Master's Thesis

The effectiveness of forest certifications in protecting biodiversity

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Biodiversity is the entire variety of life on earth, from genetic level to ecosystems and landscapes. There is an ongoing loss of global biodiversity, and the biggest driver along with the global warming is habitat loss due to the intensive land use, for example by forestry. Forest certifications (PEFC, FSC) aim for more sustainable use of forests, and they are widely used for Finnish forests, but at the same time forest habitats and species are declining. Certifications' criteria have recently been renewed, and their effectiveness in protecting forest biodiversity needs more understanding. Forestry is important for Finland, and it is necessary to also consider the costs of different forest managements. The aim of this master's thesis was to research 1) how do the certification schemes differ in terms of requirements related to biodiversity, 2) what are their effects on forest biodiversity, and 3) what are their effects on timber revenues. The thesis was executed using forest growth simulation with which the different forest management alternatives were simulated into the future. Random sample of 2857 stands in Central Finland was selected for the simulations. Biodiversity related criteria from the renewed versions of the certifications were compiled and adapted to adjustments to forest managements (criteria concerning energy wood harvesting, retention trees and deciduous trees). Managements were restricted based on spatial features (buffer zones for water bodies, groundwater areas, conservation areas, and special sites). Results show that forests managed with the certification schemes are generally far from protected forests in terms of biodiversity values. From the three scenarios — forests managed without certifications, with PEFC, and with FSC — FSC certified forests had the highest biodiversity values. PEFC certified forests' biodiversity values were rather close to uncertified forests. FSC forests brought 20.4% and PEFC forests 0.8% less income from wood than forests managed without certifications, but in practice the better price of the FSC certified wood would narrow the gap. The methods and results of this thesis can be used in the evaluation and developing the certification criteria concerning the forest biodiversity.

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Luonnon monimuotoisuus sisältää koko maapallon elämän monimuotoisuuden geneettiseltä tasolta ekosysteemeihin ja maisemiin. Luonnon monimuotoisuus vähenee, ja suurin syy sille on ilmastonmuutoksen ohella elinympäristöjen häviäminen ja niiden laadun heikkeneminen maankäytön, kuten intensiivisen metsätalouden vuoksi. Metsäsertifiointijärjestelmät (PEFC, FSC) pyrkivät kestävämpään metsien käyttöön ja ovat laajasti käytössä Suomen metsissä, mutta samalla metsäelinympäristöt ja -lajit hupenevat edelleen. Sertifiointikriteerit on vasta uudistettu ja niiden tehokkuus metsien monimuotoisuuden suojelussa vaatii enemmän ymmärrystä. Samalla on huomioitava, että Suomen talous nojaa edelleen vahvasti metsätalouteen, ja tarkasteltava myös eri metsänkäsittelyiden kustannuksia. Tämän pro gradu -työn tavoitteena oli tutkia 1) miten sertifiointijärjestelmät eroavat luonnon monimuotoisuuteen liittyvien vaatimusten suhteen, 2) mitkä ovat niiden vaikutukset metsien monimuotoisuuteen, ja 3) mitkä ovat niiden vaikutukset puusta saataviin tuloihin. Työ toteutettiin käyttäen metsänkasvusimulaatiota, jolla erilaiset metsänkäsittelyvaihtoehdot simuloitiin tulevaisuuteen. Simulaatioihin valittiin satunnaisotannalla 2857 metsikköä Keski-Suomesta. Sertifiointien uusittujen versioiden luonnon monimuotoisuutta koskevat kriteerit koottiin ja mukautettiin metsänkäsittelyihin (energiapuun korjuuta, säästöpuita ja lehtipuusekoitusta koskevat kriteerit). Metsänkäsittelyä rajoitettiin alueellisten ominaisuuksien perusteella (vesistöjen puskurivyöhykkeet, pohjavesialueet, suojelualueet ja erityiskohteet). Tulokset osoittavat, että sertifiointikriteereillä käsiteltyjen metsien monimuotoisuusarvot ovat pääosin huomattavasti alhaisempia verrattuna suojeltuihin metsiin. Kolmesta skenaariosta — metsät, joita käsiteltiin ilman sertifikaattikriteereitä, PEFC:n kriteereillä ja FSC:n kriteereillä — korkeimmat monimuotoisuusarvot olivat FSC-sertifioiduissa metsissä. PEFC-sertifioidut metsät olivat monimuotoisuusarvoiltaan melko lähellä sertifioimattomia metsiä. FSC-metsät tuottivat 20,4 % ja PEFC-metsät 0,8 % vähemmän puusta saatavaa tuloa kuin sertifioimattomat metsät, mutta käytännössä FSC-sertifioidun puun parempi hinta kaventaa eroa. Tämän opinnäytetyön menetelmiä ja tuloksia voidaan käyttää metsien monimuotoisuutta koskevien sertifiointikriteerien arvioinnissa ja kehittämisessä.

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1 INTRODUCTION

1.1 Biodiversity

Biodiversity means the entire variety of life on earth, from genetic level to ecosystems and landscapes including the complex interactions between organisms but also with their nonliving surroundings (Laverty et al. 2008). In nature biodiversity can be seen as population's ability to respond for changing environment, species richness in communities, or different landscapes, to name a few (Walker 1992). Biodiversity is essential for the structure and function of an ecosystem, and for the ecosystem to maintain its characteristic ecological processes like primary production, nutrient cycling or energy exchange (Walker 1992). Finally, biodiversity affects ecosystem services, life supporting benefits from nature, that also human well-being is dependent on (Brockerhoff et al. 2017, Perera et al. 2018).

1.2 Forest biodiversity and boreal forests

Forests cover 31 % of the world's land area (FAO and UNEP 2020). According to The State of the World's Forests 2020 "approximately half the forest area is relatively intact, and more than one-third is primary forest". Ecological factors such as climate, disturbances and ecological interactions have influenced on evolutionary processes that over time have led to forest biodiversity (Korhonen et al. 2021). Adaptation, that is enabled through biodiversity, leads to forest ecosystem diversity with its unique physical and biological features (Laverty et al. 2008). Forests with their massive biodiversity are the most species-rich habitat type in the world (Brockerhoff et al. 2017).

World's forests can be categorized into naturally generating (primary and other naturally generating) and planted forests (forest plantations and other planted forests) (FAO and UNEP 2020). Naturally generating primary forests', or old-growth forests', ecological processes are not significantly disturbed by human activities (FAO and UNEP 2020). According to The State of the World's Forests 2020, about 34% of world's forests are primary forests from which 61% are in Brazil, Canada, and Russia. Planted forests typically have lower biodiversity of species and reduced ability to provide certain ecosystem services compared to naturally generating forests (Brockerhoff et al. 2017). Forests can also be divided by climatic domain, from which the tropical has the largest parts of forest, boreal coming as second (FAO and UNEP 2020). Further the division can be made by ecological zone; in the years 1992–2015 the largest negative change in tree cover was in rainforests and largest positive in boreal tundra woodland (FAO and UNEP 2020).

Boreal coniferous forest is located at the latitudes about 50°N–70°N (Esseen et al. 1997), and from Finland 98% is in the boreal zone (Korhonen et al. 2021). Latitude and climatical and geological factors have influenced on the birth of boreal forest zone, which is the youngest forest biome (Kuuluvainen et al. 2004), yet it covers almost one third of world's forests (Mönkkönen et al. 2018). Variation of light, moisture, fertility and disturbances, for example, have caused also vegetation variation in the boreal forest zone, even though Fennoscandian boreal forest structure is relatively homogenous because of the low tree species diversity (Esseen et al. 1997). Natural large and small scale disturbances, such as windthrows, insect outbreaks, and forest fires have been an important factor behind the structural and functional boreal forest diversity (Esseen et al. 1997, Korhonen et al. 2021). Common principle is that species biodiversity decreases from southern to northern, but the case is not that simple (Esseen et al. 1997, Mönkkönen 2004). This depends on what species are considered: for example, diversity of some bird and beetle taxa, and willow and lichen species richness increase towards north (Esseen et al. 1997, Mönkkönen 2004). Species diversity can strongly vary spatially also in the boreal zone, and be locally as great as in any forest zone (Kuuluvainen et al. 2004). Traditionally biodiversity can be viewed as taxonomic, genetic and ecological diversity (Mönkkönen 2004). Species diversity correlates with habitat diversity, and vice versa, and both are commonly used meters for biodiversity (Mönkkönen 2004.)

Typical structural features that have characterized Fennoscandian boreal forest are different age conifer species and spruce domination (which have the potential to live up to several hundred years old) but also broad-leaved trees among them (Esseen et al. 1997). The shrub layer has typically been rather low, and forest floor vegetation consisted of bryophyte and lichen species. Fallen and standing dead trees and coarse woody debris have been important components for the construction of unique species compositions (Esseen et al. 1997, Siitonen and Hanski 2004). However, due to the intensive forestry practiced for at least the last 100–150 years these kind of natural forest structures and functions, and diversity of them have diminished greatly (Esseen et al. 1997, Mönkkönen et al. 2022).

1.3 Biodiversity loss and forestry

In addition to climate change, habitat loss is a primary threat driving the ongoing global biodiversity loss, the decline or disappearance of biological diversity (Mantyka-Pringle et al. 2012, Fletcher et al. 2018, Chase et al. 2020). It has also been suggested that climate change will interact with habitat loss, and this will boost the biodiversity loss at the genetic, species and habitat level (Mantyka-Pringle et al. 2012). Habitat loss is often acting along with habitat fragmentation, which includes patch size and edge effects, and habitat isolations (Schmiegelow and Mönkkönen 2002). These can show up as declining patch areas and connectivity reduction (Fletcher et al. 2018). Due to the species–area relationship, if habitat area is reduced the species are lost (Chase et al. 2020). Also, the biological processes in the remaining smaller area will differ from the larger one, and this can lead to ecosystem decay (Chase et al. 2020). Ecosystem functioning is critical also for humans by its effect on so called ecosystem services (Brockerhoff et al. 2017). The impact of human actions on habitats and biodiversity is expected to increase during this century (Powers and Jetz 2019). In Finland, one of the most significant drivers of habitat degradation is forest management (Kontula & Raunio 2019).

From Finnish forestry land, 52% is privately owned by individuals or families, 35% is owned by state and 7% by forestry companies (FSC 2021). In Fennoscandia most of the productive forest area is used for timber production, while less productive areas are not that highly affected (Mönkkönen et al. 2018). Before 2014 forest legislation changes, even-aged forest management has been dictated by law in Finland for more than 60 years (Savilaakso et al. 2019, Korhonen et al. 2021). In this management, clearcutting with soil preparation for new planted or from seeds grown trees is used (Korhonen et al. 2021). Other option is to leave some seed trees for 4–8 years for new tree generation to grow (Korhonen et al. 2021). By juvenile stand management and commercial thinning, the unwanted tree species are reduced, and tree size increased (Korhonen et al. 2021). After year 2014, also uneven-aged forest management became again a legal management option in Finland (Kuuluvainen et al. 2019, Korhonen et al. 2021), but the even-aged forest management is still the most used management practice (Kuuluvainen et al. 2019). In uneven-aged management, selective cutting or gap felling is used, which aims to grow different aged trees and canopy layers in the same stand; regeneration is based on natural regeneration and the aim is to remove mainly the biggest and dominant trees (Korhonen et al. 2021). Uneven-aged forest management is assumed to be less damaging to forest biodiversity than even-aged management for example due to its aim for more heterogenous stand structures (Savilaakso et al. 2019).

The latest inventory of threatened habitat types in Finland is from 2018 (second assessment made) and species from 2019 (fifth). In total, 76% of the Finnish forest habitat types are classified as threatened (26 types from 34 assessed): in southern Finland 79% and northern 56% (Kontula and Raunio 2019). About 47% of all species in Finland were assessed: 12% of them were threatened and 1,4% regionally extinct (Hyvärinen et al. 2019). For Finnish species, forests are the most important habitat, and for about 30% of the threatened species they are the primary habitat (Hyvärinen et al. 2019).

Main reason behind this negative development of forest biodiversity is the intensive forestry with its regeneration and management activities that have weakened the natural ecological characteristics of Finnish forests (Larsson and Danell 2001, Kontula and Raunio 2019, Mönkkönen et al. 2022). Forestry disturbs the natural forest dynamics, and it has significantly reduced the features of most forest habitats:

old forests, and old and dead trees in particular have declined, and tree species ratios have changed, but also young forests originating from natural disturbances are nowadays rare (Kontula and Raunio 2019). These same factors are estimated to be the most significant threats also in the future, and the trend shows that we have failed to stop the biodiversity loss (Hyvärinen et al. 2019).

The actions that aim to stop habitat loss or restore habitats are the most important ones when aiming to stop or slow down the biodiversity loss (Fahrig 1997). It seems that by minimizing human intrusion into undisturbed and unfragmented landscapes the biodiversity would be best conserved (Betts et al. 2017). In addition to the proportion of the land covered by protection, the protected areas should also be ecologically representative and well connected (Määttänen et al. 2022). About 13% of Finnish forest is protected when combining productive and poorly productive land, and 6% is strictly protected productive forest land (Natural Resources Institute Finland 2019). Most of it is located in the northern Finland (Korhonen et al. 2021).

In maintaining overall forest biodiversity on an area the main principles are connectivity of the habitat fragments, heterogeneity of the landscape, structural complexity of stand, integrity of aquatic ecosystems and using natural disturbance regimes to guide human ones (Lindenmayer et al. 2006). In addition to ensuring the establishment of large ecological reserves, for forest biodiversity conservation it is essential to have protected areas also within the production forests, buffers for aquatic ecosystems, and to design and arrange appropriately the road networks, harvest units and disturbance management practices (Lindenmayer et al. 2006). The structural complexity of stands should be taking care of by, for example, retaining large living and dead trees (Lindenmayer et al. 2006). The harvest rotation times should be long and maintain the forest structure; also other options for clear-cutting should be encouraged (Lindenmayer et al. 2006).

Finland's economy still relies strongly on the activities of the forest sector: in 2019 from the value of Finnish exported goods 19,2% was from forest industry (Ministry of Agriculture and Forestry of Finland 2020). In the Finnish forest industries, the most significant user of harvested round wood is the pulp industry (Ministry of Agriculture and Forestry of Finland 2020).

1.4 Forest certificates

The current forest management legislation in Finland, the Forest Act (1093/1996), sets the minimum standards for forest management (Mönkkönen et al. 2018) and leaves much to the individual's consideration (Korhonen et al. 2021). However, the international sustainability goals, such as EU biodiversity and forest strategies, apply also to Finland (Kuuluvainen et al. 2019). In order to counteract the negative impacts of large-scale forestry on habitats and biodiversity, biodiversity-oriented management practices have been introduced (Larsson and Danell 2001). These also ensure the access to the changing markets, as they aim to respond to stakeholders' concerns and demands related to the sustainability of forestry (Kuuluvainen et al. 2019). Forest certificates are one tool in trying to stop or slow down biodiversity loss, yet there have been debate on their sufficiency and effectiveness on protecting biodiversity and ecosystem functions (Kuuluvainen et al. 2019, Jyväsjärvi et al. 2020).

There are two different forest certification standards in use in Finland: PEFC — Programme for the Endorsement of Forest Certification, and FSC — Forest Stewardship Council (Siitonen et al. 2021). From these two, PEFC is more widespread in Finland. Currently PEFC covers about 18 million hectares, 92%, of Finland's commercial forests, while FSC covers about two million hectares, 10% of Finland's commercial forests (Siitonen et al. 2021). Both certificates have recently been renewed: for PEFC it is the fifth revision (PEFC 2020) and for FSC the second (FSC 2021). Besides other criteria, both certificates have biodiversity-oriented criteria, that include for example retaining living retention trees and dead trees, leaving riparian buffers and promoting prescribed burning (Jyväsjärvi et al. 2020, Korhonen et al. 2021).

In general, the minimum level of protecting biodiversity have been set higher in FSC criteria than in respective criteria in PEFC (Korhonen et al. 2021). When considering the particularly important habitats referred to 10 § of the Forest Act, the PEFC certification standards have not protected valuable habitats in practice any more than required by the Forest Act, and both PEFC scheme and Forest Act have mostly allowed low-intensive harvesting at the sites (Siitonen et al. 2021). FSC certification standard has obliged at least 5% of certified forest land to be completely excluded from forestry management (Siitonen et al. 2021). Jyväsjärvi et al. (2020) found that PEFC criteria concerning riparian buffer widths did not provide sufficient protection for stream ecosystems and biodiversity while FSC criteria performed reasonably well. However, the results of Jyväsjärvi et al. (2020), Korhonen et al. (2021) and Siitonen et al. (2021) concern the older versions of certifications. Also, the effects of certificates on the forest biodiversity and timber revenues have not previously been extensively evaluated and both certification schemes were relatively recently renewed making it timely to evaluate their effectiveness and efficiency.

1.5 Aim of the study

The aim of this master's thesis was to investigate how effective the renewed forest certification schemes (PEFC, FSC) are in protecting biodiversity, and what is the cost of using them. The study questions were:

1. How do the certification schemes differ in terms of requirements related to biodiversity?

2. What are their effects on forest biodiversity?

3. What are their effects on timber revenues?

The hypotheses were that FSC is more effective in protecting forest biodiversity, but it brings fewer timber revenues compared to PEFC. The hypotheses based on the results of Jyväsjärvi et al. (2020), Korhonen et al. (2021) and Siitonen et al. (2021) concerning the earlier versions of certificates, and to the fact that PEFC is widely used for Finnish forests but at the same time forest biodiversity has continued to decline (Hyvärinen et al. 2019, Kontula and Raunio 2019).

The thesis was executed using forest growth simulation with which the different forest management scenarios were simulated into the future. Scenarios where all landscape was managed for timber production using each certification management (PEFC, FSC) were compared to a scenario where the landscape was managed for timber production without certifications, and to a scenario where all landscape was protected.

2 METHODS

2.1 Study area and initial forest data

The study area was Central Finland, covering 20 861 km^2 (Figure 1; In this study, Kuhmoinen was included in Central Finland. It is nowadays part of Tampere Region). Open spatial data from Finnish Forest Centre (www.metsaan.fi) about forest stand information from landscapes in Central Finland was used as the initial forest state. The data contained stand-level forest characteristics (for example, tree species, tree heigh, number of trees, deadwood) in 2016 (Blattert et al. 2022). A similar plot setting than the Finnish National Forest Inventory design was used (but note that locations were not the same than in the national inventory, for which the exact locations are not public) to randomly select a representative subset of stands from the region. This resulted in 2857 selected forest stands for the study area (Figure 1). A general framework of the study is presented in Figure 2.

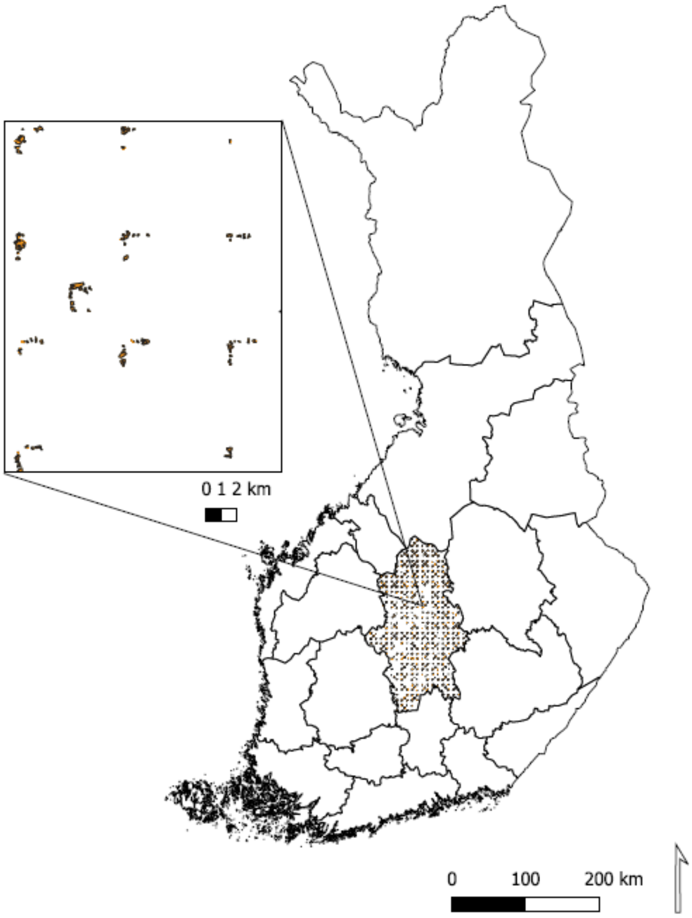

Figure 1. The study area was Central Finland and random sample of forest stands (2857 stands) was selected with similar plot setting than the Finnish National Forest Inventory design.

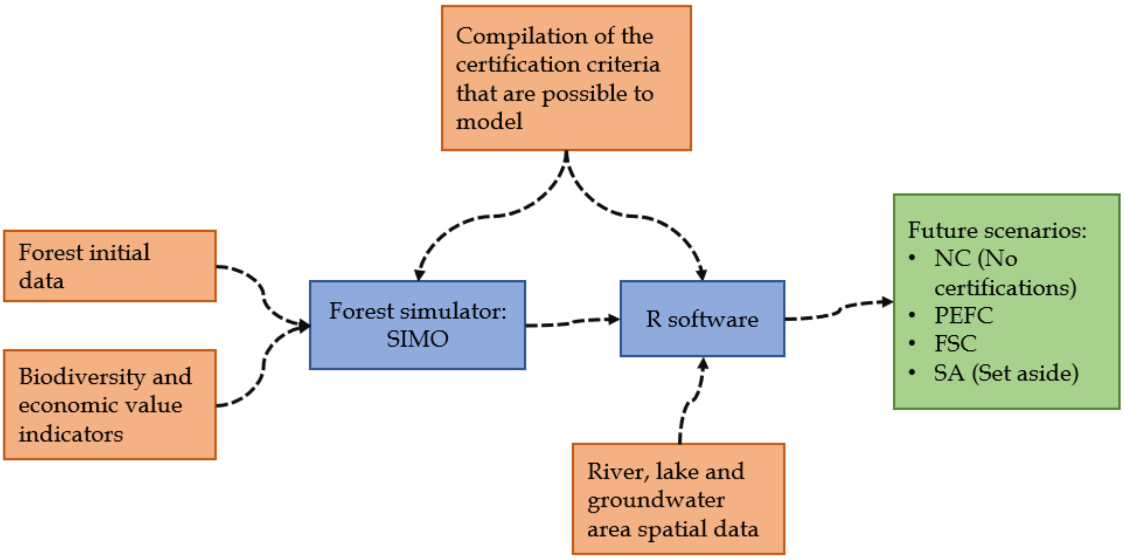

Figure 2. General framework of the study. In orange boxes are the input data, in blue boxes the tools, and in green box the outputs. The left arrow from the top box (certification criteria) indicates the management regime alternatives described in Table 2, and the right arrow indicates spatial restrictions described in Tables 4–7.

2.2 Compilation of certification criteria

The biodiversity-related criteria were compiled from the PEFC and FSC certification schemes. The versions used were the second draft of FSC that was at the time been sent to the international FSC to be approved (FSC-STD-FIN-01-2021), and the final draft version of the PEFC that had been sent to the international PEFC to be approved (PEFC FI 1002:2022). Later during the thesis project both renewed certifications were approved with only minor changes; the contents of the criteria used in this study remained the same (information received based on personal communication). From the compiled criteria, suitable ones were chosen and simplified for simulation considering the restrictions set by the forest growth simulator used to project forest growth under different management regimes (Table 1, see section 2.3).

Table 1. Simplified biodiversity related criteria of the certifications that were included in the study considering the restrictions set by the simulation.

	PEFC	FSC
Energy wood harvesting	No energy wood harvesting on heathland sites poorer than sub-xeric heaths and corresponding heathy peatlands In woody biomass harvesting, 30% of the residues is retained evenly distributed over the harvesting site. 25 stumps per ha are left unharvested.	No energy wood harvesting on heathland sites poorer than sub-xeric heaths and corresponding heathy peatlands. In woody biomass harvesting, 30% of the residues is retained evenly distributed over the harvesting site. 25 thicker than 15 cm stumps per ha are left unharvested as well as stumps less than 15 cm.
Retention trees	10 per ha with a min. diameter of 15 cm.	10 per ha with a min. diameter of 20 cm, and another 10 with a min. diameter of 10 cm, except if at least five of the trees in the previous section are over 30 cm.
Deciduous trees	-	In coniferous-dominant forests, the proportion of deciduous trees is in thinning 10% of the number of trees left for growing, and in tending of seedling stands 10% of the number of stems.
Buffer zones	A buffer zone is left along water bodies (lakes and rivers), where only selection fellings are allowed. Min. average width of the buffer zone is 10 m, (the absolute min. is 5 m). Trees in the zone are included in retention trees. No harvesting of stumps at groundwater area.	Requirements for the width of the riparian buffer zones and the allowed management are more variable and depend on the watercourse. In this study, if a stand is contacted with a river, 20 m buffer zone is left without management, plus 10 m zone where only selection fellings are allowed. If a stand is contacted with a lake, 10 m buffer zone is left without management, plus 5 m where only selection fellings are allowed. Trees in the zone are not included in retention trees. No harvesting of stumps at groundwater area.

Conservation	-	5% of the productive forest land.
Special sites with particular significance for biodiversity: management that doesn’t lead to regeneration obligation	-	5% of the productive forest land.

2.3 Management regimes and forest growth simulations

Forests in sampling plots were simulated 100 years into the future under different management alternatives (Table 2). Simulation produces data on forest development with five-year steps. Simulation was executed by using the open-source forest simulator SIMO (SIMulation and Optimization) that “simulates tree growth, mortality and regeneration for even-aged and uneven-aged boreal forests” and can be used for example in forest management planning (Rasinmäki et al. 2009, Blattert et al. 2022). Using simulation, it is possible to use significantly longer timescale than what would be possible in a field study.

Table 2. Management regimes used in the forest growth simulations. SC indicates site class (1 = very rich, 2 = rich, 3 = damp, 4 = sub-dry, 5 = dry, 6 = barren, 7 = scrub). RFM = rotation forest management, CCF = continuous cover forestry.

Management regime	Number of retention trees	Retention tree diameter	Stump removal
RFM intensive	0	20 cm	75% with a min. diameter of 15 cm SC1-4
PEFC_V1	10	20 cm	75% with a min. diameter of 15 cm SC1-4
PEFC_V2	10	20 cm	0%
FSC_V1*	10 at 10 cm, 10 at 20 cm	10 cm, then 20 cm	75% with a min. diameter of 15 cm SC1-4
FSC_V2	10 at 10 cm, 10 at 20 cm	10 cm, then 20 cm	0%
CCF	Thinning from above, basal area threshold +/- 0 m^2/ha as to the standard (Tapio) recommendations, 0% stump removal		
CCF extensive	Thinning from above, basal area threshold + 6 m^2/ha, 0% stump removal		

* FSC_V1 and FSC_V1 had also higher proportion of deciduous trees (Birch species) to account for the FSC certification promoting more mixed tree forests, requiring less thinning intensity on deciduous trees.

2.4 Creation of certification scenarios

Different management scenarios (combinations of managements) were coded in R with RStudio (version 4.3.1, R Core Team 2023): 1) intensive forest management without certifications (NC = No certifications), 2) intensive forest management with biodiversity related PEFC criteria, 3) intensive forest management with biodiversity related FSC criteria, and 4) without any management which in practice meant protection (SA = Set aside, Table 3). Certification criteria from PEFC and FSC that were included in simulation are described earlier in Table 1.

Table 3. Forest management scenarios that were coded in R based on the combinations of managements in the simulation.

Management scenario	**Acronym**	**Description**
No certifications	NC	Intensive management without certifications or management recommendations, but with restrictions imposed by Finnish law.
PEFC certified	PEFC	Intensive management but with constraints due to biodiversity related PEFC criteria.
FSC certified	FSC	Intensive management but with constraints due to biodiversity related FSC criteria.
Set aside	SA	No management, no timber production, protection.

2.4.1 Criteria regarding distance to water bodies

The first stage in coding the scenarios in R was creating the rules regarding the distance to water bodies: if there was river or lake at a certain distance from the stand, a certain management alternative was chosen (Table 4). In Table 4, the last column shows the final share of the total area that was managed with the certain management alternative. In this stage, the GIS data Ranta10 for rivers and lakes from Finnish Environment Institute was used (Finnish Environment Institute 2023). Figure 3 visualizes an example stand that was pounded by water courses, and the forest managements used.

Table 4. First iteration to assign managements to stands, based on proximity to water bodies. Included water bodies in this study were rivers and lakes. Buffer distance indicates the distance of the buffer from the water body, and in this buffer zone a certain management option is applied based on the criteria of the certifications. SA = set aside, CCF = continuous cover forestry, RFM = rotation forest management.

Scenario	**Water body**	**Buffer distance (m)**	**Management**	**% of total area**
FSC	River	5, 10, 15, 20	SA	1.1
	River	30	CCF	0.6
	Lake	5, 10	SA	0.4
	Lake	15	CCF	0.2
	Lake	20, 30	RFM intensive	0.8
	Has a buffer with water	> 30	RFM intensive	24.5
	Not by water buffer	-	FSC_V1	72.5
PEFC	River or Lake	5, 10	CCF	0.9
	River or Lake	> 10	RFM intensive	26.6
	Not by water buffer	-	PEFC_V1	72.5
NC	River or Lake	5	CCF	0.3
		30	RFM intensive	99.7

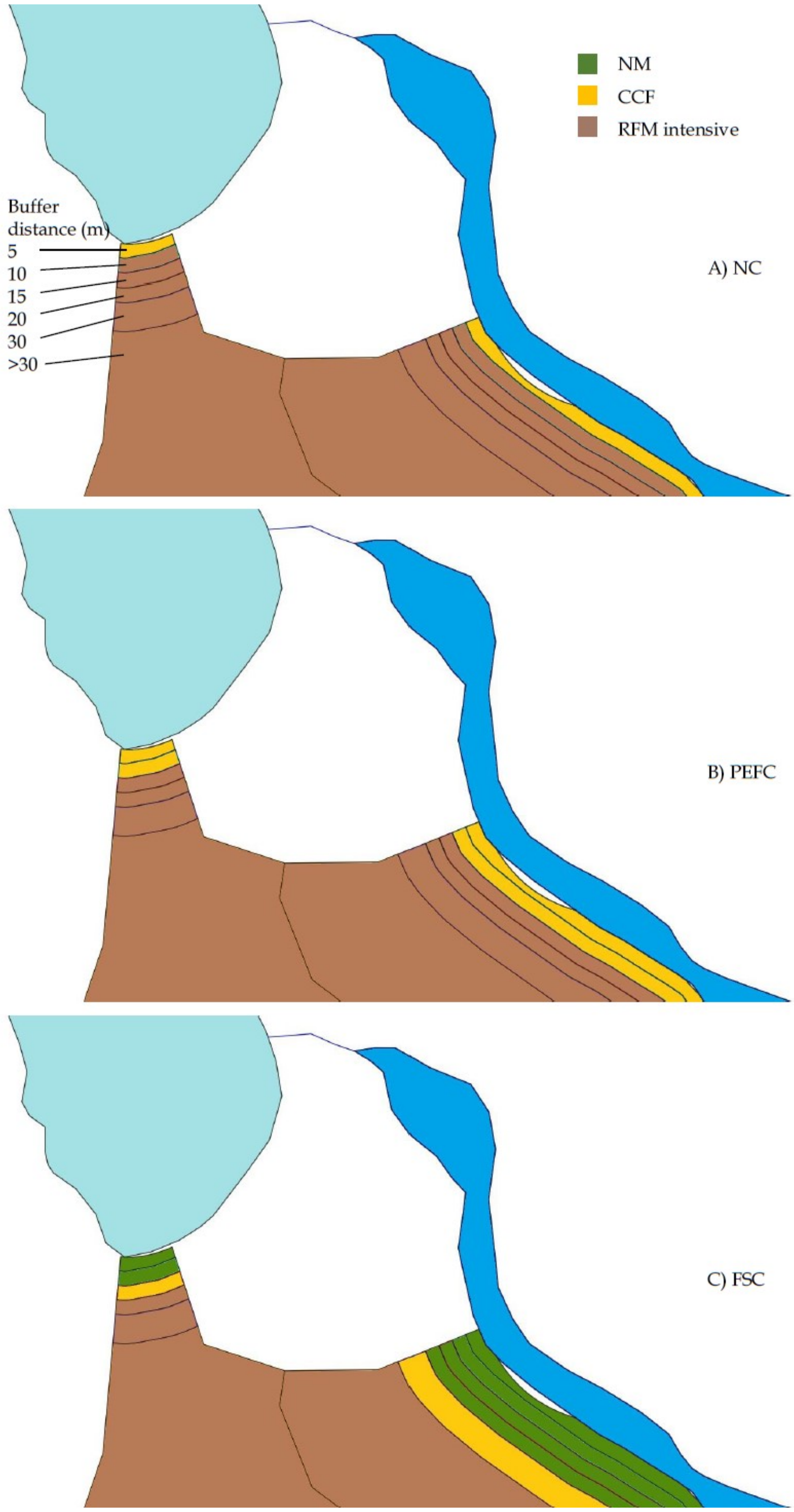

Figure 3. Example of a sample patch bounded by water courses (a lake, lighter blue, and a river, darker blue), which that for has buffer zones according to the criteria of the scenarios. A) is no certification scenario, B) is PEFC scenario, and C) is FSC scenario. Management measures in the buffer zone are NM = no management (green), CCF = continuous cover forestry (yellow), and RFM intensive = rotation forest management intensive (brown).

2.4.2 Criteria regarding groundwater areas

The second stage in coding the scenarios in R was creating the rules for groundwater areas (Table 5). Groundwater areas are classified into class 1 that includes groundwater areas important for water procurement, class 2 that includes other groundwater areas suitable for water procurement, and class E that includes groundwater areas on which the surface water or soil ecosystem is directly dependent on (Finnish Environment Institute 2022). The last column of Table 5 shows the final share of the total area that was managed with the certain management alternative. In this stage, the groundwater area GIS data from Finnish Environment Institute was used (Finnish Environment Institute 2023).

Table 5. Second iteration to assign managements to stands, based on stands on groundwater area classes and the management assigned on the previous iteration. No extraction of stumps in groundwater area.

Scenario	Groundwater area	Management after first iteration	Management assigned after second iteration	% of total area
FSC	1, 1E, 2, 2E	FSC_V1	FSC_V2	1.5
PEFC	1, 1E, 2, 2E	PEFC _V1	PEFC_V2	1.5
NC	-	-	-	-

2.4.3 Criteria regarding 5% share of protected forest

The third stage in coding the scenarios in R was creating the rules for 5% share of protected area in productive forest land (criteria of FSC, Table 6). In the FSC criteria, buffer zones that are excluded from forestry can be included in the 5% share of protected area. Third stage was executed based on the ranking within each watershed of the forest with highest potential of deadwood provision (average over 100 years) under SA regime: starting from the summed area of SA stands (buffers) in the area and adding to it one by one the stands with highest priority until reaching 5% of the area covered by SA stands within the watershed. In this stage, the watershed GIS data from Finnish Environment Institute (Finnish Environment

Institute 2023) was used (more specifically the watershed level three, to get enough stands inside the area).

Table 6. Third iteration to assign managements to stands in order to reach 5% protected forest (SA = set aside). CCF = continuous cover forestry.

Scenario	Criteria	Management after previous iterations	Management after third iteration	% of total area
FSC	Highest potential of deadwood under SA option for the watershed	Any except SA and CCF (i.e. protection buffers)	SA	5
PEFC	-	-	-	-
NC	-	-	-	-

2.4.4 Criteria regarding 5% share of special sites with particular significance for biodiversity

The fourth stage in coding the scenarios in R was creating the rules for 5% share of special sites with particular significance for biodiversity with management that does not lead to regeneration obligation (criteria of FSC, Table 7). This was executed based on the ranking of potential of deadwood provision (average over 100 years) within each watershed under "CCF extensive" regime: starting from initial value of 0% of total area within watershed and adding to it one by one the stands with highest potential until reaching 5% of the area covered by "CCF extensive" stands within the watershed. The same GIS data was used than in the previous stage.

Table 7. Fourth iteration to assign managements to stands in order to reach 5% special sites with particular significance for biodiversity with management that does not lead to regeneration obligation (applied extensive continuous cover forestry). SA = set aside, CCF = continuous cover forestry.

Scenario	Criteria	Management after previous iterations	Management after fourth iteration	% of total area
FSC	Highest potential of deadwood under SA option for the watershed	Any except SA and CCF (i.e. protection buffers)	CCF extensive	5
PEFC	-	-	-	-
NC	-	-	-	-

2.5 Biodiversity and economic indicators

Indicators for biodiversity (Peura et al. 2018, Blattert et al. 2022) and economic value (Eyvindson et al. 2021) were calculated for every scenario (Table 8). The biodiversity indicator species require, for example, different forest structures and thus represent different forest habitats (Table 8). They also can be considered umbrella or keystone species, and by protecting them several other species can be promoted simultaneously.

Forest's overall capacity to maintain species populations can be measured by habitat availability for species. Habitat suitability index (HSI) was calculated for the indicator species between 0 (unsuitable habitat) and 1 (the most suitable habitat). The equations used in HSIs are described in the research by Mönkkönen et al. (2014). Habitat availability was calculated across the entire landscape as a sum of products between stand specific HSI-values and the area of a stand.

Net present income (NPI) (Table 8) can be used in describing the economic value of the forest, and for example Metsähallitus (Finnish governmental organization managing state owned forests) selects stands for harvesting by it (Eyvindson et al. 2021). Higher NPI values indicate a greater degree of timber extraction intensity. In estimating the timber NPI the interest rate of 3% was used. Since the prices of the wood vary depending on the buyer, and the information about the exact euro amounts for the price of certified wood is not necessarily publicly available (Karppinen 2019), the effect of certification on wood's price was not included in the NPI in this study.

Table 8. Biodiversity indicators (adapted from Peura et al. 2018 and Blattert et al. 2022), and economic indicator (adapted from Eyvindson et al. 2021) calculated for the scenarios.

Indicator	Description
Dead wood	Volume of dead wood weighted by diversity (decay stage and tree species).
Deciduous trees	The volume of deciduous trees.
Large trees	Number of large trees (DBH > 40 cm).
Habitat availability for Capercaillie	The species is associated with pine volume with intermediate spruce mixture and steam density.
Habitat availability for Hazel grouse	The species indicates adequate levels of deciduous mixture with spruce.
Habitat availability for Lesser-spotted woodpecker	The species is associated with old deciduous trees and deciduous snags.
Habitat availability for Tree-toed woodpecker	The species is associated with high volume of trees and fresh deadwood.
Habitat availability for Long-tailed tit	The species is associated with mature forests deciduous trees.
Habitat availability for Flying squirrel	The species is associated with high volume of spruce with deciduous mixture.
Bilberry	Bilberry yield (kg ha^{-1} $year^{-1}$).
Cowberry	Cowberry yield (kg ha^{-1} $year^{-1}$).
Mushrooms	Marketed mushrooms yield (kg ha^{-1} $year^{-1}$).
Timber NPI	Timber net present income (€/ha). The present income of the sum of timber benefits and sum of costs.

2.6 Comparison of the scenarios

Scenarios where all landscape was managed for timber production using each certification management were compared to a scenario where the landscape was managed for timber production without certification, and to a scenario where all landscape was protected. Graphical and statistical scenario comparison was conducted in R with RStudio, and QGIS Desktop (version 3.22.5) was used in visualizing the study area.

3 RESULTS

3.1 Biodiversity related requirements of the certifications

The requirements of PEFC certification were expressed as titles and related criteria, sub-criteria, and indicators with definitions (overall length of the certification was 60 pages). FSC certification consisted of principles and related criteria, indicators, sub-indicators, and notes (overall 97 pages). All biodiversity related requirements of the certifications are presented in Appendix 1 at the criterion level. Both renewed certification documents are freely available online.

In addition to other requirements, both certifications contained several requirements related to biodiversity. Many of the biodiversity related requirements were of a general nature or did not set clear directives to follow, and thus could not be simulated in this study. These were related, for example, to documentation, following the instructions of authoritative or best available knowledge, quality, education, and planning or evaluating the actions. Some of the requirements were such that are already included in the Finnish law, such as the forest regeneration obligation, and consideration of the Natura 2000 network and particularly important habitats referred to 10 § of the Forest Act in forest management.

From the requirements that set clear directives but could not be included in the simulation due to the restrictions of the available data and the simulation itself, worth of pointing out are especially the requirements related to safeguarding the habitats of certain forests species, in case of FSC rare and threatened forest species, and in case of PEFC threatened forest species. Both FSC and PEFC set also requirements related to considering certain habitats of special importance, that are extra to Finnish Forest Act, Nature Conservation Act (9/2023) and Water Act (587/2011), but which could not be included in the simulation.

The expression of the indicators and definitions in the certifications was in places rather complex and detailed, and certain assumptions needed to be made regarding to them. Certifications also included many exceptions to the requirements, by the wording of the requirements (for example, "the organization shall *normally* --") or as named exceptions (for example, "-- may be excluded from the restrictions listed above"). The requirements did not necessarily insist 100% implementation either: in certain situations, following the requirement in at least 90% of the total surface area of the sites was enough (example from PEFC).

The biodiversity related criteria with indicators that were included in the simulations are summarized in Table 1. Note that the indicators in the table are simplified for the simulation. Main differences between the requirements that could be included in the simulations were that FSC set requirements of proportion of deciduous trees, share of conservation area, as well as share of special sites with soft management that lacked from PEFC requirements. FSC also set more requirements for the diameter of retention trees or stumps. Buffer zones for the watercourses were generally set wider in FSC requirements compared to PEFC.

3.2 Effects on forest biodiversity

In NC scenario the amount of deadwood was 4.0 m^3/ha, in PEFC 5.9 m^3/ha, and in FSC 10.9 m^3/ha, while in SA the amount was 35.9 m^3/ha. The amount of deadwood was 11.1% in NC, 16.3% in PEFC, and 30.3% in FSC compared to the amount of deadwood in SA forests (Figure 4). In NC the amount of deciduous trees was 11.7 m^3/ha, in PEFC 12.0 m^3/ha, and in FSC 14.8 m^3/ha, while in SA the amount was 29.1 m^3/ha. The amount of deciduous trees was 40.3% in NC, 41.1% in PEFC, and 51.0% in FSC compared to the amount of deciduous trees in SA forests (Figure 4).

The biggest difference between the scenarios arose in the number of large trees, in which the FSC had significantly the highest value compared to all the other scenarios (Figure 5). In NC the number of large trees was 0.08 ha^{-1}, in PEFC 0.25 ha^{-1}, and in FSC 2.2 ha^{-1}, while in SA the number was 0.4 ha^{-1}. The number of large trees was 20.6% in NC, 61.6% in PEFC, and 543.3% in FSC compared to the SA scenario (Figure 5).

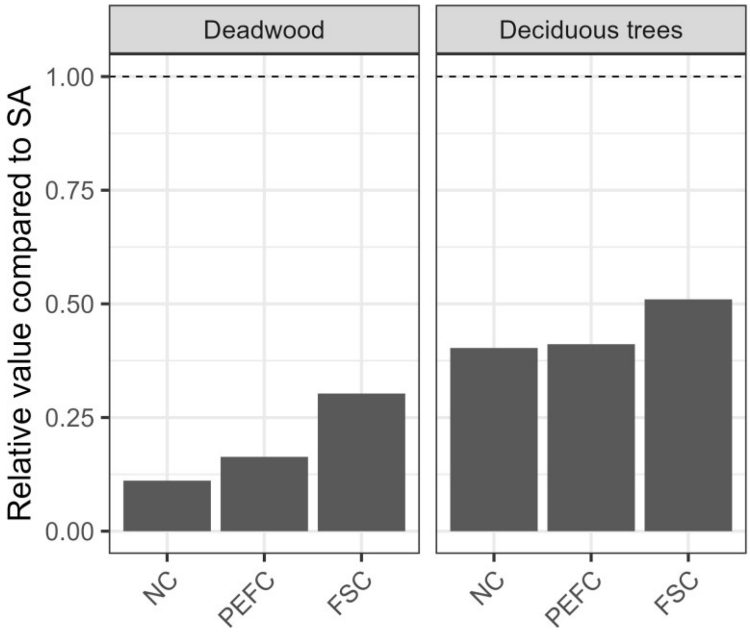

Figure 4. Relative values of deadwood and deciduous trees in forest managed without certifications (NC), with PEFC criteria (PEFC), and FSC criteria (FSC) compared to forest without management (SA = 1, dashed line).

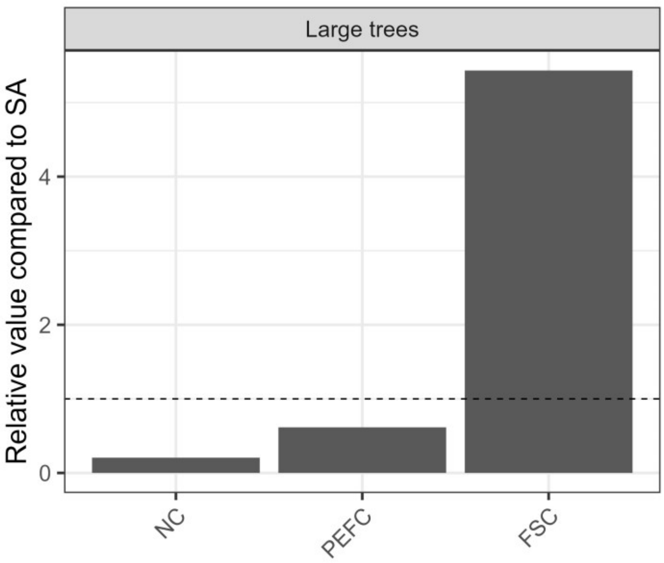

Figure 5. Relative values of large trees in forest managed without certifications (NC), with PEFC criteria (PEFC), and FSC criteria (FSC) compared to forest without management (SA = 1, dashed line).

In the values of vertebrate biodiversity indicator species, FSC had the highest HSI values of every of the six species compared to NC and PEFC, but also the values of FSC were far lower than the values of SA (Figure 6). The relative value of Capercaillie was in NC 11.5%, in PEFC 11.8%, and in FSC 15.1% compared to the SA forests. For Flying squirrel, the values were 30.2%, 30.5% and 48.1%, for Hazel grouse 65.7%, 66.0% and 74.0%, for Lesser spotted woodpecker 33.9%, 35.3% and 52.7%, for Long-tailed tit 32.2%, 35.0% and 43.1%, and for Three-toed woodpecker 59.3%, 60.2% and 68.7%, respectively.

The value of bilberry was lower in all scenarios (NC, PEFC, FSC) compared to SA, but the values of cowberry and mushrooms were in all scenarios higher compared to SA (Figure 7). In NC the value of bilberry was 68.2%, in PEFC 68.7%, and in FSC 77.6% compared to the value of bilberry in SA forests. The value for cowberry was 153.2%, 152.8% and 146.0%, and for mushrooms 114.3%, 114.2% and 111.6%, respectively.

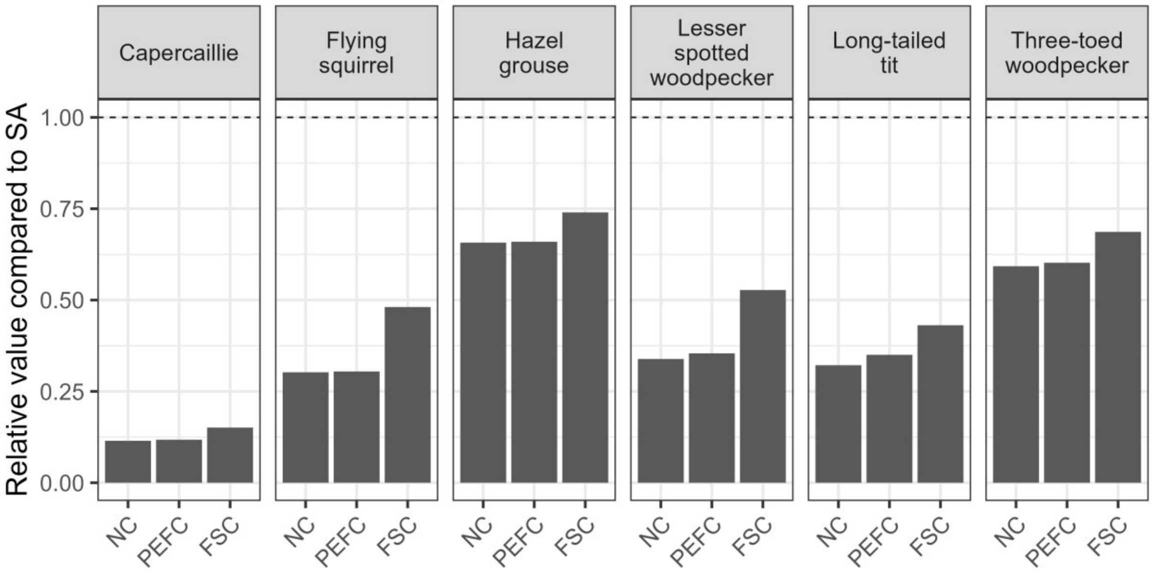

Figure 6. Relative values of vertebrate biodiversity indicator species in forest managed without certifications (NC), with PEFC criteria (PEFC), and FSC criteria (FSC) compared to forest without management (SA = 1, dashed line).

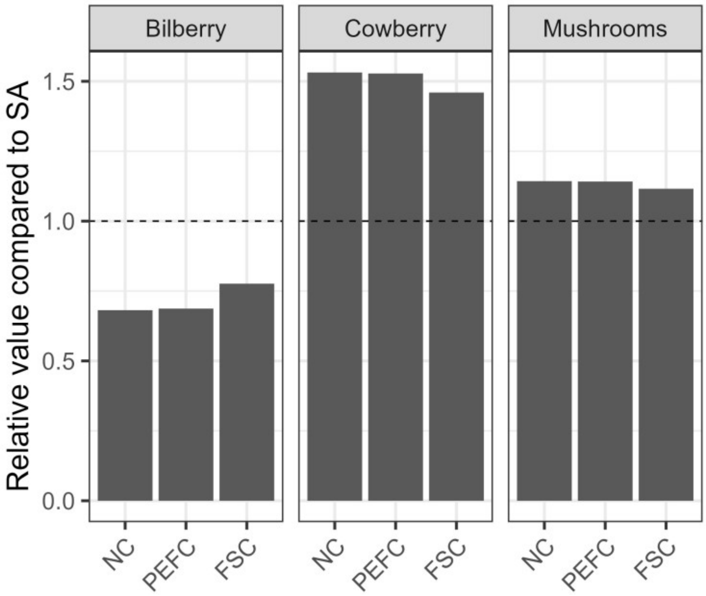

Figure 7. Relative values of bilberry, cowberry and mushrooms in forest managed without certifications (NC), with PEFC criteria (PEFC), and FSC criteria (FSC) compared to forest without management (SA = 1, dashed line).

3.3 Effects on timber revenues

Highest net present income from timber came from NC (4926 €/ha), second highest from PEFC (4886 €/ha), and lowest from FSC (3922 €/ha) (Figure 8). Certified forests provided 0.8% (PEFC) and 20.4% (FSC) lower net present income than uncertified forests (Figure 9). Note that the different market price of certified wood is not considered in the incomes here.

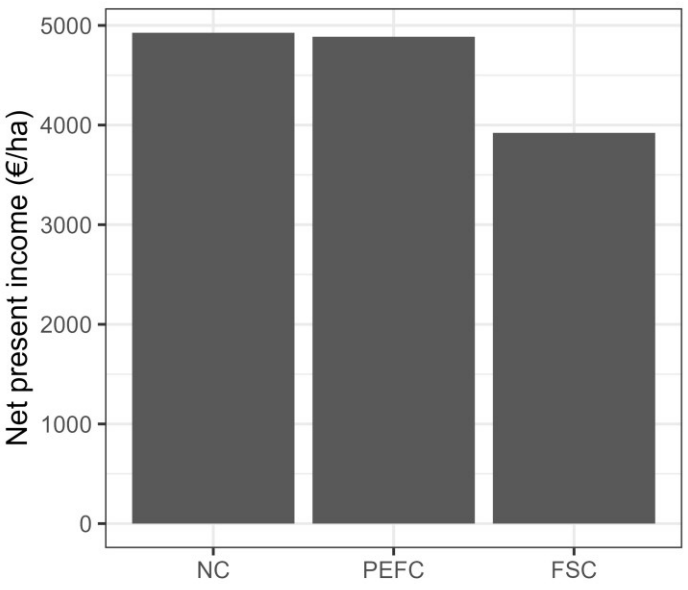

Figure 8. Net present income (€/ha) of the forest managed without certifications, and with PEFC and FSC criteria. The different market price of certified wood is not considered in the results.

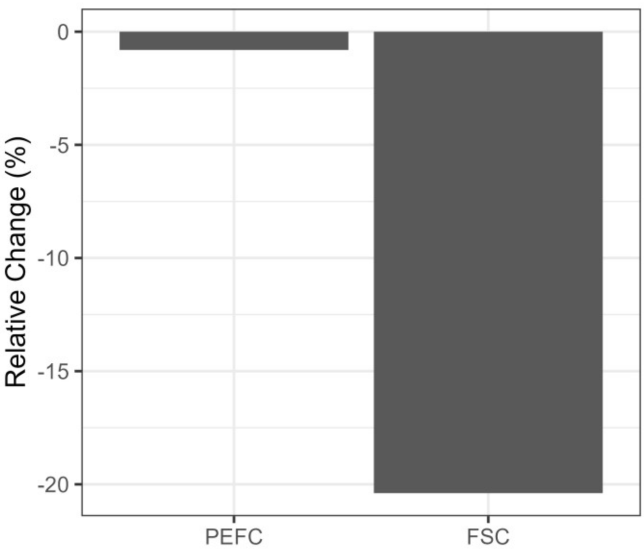

Figure 9. Relative change (%) in net present income of the forest managed with PEFC criteria and FSC criteria compared to forest managed without certifications. The different market price of certified wood is not considered in the results.

4 DISCUSSION

The aim of this master's thesis was to study the effectiveness of forest certifications in protecting biodiversity. This was done by comparing the simulated forests managed intensively without certification criteria, managed with PEFC criteria, and with FSC criteria in relation to forests without any management (protection). In general, the biodiversity values of certified forests fell far short of the biodiversity values of unmanaged, protected forests. From biodiversity indicators cowberry and mushrooms were exceptions from this, as well as large trees in case of FSC. The biodiversity values of FSC certified forests were higher than PEFC certified forests, and the values of PEFC certified forests were rather close to the values of uncertified forests.

Cowberry is a light demanding species, and it recovers rather quickly from disturbances (Turtiainen et al. 2013). Hence, it suffers from intensive forest management measures less than for example, bilberry (Turtiainen et al. 2013). Mushrooms' demands vary depending on the species, but in a young forest stands the yields may have already recovered after the final fellings (Miina et al. 2013). In some research, mushroom yields have been highest after thinnings (Miina et al. 2013). In this study large trees were defined as trees with a breast height of more than 40 cm. The high value of large trees in FSC forests compared all the other scenarios (even SA) may be because in addition to that FSC scenario included more SA areas, it included more CCF management, due FSC certification's requirements concerning for example the 5% share of protected areas, and 5% share of special sites with particular significance for biodiversity with management that does not lead to regeneration obligation. Both SA and CCF are good in producing large trees, but based on simulations and modelling CCF produces large trees rather quickly (Peura et al 2018). This can be explained with better resources, light and space, for the growing trees. However, in case of biodiversity protection, we should not be too optimistic of having a lot of fast-growing trees in the forest, since large trees are not necessarily old trees, which are especially important for biodiversity (Mönkkönen et al. 2022).

The results showed that in general, the lowest biodiversity values were in NC forests, and PEFC forests' values were rather close to them. From the three scenarios FSC forests' biodiversity values were the highest (except in case of cowberry and mushrooms), but they too mainly fell far short of the SA forests. The results showed that FSC scenario provided higher habitat availability to all vertebrate indicator species and bilberry compared to NC and PEFC. The animal indicator species require different forest structures, for example high volume of trees, mature trees, deadwood, and deciduous trees. Bilberry is an important source of food for many organisms and its yields significantly reduce after regeneration fellings (Raatikainen et al. 1984).

Reasons behind the differences between the scenarios in deadwood, deciduous trees and large trees may be related, for example, to the certifications' criteria concerning the width of the buffer zones, in which the criteria of earlier version of FSC have been considered to quite successfully protect the stream biodiversity compared to PEFC (Jyväsjärvi et al. 2020). PEFC and FSC had also differences in criteria related to retention trees, which FSC criteria requires more, and also the diameter of them is set bigger. Kuuluvainen et al. (2019) state that retention level and biodiversity have a positive correlation, and "few individual retention trees, or small routinely left retention groups of 5–10 small-sized trees, simply do not provide the habitat quality and continuity needed by various species groups". In case of PEFC, if there is a water buffer zone in a forest area, the retention trees in it replace the required retention trees in the rest of the area, whereas in FSC they come as an addition to the required retention trees. FSC also provides requirement of minimum protected area of productive forest land, and besides that a share of special sites with particular significance for biodiversity with management that does not lead to regeneration obligation. Old forests are scarce in Finland, and many forest species require old trees and old forests (Mönkkönen et al. 2022). In addition to these differences between the certifications, PEFC lacks criteria for proportion of deciduous trees, which is set to 10% in FSC. Typically, boreal natural forests, in contrast to commercial forests, consist of mixtures of tree species: different conifers and deciduous trees (Wallrup et al. 2006). Deciduous trees in conifer forests have positive effect on for example, local species richness of vascular plants, and mixed stands have a potential to maintain higher biodiversity (Wallrup et al. 2006). Mixed tree species can make a forest more resilient to climate change and insect epidemics (Chavardès et al. 2021), and this could also be seen as added value for the FSC forests.

One aspect that was in practice included in FSC certification, but not in PEFC, was the use of CCF (requirement of 5% share of special sites with particular significance for biodiversity with management that does not lead to regeneration obligation). Increasing the share of continuous cover forestry would bring landscape level variation (Peura et al. 2018). In research it has also brought higher timber net present value (Peura et al. 2018). At the moment, rotation forest management that is based on clear-cuts is still the dominating management in Finland (Kuuluvainen et al. 2019.) Diversifying management regimes on landscape level can maintain biodiversity (Mönkkönen et al. 2014). In the study of Mönkkönen et al. (2014) an optimal combination of different regimes brought also more economic returns than rotation management alone. Landscape level planning of forest management can thus be a cost-effective way in biodiversity protection in productive forest land (Mönkkönen et al. 2014) and integrating ecological knowledge into management schemes should be a foundation in it (Kuuluvainen et al. 2019).

All the requirements from the certifications could not be included in the simulations even though they might have set clear directives, because simulation itself sets some limitations. For example, both certificates set requirements on safeguarding the habitats of certain forests species. It seems that FSC's requirements are stricter also in this case: it includes rare and threatened species for the requirement, whereas PEFC includes only threatened species. Overall, the threatened forests species exhibit a wide range of differences in their habitat preferences and resource needs (Tikkanen et al. 2006), and thus can represent an even more diverse forest structure. Moreover, the biodiversity indicators used in this study do not reveal all the biodiversity effects, for example the local effects of the riparian buffer zones on stream habitats or small waters. Also, the effects of the certifications were calculated for the entire landscape level, under which the effects of the local level may be hidden; if the amount of deadwood would be looked, for example, only in forests near the streams, the differences between the scenarios could be bigger. For the buffer zones, springs and brooks were not included in this study because there was no reliable GIS information about them available at the time of planning the thesis. However, after doing the analyses we found that the recently published spatial database on small water bodies (Aroviita et al. 2022) would help fill the gap for some of the brooks. A better accounting for brooks in this thesis would have the following consequences: PEFC would get more areas with CCF regimes, and this would produce larger standing trees, although not much change in timber revenues based on Peura et al. (2019). For FSC there would be more areas under SA, but because all the water buffers in FSC are counted within the total 5% of protected area over the watershed area, then the difference is likely not much relevant.

A minor shortcoming of the analyses of this thesis is that the initial forest data used in the study was from 2016, and it does not perfectly describe the current state of forests in Central Finland. This is not a major limitation as the main aim was to compare certification alternatives, for which the initial states are the same across certification scenarios.

European Union has a strategy that aims for putting Europe's biodiversity on a path to recovery by 2030, which also applies to Finland (European Commission 2021). Managed forests cover nearly 90% of Finland, so the measures taken in them are of great importance for forest biodiversity (Mönkkönen et al. 2022). Developing and putting into practice biodiversity-friendly practices in forestry is one part of the solution for achieving the target (Korhonen et al. 2021). Korhonen et al. (2021) describe the closer-to-nature forest management practices, that were introduced in Finland already in 1990s, including "retention tree, protection of key habitats and transition zones, preserving species mixture in all development phases, considering game and wildlife in management operations, protection of water bodies and promoting varying management approaches (both even-aged and uneven-aged forestry), and the use of prescribed burning". Both PEFC and FSC have requirements concerning for example the prescribed burning (that could not be included in the simulation), however, implementing these practices as a mainstream in forest management has not succeeded (Siitonen et al. 2020). Utilizing natural disturbances in managed forests would bring cost-effective opportunities in restoring biodiversity increasing features that are lost from forests (Mönkkönen et al 2022).

In this study, SA was set as a reference to which other scenarios were compared to see the relative impact of different criteria on biodiversity. Neither of the certificates produced enough biodiversity values compared to protected forests, but their use to some extend reduced income. However, since the prices of the wood vary depending on the buyer and the information about the exact euro amounts for the price of certified wood is not necessarily publicly available (Karppinen 2019), effect of certification on wood's price was not included in the NPI in this study. Nevertheless, it seems that the market price of FSC certified wood is higher compared to PEFC certified wood, and the price of the uncertified wood is the lowest (Karppinen 2019), and this would in practice lower the gap in NPI between the PEFC certified and FSC certified wood. Protection of the biodiversity values in natural systems often conflicts with the production of marketable goods, and resolving this conflict needs strategies (Mönkkönen et al. 2014). At the same time when human needs keep expanding, it is clear that intensive land-use is one of the primary drivers of current biodiversity loss (Mönkkönen et al. 2014, Chase et al. 2020). The use of forests involves several simultaneously conflicting needs and desires, and balancing these needs is important. Finnish National Forest Inventories have shown that tree growth, total forest area, and total timber volume have increased (Mönkkönen et al. 2014). At the same time forest species and habitats keep declining (Hyvärinen et al. 2019, Kontula & Raunio 2019). Reason behind this paradox is changed forest structures compared to natural forests (for example, declined dead wood volume and old forest area), and the current state cannot maintain ecologically diverse forests (Mönkkönen et al. 2022).

One aspect to consider in forest certification systems is the comprehensibility of the certifications and applicability of them in practice. For the certification system to appear credible and efficient, the possible violations against following the certification criteria should be observed efficiently, and the sanctions made possible by the system should be applied in these cases. It has been observed in inventories that despite the criterion that requires leaving retention trees permanently after clearcutting, almost in every third area the retention trees were later removed (Kuuluvainen et al. 2019).

4 CONCLUSIONS

The aim of this master's thesis was to research the effectiveness of forest certifications (PEFC, FSC) in protecting biodiversity, and their effects on timber revenues from forest. This study showed that forests managed with the certification schemes are mainly far from protected forests in terms of biodiversity values. From the three scenarios — forests managed without certifications, with PEFC, and with FSC — FSC certified forests had the highest biodiversity values. PEFC certified forests' biodiversity values were rather close to uncertified forests. FSC forests brought less net present income that two other scenarios, but in practice the better price of the FSC certified wood would narrow the gap. It would be useful that the prices of wood were public information, and the price should compensate for the loss of income caused by the use of the certification. The result of this study gives an indication of how much the compensation should be. By the results of this study and previous research it seems clear that forest certifications' current criteria need further development, in interaction with different experts and interest groups, to be effective in protecting forest biodiversity, and to fulfil their promise on sustainably managed forests.

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APPENDIX 1 BIODIVERSITY RELATED REQUIREMENTS OF THE CERTIFICATIONS AT CRITERION LEVEL

Table 9. Biodiversity related requirements of the certifications at criterion level. Both certification documents are freely available online (pefc.fi, fi.fsc.org/fi-fi).

PEFC	FSC
6.1 The legality of a felling operation shall be shown and environmental aspects clarified by means of a forest use declaration	5.2 The Organization shall normally harvest products and services from the Management Unit at or below a level which can be permanently sustained.
6.2 The management and use of forests shall be based on the use of up-to-date data on nature and forest resources	6.1 The Organization shall assess environmental values in the Management Unit and those values outside the Management Unit potentially affected by management activities. This assessment shall be undertaken with a level of detail, scale and frequency that is proportionate to the scale, intensity and risk of management activities, and is sufficient for the purpose of deciding the necessary conservation measures, and for detecting and monitoring possible negative impacts of those activities.
7.3 The quality of forestry operations shall be ensured	6.2 Prior to the start of site-disturbing activities, The Organization shall identify and assess the scale, intensity and risk of potential impacts of management activities on the identified environmental values.
8.1 The tree stock in a forest shall be maintained as a carbon sink	6.3 The Organization shall identify and implement effective actions to prevent negative impacts of management activities on the environmental values, and to mitigate and repair those that occur, proportionate to the scale, intensity and risk of these impacts.
8.2 Energy wood shall be harvested sustainably	6.4 The Organization shall protect rare species and threatened species and their habitats in the Management Unit through conservation zones, protection areas, connectivity and/or (where necessary) other direct measures for their survival and viability. These measures shall be

	proportionate to the scale, intensity and risk of management activities and to the conservation status and ecological requirements of the rare and threatened species. The Organization shall take into account the geographic range and ecological requirements of rare and threatened species beyond the boundary of the Management Unit, when determining the measures to be taken inside the Management Unit.
8.3 Non-wood forest products shall be utilized sustainably	6.5 The Organization shall identify and protect representative sample areas of native ecosystems and/or restore them to more natural conditions. Where representative sample areas do not exist or are insufficient, The Organization shall restore a proportion of the Management Unit to more natural conditions. The size of the areas and the measures taken for their protection or restoration, including within plantations, shall be proportionate to the conservation status and value of the ecosystems at the landscape level, and the scale, intensity and risk of management activities.
8.4 Sites of importance for biodiversity and ecosystem services shall be safeguarded during the clearing of forests and afforestation	6.6 The Organization shall effectively maintain the continued existence of naturally occurring native species and genotypes, and prevent losses of biological diversity, especially through habitat management in the Management Unit. The Organization shall demonstrate that effective measures are in place to manage and control hunting, fishing, trapping and collecting.
8.5 Tree health shall be looked after	6.7 The Organization shall protect or restore natural watercourses, water bodies, riparian zones and their connectivity. The Organization shall avoid negative impacts on water quality and quantity and mitigate and remedy those that occur
8.6 Tending of young stands shall be timely	6.8 The Organization shall manage the landscape in the Management Unit to maintain and/or restore a varying mosaic of species, sizes, ages, spatial scales and regeneration cycles appropriate for the landscape values in

	that region, and for enhancing environmental and economic resilience.
8.7 Tree species native to Finland shall be used in forest regeneration	6.9 The Organization shall not convert natural forest to plantations, nor natural forests or plantations on sites directly converted from natural forest to non-forest land use, except when the conversion: a) Affects a very limited portion of the area of the Management Unit, and b) Will produce clear, substantial, additional, secure long-term conservation benefits in the Management Unit, and c) Does not damage or threaten High Conservation Values, nor any sites or resources necessary to maintain or enhance those High Conservation Values.
8.8 No waste or litter shall be left in forests as a result of forestry operations	6.10 Management Units containing plantations that were established on areas converted from natural forest after November 1994 shall not qualify for certification, except where: a) Clear and sufficient evidence is provided that The Organization was not directly or indirectly responsible for the conversion, or b) The conversion affected a very limited portion of the area of the Management Unit and is producing clear, substantial, additional, secure long-term conservation benefits in the Management Unit.
8.9 Plant protection products shall be used responsibly	9.1 The Organization, through engagement with affected stakeholders, interested stakeholders and other means and sources, shall assess and record the presence and status of the following High Conservation Values in the Management Unit, proportionate to the scale, intensity and risk of impacts of management activities, and likelihood of the occurrence of the High Conservation Values.
8.10 The conservation values of protected areas shall be safeguarded	9.2 The Organization shall develop effective strategies that maintain and/or enhance the identified High Conservation Values, through engagement with affected stakeholders, interested stakeholders and experts.

8.11 The characteristic features of habitats of special importance shall be preserved	9.3 The Organization shall implement strategies and actions that maintain and/or enhance the identified High Conservation Values. These strategies and actions shall implement the precautionary approach and be proportionate to the scale, intensity and risk of management activities.
8.12 The known habitats of threatened species shall be safeguarded	9.4 The Organization shall demonstrate that periodic monitoring is carried out to assess changes in the status of High Conservation Values, and shall adapt its management strategies to ensure their effective protection. The monitoring shall be proportionate to the scale, intensity and risk of management activities, and shall include engagement with affected stakeholders, interested stakeholders and experts.
8.13 The biodiversity of forest species shall be promoted with prescribed burning	10.1 After harvest or in accordance with the management plan, The Organization shall, by natural or artificial regeneration methods, regenerate vegetation cover in a timely fashion to pre-harvesting or more natural conditions.
8.14 In forestry operations, living retention trees and deadwood shall be left and a variety of tree species and thickets shall be spared	10.2 The Organization shall use species for regeneration that are ecologically well adapted to the site and to the management objectives. The Organization shall use native species and local genotypes for regeneration, unless there is clear and convincing justification for using others.
8.15 Genetically modified forest reproductive material shall not be used	10.3 The Organization shall only use alien species when knowledge and/or experience have shown that any invasive impacts can be controlled and effective mitigation measures are in place.
8.16 The biodiversity and ecosystem services of peatlands shall be maintained	10.4 The Organization shall not use genetically modified organisms in the Management Unit.
8.17 Operations in the vicinity of water bodies, including small ones, shall take into account water protection and nature management	10.5 The Organization shall use silvicultural practices that are ecologically appropriate for the vegetation, species, sites and management objectives.

8.18 During forestry operations, the quality of ground water shall be safeguarded	10.6 The Organization shall minimize or avoid the use of fertilizers. When fertilizers are used, The Organization shall demonstrate that use is equally or more ecologically and economically beneficial than use of silvicultural systems that do not require fertilizers, and prevent, mitigate, and/or repair damage to environmental values, including soils. 10.7 The Organization shall use integrated pest management and silviculture systems which avoid, or aim at eliminating, the use of chemical pesticides. The Organization shall not use any chemical pesticides prohibited by FSC policy. When pesticides are used, The Organization shall prevent, mitigate, and/or repair damage to environmental values and human health. 10.8 The Organization shall minimize, monitor and strictly control the use of biological control agents in accordance with internationally accepted scientific protocols. When biological control agents are used, The Organization shall prevent, mitigate, and/or repair damage to environmental values. 10.9 The Organization shall assess risks and implement activities that reduce potential negative impacts from natural hazards proportionate to scale, intensity, and risk. 10.10 The Organization shall manage infrastructural development, transport activities and silviculture so that water resources and soils are protected, and disturbance of and damage to rare and threatened species, habitats, ecosystems and landscape values are prevented, mitigated and/or repaired. 10.11 The Organization shall manage activities associated with harvesting and extraction of timber and non-timber forest products so that environmental values are conserved, merchantable waste is reduced, and damage to other products and services is avoided.