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Summary

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The European Commission Biodiversity Strategy for 2030 proposes to continue and further develop biodiversity-friendly practices, such as closer-to-nature-forestry, to achieve the ambitious biodiversity targets. In Finland, forestry land covers 86% of the land area and thus the protection of biodiversity is closely connected to forest management. In this report we review the elements in Finnish forest legislation, PEFC-forest certification scheme and forest management guidelines that are related to and support closer-to-nature forest management practices. We include a brief description of the specific features of boreal forest ecosystems, forest resources of Finland as well as a brief description of the forest management practices and governance.

Keywords: forest management, biodiversity

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1. Introduction

1.1. Background

Forestry land, consisting of productive forest land, poorly productive forest land, and unproductive land, covers 26.5 million hectares which constitutes 86% of the land area of Finland (Natural Resources Institute Finland, Forest resources). The area of productive forest land where the potential annual yield is at least 1 m^3 per hectare is 20.2 million hectares, and the area of poorly productive forest land is 2.6 million hectares. The proportion of protected forest is 13% of the combined productive and poorly productive land. Of the total forestry land, 18% is protected. Most of the protected forests are in the northern Finland.

Almost all (98%) of Finland is located in the boreal vegetation zone, and the remaining 2% in the hemiboreal zone. Species richness in the forests of the boreal zone is lower than in the vegetation zones in central and southern Europe. There are 24 native tree species, but Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* [L.] Karst.), and two birch species (*Betula pubescens* Ehrh. and *B. pendula* Roth.) form 97% of the growing stock. The landscape is fragmented due to lakes, other water systems, and also due to human intervention. The percentage of built-up land and agricultural land is only 14% of the total land area. Private individuals and communities own 66% of the productive forest land, forest industry companies own 9%, and state 13%. Due to fragmented landscape and ownership, the average size of management unit, for example in clear felling, is only about 1.5 hectares.

The average annual increment of growing stock has been 108 million cubic meters in 2019–2018. (stat.luke.fi). In 2015–2019 the annual removals have varied from 68 to 78 million cubic meters and the annual drain from 82 to 94 million cubic meters. Large biotic or abiotic forest damages have been very rare in Finland. The largest storm damage in recent decades was estimated to fell around 8 million cubic meters of trees in 2001. This was about 10% of the annual increment at that time. Epidemic insect damages occur frequently mainly due to pine sawflies and other defoliators, but large-scale bark beetle damage similar to central Europe and southern Sweden have not occurred so far. Due to the good forest health status, salvage and sanitary cuttings represent a negligible proportion of the annual timber production. The main aim of sanitary cuttings in Finland is to prevent breeding of bark beetles in storm-felled or other damaged, coniferous trees.

The use of forests in Finland is mainly guided by forest legislation, forest certification criteria and forest management guidelines.

1.2. Aim of the report

The European Union Biodiversity strategy for 2030 (European Commission 2020) aims to put biodiversity on the path to recovery by 2030 by protection and restoration of nature. Continuing and further developing biodiversity-friendly practices, such as closer-to-nature forestry, is proposed as one solution for achieving the biodiversity targets. In the strategy, the EU Commission plans to develop guidelines on closer-to-nature forestry practices. The aim of this report is to describe the already existing elements supporting closer-to-nature forest management in the current Finnish forest legislation, forest certification criteria and forest management guidelines (FMG). Regarding FMG, we consider the guidelines of Tapio for private forests (Äijälä et al. 2019). Metsähallitus, managing the state-owned forests, and the forest companies have guidelines for their own forests, but we exclude these from this report because most of the forests are privately owned in Finland. As forest certification, we consider the PEFC-certification system that covers more than 90% of the production forests (PEFC Suomi 2021) but exclude the FSC-certification system because it covers less than 10% of the Finnish forests.

2. Boreal forests, their management and governance in Finland

2.1. Boreal forest dynamics

The structural and functional diversity of boreal forests is maintained by natural disturbances, and forest species and habitats are adapted to the variability of disturbance dynamics (Esseen et al. 1997). In addition to successional variation caused by disturbances, the variation of site fertility coupled with moisture and latitude generate other important ecological gradients in the forest vegetation in Finland (e.g. Tonteri et al. 1990).

In natural conditions, the successional cycles of boreal forests of north-western Europe were driven both by wildfires with varying severity and size, and by variable small-scale disturbances which led to different types of successional dynamics. These included cohort, patch and gap dynamics which occurred with varying frequency in both pine- and spruce-dominated forests (Kuuluvainen 2009; Kuuluvainen & Aakala 2011). The disturbance agents included abiotic ones such as windstorms, wildfires, floods and snow breaks, and biotic ones such as insect outbreaks and fungal diseases. These disturbances occurred mostly on a small scale, and the pristine landscapes were hence dominated by old-growth forests. Old, living trees and dead wood were abundant in such landscapes. Today, natural disturbance agents have largely been replaced by forest management, and the decline of old trees and dead wood in the present managed landscapes are the main causes of threat for red-listed forest species and habitat types (Hyvärinen et al. 2019, Kouki et al. 2019). Consequently, forest management guidelines and forest certification standards have promoted the retention of old, large-diameter living trees and dead wood in forest management operations from the 1990s onwards in many countries, including Finland. However, the retention levels have been generally low (Gustafsson et al. 2010, 2012, Jonsson and Siitonen 2012, Lindenmayer et al. 2012, Kuuluvainen et al. 2019).

In Finland, forest fires have almost disappeared owing to efficient fire suppression, forest management and extensive forest-road network (Lindberg et al. 2020). The fire regime has varied a lot in Fennoscandia depending on the location and the time period considered, and human influence has been significant in both increasing and decreasing the fire frequency. Climate and lightning-activity based estimates of fire cycles have varied from 100 years in southern Finland to 1700 years in northern Finland (Larjavaara 2005), i.e. the average proportion of forest area burned annually may have varied between 1% and 0.06%, respectively. Lindberg et al. (2020) estimated that in recent years the area of annual fires has been mostly less than 1000 hectares. More than 50% of this area has been burned by wildfires, the rest consisting of prescribed burnings and restoration burnings. The area of annual fires represents ca. 0.004% of forestry land in Finland, indicating a fire cycle of 26,000 years at present (Lindberg et al. 2020). The decline of forest fires has led to the decline of fire-adapted habitat types and species such that many of these are now red-listed. Because of these reasons, the Finnish FMG and forest certification standards have promoted the use of fire in forest management from the 1990s onwards (Lindberg et al. 2020).

2.2. Forest management approaches

Since 1940s till 2014, the forest legislation and FMG have mainly supported even-aged forest management. In this management system, the regeneration cutting method is either clear

felling or natural regeneration with seed trees. After clear felling, the establishment of new growing stock is ensured by soil preparation and either planting or direct seeding. In the case of natural regeneration, seed trees are left standing to ensure production of seeds for the regeneration site. Soil preparation is used in most sites also in the case of natural regeneration. The seed trees are removed when the new seedling stand is established, typically 4–8 years after the regeneration cutting depending on site type /site conditions and vegetation zone.

Juvenile stand management, which includes early cleaning and pre-commercial thinning, is applied to seedling stand one or two times, depending on site and vegetation zone. The aim of juvenile stand management is to reduce the competition effects of the less wanted species on the planted or other favoured species in the seedling stand. The early cleaning is performed typically 4–5 years after the regeneration and the pre-commercial thinning a few years later.

Commercial thinnings (also called intermediate cuttings) are applied typically two times during the rotation, in fewer cases only once or three times. The aim of commercial thinning is to increase the production of large-dimension saw log trees, to reduce mortality and to select appropriate tree species for further growing. The FMG recommend regeneration cutting at the age of 40–120+ years or at the mean diameter of 22–30 centimetres, depending on the vegetation zone, site type and dominant tree species. The proportion of commercial thinnings has in recent years been more than 70% of the total area of fellings.

Production of roundwood for forest industry is the main objective of harvesting operations. Wood-based energy is mainly a side product of industrial processes or harvesting of industrial roundwood. Harvesting of energy wood without industrial roundwood may occur in young forests where the yield of commercial roundwood remains low due to small size of removed trees.

In the United Nations Convention on Biological Diversity (CBD) in 1992, Finland, among other countries, committed to conservation and sustainable use of biodiversity. This was reflected in the Forest Act 1996 (1093/1996) that introduced the protection of habitats of particular interest (key habitats, see sub-chapter 3.1). Subsequently, the FMG were renewed in 1994 and, besides key habitats, included new elements concerning biodiversity protection in forest management (Metsäkeskus Tapio 1994). It is worth mentioning that the 1994 FMG were titled Close-to-Nature Forest Management Guidelines (free translation). The FMGs have been regularly updated with about five-year intervals, the most recent ones being from 2019 (Äijälä et al. 2019). According to the FMG, the most important means of closer-to-nature forest management include woodland key habitats which should be set aside from management or managed so that their natural characteristics are preserved, retention of valuable living trees and dead wood in fellings, enhancement of deciduous admixture, leaving unharvested buffer zones along waters and the use of prescribed burning.

Since 2014, the forest legislation and FMG have recognized also uneven-aged forest management practices. These practices include selective cutting and regeneration through gap felling. In selective cutting, the aim is to grow trees of different age and canopy layer in the same stand. The removed trees are mainly the biggest and dominant trees of the stand. The basal area of growing stock may be thinned down to 8–15 m^2/ha in southern Finland, depending on site type, to enable regeneration of new trees. Regeneration through gap felling can be implemented with varying opening sizes and also accompanied by selective cuttings in the zones between the openings.

2.3. Forest legislation

Finland has had a Forest Act setting the statutory obligations for forest management since 1886. For over a century, the guiding principle of the Forest Act was that "forest shall not be devastated". The two main regulations in the subsequent versions of the Forest Act mandated that forest regeneration must be secured after final cutting, and that regeneration cutting of young growing forest was not allowed. These regulations were sufficient to secure the sustained production of timber but did not consider other aspects of sustainability.

The main elements of the current forest legislation are the Forest Act (1093/1996), amended in 2014, and the Forest Decree on sustainable forest management and use (1308/2013). Forest management and use are mentioned with some guidance also in other legislation like the Forest Damages Prevention Act (1087/2013), the Act on Trade in Forest Reproductive Material (241/2002) and the Wilderness Act (62/1991). The Temporary Act of the Financing of Sustainable Forestry (34/2015) promotes closer-to-nature forest management by granting environmental subsidies if "*measures relating to the management or use of forests take account of the maintenance of forest biodiversity, nature management or use of forests for purposes other than wood production more extensively than what is laid down in the Forest Act as an obligation of the landowner*". Based on the Land Use and Building Act (132/1999), municipalities can promote closer-to-nature forestry by restricting the use of methods like clear cutting close to communities.

The guiding principle of the current Forest Act is balancing economic, ecological and social sustainability. The purpose of the current Forest Act (1093/1996) is as stated in Section 1 "*to promote economically, ecologically and socially sustainable management and utilisation of forests in order that the forests produce a good output in a sustainable way while their biological diversity is being preserved.*" The current Forest Act has a particular Chapter 3 on "Safeguarding the biodiversity of forests". The first subsection (10 §) defines the general aim of forest management in relation to biodiversity: "*Forests shall be managed and used in such a manner that the general conditions for the preservation of habitats important for the biological diversity of forests are safeguarded.*" The second subsection defines a set of habitats of particular importance whose characteristic features must be preserved in all management operations (see Chapter 2.1 for further details). This requirement of the Forest Act in safeguarding the biodiversity of forests applies to all forest management and therefore is not repeated later in describing different forest management activities.

The current forest legislation does not include any obligations to do active forest management like thinning and it is very liberal with respect to all management practices like even-aged or uneven-aged management. The legislation does not include any minimum diameter or age thresholds for regeneration cutting. However, there are some clear restrictions which are related to thinning, final felling, and preserving biodiversity and habitats of special importance. There is also an obligation to the landowner (or holder of the right of possession) to make a forest use declaration to the Finnish Forest Centre before the intended felling. Chapter 3 in the Forest Act is dedicated to safeguarding the biodiversity of forest by preserving biodiversity and habitats of special importance. The Forest Decree on sustainable forest management and use (1308/2013) clarifies the statutes of Forest Act.

The Forest Damages Prevention Act´s (1087/2013) scope is "to maintain a good health status of forests and prevent forest damages" and it requires to remove coniferous damaged trees exceeding 10 m^3/ha (spruce) or 20 m^3/ha (pine). According to the Wilderness Act (62/1991) the wilderness areas should be preserved in their natural state or managed based on closer-to-nature forest management.

2.4. Forest certification standards

In the late 1990s, the increasing concern about maintaining biodiversity led to the development of new type of forest policies, and to the development of forest-certification systems to promote ecologically, socially and economically sustainable forestry.

Compared with legislation, the forest certification standards with their specific criteria set additional obligations to safeguard biodiversity in managed forests. The main criteria connected to biodiversity are those to safeguard valuable habitat types (various kinds of woodland key habitats to support forest species confined to these), to retain living retention trees and dead trees, and to promote prescribed burning (to maintain fire-dependent species and habitat types). In the forest legislation, there are no obligations for retention trees nor prescribed burning, and only certain valuable habitat types are obliged to be safeguarded by the Forest Act (1093/1996). Forest certification involves some additional habitat types to be protected depending on the forest certification standard (see Chapter 2.1). There are two different forest certification standards applied in Finland, the national PEFC (Programme for the Endorsement of Forest Certification) and FSC (Forest Stewardship Council) standards. The minimum level of safeguarding biodiversity is set higher in most of the criteria in the FSC standard than in the respective criteria in the PEFC standard.

In Finland, forest certification started in 1999–2000 with Finnish forest certification standard (SMS standard; Suomen metsäsertifiointijärjestelmä 1998). This certification standard was applied practically in the whole country from the very beginning. SMS standard was the first version of the present PEFC standard. The standard has been revised three times, at ca. five-year intervals by now (Metsäsertifioinnin standardityöryhmä 2003; PEFC Finland 2009; 2014). The present PEFC standard (PEFC Finland 2014) has been applied since 2016, and the revised 5th version of the standard is planned to be enforced by the end of 2021. At present, PEFC standard covers18.5 million hectares, corresponding to more than 90% of managed forests of Finland (PEFC Suomi 2021).

In the 2000s, FSC forest certification covered only ca. 10,000 ha, but in the beginning of the 2010s, the coverage of FSC has increased rapidly owing to application of the standard by large Finnish forest industry companies. At present, FSC certification covers about 2 million hectares (FSC Suomi 2020). The Finnish FSC standard has been revised once by now (The Board of the Finnish FSC Association 2005; Finnish FSC Association 2010), and also this standard is currently under revision.

Below, we concentrate on the PEFC-forest certification standard because of its high coverage in Finland.

2.5. The National Forest Strategy

The National Forest Council approved the National Forest Strategy in December 2018, and the Government of Finland adopted the National Forest Strategy 2025 in its resolution on 21st February 2019.

The National Forest Strategy aims to achieve the 2030 Agenda goals related to forests and now takes into account climate sustainability and safeguarding forest biodiversity more clearly than the previous forest strategies. The strategy sets the following strategic objectives:

1. Finland is a competitive operating environment for forest-based business.
2. Forest-based business and activities and their structures are renewed and diversified.
3. Forests are in active, economically, ecologically, socially and culturally sustainable and diverse use.

The strategy describes the priority areas and measures concerning forest sector development that the public sector will focus on as part of joint development work. The strategy is implemented through ten strategic projects, each aiming to specified targets. An entirely new project added to the strategy deals with climate-sustainable forestry. In addition to this, most of the projects in the strategy now take into consideration the diversification of forest management methods along with the safeguarding of biodiversity and protection of water resources.

As regards forests, the National Forest Strategy also supports the implementation of the Finnish Bioeconomy Strategy. Policies on forest issues are also laid down in other national strategies and programs like the Forest Biodiversity Programme for Southern Finland (METSO), Finland's National Energy and Climate Strategy 2030, Finland's National Biodiversity Strategy, and rural and regional policy strategies and programs.

The METSO programme is based on a Finnish government resolution that contains 14 main categories of measures to halt the ongoing decline in the biodiversity of forest habitats and species, and to ensure that a favourable trend in forest biodiversity will be established by 2025. The measures include actions to promote closer-to-nature forestry such as enhancing habitat management in commercially managed forests.

3. Current management practices promoting closer-to-nature management

3.1. Preserving valuable habitats and buffer zones

Preserving valuable habitats in managed forests is an essential part of biodiversity-oriented forest management in northern Europe. The woodland key habitat (WKH) concept is used in Finland and other Nordic and Baltic countries. The idea behind the concept is to conserve the biodiversity of production landscapes by preserving small habitat patches that are supposed to be particularly valuable for biodiversity (for a review, see Timonen et al. 2010). WKHs are usually small and deviate clearly from the surrounding forest based on edaphic, geomorphological or hydrological features. In addition, WKHs have generally been less intensively managed than the surrounding forest, which means that they have retained close-to-natural stand structure. The habitat types and criteria for delimiting WKHs vary to some extent among countries (Timonen et al. 2010). However, the basic premises are similar: 1) WKHs are assumed to be important for rare, habitat-specialist or red-listed species, 2) it is possible to identify such habitats based on their structural features or indicator species, and 3) setting aside these habitat patches from intensive forest management contributes to maintaining landscape-level biodiversity.

Preserving valuable habitats aims mainly at maintaining forest biodiversity. In addition to these habitats, untreated buffer zones are left along water bodies for water protection, i.e. to reduce erosion and nutrient emissions. Forest Act does not include statutory requirements concerning buffer zones.

Research results from Finland show that brook-side key habitats have more deciduous trees, less cut stumps, higher stand diversity and about twice as much dead wood as comparable managed forests on similar site types and belonging to the same age class (Siitonen et al. 2009). Key habitats hosted more polypore species and more specialists of deciduous trees than control stands (Hottola & Siitonen 2008). A systematic review on the biodiversity effects of WKHs based on Nordic studies (Finland, Norway and Sweden) indicated that WKHs are relative hotspots for dead wood volume, diversity of dead wood, number of species and number of red-listed species (Timonen et al. 2011). Together with nature reserves, WKHs can form a part of a functional reserve network. Modelling results indicate that WKHs enhance habitat connectivity, especially for species with an intermediate dispersal ability (Laita et al. 2010).

Legislation

In Finland, so-called habitats of special importance are defined in the Forest Act. To qualify as such, a habitat should belong to specific habitat types defined in the Forest Act, have natural or semi-natural stand structure, be clearly distinguishable from the surrounding forest and small in size or have little significance for forestry. Habitats of special importance are either set aside from management, or only cautious management and utilisation operations may be undertaken where the characteristic features of the habitats are preserved or reinforced. Cautious selective logging is allowed in most cases. Some additional valuable habitats are defined in Nature Conservation Act and Water Act.

The Forest Act defines seven especially important habitat types or habitat type categories. These include 1) the immediate surroundings of small water bodies, i.e. springs, brooks, rivulets

and small ponds; 2) undrained herb-rich and mesic hardwood-spruce swamps, undrained eutrophic fens and certain other mire types; 3) herb-rich forest patches; 4) heathland forest islets in undrained peatlands; 5) gorges and ravines; 6) steep bluffs; 7) unproductive sandy soils, exposed bedrock and boulder fields with sparse tree stand (Forest Act 1093/1996). The total number of Forest Act habitats is about 130,000 at present, with a total area of about 76,000 hectares according to the forest database upheld by the Finnish Forest Centre (Siitonen et al. 2021). The proportion of Forest Act habitats of the privately-owned forestry land is about 0.8% (Siitonen et al. 2020).

The Forest Act does not include statutory requirements concerning buffer zones along water bodies.

PEFC certification

The PEFC forest certification criteria include protection of the Forest Act habitats. In addition, the PEFC criteria define six other habitat types considered as ecologically valuable (PEFC Finland 2014). These include 1) kettle holes and treeless or sparsely treed sunny eskers, 2) undrained hardwood-spruce swamps, 3) broad-leaf dominated herb-rich forests, 4) old-growth forests, 5) undrained eutrophic fens and 6) alluvial forests and flood meadows in their natural state. More exact criteria for each of these habitat types are listed in the certification standards. For instance, old-growth forests should be at least 160 years old in southern Finland, with no cutting for the past 60 years, and the volume of dead wood should amount to 15% of the stand volume. The additional habitat types protected by certification criteria are very rare. Monitoring results show that PEFC habitats cover only about 0.03% of the privately-owned forestry land and about 1.5% of all valuable habitats (Siitonen et al. 2020).

PEFC criteria require that all forestry operations taking place close to watercourses and small water bodies shall safeguard water protection by leaving a buffer zone at least 5 to 10 meters wide. Tree harvesting on buffer zones is allowed, however, but shrub layer and small trees shall be preserved. Soil scarification, fertilization, stump removal, clearing of shrub vegetation and use of chemical pesticides or herbicides are forbidden on buffer zones.

Forest management guidelines

The FMG recommend that both the Forest Act habitats and the PEFC habitats should be generally excluded from forest management operations. The guidelines also recommend that habitats which belong to the habitat types defined in the Forest Act, but which do not quite fulfil the requirements of natural or semi-natural stand structure and small size, should be only cautiously managed or excluded from management. Moreover, the guidelines list several other habitat types that should be set aside or taken into consideration by cautious management. These include paludified depressions in heathland forest, shores of rivers and lakes and ecotones between heathland forests and mires. These so-called other notable habitats cover about 1.6% of the privately-owned forestry land (Siitonen et al. 2020).

In total, the different categories of valuable habitats (with their status based on Forest Act, PEFC criteria or FMG) cover about 2.5% of the forestry land (Siitonen et al. 2020). Based on monitoring results, almost 90% of valuable habitats that were located within regeneration cutting areas had remained in their original state in forestry operations (Siitonen et al. 2020).

3.2. Even-aged forest management

3.2.1. Final felling and regeneration

Leaving living and dead retention trees in final felling is another important measure of biodiversity-oriented forest management in northern Europe. The concept of green tree retention refers to management in which mature living trees are intentionally left on regeneration cutting areas to maintain ecological processes and to enhance biodiversity. The aim is that the retention trees will grow old and eventually die and thus provide important structural features in the stand throughout the rotation period. Tree retention can also include leaving existing dead wood and creating high stumps in the harvesting. A more general concept is variable retention, in which a certain proportion of the stand (usually 5 to 50%) is left unharvested, as aggregated or dispersed retention, in each logging pass. In Finland, retention of living and dead trees in cutting operations has been systematically practiced since 1994 due to the renewed management guidelines, and since 1999 due to forest certification criteria. According to monitoring results, the average number of living retention trees in regeneration areas has been 10 trees per hectare and the average volume about 3 m^3/ha, which is 1–2% of the stand volume (Kuuluvainen et al. 2019, Siitonen et al. 2020).

A review of tree retention based on studies conducted in the Nordic countries found about 50 peer-reviewed publications about its biodiversity effects (Gustafsson et al. 2010). Most studies were directed towards beetles and dead wood, especially high stumps. General conclusions were that retention trees provide some of the substrate types required by early successional species and alleviate the most serious consequences of clear-cutting on biota. However, single retention trees or small groups cannot maintain characteristics of intact mature forests.

A recent review (Koivula &Vanha-Majamaa 2020) scrutinized the results of Nordic long-term experimental studies in which the effects of variable retention harvest, artificial creation of dead wood and prescribed burning on different taxa have been studied. According to these results, many species respond positively to felling due to released ephemeral resources. The initial effects of prescribed burning are negative (apart from fire-dependent species), but within 10–15 years post-fire sites begin to support many rare and threatened deadwood-dependent species. Artificial addition of dead wood supports a wide spectrum of deadwood-dependent species. Epiphytic lichens, however, remain negatively affected of these measures.

Legislation

According to the Forest Act, "*final felling means wood harvesting where the treatment area is felled to result in an open area except for the retention, seed or shelter trees left, where necessary, to produce a new tree stand*."

The Forest Act recognizes regeneration by cultivation or by natural regeneration. The Forest Act defines that "*cultivation means forest regeneration by planting seedlings suitable to the site or sowing seed suitable to the site"* and that "*natural regeneration means forest regeneration by means of seed or shelter trees in the treatment area or by utilising seed-producing margin forest.*" The Forest Act also lists the tree species to be used in forest regeneration: Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* [L.] Karst.), silver birch (*Betula pendula* Roth .), European aspen (*Populus tremula* L.) , Siberian larch (*Larix sibirica* Lebed.), Norway maple (*Acer platanoides* L.), common alder (*Alnus incana* [L.] Moench), pedunculate oak (*Quercus robur* L.), European white elm (*Ulmus laevis* Pall.), Scotch elm (*Ulmus glabra* Mill.), littleleaf linden (*Tilia cordata* Mill.), European ash (*Fraxinus excelsior* L.) and hybrid aspen (*Populus* × *wettsteinii*)

suitable as regards their origin and the site. Downy birch (*Betula pubescens* Ehrh.) may be used only in peatland, paludified sections of mineral soils and compact soils dominated by clay or silt. In other sites downy birch may be used as a supplementary tree species depending on soil fertility and the geographical location of the regeneration site.

The Forest Act promotes strongly the use of natural domestic tree species in regeneration as part of the closer-to-nature forest management. If other tree species than those listed are used, the Forest Act demand that a sufficient account shall be given in the forest use declaration on their usability for being grown and suitability of their origin with regard to the conditions in the area to be regenerated. The Act on Trade in Forest Reproductive Material controls the production, marketing and import of forest reproductive material (seeds, seedling) and lists the requirements for the material and thus promotes the use of local domestic origins.

PEFC certification

Regarding final felling, the PEFC certification criteria (PEFC Finland 2014) include requirements on protecting specified valuable habitats and leaving of retention trees.

According to PEFC criteria, all forest management operations should be planned and implemented so that typical features of the specified valuable habitats are preserved (criterion 10, see Chapter 2.1 for more details). Similarly, the known habitats of endangered species shall be safeguarded (criterion 12).

In the PEFC standard, the retention-tree criterion obliges that retention trees and decaying tree stems are left in forestry operations. Specifically, the criterion states that "*retention trees and large dead trees with decaying stems shall be permanently left on site in intermediate felling and clear-cuts to safeguard the biodiversity of forest nature*". Retention trees are living trees of native tree species of preferably the following types: nest trees of birds of prey; large junipers; old trees with fire scars; larger trees from previous tree generation; trees with unusual form; broad-leaved trees; large aspens; treelike goat willows, bird cherries and rowans; black alders; cavity trees. Decaying tree stems are defined as dead standing, broken or fallen trunks with the diameter (at breast height) over 20 cm.

Additionally, the criterion states that if above mentioned retention trees and large dead trees with decaying stems are not found on site, retention trees may include living trees that exceed 10 cm in diameter at breast height and have a good potential to develop into old trees.

In forest regeneration, native tree species to Finland shall be used, except in special cases. In the criteria, Siberian larch is included among Finnish native tree species. Special cases include parks and urban forests and growing of Christmas trees and conifer branches for decorative purposes. In addition, cultivation of hybrid aspen is allowed.

When operating near water bodies (including lakes, small rivers, ponds) and near open peatland areas in natural condition, buffer zones are retained. Inside these buffer zones, there should be no soil scarification, fertilization, stump removal, clearing of shrub layer vegetation or use of chemical pesticides or herbisides.

In addition, PEFC certification includes recommendation to promote prescribed burning to safeguard biodiversity of forest fire-dependent habitat types and species. The burning can take place on sunny eskers, regeneration sites and retention tree groups. The recommendation to use prescribed burning is based on the known positive impacts on biodiversity, on the fire-dependent habitat types (e.g. sun-exposed eskers) and species (Lindberg et al. 2020). The area

treated with prescribed burning has continuously decreased (Korhonen et al. 2016; Lindberg et al. 2020). According to the present PEFC standard, it is sufficient to carry out 1 burning per year per 200,000 hectares of certified forest holding (i.e. 90 fires in the whole certified area of 18 million hectares) without any area requirements.

Forest Management Guidelines

The FMG include the following recommendations for final felling and regeneration activities (soil preparation, selection of the regeneration method and tree species) that aim at promoting closer-to-nature forest management.

- Regeneration areas should be delimited following natural boundaries of the site types and terrain.
- Groups of retention trees, high stumps, decaying living trees, dead trees and thickets should be left in felling. Multi-species retention trees and understorey groups increase diversity, are important habitats for many species and form decaying wood in time.
- Harvesting at the transition zones between forests and peatlands or other open areas is possible, but the those features that are valuable for the game, biodiversity and landscape should be preserved.
- In final felling and soil preparation, the following areas should be excluded: valuable habitats, buffer zones near water bodies, buffer zones around retention trees. Breaking of decaying trees should be avoided. The buffer zone width around retention trees should be at least two meters. The buffer zone width along water bodies can vary depending on the natural variation in terrain and vegetation but should be at least five meters. Wider zones are used on clay and silt soils and on large watershed areas.
- In soil preparation, as light as possible methods, suitable for given sites, should be used. Only part of ground layer area should be treated with soil preparation.
- In regeneration, native tree species suitable for given sites must be used, aiming at productive, healthy and fully stocked forest stands. Scots pine is recommended for infertile sites and spruce and birch for fertile sites. Broadleaved admixture is preferred in all sites except the most barren ones.

3.2.2. Juvenile stand management

Legislation

In the Forest Act, there are no special requirements concerning juvenile stand management with respect to closer-to-nature forest management except for the general requirement that after thinning the remaining growing stock must be vital.

PEFC certification

PEFC does not have criteria related to biodiversity management in juvenile stands.

Forest Management Guidelines

For juvenile stand management (including early cleaning and pre-commercial thinning), the FMG include the following elements that aim at promoting closer-to-nature forest management.

- Management operations should be implemented so that the retention trees, including the seedlings and shrubs under the retention trees are not cleared or felled. Buffer zones alongside water bodies should be left unmanaged. Understorey groups (thickets) should be left on rocky outcrops, wetland sites, or other suitable sites for serving biodiversity, proliferation of game and scenic values.
- Monocultures should be avoided. Up to 20% mixture of broadleaved trees is recommended for juvenile coniferous stands. Stand density of growing stock and proportion of broadleaves should be higher near water bodies.
- To increase natural diversity of tree species, none of the tree species existing in the seedling stands should be completely removed. Junipers (*Juniperus communis* L.), goat willows (*Salix caprea* L.), hazels (*Corylus avellana* L.) and rowan (*Sorbus aucuparia* L.), and those temperate deciduous tree species (linden, oak, ash, elms and maple), that are rare in Finland, should not be removed if they do not harm the development of crop seedlings.

3.2.3. Thinnings

Legislation

In the Forest Act, there are no special requirements concerning thinning in relation to closer-to-nature forest management except for the general demand of a vital stand left after thinning. The Forest Act states that "*Thinning shall be done such a way that after the thinning a sufficient and evenly distributed stand with growth potential is left in the treatment area*." Matters to be taken into account in assessing this include the geographical location, site, method of thinning and stand density and height. These minimum requirements for the stand after treatment are listed in detail in the Forest Decree on sustainable forest management and use. According to the Forest Act, if the stand is too sparse after thinning, forest regeneration obligation comes into force.

PEFC certification

In the present PEFC standard, the retention-tree criterion is titled "*Retention trees and decaying tree stems shall be left on site in forestry operations*", and it states that retention trees and large dead trees with decaying stems shall be permanently left on site in thinning and clearcutting to safeguard the biodiversity of forest nature. For details, see above (3.2.1 Final felling and regeneration). Decaying stems are defined as dead standing, broken or fallen trunks with the diameter (at breast height) over 20 cm.

Forest Management guidelines

The FMG include the following elements to be considered in commercial thinning (intermediate felling) that aim at promoting closer-to-nature forest management.

- Retention trees, cavity trees and large dead trees should be left untouched. Dying and wind-thrown trees should not be harvested if they do not risk the health of the

surrounding forest. However, for recently dead spruces, the amounts exceeding 10 m^3/ha shall be removed before mid-July (to avoid *Ips typographus* damage) and for recently dead pines, the amounts exceeding 20 m^3/ha shall be removed before the beginning of July (to avoid *Tomicus piniperda* and *T. minor* damage).
- Adequate tree species mixture should be maintained. It is recommended to open growth space for tree individuals valuable for nature and game management, such as temperate deciduous tree species, aspens, goat willows, birches, alder groups and pines that are capercaillie feeding trees.
- Buffer zones along water courses and open mires should be managed only cautiously.
- To leave protection for the game species and to generate decaying wood during the whole rotation, thickets (uncleared patches containing trees in various sizes) should be left in thinning, and dead wood should be produced by creating high stumps (artificial snags).

3.3. Uneven-aged forest management

Legislation

In the Forest Act, there are no special requirements concerning the uneven-aged management with respect to closer-to-nature forest management except for the general demand of a vital stand left after cutting. The Forest Act states that "*Intermediate felling shall be done such a way that after the intermediate felling a sufficient and evenly distributed stand with growth potential is left in the treatment area.*". These minimum requirements for the stand properties after treatment are listed in detail in the Forest Decree on sustainable forest management and use. According to the Forest Act, if the stand is too sparse after cutting forest regeneration obligation comes into force.

PEFC certification

No specific requirements are stated in the PEFC criteria, other than those described for even-aged stand management practices.

Forest Management Guidelines

The same principles in nature management should be considered in uneven-aged forest management as in even-aged forest management: valuable habitats should be excluded from fellings, retention trees and thickets should be left and tree species admixture should be favoured.

The following positive effects on biodiversity are specially targeted at uneven-aged forest management:

- Continuous preservation of forest cover benefits fauna and flora that thrive in shade or semi-shade, as well as species with poor dispersal ability, the movement of which may be hindered by clear cuttings. On the other hand, small openings created in selection and gap felling benefits species that prefer semi-shaded or semi-open conditions.
- The buffer zones of water bodies and transition zones between peatlands and mineral soils are in many cases suitable sites for uneven-aged forest management.

3.4. Energy wood harvesting

Legislation

Most of the wood fuels in Finland come as by-product of wood processing, such as bark and dust from sawmilling industry, waste liquors from pulp industry, and cutting residues not suitable for forest industry from thinning and clear felling. In the Forest Act, energy wood harvesting is not mentioned at all. Temporary Act of the Financing of Sustainable Forestry (34/2015) grants aid "*for the clearing and thinning of a seedling stand and the removal and thinning of nurse crop*" meaning also small-diameter trees for energy use.

PEFC certification

Criterion 7 states that "*Sustainable methods shall be used in energy wood harvesting*". When removing cutting residues and stumps from harvested sites, the applied methods shall take into consideration the wood production capacity of the site, its biodiversity as well as the aspects related to water protection.

The contents of the criterion are as follows regarding safeguarding biodiversity:

- If possible, harvesting of energy wood during intermediate felling should protect thickets for game.
- Peatlands in their natural state shall not be transferred into energy wood cultivations.
- After final felling a certain amount of biomass should be left on these areas: around 30% of canopy mass as evenly as possible, at least 25 stumps/ha, and on clay and silt soils at least 50 stumps/ha, and in addition, stumps left in previous fellings and stumps which are less than 15 cm in diameter should be retained. However, all coniferous stumps can be extracted from areas that are infected with the *Heterobasidion* root rot.
- Living retention trees determined in the criterion 14 shall not be harvested and large-diameter decaying wood (dead trees) shall not be damaged.

Forest Management Guidelines

The FMG include the following elements for energy wood harvesting that aim at promoting closer-to-nature forest management.

- Similar to the PEFC criteria, to maintain biodiversity and soil productivity, at least 25 stumps of different tree species per hectare should be left in stump harvesting, on clay and silt soils at least 50 stumps/ha. All old stumps, left in previous fellings, and stumps less than 15 cm in diameter should be left. However, it is recommended to remove coniferous tree stumps from the root-rot contaminated harvesting areas that are infected with the *Heterobasidion* root rot.
- It is recommended not to harvest stumps at the buffer zones of water bodies, at ditch banks or places where harvesting may damage natural or cultural heritage sites, retention trees or other special sites.
- The existing dead trees are retained undamaged in all cuttings, including harvesting of energy wood.

3.5. Sanitary cuttings

Legislation

Forest Damages Prevention Act´s (1087/2013) scope is "*to maintain a good health status of forests and prevent forest damages*", and it requires to remove amounts exceeding 10 m^3/ha (spruce) or 20 m^3/ha (pine) of such damaged coniferous trees that may cause spreading of damaging insects. In addition to the Forest Damages Prevention Act, the provisions of the Plant Health Act (1110/2019) and EU regulation on protective measures against pests of plants (EU 2016/2031) list measures targeting prevention and elimination of infestation of cultivated and wild plants. These management activities promote good forest health in closer-to-nature forest management.

PEFC certification

The PEFC certification criteria on protecting decaying stems (large diameter dead trees) (see sub-chapter 3.3.1) indirectly relates to sanitary cuttings in such a way that dead trees must be removed only if they cause a risk of spreading damaging insects.

Forest Management guidelines

Similar to the PEFC criteria, the FMG recommendation to protect large diameter dead trees in cuttings indirectly relates to sanitary cuttings in such a way that dead trees should be removed only if they cause a risk of spreading damaging insects.

4. Discussion

In forestry and ecological literature, the concept of close-to-nature forest management is widely used, however, often without a clear definition of the concept (Duncker et al. 2012, Bauhus et al. 2013, Gustafsson et al. 2013). Bauhus et al. (2013) concludes that close-to-nature forest management *"cannot be regarded as an approach with a single commonly agreed definition and a well-defined, established scientific basis"*. The EU Biodiversity strategy uses the concept closer-to-nature forests management. We assume that this selection of terminology is intentional and, in any case, the selected wording emphasizes that the EU Commission is not proposing one single approach for forest management for the largely diverse forest types of Europe.

Our review of the Finnish forest strategy and legislation, forest certification criteria and forest management guidelines show that closer-to-nature management practices are widely recognised in Finnish forestry. These practices include 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 (i.e. both even-aged and uneven-aged forestry), and the use of prescribed burning. Many of these practices supporting closer-to-nature forest management were introduced in 1990s. The study of Korhonen et al. (2020) indicates that several biodiversity indicators show positive development in Finland between 1980s and 2015: the area of protected forests, amount of retention trees, number of large trees, especially large aspens, and in southern Finland, also the amount of dead wood. The study of Korhonen et al. (2020) does not prove causal relationships, but it is probable that the closer-to-nature forest management approaches introduced in forest management are at least partly explaining this positive development.

However, the study of Siitonen et. al (2020) indicates that the mainstreaming of these practices has not fully succeeded. For example, the amount and quality of retention trees have decreased in recent years (Korhonen et al. 2016, Kuuluvainen et al. 2019, Siitonen et al. 2020) and there has been a strong decline in prescribed burnings (Korhonen et al. 2016, 2020, Lindberg et al. 2020) due to increased costs and safety reasons (Lindberg et al. 2018). In both Finnish and more generally Fennoscandian forest management practices, the ecologically most important and most effective measures to support forest biodiversity include setting aside valuable woodland key habitats (including buffer zones along water courses), the retention of old, large-diameter living trees, the retention of dead trees, and the use of prescribed burning to maintain fire-affected habitats and to support fire-dependent biota (e.g. Korhonen et al. 2016, Keto-Tokoi 2018, Gustafsson et al. 2020). These measures form the basis of closer-to-nature forest management practices in Finland and other Fennoscandian countries. We showed how the existence and requirements of these individual closer-to-nature management measures varies among the instruments (legislation, PEFC certification and forest management guidelines). Generally, forest legislation set the least demanding requirements. In forest management guidelines, such practices were widely presented but usually without numerical requirements (e.g. minimum levels), which were strictly set only in the forest certification criteria.

There are various societal demands related to the management and protection of forests, expressed e.g. in the EU level strategies. The future will show how the closer-to-nature forest management methods that are expressed at the different levels of forest management guidance will develop when these demands enter to the practical implementation phase.

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