and have often been necessary to help the regeneration process, as naturally regenerated deciduous forest is often of low quality. The way one would restore at a site where deciduous forest has previously existed, include reintroduction of native trees, soil improvement, and a broad genetic base. In most places active, and adaptive, monitoring and management is required (Vasseur, 2012).

Ecological restoration are actions taken to improve degraded, damaged, or destroyed ecosystems, this also includes mitigation and compensation efforts. Restored ecosystems can never replace already intact ones, but it can improve degraded areas and help species and habitats existing there (Hagen & Skrindo, 2023). According to Hagen, et al 2002, restoration purposes and projects are based on the values held by managers and other social aspects connected to restoration efforts. The paper states that *"The goal for restoration ecology can be expressed as establishing a predefined state in a given landscape or area. In our view this predefined state is best described as a 'desired state', a state preferred by some actor*". This opposes the view some may have of restoration as something that will bring the degraded ecosystem back to its "original state", which Hagen, D., et al. 2002 claim to be scientifically unachievable and even misleading. Furthermore, they say that if an "original state" was even defined or established, this would simply be one of the possible "desired states". The concept of "original state" drives many to only focus on finding one best solution instead of exploring other alternatives. When it comes to the concept of "desired state", the focus cannot solely be scientific, it also needs to be based on societal values and what the actors responsible want for the area to be restored (Hagen, et al. 2002). Depending on the degree of degradation, restoration of forest can have various different approaches. In Scandinavia the forest mass is high, and the need for more forest isn't necessary, however, the state and ecological status of many plantations have a tendency to be low which gives reason to restore certain forests to increase their biodiversity (Nordén, 2022).

The concept of Limits of Acceptable change (LAC) is quite old. The framework is there to help establish acceptable and appropriate conditions, and how much human-induced change will be allowed in say, a forest. This also includes how to then control, maintain, and achieve these conditions based on desired wilderness state or condition. There are a variety of things that impact the forest and thus the desired conditions one wants for this forest, such as recreation, grazing, and other human impacts. The process of LAC pays attention to the conditions that are already existing and deemed acceptable (Stankey, et al. 1985). Management practices are often based on wanting to achieve some sort of conditions that they, or others, want, and thus need to look at what management practices are needed to achieve them. LAC is a process that then requires the forest owners,

the municipality, or the state to decide what wilderness conditions they deem acceptable, and from there defining actions to either both protect or achieve these conditions. As any disturbance in a forest causes varying degrees of impact, this process requires the given person or team to identify where, and which types of changes are deemed acceptable to the image they want. This process consists of four components "*(1) the specification of acceptable and achievable resource and social conditions, defined by a series of measurable parameters; (2) an analysis of the relationship between existing conditions and those judged acceptable; (3) identification of management actions necessary to achieve these conditions; and (4) a program of monitoring and evaluation of management effectiveness"* (Stankey, et al. 1985).

1.1.1 Norway

Due to heavy deforestation and various human-forest interactions over the years, the composition of the forests and species have changed significantly from earlier primeval forests (Fjellstad & Skrøppa, 2020). However, forest volume has gone up significantly in the past decades, though the amount of conifers being cut has also increased by 27.6% in the last 10 years (SSB, 2022 (1)). Currently the only species economically important and actively used for wood production in Norway are two conifers, spruce *Picea abies* and Pine *Pinus sylvestris*, these two covers 48% of the total forest area, as well as constituting to 88% of the total annual forest fellings (Fjellstad & Skrøppa, 2020).

The boreonemoral biome extends along the coast of Norway and is often mixed forest with both deciduous and coniferous trees (Bryn, et al, 2012). What remains of the once huge deciduous forest is now only fragments (Olsen, et al, 2020), and it now amounts to only 1.5% of the total forest area in Norway (Nordén, et al, 2021). Deciduous forest also possesses the highest share of red-listed species in Scandinavia, making it important to increase and restore deciduous forest areas (Nordén et al, 2021). The number of broad-leaved species in Norwegian forests have gone up in recent decades, however the cutting has also increased by 180,3% in the last 10 years (SSB, 2022 (1)).

Oak *Quercus robur*, referred to as oak in this thesis, is a common broadleaved species in Europe that can live up to more than 1000 years. Oak has a cultural significance across Europe, and it has been valued for centuries for its hard and durable wood; used for wine and spirit barrels, and historically for shipbuilding. Furniture and floorboards are other important uses of the oak wood. *Quercus robur* and Sessile oak *Quercus petraea* are considered amongst the most economically important deciduous trees in Europe. Oak can be found in the southern part of Norway, however due to human interest and usage, there is a disturbance to their distribution all over. It is a tree with a large ecological amplitude that prefers fertile and moist soils and occurs as a main component in temperate deciduous mixed forests. It can be a pioneer species, having acorns that possess large reserves that are able to survive among other species until the roots are deep enough to allow for rapid shoot growth. However, if the temperatures in winter remain under –6 degrees Celsius, the acorns may die (Eaton, et al. 2016). The deep roots they are able to grow allow oak to remain standing in strong winds and storm, including moderate drought as the roots can access deeper water. Under natural conditions, the oak rarely forms a mono-cultured forest, as their main competitors are other more shade-tolerant species and beech *Fagus sylvatica*. To have successful oak silviculture needs particular attention, where one must select the proper mixture of deciduous species, proportion, and density, which will impact the tree diameter, ring width, and wood knots and thus the quality of the oak. Another important factor is choice of site and management, if the wrong

site is chosen you increase the risk of the oak developing cracks in the timber that can be influenced by soil type and other stressors. Abundance of natural regeneration is also very important. Oak trees are also very ecologically important, supporting many insects, birds, and mammals. In recent years, oak has been subject to a number of threats and diseases which largely affect Qurecus robur and Quercus petraea, it has, as of yet, not been substantial in Europe, but it is under observation (Eaton, et al. 2016).

Red elderberry *Sambucus racemosa* is an invasive species, establishing itself quickly as a pioneer species, and spreading fast in clearcut forests and plantations (Elven, et al., 2018). It is considered a low-growing deciduous shrub, that grow as single shrubs, trees or in clumps (Fryer, 2008). It was introduced in Norway in the 1700s and started as a planted garden bush. And from the 1900´s it spread faster and faster. It´s been found in most parts of Norway and gets spread through its many juicy berries that are highly sought out by birds, potentially over large distances. The species scores high on invasion-potential, longevity, and expansion rate. Red elderberry is found, and establishes, in a wide spectre of nature types. It is hardy and can grow both fully exposed and under cover of shadow, as well as poor soil quality places, but also deep nutritious soil that can be both dry and moist. It can grow anywhere from a forest, fields, roadsides, gardens, farms, and cities. While it does not outcompete other native bushes in forests to any significant degree, it may have an effect on the native trees' possibility for regeneration (Elven et al., 2018).

The Norway Spruce *Picea abies,* referred to as spruce in this thesis, makes up the main mass of the Norwegian forest, because of its high viability and high competitiveness (Caudullo, et al. 2016). In Europe it is one of the most important trees for economy and ecology, it has a long history of cultivation and is used for furniture and timber constructions. Because of its high performance in different site conditions, and the fact that it has been planted massively up to its niche limits, it can be found outside of its natural distribution and in more temperate areas. Most Norway spruce forests are no longer natural forests, but artificial because of cultivation practices. Spruce has the ability to acidify soil and also prefers soil high in nutrients with higher acidity and enough moisture. Seed dispersal occurs mainly by wind, but also by birds and other animals. It is also quite vulnerable to drought and heat, and it is thus expected that climate change will have a large impact on spruce. It is also very affected by storms; it has a shallow root system which causes them to easily be blown down. In later years bark beetle attacks have been prevalent in the spruce ecosystems across Europe (Caudullo, et al. 2016).

1.1.2 Forestry Sector

Social expectations and values of forest use and management will differ and even contradict depending on whether it is public or governmental opinion. Previously there was more emphasis on restoring boreal forests in Scandinavia and northern Europe, but because boreonemoral forests protect biodiversity and could be used as a measure for climate change mitigation, it deserves more attention (Nordén et al., 2019). As of 2022 there are 120 254 forest properties privately owned, and only 474 forest properties that are owned either by a municipality or by county. The states own a fraction more with 747 forest properties (SSB, 2022 (2)).

The foundational laws of the forestry sector are stated in *skogbrukslova* (Lov om skogbruk av 01.01.2006), Norway's forest law. This law's purpose is to promote sustainable management of our forest's resources, with the aim to have active local and national value creation. Further, it is there to secure biodiversity, consideration toward the landscape and the recreational- and cultural values of the forest. The municipalities responsibilities for forest management are visible, forest owners' obligation to report expands, and they are also imposed to have an overview of the ecological values of their forests, which they also need to take into account when practicing forestry. About 30 000 forest owners are a part of Norway's Forest owner association *Norges Skogeierforbund* (Norges Skogeierforbund, 2023). This association has the main task of ensuring forest owners' rights and the best possible framework conditions for a sustainable forestry sector after Norway's PEFC forest standard (PEFC, 2022).

For a forest owner, forest management plans are important to ensure both commercial purposes and the protection of values such as biodiversity, landscape, recreation and culture. All forest owners are offered management plans every 10 to 15 years, depending on plans and grant per county. These plans are developed through analyses and descriptions from remote sensing and field registrations, and thereafter customized to the individual forest owner (Regjeringen, 2011). The ministry of agriculture and food is the highest forestry governing authority in Norway (Lov om skogbruk av 01.01.2006). While the state administrator and county governor's agricultural department are responsible for the states' forestry management, which is based on the politics from the ministry of agriculture and food. The municipality is an independent agricultural authority that is based on *jord – og skogbrukslova*, land and forestry act, their responsibilities lie on smaller scale municipality-based cases. Most municipalities have a forestry manager who appoint forestry grants for forestry measures, manage the forest fond for the forestry owners in the municipality, and offer advice and guidance.

In Moss municipality, all forest owners who have 1 hectare or bigger in productive forest area must have a forest fond account. Together with neighbouring municipality Råde, the total amount in these forest fond accounts were 2.5 million NOK in 2022. This money circulates back to the forest via for example management and silviculture done by current regulation on the forest fonds (Landbruksforvaltningen Moss og Råde, 2022).

1.2 RESEARCH QUESTIONS AND EXPECTATIONS

Main goal: Re-establishing a deciduous forest ecosystem for nature, climate, and sustainable production of deciduous material services. As the restoration of deciduous forest is a complex matter considering its lesser economic value, but high social value in the matter of cultural significance and beauty, as well as its importance for biodiversity and future climate, this needs to be a socio-ecological case study. We need to look at both ecological prerequisites and social prerequisites, such as what important stakeholders think to achieve this so-called "desired state".

The ecological part of this thesis focuses on the recruitment of oak and of two key "invasive" species, red elderberry and spruce. Spruce is counted as invasive in this thesis because we don't want spruce on these former spruce plantations. We wanted to get an overview of the state these sites are in after clear-cutting, and whether the amount of these invasive species have an impact on a potential deciduous (oak) forest. Because the sites are former spruce plantations, we expected a high number of spruce sprouts, and not a significant number of deciduous species. As stated in the introduction, according to Elven, et al., 2018, red elderberry has the potential to hinder the regeneration of native trees. Considering red elderberry is now found in most parts of Norway, and is still spreading, we expected to find red elderberry on these sites, as it can establish itself quite densely in clear-cut fields (Elven et al., 2018).

- What is the density and development of the invasive species red elderberry on the former plantations?
- Are there any positive or negative associations between oak and red elderberry?
- What is the density and development of the spruce recruits?
- Are there any positive or negative associations between oak and spruce?

The second objective is to examine the views that governmental, and NGO (Non-Governmental Organizations) stakeholders involved in forest management hold and what they want for the forest in Moss municipality, and for a deciduous forest in general, to figure out; (1) Potential visions and targets for a broadleaf dominated forest ecosystem. (2) Possible pathways to restoring broadleaf dominated forest ecosystem, and eventual barriers of establishing deciduous forest, including both direct and indirect drivers. (3) Compare the views. We expect that different stakeholders will have different views and values based on their interpretations of their roles when it comes to the restoration of deciduous forests. Many not only have to relate to their own attitudes but also to politics as they represent someone. We are interested in identifying government agencies and NGOs´ perspectives to investigate the different expectations they might have. To restore a deciduous forest ecosystem, including the ecosystem services that follow with sustainable production in mind, we must answer the following questions:

- What are the primary objectives of this forest?
- What type of ecosystem services are desired?
- What do they want for the future use of this forest? How do they imagine getting there?
- What are the potential visions, targets, and possible pathways for a broadleaf-dominated forest ecosystem?

2 METHODS

In this chapter I will talk about the methods and my methodical choices. It is separated into two parts; Quantitative and Qualitative, as this is a socio-ecological case study. This will show the whole process from start to finish, the challenges, and the positives with the chosen method.

2.1 Study area

The study is based in the southeast of Norway in the municipality of Moss (59°26′09″N 010°39′59″E, altitudinal range 0-140 m.a.s.l.). Moss has a population of 51 541 of which 215 people have agriculture as their work. 59,09% of Moss municipality's total land area of 127,76 km² is forested (SSB, 2023 (1), SSB, 2023 (2)). 170 of the forest owners in Moss have 1 hectare or more in productive forest, and there's also many more with less forest area. The municipality owns some forested areas too, two of which are eligible for production. The rest, such as forests near the city or close to neighbourhoods, need to be managed with consideration for many user groups, and the consideration for biodiversity and recreation is important in management decisions (Landbruksforvaltningen Moss og Råde, 2022). In general, the owned forests in Moss are not that big, and the forest owners usually have other main work. The forest owners who lent us their sites did not earn much when they clear-cut their forests and are not particularly interested in earning money from it either. Recreation and taking care of "Rygge Joggen" and making sure that people are still able to enjoy their forests were more important than other things (Berg, 2023).

There are a total of four study sites, each at different sizes ranging from 1-2 ha (FIGURE 2.1, TABLE 2.1), all of them earlier spruce forests/conifer forest. With the exception of site two and four, roughly half of each site was examined due to time constraints. We tried to examine roughly the same amount of each site so that they are comparable. Sites two, three, and four are in close proximity to each other, while site 1 is roughly 1.38 km away (straight-line distance) (FIGURE 2.1).

Table 2.1 *The characteristics of the four sites in Moss municipality.*

Site	Municipality	Forest type	Year of clear cutting	Entire Site (ha)	Examined part of site (m²)	Productivity index
1	Moss	Conifer forest	2020	0,8 ha	4527 m²	14-20
2	Moss	Conifer forest	2021	0,52 ha	5299 m²	14-20
3	Moss	Conifer forest	2021	1,07 ha	5173 m²	14-20
4	Moss	Confier forest	2021	2,3 ha	5 450 m²	14-20

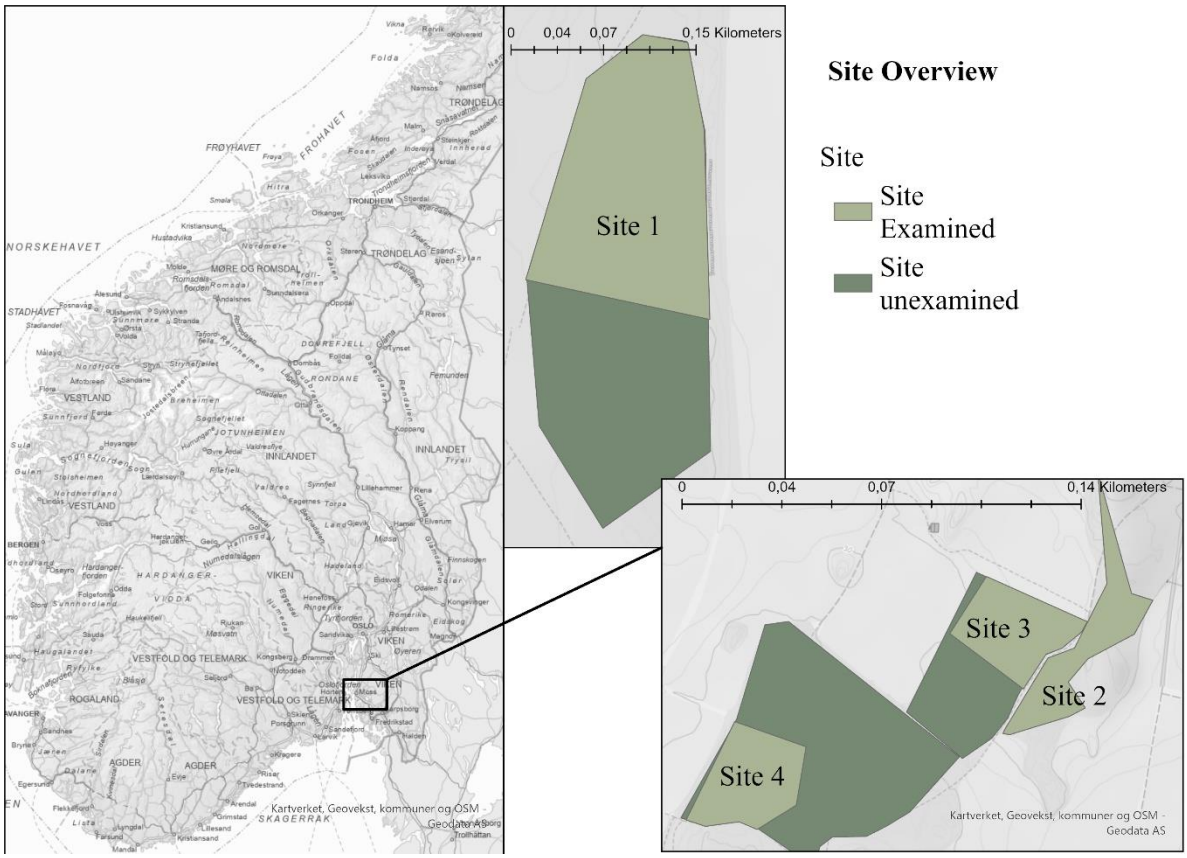

Figure 2.1 *Four sites of different shapes and sizes were studied, light green shows the part of the sites that were examined, while the dark green show the part of the sites that were left unexamined. The whole of site 2 was examined.*

Sites two, three, and four were clearcut during 2021, while site one was clearcut during 2020. The sites have remained almost unmanaged since cutting, where only some tidying (e.g. removing branches etc.) has been done. As site one was "older" than the other three there was a lot more growth of other primary species (raspberry *Rubus idaeus* bushes, tall grass, tiny birch *Betula pubescens* trees thickets) which made the site somewhat difficult to scale at some points. Site two was however the most difficult, with a lot of cut-offs spread across the site, making some spots impossible to walk on, with long stretches of very tall grass as well, which was difficult to examine when wet. Site three also had some difficult terrain, with some thick spruce forest left standing and thickets of high ferns inside, making site three one of the sites that took the longest to scale. Site four stood out as the only site to have ditches across it but was otherwise open except for a little thicket with trees left standing at the start of our first few transects. All four sites had oak trees nearby or surrounding the sites, including other broad-leaved and deciduous trees. The unexamined parts of the sites were for the most part similar to the examined parts. Site one had more grass and growths the further in we got, however. Site three looked overall similar, but also had more grass and trees left standing spread across the site. While site four was more barren the further out we got.

2.1.1 Collecting Field Data and Experimental Design

The protocol was designed after an initial exploration of the sites during early April before field-work in June-July. Using three categories; Target species (Oak), invasive species (spruce, red elderberry), and non-target

species (birch *Betula spp*., rowan *Sorbus aucuparia*). Non-target species were only recorded if found within the same quadrant as a target species. We registered these species by walking in transects across each study site (FIGURE 2.2) and using the protocol created to record our findings (APPENDIX 7.1), we also used a GPS (GARMIN GPSMAP 66SR) to record the position of the species. For each transect, there was a 2.5m search view, and 5m between each transect, the transects varied in length according to the sites.

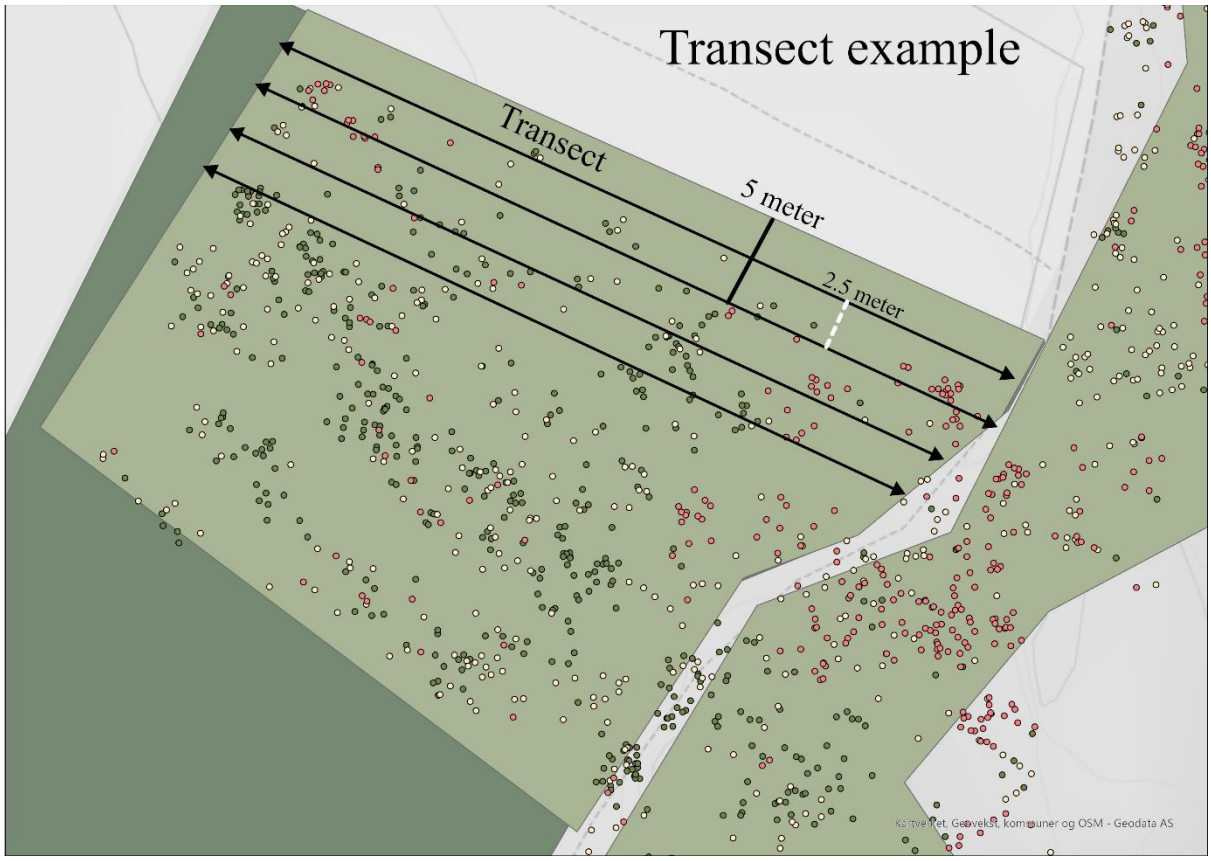

Figure 2.2 *The transects varied in length according to sites, each transect had a 2.5-meter search radius on each side. Meaning one transect was 5 meters wide in total.*

Target species

For each target species we found, we placed down a quadrant (FIGURE 2.3), 50cmx50cm meters large 36 cm above the ground, and marked them with plastic bands, the species were placed as close to the midpoint of the quadrant as possible. Here we recorded distance from the transect, height, diameter, amount of branches, colour of leaves, browsing, bark damage, seeds in the quadrant, point intercept, soil moisture, canopy coverage, and convex or concave ground. If non-target species or invasive species were also found within the same quadrant, they were measured on height and diameter (where relevant), and distance from the transect.

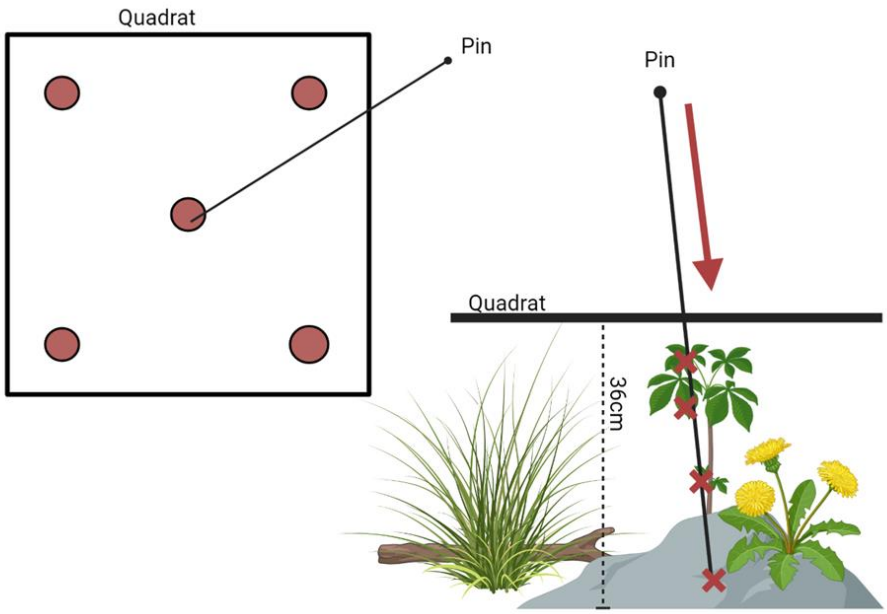

Figure 2.3 *Illustration of how the quadrant and Point intercept works. Source: Berg, 2023.*

Distance from the transect, height, and diameter were all measured with measuring sticks, measuring tape, and calliper. Height was measured from the soil to the top of the bud or basis of the leaf, whilst diameter was recorded at the base of the stem where it is at its widest, to measure growth. Height was recorded for individuals up to 300 cm, those over were recorded as 300cm +. The colour of the leaves was written down to account for the health of the plant.

Browsing was measured on a scale from 0-3, 0 being not browsed and 3 being very browsed. For more details see Berg, 2023.

Point intercept (FIGURE 2.3) was done using a straight metal “pin” with a diameter of 5 mm, the pin is placed in each of the corners of the quadrant roughly 20 cm out, and in the middle. For each corner we counted how many times plant biomass touched the pin, to measure for competition and ground coverage. Here we counted other species, soil, and miscellaneous (stones, dead leaves, sticks, etc.) (TABLE 2.2).

Table 2.2 *Groups we counted for the point intercept and description*.

Groups	Definition
Strø	Dead vegetation on the ground, stones, etc.
Graminider	Herbaceous plants with grass-like morphology (Graminoids)
Andre karplanter	Other Vascular plants
Eik	Oak *Quercus robur*
Bøk	Beech *Fagus sylvatica*
Bjørk	Birch *Betula*
Rogn	Rowan *Sorbus aucuparia*
Rødhyll	Red Elderberry *Sambucus racemosa*
Furu	Pine *Pinus ssp*.
Gran	Spruce *Picea abies*
Bregner	Ferns (class Polypodiopsida)
Mose	Bryophytes
Lav	Lichens
Bringebær	Raspberry *Rubus idaeus*
Blåbær	Blueberry *Vaccinium myrtillus*
Tyttebær	Lingonberry *Vaccinium vitis-idea*
Jord	Soil

Soil moisture was measured from 1-3, 1 being dry and 3 being moist. This was roughly measured by looking at the vegetation and feeling the soil around the plants. If the ground where the plant stood was concave, we wrote down "1", if convex "-1", and if neutral "0".

Canopy coverage was calculated with an app (Canopy Cover Free, heaslon, version: 1.03, released 2016), the phone was placed over the plant with the camera facing the sky. By taking a picture, the app would calculate the canopy coverage. This was done to account for light availability and density around the plant.

Non-target species

Non-target species were only recorded if found within the same quadrant as a target species. The goal was to see how many non-target species are growing in close proximity to the target species, to see if there are any interactions between these species.

Invasive species

Because of how the red elderberry grows (many stems, often spread apart, difficult to find the "main" stem) we only recorded height and distance from the transect, a quadrant was not used. Height and distance from the transect were not recorded for elderberry shrubs under 10cm. For spruce, we did not use a quadrant and only recorded distance from the transect, height, and diameter.

2.1.2 Quantitative Analysis

The analyses were performed using R-Studio [Version 4.3.2] and ArcGIS Pro [Version 3.1.3]. To make figure 3.1 and to show spread, all GPS points were put into ArcGIS pro, oak, spruce and red elderberry were made into their own point map layers. For making the heat maps, density per 4 m^2 was used, as anything smaller did not show on the maps. The heatmaps were made using points to raster specifying a cell size of 2. Further, the maps showing overlap between the species were made using raster to polygon that were based on the density raster, to visualize growth areas for the species.

Standard deviation and mean were calculated by running a simple summarize in R. Two simple histograms were created of the species density and count per site, and a box plot was generated to show an overview of the height spread between the species per site.

For density calculations, spread patterns were not taken into account because of how we transcribed the data. Density was calculated by dividing the number of trees by the m² of each site, $\frac{Number\ of\ trees}{Area\ in\ m^2} = Trees\ per\ sqm.$ This provides an estimate of the tree density in the sampled area; however, it is specific to the sampled area and assumes that the tree distribution in the unsampled areas is similar.

ANOVA analyses were used to test whether there is a difference in height per site $height \sim site\ =$ $height\ differences\ per\ site$. A Tukey post hoc was done to further test the height ANOVA. These simple tests were used considering the limits of my data and are considered acceptable to showcase differences between sites.

Further testing was done via a multiple linear regression model and a generalized linear model. An MLR was used to test the formula $density \sim species\ +\ site$, to see whether site and species have an effect on density. The GLM was used to test whether there is a difference in height based on species and site. This was done using the Gaussian distribution, as height is considered a continuous measurement. For the height models, trees up to 300cm was included. The trees recorded as 300cm + were counted as 300cm tall trees. In addition to the GLM, an accompanying ANOVA and post hoc on the height difference between species was also done $height \sim species\ =\ height\ difference\ between\ species$. The q-q plots of the residuals were generated and can be found in the appendix.

As the models are simple, they may overlook site specific effects. The density models were made without shortening the decimals of the density data. While the models are all based on site level, they could have been tested on transect level as well for more detailed analysis. Overall, these tests are adequate to represent recruitment data, and to look at the differences between the species.

2.2 Interviews

To examine the potential visions, targets and possible pathways for a broadleaf dominant forest ecosystem, interviews with 5 government representatives and 2 NGO representatives were conducted. These were chosen with forestry in mind, choosing those who are most involved with the forestry aspects of Norway's governmental and non-governmental systems. The two NGO's chosen is one of the forest owner associations, as it is important to get the views of someone directly involved with how the forestry currently works, and a nature preservation organisation to also get views from a more eco-centric side. They were all contacted via mail. The interviews were conducted in Norwegian (Native language of all involved), with a recorder and notebook either in person or over Microsoft Office365 Teams with each person separately.

There were 44 questions in total (APPENDIX 7.2), containing main questions and follow-up questions sorted into 5 sections. The five sections were: *Introduction (introduksjon), deciduous forest (edelløvsskog), implementation (Gjennomføring), ecosystem services in forest (Økosystemtjenester i skog), invasive species/threats (fremmed arter/trusler).* The interview guide and the consent form were sent to each individual prior to the meetings, to give them time to potentially prepare. The interviews started off by asking about their background and age, and whether they have heard about any similar projects. The first section is an introduction to the project and questions about their background. The second section is about what they think about deciduous forests in general, their use, their values, and their importance. Section three contains questions about implementation, some questions about economic prospects, and whether oak can be used on the same level as spruce when it comes to production. The fourth section is about ecosystem services in forests, containing questions about biodiversity, ecological value creation, and nature benefits. And the fifth section contains questions about invasive species and other threats and dangers to oak and other deciduous trees. When we were done, they could provide additional input or comments, and I told them they could send an email if they thought of anything else. The interviews ranged from half an hour to an hour and a half in length. The interviews were voluntary, and they were assured the data they provided, including their identities, would be and remain anonymous. Depending on the individual, some questions were not asked as they were not relevant to a particular person. Additional questions were also asked where it was fitting as the interviews went on.

2.2.1 Description

Table 2.3 shows an overview of the chosen participants, everyone except 3M has a background in either biology or forestry. However, 3M has been working as the department manager for nature, climate, and city environment for years and participates in a lot of the planning surrounding the planting of trees and managing trees in and around the city environment. The participants range from 37-62 in age, and all of them have worked with either nature or forest for many years. The participant aliases were made from the order I analysed them and by shortening down the name of their workplaces.

Table 2.3 *A description regarding age, agency, work title, and education for each of the 7 interviewees in this study.*

(ALIAS)	AGE	AGENCY	WORK TITLE	EDUCATION
1NF	~60	Environmental NGO	Supervisor	Biology & Botany
2SF	59	Governmental	County forester	Forestry
3M	51	Governmental	Department manager nature, climate and city environment	Limnology
4SF	61	Governmental	Senior Advisor	Natural Resources Management
5MD	~50-60	Governmental	Specialist forest manager/director	Forestry and biology
6GM	62	Forest association NGO	Forestry manager	Forestry technician
7MR	37	Governmental	Consultant forest and nature management	Forestry

2.2.2 Qualitative Analysis

For transcribing the interviews, I used my notes, listened to the recordings, and wrote them down in Microsoft Word. Some of the interviews did not get recorded, and thus I had to rely on the notes and memory. Responses were then reviewed individually and sorted into categories, and then translated into English.

I have based my analysis on the concept of deductive and inductive methods from a paper by Bingham, 2023. By blending these two methods, one can prevent premature conclusions while also maintaining a systematic and robust analytical process. Codes (TABLE 2.4) were made before going through the responses (deductive method), these were based on the research questions, themes such as threats, based on the interview questions and overall made to fit with what I had learned through the interviews, what I already knew, and what I wanted to find out. However, some codes were also made during the process where new information came up, or if it made sense to make a new code on a certain topic. I aimed to keep the codes as empirical as possible which also reflected the interview content well. The responses were sorted into these codes by making short summaries of the relevant things they said. The entire analytical process was done manually without any automated software assistance. By doing the methodology like this it opened up for a comprehensive analysis of the interview data, providing a deeper understanding of the complexities and many themes involved in forest and nature management. The findings are further connected to the relevant topics of LAC (Limits of acceptable change) and desired states. Deeper analysis than this is beyond the scope of this study.

Table 2.4 *Overview of codes created while analysing interviews.*

Group	*Codes*	*Who talked about it*
Forest Management	Forest Owners	All
	Visions	All
	Targets	All but 6GM
	Pathways	All
	Uses	All
	Forestation	All
	Balance	1NF, 3M, 4SF, 5MD, 7MR
	Fertilization	1NF, 5MD, 7MR
	Threats	All
	Treatment	All
	Acceptable to use invasive species?	All
Forest	Values	All
	Uses	All
	Importance	All
	Current Status	All
	Future Forest	All
	Ecosystem Services	All

2.3 Methodological reflections

Due to not finding any of the species I was originally going to collect data on, my research questions had to change after the field work. Spruce and red elderberry were originally meant to be something additional to the main research questions, not the main focus themselves. I am also limited by my knowledge on statistical analysis, as that is not my strongest side. Had we changed our methodology early during the fieldwork, my dataset may not have been as limited, as most of the things we collected ended up being irrelevant for this thesis due to changing it. However, I believe that we most likely did not have the capacity or the time to add additional "measurements" for spruce and red elderberry, as we already had to cut down on the amount of sites we wanted to look at and also had to cut the remaining four in half. Otherwise, our protocol worked well when we got into the workflow, and it provided a lot of information and reliable data for both of us. The methods we chose were effective and did not take long to do for each individual. Reflecting upon it after the fieldwork and after working with the data collected, there are some things that we could have done better. Such as integrating the GPS data with our protocol instead of them being separate, this would have opened up more analysis and easier data handling. A more detailed look at the sites, and perhaps during a time when the sapling has leaves, could have prevented us going into this thinking there would only be a couple of deciduous species and assimilating thereafter.

The decision to also include interviews with the government sector and NGO's I think contributes more relevance to this study and adds multidimensionality. It is important to hear from those who make the decisions and will be using what comes out of this thesis in practice. It gives insight into the human perspectives and complexities that surround nature management. Knowing what management perspectives already are surrounding oak and red elderberry can be helpful when discussing the biological data and further possibilities.

However, this also means that this thesis does not have a singular focus, and that there was and is a split attention between the two sections which means less time for each section and perhaps broader, less in depth, results. Another factor for the sociological section is that not all interviews got recorded, giving way to potential missing information. As for my positionality I chose to interview those I "deemed" fitting, meaning, some who should perhaps have been a part of the thesis and who could have been very central were not included. The questions that were asked are also very specific to what I wanted to find out and hear about. As a person invested in the biological factors and mostly on natures "side", that might have impacted the questions and interviews despite doing my best at objectivity. The interview guide I think has a good base and questions, but also ended up feeling somewhat the same, and often gave the same answers they had already given. There are also questions that I should have asked that could have been helpful or that I could have gone deeper into.

3 RESULTS

3.1 Governmental and NGO Perspectives

Draught and climate change was mentioned as a big problem and challenge for our current forest by 2SF, 3M, and 7MR. 1NF said that the status is sad and critical, with reduced ecological value, and that there is little old forest left, were 1NF said that under 20% of our forests have dead or old trees, and 70% of the forest is affected by clearcutting. However, 4SF said that the status is both good and bad and that forest reserves have gone up by 10%, and they get more valuable. 4SF also mentioned that forest owners have started trenching in the forests out of nowhere, without consultations or advice to do so, and that there are a lot of different agendas internally within the forestry sector. 2SF said that economically, these are good times with high prices and that we've never had a bigger volume of forest than today in known history. 2SF also mentioned that monocultural forests will be more at risk from climate change and insect attacks. 1NF, 2SF, and 5MD also mentioned that half of our red-listed species are in forests, and that deciduous forest in itself is also red-listed. There's been a lot done in recent years according to 5MD, but also said that according to NIBIO, our natural forest is steadily decreasing, so there is room for improvement. 6GM, who is most in contact with the production side of forestry, said that the trend seems to go upwards and that the "so-called" green shift is much discussed now. However, there is a conflict between biodiversity and production, which there is a lot of.

Most of them (2SF, 4SF, 5MD, 6GM, 7MR) answered that there will be more broad-leaved trees, more pine, and less spruce as that will be affected by drought and other climatic challenges, regarding our future forests. However, 6GM thinks that spruce will continue to dominate together with other conifers, because that is the norm today, and that norm will continue for a long time. Both 1NF and 7MR mentioned that we will have more forest because of the tree line rising. Change will happen both in the forest and the forestry sector, and that is not a choice we have, according to 5MD, but how it will change is difficult to say. 5MD also points out that if an area is unable to have healthy spruce, this doesn't necessarily mean that the area is able to hold other tree species.

3.1.1 Visions and targets for a deciduous forest

Overall, the targets mentioned for the forests were more types of trees for biodiversity, and more robust forests (1NF, 2SF, 4SF). Transitioning from clear-cutting to selective cutting instead was also mentioned (1NF, 3M, 7MR). 2SF says more knowledge is needed as many forest owners don't know or aren't interested in their forests. Targets for the forests also depend on whether the forest is for recreation or lumber production. 3M wants to manage the forest in the best way possible and to keep the city and city environment green by preserving the city trees; Targets for management should include biodiversity, climatic challenges, recreation, aesthetics, and landscape. Moss municipality also has the slogan "*Skapende, varmere, grønnere*": Inventive, warmer, greener. Three objectives fall under this slogan: reducing greenhouse gas emissions, climate adaptation, and preserving biodiversity. 4SF thinks we need paths for people to hike on. And instead of planting a new generation of spruce, plant a new generation of deciduous trees, which will give the forest a new and different

biodiversity aspect than if we plant more spruce. 4SF also says that Norway will have more biodiversity if we turn the production forests into broad-leaved trees, where birch also count because they let more light in, which then gives different life to the ground. Furthermore, 4SF also says that biodiversity and climatic challenges play a big role in the management of the forest. And the bigger the population gets, the more important recreation, aesthetics, and landscape get in the management of the forest. 5MD said that for the environmental aspect, they want to restore the important habitats for threatened species and nature and to get the ecosystem back. 5MD also pointed out that a pure oak forest or a pure spruce forest is not a well-functioning ecosystem. 7MR said leaving behind trees so they don't have to plant more all the time, and that changing the forest is a must.

Their visions for the forests were varied, a couple of them mentioned the same things, such as letting the forest have varied age spectrums, dead wood, and old trees. Both interviewees who work for Moss municipality (3M, 7MR) want more focus on biodiversity and making the forest accessible for recreational purposes. 3M argued that we should be restrictive when it comes to taking down trees, having various tree species of various ages, and making people happy by using the forest. While 7MR said that when it comes to municipality-owned forests, the economic aspect should not be the most important, and that they should be more considerate toward the general public. 7MR described a forest with different strata, leaves on the ground, different-sized trees and trunks, wildlife, and bird song, and that you don't necessarily see the animals, but you are aware of them being there. 7MR commented that this mindset is more for the good of the local population than the economy. 2SF said that they don't count a forest as a forest unless it is 1 hectare or more, and if the climate develops like it seems it will, then deciduous trees will multiply no matter what we do. While 4SF thinks it will be interesting to see if it is possible to do something other than spruce. 4SF's vision is a forest with many old trees, but with huge variety, in terms of age and species, and that it will cover the biggest possible area. And also mentioned that production and biodiversity need to go hand in hand in an environmentally friendly and sustainable way. 5MD said it is difficult to answer what a deciduous forest can look like, as they can be quite varied. However, 5MD mentioned good condition, varied age spectrum, letting the trees grow old, dead wood, and different layers/strata, a "natural ecosystem". In the aspect of a production forest, 5MD also thinks it's nice with both spruce and beech. We also need more restoration of different ecosystems, and sustainable management of the forest's recreation, aesthetics, and landscape play an important role in the management of forests, but which one of these aspects gets the focus depends on the politics at play. 6GM thinks that in many cases, a mixed forest could be okay or even the best option. But it is important to not let the spruce take over if so, and mixing in pine is already in practice. Pine also needs a lower site productivity index than broad-leaved trees according to 6GM.

3.1.2 Pathways and potential barriers

Regarding pathways to a deciduous forest, 1NF said that the forestry sector needs to change from mainly spruce and that Norway must keep its word on restoration according to the UN's 10-year plan. The forestry sector also needs a change in mentality, and the Ministry of Agriculture and food needs to be challenged on the topic of deciduous forests. 1NF also said that we need to think about quality AND quantity, the continuity of the dead trees, improvement of knowledge for forest owners, better strategies, and effect mapping. Pricing deciduous trees similarly to spruce is also needed. 2SF pointed out that barely anyone plants deciduous trees today, as people are mostly reliant on natural growth when it comes to these species. To grow a deciduous forest, one must thin it every couple of years to allow for light. It needs some sort of overwood that casts a shadow, such as birch

or aspen *Populus tremula*. A species that grows quicker at least, to stand over the small deciduous trees as they grow, as some sort of "screen". Afterwards, this "screen" needs to be opened slowly and carefully, if you remove it too fast the oak will grow too quickly and grow "light shoots", which reduces the quality of the lumber. So, if you want quality lumber, you need to ask yourself what you want to do with this forest. Additionally, 2SF said that we need more professionals and to reevaluate how we do things. In the same vein as 2SF, 3M said that it is important to have good academic competence to do it right. 3M also mentioned that municipality-owned forests could be used as "experimentation" grounds and be in the lead with for example selective cutting. And then afterward, show what they have learned from the process to the forest owners. Additionally, 3M said to facilitate where the forest is less vulnerable, because if the population uses the forest more it is easier to protect, as that forest then gains the affection of the locals.

4SF mentioned an example of a forest that was bought by the state, where they clear-cut all the spruce and then let the forest naturally regenerate, it is now a big broadleaved forest. 4SF called this "restoration clear-cutting". When it comes to oak, 4SF said that oak is slow to come by itself, and therefore needs to be planted, preferably with local genetic material. However, for nature reserves that are mostly used by people, 4SF said that natural growth is preferred, letting the forest take its time and go through all its phases. But if we want more deciduous forests, then we need to look at sites that are not reserves, which means production forests. Here economy is a key aspect, and forest owners need to know they'll get as much money as they do for spruce. We and the forestry sector need to think new and use public means, 4SF said. Lastly, 4SF mentioned "Innovasjon Norge" (provides various services to Norwegian businesses) should research deciduous tree production. 5MD has the same idea when it comes to reserves vs. production forests, where if it is a nature reserve/protected forest you simply let nature run its course. However, 5MD said that you need clear goals for what you want to achieve, what services you expect, and what condition you are aiming for. And further, what are the possibilities to achieve these goals? 5MD also pointed out that where you are makes a difference, what exists there today? And if you already have a mix, then seed dispersal might happen. Furthermore, production forest owners will have to leave behind certain key biotopes, where it then might be possible to do some restoration. 6GM, who deals with forest owners of production forests, said that you need deep and correct soil and that you need to both plant and have natural growth. Additionally, there must be a market for it in the future, and a climate that accommodates a deciduous forest. 6GM also mentioned that it will be expensive, so the forest owners need to accept this shift, and accommodation for them to be able to do it as well. 7MR again pointed out that at least in the first round of experimenting with deciduous forests, you must look away from the economic aspect. And that it will involve a lot of trying and failing, you need to have time, and the best thing to do is to keep the attention on it. 7MR said to leave behind seed trees that can regenerate and to keep down the other species that start sprouting. However, 7MR did say that you can't completely ignore the economic aspect, as it is important for building houses and so on, which means you also need space in the forest for that as well.

Though some management aspects have been mentioned earlier in the text, 6GM and 7MR had a bit more to say on the topic. Where 6GM said that climate needs to be considered, as the forest is very wind resistant, however, this is dependent on where you are. Additionally, 6GM said that recreation, aesthetics, and landscape also need to be considered, but you need to keep in mind that one day the forest will be felled. Location is also mentioned by 7MR, who pointed out that when the forests are near a city there's more focus on recreation, while for forests

that are far away from people, they put more focus on biodiversity. When the forest isn't meant for recreation, it doesn't matter if there is a lot of dead wood around, but with a recreational forest there needs to be space for tents and hammocks.

An important aspect of this topic is also the threats and potential barriers that can hinder the possibility of a deciduous forest, or a different forest at all. 7MR said that it will be difficult to change the forestry sector in a small timeframe such as 10 years, because the forestry sector adapts slowly. Additionally, everything called "forest culture" and "forest theory" is based on spruce and pine. It is what we know best in a production and economical aspect, and our sawmills are calibrated to it. 7MR also said that maybe we will change values, but at the same time we don't have many alternatives (considering the spruce struggling), and because of the climate we are limited in what we can do. Elm- and ash-sickness was mentioned by 1NF, 2SF, and 6GM as a threat. Invasive species were mentioned by most of them as a threat (1NF, 2SF, 4SF, 5MD, 6GM). 5MD thinks invasive species will cause pressure in the future. While invasive species were also mentioned by 3M and 7MR, they did not consider them a very big threat in the forest, 3M thinks they are a bigger problem in open fields. In the context of invasive species, 2SF said red elderberry is a big competitor that is hard to beat, and the seeds are also spread by birds. 4SF also said that red elderberry is a big threat and that it is difficult to produce forests because of it. In the context of oak, 6GM said that the oak needs to get a proper take in the forest so that the red elderberry doesn't take over. A problem that was mentioned by both 1NF and 2SF is the possibility of the earth being "ruined" by pine needles that have acidified it. 2SF pointed out that past spruce plantations won't have the ideal soil quality that deciduous trees require. However, 1NF said that oak is more robust and handles acidified soil better than other deciduous trees.

Storms were mentioned as a big threat for trees when they have leaves, by 2SF, because they are more likely to fall. However, 2SF also mentioned that there aren't many big threats toward deciduous forests, as there will be more of them either way as a result of climate change. 2SF did however say that everything deciduous or broad leaved is threatened by grazing, this was also mentioned by 5MD, though 5MD said grazing might be more of a problem for the ground vegetation. Browsing is also considered a threat by 7MR. Construction and urbanization are considered a big threat by 3M, pointing out that they use areas for train tracks, apartment buildings, and so on. And that this causes loss of green corridors, and that animals lose their habitats. 3M also mentioned a potential threat from pesticides in the context of agricultural land, where it drains into the forest for example. 7MR thinks the transition to deciduous forest will be difficult, as 7MR thinks the silviculture will be completely different. 7MR said the economic aspect of it will be a lot more difficult and also a difficult transition. *"From, call it, easy spruce forests, where it's just planting and tending of young stands. For deciduous forest, you need a lot more silviculture and tree trunk branching, which is very heavy work and a lot of action to take."* Another thing, 7MR said, is perhaps the view we have on the deciduous forest, the forestry sector is not used to forestry in these types of forests. *"And people cry when you clear-cut a spruce forest, but if you cut down an oak forest for example, you might as well flee the country"*. The problem is then the transition over to using such a forest, and then viewing it as a resource, 7MR said, considering it is today viewed as a recreational forest.

3.1.3 Treatment of invasive species

Overall, the consensus is that we don't know how to deal with sickness or invasive species effectively yet. 1NF says that it is important to not introduce more invasive species at the very least. 2SF suggest that we let other trees grow big enough to outcompete the red elderberry as they need a lot of sunlight and cutting them down does nothing. 6GM said that spraying with chemicals is one way, but that it may be expensive and could affect other nearby species. 4SF also said a lot of money, effort, and resources. While 5MD thinks that it is a challenge to get nature prioritized, but when it comes to invasive species, we need to do something about those already here and it is very important to stop more from spreading or introducing new ones. Once they are here, they are very difficult to get rid of, but 5MD said that we could potentially have a continuous felling of red elderberry.

3.1.4 Importance, values, and uses

All seven answered yes when asked if it is important to conserve/preserve deciduous forests, and biodiversity was listed as one of the factors making it important by all of them. 1NF considers its values as its extreme biodiversity and distinctive populations and said that we have a special responsibility for the deciduous forest. 1NF also mentioned that there are many threatened species in the deciduous forest and that this type of forest is more adaptable to climate change, and that more varied forests have fewer insect attacks and sicknesses because of their more balanced biodiversity. 2SF said that there are bigger ecological and aesthetic values than economic values, and because of this, the trees that aren't protected are often left standing anyway because people value them. 2SF also mentioned historical value in the context of boatbuilding. 3M considered the importance to be the preservation of what makes Moss municipality special and said that old-growth forest is very good for public health. And pointed out that walking in the forest 3 times a week for 20 minutes does a lot for mental health. Furthermore, 3M mentioned that they have a responsibility to care for the forest in Moss, and that the forest is important for sustainable development in Norway, which 3M considered a conflict with earning money from it. Additionally, 3M mentioned that the forest is important for the protection of people and buildings. 4SF said that we could use more of deciduous forest, but many of the nature reserves won't get any bigger or smaller, as of now they are static. 4SF added that forest is one of the most important nature types we have, and big parts of Norway is forest, which is why it is important for sustainable development. 5MD considered the deciduous forest values as timber, temperature control, and its effects on the local climate. 6GM said that more deciduous forest creates a more varied forest picture than what we have now and said that the forestry sector might have planted spruce a lot where it shouldn't have been planted. Other than that, 6GM said that for the general population, recreation is probably most valued. Recreation was also mentioned by 7MR, and that recreation is more important than we think, and trees are important for health. *"Forest is important personally, because of wildlife and recreation, but work-related also economically."* 7MR mentioned wildlife that only have small corridors left as another value. And lastly, said that Norway is built on lumber, all our houses are timber, and it's what we've based our lives on for a long time.

As for uses, recreation, furniture material, and flooring were most mentioned. Burn-value was mentioned twice (2SF, 6GM). 4SF said that there are high prices for good quality oak, and deciduous forests could be used as plantations if there is silviculture. Additionally, 4SF said that a form of use is to just let the forest be for its biodiversity, for example, society uses the protected areas as deciduous reservoirs – society has decided to use it to promote biodiversity.

3.1.5 Possibility of forestry

When asked about whether they are often in contact with forest owners, all of them, but one, answered that they rarely are. The outlier is 6GM who is often in contact with them regarding timber, where they offer consultations about felling and regeneration. However, 6GM said that even though they have information on their website, they could have more about deciduous forests. I also asked whether they have easily available information for forest owners, either on their websites or in pamphlet form. The consensus was that this was lacking. 1NF said they have information about forest protection and upkeep of forest, however. 5MD also said that they have a website with information, but it is only about voluntary protection of the forest. 7MR said they have some information on their website; however, the plan is to have more forest sites available on the municipality website. 7MR did mention that they are not a very big forestry municipality and that they do send out newsletters that offer reminders about planting and tending. But when forest owners were asked if they wanted the newsletter regularly, only one out of 150-200 answered. 7MR said this was a bit surprising, but continued saying that most have small forests they never do anything with, and the bigger ones know what they are doing or use Glommen-Mjøsen.

On the possibility of forestry in deciduous forests, 1NF said that it is possible in the long run, but only parts of it can be used for production with selective cutting, while the remaining parts stand as conserved forests. And for this to work it needs a large and well-made plan. Another problem 1NF mentioned is the fact that no one produces deciduous trees in Norway. 2SF considers forestry in deciduous forests as expensive and not for "regular" people. Additionally, 2SF also mentioned there is no planting of deciduous trees today. However, in bigger volumes, it could be possible to do forestry in such forests. Furthermore, 2SF said that it will be difficult both in theory and in practice, it is a lot easier to plant spruce, as deciduous trees have triple the growth time and need a lot more resources. Multiple species will also mean less volume in the spirit of economic value, and the main focus should be beech and oak if so. Another thing to be considered 2SF said, is the time perspective, forest owners won't get the money for what they plant, but maybe the grandchildren will. Additionally, very few of them have their forest as their main income, and few have large enough areas to live off. This also means that they have limited time and knowledge to actively manage a deciduous forest he said. 3M leans more towards protecting the forest so that she can help make sure we don't cut down everything. 4SF pointed out that there is no tradition for deciduous forest in Norway, but if there were to be forestry it needs to have silviculture, as free-growing deciduous forest won't produce quality timber. 4SF also said it needs to be Norwegian oak that gets planted, and that we need to systematically produce oak for planting, it should be a mix of planting and natural growth. 4SF also pointed out that biodiversity will still increase even if the forest is cut down in a hundred-plus years, but change will only happen if the market sees it as profitable. 5MD said it is possible to make a production forest out of the deciduous forest, but here in Norway it isn't really bet on *"Spruce is quick and easily dealt with, so whether it outcompetes the spruce is difficult to say, but all timber is a product"*. 6GM said that yes, it is a possibility, but first and foremost there needs to be an interest in buying. *"There aren't many sawmills here, but in Sweden there are a couple of sawmills that take in deciduous trees, so it should be possible here too"*. 6GM said that there isn't any deciduous timber coming in now, but there were some years ago when there were still sawmills for it. However, today when there is talk about broad-leaved trees, it is primarily birch they get questions about. *"If we were to focus on a deciduous species it would be oak, ash too, the timber has a nice structure. Planted beech could also be relevant".* 7MR said that the way the forestry sector is today, if we

plant oak, you don't really get any income from it in the future, even if that shouldn't be the main focus, there needs to be a balance. *"I don't really want to plant spruce, but I don't really know what else to do"*. Furthermore, 7MR said that they have planted spruce in some places but are holding back to look at alternatives, such as a mixed forest for example, because spruce has biodiversity too. When it came to a pure deciduous forest for production, 7MR was a bit unsure, pointing out that the quality isn't particularly good. And that might be because of the silviculture, or lack thereof. *"It's exciting to look at, how will the silviculture be for deciduous forest? And will it be profitable?"*.

When asked if it is possible to have a balance between forestry and biodiversity five out of 7 said yes, it is possible, the other two either hadn't thought about it or it didn't come up in the interview. 1NF said we need more conservation areas for it to be possible. 3M said *"One has to believe that it is possible, but it isn't obvious how. If we can get a more careful forestation, it will be more expensive, but we will get a more balanced forestry sector"*. 4SF said that we might need a combination of carrot and whip for it to be possible, *"We don't have a perfect forestry sector, but they do a lot of good as well"*. 5MD said that there will be discussions, and what the outcome of those are, 5MD doesn't know *"protection of parts of the forest will be, and is, the most discussed and I think that discussion will last forever"*. 7MR said that selective cutting matters then, and what/where the forest is. And said that if the forest has a good site index and is far from people, then maybe it could be selectively cut or potentially cut more. And then for places that are used a lot, cut less there, and to keep in mind that there is always a trade-off.

3.1.6 Using invasive species

There were some mixed answers when asked if it is acceptable to use invasive species, with most of them answering no or being sceptical. However, two did mention Christmas trees that get taken down before they can spread their seeds (2SF, 4SF). 1NF brought up Sitka spruce *Picea sitchensis* and sycamore *Platanus occidentalis*, two species that have become uncontrollable, and also said that some invasive species possess root systems that can hurt other plants. 1NF also pointed out that it would be politically unwanted considering the amount of invasive species we already have, and that it would not be sustainable either. 2SF said that Norway is one of two European countries that have the strictest laws surrounding invasive species and thinks it's too strict. And continued by saying that there are some species that would do well in Norway, and that a lot of the trees we consider invasive have been here before *"With the way the climate is evolving, maybe we need to use something better than what we have"*. 3M pointed out that they are currently trying to fight invasive species, they've made a position specifically to fight invasive species, used many hours to fight them, and they can't defeat it other than keeping it a bit in line. However, 3M said, if there is a species we currently "lack" or are "missing" then 3M wouldn't particularly view it as a threat. 5MD, who is sceptical, said that the world has a long history of moving species, and the amount of successful stories is relatively small. The risk of using invasive species is so big, that it's difficult to imagine there will be any success. 7MR, who said no, said that theoretically speaking, everything has been an alien species at some point in some way. However, ideally, we should just let it be, because 7MR doesn't know the consequences of it *"Look at those that we have planted, we planted them and it was fine, and then 60-70 years later it isn't fine. We don't know the consequences of it, and that's what I'm scared of, the long-term consequences are scary"*.

3.2 Field results

3.2.1 Species composition

The spread of the three species oak, red elderberry and spruce can be seen in figure 3.1. Overall, site one had the lowest count on all species except for red elderberry. Site two had the highest count of both oak and red elderberry. Site three had the highest number of spruce, and, lastly, site four had the lowest number of red elderberry.

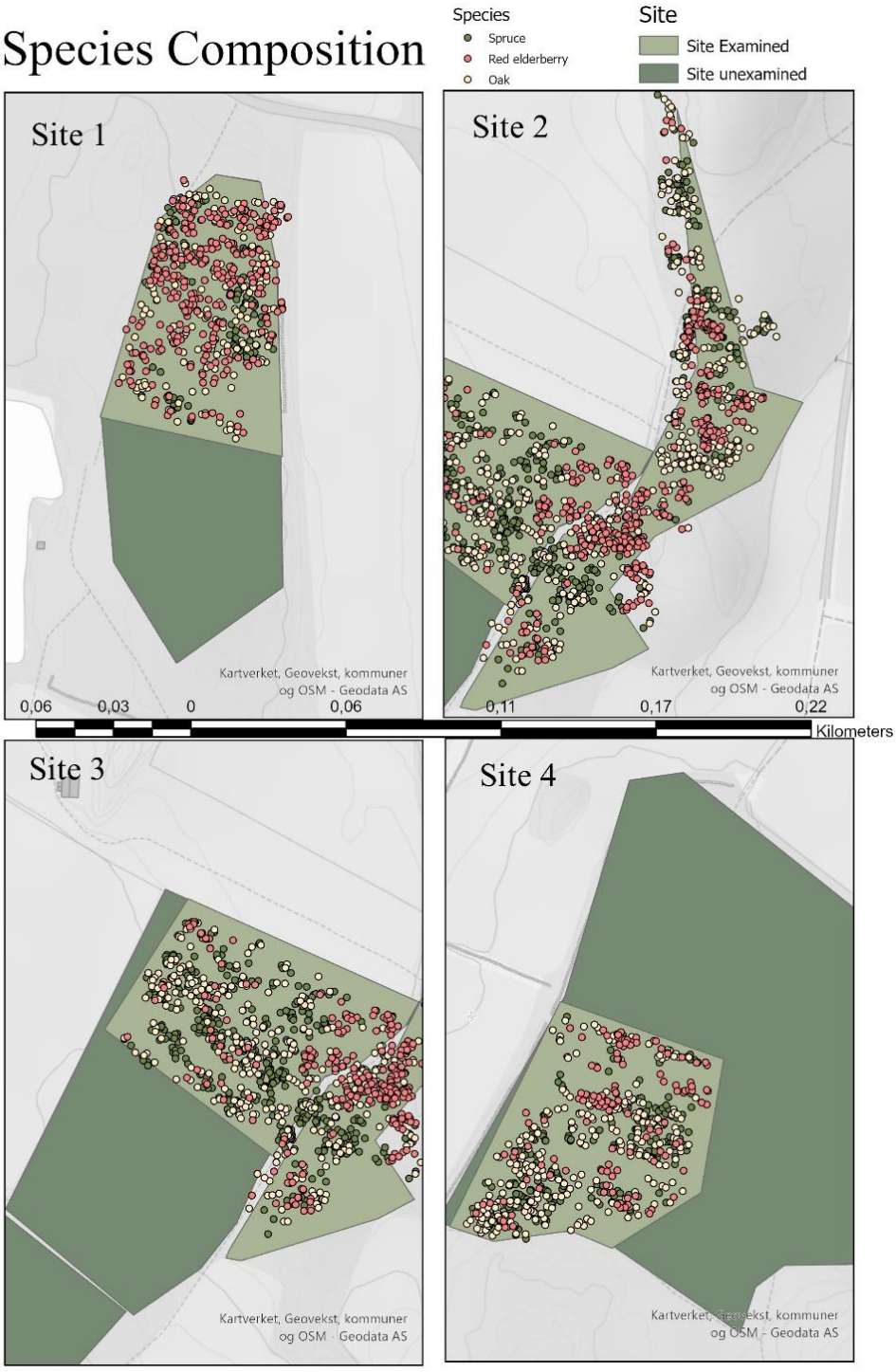

Figure 3.1 *The point overview of red elderberry (red), oak (yellow), and spruce (green) for all sites.*

Across the four sites, the mean number of oak is 271, with an SD ± 73. Spruce has a mean of 236 and an SD ± 95, while red elderberry has a mean of 323, and an SD ± 67. Overall, site two had the highest number of all individuals found, with 1057 combined (FIGURE 3.2).

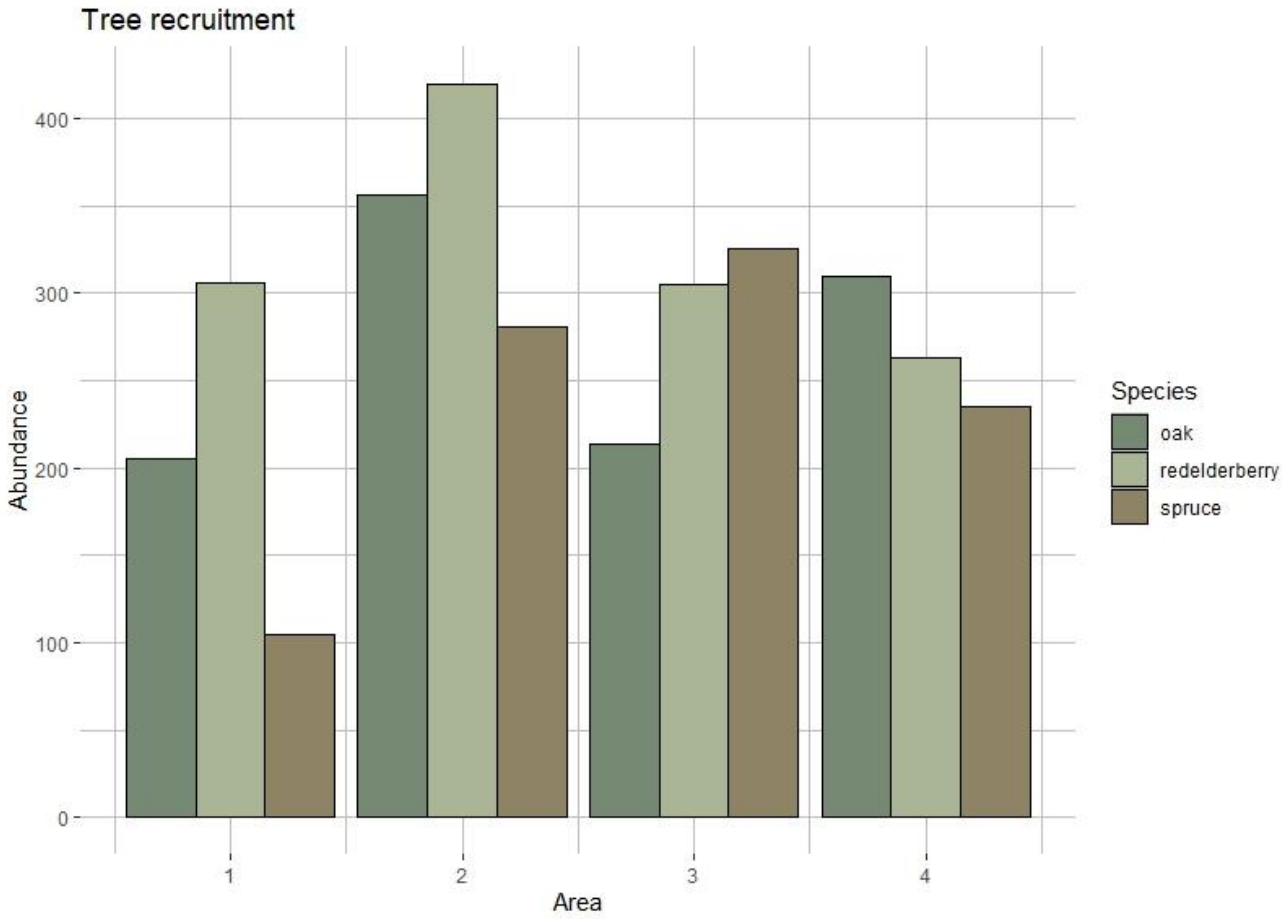

Figure 3.2 *Depicts the tree recruitment of oak, red elderberry, and spruce across the four sites.*

3.2.2 Species density

By dividing the number of trees found by the square meters (m^2) of each site (TABLE 2.1), the number of trees per m^2 was found (FIGURE 3.3). Oak has a density range of 0.04-0.07 trees per m^2 across the sites, red elderberry ranges from 0.05-0.08 trees per m^2, and spruce ranges from 0.02-0.06 trees per m^2 across the sites.

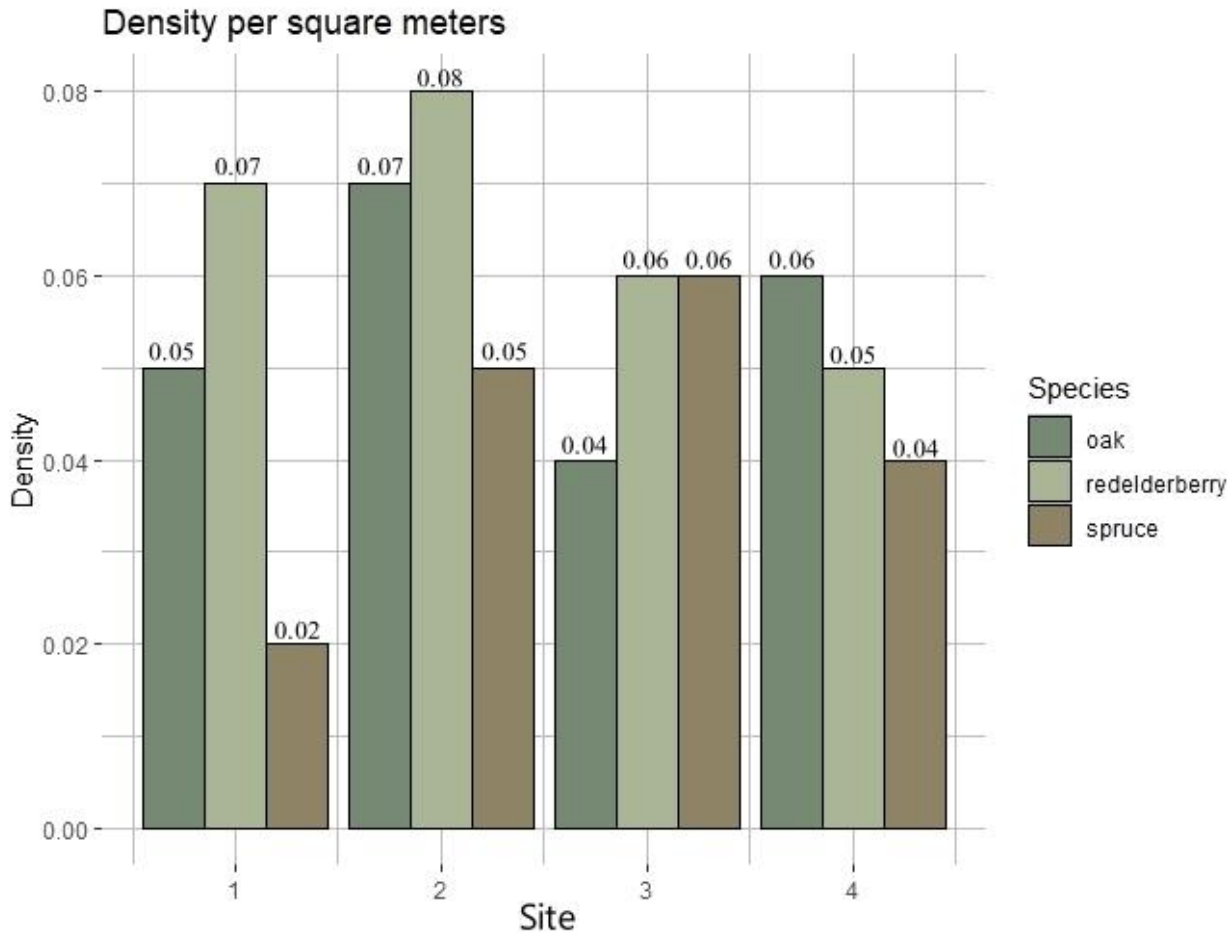

Figure 3.3 *Amount of trees per* m² *is based on numbers from each site: nr trees / area_ m² = trees per m².*

An ANOVA analysis shows that there is no significant difference in density between sites for oak, spruce, or red elderberry (TABLE 3.1).

Table 3.1 *ANOVA analysis testing if there is a difference in density between sites.*

ANOVA	Df	Sum Sq	Mean Sq	F-value	Pr(>F)
Oak	1	0.0	0.0	0	1
Spruce	1	0.000245	0.000245	0.778	0.471
Red elderberry	1	0.00032	0.00032	3.556	0.2

Further, an MLR suggests that there is no significant overall effect on density by species or site (TABLE 3.2).

Table 3.2 *Multiple linear regression model analysis on the formula density ~ species + site.*

MLR	Estimate	Std. Error	T-Value	Pr(>|t|)
(Intercept)	0.047500	0.009930	4.783	0.00305 **
Red elderberry	0.010000	0.009930	1.007	0.35280
Spruce	-0.012500	0.009930	-1.259	0.25487
Site 2	0.020000	0.011467	1.744	0.13174
Site 3	0.006667	0.011467	0.581	0.58214
Site 4	0.003333	0.011467	0.291	0.78107

Density is further visualized with heatmaps made in ArcGIS pro. As previously stated, red elderberry has a density range of 0.05-0.08 trees per m^2. This is visualized in a spatial analysis heatmap, figure 3.4.

Figure 3.4 *The red elderberry spread and density for all four areas. Each square is 4* m^2*, where the colour red indicates low (light red) to higher (dark red) density. Does not show red elderberry under 10 cm.*

Spruce, with a density range of 0.02-0.06 trees per m^2, is visualized in a spatial analysis heatmap figure 3.5.

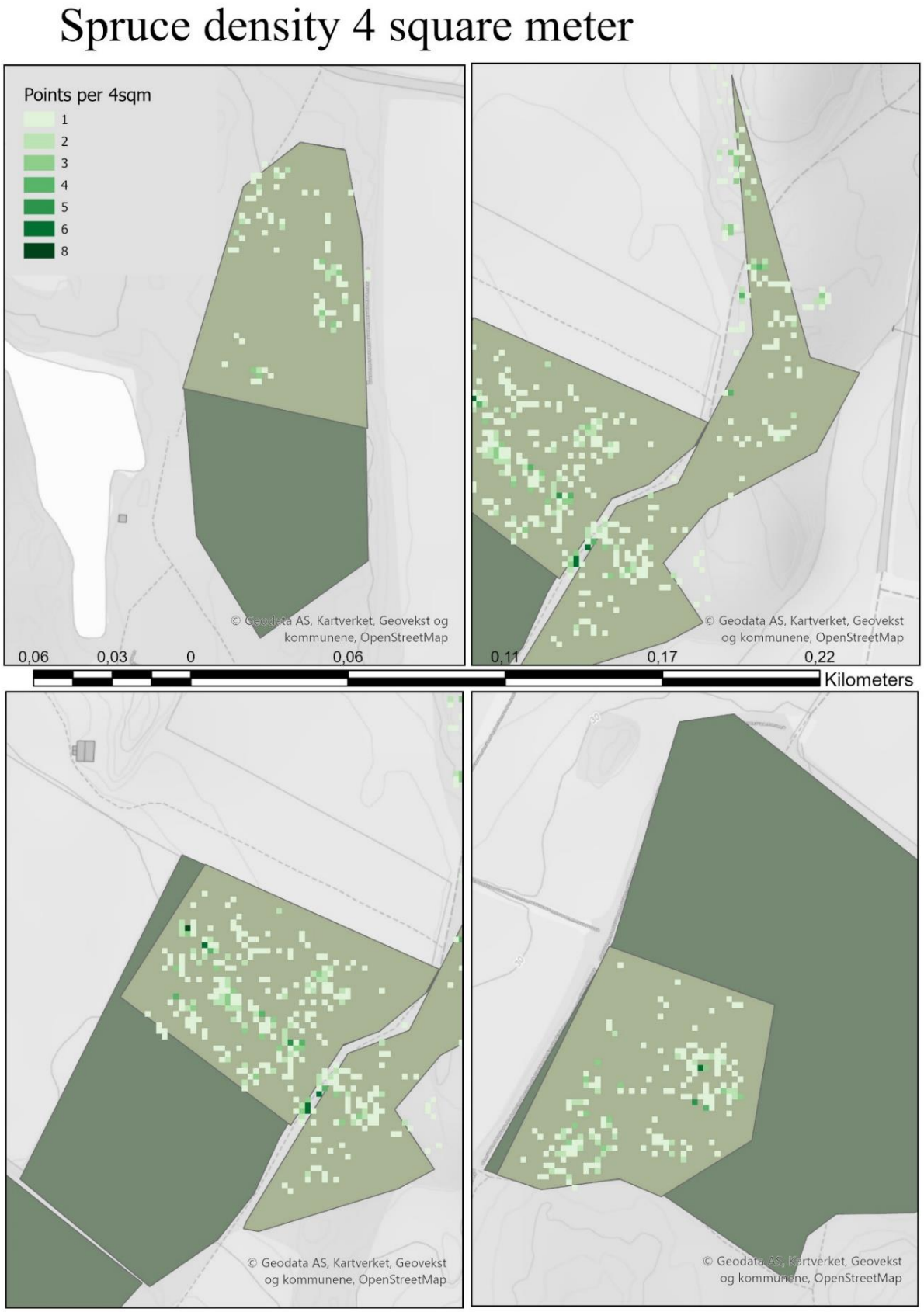

Figure 3.5 *The spruce spread and density for all four sites. Each square is four* m^2*, where the colour green indicates low (light green) to higher (dark green) density. Highest amount and densities of spruce is found on site three.*

Oak, with a density range of 0.04-0.07 trees per m^2, is visualized in a spatial analysis heatmap, figure 3.6.

Figure 3.6 *The oak spread and density for all four areas. Each square is four* m^2*, where the colour white indicates low density, to dark green indicates higher density.*

By making polygon specific maps based on the density data from the previously mentioned heatmaps (FIGURES 3.4, 3.5, 3.6), one can see a visualization of overlap between the species (FIGURES 3.7, 3.8).

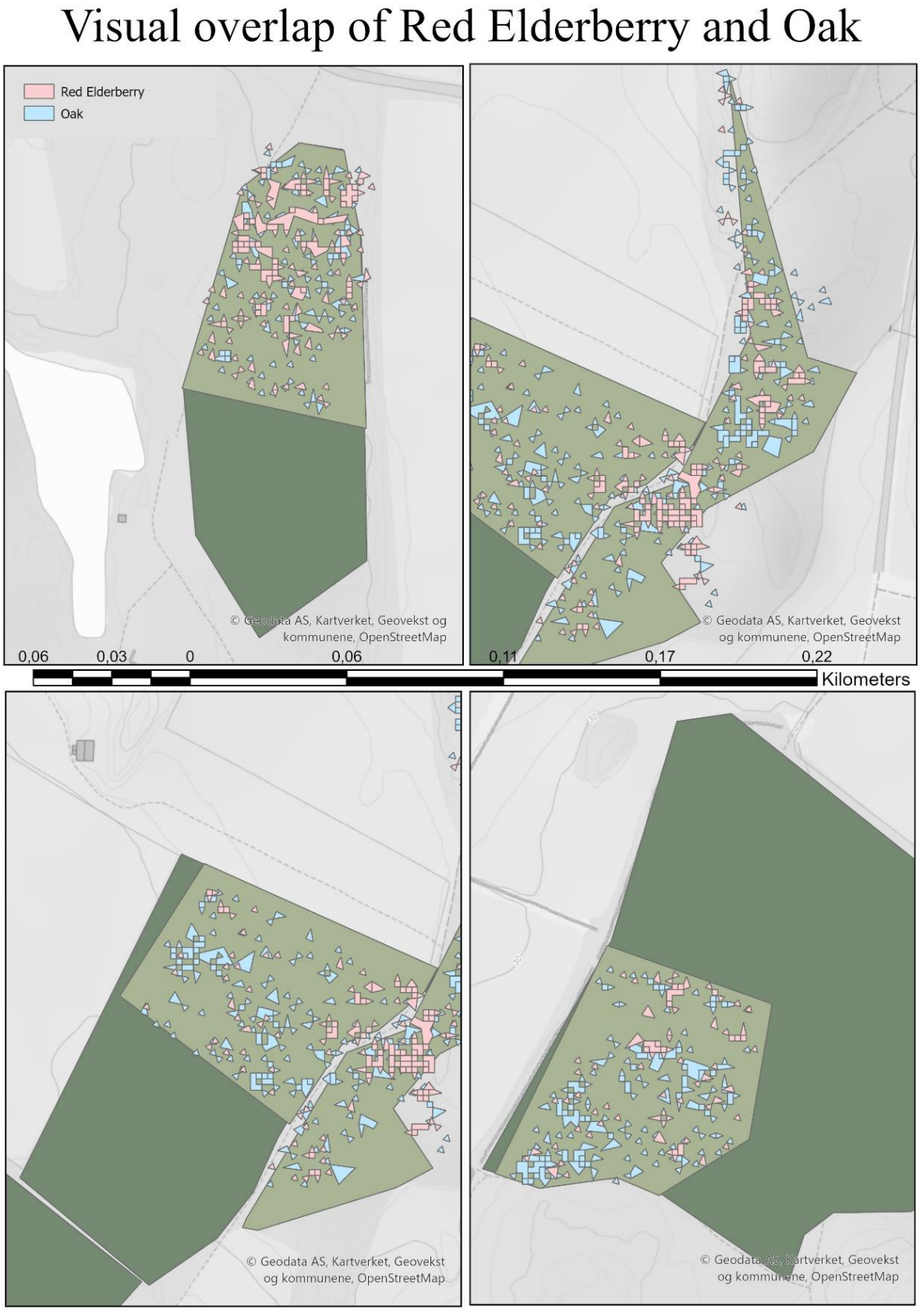

Figure 3.7 *Polygon specific maps based on density data. Overlapping spread/density of red elderberry and oak.*

Figure 3.7 shows the overlap between red elderberry and oak and visualizes the species “choice” of growth place compared to each other.

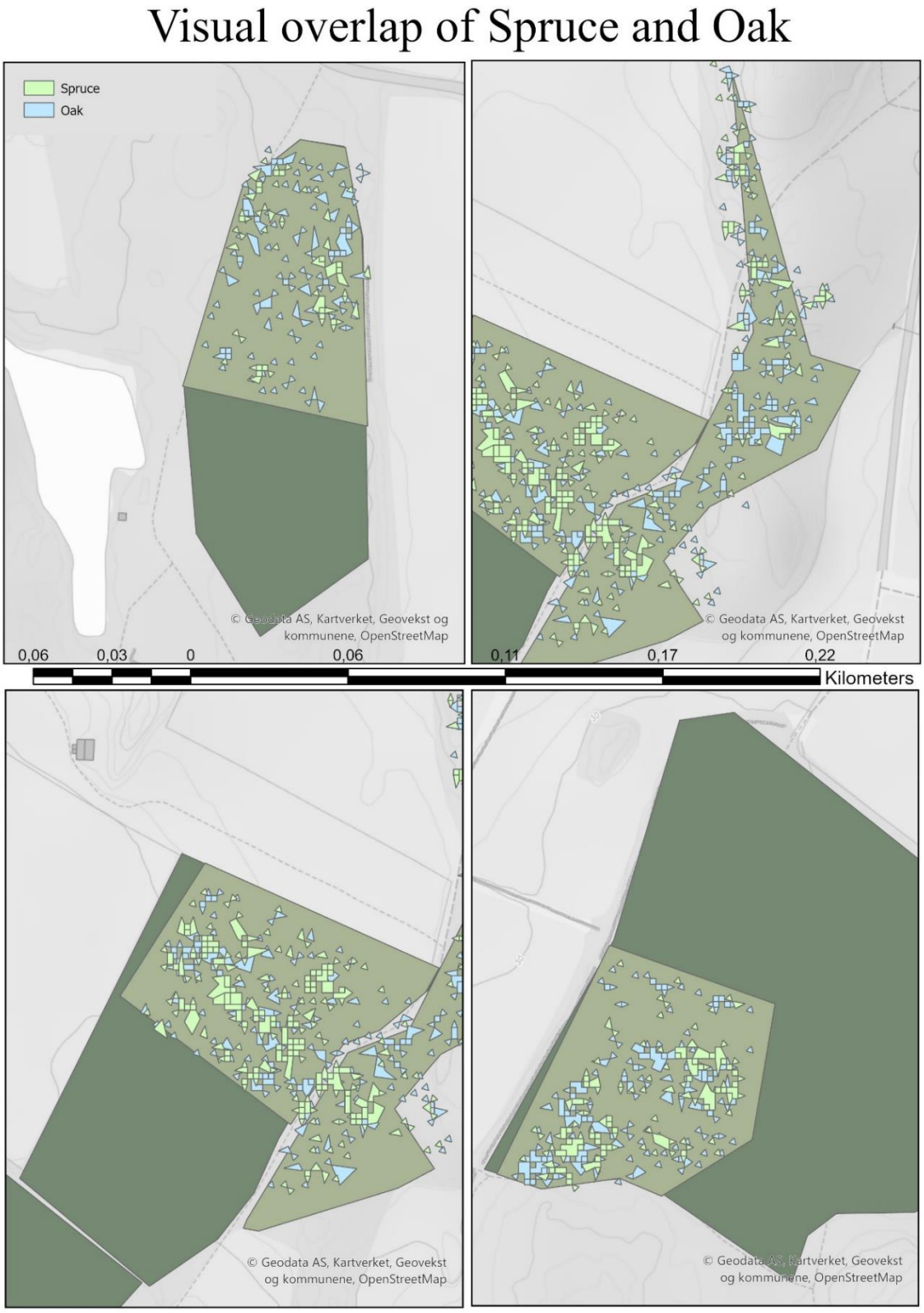

Figure 3.8 *Polygon specific maps based on density data. Overlapping spread/density of oak and spruce.*

Figure 3.8 shows the overlap between oak and spruce and visualizes the species preference for growth places compared to each other.

3.2.3 Species height across sites

The height of oak, red elderberry, and spruce across all four sites can be seen in figure 3.9. The mean height for oak across all sites is 36.3 cm (± 5 SD). For red elderberry the mean height for the sites is 45.5 cm (± 49.9 SD). And for spruce, the mean height is 106.8 cm (± 15.6 SD). Spruce has the tallest growths across all the sites, while oak generally has smaller growths across the sites (FIGURE 3.9).

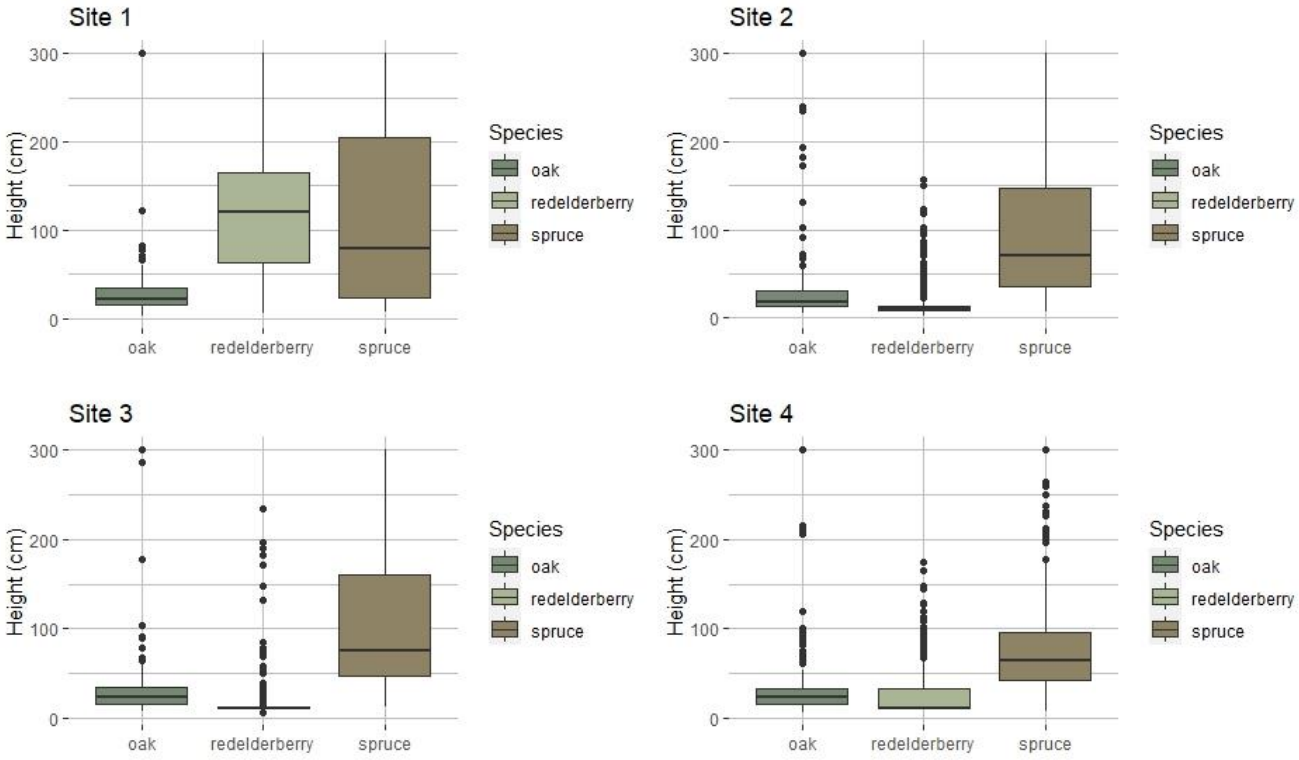

Figure 3.9 *The height (cm) distribution of oak (dark green), red elderberry (light green), and spruce (brown), across all four sites.*

Testing for whether there is a difference in height per site, an ANOVA test was used with the formula height ~ site. This test was done with all species combined (TABLE 3.3).

Table 3.3 *ANOVA test on the difference in height per site, height ~ site.*

ANOVA	DF	Sum Sq	Mean Sq	F-Value	Pr(>|t|)
Site	3	978527	326176	60.87	<2e-16***
Residuals	3309	17732538	5359		

Based on the results, the ANOVA test suggests that there is a highly significant difference in height among the different sites for all species combined. In other words, the site variable has a significant impact on the height of the species observed.

A Tukey post hoc test further showed that there is a significant difference in height between all sites except for 4 vs 2 (TABLE 3.4).

Table 3.4 *A Tukey multiple comparisons test on the formula height ~ site.*

Tukey's Method	Differences	Lower confidence	Upper confidence	p-adjusted
2-1	-45.6278634	-55.175663	-36.080064	0.0000000
3-1	-33.7115360	-43.687608	-23.735464	0.0000000
4-1	-46.4482207	-56.523405	-36.373036	0.0000000
3-2	11.9163274	3.213806	20.618849	0.0024715
4-2	-0.8203574	-9.636321	7.995606	0.9951886
4-3	-12.7366847	-22.014764	-3.458606	0.0023917

Further, running a generalized linear model analysis in the Gaussian family, to test if there is a difference in height based on species and sites indicates that species and site significantly impact the predicted mean of height (TABLE 3.5). The model uses oak as the reference level.

Table 3.5 *GLM analysis in the Gaussian family of the formula height ~ species + site.*

GLM	Estimate	Std. Error	t-value	Pr(>|t|)
(intercept)	73.393	3.404	21.558	< 2e-16***
Red elderberry	16.323	3.254	5.016	5.58e-07***
Spruce	71.639	3.157	22.693	< 2e-16***
Site 2	-48.198	3.649	-13.210	< 2e-16***
Site 3	-37.653	4.096	-9.192	< 2e-16***
Site 4	-47.339	4.013	-11.796	< 2e-16***

An Anova test on height differences between the species shows that overall, there is a significant difference in the height between the species (TABLE 3.6).

Table 3.6 *ANOVA analysis on the formula height ~ species.*

ANOVA	Df	Sum Sq	Mean Sq	F-Value	Pr(>F)
Species	2	2937515	1468758	308.2	<2e-16***
Residuals	3310	15773550	4765		

A post hoc Tukey test indicates further that there is a significant difference in height between the species (TABLE 3.7). The pairings spruce – oak and spruce – red elderberry is highly significant compared to the moderate significance of the pairing red elderberry – oak.

Table 3.7 *Post hoc Tukey Test of the ANOVA table 3.6. Shows the difference in height between the species.*

TUKEY	Diff	Lwr	Upr	P adj
Red elderberry - Oak	6.76188	0.08823837	13.43552	0.04620899
Spruce - Oak	69.41123	62.19309050	76.62936	0.00000000
Spruce – Red elderberry	62.64935	55.71242357	69.58627	0.00000000

4 DISCUSSION

4.1 Discussion of interviews

Talking with the governmental and non-governmental organizations was very insightful, with little to no disparity between the different actors. Most of them held the opinion that either way, no matter what we do, the forest will change because of climate change and the consequences thereof. Meaning, we do not have a choice. And, overall, what they wanted to focus on was recreation and biodiversity when it came to deciduous forest. Though they hold the opinion that production forest is possible with oak and other deciduous trees, it is more difficult to manage than a spruce forest. And as of now, there is no profit to be made from oak forests, as it requires so many resources to manage, and it takes significantly more years to grow than spruce trees. Mixed forest was also mentioned quite a lot, because monocultures are more at risk from disaster and disturbances and has less biodiversity. An interesting thought was taken up by 5MD, who said that if a site can't hold spruce, who's to say it can hold other species? There is a point to be made that spruce acidifies the earth, which deciduous species are less tolerant of. However, oak is one of the more tolerant, though pine is even more so and is already mixed in together with spruce. Concerning red elderberry there was no clear answer to whether it is a threat or not. Some seemed to think it wasn't really a threat at all, or that it's only a bigger threat in open fields. And trying to get rid of red elderberry, everyone believed it is difficult and almost a useless task. They had some suggestions, but overall, trying to hinder more invasive species from being introduced was the better task to focus on. However, the Norwegian list of invasive species consider red elderberry a high threat, as it spreads easily by birds, fast on clear-cut fields, and there is reason to believe that it outcompetes other native species (Elven, et al., 2018). The effect of other invasive species on for example oak is also something to consider, and other threats that are known to exist such as mildew, sudden oak death, and caterpillars (Eaton, et al., 2016).

According to the interviewees there is a general lack of knowledge surrounding forestry and especially concerning oak forest ecosystems, both for the private landowners and the governmental sector. Outside of the forest organisations, there is little information, or not easily accessible information on how to manage a broad-leaved forest. All available information is on spruce production, which as they mentioned, is what we know best and what almost all the production forest in Norway consists of today. All our research on forest theory, practice, and culture is based on spruce or pine. This means that deciduous forest production here in Norway is basically an unknown and needs to be researched and tried before anything significant will happen to Norway's forestry sector. According to the statistics of forest and forest resources from 2021, only a small portion of area is production of what they call "hardwood forest" (oak, ash, elm, etc.), however what they label as other deciduous forest (birch, etc.) covers the second largest amount of production area after spruce (Svensson, et al. 2021).

Most forest owners in Moss municipality do not own big forests and mostly care about recreational aspects more than the economical (Berg, 2023). There is a point to be made that there is a difference between active and inactive forest owners that this thesis does not encompass. According to Bashir et al. 2020, who interviewed forest owners in Norway in collaboration with Statistics Norway, 33% of the active forest owners did not consider their forest property as an important economical asset, compared to 60% of the inactive owners. Though all of them whether active or inactive considered recreation as the most important factor. They also noticed a big difference between gender, though not relevant for this thesis, it important to note.

According to 2SF the process of growing and managing a deciduous forest is an arduous one, requiring you to thin it every couple of years to allow for light. As well as a less competitive species to provide a canopy cover and cast a shadow creating a "screen" for the oak. This "screen" then needs to be slowly opened over the years for the oak to grow straight and produce quality lumber. 6GM also said that the soil needs to be deep and suitable. But if recreational and biodiversity purposes are the only concerns, then just letting it grow with perhaps some additional planting and clearing of other species is the optimal way to move forward. An interesting take from 4SF was the example of one of the forests where they clear-cut all the spruce and then let the forest naturally regenerate without any interference. Something 4SF called restoration clear-cutting, this is something those who don't care about the production aspect could learn from, as that forest is currently a broad-leaved forest. Though this is an interesting thought, and as previously mentioned, many of them are focused on recreation, meaning the forest needs additional management even if it is a "natural" forest. As outlined in the introduction the concepts of limits of acceptable change (Stankey et al., 1985) and desired states (Hagen, et al., 2002) seem appropriate here. Where both the desired state and LAC interconnect. The different actors want a forest brimming with biodiversity, but it also needs to be available for production, and recreation, and it needs to be aesthetically pleasing. As mentioned earlier, forests that are far from cities or the local population could be used as natural habitats with natural regeneration, but those forests are also more fitting for production, so how do you balance this? And forests closer to the population can be used for recreation, but also need to have biodiversity and an active wildlife, but how do you balance this when wildlife graze on deciduous trees? Especially in the beginning of the growing phase. Letting it regenerate naturally also means the inclusion of dead wood, old trees, and age variation, which was desired by some of the respondents. The challenge then, is these trees need to be cleared from the paths and "camp sites", and make sure it doesn't hinder other recreational activities while still also contributing to the ecosystem as a whole. Another aspect is the growth stage up until it becomes a forest, what will it look like and how will they manage it? What is the desired state at this early successional state?

For many the desired state included: more types of trees and more robust forests, moving from clear-cutting to selective cutting, quality and quantity, more focus on biodiversity, recreation, and landscape, and that it is better for the people rather than the economy. As this is the point of view of the governmental sector and at least one NGO, I assume this is more what they desire for state owned forest. Although, they might wish for more change in the privately owned forests, there needs to be a revision and change of ways in the forestry sector first for this to happen. And it needs to be profitable for many landowners, meaning they are willing to change as long as there's also profit to still be made from their forests, and that there is support for them to do it as well. For many, change for the sake of change is not worth it unless they benefit as well, and thus reach the limit of what landowners might be willing to accept. This is where we mostly find the conflict between production and biodiversity. And unless oak and spruce provide similar long-term income, why would they change from one to the other? Another limit is politics, which aspect weighs heavier than the other depends largely on what political party is now in the government, what they want to focus on, and what they want to evolve. This also includes how much money goes into the forest fond that then contributes to the management that private landowners are obliged to do. Workload and time allocation is also important to consider, how much resources and time is the landowner willing to spend on the management of a whole new forest ecosystem and production cycle?

4.2 Discussion of field results

Overall, the results of the field work show that there is high recruitment and many height differences across the sites for all species. Oak, spruce, and red elderberry all recruit everywhere, and there are no significant differences or variance between them. There was no significant relationship between the densities of the three species. But there was a high significant difference in height among the sites for all species combined, and the sites impact the height of the species. The unexpected amount of both oak and spruce on these sites tells us a lot about the future of these forests. Although bigger spruce was counted in the total found across all sites, the high number of small self-regenerated spruce saplings was surprising. We did not expect to find as many oak saplings as we did either. However, we did expect to find a lot of red elderberries considering it is a pioneer species and an invasive problem species that has spread almost across the entire country (Elven et al. 2018). Considering the age of the sites, the number of smaller red elderberries was surprising, with the exception of site one.

As previously mentioned, spruce acidifies the earth, making it less hospitable to deciduous species. However, we still found a huge amount of oak saplings despite this. And the results show no significant interactions between oak and spruce, and oak and red elderberry. However, we do not know the long-term interactions. As we know, spruce grows faster than oak, and whether spruce may outcompete the oak on these sites remains to be seen. Either way, concerning Moss municipality and these 4 sites in particular, natural regeneration of oak seems to not be a problem. If they want their forests as recreational areas, then occasionally doing some clearing might be the most that they need to do. And even if they wish to continue with a spruce forest, we found many recruits of spruce as well on each site, meaning that for both oak and spruce less planting is needed than perhaps first expected.

A natural secondary succession begins after a disturbance has occurred, such as clear-cutting a forest (Aarnes, 2003). This creates gaps, or in this case, a whole open area for shade-intolerant deciduous species to regenerate. As the deciduous trees grow, other more shade tolerant coniferous species grow in the shaded areas in which the deciduous species did not. This creates a multi-layered, mixed canopy, which enhances the range of habitats and general biodiversity. Eventually however, without any interference the coniferous species may dominate (García-Tejero, et al. 2018) depending on disturbances, as drought can cause spruce to die (Venäläinen, et al 2020) though according to ecological theories this later stage of succession might sustain a higher level of species diversity because of species specialisations and niches. On smaller scale sites there will be a different tree species composition. And age, size and the spatial distribution will vary and influence light availability. As well as water, carbon, and nutrient availability (García-Tejero, et al., 2018). This means that for smaller scale sites it may be more difficult for deciduous species to survive. According to Taylor, et al. 2020 the course of secondary succession impacts the relationship between species diversity and tree growth, and the mid-succession stages had higher functional diversity with the strongest relationship. Individual responses to successional drivers were found in different tree species, and broadleaved species showed a general negative response, while coniferous species had a more positive response.

As mentioned in the introduction, the regeneration of temperate deciduous forest depends on past activities and disturbances of a site, and the successional dynamics of the forest ecosystem. The restoration of temperate deciduous forest has often been to help the regeneration process because a naturally regenerated deciduous forest is often lower quality (Vasseur, 2012). This may mean that for landowners who only want the forest for

recreational purposes, may still need to do some management if they want higher quality for their forests, independent from whether they want a production forest or not. Activities may include reintroducing other native species with a broad genetic base, soil improvement, active and adaptive management (Vasseur, 2012). Through the transition from fast-growing pioneer species to the slower-growing shade-tolerant species, a stronger niche disparity may appear due to more species diversity with different requirements. If disturbances do not occur in intervals, the forest may be overtaken by climax communities and shade tolerant species (Taylor, et al. 2020). Nordèn et al, 2021 suggest that former spruce forests in boreonemoral areas could be suitable for restoring temperate deciduous forest after clearcutting, and in particular in areas where agriculture is a more common land use as compared to forestry. However, diligent management might be necessary to avoid spruce dominating the sites. Oak is considered to be a pioneer species, that like heavier soils, and are light demanding trees, and rarely under natural conditions form pure forests (Eaton, et al., 2016). Beech is considered one of the main competitors, while other shade or half shade trees are minor competitors. However, in poorer more acid soils, beech does not regenerate, oak form mixed forests (Eaton, et al., 2016). Meanwhile, spruce is a secondary species, though can also be pioneer and climax species. It is versatile and has been shown to grow under various conditions, while still producing quality. It is shade-tolerant and fast growing after 5-10 years, however it is less tolerant to summer droughts and salt winds. Acidic soils are the preferred substrate, and the species does have a soil-acidifying ability (Caudullo, et al., 2016). Red elderberry thrives on clear-cut sites and survives even when surrounded by other species when the clear-cut fields grow back. It spreads fast and is considered a pioneer species (Elven, et al., 2018). From this information they are all able to grow on similar places, meaning there is reason to believe that there may be “conflict” as time goes on.

In the year 2000 Göteborg University started an oak project with the goal of improving knowledge on oak forest management. According to them, open forest is where oak thrives, especially smaller oaks. Opening the forest is therefore necessary and something to consider. Management also includes letting the forest develop naturally, so that time and nature can create space for species that do not thrive in production forests (Göteborgs Universitet, 2023). Active management is important in oak forests, but so is natural development. For forest that are managed for conservation, thinning is an option to open the canopy, which also can increase biodiversity. The trees that are felled are suggested to be used for either timber or to be left as dead wood if deemed appropriate. Conservation of a forest consisting of oak and spruce according to them, is about felling spruce (Göteborgs Universitet, 2023). One can assume that if this is the case for simply conserving oak, then it may be necessary for oak production forests as well if the desire is for oak to thrive. They also point out that opening the forest in this way and clearing spruce is good for larger oaks, but oak regeneration is more problematic and sparing (Göteborgs Universitet, 2023).

4.3 Management recommendations

The consensus was that production forest with oak or other deciduous trees is more time consuming and resource expensive, but if the right incentives are in place and landowners get compensated accordingly, then it might be a possibility. As, presumably, they don’t need to plant that many extra saplings, the workload may lessen somewhat. However, the main workload lies in the silviculture and the many years of carefully giving light to oak for it to grow straight and produce quality wood. There are three available management regimes according to Löf et al 2015: Intensive timber production of oak, a combination strategy for both production and biodiversity,

and conservation of the forest without any interference. Where the first option provides the most economic result and less biodiversity, while the third option comes at the expense of timber production altogether.

We do not know what the future of these sites will look like, and how these species will interact over the years, but it seems that there is a good starting point for an oak forest. 7MR and 3M mentioned using the municipality owned forest as experimental forests for research and trying new methods. Sadly, we did not have time to inspect one of these sites, but I think this would be a good idea, though also a very long experiment. The information gathered could then be passed on to private landowners, and it doesn't necessarily mean only experimentation on oak forest, but also just natural regeneration in general, or other types of mixed forest. However, no matter the species, this process will take many years, and the future is uncertain.

Through this study it becomes clear that some changes in management is needed. Selective cutting instead of clear cutting is a big one. Clear-cutting is an unnatural disturbance that alters the natural dynamics of an ecosystem and as a result simplifies the environment, reducing a landscapes heterogeneity and complexities by replacing a varied forest with different successional stages with same-aged stands. Clear-cutting also keep fewer important keys to biodiversity such as dead fallen wood, dead trees, and old growths. These are important resources for a variety of species. Clear cutting has also been found to decrease species associated with old growths such as bryophytes, lichens, vascular plants, and invertebrates in the boreal zone (García-Tejero, et al., 2018).

Whether it is a production forest or a recreational one, it seems that most want "clean" forest, and for the oak it is important to clear other shade-tolerant species and utilize good silviculture. And for production forests it is important to leave space for biodiversity and consider mixed forests over monocultures. As no significant interactions were found between spruce, oak, and red elderberry at this successional stage, it is difficult to define the correct management strategy going forward. Though advice from the different interviewees is if you want a production forest containing mainly oak and other deciduous trees, you need a lot of resources and time to maintain quality timber from oak. Additional planting with genetically native Norwegian deciduous saplings and clearing of invasive species might also be needed. Maintaining quality oak requires in the early stages species that cast shade, where you slowly open the canopy as the oak grows, hindering "light shoots" (branching that make the timber undesirable by creating marks) from developing. Otherwise, for recreational purposes, clearing of invasive species and making sure shade-tolerant species don't outcompete the deciduous species is important to consider.

How to manage invasive species has been a dilemma for many years, and yet there are few long-term experimental studies on silvicultural practices on the management of invasive species. However, instead of using traditional silvicultural methods to manage them, the management should be specific to the circumstances, like the intensity of invasion, direct mortality, and various stressors. Pre-emptive management is good practice for both plantations and natural forests. Given that invasive species can dominate an ecosystem as well as disturb its processes, silviculture becomes an important restoration tool. Restoration after damage by invasive species could be to cause shifts in species composition to maintain a resilient forest ecosystem. Though evidence of silviculture being successful against invasive species damage remain more unknown than other efforts , silvicultural management should be included into the extensive management regimes of controlling invasive species (Muzika, 2017).

The Göteborg university project is huge and expansive, and I think Norway and, in this case, Moss municipality, could benefit massively from a collaboration with them, and they might in turn be interested in the information that comes from this.

According to previous NTNU student Berger, 2018, studies like these show the importance of the involvement of the social aspect in the socio-ecological system in cases such as forest management. Further she wrote that forest management plans should be consistent, more helpful, and more informative for all stakeholders including landowners. And integration of sociological and ecological knowledge into the plans would make way for a more sustainable management which then promotes taking care of ecosystem services and functions, because trade-offs between ecosystem services are probable. To limit these trade-offs a suggestion is a combination of various management methods across the landscape, this also contributes to a varied landscape with forests that offer different services. As forest succession is a slow process, this will impact the management and also our thoughts during this process (Berger, 2018). Long term studies on the relationship between oak and red elderberry, and oak and spruce are needed. Literature on landowner and actor opinions is not common, this presents further research on the topic. The study also takes place in a limited area in Norway, and only concerns four sites. Studying both topics in more places will open for comparisons and more in-depth knowledge. Berger, 2018 also mentioned including the general public into this research, which is relevant considering there was a lot of talk on the subject of recreation. Further she explained that newer generations might bring change and new perspectives, new research will present change.

5 CONCLUSION

All in all, the future of these sites, and others, relies on politics, the landowners, and the current management laws. This study has presented many possibilities for future research on these sites, and better, for more sites as well in not just Moss municipality but for other areas in Norway as well. The field results show high recruitment across all sites and for all the species: oak, red elderberry, and spruce, with recruitment everywhere. Though there was difference in heights across the sites, there were no other significant relationships from the data analysed.

Most of the interviewees were more interested in biodiversity and recreation than production, though they think production is important too. They also think that climate change will force a change no matter what we do. Many of the respondents want "clean" forests, with space for recreation, clear paths and so on. Moving from clear-cutting to selective cutting was considered important, whether it is an oak forest or spruce forest. And most of them said that smaller landowners are more focused on recreation than production, as they don't gather much income from smaller forests anyway. The different actors seemed to not consider red elderberry much of a threat, however the Norwegian list of invasive species does. What the interaction between oak, spruce, and red elderberry at a later stage is unknown, but as oak is a pioneer species that is not particularly shade tolerant, and spruce is a secondary species that is shade tolerant, some interaction could present itself at some point.

An oak forest will require more resources and time than a spruce forests, which means that a potential oak forest should be at least as profitable as a spruce forest. Active management will be necessary if a quality forest is desired, no matter if it is planned as a production forest or simply a recreational forest. Some choices for how to manage it is: pure production, production with biodiversity, and purely a biodiversity focused forest. Additional planting in larger amounts may not be necessary considering the recruitment rate, though with additional planting local and genetically Norwegian sprouts should be used. Involvement of socio-ecological concepts is important for studies like these, and adapting to a more sustainable management of forest is necessary if we want to adapt to climate change.

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7 Appendix

7.1 Field Protocol

Codes	Explanation	Definition
t	Transect number	
q	Quadrant number	
nsq	Number of species in quadrant	
sq	Species in quadrant	
w	Width cm	
h	Height cm	
bd	Bark Damage	Yes – 1 No - 0
color	G – Green Gul – Yellow, bf – brown spots, gulf – yellow spots Hvit – White, vissen – Dry/dead, b – brown, hf – white spots, hb – white and brown, hfbf – white and brown spots	"Healthy" - 1 "Intermediate" - 2 "Sick" - 3
nb	Number of branches	
broi	Browsed by inects	Yes – 1 No - 0
brov	Browsed by vertebrates	Yes – 1 No - 0
vpos	Shoots eaten by vertebrates	Nothing – 0 A little – 1 Intermediate – 2 A lot - 3
vpol	Leaves eaten by vertebrates	Nothing – 0 A little – 1 Intermediate – 2 A lot - 3
ipol	Leaves eaten by insects	Nothing – 0 A little – 1 Intermediate – 2 A lot - 3
lat	Latitude	
long	Longitude	
cc	Canopy Coverage	
cacx	Concave or Convex ground	Convex - -1 Neutral – 0 Concave - 1
SM	Soil Moisture	Dry - 1 Intermediate – 2 Humid - 3
On point intercept we wrote 20+ when the hits exceeded this amount. There were some quadrants that could have reached an unreasonable amount. On height we wrote 300+ for trees that were 3m or higher.		

7.2 Interview Guide (Norwegian)

Intervju guide

Start

Møte og detaljer blir organisert over mail.

Møte starter med en forklaring av dine personlige rettigheter og privatliv omhandlende:

- Opptak -> Det er bare jeg og min medstudent som vil ha tilgang til opptaket som blir tatt i dag. Når masterprosjektet og oppgaven er levert vil opptaket bli slettet. Jeg tar opptak ettersom det da er lettere å holde intervjuet gående, men jeg vil i tillegg ta noen notater.
- Bruken av intervjuet -> Intervjuet vil bli brukt til å sammenligne med andre organisasjoner, i tillegg til private grunneiere. Alt unntatt aldersgruppe, utdanning og arbeidstittel vil være anonymisert.

Introduksjon til prosjektet

Formålet med prosjektet er;

1. Undersøke tidlig rekruttering av eik og andre løvtrær i tidligere granplantasjer. Hvordan påvirkes rekruttering av miljøet (konkurranse, beiting, tørke, næringsforhold mm)? **Hvordan få til en eike/edellauvskog?**

2. Undersøke visjoner og mål for edellauvskogøkosystem basert på litteraturstudier, diskusjoner med grunneierne, forvaltning etc. **Hvilken skog vil vi ha?**

3. Undersøke mulige tiltak/strategier for å gjenopprette et edellauvskogøkosystem basert på litteraturstudier, diskusjoner med grunneierne, forvaltning etc. **Hvordan skal vi komme dit?**

- Er du involvert i lignende prosjekter?
    - Hvis ikke, følger du eller har du hørt om lignende prosjekter?

Kort om bakgrunnen din

- Kan du fortelle oss litt om bakgrunnen din?
    - Utdanning og dine hovedoppgaver i jobben din/jobbtittel.
- Er du ofte i kontakt med skogeiere i jobben din?

Seksjon 1 Edelløvsskog

Hva tenker din organisasjon om edelløvsskog generelt?

- Hvordan ser en slik skog ut for din organisasjon?
- Hvordan kan den bli brukt?
- Hvilke verdier har en slik skog?
    - Tenker dere at trevirke/andre økonomiske virker er mulig i en slik skog?
    - Til hvilken grad mellom naturlig skog og plantet produksjonsskog tenker dere for disse restaurerte skogene?

    - Hva tenker du om denne type skog i disse klassifikasjonene?

Er det viktig å ta vare på edelløvsskog?

- Hvorfor/hvorfor ikke?
- Tenker dere at det er nødvendig å restaurere edelløvsskog?
- Hva tenker dere når jeg sier restaurere? Naturlig tilvekst eller planteskog?
- Hva er deres tanker rundt dette og hvordan ville dere ha restaurert?

Hva tenker dere er statusen til skog i dag?

Har dere erfaring med edelløvsskog som sortiment?

- (Hvis tømmer omsetter?): Har dere noe erfaring/tanker rundt kvaliteten til disse typer skog/tre.
    - Hvilke edelløvstrearter ville dere fokusert på, og hvordan ville dere rangert dem?
    - Tenker dere mer økonomisk eller økologisk med disse valgene?

Seksjon 2 Gjennomføring

For å kunne oppnå edelløvsskog i for eksempel Moss i fremtiden, hvordan tenker dere dette kan bli en mulighet?

- Økt kunnskap
- Tilskudd til skogeiere
- Konsultasjoner til skogeiere
- Lovlige/juridiske krav
- Kommunal planlegging
- Endringer i forvaltnings strukturer og praksiser.

Hvis vi skal restaurere edelløvskog, hvilke restaurerings mål burde veilede et slikt vedtak/politikk?

- Tror dere det er mulig å vedta en så stor endring i nærmeste fremtid? (~10 år)

Hvis vi restaurerer edelløvskog, vil den ikke se ut som en skog på mange år.

Forvaltnings mål kan endre seg gjennom årene, og det kan tanker rundt skog også.

- Hva tenker dere om dette?

Hvordan tror dere vi kan oppnå endringen fra granskog til for eksempel en eikeskog?

- Hva tror du er nødvendig for å få det til å skje?
- Hva er deres tanker om å endre skogen fra hovedsakelig gran til edelløvskog, eller da en blanding?

Hvordan ser dere for dere Norges fremtidige skog?

Tilbyr organisasjonen din hjelp, informasjon eller konsultasjoner til skogeiere?

- Til hvilken grad?

Har organisasjonen din lett tilgjengelige informasjonshefter, eller noe lignende som er enkelt å fordøye for skogeiere og andre interesserte parter?

Seksjon 3 Økosystemtjenester i skog

Med tanke på forskjellige natur fordeler folk får fra skog, hvilke av dem tenker dere er de mest viktige?

Til hvilken grad, ifølge din organisasjon, burde biodiversitet og klimatiske utfordringer spille en rolle i forvaltningen av en skog?

Videre, til hvilken grad ifølge din organisasjon, burde rekreasjon, estetikk og landskap spille en rolle i forvaltningen av skog?

- Hvordan rangerer dere økosystemtjenester i edelløvskog i forhold til en granskog?

Hvor viktig er skog for bærekraftig utvikling i Norge? Kan du utdype på svaret ditt?

Er det mulig å balansere bevaring av biodiversitet og skogvirke?

Vi kan se for oss at i en såkalt restaurert edelløvskog, altså skog restaurert fra gran til edelløvskog, vil vi få det vi kaller økologisk verdiskapning.

Når du tenker på dette konseptet, hva føler din organisasjon at dette involverer?

- Viktighet
- Realisme
- Økonomi

Seksjon 4 Fremmed arter/trusler

Hva vil dere påstå er den største trusselen for edelløvskog

- Andre trusler?

Hvor stor vil dere påstå trusselen fra fremmed arter som for eksempel rødhyll er på skog og da spesielt edelløvskog?

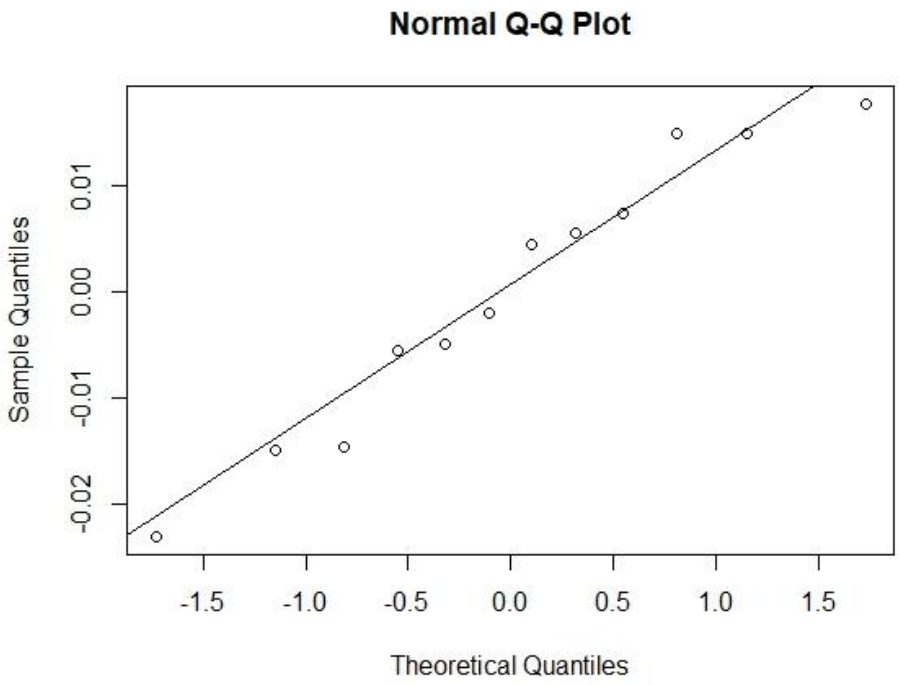
- Hva tror dere er den beste måten å behandle disse truslene på er?
- Er det under spesifikke situasjoner akseptabelt å bruke fremmed arter, og hvis ja, hvorfor og hvilke?

Slutt seksjon

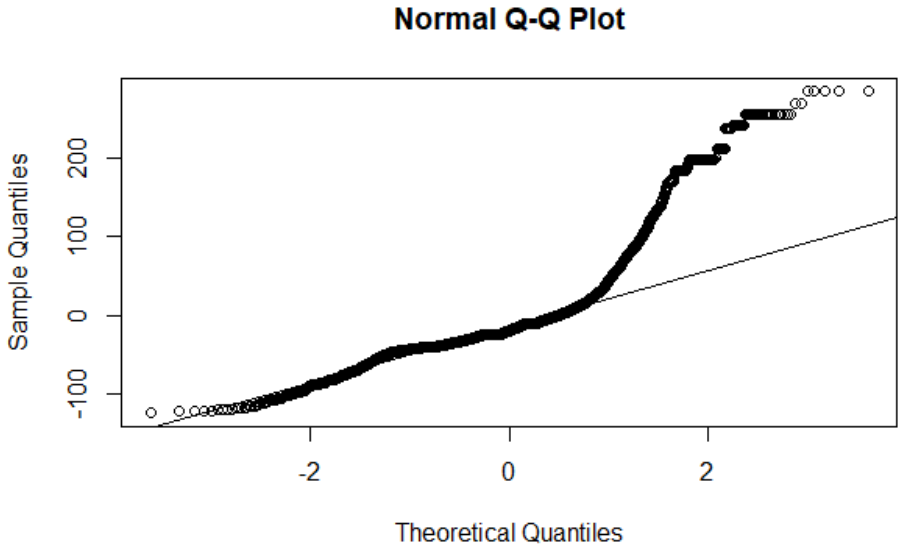
Hvis du har noe ekstra innslag/informasjon, føl deg fri til å si det nå! Eller så kan du maile meg tilbakemelding.

Takk for at jeg fikk snakke med deg og for at jeg fikk bruke litt av tiden din.

7.3 Linear regression model fit of species and site effects on density



7.4 GLM Model fit of species and site effects on height



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