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Current versus alternative forest management practices in southern Sweden

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Cover: Typical production stand of Norway spruce (*Picea abies*) in southern Sweden (left). Birch (*Betula* spp.) thinning trial with a lot of spruce undergrowth, Rottne, Kronoberg County (middle). Production forest of oak (*Quercus* spp.) on the island of Visingsö in lake Vättern (right).

Photos: Pär Fornling (left and right), Eric Agestam (middle).

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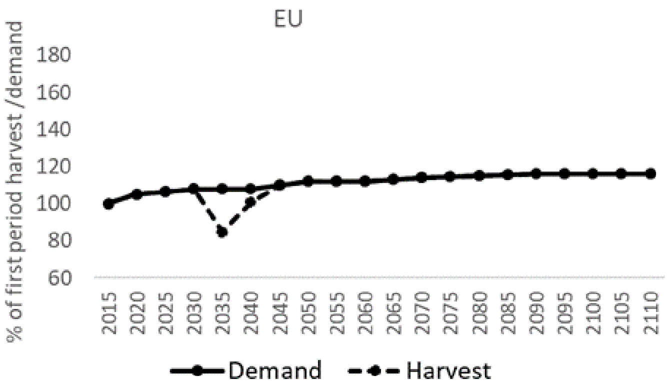
Page 45	Location: Middle of the page Is now: (except a small wood shortage in 2050) Should be: (except a small wood shortage 2050 in REF)
Page 46	Location: Figure 5 Is now: The figure for EU (EU Bioenergy) is wrong. Should be:



Current versus alternative forest management practices in southern Sweden

Abstract

Forest management in southern Sweden is facing numerous challenges spurring the need for change. Futures studies are instrumental for addressing such challenges. This thesis reports on futures studies investigating current practices and alternatives developed together with stakeholders. Current and alternative practices were investigated in projections under different climate change mitigation scenarios in Kronoberg County as a case. Reflecting the rivalling interests of stakeholders, the developed alternatives represent conflicting forest management pathways. The research shows that ambitious mitigation might push for further intensification to meet increasing demands. Together with the forest owner association Södra alternatives for increased production were investigated, such as exotic species, fertilization and spruce clones. At the same time, the biodiversity crisis calls for more diverse practices, and such alternatives (spruce-birch mixtures, oak and border zones) were explored in collaboration with the County Administrative Board (länsstyrelsen). The thesis also investigates drivers behind current practices as well as barriers and opportunities for change with help of qualitative research. The owner diversity is already today complicating advisors' efforts with promoting the current production-orientated ideals and is a likely barrier to further intensification. The current lock-in to spruce dominated practices complicates diversification, which was manifested in the failure to promote diverse regenerations after the storm Gudrun. A substantial diversification towards other species will require a contextual setting that facilitates such a shift, including such factors as lesser browsing, better markets for alternative assortments and diverse advisory services.

Keywords: small-scale forestry, futures studies, scenarios, climate change, production, biodiversity, practice based approach, situated agency, the RIU-model, silvicultural ideals.

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Dagens kontra alternativa skogsskötselmetoder i södra Sverige

Sammanfattning

Skogsbruket i södra Sverige står inför utmaningar som kräver förändring av skogsskötseln. Framtidsstudier är viktiga för att hantera dessa utmaningar. I denna avhandling beskrivs framtidsstudier som undersöker dagens skogsskötsel och olika möjliga alternativ som utvecklats tillsammans med skogliga aktörer i Kronobergs län. Konsekvenserna av olika skötselalternativ undersöktes genom Heurekasimuleringar i scenarier med olika ambition i arbetet med att hejda den pågående klimatförändringen. Våra samarbetspartners behov och intressen resulterade i alternativ med helt olika inriktning. Resultaten visar att ett ambitiöst arbete med att motverka uppvärmningen kan leda till en ökad efterfrågan på virke och därmed skapa incitament för ett mer intensivt skogsbruk. Tillsammans med skogsägarföreningen Södra undersöktes olika alternativ för att öka skogens tillväxt (t.ex. exotiska arter, grankloner och gödsling). Samtidigt kräver hotet mot den biologiska mångfalden en mer varierad skogsskötsel. Sådana alternativ (blandskog, ek, kantzoner) undersöktes tillsammans med länsstyrelsen. Denna avhandling undersöker även drivkrafterna till dagens dominerande skötselmetoder och hinder och möjligheter för förändrad skogsskötsel med hjälp av kvalitativ forskning. Heterogeniteten inom privatskogsbruket komplicerar skogliga rådgivares arbete med att främja produktionsinriktad skötsel och utgör ett troligt hinder för framtida intensifiering. Dagens inlåsning i ett starkt grandominerat skogsbruk komplicerar ökad variation, vilket visade sig i svårigheten att främja variation i föryngringarna efter stormen Gudrun. En mer omfattande användning av andra arter kräver en omgivning som kan främja en sådan förändring, så som ett lägre betestryck, bättre marknad för alternativa arter och skoglig rådgivning med olika inriktning.

Nyckelord: privatskogsbruk, framtidsstudier, scenarier, klimatförändring, produktion, biodiversitet, kvalitativa metoder, RIU-modellen, skogsskötselideal.

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Dedication

Till min mormor Doris

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List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Lodin, I., Eriksson, L-O., Forsell, N., Korosuo, A., (2020). Combining Climate Change Mitigation Scenarios with Current Forest Owner Behavior: A Scenario Study from a Region in Southern Sweden. *Forests*, 11 (3), 346.

II. Lodin, I., Brukas, V., (2021). Ideal vs real forest management: Challenges in promoting production-oriented silvicultural ideals among small-scale forest owners in southern Sweden. *Land Use Policy*, 100, 104931.

III. Lodin, I., Brukas, V., Wallin, I., (2017). Spruce or not? Contextual and attitudinal drivers behind the choice of tree species in southern Sweden. *Forest Policy and Economics*, 83, 191-198.

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The contribution of Isak Lodin to the papers included in this thesis was as follows:

I. Developed the research idea together with L-O.E. Gathered and compiled information about current forest management practices to include in the modelling. Wrote the manuscript in collaboration with the co-authors.

II. Developed the research idea together with V.B. Conducted and analyzed the interviews. Compiled information about forest management in small-scale forestry from various written sources. Wrote the manuscript in collaboration with V.B.

III. Developed the research idea together with the co-authors. Conducted and analyzed the interviews. Performed the contextual analysis with assistance from the co-authors. Wrote the manuscript in collaboration with the co-authors.

Abbreviations

CAB - County Administrative Board
CCF - Continuous Cover Forestry
CSA - Case Study Area
DSS - Decision Support System
ES - Ecosystem Service
EU - the climate change mitigation scenario EU Bioenergy
FOA - Forest Owner Association
GDP - Gross Domestic Product
GLOBAL - the climate change mitigation scenario Global Bioenergy
GLOBIOM - the Global Biosphere Management Model
LULUCF - Regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry
PCT – Pre-Commercial Thinning
REF - the climate change mitigation scenario Reference
SFA - Swedish Forest Agency
SFM - Sustainable Forest Management

1. Introduction

1.1 Futures studies at the crossroad between intensification and diversification

Sweden is a nation where forests cover a large proportion of the land area, and forestry and forest industry play an important role for the national economy. Multiple demands have for long been put upon the Swedish forest resource, and the resulting conflicts have been addressed and regulated differently in different periods (see Mårald et al., 2017, pp. 39-50). Balancing production and conservation goals is at the heart of contemporary Swedish forest policy (Beland Lindahl et al., 2017a). In this balancing act, matching overarching goals with suitable forest management is a difficult, but crucial component, and forest management practices remain a source for conflicts and discussions in both the forest sector and the wider society (e.g. Zaremba, 2012; Mårald et al., 2017; pp. 112-117). Reflecting differences in underlying interests among the involved parties, different actors and their coalitions advocate for very different forest management pathways for the future (Sandström et al., 2016; Eggers et al., 2020).

Equal prioritization of production and conservation goals has been stipulated in Swedish forest policy since 1993 (Bush, 2010). Despite this, Sweden is characterized by intensive forestry in an international perspective (Levers et al., 2014; Forest Europe, 2015, p. 114). There is a strong legacy from a long tradition of production-oriented forestry (Beland Lindahl et al., 2017a) and current management practices still favor the economic dimension of sustainability (Eggers et al., 2019). As a result, Sweden does not meet its environmental objectives relating to forests (SEPA, 2020, p. 289), and there are 2400 red-listed forest-dependent species (SLU, Swedish Species

Information Centre, 2020a, p. 19). This conservation challenge is calling for more diversified forest management practices in the production forest matrix (e.g. including longer rotations, mixed forest, continuous cover forestry) combined with increases in the proportion of set-asides (Eggers et al., 2019; Felton et al., 2020a). More diversified management is also motivated by risks coupled with the ongoing and future expected climate warming (e.g. drought, spruce bark beetles) (Seidl et al., 2014; Belyazid and Giuliana, 2019), as well as other risks such as storm damages (Valinger et al., 2014). This implies high risks especially for the current management practices in southern Sweden, which are strongly dominated by Norway spruce (*Picea abies*), and calls for increased use of alternative species in regenerations (Felton et al., 2016a; Felton et al., 2020b).

At the same time, studies indicate that the global wood demand will increase substantially in the future, partly driven by efforts to mitigate climate change (Kraxner et al., 2013; Lauri et al., 2017). Trying to meet the expected demand would put pressure on the Swedish forest resource (Nordström et al., 2016), and create incentives for further intensification of forest management (Bostedt et al., 2016). Several studies have shown how forest growth and wood supply can be increased substantially through intensified forestry (e.g. better regenerations, fertilization, exotic species) (Nilsson et al., 2011; Poudel et al., 2012; Lundmark et al., 2014; Cintas et al., 2017). Not surprisingly, the forest industry perceives climate change mitigation as a business opportunity, which also provides them with "green arguments" to legitimize a continued strong focus on production (Beland Lindahl, 2015).

Consequently, the present is characterized by conflicting ideas about desired future forest management pathways, stemming from differences in underlying values and interests among the involved actors (Beland Lindahl, 2015; Sandström et al., 2016; Eggers et al., 2020). These desires are difficult to reconcile, stressing the importance of priority setting and trade-offs. At the same time, there is a great uncertainty regarding the development of external drivers important for forestry. This concerns the future level of warming and associated effects on forests (Lindner et al., 2016), as well as future mitigation efforts, the global socio-economic development and the use of natural resources including wood (Forsell et al., 2016; Fricko et al., 2017). Altogether, this highlights the importance of futures studies as a branch in forest-related research (see Mårald et al., 2017, pp. 51-53). By investigating the outcomes of current and alternative forest management practices in various future scenarios, we can increase our preparedness for the future, which can facilitate decisions that are better informed. To exemplify, modelling the landscape level provisioning of ecosystem services (ESs) under different management scenarios provides knowledge about strategies to improve ES provisioning (e.g. Eggers et al., 2019), which potentially can be used to reduce conflicts and/or increase the attainment of policy goals. Alternatively, studies exploring wood demands in different climate change mitigation scenarios can increase our preparedness for different possible futures (e.g. Jonsson, 2013; Nordström et al., 2016), and provide an indication of the future range we can expect. However, regardless of the specific topic of the future-oriented forest research, a key issue is how to make them truly matter. So that such studies can be dispersed outside the research community and feed into existing decision-making processes in the sectors that we study.

In their review of 31 future-oriented studies conducted within the frames of the Future Forest program Mårald et al., (2017) p. 83 conclude that: "*In addition, none of the future studies were conducted in cooperation with stakeholders and focused on forest practice. However, such studies may be useful (or even essential) to enable local engagement and development of practical solutions to the challenges we face. Thus, when designing studies on future forest land use, there is clearly scope to improve the integration of established methods and involvement of stakeholders*". Consequently, by collaborating with stakeholders the research can be oriented towards problem formulations that matter in practice, thereby potentially increasing its usefulness. However, this strategy comes with a potential pitfall. By closing down around future visions that reflect the desires of current dominant interests and stakeholders there is a risk that the present colonize the future (see Mårald et al., 2017; pp. 51-53). Thereby crippling the ability of futures studies to open up for multiple futures and/or find creative solutions to contemporary problems. This calls for increased reflexivity on the side of researchers, thereby becoming more conscious about whose future visions and problem formulations that are given voice in the future-oriented research.

Not surprisingly forest-related futures studies often investigate different alternatives for change of the prevailing forest management practices (Mårald et al., 2017; pp. 64-75; Hoogstra-Klein et al., 2017). In this regard, it is important to bear in mind the deep gap between modelling a change and implementing a change in practice. While the modelled provision of ESs can be improved by an experienced modeler in a decision support system (DSS), steering complex socio-ecological systems (Berkes et al., 2008) in a certain direction is a much more challenging task. Researchers might find a strategy theoretically sound for solving a particular problem. However, it may fit poorly with practice for a wide range of reasons, and therefore never be considered for practical implementation. Alternatives to the well-established conventional forest management practices are often constrained by a wide range of implementation barriers (Moen et al., 2014; Puettmann et al., 2015). Studying such barriers, along with potential opportunities for practical implementation, can therefore serve an important complement to quantitative modelling studies of the investigated alternatives. It helps with avoiding naïve and overoptimistic beliefs in the possibilities of change, and can instead pinpoint implementation barriers that need to be addressed if society finds a particular alternative suitable for wider application. Here a rich suite of methods, including social science and qualitative research, are needed to understand the different components (e.g. actors, social structures, ecosystem properties) of the socio-ecological systems that are interacting to support some forest management practices, while severely constraining others.

1.2 Thesis scope and aim

This thesis presents future-oriented forest research conducted in the small-scale forestry of southern Sweden. Inspired by the limitations and challenges presented in the review above, the thesis includes the following two innovations. Firstly, the investigated alternatives to current practices have been developed collaboratively with important stakeholders in the study region. Secondly, quantitative modelling of different alternatives has been complemented with qualitative in-depth research exploring drivers to current management practices, as well as barriers and opportunities for change. By doing so I hope to provide futures studies that matter, i.e. research that can facilitate decisions about future forest use that are more informed.

This thesis provides an overview of the research about current and alternative forest management practices carried out in a southern Swedish case study. This includes research papers addressing the following issues or research questions:

- To what extent can increasing wood demands in different climate change mitigation scenarios be satisfied with current forest management approaches? Is it important to account for the existing variation in management intensity among small-scale owners in such studies? (Paper I)
- What are the main deviations from the production-oriented silvicultural ideals among small-scale owners? And why do these deviations occur according to forestry advisors? (Paper II)
- Barriers and opportunities for change of forest management practices. Exemplified by a qualitative in-depth investigation of small-scale forest owners reforestation decisions after the catastrophic storm Gudrun, which often is considered as a missed opportunity for more diverse forestry (Paper III).

2. Background

2.1 Forest management and forest governance in Sweden

Due to the proximity to large foreign markets, the industrial revolution in 19th century Europe opened up great business opportunities in exploiting Sweden's forest resources. Large areas of relatively pristine coniferous forests remained, especially in the interior of northern Sweden (Nordström, 1959). Initially dominated by sawn timber, pulp and paper exports gradually grew in importance and by 1917 became the biggest source of revenues (Pettersson, 2005, pp. 363-364). In the 1930s approximately half of Sweden's export revenues were derived from the forest sector. The boom in economic growth after the Second World War along with diversification of the economy led to a reduction of the sector's relative importance. However, the forest sector still constitutes an important part of the national economy, accounting for approximately 3 % of the gross domestic product (GDP) (Forest Europe 2015, p. 182), and today Sweden is the third largest exporter of forest products globally (SFIF, 2018). The industry is heavily oriented towards the native conifers, Norway spruce and Scots pine (*Pinus sylvestris*), that combined constitute 89 % of the annual consumption of industrial round wood (SFA, 2014, p. 193).

The first wave of harvesting in northern Sweden during the 19th century had an exploitative character, with high-grade cuttings of the largest trees, leaving residual stands with low volume and poor regeneration (Lundmark et al., 2013). Meanwhile, in southern Sweden the forests had suffered severe declines for centuries due to population pressure and associated agricultural practices (Ekelund and Hamilton, 2001, pp. 6-9). In the early 20th century there was a broad consensus regarding the poor forest state and the need to reverse the forest overuse (Ekelund and Hamilton, 2001, pp. 25-26). Guided by a quest for modernity, and to break with the past, the subsequent development has been narrated as the restoration of the Swedish forests (e.g. see Hagner, 2005; Lisberg Jensen, 2011). It involved large-scale efforts intended to secure wood supplies for industrial use. Two developments, which have had a major impact on the contemporary appearance of the Swedish landscape, are worth mentioning. First, increases in agricultural productivity and accompanying abandonment of agricultural lands caused natural forest expansion and triggered active afforestation of large areas in southern Sweden, especially with Norway spruce (Ekelund and Hamilton, 2001, pp. 6-9). Second, from being heavily debated and used in parallel during the first part of the 20th century, clearcutting replaced selective cutting in the 1950s, and has been totally dominant ever since (Lundmark et al., 2013).

The large-scale efforts to increase production were coupled with, and supported by, an establishment of forestry legislation and governmental institutions during the 20th century. The first Forestry Act, passed in 1903, was followed by gradual expansions of governmental authority in subsequent revisions (Enander, 2011). Production-orientation peaked in the 1970s and 1980s, with a quest for industrial expansion legitimizing, by Swedish standards, strong top-down "command and control" (Puettmann et al. 2009, p. 68). This involved large-scale application of herbicides, intensive scarification, ditching, fertilization, widespread reforestation with exotic species and conversion of sparse broadleaved woodlands to spruce plantations in southern Sweden (Hagner, 2005; Ekelund and Hamilton, 2001, p. 98). Meanwhile, the Forestry Act obliged owners to manage their forests in line with the strongly production-oriented paradigm (Enander, 2011). However, in 1993, spurred by international discourses as well as domestic tensions with environmental interests, the currently prevailing forest policy, stipulating equal prioritization of production and environmental goals, was established (Bush, 2010). Concurrently, guided by the core principle of 'freedom with responsibility', the prescriptive regulations were abandoned, which since then has been giving forest owners substantial management freedom (Appelstrand, 2012; Nichiforel et al., 2018). This dramatic shift also reflected a new situation regarding the actual and future projected supply of wood. The previous efforts had been highly effective in increasing the supply of timber for industrial use, thereby giving policy-makers greater leeway in meeting demands of other interest groups (Enander, 2007).

During the last two decades, implementation of the new forest policy has resulted in steady increases in shares of voluntary and formally protected areas, as well as integration of conservation measures into the management of production stands (Gustafsson and Perhans, 2010). In addition, due to changes in various silvicultural measures, including abandonment (e.g. of herbicide use), reduction (e.g. in reforestation with exotic species) and modification (e.g. of scarification techniques and drainage), the forest management intensity, defined as the degree of alteration from natural conditions (Duncker et al., 2012), has declined.

The current forest governance model, labelled 'the Swedish forestry model' (Beland Lindahl et al., 2017a), can be seen as a national response to the proposed global paradigmatic shift from sustained yield of timber to sustainable forest management (SFM) (Farell et al., 2000). However, due to the vagueness of the SFM concept and lack of international binding conventions the implementation of SFM is contextual, thereby enabling remarkably different pathways, in terms of prioritized SFM dimensions and implementation strategies, towards sustainability in different countries (Sandström et al., 2017; Beland Lindahl, et al., 2017b). The Swedish governance model includes policy objectives emphasizing the importance of wood production, biodiversity conservation, social and aesthetic values on policy formulation level (Beland Lindahl, et al. 2017a). Among these objectives, wood production and biodiversity are prioritized and should carry equal weight. This is manifested in the preamble of the Forestry Act: "*The forest is a national and renewable resource. It shall be managed in such a way as to provide a valuable yield and at the same time preserve biodiversity"* (SFA 2020a, p. 8). However, the effectiveness of the model to achieve outcomes in line with the new orientation has recently been questioned (Beland Lindahl et al., 2017a; Mårald et al., 2017, pp. 111-112). This is because although the Swedish forest governance model definitely has broadened in terms of objectives since 1993, weak link between new policy objectives and forest management on the ground implies that the traditionally strong wood production objectives and economic dimension of sustainability still dominate the practical implementation (Beland Lindahl et al., 2017a).

Recently the focus has also partly swung back towards increased emphasis on wood production, which is advocated as an important contributor to climate change mitigation (Holmgren and Arora-Jonsson, 2015; Beland Lindahl et al., 2017a; Sotirov and Storch, 2018). The harvest of wood has continued to increase (SLU, 2019a, p. 127), while the area available for wood supply has been reduced due to the increases in protected areas. This implies that the harvest potential on the area available for wood supply now is close to fully utilized (SLU, 2019b, p.15), thereby creating incentives for intensified forestry. The resulting "production comeback" is reflected in the outcome of the recent state-initiated collaborative process regarding wood production (Normark and Fries, 2019). It resulted in 88 suggested measures aiming to increase the increment with 20 % until 2050.

2.2 Small-scale forestry in southern Sweden

2.2.1 Forest conditions

Southern Sweden, here defined as the part of Sweden called "Götaland" (see map in section 3.2), has a forest cover of 63 % (Table 1). The cover of productive forestland (> 1 $m^3ha^{-1}year^{-1}$), where forest management is allowed (SFA, 2020a), is 58 %. The forests are dominated by Norway spruce, Scots pine and birch (*Betula spp.*). There is also a small share of other broadleaved species (e.g. aspen and alder) and noble broadleaves (e.g. oak and beech). The forests of southern Sweden are managed landscapes heavily altered by human influence. During the last centuries abandonment of traditional land-uses (forest grazing, slash-and-burn cultivation), reforestation of abandoned agricultural lands, selective cuttings in the early 1900s and the introduction of modern forestry have all increased the dominance of Norway spruce (Lindbladh et al., 2011; Lindbladh et al., 2014).

Table 1. Characteristics of the forests in southern Sweden (SLU, 2019a).

Attribute	**Description**
Forestland	5.4 million ha/ 63 %
Productive forestland	5.1 million ha/ 58 %
Increment	7.3 $m^3ha^{-1}year^{-1}$
Average standing volume	181 m^3ha^{-1}
Tree species composition	**% of total volume***
Scots pine	28.9
Norway spruce	48
Birch	10.5
Other broadleaves[1]	5.6
Noble broadleaves[2]	6.9
Exotic species	0.2

*on productive forestland

2.2.2 The small-scale owners

The forests of southern Sweden are mainly owned by small-scale forest owners, who control approximately 80 % of the productive forestland (SLU, 2019a, p. 84). Other major owners are the state forest company Sveaskog, the Swedish church and different private companies.

There are approximately 136,000 small-scale private forest owners in southern Sweden (SFA, 2014, p. 32). The average property has 40 ha of productive forestland (calculations based on SFA, 2014, pp. 31-32), which is large compared to the situation in many other European countries (Keskitalo et al., 2017). A century ago, forests were utilized for multiple-purposes (e.g. forest grazing, timber and wood for household needs, selling industrial round wood) by residential farmers (Törnqvist, 1995, pp. 67, 126), and was often a crucial complement supporting the owners' livelihoods. Nowadays farmers are in a minority, most owners earn their incomes outside of their properties (Lidestav et al., 2017, pp. 118-119; Westin et al., 2017, p.

[1] Aspen (*Populus tremula)*, alder (*Alnus spp.)*, rowan (*Sorbus acuparia*), Goat willow (*Salix caprea*).

[2] Beech (*Fagus sylvatica*), oak (*Quercus spp*.), ash (*Fraxinus excelsior*), elm (*Ulmus spp.),* lime (*Tilia Cordata*), hornbeam (*Carpinus Betulus*), cherry (P*runus avium*) and Norway maple (*Acer platanoides*).

65) and are not dependent on the incomes from harvesting to support their livelihoods (Andersson et al., 2010; Nordlund and Westin, 2011). Recent and ongoing trends among small-scale forest owners are an increasing ownership by non-residential owners (28 % lived in a different municipality than their property in 2010) and woman (38.5 %) (Haugen et al., 2016). Forest owners are also becoming older (average 58 years) and the prevalence of properties with multiple owners has increased.

Studies show that owners attach multiple benefits to owning and managing their forests (e.g. wood production, nature conservation, hunting and aesthetics) (Hugosson and Ingemarson, 2004; Nordlund and Westin, 2011), and there is a substantial variation in how different objectives are prioritized. As in other European countries (Ficko et al., 2019) this variation has been used to categorize owners into different types. The well cited typology study by Ingemarson et al., (2006) categorized Swedish small-scale forest owners into five types based on owner's objectives: "the economist", "the conservationist", "the traditionalist", "the multiobjective owner" and "the passive owner".

Swedish small-scale forest owners are well integrated into industrial forestry, which stands in contrast to the situation in some other European countries (Keskitalo et al., 2017). This can be explained by a combination of factors, e.g. comparably large properties, long forestry tradition and well developed markets, which together form a favorable context for active forestry. In this regard, forest owner associations (FOAs) have played an important historical role in strengthening Swedish small-scale forestry, e.g. through improved bargaining power in round wood sales (Keskitalo et al., 2017, pp. 34-35). FOAs are still playing an important role in promoting active forestry and lobbying for the owners' economic interests (Lönnstedt, 2014; Kronholm, 2016). In southern Sweden, the FOA Södra organizes 2.6 million hectares of forestland (Södra, 2019a), which is approximately half of the forestland owned by small-scale forest owners in this part of Sweden. Södra is by far the largest Swedish FOA in terms of total turnover and owns three pulp mills and seven sawmills (Lönnstedt, 2014; Södra 2019a). They thereby provide their members with dividends from the industrial revenue, in 2019 the total dividend was 1,795 million SEK (Södra, 2019b).

2.2.3 Management practices and wider management context

In a European context, southern Sweden is characterized by intensive forestry (Levers et al., 2014; Schelhaas et al., 2018). The utilization intensity (harvest/gross increment ratio) on productive forestland excluding formally protected areas during 2014-2018 was 83 % (calculations based on SLU, 2019a, pp. 117, 131). The management practices are dominated by even-aged management of Scots pine and Norway spruce (Berquist et al., 2016). Regenerations are strongly dominated by Norway spruce (Claesson et al., 2015, p. 33), which currently is planted extensively on typical pine sites due to the fear of browsing damages (Felton, 2020b). A typical management program (for pine and spruce) involves reforestation through planting (87 % of the total regenerated area 2016/2017-2018/19) (SFA, 2020b) and one to three pre-commercial thinnings (PCTs) oriented towards removing naturally regenerated birches. This is followed by one to three commercial thinnings yielding round wood and final felling after 50 to >100 years depending on site fertility and owner preferences (e.g. see Södra, 2017, pp. 63-64).

In Sweden, it is common practice to evaluate forest management practices with standard investment analysis techniques, more specifically using the Faustman formula with a discount rate of 2-3 % (Brukas and Weber, 2009). The dominant economic philosophy, that considers the value of time and the opportunity cost of capital, promotes more cost-effective silvicultural practices (e.g. planting less seedlings) and shorter rotations compared to the situation in many other European countries. However, despite being a stronghold of intensive and profit-oriented forestry at the European level (Brukas and Weber, 2009; Levers et al., 2014; Schelhaas et al., 2018) the management intensity of small-scale private forests still varies considerably (Eggers et al., 2014). To exemplify, PCTs are not always carried out according to the silvicultural guidelines, resulting in large areas (392,000 hectares in southern Sweden for all ownership groups) that are in "immediate need of PCT" (SLU, 2019a, p. 91). Moreover, the rotations periods are often longer than what is economically optimal (Berquist et al., 2016, p. 60).

Alternative species to the native conifers are actively established (e.g. planting broadleaves) only to a limited extent and continuous cover forestry (CCF) remains a rare silvicultural outlier in Swedish forestry (Sténs et al., 2019). To remedy the low variation, the Swedish Forest Agency (SFA) has during the last years promoted more varied forest management practices (SFA, 2020c), and has stated that the use of broadleaves, mixed forest and CCF should increase (Berquist et al., 2016, p. 94, 126). The main diversification actually taking place in the production forests is arguably an increased share of naturally regenerated birches in regenerations and younger forests (Berquist et al., 2016). Birch is a pioneer species which normally establish richly after final felling (Karlsson and Nilsson, 2005) and has been an accepted production species on most sites since the policy shift in 1993 (Berquist et al., 2016, pp. 26, 103), and without naturally regenerated birches only 50 % of the regenerations in southern Sweden would pass the minimum legal threshold. However, birch is concentrated to young forests, and its volume share is reduced in subsequent PCTs and commercial thinning operations that are oriented towards promoting the native conifers (Berquist et al., 2016, pp. 108-112).

Approximately 3 % of the productive forestland in southern Sweden is formally protected for conservation purposes, e.g. through nature reserves and nature conservation agreements (Statistics Sweden, 2019, p. 9), which involves financial compensation to the owners. Another 6 % of the productive forestland is voluntary protected (Statistics Sweden, 2019, p. 18), which is required for owners that want to certify their estates with FSC (Forest Stewardship Council) and/or PEFC (Programme for the Endorsement of Forest Certification) (Brukas et al., 2013). Some set-asides are actively managed for conservation, where the promotion of broadleaves via the removal of Norway spruce is the dominant treatment (Grönlund et al., 2020). In line with the Swedish integrated model to biodiversity conservation, the certification standards and the Forestry Act require retention (e.g. trees, patches and deadwood) and active creation (high stumps) of important structures at final felling (PEFC 2017; FSC 2020, SFA, 2020a). On average small-scale owners in southern Sweden leave 6 % of the area notified for final felling as retention patches, and leave 13 retention trees and create four high stumps ha^{-1} on the remaining part that is logged (Claesson et al., 2015, pp. 31, 36).

Except the minimum rotation ages and the requirement to regenerate forest after felling as stipulated in the Forestry act (SFA, 2020a), Swedish forest owners have a large management freedom. The main detailed requirements can instead be found in the voluntary certification standards FSC and PEFC (Brukas et al., 2013), which *inter alia* include minimum requirements regarding set-asides, broadleaved dominated stands, broadleaved admixture in production stands and restrictions regarding the use of exotic species (PEFC, 2017; FSC, 2020). Certified owners are also required to have an updated so called "green forest management plan", "green" in this case referring to the fact that the planned management practices for the next 10 years are in line with the conservation requirements (Brukas and Sallnäs, 2012). In total 41 % of the productive forestland owned by small-scale forest owners is certified at the national level (SFA, 2019a, p. 6) and in southern Sweden 3.4 million ha or 67 % of the productive forestland is certified (all owner types) (SFA, 2019a, p. 11).

The SFA is the governmental agency in charge of implementing the national forest policy. In line with the deregulated governance model, they mainly work with soft policy tools such as education campaigns, information and advice (Appelstrand, 2012). Advisory services to private forest owners are also provided by locally stationed wood buyers from industrial actors, such as the FOA Södra (where they are called inspectors), various sawmills (e.g. VIDA) and wood procurement organizations (e.g. Sydved). These industrial actors are increasingly dominating the advisory system (Andersson et al., 2017; Lawrence et al., 2020) as the SFA reduced the time allocated for costly face-to-face consultations with forest owners due to budgetary cutbacks (Appelstrand, 2007, pp. 198, 218; Lidskog and Löfmarck, 2016). Thus, the industrial actors play the dual role of providing advisory services and sourcing round wood from small-scale forest owners (Guillén et al., 2015). They also provide the forest owners with access to certification (Keskitalo and Liljenfeldt, 2014) and assist owners with conducting various silvicultural treatments through their entrepreneurs. While the level of self-activity in planting (36.5 %) and PCT (63.1 %) still is substantial, only a minority of owners carry out commercial thinning (18.4 %) and final felling (9.8 %) by themselves (Lidestav et al., 2017, p. 129).

2.2.4 Summary: Swedish small-scale forestry in a nutshell

In conclusion, small-scale forestry in southern Sweden is:

- Situated in human-altered ecosystems dominated by Norway spruce and Scots pine. These two species are managed actively for timber and pulpwood for industrial use through the clearcutting system over most of the forestland. Biodiversity conservation is addressed through a small share of set-asides combined with retention forestry in production forest stands.
- A hot spot of intensive and profit-oriented forestry at the European level. The comparable large properties, presence of FOAs, well developed markets and industries create a favorable context for active forestry.
- Dominated by owners that overall not are financially dependent on the incomes from harvesting to support their livelihoods. The share of non-residential owners is increasing due to urbanization and most owners depend on the industrial actors for assistance with conducting various silvicultural treatments (especially thinning and final felling).
- Characterized by extensive management freedom, soft steering and large industrial influence.

3. Material and methods

3.1 The ALTERFOR project

With the exception of Paper III all research reported in this thesis was conducted within the frames of the research project ALTERFOR[3] (Alternative models and robust decision-making for future forest management), a project running 2016-2020. In ALTERFOR, I worked as the local case coordinator in the Swedish case study area (CSA), where I was the main person responsible for the research activities.

ALTERFOR was a European research project with ten CSAs in nine participating countries. These countries were chosen to represent the variety of forest management orientations (amenity vs commodities) and governance styles (centralized state steering vs management freedom) that can be found in Europe (Figure 1). The main goal of ALTERFOR was to investigate the provisioning of ESs at landscape level with current and alternative forest management practices under different future scenarios. Quantitative modelling of different forest management alternatives in DSSs therefore formed the core of the project. To strengthen the practical usefulness of the research the project also involved various stakeholder oriented research activities, such as the organization of workshops in the CSAs. The alternative forest management approaches would also be developed collaboratively with stakeholders (see further in 4.1.2), thereby aligning the research with important forest management issues and/or ongoing policy processes in the CSAs.

[3] https://alterfor-project.eu/

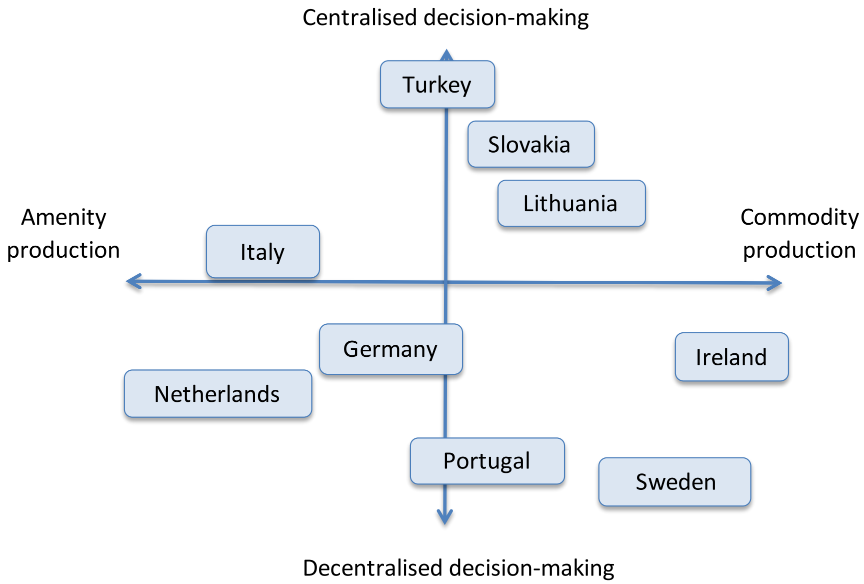

Figure 1. The ALTERFOR countries organized according to their overall goal orientation and degree of centralization in forestry. Source: ALTERFOR, (2020).

3.2 The case study area

The Swedish CSA in ALTERFOR was Kronoberg County (Figure 2), covering 660,000 hectares of productive forestland (SLU, 2019a, p. 80). Kronoberg was chosen to represent small-scale forestry of southern Sweden, but the selection was also influenced by the fact that the area was the CSA in the previous project INTEGRAL (see European Commission Cordis, 2020) (Vilis Brukas, personal communication). Kronoberg is overall characterized by the typical southern Swedish conditions (see section 2.2) but stands out in one regard. Kronoberg County was situated in the core area of two catastrophic winter storms in 2005 and 2007 (Andersson and Keskitalo, 2016), where the storm Gudrun in 2005 was the most devastating storm in terms of felled trees in modern Swedish history. As a consequence of the massive damages, the forests in Kronoberg County still have a lower standing volume (144 m^3ha^{-1}) and increment (6,2 $m^3ha^{-1}year^{-1}$) (SLU, 2019a, pp. 106, 117) than the average found in southern Sweden (181 m^3ha^{-1} and 7,3 $m^3ha^{-1}year^{-1}$, respectively, see Table 1).

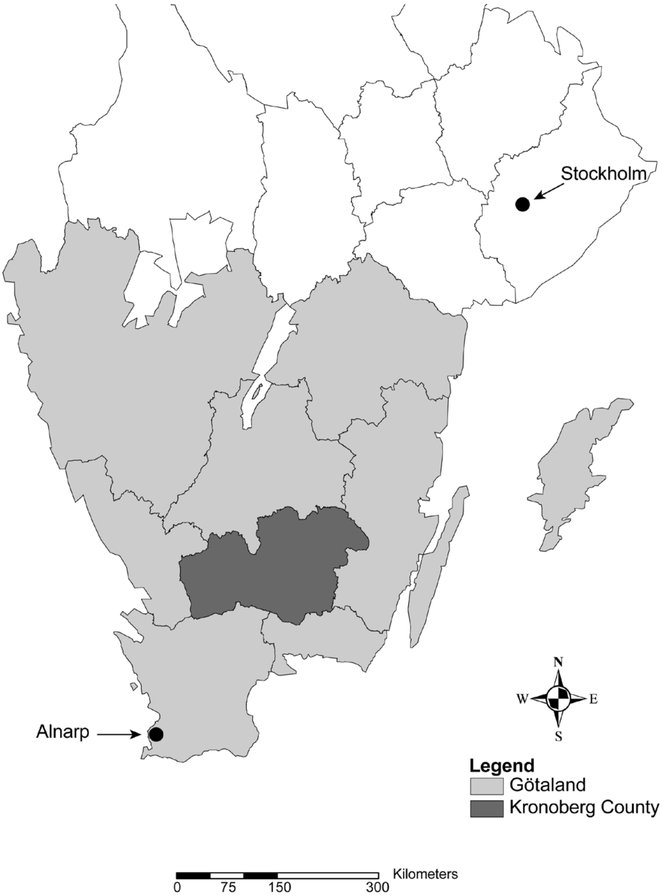

Figure 2. Map showing the location of the case study area Kronoberg County (dark grey) in southern Sweden (Götaland) (light grey). Source: Shape file with polygon layers for the counties in Sweden © The Swedish Election Authority 2019. The map was made by Adrian Villalobos.

The CSA was the geographical area in which the different types of research questions in this thesis were addressed. First, this involved quantitative modelling of forest management practices to answer "what" questions, e.g. what are the consequences of current practices (Paper I), what are the consequences of alternative x, y, z.. (see 5.2)? The alternatives (i.e. the whats) were to be determined through collaboration with important stakeholders (see 4.1.2). For his purpose, the CSA was selected as a representative case and the findings from the modelling were intended to provide knowledge about current and alternative management practices relevant to forestry in southern Sweden at large. These activities were predefined by the ALTERFORs research plan and as a local case coordinator I was in charge of making sure that the research was executed according to the plan.

Second, the CSA was also the geographical area in which case study methodology was applied to map current forest management practices and investigate their underlying drivers. The mapping of current practices was needed for the modelling, but beyond that, the research activities resulting in Papers II and III were not predefined by the project plan of ALTERFOR. According to Yin (2003, p. 9) the case study is a suitable research strategy in social science when "*a "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control*". The drivers to the current practices are situated in the present, although historical events of course also have a major impact. Moreover, understanding why forests are managed in a particular way cannot be achieved through manipulation, as the socio-ecological systems that reproduce them are outside the control of the researcher. This thesis, and especially Paper II and Paper III, partly used case study methodology to provide a better understanding about why forests in southern Sweden are managed as they are. A better understanding of the drivers to current practices can provide valuable insights about likely barriers and opportunities for future change.

3.3 Overview of methods and data sources

Reflecting the multifaceted research questions, multiple methods have been applied to fulfill the aims of this thesis. Table 2 provides an overview of the methods and main data sources used in the three papers included in this thesis. More information about the research can be found in section 5, and for further details, I refer to the individual papers at the end of the thesis.
Paper I focus on "what" questions by investigating consequences of the current forest management approaches in different future scenarios through quantitative modelling in computerized DSSs. DSSs are tools used to model forest development and the provisioning of ESs with different management

alternatives over long temporal scales on landscape level (Borges et al., 2014). Similar to all modelling of forest management practices in the project Paper I relied on the Swedish DSS Heureka, interface Planwise (Wikström et al., 2011; Heureka, 2019).

Table 2. Overview of methods and data sources used in the three papers included in this thesis.

Paper	Methods	Main data sources
Paper I (section 5.1)	Quantitative modelling in Heureka Planwise.	Forest and property data, 12 interviews with forestry advisors, forest statistics and SFA reports.
Paper II (section 5.1)	Qualitative interviews, desk research.	12 interviews with forestry advisors, other written sources.
Paper III (section 5.3)	Qualitative interviews, contextual analysis.	Seven interviews with small-scale forest owners, other written sources.

Papers II and III investigate drivers of current forest management practices in the CSA (both), which also involves studying barriers and opportunities for changed practices (Paper III). Both studies relied on qualitative interviews, but with different informants, thereby providing experiences from small-scale forestry from different perspectives. Forestry advisors were interviewed in Paper II and small-scale owners in Paper III. Case study research in social sciences is characterized by a will to deliberately cover contextual conditions, since it often address topics where the boundaries between phenomenon and context are blurry (Yin, 2003, p. 13). This understanding is underlying the analytical approach adopted in Paper III (practice based approach, situated agency see 4.2.) where the interview study also was complemented with a contextual analysis. Another key feature and advantage of case study research is the use of multiple-sources of evidence (Yin, 2003, p. 101). Analysis of various written sources such as previous peer-reviewed papers, SFA reports and forest management statistics formed important complements to the interview data in both studies. Finally, the interviews with the forestry advisors (see interview guides in the appendix) provided empirical data about current forest management practices that was used in both Paper I and II.

4. Methodological and theoretical considerations

4.1 Futures studies in ALTERFOR

4.1.1 Scenarios

Futures studies in forest research are conducted with different types of scenario approaches (Hoogstra-Klein et al., 2017). Scenario typologies are tools used to make this rather complex research field easier to overview. They can also facilitate communication among involved researchers and between research and the wider society. The scenarios used and the futures constructed in the research reported in this thesis are categorized according to the typology by Börjeson et al., (2006). The same typology was applied by Mårald et al., (2017) when categorizing the 31 future-oriented studies conducted in the Future Forest program (see pp. 65-72).

Table 3 shows the three broad types of scenario studies (probable/predictive, possible/explorative and preferable/normative), along with references to example studies for each type. Predictive scenarios investigate probable futures, future developments that are likely if current structures (e.g. wood markets) and trends (e.g. GDP growth, population growth) are extended into the relatively near future (Hurmekoski and Hetemäki, 2013). Explorative scenarios explore possible future developments and include two sub-types; external and strategic (Table 3). External scenarios explore changes in external drivers, often relating to global developments that are considered hard to influence at the national or regional level (Mårald et al., 2017, p. 74). Strategic scenarios explore what may happen if we act in a certain way e.g.

large-scale shifts in silvicultural systems (e.g. see Korosuo et al., 2014). Finally, normative scenarios investigate preferred futures by various actors (e.g. Sandström et al., 2016), and can be complemented with back casting to investigate what obstacles in the present that need to be tackled for the desired future to materialize (e.g. Sandström et al., 2020).

Table 3. Different types of scenario studies and examples of forest related futures studies belonging to each type (modified from Börjeson et al., (2006) and Mårald et al., (2017)).

Question	Type	Sub-type	Examples
What will happen?	Probable/Predictive	-	Malmberg, (2015)
What could happen?	Possible/Explorative	External	Nordström et al., (2016)
		Strategic	Korosuo et al., (2014)
What should happen?	Preferable/Normative	-	Sandström et al., (2016)
			Sandström et al., (2020)

Three climate change mitigation scenarios were used in ALTERFOR (Figure 3) (Forsell and Korosuo, 2016). They were all prepared with GLOBIOM, a global recursive dynamic partial equilibrium model of the forest, agricultural, and bioenergy sectors (Havlik et al., 2014; Lauri et al., 2017) (see section 2.4 in Paper I for more information about GLOBIOM). The scenarios are all based on the intermediate scenario in the SSP (Shared Socioeconomic Pathway) framework for the future development of populations, GDP and use of natural resources (Fricko et al., 2017), combined with different levels of ambition in climate change mitigation (Forsell et al., 2016). All scenarios assume that climate change mitigation will increase the demand for wood (Forsell and Korosuo, 2016), and there is a correlation between the level of control of climate change and expected increase in wood demand (see Figure 3). According to the typology by Börjeson et al., (2006) the scenarios can be classified as **possible-external**. They explore possible future trajectories for the global development of climate change mitigation efforts, over which Sweden overall exercise limited control. The external scenarios provided three different future trajectories for the demand of wood, prices and level of warming at national level (for the different ALTERFOR countries).

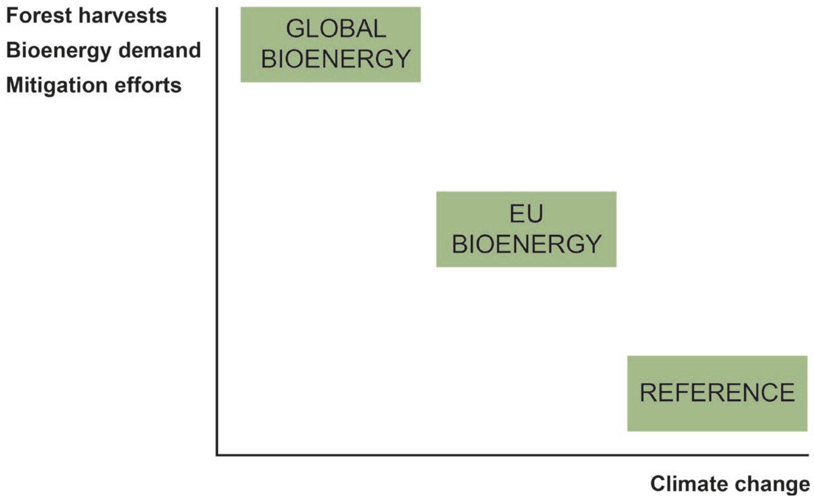

Figure 3. Overview of the three climate change mitigation scenarios used in ALTERFOR. Source: Remade from Forsell and Korosuo, (2016).

REFERENCE (REF) (see Forsell and Korosuo, 2016 for details) is based on an extension of the historical development of mitigation efforts into the future but accounts for the EU climate targets until 2020 (in place 2016). In 2100, the global temperature is assumed to be ca 3.7 °C higher than the pre-industrial level and the demand for roundwood in Sweden has increased with 24 % compared to 2015 (Figure 4). EU BIOENERGY (EU) takes into account EU policies (in place 2016) that aim at an 80% reduction in emissions by 2050 and assumes that climate policies are in effect globally. The global temperature will be ca 2.5 °C higher by 2100 and the demand for roundwood has increased with 16 % (Figure 4). The lower demand in Sweden in EU compared with REF is due to trade within and outside Europe. GLOBAL BIOENERGY (GLOBAL) assumes that very ambitious mitigation policies are implemented globally. The global temperature will only be 1.5-2 °C higher by 2100 and the demand for roundwood increase with 68 % (Figure 4).

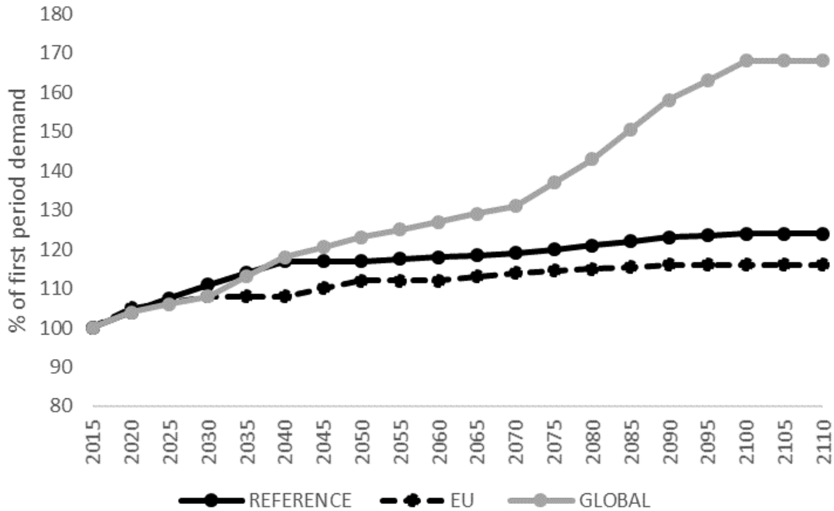

Figure 4. Development of demand for roundwood (sawlogs and pulpwood from thinning and final felling) in Sweden in the three climate change mitigation scenarios (REF, EU, GLOBAL) relative to the demand in the first period. Source: Lodin et al., (2020).

4.1.2 Development of alternatives with stakeholders

The forest management alternatives investigated were developed collaboratively with stakeholders in the CSA. This work was theoretically guided by the RIU (research, integration, utilization) – model for scientific knowledge transfer (Böcher and Krott, 2016), a model that aims to increase the likelihood of research results being utilized in practice. The main innovation of the model is arguably its integration component (i.e. step two). Here research topics and questions are selected based on practical issues and needs (Böcher and Krott, 2016, pp. 24, 29). This is achieved through collaboration with powerful actors, who select topics and issues for investigation based on their interests and problems. The model is theoretically anchored in the actor-centred power approach by Krott et al., (2014) and in an analytical tradition where actors' interests and power resources are considered central for understanding policy making and other processes in the forest sector (see Krott, 2005). Accordingly, the idea is that stakeholders from practice should act as allies of research, and that the scientific knowledge transfer should be aided by the power resources these actors have at their disposal to influence other actors (see Böcher and Krott, 2016, pp. 21-22).

The procedure selected for the development of alternative management approaches had certain implications. First, it implied that normative elements were included into the research project, where the investigated alternatives would constitute **preferable futures** for the involved allies from practice. This raised important issues, such as the importance of getting different interests represented and the importance with a general reflexivity from the involved researchers (e.g. whose future is represented, who benefits or loses in the investigated futures) (see 6.3 for critical reflections about the research process). Second, the future-oriented research would include studies of both **possible and preferable futures**. How this challenge was addressed in the research is described in section 5.2.2.

4.2 Studying barriers and opportunities for change

Paper III investigates barriers and opportunities for change of forest management practices by studying small-scale owners' reforestation decisions since the storm Gudrun (see 5.3). This was done through the theoretical lens of the practice based approach by Arts et al., (2013). The approach challenges what is perceived as the simplistic assumptions made in mainstream theories in forest policy analysis, focusing on either individual agency (rational choice) or social structures (institutionalism) as the drivers of human behavior (Arts et al., 2014). To avoid detached overly anthropocentric forest governance studies, the approach also stresses the need for better consideration of material aspects, i.e. nature and things. The resulting practice based approach aims to study practices in nature and forest governance, defined as "*an ensemble of doings, sayings and things in a specific field of activity*" (Arts et al., 2013, p. 9). Based on this understanding, forest management practices are seen as emerging from entwinement of actors (e.g. forest owners, advisors, forest industry), institutions (regulations, norms, beliefs), knowledge (e.g. experience-based, expert-based) and ecosystem properties (e.g. growing conditions, disturbances, main species) in specific material settings. Consequently, the approach provides a holistic framework for studying forest management practices, factoring in the different components of the socio-ecological system that are interacting in specific contexts to shape current practices. The approach's analytical core is based on three sensitizing concepts: situated agency, logic of practice and performativity (see Arts et al., 2013, pp. 9-12).

Following is a short description of two of these concepts, which were applied in Paper III.

The first sensitizing concept employed was **situated agency** that challenges the assumption of the autonomous rational actor in the rational choice model (Arts et al., 2013, p. 10-11, Arts et al., 2014). Agency is conceptualized as situated rather than individual, implying that actors' interpretations and subsequent actions are shaped by previous experiences from the practice where they are situated. Hence, to understand agency in a particular field, we need to study the decision-makers together with detailed scrutiny of their past and current contextual setting. This concept is attractive for conceptualizing forest management practices in the small-scale forestry of southern Sweden, because although owners legally have large decision-making freedom, their forest management contexts are characterized by a wide range of potentially constraining factors, which might explain why certain practices are reproduced over others. It also provides a useful middle ground in the agency-structure dualism in social science theory (see Arts, 2012). According to the concept, actors are allowed to interpret and act in different ways, at the same time as their interpretations are influenced by previous experiences from the practice they are engaged in (Arts et al., 2013, p. 10).

The second sensitizing concept, **logic of practice,** is *inter alia* used to challenge overoptimistic beliefs in the capacity of formal institutions to steer human behavior (Arts et al., 2013, p. 10). "*Practice has a logic which is not that of the logician*" (Bourdieu 1990, p. 86), and implementing policies to steer practices in line with a certain logic can therefore be challenging. Arts et al., (2013) state that the practice based approach is suitable for detailed studies of puzzles, i.e. situations where outcomes not are in line with what you would expect from externally looking at the situation. For example, this can be the failure of what seems to be a well-designed policy instrument to create its desired effect. The reforestation after the storm Gudrun can from the outside be seen as such a puzzle. The dominance of spruce was one factor behind the massive storm damages (Valinger and Fridman, 2011) and the government provided subsidies to compensate for the higher establishment costs of alternative species (Wallstedt, 2013). Still, previous practices remained intact and Norway spruce was planted on 90 % of the storm-felled area (Valinger et al., 2014). Consequently, this is a case where in-depth qualitative research with the practice based approach can provide insights into why this window of opportunity, that from the outside seem to have been characterized by a favorable context for change, overall did not facilitate more diverse plantations. Better understanding of such internal logics of practices can also provide input that makes steering more successful (Arts, 2013, p. 254), i.e. steering that considers the internal logics.

5. Summary of research activities including papers

Following is a summary of the research conducted in the ALTERFOR project in the Swedish CSA. This goes beyond summarising the individual papers, since, to understand the research process, the work needs to be placed in a wider project context. This also sets the ground for a broader discussion about future forest use (see section 6).

5.1 Current management practices (Papers I and II)

The first phase of the project focused on describing current management practices (Agestam et al., 2017) and investigating their performance with regard to the provisioning of ESs and the different challenges laid out in the climate change mitigation scenarios (Biber et al., 2018). This was crucial for establishing problem formulations for the subsequent work. It would also provide the stakeholders with background information related to their problems and needs, which would be addressed in the subsequent **integration** step in the RIU-model for scientific knowledge transfer.

When investigating current management practices it was considered crucial to account for the well-documented variation in management intensity among small-scale owners (see 2.2.3) in the projections. Hence, "current" would not simply mean management according to current silvicultural guidelines, it would also factor in to what extent such guidelines are implemented in practice. Otherwise, there is a risk that what is intended to be a projection with current practices in fact entails an intensification of forest management. To accomplish this, a lot of work was invested into investigating the current management practices in the CSA, which resulted in **Papers I and II**.

Paper I has two aims. First, to investigate to what extent the current forest management practices in Kronoberg could meet the increasing wood demand in the three climate change mitigation scenarios (i.e. REF, EU and GLOBAL). Second, to assess to what extent high demand (in GLOBAL) could be satisfied by increasing the management intensity within the frames of the established approaches (i.e. mainly clearcutting with Scots pine and Norway spruce). This was done by projecting the current forest management approaches with different levels of intensities (the current intensity and two levels of intensification) in the climate change mitigation scenarios at landscape level over 100 years in the DSS Heureka. Current management was mapped based on statistics, reports and interviews with forestry advisors, and translated into five "frozen"[4] management strategies determining forest management on property level. These strategies were differentiated based on different rules for regeneration, PCT, commercial thinning, final felling and nature conservation. The strategies were partly based on previous research by Eggers et al., (2014 and 2015). The Forestry Act's restrictions limiting the share of barren land and younger forests (<20 years) on properties >50 ha (SFA, 2020a, pp. 28-29) were also accounted for in the projections. The demand in the beginning of the projections was set to reflect the utilization intensity (harvest/growth) in southern Sweden during the period 2006/2007–2015/2016. From this level, the demand followed the national trajectories provided by the scenarios (see Figure 4 and 5). The projections took the effect of climate change on growth into account by using the functionality for RCP 8.5 (REF) and RCP 4.5 (EU) implemented into Heureka (Eriksson et al., 2015). GLOBAL (RCP 2.6) was projected as if the

[4] "Frozen" here means that the strategies did not respond to changes in external drivers in the scenarios (e.g. prices). This implies that the distribution of the strategies and the strategy rules were the same during the entire projection period. Our approach, which differed from similar studies in this research field (see Hengeveld et al., 2017; Trubins et al., 2019), was used due to the aim of the paper. A current projection with low responsiveness to external drivers was needed as a benchmark to investigate the increase in harvest that could be obtained through an intensification.

growth would be unaffected by climate change, because Heureka do not have any climate change effect functionality for this scenario.

Figure 5 shows the round wood harvest for each 5-year period in the projections with current forest management practices (i.e. the current intensity, where the owner heterogeneity has been accounted for) in all scenarios. In all three scenarios, a lack of potential final felling areas results in a roundwood shortage around 2035-2040. In REF and EU the more modest increases in demand, combined with an increased growth due to climate warming (see section 6.2 for a discussion about the climate change impacts), imply that the demand otherwise is easily satisfied (except a small wood shortage in 2050). In contrast, in GLOBAL the harvest is highly fluctuating and the demand cannot be met during many periods (Figure 5). A closer look at the utilization intensities (felling/net increment) shows that the required harvest in this scenario is significantly higher than the increment on the area available for wood supply towards the end of the projection period (see Paper I).

In summary, the **possible-external scenarios** provide different trajectories with regard to future drivers of forest management in the CSA, enabling diversification towards less intensive practices in REF and EU, while pushing for further intensification in GLOBAL.

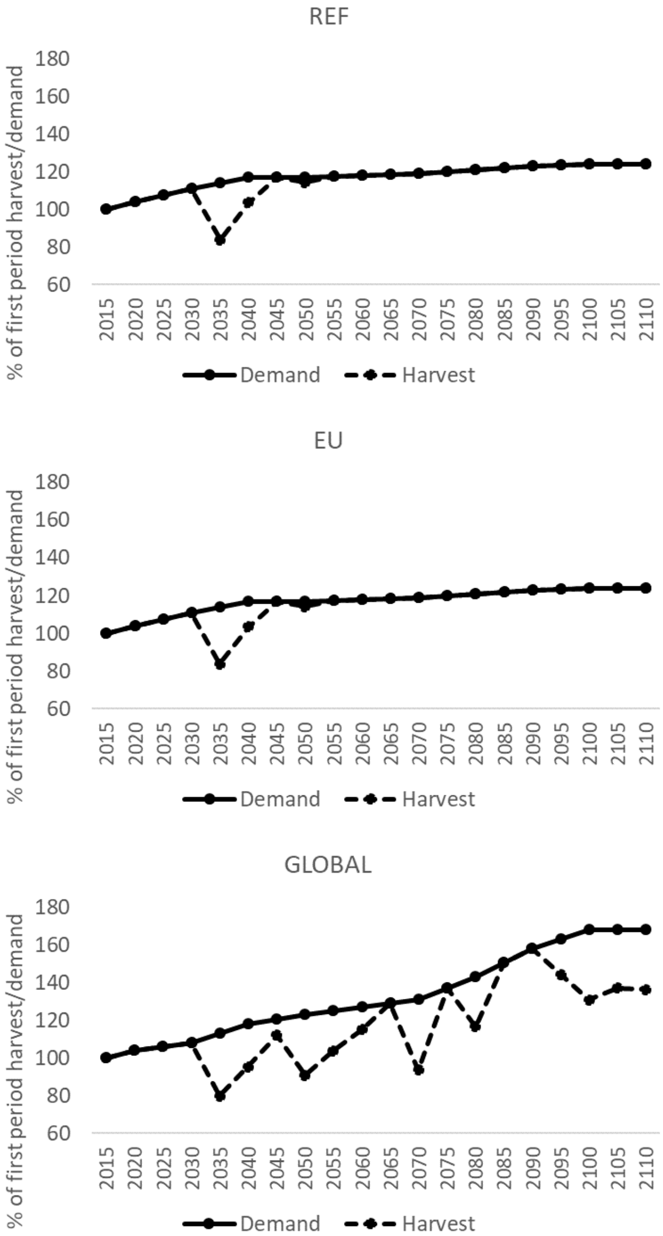

Figure 5. Projected demand vs harvest (relative to the demand/harvest in the first period) of roundwood (sawlogs and pulpwood from thinning and final felling) with current forest management practices in the three scenarios (REF, EU, GLOBAL).

Figure 6 shows to what extent the large increase in demand in GLOBAL can be met through intensification within the frames of the established approaches. Making all owners manage their forests according to the most intensive strategy reduced the wood shortage from twelve (in Current_GLOBAL) to seven periods (in Intensive_GLOBAL). Further intensification, implemented by allowing final felling in all production stands older than the minimum age in the Forestry Act (with some exceptions[5]), further reduced the wood shortage to five periods and the demand was satisfied until 2085 (in Intensive_Short_GLOBAL). The harvest level required in the scenario GLOBAL towards the end of the projection period is well above the level that can be sustained with the current approaches.

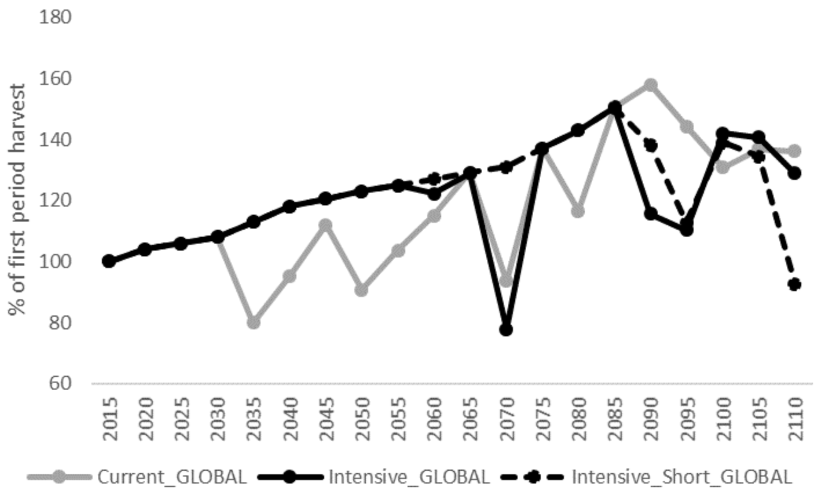

Figure 6. Projected harvest (relative to the harvest in the first period) of roundwood (sawlogs and pulpwood from thinning and final felling) with current management approaches of different intensities in the GLOBAL BIOENERGY scenario. Source: Lodin et al., (2020).

[5] Final felling was not allowed if it conflicted with the stipulations limiting the share of barren land and younger forests (<20 years) in the Forestry Act (SFA, 2020a, pp. 28-29). This was the case in all projections made for Paper I (i.e. in the projections with the current intensity and in the two projections with intensification).

To conclude, the intensification needed to meet the long-term demand in GLOBAL goes well beyond an intensification within the frames of the established approaches. It would require large-scale implementation of new/uncommon more productive management programs with likely detrimental effects on other ESs such as biodiversity. Moreover, this study also shows that how current management is conceptualized (e.g. current guidelines vs current practices), and at which detail it is taken into account in the projections, have large implications for the results in scenario modelling studies in landscapes dominated by small-scale forest owners.

Paper II looks in detail into the drivers behind the current management practices modelled in Paper I by investigating what the interviewed forestry advisors perceive to be the main causes to the witnessed deviations from the dominant production-oriented silvicultural ideals (clearcutting with either Norway spruce or Scots pine). Reflecting the Swedish deregulated governance approach, these programs are promoted among small-scale forest owners by various forest organizations through soft means, mainly information and market incentives. The forestry advisors' perspective on forest management among small-scale owners was complemented with analysis of additional written sources and statistics to validate, and further describe, the deviations between the production-oriented ideals and real practices.

Table 4 shows a summary of main deviations and perceived causes according to the 13 interviewed forestry advisors working in the CSA. First, biotic (e.g. browsing, spruce bark beetles) and abiotic (e.g. storms) disturbance factors have recently played a large role in shaping forest management practices in the CSA. Owners reforest with Norway spruce on Scots pine sites due to the fear of browsing damages. The devastating storms in 2005 and 2007 caused massive direct damages, followed by indirect effects (e.g. lower activity in other treatments), some of which are still perceived to influence owners willingness (e.g. increased attachment to the remaining "mature" forest) and/or possibilities (e.g. large storm felled areas now in need of time consuming or costly PCT) to adhere to the production-oriented programs. Here it is good to keep in mind that data collection for this study was made before the hot and dry summer of 2018 and the resulting major outbreak of the spruce bark beetle. Second, the other type of perceived causes are related to the agency of the small-scale owners and concerns factors that in the literature often are associated with their increased heterogeneity. Limited silvicultural knowledge, low income needs and attachment to "mature" forests are perceived to sometimes cause deviations from the promoted silvicultural ideals. Finally, PCT is the treatment associated with most deviations according to the informants. In line with findings of previous Scandinavian research (Fällman, 2005; Karppinen and Berghäll, 2015), advisors perceive that the high short-term costs and time constraints among self-employed owners act as barriers to "ideal" outcomes.

Table 4. The most prominent deviations between the silvicultural ideals and the real practices, together with the witnessed (storm felling) and perceived (owners' motives) causes according to the informants. Source: Lodin and Brukas, (2021) with some smaller changes.

Silvicultural treatment(s)	Type of deviation	Description	Main cause(s)
Regeneration	Tree species choice	>50 % of the pine sites planted with Norway spruce (SFA, ÄBIN 2015-19).*	Fear of browsing damage
PCT	Level of activity	37 % of the young forest area (dbh <10 cm) in immediate need of PCT (SLU, 2017, pp. 82, 89). ** 25% of the young forest area never treated with any PCT (Claesson et al., 2015, p. 34). **	Short-term costs, lack of time
Thinning	Poor economic result	High harvesting costs in the first thinning due to high stand density.	No or low intensity PCTs
Final felling	Timing	Longer rotations than silvicultural ideals (Fries et al., 2015). **	Owners' preferences
PCT, thinning, final felling	Level of activity, timing	Reduced activity in PCT and commercial thinning after the storm Gudrun (Valinger et al., 2014).* 18% of the standing stock in Kronoberg felled by the storm Gudrun (Holmberg, 2005). *	Storm felling

In: *Kronoberg county, **southern Sweden

Seen from a larger perspective, the described deviations constitute moderate variations within a stronghold of intensive forestry, characterized by one of the highest utilization intensities in Europe. Regarding the harvest of round wood, the deviations are overall not related to the amount of harvested wood, but instead to when harvest occur in time (i.e. timing). In Sweden, the ecological quality (e.g. presence of large old trees, deadwood) of the production forests remains crucial for conservation outcomes (Felton et al., 2020a). Some of the identified "deviations" (e.g. longer rotations) can therefore provide increased matrix heterogeneity for the benefit of conservation.

5.2 Alternative management practices

5.2.1 Development of alternatives for stakeholder workshops

In the RIU-model's **integration** component, research is connected with practical demands through the selection of "bricks of knowledge" by actors from practice (Böcher and Krott, 2016, p. 34). In this case, the "bricks" would be forest management alternatives addressing practical issues and needs faced by forestry actors in the CSA. According to the RIU-model scientific knowledge is transferred through unbalanced power relations (see Krott and Böcher, 2016, pp. 21-22), and effective knowledge transfer therefore requires collaboration with powerful actors. Thus, a key priority was to find influential actors in the CSA that were interested and willing to collaborate with ALTERFOR. The search for allies was assisted by an actor analysis carried out early in the project (Lodin, 2017). This investigation mapped the main actors, their interests and power resources, as well as current conflicts and main forest management issues in the CSA.

The first partner willing to collaborate was the FOA Södra, who also was the official non-academic partner of the ALTERFOR project in Sweden. Due to their influential role in shaping forest management practices in southern Sweden (see 2.2.2 and 2.2.3), Södra served as a fitting partner for representing wood production interests in the CSA. The second key partner, primarily representing conservation interests, was the County Administrative Board (CAB) in Kronoberg. The CAB is a regional governmental organization that in a forestry context is influential in nature conservation, where they *inter alia* work with creating and managing nature reserves. The CAB was interested in collaboration due to the needs emerging from their work with the regional implementation of "Green infrastructure", a national project aiming to promote an improved landscape level perspective on biodiversity conservation and management of other ESs (SEPA, 2018).

Together with these two actors, the FOA Södra and the CAB, we jointly developed forest management alternatives for detailed investigations. Results from long-term landscape level projections with these alternatives were subsequently presented during two workshops targeting forestry actors in the CSA.

Preliminary projections with current forest management practices provided important background information for the selection of alternatives by the CAB (see Lodin et al., 2018a). These projections showed that the current reforestation practices would result in a large future increase of Norway spruce. The CAB was therefore interested in investigating alternatives that could increase the share of broadleaves in the production forests. This constitutes a well-recognized strategy for promoting biodiversity conservation in Sweden (Felton et al., 2016a), where the ecological quality (including its species composition) of the production forest matrix is of crucial importance for conservation outcomes (Felton et al., 2020a). The broadleaved-oriented alternatives selected by the CAB for inclusion in the alternative landscape level projections are shown in Table 5. In summary, the CABs **preferable future** contained increased emphasis on nature conservation. This would stimulate more diverse management practices through an increased use of broadleaves.

Table 5. The alternatives investigated for the stakeholder workshop organized with the County Administrative Board (CAB) (for more information see Lodin, 2018a).

Alternative	Motivation
Border zones with/without management	Forest borders towards water, such as streams (Ring et al., 2018), and open areas, such as agricultural land (Essen et al., 2016), are often rich in broadleaves. Excluding these zones from conventional conifer–oriented forestry might therefore increase the share of broadleaves.
Spruce-birch mixture	Alternative to increase the share of broadleaves with lower implementation barriers, since the birches are established through natural regeneration. Partly replacing spruce monocultures with birch-spruce mixtures would be positive for biodiversity (Felton et al., 2016b).
Oak for wood production	Oak has very high biodiversity values in southern Sweden (SLU Swedish Species Information Centre, 2020b, p. 18) and increasing the cover of oak would therefore be beneficial for conservation.

Picture 1. Group work during the first stakeholder workshop organized together with the County Administrative Board (CAB). Photo: Pär Fornling.

In contrast, our work with Södra mainly focused on alternatives to increase growth and harvest opportunities (Table 6). This is in line with Södra's current goal to increase the growth in their members' forests with 20 % (from the level in 2015) until 2050 (Södra, 2019a, p. 13). The future laid out in GLOBAL is well aligned with Södra's interest to promote wood production as an important mitigation strategy. The projections developed for the workshop were therefore focused on investigating alternatives that could meet the large increase in demand in this scenario. This included intensification within the frames of the established approaches (better regenerations and PCTs), as well as large-scale implementation of other measures to increase growth (hybrid larch, fertilization, and spruce clones) (Table 6). In summary, in Södra's **preferable future** the climate change challenge motivates a continued strong focus on production, as well as implementation of measures to increase production even further. Based on Södra's wishes, we also investigated some other alternatives for the workshop. This included increased regeneration with Scots pine and investigations of harvest opportunities lost due to current (comparing the current level with no conservation) and future expected (the new Swedish FSC standard) conservation requirements (Table 6).

Table 6. The alternatives investigated for the stakeholder workshop organized with Södra (for more information see Lodin, 2018b).

Alternative	Motivation
Improved regenerations and PCTs	Increased wood production and revenues.
Exotic species (hybrid larch)	Increased production. Several exotic species, such as hybrid larch, can increase growth in southern Sweden if established on suitable sites (Nilsson et al., 2011; Westin et al., 2016). Hybrid larch also has a shorter rotation period that can be exploited strategically to bridge future expected wood shortages.
Fertilization in pine forests	Increased production. In southern Sweden fertilization in pine forests increase growth (Bergh et al., 2014).
Spruce clones	Higher production compared to normal spruce seedlings. By mass-producing the best spruces in the Swedish breeding program through somatic embryogenesis it is possible to get seedlings that will be available through conventional techniques 20-30 years earlier (Rosvall et al., 2019).
More pine	The low level of reforestation with pine is an issue of concern in the forest sector. There is a broad consensus (including Södra) that pine regeneration should increase.
Continuous cover forestry (CCF)	The new Swedish FSC-standard includes requirements on additional 5 % set-asides or management with increased consideration (such as CCF) (FSC, 2020, p. 41).
No conservation	To investigate harvest opportunities that are "locked-up" in voluntary set-asides and retention patches a projection with minimum conservation (only formal set-asides) was compared with the projection with the current conservation level.

Picture 2. Group work during the second stakeholder workshop organized together with the forest owner association Södra. Photo: Pär Fornling.

Both jointly organized workshops targeted forestry actors in the CSA. The agendas of the workshops included presentations of results from the landscape level projections with the alternatives (by myself), other presentations from our stakeholder partners and invited guests and group work (see Lodin, 2018a; 2018b for details). Table 7 summarizes some other key features of the workshops. Reflecting the primary interests of our stakeholder partners, the two workshops had a very different focus and explored radically different forest management pathways (diversification for conservation vs intensification for production). Another key difference was the level of importance of the scenarios. Trying to meet the demand challenge laid out in the **possible-external** scenario GLOBAL would require more intensive management practices (see 5.1). This matched well with Södra's interest in a (**preferable**) future where climate change mitigation creates new business opportunities and motivates further measures to increase production. Therefore, most of the developed projections for this workshop investigated how the demand in GLOBAL could be met through intensified practices. In contrast, for the CAB, biodiversity conservation and their ongoing work with green infrastructure were the major areas of concern, not the future development of wood demand related to climate change mitigation. For this workshop, we used the intermediate scenario EU, but the scenario had no influence on the selection of alternatives. This selection was instead guided by the performance of indicators related to broadleaves, e.g. volume share of broadleaves.

Table 7. Overview of some key features of the two stakeholder workshops organized in the Swedish CSA during the ALTERFOR project.

	Workshop 1	**Workshop 2**
Partner	CAB Kronoberg	FOA Södra
ES in focus	Biodiversity	Wood production
Main orientation of investigated alternatives	Increase the share of broadleaves	Increase production
Scenario	EU BIOENERGY	GLOBAL BIOENERGY
Scenario importance	Low	High
Documentation	Lodin, 2018a	Lodin, 2018b

5.2.2 Subsequent utilization in research

Utilization of scientific knowledge produced by the RIU-model model can take place both in practice and in the scientific research community (Böcher and Krott, 2016, p. 34). Practical utilization is discussed in section 6.3. Following is a short summary of the utilization of the alternatives developed for the stakeholder workshops in the final alternative landscape level projections in ALTERFOR (see Biber et al., 2019), arguably the most important and extensive deliverable in the project.

In Sweden, the work with the stakeholder partners' **preferable futures** had resulted in the development of a number of alternatives that could be used to alter the long-term provisioning of ESs in the Swedish CSA in distinct directions (promoting wood production or conservation). In the projections for the final deliverable we "cherry-picked" among current practices and the developed alternatives. The selection was guided by the following strategic aim: "Improve the provisioning of ESs within the frames of the roundwood demand trajectories of the scenarios". Consequently, the end product was a **possible-strategic** scenario study, showing how the challenges laid out in the **possible-external** climate change mitigation scenarios could be addressed strategically. In GLOBAL, not much could be done for other ESs due to the large increase in demand. All implemented changes (except increased reforestation with Scots pine) entailed intensification compared to the projections with current forest management practices (Table 8). In REF and EU, the ease of meeting demand enabled implementation of less intensive and/or more "biodiversity friendly" alternatives (e.g. oak, spruce-birch mixture, CCF). The change towards regenerations less dominated by Norway spruce (more pine, broadleaves and Douglas fir (*Pseudotsuga menziesii*)) would also reduce climate change-related risks considering the high level of warming in these two scenarios.

Table 8. Summary of the implemented changes in the alternative landscape level projections in the Swedish CSA compared to the projections with current management practices. Source: Biber et al., (2019).

Scenario	Implemented changes
GLOBAL BIONERGY	Intensification within the frames of current approaches (better regenerations and PCTs, shorter rotations, increased extraction of harvest residues), more Scots pine, hybrid larch, fertilization in pine forests, spruce clones.
EU BIOENERGY	More Scots pine, prioritize border zones for retention, oak for wood production, spruce-birch mixture, CCF.
REFERENCE	More Scots pine, prioritize border zones for retention, more oak for wood production and spruce-birch mixture (compared to EU Bioenergy), Douglas fir, CCF.

Consequently, the challenge of combining studies of **possible and preferable** futures within the same project (see 4.1.2) was handled through a two-step process. A range of alternatives was first developed together with stakeholders in the work with their **preferable** futures. These alternatives, along with current management practices, were then strategically combined in the final alternative landscape level projections to address the challenges laid out in the **possible-external** climate change mitigation scenarios.

5.3 Barriers and opportunities for change (Paper III)

The projections developed for the workshops and the final deliverable (Biber et al., 2019) entailed major changes of forest management that all involved (to different degrees and for various reasons) a move away from the current practices strongly dominated by Norway spruce. While such changes can be implemented when modelling landscapes in DSSs, they are harder to achieve in practice. In this regard, **Paper III** provides some insights about barriers and opportunities for practical implementation.

The paper investigates small-scale owners' reforestation decisions since the storm Gudrun through the lens of the practice based approach (see 4.2), spotlighting the decision to plant spruce as well as other species. The shared socio-ecological system where the owners are situated is characterized by a wide range of factors that have been, and still are, favoring the use of spruce at the expense of other species. The most important factors include market conditions, the high browsing pressure, dominant soil conditions, and the Swedish profit-oriented forest management paradigm in general. However, at an individual level the factors shaping the reforestation practices (e.g. owner motives and experiences, advisory services), as well as their interactions, undoubtedly vary. A contextual analysis at the macro-level was therefore complemented with qualitative interviews with owners to provide in-depth insights into reforestation logics in specific settings. Interviews with owners revealed that their selection of Norway spruce often stemmed from experiential knowledge of the species' own merits (e.g. easy to manage, high growth, profitability). However, in other situations the perceived level of contextual steering towards spruce was more pronounced (e.g. due to browsing on pine, influence from advisors). The main factors guiding owners who selected other species were risk-awareness (mainly favoring broadleaves), consideration of aesthetical values (favoring broadleaves) and a curiosity to try new species (mainly favoring exotic species).

The reforestation grants offered by the SFA, which compensated for the higher establishment costs, were pivotal for the owners planting broadleaves. However, the more positive attitude towards broadleaves among several of the interviewed owners was often manifested through natural regeneration of birch instead of planting broadleaves. In total only 3000 hectares out of the 88,000 hectares that were financially supported after the storm received support for establishment of broadleaves, the rest was supported with the lower sum grant for conifers, where almost everything was planted with spruce (Wallstedt, 2013). In our study, naturally regenerated birch was an important alternative pathway to diversity among several owners. This suggests that we might underestimate owners' willingness to change if we only assess the outcome based on the granted area, where the diversification pathway financially promoted by the SFA (a planted fenced broadleaved plantation) had a low level of uptake compared with conifer plantations.

In conclusion, the sensitizing concept **situated agency** offers a perspective that provides a more nuanced understanding of the reasons behind the continuation of the spruce-oriented practices and challenges for future diversification. Small-scale owners' interpretations are shaped by a long-tradition of, and favorable context for, spruce-oriented forestry. Abandoning old habits and establishing new types of experiential knowledge can be a challenging and slow process. At the same time, there is already a lot of practical knowledge in Swedish forestry regarding Scots pine. However, the use of this species is severely constrained by the high browsing pressure.

The owners' described reforestation experiences could often be connected to general (spruce favoring) factors characterizing small-scale forestry in southern Sweden, as revealed in the contextual analysis. Nevertheless, the small sample complicates generalizations, which is certainly the case for the drivers favoring regeneration with alternative species. Instead, small-sample in-depth qualitative methods is better equipped for revealing specific logics to forest management practices not predefined by the researcher (see Stanislovaitis et al., 2015), nor actively promoted through governmental programs (such as SFA reforestation grants supporting planting and/or fencing) (Arts et al., 2013). In this study, naturally regenerated birch emerged as an alternative pathway to species diversity. For various reasons, deliberate (leaving an area for natural regeneration) as well as quite random (e.g. delayed regeneration decision, failed spruce plantation), many owners in this study ended up with stands with a lot of naturally regenerated birch. Better exploitation of this low barrier alternative, which is legal on most sites according to the current legislation, can aid future efforts to promote species diversity in southern Sweden. Regardless, small-scale owners will also in the future have to face the question: What to do with all the naturally regenerated birches?

6. Discussion

6.1 Current versus multiple alternatives. Standing at the cross-road

This thesis was introduced by presenting futures studies as an important tool for investigating future challenges and alternative forest management pathways. In response to identified shortcomings in previous research, much of the future-oriented research presented in this thesis was conducted in collaboration with stakeholders (cf. Section 5.2.1). This resulted in investigations of very different alternatives, representing rivalling interests in contemporary Swedish forestry. Informed by the research in this thesis, I will here connect my findings to some recent research, ongoing debates and policy developments regarding future forest use in Sweden. I will also pinpoint some barriers and opportunities for practical implementation of the investigated alternatives. This is done by relating the alternatives to two conflicting forest management pathways for future forest use in Sweden: the intensification trajectory and the diversification trajectory (see Felton et al., 2020a). These two pathways largely conform to the orientation of the work with stakeholders in the project, intensification for production with Södra, and diversification for conservation with the CAB.

6.1.1 Intensification

The scenarios used in this thesis are based on the assumption that active forestry and increased harvests are important components of effective climate change mitigation. Consequently, and similar to findings in previous research using similar scenarios (Nordström et al., 2016), Paper I shows that ambitious mitigation will put pressure on forests in southern Sweden. The current harvest level in Sweden is already close to the increment on the area available for wood supply (SLU, 2019b, p. 15), and as shown in Paper I the utilization intensity is even higher in southern Sweden. At the same time the share of set-asides is not likely to go down, but rather increase due to the gradual expansion of formal set-asides (SEPA-SFA, 2017) and requirements in the new FSC standard (FSC, 2020). This implies that the long-term harvest level only can be augmented by increasing the growth on the area available for wood supply, thereby creating incentives for further management intensification of production forests. The alternatives developed for the workshop with Södra (e.g. better regenerations and PCTs, exotic species, fertilization, spruce clones), many of which also are discussed in the recent SFA report about measures for increased production (Normark and Fries, 2019), should be seen against this background. They represent alternatives that can increase the harvest level for the benefit of the Swedish forest industry and owners with strong production goals.

The future development of the rotation periods is influential for determining the volumes available for harvest in the coming decades, and thus the possibility to meet a possible future increasing demand for wood. According to the most recent Swedish outlook study it is likely that rotations in Swedish forestry need to be reduced in the near future (within 10-30 years) to maintain a high and even utilization level (Claesson et al., 2015, pp. 86-88). This was shown in Paper I in the CSA, where reduced rotations in the rather near future (from 2035) were required to maintain the high utilization intensity and satisfy the demand in scenario GLOBAL (see Figure 8 and 11, pp. 14-15 in Paper I). The wood shortage also appeared in EU and REF as all scenarios have rather similar demand trajectories in the beginning of the projection period. Reduced rotations might also alleviate major risks in southern Sweden, such as storm felling and damage from spruce bark beetles (Valinger and Fridman, 2011; Roberge et al., 2016). However, the forest state in the CSA is heavily impacted by recent major storms. The projected wood shortage in the near future with increasing demand would probably not be as severe in other parts of southern Sweden.

Some of the investigated production-oriented alternatives are constrained by current legislation and certification requirements. The Swedish FSC standard restricts the use of plantations with exotic trees to maximum 5 % of the productive forestland on estate level among certified owners (FSC, 2020). General advice in the Forestry Act states that fertilization with nitrogen not is recommended in southern Sweden (SFA, 2020a, pp. 66-67), and owners certified with FSC need to follow these recommendations (FSC, 2020, p. 67). In contrast, current policies enable an extensive use of spruce clones developed through somatic embryogenesis in southern Sweden, since the Forestry Act allows vegetative propagated material on 20 ha at the property level (SFA, 2020a; p. 21). Finally, the new EU LULUCF legislation adopted in 2018 (European Commission, 2018) might influence the strategies that are suitable for meeting a possible increasing demand for roundwood with domestic forest resources. The new legislation implies that the carbon sink in Swedish forests during the first compliance period (2021-2025) will be compared with a Forest Reference Level (FRL) representing a continuation of the forest management practices during the reference period 2000-2009 (Forsell et al., 2019). Substantial increases in harvest that reduces the forest carbon sink at national level compared with the reference level would be accounted as carbon debits, which need to be compensated for elsewhere (i.e. in other sectors or by acquiring credits from other EU Member States).

Seen from a European perspective small-scale owners in southern Sweden manage their forests intensively for wood production. However, as explored in Papers I and II there still exists variation in their management intensity, silvicultural guidelines are not fully implemented and forestry advisors experience a number of challenges in their efforts to promote production-oriented ideals in practice. The existing owner diversity in southern Sweden is a likely barrier to any future efforts to intensify forest management even further, as not all owners are likely to share such ambitions. To this date, the trend towards increased owner diversity (e.g. in terms of objectives, life-styles, knowledge, economic dependence) often reported in the literature (Ingemarson et al., 2006; Haugen et al., 2016; Westin et al., 2017; Andersson and Keskitalo, 2019) has not yet impacted the possibilities to increase harvests (Lidestav et al., 2017, p. 129). However, promoting (or even enforcing) further intensification in a context where such societal trends would continue might be challenging, potentially creating ideological tensions between powerful forestry actors and owners that put less emphasis on production. In addition, substantial uptake of new intensive measures requires that they not only increase production substantially, but also are judged profitable and practically suitable for small-scale forestry. In this regard, the level of profitability of different measures varies (e.g. see Simonsen et al., 2010), as well as the time before the investments are realized through increased growth and harvest opportunities (e.g. fertilization in mature forests vs better more costly regenerations) (Nilsson et al., 2011). Similar to any other forest investment practical implementation depends on forest owners' willingness to refrain from consumption now for potentially larger benefits to be realized in the (often) distant, and therefore uncertain, future.

Table 9. Summary of some likely barriers and opportunities for intensified management of production forests in southern Sweden including the alternatives investigated in the Swedish CSA in ALTERFOR.

Alternative	**Barriers**	**Opportunities**
Intensification in general	Owner diversity, high costs, conflicting conservation goals.	Ongoing national efforts and policy goals to increase production (i.e. Normark and Fries, 2019).
Intensification within the frames of current approaches (better regenerations and PCTs, shorter rotations)	Browsing (preventing better regenerations), owner diversity.	Good knowledge compared with more unfamiliar alternatives. Shorter rotations can reduce major risks (spruce bark beetles, storms).
Fertilization in pine forests	General advice in the Forestry Act, certification.	
Exotic species	The Swedish FSC standard.	
Spruce clones (somatic embryogenesis)	High costs, not available on the market yet.	20 ha allowed on all properties.

6.1.2 Diversification

A future diversification of forest management is motivated by benefits to biodiversity conservation (Felton et al., 2020a), and also involves alternatives suitable for adapting forests to future expected warming (Felton et al., 2010; Felton et al., 2016a). From a conservation perspective, the matrix heterogeneity stemming from the existing owner diversity investigated in Papers I and II is also important (Eggers et al., 2015). Any further intensification of the management of production forests should be compensated for by reduced intensity in production forests elsewhere, or increases in set-asides (Felton et al., 2020a). Many of the more “biodiversity friendly” alternatives investigated within the frames of the ALTERFOR project are currently promoted in the Swedish forest sector. This includes the SFA’s recent campaign promoting varied forestry (SFA, 2020c), guided by an ambition to increase the use of broadleaves, CCF and mixed forest stands (Berquist et al., 2016, pp. 94, 126). In addition, the new Swedish FSC standard entering into force in October 2020 will likely stimulate an increased interest in and use of CCF. The standard requires additional 5 % (of the productive forestland) of set-asides or management with increased consideration/CCF (all with >50 % of the volume left after harvest) on certified properties (FSC, 2020, p. 41).

This thesis offers insights about barriers and opportunities for change away from current practices strongly dominated by even-aged management of Norway spruce. First, our investigations of border zones for the stakeholder workshop organized with the CAB indicate that these areas are richer in broadleaves and should be prioritized as retention patches at final felling. Requirements to retain border zones already exist in the Forestry Act and in the certification standards (SFA, 2020a; FSC, 2020) and is according to comments at the CAB workshop accepted among forestry actors in the CSA (Lodin, 2018a). However, our investigations show that the border zones cover substantial areas (6 % of the area of production forest in Kronoberg), which most likely complicate the practical implementation. Secondly, Papers II and III, as well as comments during the stakeholder workshops (Lodin et al., 2018a; Lodin, 2018b) highlight the already well-known fact that the browsing pressure currently constrains more varied forest management practices in the CSA. Thus, to enable diverse regenerations, a reduction of the browsing pressure is necessary. Third, in a situation where browsing makes workable alternatives to spruce difficult (pine on the typical pine sites) or very costly (e.g. the investigated alternative “oak for production” requires fencing subsidized by the government) naturally regenerated birch can be an important complement with lower barriers and costs. The young forests of southern Sweden are already rich in naturally regenerated birch (Berquist et al., 2016, pp. 26, 107), and a small admixture (10 %) of broadleaves in all production stands is required for certified owners (PEFC, 2017; FSC, 2020). However, investigations by the SFA show that much of the birch is removed in subsequent PCTs and thinnings (Berquist et al., 2016, pp. 109-110). The alternative birch-spruce mixture, which was investigated in our project, represents an option for better exploitation of naturally regenerated birch throughout the rotation for the benefit of conservation and other ESs (e.g. aesthetical and recreational values) (Felton et al., 2016b). At the same time, forest management in Sweden has until today mainly been based on monocultures and the more complicated management of mixtures is a likely implementation barrier. In addition, better exploitation of natural regeneration of birch, in pure birch stands or in mixtures, partly conflicts with the Swedish “high input” tradition (e.g. reflected in the quote by FO 6 on p. 195 in Paper III), promoting active regeneration through planting. Natural regeneration implies lower growth than planting birch and on similar sites the growth rates of naturally regenerated birch is much lower than plantations of Norway spruce (Ekö et al., 2008).

The practice based approach applied in this thesis, and especially its sensitizing concept situated agency, led to better understanding of the current lock-in to practices strongly dominated by Norway spruce. Is this lock-in resulting from social structures (e.g. norms, beliefs, regulations) that predetermine owners’ decisions (i.e. structure > agency[6])? Or from rational actors that consider the various pros and cons with spruce and autonomously

[6] The structure-actor dichotomy is a classical debate in social sciences. Are outcomes (e.g. in history) resulting from intentions and motivations by individual agents (voluntarisms i.e. agency> structure)? Or from social structures of societies, like political institutions, shared norms and beliefs (determinism i.e. structure>agency)? The structure-actor dimension was one out of two dimension used by Arts (2012) to categorize theories used in forest policy analysis by distinguishing differences in fundamental assumptions, e.g. rational choice favors voluntarism while institutionalism favors determinism.

decide that it is the best alternative, despite the risks involved (agency > structure)? According to the practice based approach, it is impossible to separate agency from social structures, as they have entwined in the situated agent. In addition, in a field such as forestry, material aspects (e.g. ecosystem properties, forest machines etc.) need to be considered, as they are crucial for understanding forest management practices. Thus, current practices are reproduced by owners colored by past experiences, interpreting and acting in contexts where a wide range of factors might influence the outcome (e.g. ecosystem properties, exposure to advisory services and markets). At large, Paper III suggests that a major diversification towards other species requires a contextual setting that facilitates such a shift (e.g. less browsing, better markets for alternatives, diverse information). In the long run this would probably stimulate a more extensive reinterpretation of the possibility and suitability of utilizing alternative species among owners. Moreover, the continuous problems experienced with spruce in Sweden and elsewhere in Europe (storms, drought, spruce bark beetles) is likely to stimulate such reinterpretations, perhaps creating a more permanent opportunity for change.

Paper III provides insights into specific decision-making processes, revealing the importance of the social surrounding (including advisory services) for the final outcome when owners were open for change, as exemplified by the partly suppressed ambition to establish alternatives species by the recreationally-oriented FOs 7 (see pp. 195-196 in Paper III). Since experiential knowledge with alternatives often is lacking among owners, it is likely that informational steering through advisory services will play an important role for the future success of diversification, either aiding or constraining the needed change. In this regard, advisors from the SFA have been found to embrace contextualization, articulate uncertainties and promote risk diversification as main strategies in their advisory practice (Lidskog and Löfmarck, 2016). Thus, seemingly suitable strategies in the light of current uncertainties and challenges in Swedish forestry. The strong dominance of industrial actors in the Swedish advisory system (Lawrence et al., 2020) might therefore be problematic, and has been suggested to be a constraining factor to climate change adaptation (Andersson et al., 2017). Considering the need to diversify Swedish forest management in response to biodiversity threats and climate change it is crucial with an advisory system that can facilitate such a shift. This is especially pivotal in Sweden, where steering mainly is conducted through soft means, rather than through strict regulations.

Table 10. Summary of some likely barriers and opportunities for diversified management of production forests in southern Sweden, including the alternatives investigated in the Swedish CSA in ALTERFOR.

Alternative	**Barriers**	**Opportunities**
Diversification in general	Contextual constraints (browsing, markets, and the industry-dominated advisory system) and lack of knowledge and experience among owners and their advisors.	Continued campaigns promoting more diversified forestry through information and advice (e.g. SFA, 2020c). New requirements promoting diversification in the certification standards.
Spruce-birch mixtures	More complicated management.	Low barriers compared to planting broadleaves.
Oak for production	High establishment costs (for the state or the owners) imply that a large-scale increase would be costly.	Subsidies for re- and new-establishment of noble broadleaves are available through the SFA. Markets for Oak timber exist.
Border zones	Lack of detailed mandatory requirements, cover substantial areas.	Soft requirements/recommendations are already included in key documents governing the management of Swedish forests, such as the Forestry Act, certification standards and the target goals for environmental consideration.
CCF	Lack of practical knowledge among owners, forestry actors and their harvest entrepreneurs.	Requirements in the new FSC standard.

6.2 Challenges with modelling effects of climate change and disturbances

The growth models in Heureka have been found to provide reliable results for long-term projections in even-aged forests (Fahlvik et al., 2014). At the same time, the models for uneven aged forests are less certain (e.g. CCF) (Drössler et al., 2013). Another weakness is the climate change models. The models used in EU and REF predict increased forest growth in southern Sweden with climate warming. By the end of the century the positive effect correspond to 19% and 36% for RCP 4.5 (i.e. EU) and RCP 8.5 (i.e. REF) respectively (Eriksson et al., 2015, p. 26). Recent research with more sophisticated models that better incorporate the effects of extreme weather (such as droughts) indicate that these predictions overestimate the positive effect on growth (and instead predicts + 21% in RCP 8.5 and + 8.6 % in RCP 4.5) (Subramanian et al., 2019). Hence, the massive buildups of standing volume in EU and REF (in Paper I), which resulted from a growth that greatly exceeded the demand, are probably overestimated. In addition, the storm Gudrun in 2005 and the recent outbreak of the spruce bark beetle, show that disturbances can have a major impact over the development of standing volume and increment. The impact of disturbances is also likely to increase in a warmer climate (Lindner et al., 2014). In our projections, we did not account for any effects of catastrophic events, such as storms, which is important to keep in mind when interpreting the results.

Studies show that we can expect major shifts in the potential range of tree species in Europe with future warming, with a shift from spruce to broadleaves in southern Sweden (e.g. see Hanewinkel et al., 2013). The strategic increase of broadleaves in the final alternative landscape level projections in EU and REF (i.e. Biber, 2019) was partly (also due to biodiversity) made considering the need for future climate change adaptation. However, this adaptation challenge is not reflected in our modelled performance of Norway spruce with climate warming, whose growth was predicated to increase considerably. This highlights the importance of developing models that not only can factor in the positive effects of warming on growth, but also the likely negative effects due to increased risks of disturbances.

6.3 Futures studies in the ALTERFOR project: Some reflections

Futures studies construct futures through a range of different approaches (e.g. probable, possible, preferable futures) and methods (e.g. quantitative modelling or qualitative narratives) (Börjesson et al., 2006; Hoogstra-Klein et al., 2017; Mårald et al., 2017). Ideally, these constructions should inform decision-makers in the present about ways to address current and future problems, and thus influence action. As a response to the call for reflexivity by Mårald et al., (2017) I will here openly reflect about the future-oriented research that I coordinated in the Swedish CSA within the frames of the ALTERFOR project.

The project had an ambition to consider major global challenges (the possible external scenarios), as well as local stakeholder concerns (development of alternatives in collaboration with stakeholders) (see 4.1). Reconciling the two scenario types (possible and preferable futures) resulting from this ambition was sometimes challenging. The possible external scenarios produced by the GLOBIOM modelling system are based on the assumption that increased harvest is important for climate change mitigation (Forsell and Korosuo, 2016). Similar to many of the scenario studies in the Future Forest program (Mårald et al., 2017, p. 78) there was a correlation between future control of climate change and high demand for wood in the scenarios. Consequently, Paper I showed that ambitious climate change mitigation might push for further intensification in the CSA. Climate change mitigation is a key priority in contemporary society. The scenarios used in ALTERFOR therefore tend to close down around a certain future, a future where measures to increase production are needed. This future can be easily reconciled with powerful industrial actors' interests in a preferable future where measures are implemented to increase forest growth to feed an industrial expansion (i.e. the Södra workshop, see 5.2.1). At the same time, the scenarios were not useful when working with the CABs preferable future, where the management of production forests would be diversified for the benefit of conservation. Because as shown in the final alternative landscape level projection (i.e. Biber et al., 2019) (see 5.2.2), with ambitious mitigation, there was no room to implement any of these alternatives due to their lower growth rates. At the CAB workshop, the EU scenario was used. We could show to the forestry actors that in this intermediate (and therefore perhaps more realistic) future scenario there was room to implement alternatives promoting biodiversity and still increase harvest to some extent (see demand trajectory in 4.1.1) i.e. sell some “win-wins”. However, in retrospect it would have been better to disregard the GLOBIOM scenarios altogether for the CAB workshop.

The used climate change mitigation scenarios rest on certain assumptions about future climate change mitigation strategies and societal development that here will be shortly discussed. First, what is the most effective strategy for using forests for the benefit of climate change mitigation? Increased carbon storage in the forest, or maximising the growth of younger forests to enable increased fossil fuel substitution and replacement of fossil-fuel intensive materials with renewable wood? And what wood products should be produced e.g. is harvesting for bioenergy ok? By working with climate change mitigation scenarios you engage in a complicated field of research, where there is no clear consensus regarding the most suitable strategy among the engaged experts (e.g. see Werner et al., 2010; Schulze et al., 2012; Vass et al., 2016; Taeroe et al., 2017). It is also highly political, as different stakeholders tend to promote a strategy that is in line with their underlying interests (Beland Lindahl, 2015), e.g. increased growth and substitution by forestry actors, and increased emphasis on storage in the forest by environmental NGOs. The assumption on large increases in future demand (including bioenergy) for substitution with ambitious mitigation in our scenarios is based on EU policies in place 2016 (Forsell and Korosuo, 2016).

Second, all scenarios were based on the intermediate scenario in the SSP (Shared Socioeconomic Pathway) framework (Fricko et al., 2017). This scenario extends regional historical trends of economic growth into the future and by the end of the century global average GDP/Capita has increased with a factor of six. The most ambitious mitigation scenario is thereby positioned within the frames of ecological modernisation, and the idea that environmental problems and sustainability challenges can be addressed within the frames of continued economic growth (Pülzl et al., 2014). Ecological modernization is a common pathway to address sustainability challenges in western capitalist countries, including Sweden (Beland Lindahl et al., 2017a). According to some scholars’ it is a weak and overoptimistic pathway to sustainability that fails to address the fundamental contradiction in contemporary capitalist societies, namely the problem of increased consumption due to economic growth in a world with finite resources (Baker, 2007). Scenario assumptions about economic growth decide the size of the future global economy that needs to be transformed for successful mitigation, and can thus play a pivotal role for the demands (for substitution and/or on site carbon sequestration) projected to be put upon the forest resource. Possible scenarios that more clearly brake with current structures (such as the growth paradigm in already comparably rich western countries) in contemporary society might reveal possibilities for more radical change.

The futures studies in the ALTERFOR project were conducted in collaboration with stakeholders in the CSA. This collaboration was theoretically guided by the RIU-model for scientific knowledge transfer (Böcher and Krott, 2016), a model stressing the need for collaboration with powerful actors. Due to its national economic importance the forest industry promoting wood production has a dominant position in the Swedish forest sector (Lodin, 2017). Unreflexively applying the RIU-model in Sweden could therefore result in futures studies strongly colonized by agendas and problem formulations of the most powerful industrial actors in the present, a major risk with future-oriented research raised by Mårald et al., (2017, pp. 52-53). Getting non-production interests involved was therefore a key priority guiding the search for stakeholder partners. Our institutionalised pre-defined collaboration with Södra (due to their role as a non-academic partner) was complemented with collaboration with the CAB, an influential actor in nature conservation. In addition, we were also able to relate the investigation of forest management alternatives to their regional work with the national policy project "Green infrastructure". In conclusion, we avoided the risk presented by Mårald et al., (2017), and succeeded with pluralistic integration of research and practice.

The purpose of the integration component in the RIU-model is to serve the main goal of promoting utilization of research in practice (Böcher and Krott, 2016). However, in this regard it is not likely that the project will have a major impact on forest management in the studied case or elsewhere in Sweden. This is expected considering the limited amount of resources (budget, time for the involved researchers) that a project such as ALTERFOR project has at its disposal. The alternatives for future forest use presented in this thesis are already advocated for by different actors in the Swedish forest sector. The processes determining their wider adoption involves future development of national forest policies and certification standards, and day-to-day interaction between owners and their advisors (see 6.1). In this regard, our two stakeholder partners' possibilities to promote their preferable futures in practical forestry differ greatly. Södra is arguably the most powerful forestry actor in southern Sweden (Lodin, 2017). They promote production-oriented ideals in their members' forests covering half of the productive forestland in southern Sweden. They are also well represented in the national policy processes where possible future alternatives for increased production are discussed, such as the recent collaborative process regarding wood production (Normark and Fries, 2019). In contrast, the CAB is mainly working with protected areas, while the SFA is the governmental organization in charge of policy implementation and advisory services among forest owners. Consequently, while the CAB undoubtedly is an influential actor in nature conservation, their possibilities to promote the investigated "diversification alternatives" in production forests are limited.

Instead of assessing success based on practical implementation of the investigated alternatives it is more suitable and feasible to consider to what extent the research has been utilized in ongoing relevant policy processes in the CSA. The collaboration with the CAB implied that research carried out in ALTERFOR was used in an ongoing policy project on regional level, where results from the work were included in the CABs action plan for green infrastructure (CAB Kronoberg, 2020). This can be regarded as a success in terms of practical utilization. However, after finalizing the action plan, the CABs work with green infrastructure has not been active and our contact person has left the organization. Our hope to continue the collaboration with more activities within the frames of green infrastructure has therefore not yet materialized.

The RIU-model by Böcher and Krott (2016) is a relatively new model for scientific knowledge transfer, and some lessons can be learned from this first application in future-oriented forest research in Sweden. The experience from the Swedish CSA in ALTERFOR indicates that the pragmatic tenets of the RIU-model can instigate collaboration between science and practice.

Most stakeholders are likely to be interested in getting scientifically based information and "ammunition" to solve problems and promote their interests, without having to compromise their own position. The RIU-model is well equipped for working with scenarios labelled as preferable according to the typology by Börjesson et al., (2006) but probable/possible scenarios might sometimes match actors' desires, as shown in our work with Södra. The drawbacks with the RIU-model are the ethical dilemmas that arise due to its focus on powerful actors, and the preserving scenarios that might be produced if the model is unreflexively applied to settings characterized by uneven power relations. With its focus on needs and interests of powerful actors the RIU-model seems analytically sound for understanding how knowledge transfer actually works. However, the present state of affairs (e.g. power balance between different advocacy coalitions) might result in unsustainable outcomes and voices of the less powerful might not be heard. During recent decades inclusive participation has been highlighted as an important tool to address sustainability challenges in forestry in a more legitimate way, *inter alia* trying to foster collaboration and mutual understanding among the involved actors (Buchy and Hoverman, 2000; Appelstrand, 2002; Appelstrand 2012). This thinking has also affected methodology in futures studies, where Wallin et al., (2016) is a recent example that tried to foster collaboration and empower the local level by engaging multiple local stakeholders in envisioning a common future. Such consensus-oriented participatory scenario studies are important complements to the more polarizing preferable futures that were produced from the application of the RIU-model in this project.

6.4 Open reflections about my multi-disciplinary journey, epistemology, validity and study limitations

My work in ALTERFOR, including the parts reported in this thesis, investigated various aspects of forest management such as ES provisioning with different management alternatives, specific decision-making processes and drivers behind forest management practices. This involved engaging in multiple scientific disciplines within social science and natural science (e.g. quantitative modelling, qualitative interviews), as well as transdisciplinary research (the stakeholder collaborations). Such problem-driven research has clear advantages, since understanding and addressing sustainability challenges often requires research that crosses disciplinary boundaries (Clark, 2007). The coordination role in ALTERFOR has also offered good opportunities for personal development including generic skills (e.g. in connection with organizing workshops), better understanding of complex multi-faceted problems and possibilities to publish research that I never would have been able to do without collaboration from specialists in other disciplines (Paper I).

However, there is a trade-off between breadth and depth in research (Haider et al., 2018). As an example from my PhD, one day I might have tried to address reviewers' comments that a paper lacked sufficient social science theory connections, the next day I might have worked with a report about the likely ESs implications of the investigated forest management alternatives. Of course this breadth can influence the quality of the research, especially when time is limited. Haider et al., (2018, p. 199) present the following quote about a risk with mixed discipline research from one researcher: "*The biggest risk I see in people that go very interdisciplinary in their PhD is that they end up being conceptually very broad, but get stuck in what has sometimes been called "conceptual la-la-land", they now a little bit about everything but they are not actually good at anything, and that is a real problem*". I hope this is not true for the research I produced for this thesis, but quite often during my PhD I have felt broad and shallow, especially when I got comments from reviewers or listened to presentations from more specialised researchers at scientific conferences. The challenge of combining the coordinator role with own research also implied limited time to collect and analyse primary data. Papers I and II build to a quite substantial extent on information from available written sources and statistics. Using multiple-sources of evidence, in this case interviews and written sources, is a key feature of good case study research (Yin, 2003, pp. 101-102) but the reliance on desk research also reflects time constraints. Own analysis of data from the Swedish Data Base for Forest Owner Analysis (Berg Lejon et al., 2011) and the national forest inventory, could have provided valuable additional information. In addition, qualitative interviews with forest owners could have provided valuable empirical data related to the deviations from the production-oriented ideals investigated in Paper II from a different perspective.

Haider et al., (2018) consider "epistemological agility" to be a key skill to master for researchers working with multi- or transdisciplinary research. The term has to do with researchers' ability to understand different ontological and epistemological standpoints, which is crucial for collaboration and communication with researchers from different backgrounds. In my thesis work I have practiced this skill by engaging in disciplines that tend to adhere to different schools of thought in the philosophy of sciences. Forestry science and even forest policy sciences until rather recently (Arts et al., 2013, p. 37) are characterised by a long tradition of positivism. Positivists hold the view that reality exist independently of our knowledge, and appears as facts that the researcher quantifies and systematizes into knowledge (Alvesson and Sköldberg, 2009, pp. 15- 23). However, in later versions (post-positivism) it is acknowledged that the "mining of objective knowledge" from the world as it appears not is unproblematic, since various biases might influence what is observed. In contrast, among social scientists working with qualitative methods, and in forest policy sciences during the latest decades (Arts et al., 2013, p. 37), social constructionism is more common. Social constructionism comes in versions with different degrees of radicalism, from a critical version investigating the construction of certain specific assumptions taken for granted in society (e.g. ideas about gender), to an ontological version, stressing that everything is socially constructed (Alvesson and Sköldberg, 2009, p. 35). For example, the practice based approach applied in this thesis belongs to the branch of critical policy analysis, which *inter alia* stresses that knowledge is socially constructed (Arts et al., 2013, p. 41). Finally, critical realism is another overarching philosophy of science. Similar to positivism it is based on the view that there is a world "out there" independent of humans, and that we can produce objective knowledge about it (Alvesson and Sköldberg, 2015, p. 15). Researchers working within this school of thought are often interested in identifying deeper underlying mechanisms that generate empirical phenomena. For example, the concept of "interests" in the actor-centred power approach by Krott et al., (2014), which also is central in the RIU-model, is an example of such a mechanism that is considered valuable for understanding actors' behaviour and various processes in the forest sector. After this short review of different schools of thought, I will in the following sections touch upon some epistemological issues related to the research in this thesis. I will also discuss validity and pinpoint some study limitations.

Quantitative modelling in a DSS formed a major part of the research reported in this thesis. The starting point for the projections with current and alternative forest management practices is data about the forest state in the CSA. The representation of the forest is never perfect, and the entities (e.g. trees instead of bryophytes) and variables (tree diameters) used to describe forests in Heureka reflect foresters' thinking. Nevertheless, I claim that the forests undoubtedly exist independent of our knowledge and that we can represent it (with biases) and produce knowledge about it. The subsequent modelling of forest development in the different futures are undoubtedly social constructions, as the future has not yet happened. These constructions were *inter alia* influenced by assumptions about forest owner behaviour, the scenarios and the interests of our stakeholder partners, issues that already have been described and discussed in detail. The quality of these constructions as decision-making support depends on the reliability of the used models, and some model weaknesses have been described in section 6.2. Kronoberg was chosen as a representative case (see 3.2), with the intention to produce knowledge valid for southern Sweden. The issues addressed in the constructed futures are highly relevant for forestry in southern Sweden at large. However, due to recent storms, forests in Kronoberg currently have a lower standing volume and increment than the rest of southern Sweden. This reduces the possibilities to generalise (i.e. external validity) findings from Paper I and the work with Södra to the rest of southern Sweden. Investigating the demand-supply problem in scenarios with ambitious mitigation (such as GLOBAL) for the whole of southern Sweden would require a case study with more representative forest conditions.

In contrast to the quantitative modelling of forest development, Papers II and III applied qualitative methods to investigate human perceptions and experiences related to forest management in the CSA. The greater emphasis on social constructionism in much of the social sciences is partly related to the fact that the study objects, people and societies, are so different from entities in nature (e.g. trees) (the anti-naturalist position) (see Arts, 2012; Arts et al., 2013, p. 37). In contrast to natural sciences, the research is characterised by a double hermeneutics. First, my informants made accounts based on their interpretations from the forestry practice, and then I produced research based on my own interpretations of their interpretations. Research guided by social constructionism tries to understand (through interpretations) the interpretive frames from which people and society constructs reality (Alvesson and Sköldberg, 2015, p. 23). In this regard, the use of "forest management paradigm" and "professional habitus" in Paper II, and "habitus" and "situated agency" in Paper III, are my attempts to approximate my informants' mental frames. However, the aim of these two papers goes beyond trying to conceptualise the frames from which the informant's subjective reality are constructed in forest management. Both studies aim to look into drivers to current management practices, and barriers and opportunities for change (Paper III). This implied that, based on my empirical data, I made inferences about the reality "out there". Personally, I do not believe in the most radical version of social constructionism, where there only are different perspectives on reality, especially when investigating something as concrete as forestry. According to my epistemological position, informants' perspectives can indeed provide knowledge about shared conditions characterising forestry in southern Sweden.

Paper II and Paper III relied on interviews with advisors and owners respectively, thereby providing insights into experiences of forestry in the CSA from different perspectives. The lack of own empirical data about motivations and experiences from owners directly is a weakness of Paper II. More specifically, it relates the internal validity of the study, which addresses the possibilities to establish causal relationships (Yin 2003, p. 34), in this case causes to deviations from the silvicultural ideals. Forest advisors contacts with owners are also skewed towards the more active owners. This implies that owners with the largest "deviations" in forest management might not be well captured by our research design. This is a weakness related to construct validity, which addresses the establishment of correct operational measures for the topic of interest (Yin, 2003, p. 34). Through the utilization of other written sources (e.g. scientific papers collecting data from owners directly) we tried to alleviate these weaknesses, but they still partly remain. As a consequence, the paper do not make any claims on providing knowledge about owner-related causal links to the deviations, only perceived causes according to the interviewed advisors. On the other hand, owners' conceptualization of forest management, including their understandings of to what extent forests are actively managed, might not always match with the views of professional foresters (see Davis et al., 2010). For the specification of current practices in the DSS (Paper I), and the investigation of deviations from the production-oriented ideals (Paper II), the professional conceptualization and overview provided by the forestry advisors were considered valuable.

A widespread view of "small N research", such as qualitative interview studies and case studies, is that such research has less value due to the limited possibilities for generalization outside of the study setting (i.e. limited external validity) (Yin, 2003, p. 36; Flyvbjerg, 2006; Brinkmann and Kvale, 2015; pp. 295-300). However, in line with Flyvbjerg (2006) I believe one can question the possibilities of producing universally valid knowledge about human activities. Instead of trying to always live up to the positivistic ideal of statistical generalization, in-depth contextualised qualitative research can provide better insights into how reality are experienced by people, how factors that quantitative researchers often want to consider in isolation interact in the "messy" reality. Moreover, small N-research also allows for analytical generalizations that, according to Brinkmann and Kvale (2015, p. 297), involve "*a reasoned judgement about the extent to which the findings of one study can be used as a guide to what might occur in other situations*". In this regard, it is evident that the studied case, with the severity of recent storms damages as a clear exception, represents typical southern Swedish conditions in terms of forest management practices, ownership structure and main actors. The findings from Papers II and III thereby provide insights about forest management practices valid for southern Sweden at large. Individual experiences and perceptions will always vary, but the issues addressed in Paper II (promoting production-oriented ideals among owners) and Paper III (reforestation in a context strongly favouring spruce) reflect main features of the forest management reality in southern Swedish small-scale forestry.

Finally, working across disciplines in an international project constituted a challenging but interesting personal journey, which also made special contributions to previous research. In contrast to the lack of input from stakeholders in recent future-oriented studies (Mårald et al., 2017, p. 83), the investigated alternatives were developed in close collaboration with regional actors. A new approach to the scientific knowledge transfer, the RIU-model (Böcher and Krott, 2016), was tested for the first time in Swedish forest research. Our experience shows that if applied with care it constitutes an effective tool for developing contrasting futures, involving a broad range of forest management alternatives. This multi-disciplinary thesis also stands out by its scope and the applied nature, focusing on real-time challenges and opportunities for practical implementation of the investigated alternatives. To conclude, rather than digging deep into a specific topic this thesis explores big and broad issues relating to future forest management in southern Sweden, providing insights into the challenges that lie ahead.

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Populärvetenskaplig sammanfattning

Skogsbruket i södra Sverige står inför en mängd framtida utmaningar. Den biologiska mångfalden är hotad, klimatet blir varmare och efterfrågan på den förnyelsebara skogsråvaran förväntas öka. Hur skogen ska skötas är också ett område präglat av djupa konflikter mellan olika intressegrupper. Med argument som betonar skogens viktiga roll i arbetet med att hejda klimatförändringen driver inflytelserika industriella aktörer på för ökad produktion. Samtidigt är skogsbruket i södra Sverige redan i dagsläget intensivt och mer varierade brukningsformer och en ökning av arealen skyddad skog krävs för bevarandet av den biologiska mångfalden. Omfattande stormskador och angrepp av granbarkborre under de senaste två decennierna gör också att riskerna med dagens grandominerande skogsbruk börjar bli allt mer uppenbara, risker som förväntas förvärras i ett framtida varmare klimat. Skogssektorn och samhället i stort står därmed inför viktiga vägval där skogsbrukets tidshorisonter med omloppstider på 50-100 år gör att långsiktigt strategiskt tänkande är av yttersta vikt. I detta hänseende kan framtidsstudier som undersöker hur möjliga framtida utmaningar kan hanteras spela en avgörande roll. Denna avhandling presenterar framtidsstudier genomförda i Kronobergs län inom ramen för det europeiska forskningsprojekt ALTERFOR. Konsekvenserna av att fortsätta med dagens skogsbruksmetoder i olika möjliga framtidsscenarier undersöktes. Tillsammans med skogsägarföreningen Södra och Länsstyrelsen, undersöktes även alternativ som representerar två olika framtida vägar för skötseln av den sydsvenska skogen, intensifiering för ökad produktion kontra diversifiering för att gynna den biologiska mångfalden.

Tidigare forskning tyder på att åtgärder för att motverka uppvärmningen i form av utfasning av fossila bränslen och ökat byggande i trä kommer öka den globala efterfrågan på skogsråvara. Inom ALTERFOR använde vi oss av tre scenarier (Global Bioenergy, Eu Bioenergy och Reference) med olika ambition i det framtida klimatarbetet som alla bygger på detta antagande. I det mest ambitiösa scenariot (GLOBAL), där den framtida uppvärmningen begränsas till endast 1.5-2 °C, antas efterfrågan på virke i Sverige om 100 år vara 68 % högre än idag. Genom simuleringar i Heureka Planvis undersökte Artikel I (Paper I) om dagens skogsskötsel (huvudsakligen kalhyggesbruk med gran och tall) i Kronoberg kan möta efterfrågan i våra tre scenarier. I specificeringen av dagens skogsskötsel tog vi hänsyn till den variation i skötselintensitet som finns inom privatskogsbruket. Vi undersökte även om den kraftiga ökningen av efterfrågan i det mest ambitiösa scenariot kan mötas genom en intensifiering inom ramen för dagens skogsskötselmetoder. Simuleringarna visade att efterfrågan i det mest ambitiösa scenariot med bred marginal överskrider avverkningen med dagens skötselintensitet och att en kraftig intensifiering med dagens metoder (t.ex. bättre föryngringar och röjningar) inte räcker för att möta efterfrågan. I de mindre ambitiösa scenarierna (EU och REF) innebär den lägre efterfrågan (+16/24 % om 100 år), och den positiva effekten på tillväxten i scenariernas varmare klimat (2.5°C/ 3.7 °C), att efterfrågan på sikt kunde mötas med bred marginal med dagens skötselintensitet. I alla scenarier uppstod dock en brist på virke i närtid (2035-2040) som delvis kan förklaras av att skogstillståndet i Kronoberg är starkt påverkat av stormarna Gudrun och Pär. De klimatmodeller som finns inbyggda i Heureka tar hänsyn till de positiva effekterna av ett varmare klimat på tillväxten, men inte till de negativa effekterna orsakade av störningar (t.ex. torka, granbarkborre, stormar), som också förväntas öka i ett varmare klimat. Detta gör att resultaten i simuleringarna med kraftig uppvärmning (REF och EU) är ytterst osäkra.

Utifrån antagandena i scenarierna visar Artikel I (Paper I) att ett ambitiöst klimatarbete kan skapa incitament för ytterligare intensifiering av skogsbruket. Detta är i linje med Södras intressen och konkreta målsättningar. Södra har ett mål att öka tillväxten i sina medlemmars skog med 20 % till 2050. Med efterfrågeutmaningen i det mest ambitiösa scenariot (GLOBAL) som utgångspunkt undersökte vi tillsammans olika alternativ (bättre föryngringar och röjning, gödsling, exotiska trädslag och gödsling) inriktade mot att öka produktionsskogens tillväxt och därmed på sikt skapa ökade avverkningsmöjligheter. Resultat från dessa undersökningar presenterades på en gemensamt organiserad workshop med skogliga aktörer i länet som målgrupp.

I Sverige där skogsvårdslagen innehåller få detaljerade krav spelar skogliga rådgivare (virkesköpare, inspektorer, skogskonsulenter) en avgörande roll genom att stödja och påverka privata skogsägare i deras skötselbeslut. Artikel II (Paper II) kartlägger variationen i skötselintensitet inom privatskogsbruket och undersöker de skogliga rådgivarnas perspektiv på vad som ligger bakom avvikelser från de dominerande produktionsinriktade programmen (för tall och gran). I Kronoberg har stormar och omfattande betesskador haft en stor påverkan på skogsbruket. Skogsägare planterar gran på typisk tallmark på grund av risken för betesskador och mycket av avverkningen de senaste två decennierna kan härledas till stormar istället för aktiva skötselbeslut. Enligt rådgivarna är röjning den åtgärd där skötseln är mest bristfällig och här anses tidsbrist (hos de som gör det själv) och röjningens höga kortsiktiga kostnader vara viktiga bidragande orsaker. Känslomässiga kopplingar till äldre skog, lågt ekonomiskt beroende och bristande skogsskötselkunskap är andra faktorer som rådgivarna menar förklarar avvikelser från de produktionsinriktade programmen. Sett från ett Europeiskt perspektiv är skogsskötseln i Kronoberg och södra Sverige intensiv och avvikelser från de produktionsinriktade programmen skapar ökad variation som kan vara positivt för den biologiska mångfalden.

Det andra samarbetet utfördes tillsammans med Länsstyrelsen i Kronoberg och hade en helt annan inriktning. Samarbetet skedde inom ramen för deras arbete med genomförandet av projektet ”Grön infrastruktur”, ett projekt som syftar till att främja ett landskapsperspektiv i arbetet med att bevara den biologiska mångfalden och främja andra ekosystemtjänster. Precis som i resten av Sverige är arealen skyddad skog i Kronoberg begränsad vilket innebär att produktionsskogens naturvärden är avgörande för bevarandet av den biologiska mångfalden. Tillsammans med Länsstyrelsen undersökte vi ett antal alternativ för att öka produktionsskogens naturvärden (ek, blandskog av gran och björk, kantzoner), alla inriktade mot en ökad variation genom att öka andelen löv. Resultaten presenterades för skogliga aktörer i länet under en gemensamt organiserad workshop och vissa delar av våra undersökningar införlivades i länsstyrelsens regionala handlingsplan för grön infrastruktur. En ökad andel löv är inte bara viktig för den biologiska mångfalden utan utgör även en viktig pusselbit i arbetet med att göra framtidens skogar bättre anpassade till ett varmare klimat.

Inom ramen för ALTERFOR utförde vi landskapssimuleringar i modellringsverktyget Heureka som innefattar radikala förändringar av skogsskötseln för att svara upp mot problem och behov hos våra samarbetspartners. Stora förändringar är givetvis enklare att modulera än att genomföra i praktiken. Exempelvis begränsas (exotiska trädslag) eller omöjliggörs (gödsling) vissa av de produktionsinriktade åtgärderna av bestämmelser i dagens FSC-standard. När det gäller åtgärder för mer löv finns det redan en skogspolitisk ambition att variationen bör öka, inklusive mer lövskog. Hittills har det dock varit svårt att få till en ökad plantering av löv på granens bekostnad. Genom att studera tidigare misslyckanden mer i detalj kan vi få bättre kunskap om hinder och möjligheter som kan komma till användning i framtida insatser.

Återbeskogningen efter stormen Gudrun är ett exempel på ett sådant misslyckande som studeras i Artikel III (Paper III). Granen hade drabbats hårt i stormen och skogsstyrelsen erbjöd generösa återväxtstöd för att stimulera föryngring med andra arter. Trots detta var föryngringarna efter Gudrun starkt grandominerade. I artikeln undersöktes trädslagsval i privatskogsbruket genom intervjuer med privata skogsägare i Kronoberg som föryngrat med olika arter sedan stormen. Intervjuerna kombinerades med en analys av viktiga faktorer i skogsägarnas omgivning för att få en bättre förståelse för den miljö som besluten togs i. Sydsvensk skogsbruk har under lång tid kännetecknats av en miljö som gynnar gran framför andra arter. Skogsägarna hänvisade ofta till tidigare positiva erfarenheter och egen kunskap som viktiga faktorer bakom valet att fortsätta med gran. I vissa fall var den upplevda nivån av styrning mot gran mer tydligt, där betestrycket och skoglig rådgivning hade gjort att det blev mer gran än vad skogsägarna hade velat. Valet av andra arter motiverades av riskspridning (främst löv), estetiska värden (löv) och en nyfikenhet att testa nya arter (främst exotiska arter). Naturlig föryngring av björk var ett vanligare sätt att etablera löv än att använda skogsstyrelsens återväxtstöd för hängning och plantering. Studien ger en detaljerad inblick i skogliga beslut, där det slutgiltiga valet av trädslag var ett resultat av ägarnas motivationsfaktorer (t.ex. mål, intressen) i samverkan med olika omgivningsfaktorer (rådgivare, marknad, bete). Att bryta dagens grandominans kräver en omgivning som möjliggör och underlättar för skogsägare intresserade av denna förändring. Ett reducerat betestryck är förmodligen den viktigaste åtgärden men även rådgivningsinsatser som gynnar alternativ är viktiga. Användningen av björk hos privata skogsägare underlättas av att björken oftast etablerar sig rikligt genom naturlig föryngring efter avverkning. Detta alternativ med lägre barriärer är ett viktigt komplement till aktiv plantering av löv i det framtida arbetet med att stimulera mer varierad skogsskötsel.

Samarbetet med de två skogliga aktörerna, Länsstyrelsen och Södra, vägledes av en ny modell för vetenskaplig kunskapsöverföring, RIU (research/forskning, integration/integrering, utilization/användning) modellen. Grundantagandet i modellen är att samarbete med inflytelserika aktörer kan öka forskningens praktiska genomslagskraft. De alternativ som togs fram utgick därför från våra samarbetspartners individuella intressen och behov. Våra erfarenheter från den svenska fallstudien i ALTERFOR tyder på att RIU-modellen kan vara effektiv för etablering av samarbeten. De flesta aktörer kan antas vara intresserade av forskningsstöd för att hantera sina utmaningar. Våra erfarenheter tyder också på att RIU-modellen passar utmärkt för skoglig framtidsforskning inriktad på att ta fram ”preferable futures/önskade framtider”, d.v.s. skogliga framtidsscenarier som ligger i linje med de deltagande aktörernas preferenser. Samtidigt är det viktigt att komma ihåg att aktörer är intresserade av att föra fram framtidsbilder och problemformuleringar som överensstämmer med deras egna underliggande intressen. En aningslös användning av RIU-modellen inom den skogliga framtidsforskningen kan resultera i framtidsbilder som är starkt präglade av dagens maktförhållanden inom skogssektorn. I vår svenska applicering var det därför viktigt att etablera samarbeten med inflytelserika aktörer som representerar olika intressen (både produktion och naturvård). Genom vårt samarbete med Länsstyrelsen och Södra lyckades vi med denna ambition och tog fram framtidsalternativ med tydligt olika inriktning.

Sammanfattningsvis bidrar denna avhandling och dess tre artiklar med kunskap om dagens sydsvenska skogsskogsskötsel och olika framtida alternativ som tagits fram i nära samarbete med skogliga aktörer. Avhandlingen ger även kunskap om drivkrafterna till dagens skogsskötselmetoder och hinder och möjligheter för ökad användning av de undersökta alternativen. Jag hoppas därmed att den kan ha praktisk relevans för diskussioner om det framtida brukandet av den sydsvenska skogen.

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Appendix

<u>Interview guide Papers I and II</u>

Part 1 Introduction

1.1 Could you tell me about your job here at the organization/company?

1.2 Have you had other jobs at this organization/company? Or at other places? If yes, tell me about it.

1.3 What are your main work duties in your work with small-scale private forest owners?

Part 2 Forest owner types

2.1.1 Based on differences in forest management and objectives, could you group the small-scale owners in your area in different forest owner types and describe each type briefly?

2.1.2 Could you describe the most decisive factors that explain why different forest owner types manage their forests differently?

2.1.3 How big share of the forestland owned by small-scale owners in your area do you estimate belong to each forest owner type?

2.1.4 Which of these forest owner types do you meet most/least in your daily work? What are the reasons for this?

<u>**2.2**</u>

In a study (Eggers et al., 2014) at the Swedish University of Agricultural Sciences, the following five strategies/types were used to classify the forest management behaviour of small-scale private forest owners:

Passive – Owners where the management is characterized by low activity and a lacking interest in actively managing the forest.

Conservation – Owners where the management is governed by a large interest in nature conservation.

Intensive – Owners that manage the forest intensively to achieve a high economic return.

Productivity – Owners that are oriented towards high production and increased harvest opportunities. Differs from Intensive through a larger focus on production and a lower interest in fast revenues.

Save – Owners that want to increase the standing stock for the future, for example for a future shift of generation.

2.2.1 Do you think these strategies/types capture the types of small-scale forest owners that exist in your area? Would you like to add/remove/merge any strategies/types and if so why?

2.2.2 How big share of the forestland owned by small-scale owners in your area do you estimate belong to each strategy/type?

2.2.3 Which of these forest owner types do you meet most/least in your daily work? What are the reasons for this?

Part 3 Variation within the dominant silvicultural system

3.1. Based on the dominant silvicultural system in Kronoberg County (clearcutting system with pine/spruce) and the recommendations you give in association with your work with advisory services/wood procurement, which treatments (regeneration, PCT, thinning, final-felling) are the small-scale private forest owners generally best/worst at performing in a proper way?

3.2 What are the reasons behind the fact that the small-scale private forest owners are more/less prone to conduct this treatment (regeneration, PCT, thinning and final felling) in a proper way?

3.3 Based on the forest owner types we discussed in the beginning of the interview (part 2) could you fill in this matrix (see next page) to describe how well they perform different forest management treatments (for clearcutting with Scots pine and Norway spruce)?

Can you also explain your grading, 1. In what way do the management differ from your own/your organization's recommendations? And 2. What makes the forest owner type more/less prone to conduct this measure (regeneration, PCT, thinning, final felling) in a proper way?

Legend: (++) In line with our recommendations/High activity, (+) Good but with some shortcomings/ Good activity, (-) Bad/Low activity, (--) Very bad/passive.

Matrix 1. Based on Eggers et al., (2014)

Owner type/treatment	Regeneration (scarification, planting)	Regeneration (site adapted tree species choice)	PCT (yes/no, good/bad)	1st thinning (activity, timing)	2nd thinning (activity, timing)	Final felling (activity, timing)
Passive						
Conservation						
Intensive						
Productivity						
Save						

Matrix 2. Based on the forest consultants/wood buyers own types.

Owner type/treatment	Regeneration (scarification, planting)	Regeneration (site adapted tree species choice)	PCT (yes/no, good/bad)	1st thinning (activity, timing)	2nd thinning (activity, timing)	Final felling (activity, timing)
xxxx						
xxxx						
xxxx						

Extra questions to part 3

In your work with advisory services/wood procurement which forest owner type is easiest/hardest to influence with advice? Why is it so? Do you generally think that the forest owners in your area share your view on how the forest should be managed? Is there any particular type of owner and/or forest management treatment where opinions are more likely to differ? If yes, can you explain in what way?

Part 4 Other silvicultural systems/species/measures + Harvest residue extraction

Is there any particular forest owner type that is more prone to:

- Use natural regeneration with seed trees? Why?
- Plant exotic conifers and broadleaves? Why?
- Plant broadleaves and establish new noble broadleaved forest (i.e. on new areas where the noble broadleaves legislation does not apply)? Why?
- Set-aside less/more forest for nature conservation? Why?
- Use clearcutt-free management methods? Why?
- Extract residues from final fellings and thinnings? Why?

Part 5 Trends and future

5.1 What have been the most important trends within forestry during the last 10 years? How have these trends affected forest management in the area where you work?

5.2 Have the small-scale owners changed in some way during the last 10 years? And in that case, in what way?

5.3 How do you think forest management will look 20 years from now compared to today? Why do you believe that forest management will change in that direction?

5.4 How do you think small-scale owners as a group will look like in 20 years compared to today? Why do you believe small-scale owners will change in this direction? Which consequences do you think this will have?

5.5 What do you think are the biggest challenges for forestry in southern Sweden in the next 50 years? And how do you think these challenges will affect how the forest is managed?

Covered topics in the interviews for Paper III

General information

- General information about the forest owner, the estate and the management during the ownership period.
- Overall objectives with the management of the estate, importance of economic revenues from harvesting.
- Changes in the forest composition and land-use during the ownership period and the reason behind these changes.

Planting

- Tree species choices during the ownership period specified in time, the reasoning behind the different decisions.
- The most decisive factors that influenced the choice of species.
- Degree of perceived freedom of choice among the different species.

Natural regeneration and PCT

- The use of naturally regenerated trees in general and which species in particular.
- Changes in tree species choice in PCT and the reasons behind any changes.

Influence from the surrounding

- Sources of information connected to the tree species choices.
- Forest management plan (FMP), influence on the management suggestions in the FMP, influence of FMP on the tree species choices.
- Forest certification and its influence on the tree species choices.
- Degree of self-activity in planting and pre-commercial thinning and the use of entrepreneurs. Influence on how entrepreneur conducts planting and pre-commercial thinning.

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Forest management in southern Sweden is facing numerous challenges which calls for adjustments of current practices. This thesis reports on future studies investigating current practices in the context of future climate change mitigation together with possible alternatives developed collaboratively with stakeholders in a southern Swedish region. Drivers to current practices, as well as barriers and opportunities to change, are also explored with help of qualitative research.

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