Report 2023/16 – English translation of the summary and sections of the report concerning closer-to-nature forest management.

Conditions for continuous cover forestry and definition of closer-to-nature forest management in Sweden

Government assignment

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Preface

With this report, the Swedish Forest Agency and the Swedish Environmental Protection Agency jointly present the joint assignment to develop the conditions for continuous cover forestry and to produce a proposal for a definition of closer-to-nature forest management. The assignment is one of several government assignments about forests carried out by the authorities in 2023.

For a long time and from several perspectives, forests have been of great importance to us humans. However, Sweden's forests and Swedish forestry are facing major challenges and the need for changes and adaptations is increasing. Forestry applying a variety of different silvicultural methods can contribute to variation and thus increased goal fulfilment for both forest owners and society. It can strengthen the role of forests in sustainable development, where economic, ecological and social aspects are taken into account.

In dialogue with stakeholders in the forestry sector, we have analysed the obstacles that exist for application of continuous cover forestry methods. We present a number of suggestions that we believe can reduce these obstacles and thus develop the conditions for continuous cover forestry. We also report on available knowledge about continuous cover forestry methods and about business models based on continuous cover forestry.

The proposed definition of closer-to-nature forestry is based on the balanced objectives for production and environment and the European Commission's guidelines for closer-to-nature forestry. Our hope is that the definition will provide support for both large and small forest owners, regardless of their starting point.

The authorities would like to thank everyone who has contributed with their knowledge and commitment to the work. Special thanks to the Swedish University of Agricultural Sciences, which has contributed its knowledge and experience in the subject.

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Summary

In 2022, the Swedish Forest Agency and the Swedish Environmental Protection Agency were given the joint government assignment to investigate the conditions and possible obstacles to continuous cover forestry and to formulate a proposal for a definition of closer-to-nature forest management for Swedish conditions. In addition, the assignment included compiling knowledge about continuous cover forestry methods and making a knowledge compilation of innovation work and business models with regard to continuous cover forestry. The assignment is based on the Forest Inquiry's (SOU 2020:73) proposals and the Government's forest proposition (Proposition 2021/22:58).

Work on the government assignment has been carried out in three stages: knowledge acquisition, analysis and preparation of proposals. The knowledge gathering has been done through literature studies, consultations and dialogues with relevant stakeholders and experts, workshops with researchers from SLU, international conferences and contacts, interviews with forestry actors with a focus on business models and coordination with other government assignments underway at the authorities.

Based on this, we have analysed obstacles and assessed opportunities for development of continuous cover forestry methods using a socio-economic approach. We have also developed a proposal of a definition of closer-to-nature forest management in a Swedish context.

Continuous cover forestry

Our analysis showed that there are several different obstacles to the development of continuous cover forestry. Traditions, norms, attitudes and expectations of profitability can constitute obstacles for forest owners to manage their forests with continuous cover forestry. A further obstacle is that the state of knowledge of the various continuous cover forestry methods varies, and for several methods there is a lack of knowledge concerning regeneration, stand development and effects on environmental values. Forest owners also experience difficulties in obtaining information about continuous cover forestry methods. An additional identified obstacle was a poorly developed market structure for specialised timber assortments. Many forest values are not market-priced and forest owners lack incentives to invest in values that do not provide direct income. Based on the obstacle analysis, we therefore come to the following conclusions:

- The state needs to provide guidance to bring about a general increase in continuous cover forestry. With such a general increase, the authorities believe that it is possible to overcome several of the obstacles.

- The state also needs to provide guidance to increase continuous cover forestry in areas where it is of particular importance for society.

Based on the analyses and conclusions, we make the following proposals for the development of continuous cover forestry:

Proposal 1: The state acts as a pioneer in continuous cover forestry.

The authorities propose that it should be included in the governance of Sveaskog and the National Property Board (SFV) and that they should gradually increase their application of continuous cover forestry, so that these methods gradually will make up a not insignificant part of the land used for forestry, e.g. 20-25 per cent.

Proposal 2: Develop training and offer a skills development cheque to entrepreneurs.

The authorities propose that the government offers a temporary financial contribution, a 'skills development cheque', to individual forestry contractors to develop their skills in continuous cover forestry. It will be possible to apply for the skills development cheque for a limited period of time. It is proposed that the Swedish Forest Agency should be commissioned to develop, in collaboration with other actors, a course package and course material for continuous cover forestry that different educators can use freely. The aim is to ensure that there is good education material and suitable education sites in the field.

Proposal 3: Focused funding of applied research in forest management, forest technology and forest planning.

The authorities propose that the government, via state research funding bodies, announce funding for research in forest management, forest technology and forest planning with a focus on improving the conditions for the application of continuous cover forestry methods.

Proposal 4: Investigate how economic incentives and business models can develop continuous cover forestry.

The authorities propose that the Swedish Forest Agency, in collaboration with other relevant authorities including universities, should be commissioned to investigate how economic incentives and business models can contribute to the development of continuous cover forestry and increased delivery of important social values in the forest.

Proposal 5: Develop targeted advice to forest owners and design a better knowledge base for continuity forests.

The authorities propose that:

A. The Swedish Forest Agency is given the task to carry out targeted outreach consultancy to forest owners who have continuity forests that are suitable for continuous cover forestry.

B. The Swedish Forest Agency is commissioned to provide a better knowledge base regarding the existence of continuity forests. This primarily involves adaptations of the digital geographical data proposed by the government assignment to develop digital knowledge data on the

nature and cultural environment values of forests[1]. This knowledge base would be able to identify continuity forests with greater precision than at present.

In addition to the proposals submitted to the Government, the Swedish Forestry Agency undertakes to investigate whether there is legal support for prescribing continuous cover forestry methods in transition zones that reinforce other values, and the application of the paragraph 18b of the Forestry Act when assessing permits for final felling in mountainous areas.

In this report, the authorities also present available knowledge about the continuous cover forestry methods and about innovation work and business models linked to continuous cover forestry, see Chapter 3.

Closer-to-nature forest management

The Swedish Forest Agency and the Swedish Environmental Protection Agency have carried out an analysis based on the European Commission's guidelines for closer-to-nature forest management and available knowledge linked to closer-to-nature forest management. Based on the analysis, we present a proposal for a definition of closer-to-nature forest management for Swedish conditions where the equal objectives for production and the environment in the Forestry Act have been considered. The proposed definition applies to the whole of Sweden, with an emphasis on the boreal region, which occupies the largest areal extent of the biogeographic regions in Sweden. Closer-to-nature forest management is based on voluntariness and allows for flexibility in terms of management methods and approaches to management. The future certification for closer-to-nature forest management developed by the European Commission will likely provide a framework for how closer-to-nature forestry is to be implemented in Sweden.

The Swedish Environmental Protection Agency and the Swedish Forest Agency propose the following definition:

Closer-to-nature forestry mimics natural disturbance processes, creates diverse forests and strengthens the environmental values of the forest landscape. Management is based on a landscape perspective and includes adapted even-aged retention forestry, continuous cover forestry and certain historical forms of forest management.

The aim of closer-to-nature forest management is to strengthen the role of forests in sustainable development. Biomass extraction from forests should be done in a way that is gentle on nature. Forestry should mainly mimic a combination of small and medium-sized natural disturbances caused by fire, grazing, insect outbreaks, fungal attacks, wind and hydrological disturbance. Small- and medium-scale disturbances include gap and cohort dynamics, that is repeated disturbances that create distinct cohorts of trees. Large-scale disturbance includes stand-replacing disturbance. The forest history must be considered when choosing forest management method.

[1] Swedish Forest Agency and Swedish Environmental Protection Agency. 2023a.

The goal is to conduct an economically profitable forestry that (1) ensures a long-term supply of products and services from the forest, (2) increases the variation in the landscape with a greater proportion of mixed forests and multi-aged forests, (3) preserves and strengthens biodiversity in the forest landscape and (4) increases the resilience of forests (ability to maintain basic functions in the event of disturbances or changes) against damage and climate change.

The Swedish Forest Agency and the Swedish Environmental Protection Agency concretise the definition in ten key measures based on the European Commission's guidelines, adapted for a Swedish context. A selection is presented below. For the key measures, we present *directions (increase or decrease)* towards closer-to-nature forest management and, where the evidence is deemed sufficient, we specify numerical levels or targets.

Ensure gentle harvesting. Reduce the size of the harvest area (clear-cut), a maximum of two hectares in Götaland (southern Sweden) and a maximum of four hectares in other parts of Sweden. Increased environmental consideration, at least 20 per cent of the area is left as retention in adapted even-aged retention forestry. Increased consideration for the biological cultural heritage in forestry measures. In adapted even-aged retention forestry, an average edge zone of at least 15 metres on each side of the watercourse must be left over the harvest area. No more than 15 per cent of the watercourse may lack edge zone. Transitional habitats should be rich in leaves and flowering shrubs and at least ten metres wide.

Landscape planning. The proportion of multi-aged forest stands (containing trees of different sizes and ages) in the landscape shall be at least two-thirds of the landscape by 2050. Connectivity (the ability of animals, plants and organic matter to move and disperse in nature) and the landscape's green infrastructure with ecologically functional networks of habitats will be improved through adapted forest management plans or other landscape-based planning.

Promote natural regeneration. Increasing the proportion of naturally regenerated forest areas through the use of seed trees, gap felling and selective cutting. Inclusion of at least 30 per cent naturally regenerated trees in planted or seeded stands. Increasing the mix of tree species and the proportion of deciduous trees in stand regeneration and other forestry measures. Alien tree species can be used in some cases to strengthen the forest's climate adaptation. No or gentle soil preparation.

Adaptation to reindeer husbandry. Increase adaptation to the needs of reindeer husbandry by maintaining and increasing connectivity between lichen-rich forests and adjusting the consideration and choice of forestry practices. Apply gentle intermittent (patchy) or targeted soil scarification in lichen-rich areas and avoid soil scarification in lichen-rich areas altogether. No regeneration with lodgepole pine in reindeer herding areas.

Formal and voluntary set-asides are not included in the definition but should be seen as an important complement to closer-to-nature forestry.

A possible change of the Swedish term *naturnära skogsbruk* has been analysed as the term has raised questions since the Swedish translation does not distinguish

between the two different concepts of *closer-to-nature forest management* and *close-to-nature forest management*. The authorities' assessment is that the name *naturnära skogsbruk* should be retained at present. It is established and easy to understand and the link to *closer-to-nature forest management* is relatively strong. A change of term can of course be discussed in a continued process.

This translation of the report from Swedish to English focus on the proposed Swedish definition of *Closer-to-nature forest management*. Sections concerning conditions and possible obstacles to continuous cover forestry have not been translated.

1 Introduction to closer-to-nature forest management

The concept of near-natural forestry is not new. As early as the second half of the 19th century, Germany described *naturnahe Waldwirtschaft,* which was then further developed by Alfred Möller and others into the term *Dauerwald*[2], which can be roughly translated as perpetual or continuous forest. In modern times, the concept has been developed by the Pro Silva organisation, which uses the concept of *close-to-nature forest management*. Pro Silva has developed principles for close-to-nature forest management based on the natural processes of the forest ecosystem and a broad approach to sustainability[3]. Also, pre-industrial human disturbance such as forest grazing can resemble natural processes, which continue in some cases in the same form today and can affect entire forest ecosystems and their functions[4]. Different variants of historical management that have created a variation between forest and open land, with high biodiversity at the landscape level have been used in continental, boreal and even alpine regions.

Different forms of close-to-nature forest management exist in different countries, such as Canada, Germany, Finland, Slovenia and Sweden. What they have in common is that they are based on perceptions of forestry based on natural disturbance regimes (Figure 1) and historical impacts on forest ecosystems. The different forms go by different names in different parts of the world[5] .

In Québec, Canada, diversified forestry is practised where both continuous cover forestry methods and clear-cuts are allowed but completely open and bare clear-cuts should be avoided. On the clear-cuts, major soil disturbance should be avoided, existing small trees that were suppressed prior to harvest are favoured and natural regeneration is encouraged. These clearcuts are intended to mimic a natural fire, insect outbreak or storm. One difference between Canada and Sweden is that there are generally higher percentages of natural forests that have not been managed significantly in the Canadian forest landscape compared to the boreal region of Sweden (note, however, that in the mountainous forest in the alpine region of Sweden there are large areas that are less affected and more similar to natural forests). These conditions can affect the planning of forestry at landscape level in Sweden. In Sweden, a close-to-nature project is under way in Tiveden, which is based on ideas from Canada and elsewhere[6]. One of the basic premises is that forests should become more resilient in a warmer climate through adapted management.

The Finnish approach is based on an ambition to use management to imitate natural disturbance in the boreal forest in the form of a combination of fire, insect

[2] Troup 1927.
[3] Pro Silva 1999.
[4] Josefsson 2009.
[5] Puettman et al. 2015.
[6] Messier et al. 2013.

outbreaks, fungal infestation and wind [7] based on the so-called "multicohort model" (Figure 1).

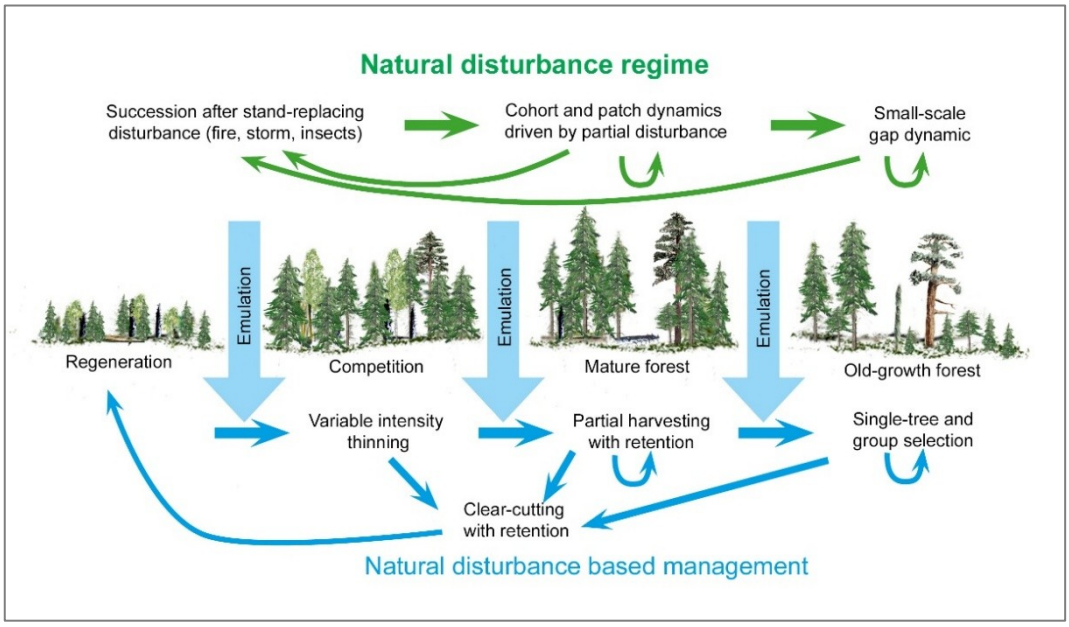


Figure 1. Adapted forest management in northern Europe based on the so-called 'multi-cohort model'. The figure illustrates four different structural cohorts from left to right with forest re-establishment in different steps, successional stages after a stand-replacing disturbance. An understanding of the natural disturbance regimes is needed to apply closer-to-nature forest management. In a reference landscape there are different proportions of the different successional stages. Modified from[8] inspired by[9, 10]. Illustration: Bo Persson.

Several environmental organisations have developed principles for close-to-nature forestry. They require that forest management should mimic the natural disturbance dynamics of the forest, that the ecosystem's natural functions, structural diversity and tree species composition are preserved and recreated, and that a landscape perspective is applied. Natural disturbances are complex and dynamic in time and space, creating variation at the landscape level. *Close-to-nature forest* management[11,12] and the relatively new concept of *closer-to-nature* management[13] are influenced by the idea of taking into account and imitating natural processes in management.

1.1 EU and closer-to-nature forest management

1.1.1 EU Biodiversity Strategy and EU Forest Strategy

The EU Biodiversity Strategy for 2030[14] presented by the European Commission in 2020 states that biodiversity-friendly practices such as closer-to-nature forest management should continue to be applied and further developed. The EU

[7] Kuuluvainen et al. 2017.
[8] Larsen et al. 2022.
[9] Kuuluvainen et al. 2017.
[10] Kuuluvainen et al. 2021.
[11] Jacobsen. 2001.
[12] Larsen, J.B. 2012.
[13] Larsen et al. 2022.
[14] European commission. 2020.

Forestry Strategy presented by the Commission in 2021[15] identified forestry practices such as closer-to-nature forest management as a key to solving the two crises of climate change and biodiversity loss.

The Forestry Strategy states that the Commission will *Develop a definition and adopt guidelines for closer-to-nature-forestry practices, by Q2 2022, as well as voluntary closer-to-nature forest management certification scheme, by Q1 2023*. The guidelines for closer-to-nature forestry were published in 2023[16] . However, no definition has been produced as part of this work. Nor has work on certification systems started yet.

The forest strategy describes that closer-to-nature forest management *seeks multifunctional forests by combining biodiversity (even in planted forests), carbon stock preservation and timber-related revenues.*

1.1.2 Taxonomy Regulation

In 2022, an EU grouping produced an input report to the EU taxonomy regulation[17] to complement the recommendations published by the Platform on Sustainable Finance[18] **.** However, it is not an official Commission document or Commission position.

The report proposes a categorisation of three broad categories ('forestry practices') to make it manageable to set and use different criteria. One of the forestry practices is *close-to-nature managed forests*. This can be compared to the Forest Strategy which uses the concept of *closer-to-nature forestry practices*.

The categories are linked to harvesting intensity and forest management, using a number of indicators such as species representation, age classes, harvesting intensity and the number of retained trees, retained dead wood, use of fertilisers, pesticides and drainage. *Close-to-nature managed forests* are described as managed forests that are only naturally regenerated (except in situations where this is not possible) with native trees and that have structural and functional characteristics resembling those of natural forests (e.g. natural forest disturbance regimes, species diversity, uneven age class and age distribution, tree continuity, dead wood and cultural heritage)[19] .

However, some members of the European Commission's expert group on sustainable finance did not support the criteria and wrote an alternative proposal which is annexed to the report. So far, the Commission has not included forestry, agriculture and fisheries and at the time of writing there is no information on the eventual process for completing these sectors.

1.1.3 Nature restoration law

The EU Council Presidency and representatives of the European Parliament reached a provisional political agreement on a regulation on nature restoration in

[15] European commission. 2021.
[16] European commission. 2023a.
[17] European Union. 2020
[18] Platform on sustainable finance: Technical working group. 2022.
[19] Larsen. 2012.

November 2023. The proposal involves restoration measures for at least 20% of the EU's land and sea areas by 2030, and for all ecosystems in need of restoration by 2050. The proposal sets specific legally binding targets and obligations for nature restoration in each of the listed ecosystems, from agricultural land and forests to marine, freshwater and urban ecosystems. The provisional agreement must be approved and formally adopted by the co-legislators before it enters into force. As a result, the proposal for the nature restoration law and its possible links to closer-to-nature forest management are only briefly discussed here.

For several of our forest habitat types listed in Annex 1 of the Habitats Directive[20] , the agreed restoration law sets requirements in terms of restoration measures pertaining to habitat area and quality. Swedish guidelines for the forest habitat types describe quality criteria and important structures and functions (see for example[21] for the forest habitat type 9010 western taiga). These guidelines provide information that can be used in the restoration of areas that do not currently fulfil the requirements for habitat status, in accordance with Article 4 of the proposed restoration law. They also describe forest habitat types in the production forest landscape that currently have habitat status and must not deteriorate according to Article 4 on non-deterioration. Normally, no or very few forestry measures are permitted in a forest habitat type if it is to maintain its habitat status according to Sweden's habitat type definitions. This also applies to closer-to-nature forest management. On the other hand, closer-to-nature forestry in the production forest landscape can be linked to the indicator in the restoration law to increase the proportion of uneven-aged forest.

1.1.4 Report by the European forest institute

In 2022, the *European Forest Institute* (EFI) published a report on *closer-to-nature forest management* that provides a scientific basis for the concept and defines it through seven underpinning principles (Figure 2). The report analyses the current situation, obstacles and conditions for the implementation of closer-to-nature forest management in the EU[22].

The EFI report highlights the importance of how the different forest disturbance regimes provide guidance on different management strategies. In the report, the researchers describe how they perceive the difference between *closer-to-nature forest management* and *close-to-nature forest management. Closer-to-nature forest management* is a management model that describes the ways in which it is possible to approach the natural disturbance dynamics. There are no fixed objectives, but rather a direction towards closer-to-nature forest management from different starting points, economic conditions, different types of forests and so on.

An important starting point is that closer-to-nature forestry should provide a direction towards forest management that improves the natural values of forests and their resilience to climate change[23] . Among other things, this could mean a move towards more integrated forestry[24] compared with current forestry, which

[20] Swedish Environmental Protection Agency. 2020.
[21] Swedish Environmental Protection Agency. 2011.
[22] Larsen et al. 2022.
[23] Larsen et al. 2022.
[24] Larsen. 2009.

makes a relatively sharp distinction between nature conservation provisions ("high nature values") and production forests ("low nature values"). It also indicates that the transition to closer-to-nature forest management can take place gradually, and that closer-to-nature forestry can be applied from different starting points; for example, in previously clear-cut young or thinning forests or in older forests originating from natural regeneration (continuity forests).

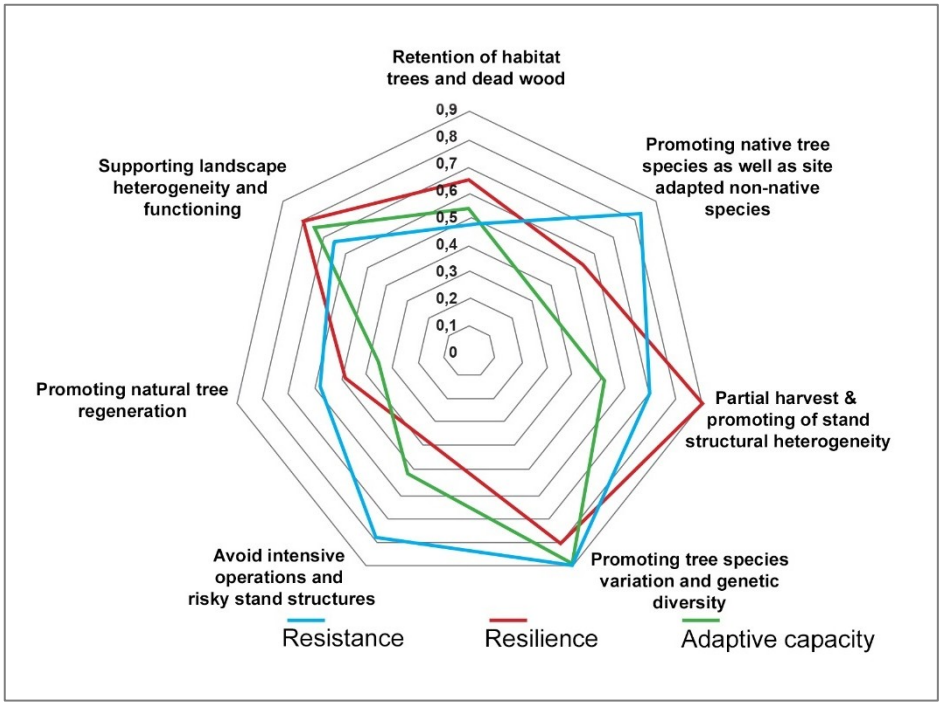


Figure 2. The figure briefly describes the measures and the consideration given to natural structures and processes that affect forest resilience, resistance and adaptive capacity according to the closer-to-nature forest management concept. Modified from the EFI report[25] . Illustration: Bo Persson.

1.1.5 The European Commission's guidelines on closer-to-nature forest management

The guidelines on *closer-to-nature forest management* were published in July 2023 under the *Voluntary guidelines on closer-to-nature forest management.* The guidelines have been developed together with Member States and with the support of the expert group *Working Group of Forests and Nature*. However, the guidelines are a product of the Commission and were not negotiated with Member States. They are voluntary and aim to provide knowledge and advice to authorities, forest practitioners and civil society. They complement national guidelines where they exist.

The guidelines describe the main objectives of closer-to-nature forest management. The aim of using closer-to-nature forest management is to create better conditions for biodiversity and resilience to climate change while managing the forest. This is achieved by creating diverse forests and designing forest management based on the natural disturbance dynamics of forest ecosystems.

[25] Larsen et al. 2022.

Forests across the EU differ in terms of environmental characteristics, conservation status, biodiversity and climate change. So do the forestry practices that have shaped them over time. Therefore, Member States in different parts of Europe have contributed to the guidelines by describing the main forest types and the application of closer-to-nature forest management in different biogeographical regions. Together with Finland, Sweden has assisted with regard to the boreal forests.[26] Three of the regions covered in the guidelines have relevance for Sweden: the boreal, continental and alpine regions (Figure 3).

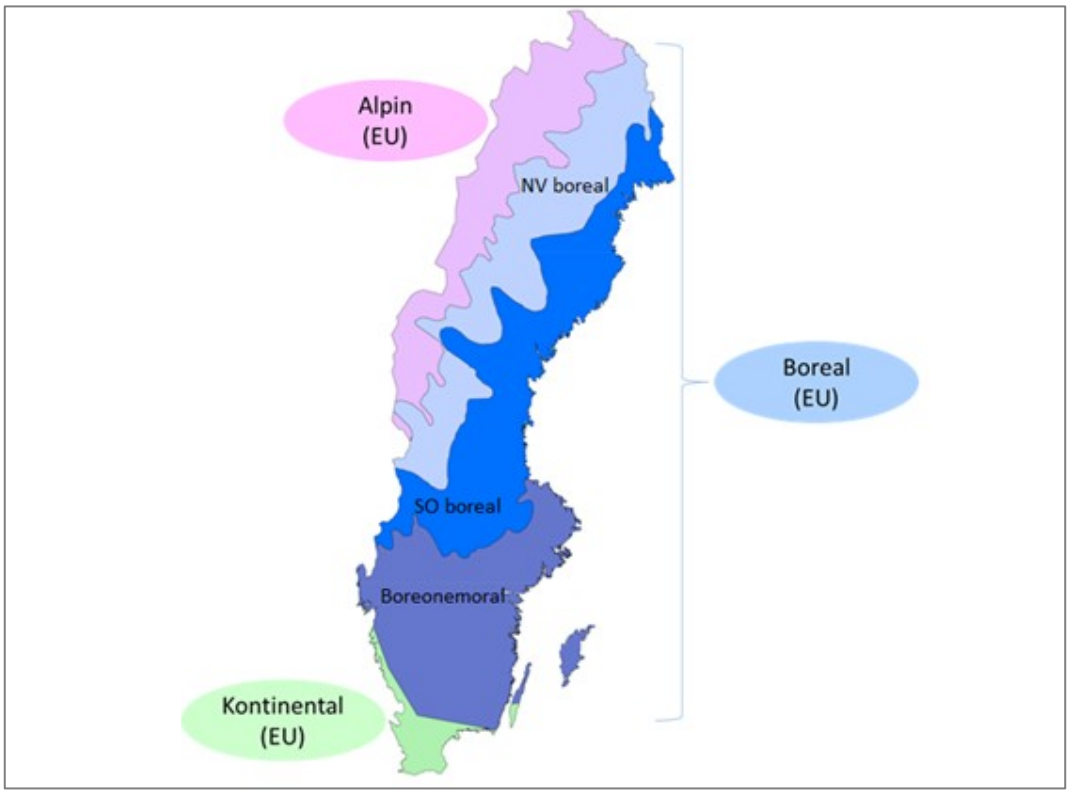


Figure 3. Map of Sweden showing the EU's three terrestrial biogeographical regions (alpine, boreal and continental region), taken from Berglund 2021.[27] The boreal region is here divided into three sub-regions, which is not the case in the EU Commission's guidelines for closer-to-nature forest management[28] .

The European Commission's guidelines include general principles based on those presented in the EFI report on *closer-to-nature forest management*.

The general principles of the European Commission's guidelines are:

- learning from and permitting natural processes to develop;
- maintaining the heterogeneity and complexity of forest structures and patterns;
- integrating forest functions at different spatial scales;

[26] Larsen et al. 2022
[27] Berglund. 2021
[28] European commission. 2023a.

- using a variety of silvicultural systems based on natural disturbance patterns of the region;

- low-impact timber harvesting with equal attention being paid to what is retained in the forest and what is removed, thus preserving habitats, forest soil and forest microclimates.

Another important starting point presented in the European Commission's guidelines is nine different key measures for closer-to-nature forest management that contribute to (i) strengthen structural complexity and natural dynamics; (ii) reduce anthropogenic pressures; (iii) protect habitats and species; and (iv) manage landscape connectivity (see Chapter 2.5; Table 1). These measures complement each other; the frequency and intensity of the different measures should be based on local conditions.

In the task of developing a definition of closer-to-nature forestry based on Swedish conditions, the various key measures are an important starting point (see section 2.5). The aim is to make it easy to identify how the Swedish definition links to the European Commission's guidelines.

2 Analysing the concept of closer-to-nature forest management

2.1 Forest production in closer-to-nature management

Important starting points for closer-to-nature forest management are that it should be both ecologically sustainable, adapted to climate change, and at the same time economically profitable for the forest owner. Closer-to-nature forest management is largely based on managing the forest in a way that mimics the natural disturbances that have influenced forest ecosystems over a long period of time. In closer-to-nature forest management, adaptations are made to mimic the historical effects of fire on forests, but consideration is also given to other natural and, to some extent, human disturbances resulting from historical use that have influenced the alpine, boreal and continental forest landscape.

More diverse forest management favours the long-term productive capacity of the forest and its resilience to, for example, large-scale disturbances such as storms, droughts and insect outbreaks. In one region of Germany, forests subjected to single-tree harvesting were affected by major damaging agents such as storms and insect outbreaks at lower rates (21%) compared to other forests (36%) in the same region[29] . This suggests that in forests where forestry is practised with smaller and repeated harvests, forest resilience is strengthened. However, it is difficult to know whether comparable conditions exist between Swedish and German forests. There is much to learn from Central Europe in terms of such patterns and observations. More diverse forestry often also creates better conditions for multiple uses, such as the combination of forestry and tourism, as well as biodiversity and carbon credits.

Closer-to-nature forestry can also create market advantages in the future. There are already certificates for timber produced with continuous cover forestry methods[30] , and various certifications for more sustainable/close-to-nature forestry are under development[31,32] . In addition, the European Commission will develop a voluntary certification scheme for closer-to-nature and is also developing a framework for the certification of carbon sinks[33] . Closer-to-nature forest management criteria will also complement the EU roadmap for planting at least three billion additional trees in the EU by 2030.

2.1.1 Forest production in a changing climate

Climate change has already led to increased temperatures in Sweden, more precipitation, and less snow cover[34], which in turn has affected and will affect vegetation zones and distribution ranges of different tree species, which will move northwards and to higher altitudes[35]. Climate change must therefore be considered

[29] Bauhus et al. 2014.
[30] Plockhugget. 2023.
[31] Ekoskog. 2023.
[32] AEFC. 2023.
[33] European commission. 2022.
[34] Schimanke et al. 2022.
[35] Expert Council on Climate Change Adaptation. 2022.

in management decisions to maintain productive and vital forests. Such decisions on climate adaptation measures[36] concern, for example, forest management practices, tree species selection, provenance selection, tree species mixtures and stand structure.

The aim of forest adaptation is to strengthen the resilience of forests to the effects of climate change. This means that the measures implemented should increase the forest's ability to withstand and recover from disturbances such as storms, floods, droughts and fires. Climate change also increases the risk of forests being attacked by existing and new pests, and of erosion and soil damage, which can lead to significant costs and consequences for society[37]. Important measures to adapt forests to climate change are to increase the degree of variation in tree species, tree age, and to choose tree species and provenance according to the location and how the climate will change at that particular location[38] .

There are several synergies between closer-to-nature forestry and climate adaptation measures, as closer-to-nature forestry implies an increased variation in the forest landscape through the application of different forestry practices aiming towards more tree species and uneven-aged stands.

- A multi-layered forest with a variety of tree species is considered to be more climate-resilient against, for example, storm damage and tree diseases than monocultures of spruce[39] .

- It is possible to start transforming the forest at an early stage with minor and frequent forest management measures to make it more resilient (e.g. gradually phasing out an infested tree species)[40]. As a result, the stand will hopefully become more productive in a time of rapid change and new pests will not spread as easily across the landscape. This may in turn have a positive impact on the diversity associated with affected tree species in neighbouring stands.

2.2 Natural disturbances

Natural disturbances in forests are dynamic processes that normally occur in nature, such as landslides, storms, fires and floods. In parts of Europe where *close-to-nature forest management*[41] has been practised, major disturbances at stand level are considered to inevitably affect the forest at regular intervals. Close-to-nature forest management in these parts of Europe is mainly focused on mimicking internal stand dynamics with the aim of obtaining more resilient forests (greater tree species mix, uneven-aged stand, trees with less damage risk) that can withstand major disturbances such as insect outbreaks. This approach differs from the Swedish view on the boreal forest, where even-aged retention

[36] Swedish Forest Agency. 2019a.
[37] Expert Council on Climate Change Adaptation. 2022.
[38] Swedish Forest Agency. 2019a.
[39] Felton et al. 2024.
[40] Puettman & Bauhus. 2023.
[41] Bauhus et al. 2014.

forestry is used, and where clearcuts to some extent resemble the open area that occurs after a large-scale disturbance such as fire.

In our boreal forest landscape, which includes large parts of the boreonemoral region of Sweden, fire as a natural disturbance has strongly affected the forest ecosystem[42] , but other disturbances such as wind, water, insect outbreaks, forest grazing by domestic animals and previously wild large herbivores and tree diseases have also had an impact. The alpine region and the nemoral forest in the continental region have also been affected by different disturbance regimes. In the nemoral forest storms have caused major disturbances in recent years. The impact of fire on forests has been gradually reduced, compared to pre-industrial times, by means of fire control and the cessation of traditional burning for grazing or cultivation[43]. Forest grazing has also decreased. Closer-to-nature forestry in the boreal region should therefore, in some parts of the landscape, endeavour to mimic fire but also take into account other disturbances, including human disturbance and human-induced disturbance. Historical maps with information on previous tree species mixtures and forest structure can be used. Fire, storm felling and insect outbreaks have not only been large-scale in their impact but also caused small- and medium-scale disturbance. The natural openness following forest fires and major storms is in most cases different from the openness of a clearcut in modern even-aged retention forestry, mainly due to the extensive removal of dead wood on the ground, but also in other ways[44, 45]. Even if the fire cannot be completely replaced, forest management practices in closer-to-nature forestry can be adapted to better mimic the effects of a forest fire by, for example, retaining more dead wood (see also 3.1.3).

2.2.1 Boreal region

In Sweden, forestry and how it mimics natural disturbances has for many years been based on the so-called ASIO model[46] . In the model, clear-cutting is considered to mimic the impact of fires, and fires are seen as often being stand-replacing. Large areas are said to have burned regularly, leaving more or less bare areas with certain structures, where the forest then regenerated.

A revised version of the ASIO model with updated percentages of the proportion of boreal forest affected by various disturbances including wind, insects and fire was recently produced[47] (Figure 4A). The revised ASIO model shows that for Swedish (and Finnish) boreal forest landscapes, large-scale disturbances have occurred on about one third of the area (Figure 4B). Small- or medium-scale disturbances have occurred in the remaining two-thirds, but with some variation depending, for example, on the dominant forest type in the landscape. Large-scale disturbances include stand-replacing disturbances, whereas small- and medium-scale disturbances include gap and cohort dynamics.

[42] Niklasson & Granström. 2000.
[43] Ericsson. 1997
[44] Esseen et al. 1997.
[45] Nilsson et al. 2001.
[46] Angelstam. 1998.
[47] Berglund & Kuuluvainen, 2021.

About one percent of the boreal forest has burned annually before modern firefighting began. In the boreal forest, many fires have historically been small, affecting small patches and single trees[48]. Large fires of more than 1000 ha have occurred less frequently, mainly during hot and dry summers. The size of a fire depends on the landscape's characteristics and the presence of fire barriers (wetlands, watercourses, recently burnt land). For example, areas with large proportions of wetlands (21-23 percent) have burned less frequently than areas with small proportions of wetlands (one to two percent)[49]. How often a fire occurs depends on lightning ignition frequency, but also on human activity. Anthropogenic fires have increased during certain periods due to different types of land use[50].

The impact of fires on forest ecosystems is complex. Forest structure and tree species composition change, as well as the presence of different substrates and species. More important than the size of the fires is their importance for fire-dependent and fire-favoured species. Seed bank species or fire-dependent insects with good dispersal abilities are not dependent on the size of the fire, while birds can benefit from large fires resulting in large-scale deciduous tree regeneration and large amounts of fire-killed trees.

Mycorrhizal fungi are negatively affected by disturbances that create large areas without living trees. They are favoured by small-scale disturbance, but can probably be hindered in the establishment phase when the moss mats become too thick as a result of lack of fire disturbance or forest grazing. The presence of mycorrhizal fungi of conservation interest is dependent on tree continuity and decreases with distance to the nearest tree in retention patches or to the forest edge[51]. Other disturbances and combinations of disturbances that are of great importance to the boreal forest are: (1) snow in combination with wind, which creates various types of gaps; (2) coniferous and deciduous tree living insects that affect everything from individual trees to groups of trees and larger stands; (3) water, which on slopes and next to watercourses creates special moist environments, seepage areas, and affects tree species composition. Grazing animals and large grazers are also historical and current disturbance factors. There are many forests with historical management of different type in the boreal region.

The regeneration of light-demanding deciduous trees and pine is favoured by creating gaps in the forest. The size of the gaps required for tree establishment and satisfactory growth varies. Gaps of about half a hectare are probably sufficient for the establishment of our Swedish species, but what is optimal for timber production is unclear.

Large, fully stand-replacing fires, or other major disturbances that can be caused by extreme weather such as storms or large insect outbreaks combined with drought, are not something to be emulated, as they can be compared to disasters with high impacts on the economy, climate and biodiversity. Such types of

[48] Niklasson & Granström. 2000.
[49] Hellberg et al. 2004
[50] Niklasson & Granström. 2000
[51] Djupström et al. 2022

disturbances are likely to inevitably affect forests to a greater extent in a future warmer climate.

The impact of fire is very different from the process of clear-cutting, where all or many trees are taken down and a completely open area is temporarily created and then planted with one or a few tree species. Species that require open conditions can temporarily thrive in the open, sunlit and warm area created. It has been reported that farmland birds as well as a number of butterflies[52] , mammals[53] , vascular plants[54] and wood-living insects favouring sun-exposed conditions can temporarily utilise the open biotope and get a boost that lasts for a few years at best. A clearcut can thus be species-rich for a short period of time. Species richness is influenced by historical land use, soil type, nature consideration taken at harvesting and soil nutritional status, as well as when the young growing forest is thinned. However, very few of the species that require open land among the aforementioned groups can cope with the conditions prevailing in the young dense and even-aged forest that eventually grows up on the clearcut.

Even-aged retention forestry followed by planting of one or a few tree species creates even-aged forests that do not have the same structure as a forest created by natural regeneration after a fire or large storm and/or the combination of fire and forest grazing. The sometimes intensive scarification in even-aged retention forestry negatively affects many species that are easily eliminated. Soil scarification gives a different result than fire. Although the soil is sometimes severely burned in a forest fire, it is a different process compared to mechanical scarification. The fire favours fire-dependent and fire-favoured species that are often fully or partially dependent on sunlit, burnt dead wood. A wildfire creates large amounts of dead wood, charred wood and leads to extensive establishment of light-demanding deciduous trees from seed sources in the surroundings. Clearcuts lack the large amount of dead wood. Even though deciduous trees often establish on the clearcuts, most of these are removed during thinning operations in the young forest phase, to favour planted pine or spruce seedlings.

To summarise, there are two major differences for biodiversity between current even-aged retention forestry in Sweden and the impact of fire disturbance.

1. Today's clearcuts lack large amounts of dead wood and substrates such as charred wood, as well as an abundant cover of deciduous trees. Fire-dependent species need the direct impact of fire on dead wood and other substrates. Many other fire favoured species such as wood-living insects and woodpeckers also benefit from fires.

2. Species that thrive on open spaces and in mosaic environments and that were previously dependent on natural fire, pasture burning with subsequent grazing or other processes that created open spaces in the forest may temporarily increase in the post-felling phase. They are often

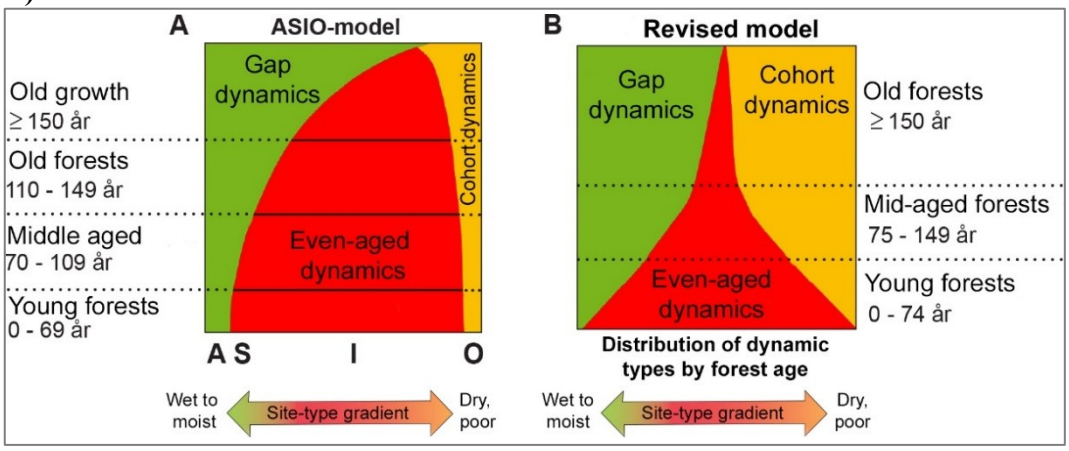
[52] Ram et al. 2020.
[53] Berglund & Persson. 2011.
[54] Lennartsson et al. 2022.

unable to cope with the subsequent even-aged and dark young forest phase.

In-depth look at the revised ASIO model

According to the revised ASIO model (Figure 4A), clearcuts resulting from even-aged retention forestry can constitute one third of the landscape if the natural disturbance dynamics are to be mimicked (Figure 4B). This is based on the best available knowledge today. It provides a direction towards what percentages are reasonable in landscape planning of closer-to-nature forestry measures to mimic natural disturbances in boreal forest landscapes. Other methods besides even-aged retention forestry mimic small-scale and medium-scale disturbances in the revised ASIO model: gap felling for gap dynamics and partial removals for cohort dynamics.

A)



B)

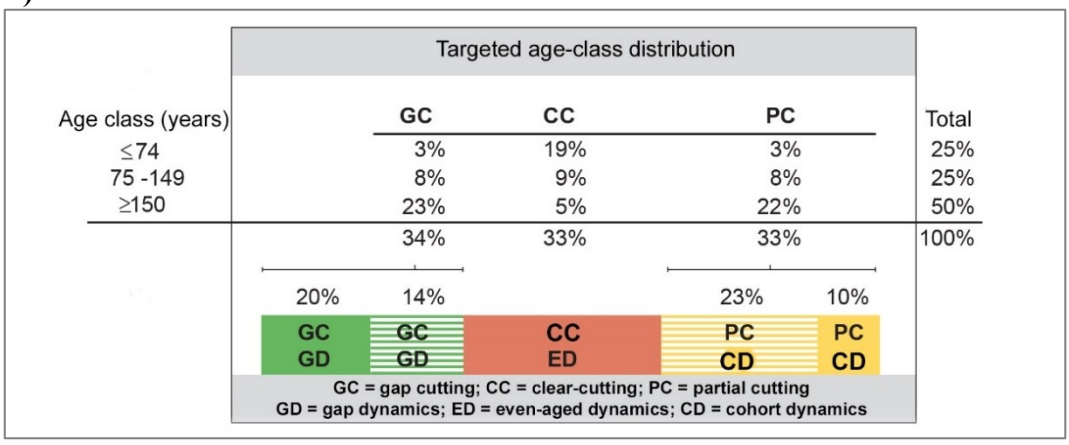


Figure 4. A) Original ASIO model (left) and revised ASIO model (right). B) Approximate percentages of different forest management types in a landscape that is managed based on the natural disturbance dynamics described in the article, distributed by age class distribution/age category and with information on forest management type linked to forest dynamics. It is mainly in the boreal region that this figure/model is relevant. Modified from the original article[55]. Illustration: Bo Persson.

In Sweden, the forest landscape is largely dominated by clearcuts with retention and by even-aged forests. If we choose to follow the revised ASIO model, there

[55] Berglund and Kuuluvainen. 2021.

will be a limited scope, in closer-to-nature forestry, to work on mimicking stand-replacing disturbance since the landscape is already dominated by clear-cuts and even-aged forests. In such landscapes, such as large parts of the boreal region of Sweden below the montane forest, small- or medium-scale closer-to-nature management practices with varied tree species composition need to be considered and increased to achieve the specified percentages of different natural disturbances in the revised ASIO model.

Adaptations may also be needed in the form of limitations on the size of clearcuts. The emerging forest also needs to contain deciduous trees and various forms of dead wood and surviving trees to mimic an area exposed to wildfire or an area where storms have created large amounts of sunlit dead wood and a sparse remaining tree layer.

Central and southern European forests generally have more tree species than the Swedish boreal region. In the boreal region, it may even be natural to have pure stands of pine on sandy soils. Natural forests in general, both in the rest of Europe and in Sweden, are often uneven-aged and less dense compared to planted even-aged stands (Figure 5). The bottom panel of Figure 5 shows a silhouette of what a closer-to-nature forest can look like[56] in the case of a spruce-dominated boreal forest, a pine-dominated boreal forest, and a south-Swedish deciduous-tree dominated forest.

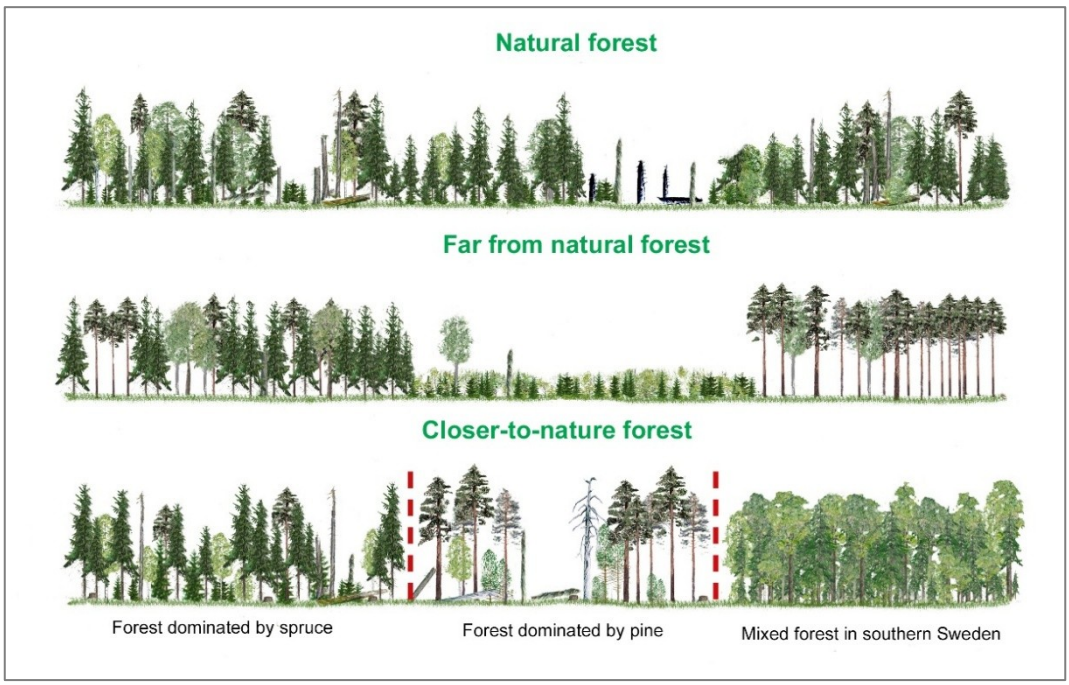


Figure 5. Silhouette images of natural forest, examples of what is not natural forest and closer-to-nature forests in a Swedish context. The figure is relevant mainly for the boreal region but also includes a southern mixed-species forest at the bottom right. Modified from Larsen et al. 2022, Illustration: Bo Persson.

Sweden has had a long history of landscape use by, for example, people that kept summer farms and maintained a kind of Nordic shieling system and the Sami people (the Sami reindeer grazing landscape and adaptations are addressed in

[56] a Swedish version of the figure found in Larsen et al. 2022.

chapters 2.5.10 and 3.1.10). Virtually the whole of Sweden has been subjected to various forms of historical use for a long time according to varying customs and traditions. The historical use has left its mark on nature. Many species and processes are linked to the historical use of the landscape. In this context, biological cultural heritage is a key concept, and in cases where we propose imitating older, historical use or at least acquiring knowledge prior to forestry measures, the aim is primarily to preserve and develop biological cultural heritage.

In large parts of the boreal forest landscape, roughly up to the county of Västerbotten and along the Northern Baltic sea coast, summer farms outside of the villages were common and the forest land was considered an important grazing resource. The forest was also used for buildings and firewood, with interspersed hayfields along watercourses and on wooded and open marshland. The intensity of forest utilization varied according to population density and tradition, and whether the forests were adjacent to for example mining villages and small industries linked to the use of various natural resources. Fires were often deliberately set and swept through different forest types to create grazing grounds and fodder for animals. This favoured the biological cultural heritage and a combination of species favoured by fire, grazing and haymaking, while other forest species linked to natural forests often could be negatively affected.

The historical use created a variation in the landscape where some parts were heavily utilised (for example the forests around the large mills in Bergslagen, central Sweden) while other parts were closer to pristine forests. Historical management in the boreal region also includes pollarding, various forms of coppicing with birch, and open areas with forest meadows and forest pastures containing a mixture of deciduous and coniferous trees[57](Figure 6). Animal feed and timber production were often combined in different forms of coppice forests. Firewood, fencing timber, garden and craft materials and other items were produced. Today's coppice forests, which are rare in some parts of Europe, often harbour a rich diversity of species living in both forests and meadows. These include various butterflies, mice and voles, field hens and small game[58].

[57] Lennartsson et al. 2022.
[58] Rydberg & Falck. 1996

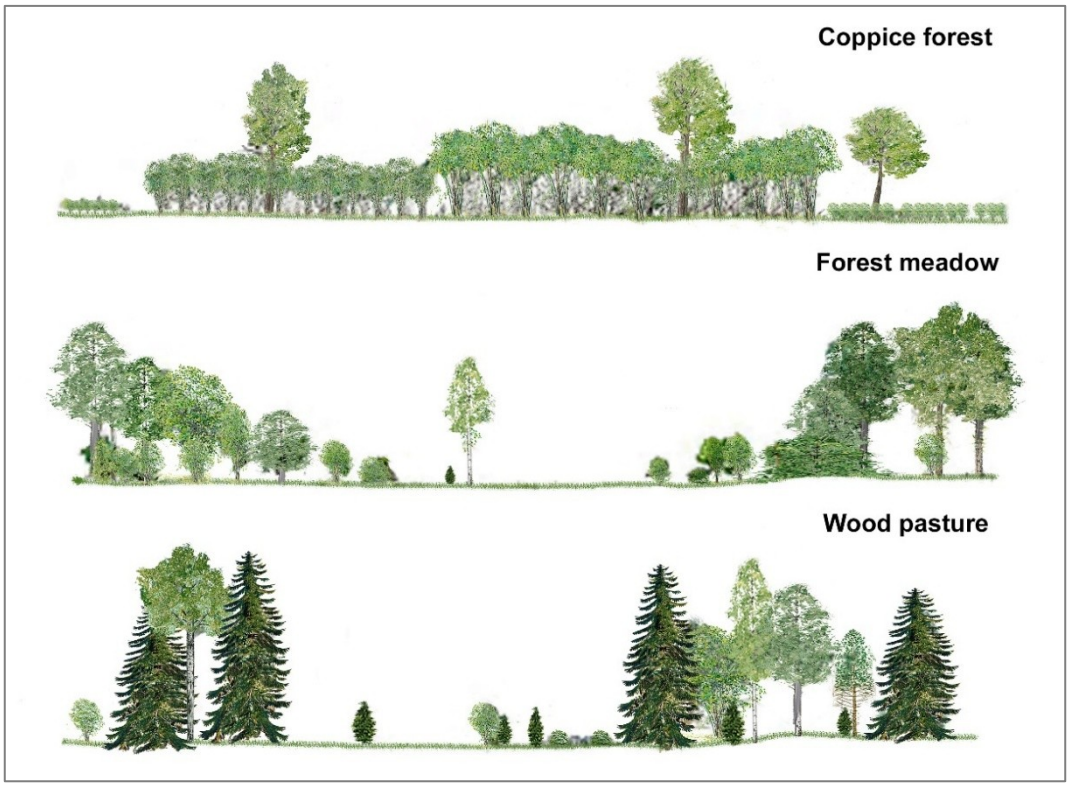


Figure 6. Some different variants of historical use resulting from both forest and meadow management and grazing animals. These forms of utilization have been common in continental, boreal and alpine regions in Sweden. Modified from[59]. Illustration: Bo Persson.

Closer-to-nature forest management at these sites does not expect a return to regular pasture burning (where this was the practice) or the resumption of forest grazing (even if this would be desirable for biodiversity). However, closer-to-nature forest management that takes into account historical use can help to create regular gaps and small-scale variation in the forest landscape. This can have a positive impact on the remaining species linked to traditional landscape use, the biological cultural heritage, as it is reminiscent of the historical forest structure. There may also be modern variants of coppice and coppice with standards that prove to be interesting for producing different types of timber qualities and are well suited to these traditional landscapes.

2.2.2 Continental region

The nemoral forest in Sweden, which is part of the continental region used as a biogeographical division in the EU, includes the southern deciduous forests. The natural disturbances have historically been characterised by grazing by megaherbivores (large grazing animals) that lived before the last ice age. These were eventually replaced by domestic livestock. Various species have long since been affected by and adapted to the human uses that have characterised the landscape, such as slash-and-burn agriculture, meadow farming, field crops, coppicing, harvesting of trees for charcoal or potash burning and single-tree selection cutting. This means that many species are adapted to a cultural landscape with a large element of semi-open environments, edge environments and large sunlit deciduous trees. There are a large number of vascular plants,

[59] Larsen et al. 2022.

insects and lichens that only live in these environments. There is an important lack of high-quality pasture forests today, which means that there is a great need for restoration. One of the most important restoration measures is to prevent regrowth of young spruce trees in previously open and semi-open forests in particular, but this may change in a future climate where shade-demanding tree species find it difficult to survive as a result of drought.

Small-scale disturbance through gap dynamics where gaps are created by the death or felling of trees by wind and storms have also been common natural disturbances in the nemoral zone. The natural beech-dominated forest is characterised by gap dynamics, largely caused by wind and wood-decay fungi that weaken the trees. Many saproxylic insects associated with beech live in sun-exposed substrates that occur in forests with small-scale gap dynamics. Disturbance by fires has had an impact particularly in the boreonemoral zone bordering the continental region[60] but also in the continental region, for example as part of the tradition of burning and grazing heather moors that are now sometimes forested[61] .

2.2.3 Alpine region

The Alpine region includes mountain birch forests, coniferous forests and mixed coniferous forests. Forests in the alpine region are often scientifically categorised as belonging to the *northern boreal zone*[62] . The Nordic Council of Ministers' "northern boreal forests" also overlap with the EU's alpine region. Disturbance dynamics are similar to those prevailing in the boreal region, such as fire, storms and insect outbreaks. In many alpine forests, especially in mountain spruce forests, disturbances are often of a small to medium scale nature caused by wind combined with snow, fungal infections and insects[63] . The processes are slow. Larger fires have occasionally occurred in highland spruce forests but with long time-intervals. They often become intense because crown fires occur and there is a lot of fuel accumulated in the forests. There are also older, dry, fire-prone pine forests along the mountain range. Here, fire dynamics are dominated by small to medium-sized fires. Trees die in patches and many pines survive several fires in succession[64] . Mountain birch forests have disturbance dynamics driven by insects whose larvae feed on leaves and defoliate the trees (for example *Epirrita autumnata* or *Operophtera brumata*). In northern Norway, there have been large-scale outbreaks of this type in recent years that have completely wiped out the mountain birch forest in some areas[65] .

There is also long-standing human utilisation in the alpine region along the entire mountain range. The utilisation is linked to Sami tradition with reindeer husbandry but also to summer farming as far back as the Iron Age in some parts of the central to southern mountain range[66] . There are also remains of other forms of utilisation and use, and extensive trade has been conducted for a long time in

[60] Niklasson. 2011.
[61] Larsson & Stenström. 2022.
[62] Ahti et al. 1968.
[63] Kuuluvainen et al. 2017.
[64] Kuuluvainen et al. 2017.
[65] Vindstad et al. 2018.
[66] Lennartsson et al. 2023.

some areas. Human utilisation has contributed to some areas having a high level of biodiversity linked to the biological cultural heritage. Grazing and haymaking linked to pastoral farming, as well as other types of cultivation and even fire in the form of, for example, pasture burning of both forest and open land have been common for a long time in some parts of the region.

Climatic conditions are changing rapidly in the Alpine region, making it difficult for long-lived trees to respond and spread. This leads to an increased risk of various disturbances, including extreme weather mixed with large-scale insect outbreaks[67].

The latest assessment of the Habitats Directive in 2019 shows that the conservation status is better in the Swedish alpine zone (68 per cent good status), compared to the rest of the EU (25 per cent). This is due to large set-aside areas and lower land-use pressure. The forest near the mountains constitutes a large contiguous area of so-called continuity forests where connectivity between valuable forest areas is high. This has led to the area being referred to as Europe's 'green belt'[68] .

2.3 Shortcomings in the forest landscape

2.3.1 Impact on forest structure and heterogeneity

The Swedish forest landscape has been shaped by even-aged forestry, which has been carried out on a large scale since the 1950s[69] (with less or no retention in the 1950s-1980s). Logging has steadily increased since the 1950s, from about 40 to about 96 million cubic metres by 2022[70] . Most forests below the mountainous region have been harvested by felling at some point and are more or less even-aged. This contrasts with natural forests, which are usually heterogeneous (layered) and consist of trees of different heights, diameters and ages.

Statistics from the Swedish National Forest Inventory show that 69 percent of the forest land consists of fairly or completely even-aged forest (see Chapter 5 for definition)[71]. The age distribution of the forest has also been greatly influenced by forestry. The majority of the country's productive forest land is now in the age classes up to 60 years or younger, and the area of old forest (average tree age over 140 years in the boreal region and over 120 years in the rest of the country) declined sharply during the 20th century. A certain positive trend can be seen for the area of old forest recently, which has more than doubled since the 1990s[72,73] , partly due to an increasing area of voluntary set-asides and environmental considerations.

Intensive even-aged retention forestry, which creates even-aged forests of pine or spruce, has greatly reduced the diversity of tree species in Swedish forests. During the 20th century, deciduous trees have been actively controlled and selected for

[67] Kuuluvainen et al. 2017.
[68] Svensson et al. 2020.
[69] Östlund et al. 1997.
[70] Swedish Forest Agency. 2022b.
[71] Riksskogstaxeringen. 2023.
[72] Swedish University of Agricultural Sciences. 2023.
[73] Swedish Forest Agency. 2022a.

timber production[74] . This, combined with browsing by ungulates, has created a shortage of deciduous trees, especially rowan, aspen, sallow and oak [75] which are particularly important for biodiversity. Since 1985, however, the proportion of deciduous-dominated forest for the country as a whole has increased from 6.4 to 9.2 per cent of the productive forest land area[76] . The increase in deciduous trees has been driven in part by forest certification requirements. Both FSC and PEFC require that at least five percent of the forest area on mesic and moist soils consists of stands rich in deciduous trees[77,78]. FSC also requires, for example, that deciduous trees should make up ten percent of the stems at the time of final felling, where suitable conditions exist.

2.3.2 Loss and fragmentation of habitats

Large-scale forestry has led to the reduction and fragmentation of important habitats such as old growth forests with continuity values (continuity forests) in the forest landscape, with major consequences for many forest species[79] . Many forest species are red-listed and/or have unfavourable status or negative trends. [80]

Several studies about the proportion of suitable habitats needed for different species point to a threshold level of around 20 percent in a forest landscape[81,82,83]. Creating coherent habitats, known as green infrastructure, for different species in the forest landscape is also a priority measure for biodiversity[84]. Since managed forests make up the largest part (86%) of the forest landscape, it is essential to preserve natural values and increase the variety of managed forests[85,86] . A greater variation in management methods, tree species mixtures and stand structure, as well as active nature conservation measures such as the creation of dead wood are examples that increase variation. Nature conservation areas are also pillars of green infrastructure and are particularly important as habitats and sources of dispersal for specialised species that do not survive in the production landscape. Today, 8.9% of the total forest land area is formally protected and 4.9% is voluntarily set aside[87]. Formal protection is unevenly distributed across the country, with 61 per cent of the protected area in the mountainous (alpine) region.

In today's managed forests, there is a lack of substrates on which many species depend, such as old living trees, dead wood, deciduous trees and moist environments. Environmental considerations in forestry, which must be taken into account in all forestry operations, aim to preserve important elements of biodiversity. In the early days of intensive even-aged forestry, very little

[74] Simonsson et al. 2015.
[75] Swedish Forest Agency. 2023e.
[76] Swedish University of Agricultural Sciences. 2023.
[77] PEFC. 2017.
[78] FSC. 2020.
[79] Swedish Forest Agency. 2022a.
[80] Ottosson. 2022.
[81] Andrén 1994.
[82] Angelstam et al. 2004.
[83] Berglund 2019.
[84] Swedish Environmental Protection Agency. 2023a.
[85] Swedish Environmental Protection Agency. 2023a.
[86] Swedish Forest Agency. 2023c.
[87] Statistics Sweden. 2022.

environmental consideration was given, often resulting in completely bare areas, and it was only when the Forestry Act was revised in 1993 that it became a legal requirement[88]. Since then, environmental consideration has been developed and improved through requirements in the FSC and PEFC certification standards and the development of industry-wide objectives for good environmental consideration[89]. Research has shown that environmental consideration at harvesting can have positive effects on species[90,91], but that the level of consideration is often too low to have a positive effect on biodiversity[92]. On average, 9.3% of the forest land area is left as environmental consideration (e.g. retention patches and riparian buffer zones). For dead wood, on which many species depend, the volume on all forest land has increased by about 30% since 2005 and is now 9.8 cubic metres per hectare, of which just over half is classified as hard dead wood and the rest as decomposed. However, current levels are low compared to the proposed reference values for boreal forests[93].

Environmental consideration along watercourses is often inadequate, with statistics showing that a third of watercourses have no riparian zone[94]. Research has also shown that the majority of Swedish watercourses included in a comparative study with Finland and Canada had inadequate protection[95]. Extensive drainage of wet forest land since the late 19th century, with peaks in the 1930s and 1980s[96], has led to a significant reduction in wetland habitats. It has also greatly reduced the role of water as a natural disturbance in the forest landscape. Today, ditching of forest land is not permitted, but ditch clearing and remedial drainage occur in connection with felling. Research shows that 25-50 percent of ditches have not led to increased production. In those ditches, clearing is not necessary; they can be plugged or filled to restore wet conditions[97]. Varied transition zones between forest and agricultural land, which are very species-rich, are also in short supply[98]. Half of today's transition zones between forest and agricultural land consist of a sharp forest edge, while more varied edges with gradual transitions between forest and open land are only found on about 10 percent of the total length of forest edge[99].

Closer-to-nature forest management involves more extensive environmental considerations than the current average. Compared with the current situation, this leads to some production losses and a reduced timber production area, particularly linked to more extensive buffer zones along water.

[88] Simonsson et al. 2015.
[89] Swedish Forest Agency. 2023a.
[90] Gustafsson et al. 2010.
[91] Lindbladh et al. 2022.
[92] Kuuluvainen et al. 2019.
[93] Müller & Bütler. 2010.
[94] Swedish Forest Agency. 2022b.
[95] Kuglerová et al. 2020.
[96] Jacks. 2019.
[97] Hasselquist et al. 2018.
[98] Swedish Board of Agriculture. 2018.
[99] Swedish University of Agricultural Sciences. 2015.

2.4 Sami indigenous people and reindeer husbandry

The Sami are the only indigenous people in the EU and have special rights related to forests and forestry that must be met in closer-to-nature forestry in Sweden. The forest landscape in northern Sweden is largely a reindeer grazing landscape, and forests are in many ways central to Sami culture, such as for example in making handicrafts.

The presence of indigenous peoples can have a positive impact on biodiversity. While biodiversity is declining globally, it is declining less rapidly in countries and areas managed by indigenous peoples[100]. Reindeer grazing itself also sometimes has a positive impact on biodiversity. Fruiting body formation of certain mycorrhizal soil fungi that are often used as conservation indicators in sandy, lichen-rich pine forests is considered to be positively affected by reindeer trampling[101]. It has also been tested whether reindeer are a good indicator of the forest landscape's green infrastructure, for example whether reindeer prefer to stay in landscapes with high nature values. There were indications of this, although more research is needed in this area to establish the connection[102] .

Reindeer husbandry is negatively affected by climate change, for example, with increased incidence of ice and hard snow crust in winter pastures, which makes it difficult to access the ground lichens. The availability of load-bearing ice on lakes and rivers also decreases in a warmer climate, which makes movement on the large rivers and across lakes and smaller watercourses between winter and summer pastures more difficult. Climate modelling of the mountain region indicates that forest and shrub vegetation will increase in a changing climate[103].

2.5 Key measures

The European Commission's guidelines present a number of key measures to help achieve the objectives of closer-to-nature forest management (Table 1). The key measures complement each other and are applied to different degrees and extents depending on local conditions. In this chapter, key measures are placed in a Swedish context with adaptations to Swedish forestry. The aim is for the Swedish definition to be comparable with the European Commission’s guidelines and to serve as a basis for the EU’s future certification of closer-to-nature forest management. In the Swedish definition, adaptation to reindeer husbandry has been added as it is a natural part of the forest landscape in northern Sweden. Many adaptations that favour reindeer husbandry also strengthen nature, cultural and landscape values.

[100] IPBES. 2019.
[101] Nitare. 2006.
[102] Bovin & Naumov. 2017.
[103] Lagergren et al. 2023.

Table 1. The table provides an overview of the measures included in closer-to-nature forest management in Sweden. The measures are adapted to a Swedish context based on the key measures described in the European Commission's guidelines. The key measures should be seen as tools for achieving the objectives of closer-to-nature forest management. They complement each other and can be used in different combinations depending on local conditions.

The European Commission's key measures ("tool box")	**Key measures with adaptation to Swedish conditions**	**Included measures**
Promoting natural tree generation	Promoting natural tree regeneration	• Natural regeneration • Non-native tree species • Soil preparation
Ensuring respectful harvest conditions	Ensuring respectful harvest conditions	• Forest management methods • Clearcut size • Environmental considerations
Minimising other management interventions	Minimising other management interventions	• Fertilisation • Ditching, ditch network maintenance, and remedial drainage • Harvesting of logging residues and ash recycling • Stump harvesting
Preserving and restoring forest soils and water ecosystems	Preserving and restoring forest soils and water ecosystems	• Driving forest machines in forest land • Ecologically functional buffer zones • Consideration to mycorrhizal fungi
Optimising dead wood retention	Preserving and creating dead wood	• Active creation of dead and dying wood • Maintaining existing dead wood
Setting areas aside	Setting areas aside for nature conservation	• Strictly protected areas and voluntary set-asides • Nature conservation management
Protecting specific species on site	Species protection and conservation	• Action programmes for threatened species • Knowledge of species and adaptation of forestry measures
Managing ungulate species at natural carrying capacity	Responsible ungulate management	• Active ungulate management • Fencing & wildlife protection products
Taking a scale-specific approach	Landscape planning	• Planning from a landscape perspective
	Adaptations to reindeer husbandry	• Connectivity between lichen-rich forests • Adapted forest management • Lodgepole pine

2.5.1 Promoting natural regeneration

Natural and artificial regeneration

Forests can be rejuvenated by natural or artificial regeneration. In natural regeneration, regeneration takes place via seeds dispersing from surrounding trees, via surviving seedlings and small trees in the stand, or via root and stump sprouts[104, 105, 106]. In artificial regeneration, regeneration takes place by sowing or planting. Planting is the most common regeneration method today and is used on 87 percent of forest land. Natural regeneration is only used on 8 per cent of the land, and its use has fallen sharply since the first survey in 2000 (34 percent). In continuous cover forestry, natural regeneration is the most common regeneration method, but planting or sowing also occurs, particularly on land that is difficult to regenerate. The growing forest in a planted or seeded stand will, to varying degrees, have an admixture of self-regenerated seedlings originating from seeding or vegetative regeneration from trees in the surrounding area[107,108]. The Swedish Forest Agency's regrowth survey shows that an average of 26 percent of the main plants in northern Sweden are self-regenerated, and that the proportion of self-regenerated main plants increases further south with a peak in Götaland (Southern Sweden) of 41 percent[109].

Planting is mainly done using seedlings originating from improved plantation seed, which can provide a growth increase of up to 25 percent over a rotation period compared to local stand seeds. In 2022, 95 percent of pine seedlings were grown from Swedish plantation seed, while spruce seedlings originated from 74 percent Swedish and 12 percent foreign plantation seed and 5 per cent and 9 percent stand seed[110]. For birch, half of the plants came from Swedish and half from foreign plantation seed in 2022.

Conditions for natural regeneration

The conditions for natural regeneration vary according to location, tree species, site characteristics and climate. Many deciduous trees are easy to regenerate naturally via seeds or stump or root sprouts[111]. On the other hand, browsing damage to deciduous trees is common in areas with high ungulate densities, and measures to control ungulates may be necessary for successful establishment of tree species vulnerable to browsing (see Chapter 2.5.8). For hardwood trees such as ash, beech and oak, natural regeneration often occurs automatically without any measures, but various methods can be used to achieve effective and more even regeneration[112].

For birch, natural regeneration is often abundant[113]. On new clearings, or in sufficiently large gaps, regeneration is often dominated by birch with admixtures

[104] Rytter et al. 2014.
[105] Löf et al. 2015.
[106] Karlsson et al. 2017.
[107] Ackzell et al. 1994.
[108] Swedish Forest Agency. 2011.
[109] Swedish Forest Agency. 2023e.
[110] Swedish Forest Agency. 2023e.
[111] Löf et al. 2015
[112] Löf et al. 2015.
[113] Rytter et al. 2014.

of other deciduous trees such as willow, rowan and aspen. Birch can also be regenerated by sowing or planting, and improved planting material is available. Production of planting material and methods for forest cultivation and management of birch are currently being developed by the competence centre *Trees for me*[114]. Aspen is mainly rejuvenated vegetatively by root sprouts, and although it produces large quantities of seeds, the germination rate is low, and the seeds are dispersed in early summer when the risk of desiccation is high. When new land is to be afforested, planting is therefore used as a rejuvenation method. Alder regenerates by seed dispersal and root or stump sprouts but requires moist soil and contact with mineral soil. Rowan, Swedish whitebeam and hazel spread naturally via birds or rodents eating the berries or nuts and can also be rejuvenated by sowing and planting. It may be difficult to obtain seed or planting material for these and other non- or less commercial tree species today, so landowners may have to collect their own seed material. For natural regeneration of pine and spruce, seed trees and shelterwood are usually used. There are also methods without seed trees where gaps (gap cutting) or long narrow clearings (edge regeneration) are created[115]. On many sites, soil preparation is essential for the successful regeneration of pine and spruce.

Advantages and disadvantages of natural regeneration

Natural regeneration can be a cost-effective way to achieve regeneration, especially if soil preparation is not required. Successful natural regeneration is often dense, which can reduce browsing damage and creates good conditions for the production of quality timber. However, successful natural regeneration places high demands on the operator regarding the choice of site and assessment of the measures required.

An increased proportion of natural regeneration can lead to reduced economic returns for the forest owner compared to forest cultivation with improved seedlings. It can also lead to a higher risk of poorer regrowth results; in the Swedish Forest Agency's regrowth inventory, natural regeneration consistently shows poorer results than forest cultivation[116,117]. Forest tree breeding also makes it possible to adapt the forest cultivation material to expected climate changes, which can contribute to better climate adaptation in the future[118].

If natural regeneration were to increase in Swedish forestry, it would contribute to increasing variation and "naturalness" in the forest landscape, as the regeneration would become more heterogeneous in height, density and naturally occurring tree species. To maintain variation and a mix of tree species in the stand over time, different tree species need to be favoured in all management measures, especially in clearing and thinning in even-aged retention forestry. Varied stands are more resilient to climate change and damage than homogeneous stands[119], and provide scope for richer biodiversity. Natural regeneration with surviving seedlings and

[114] Trees for me. 2023.
[115] Karlsson et al. 2017.
[116] Swedish Forest Agency. 2017.
[117] Swedish Forest Agency. 2023e.
[118] Swedish Forest Agency. 2023d.
[119] Swedish Forest Agency. 2021a.

small trees also increases the chances of maintaining a diverse mycorrhizal fungal flora.

Natural regeneration contributes to the conservation of local genetic variation, although it is likely that seed trees in forest stands originating from seed orchards contribute less, or not at all, to local genetic variation. There is currently a lack of knowledge about the genetic variation of forest trees in forest stands. Protected areas are an important part of the conservation of genetic variation in the forest landscape. To increase genetic variation and spread the risks in forestry, seed material from different sources should be used, both from local provenances and provenances moved to compensate for climate change, and from improved material.

Methods to increase natural regeneration

There are several ways to increase the occurrence of naturally regenerated trees in the forest landscape. In addition to rejuvenation with established methods of natural regeneration, measures can be taken to increase the presence of naturally regenerated trees also when planting and sowing. For example, fewer seedlings can be planted per unit area to allow natural regeneration to occur in between. The Swedish Forest Agency has changed the regulations for regeneration in the Forestry Act to allow fewer seedlings and more tree species, which means that there should be room for such changes. The requirements for the number of trees that need to be cleared if fewer have been planted have also been relaxed in the Forestry Act. Planting in irregular strips or groups also increases the scope for natural regeneration. Existing stand regeneration can be utilised, such as seedlings and small trees, root or stump sprouts or groups of deciduous trees in moist depressions. Increasing planting distances, and thus not having to remove planted trees at a later stage, can increase the incentive for forest owners to maintain naturally regenerated seedlings over time.

Non-native tree species

The use of non-native tree species, which have their natural range outside Sweden, has been dominated by lodgepole pine since the 1970s[120]. However, the use of lodgepole pine has declined sharply in the last decade, with 6.5 million seedlings produced in 2022[121]. The time is coming to harvest the lodgepole stands established in the 1970s, and if forest owners choose to rejuvenate the stands with lodgepole pine, the regeneration area with lodgepole pine will increase in the future. The use of other non-native tree species such as hybrid larch, hybrid aspen and Sitka spruce is very small but has increased somewhat, especially after storms such as Gudrun and Per[122]. The use of non-native tree species can sometimes be seen as a climate adaptation measure, which is likely to become increasingly important in the future. A legislative proposal on non-native species and movements of provenances has been presented by the European Commission. The Forestry Act allows non-native tree species with certain restrictions below the mountain forest border, but only in exceptional cases in mountainous forests. Special restrictions apply to lodgepole pine, which may not be used in Götaland

[120] Swedish Forest Agency. 2009b.
[121] Swedish Forest Agency. 2023e.
[122] Swedish Forest Agency 2009b

(central Sweden) and certain parts of Svealand (southern Sweden), at certain altitudes and no closer than 1 km from national parks and nature reserves. The certification rules have a more restrictive approach to non-native tree species, and there is a restriction on new plantations in the FSC standard where a maximum of five per cent of the land holding established since 1994 may consist of non-native tree species or other plantation forest[123].

Risks

There are risks associated with the introduction of non-native tree species. They can be affected by diseases or pests that are not present in their natural distribution range and negatively affect biodiversity or reindeer husbandry. They risk becoming invasive, i.e. spreading rapidly and causing serious damage to ecosystems, by displacing native trees or other vegetation. The Species Information Centre's classification of the impact of non-native species on biodiversity identifies several non-native tree species that have a high risk of becoming invasive[124]. Such examples are sycamore and horse chestnut, which are already established in southern Sweden, and lodgepole pine, which is widely used in northern Sweden. Since its establishment in Sweden in the 1970s, the lodgepole pine has been shown to spread via natural regeneration and not only after fire as previously thought. It has also been shown to have negative effects on reindeer husbandry (see Chapter 2.5.10). The EU Regulation on invasive alien invasive species prohibits the deliberate reproduction, growth or cultivation of species listed in the regulation[125]. All invasive alien species listed in the regulation must be controlled if they are found in the landscape, and the landowner is responsible for control. No trees are currently listed in the regulation.

Soil scarification

Soil scarification is an important part of forest regeneration in Sweden today, especially in the application of natural regeneration of pine through seed trees and artificial regeneration (planting and sowing) in even-aged retention forestry. For some of the continuous cover forestry methods, the need for soil scarification is lesser, but in shelterwood and gap felling, soil scarification may be needed to achieve satisfactory regeneration. Today, about 87 percent of the reported harvested forest land area is scarified. Soil scarification is used less often for natural regeneration (67 percent of the area) than for planting (92 percent)[126] .

Soil scarification creates better conditions for achieving an approved regeneration, including reduced competition for water and nutrients, lower risk of frost and reduced risk of damage from voles or weevils[127]. When sowing, soil scarification is essential. However, soil scarification can cause significant damage to soil and water. Harmful substances such as mercury can be released and leach into waterways. Improper soil scarification increases the risk of erosion. Soil scarification is the measure that causes the most damage to cultural heritage values, even though major efforts have been made to reduce the damage[128]. The

[123] FSC 2020
[124] Strand et al. 2018.
[125] European Union. 2014.
[126] Swedish Forest Agency. 2023e.
[127] Magnusson. 2015.
[128] Swedish Forest Agency. 2022d.

effects of soil scarification on biodiversity vary; a particular soil disturbance may be favourable for some species detrimental to others, such as soil fungi.

The dominant method is soil scarification with a harrow, and patch scarification and various types of mounding are also common. Ploughing on clear-cuts was banned in Sweden in 1994. Soil scarification can be adapted in various ways to be more gentle by avoiding damage and reducing the impact on, for example, dead wood, watercourses, cultural remains, reindeer grazing and outdoor life[129]. Soil scarification should not cause greater soil impact than what is necessary to facilitate rejuvenation, for example through patchy soil preparation and mounding[130]. In reindeer grazing areas, soil impact should not exceed 20 per cent where the lichen cover is more than 25 percent, or a maximum of 40 per cent if the lichen cover is 10-25 percent[131] (Forestry Act §31 general advice). In forests with a rich biological cultural heritage that is dependent on maintaining soil continuity, soil preparation should also be conducted carefully.

EU Commission guidelines

According to the European Commission's guidelines for closer-to-nature forest management, natural regeneration should be the predominant method of forest regeneration. Planting or seeding can be used when there is limited genetic diversity in the stand, when natural regeneration has failed or for climate adaptation. When planting or seeding, tree seedlings from local stand seed or local provenances from native trees should be used in priority. Non-native tree species may be used in rare cases to increase climate adaptation. Soil preparation shall be avoided or minimised. In the boreal application, natural regeneration shall be the preferred regeneration option, where appropriate in terms of economic viability and site conditions. Planting should be used as a complement where it leads to better growth, layering, tree diversity and climate adaptation. Indigenous tree species should be favoured, and non-native tree species should be used with caution. Movement of provenances (seed and planting material) of native species can be used in some cases to increase climate resilience and biodiversity.

Soil scarification should only be used if necessary to generate sufficient regeneration and should be gentle to minimise impacts on soil and lichen communities.

Assessment

The assessment of the Swedish Environmental Protection Agency and the Swedish Forest Agency is that the proportion of natural regeneration should increase in closer-to-nature forestry in Sweden, and a varied forest with several tree species should be sought. Stands that are naturally regenerated through shelterwood, seed tree stands, thinning or gap felling should be sought on sites with good conditions for achieving satisfactory regeneration. When planting or sowing, there should be a mix of at least 30 percent naturally regenerated trees over the rotation period where suitable conditions exist. A tree species mix that is

[129] Bergkvist et al. 2020.
[130] Magnusson. 2015.
[131] Carlsson and Boström. 2014.

natural for the site and considers the likely effects of climate change should be an objective.

If necessary, natural regeneration should be supplemented with planting to achieve an approved regeneration, climate adaptation, or to increase the tree species mix and the presence of the rarer deciduous tree species rowan, aspen, sallow and oak. For the establishment of these species, fencing or other measures may also be necessary (see chapter 2.5.8).

When planting or sowing, forest reproductive material from different seed sources suitable for the site should be used, both from local provenances, provenances moved to compensate for climate change, and from improved material.

Regeneration with non-native tree species can be done in some cases to strengthen the climate adaptation capacity of forests. This may involve strengthening forest resilience and maintaining its productive capacity. However, effects on both biodiversity and forest production should be carefully analysed before application. The presence of species classified as invasive should be controlled, and species with a high risk of becoming invasive should be recognised in order to take measures to prevent their spread.

Gentle soil scarification with large consideration for various environmental values can be carried out where necessary to achieve satisfactory regrowth according to legal requirements. Soil scarification should not cause greater soil impact than what is necessary to facilitate regeneration. Special consideration is given to dead wood, watercourses, lichen-rich tracts in reindeer grazing areas, the presence of red-listed soil fungi, the risk of erosion and landslides, in forests with biological cultural heritage and in recreational areas. See also chapter 2.5.10.

2.5.2 Ensuring sustainable logging

Land use types and size of clear-cuts

The Swedish forest landscape has been shaped in various ways by large-scale even-aged forestry since the 1950s (see also chapter 2.3). The average size of clear-cuts has decreased since the 1990s and is now around 3.6 ha[132]. The average clear-cut is larger in northern Sweden (about eight hectares) than in southern Sweden (about two hectares). Clear-cut size among the large forest companies is larger (4.6 hectares on average) than among individual forest owners (2.8 hectares on average). The huge clear-cuts of the 1950s, 1960s and 1970s are rare today, although very large clear-cuts are still being created, sometimes edge to edge. Clear-cuts between four and ten hectares constitute the largest accumulated area of clear-cuts in the country (Figure 7). Large clear-cuts of more than 10 hectares occur less frequently in Götaland than in the rest of Sweden. Clear-cuts of over 50 hectares are the least common, occupying a few thousand hectares. Large clear-cut areas, which include the total area of clear-cuts less than 20 metres apart, are most common in southern Norrland (northern Sweden) and least common in Götaland (Figure 8). The largest bare ground areas, over 50 hectares, cover a total of just over 25,000 hectares. The clear-cut and bare ground areas also include

[132] Swedish Forest Agency. 2023e.

clearings that are a consequence of major natural events, such as salvage harvesting after large wildfires and spruce bark beetle infestations.

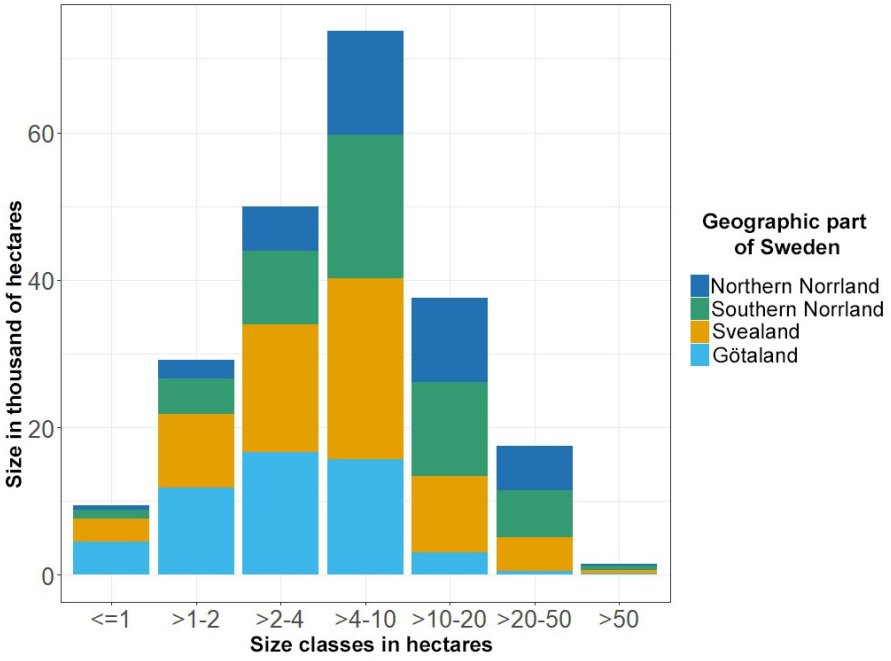


Figure 7. Accumulated areas of clear-cuts for harvested productive forest land on areas reported for felling, distributed by size class and region, for the felling season 2021/2022.[133]

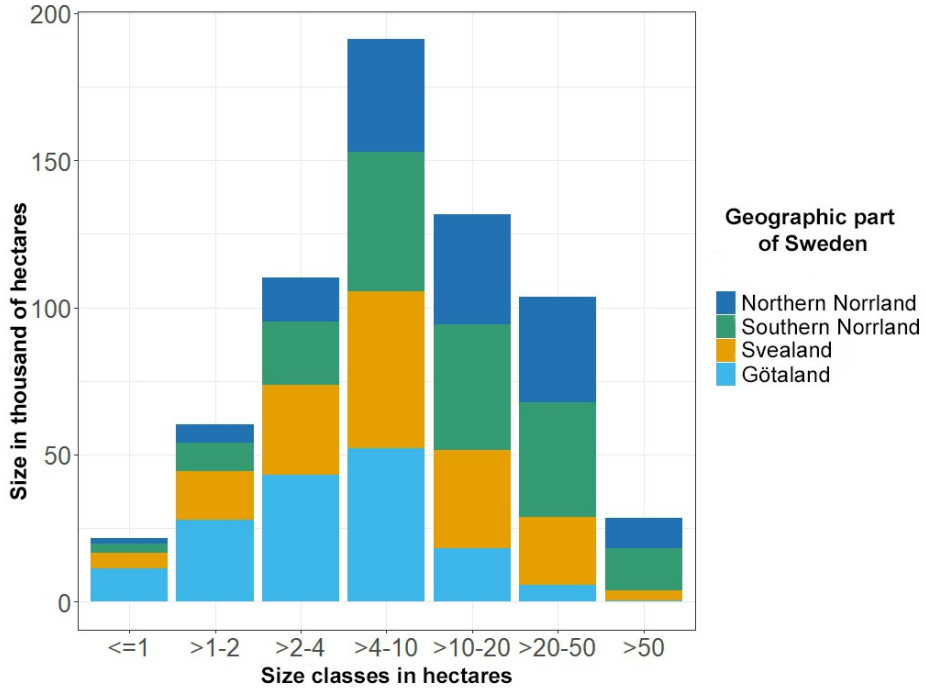


Figure 8. Contiguous bare ground areas by size class and region in 2021. The data are three-year averages for the felling seasons 2018/2019, 2019/2020 and 2020/2021.[134]

[133] Swedish Forest Agency. 2023e.
[134] Swedish Forest Agency. 2023e.

There are certain limitations on the permitted area of final felling in the Forestry Act, for example that management units over 50 hectares may consist of a maximum of 50 percent bare land and forest younger than 20 years. In mountain forests, where permits are required for felling, the size of clear-cuts is limited to 20 hectares in a continuous area within a management unit. Clear-cuts may not be taken up edge to edge. There must be a forest stand or wooded non-productive land in between. A felling permit may not be issued until the regeneration is secured and the average height is about 2.5 metres for pine and about 1.5 metres for spruce. The certifications do not further limit the size of the clear-cuts, but the FSC requires that trees and consideration areas be left to avoid large bare areas[135].

Impact of clear-cuts on forest species

Clear-cuts can have negative effects on forest species, particularly through the disappearance and fragmentation of important habitats such as older forests. Logging is identified as the most important cause of species being red-listed, together with overgrowth of for example previously open and semi-open pastures and fields that were traditionally mowed with scythes.[136] An increased proportion of clear-cuts in the landscape has a negative impact on capercaillie, both in terms of the number of young and the risk of populations becoming isolated[137]. How increasing clear-cut sizes affect different species is unclear, and there is no research showing threshold levels. However, there are studies showing that some species are negatively affected by clear-cuts. Clear-cuts in pine forests without or with few retention trees have a very large impact on the number of species and abundance of mycorrhizal fungi. A study in pine forest shows that 75 percent of the mycorrhizal species in completely cleared areas disappeared, and that the species that remained were probably linked to pine seedlings that were already established in the stand[138]. Mycorrhizal fungi are probably also negatively affected by increasing clear-cut size, as the distance to the forest edge and host trees increases (see Chapter 2.5.4).

A reduced clear-cut size in closer-to-nature forest management can reduce negative impacts on species by preserving habitats and reducing barriers to dispersal between suitable habitats. Reduced clear-cut sizes can also reduce negative impacts on soil and water in connection with harvesting, for example by reducing extreme flows and flooding, reducing the risk of landslides and erosion in sensitive areas, reducing methylation of mercury and reducing the risk of road damage. Reducing the area of clear-cuts within a catchment can also counteract water-related damage downstream[139]. Reduced clear-cut sizes can have positive effects on biodiversity and people's experience of forestry, as large clear-cuts generally impair experience values.

A more varied use, where large bare areas are avoided and where continuous cover forestry methods and multiple use take up a larger place, provides a direction towards a closer-to-nature forest management in Sweden. At present, only about three percent of the forest in Sweden is managed using continuous

[135] FSC. 2020.
[136] Swedish University of Agricultural Sciences. 2020.
[137] Kurki et al. 2000.
[138] Sterkenburg et al. 2019.
[139] Swedish Forest Agency. 2019a.

cover forestry methods, although interest in continuous cover forestry is increasing. In *close-to-nature forestry*, which is practised in a few different places in Sweden, clear-cutting is avoided[140] . The argument is that "creating bare ground of land is such a brutal disturbance that the entire local ecosystem, including the mycorrhiza, is destroyed"[141] . In Germany, where *close-to-nature* forestry is widely practised, many states have banned clear-cuts. The size limit is between 0.3-2 hectares in different states [142, 143]. Clear-cuts are only allowed to minimise major economic losses from natural events such as storms and insect outbreaks, or for measures that have a clear conservation purpose.

Forest areas that have a rich biological cultural heritage through traditional management such as forest grazing, haymaking using scythes and pollarding are favoured by small-scale management, where special consideration is given to the combination of social, cultural and biological values. Such forest areas may, for example, be located next to old crofts, summer farms or in old agricultural areas where the land has been cultivated at low intensity for a long time. It is possible to obtain many clues as to how historical use has affected the forest by using historical maps. The reindeer grazing landscape in the north also has species that are favoured by, for example, reindeer trampling.

Environmental considerations

After the introduction of a new forestry act in 1993 with equal environmental and production objectives, environmental considerations at final felling have been developed with important structures such as retention trees and tree groups, biotopes requiring consideration and buffer zones towards watercourses. The forestry certifications FSC and PEFC place higher demands on environmental considerations than the law. Around 50 industry-wide objectives for good environmental consideration have been developed in recent years and can be seen as part of the forest sector responsibility that complements the Forestry Act. Environmental consideration in final felling covered an average of 9.7 percent of the felling area in the 2017/2018 season, with the highest proportion of consideration in northern Norrland (11.6 per cent) and the lowest in Svealand (7.8 per cent)[144]. In the Swedish Forest Agency's statistics on environmental consideration in final felling, all areas that are included in the tract planning and are not documented in a forest management plan are included as voluntary set-asides. In the Swedish Forest Agency's follow-up of environmental considerations, areas smaller than 1 ha, or 0.5 hectares in broadleaf forests, within harvested tracts are counted as environmental considerations. Larger consideration areas are counted as separate stands/voluntary set-asides.

Current levels of consideration are not sufficient to maintain a high level of biodiversity, especially for red-listed species[145, 146]. There are no clear benchmarks for how much should be left to have a positive effect on biodiversity, but a

[140] Jentzen et al. 2021.
[141] Jentzen et al. 2021.
[142] Klose and Orf. 1998.
[143] Bauhus et al. 2014.
[144] Swedish Forest Agency. 2023e.
[145] Swedish University of Agricultural Sciences. 2020.
[146] Kuuluvainen et al. 2019.

minimum of five to ten percent has been suggested based on expert judgement[147] . Other studies show large positive effects of higher levels of consideration, including a North American study concluding that more than 15 per cent environmental consideration is required to maintain sensitive species and a favourable microclimate, and to gain public acceptance of logging[148].

One area where there is currently great potential for improvement is the preservation of ecological functions and biodiversity in connection with forestry measures such as maintaining or creating functional riparian zones along watercourses. A study of riparian zones of small watercourses in Canada, Finland and Sweden found that the majority of watercourses had inadequate protection. Riparian zones in Sweden were significantly narrower (four metres) than in Finland (15.3 metres) and Canada (15.9 metres)[149]. There were also issues linked to driving damage and soil preparation along the watercourses in both Sweden and Finland. The Swedish Forest Agency's monitoring of consideration shows deficiencies in the riparian buffer zones. For example, one third of the watercourses monitored have no riparian zones.

Unlike many other countries, there is no requirement for a minimum width of riparian buffer zones in Sweden, neither in the Forestry Act nor in the certification standards. In Finland, the FSC standard requires a minimum of 15 metres of edge zone and the PEFC standard requires a minimum of five metres. A research study shows that certification requirements are often not sufficient[150]. The industry-wide objectives for good environmental consideration describe how functional edge zones can be created during clearing, thinning and final felling[151]. Among other things, it describes how the width of the edge zone can vary according to needs in order to preserve ecological functions, and that no felling may take place in run-off areas or biotopes requiring consideration. Although the objectives for good environmental consideration form a good basis for adequate environmental consideration, both research and statistics show that the riparian buffer zones are not sufficient today.

Riparian zones of around 30 metres are often required to maintain the functionality of watercourses[152], and more than 40 metres to maintain biodiversity[153, 154]. There is only a weak correlation between the width of the riparian buffer zone and its functionality[155, 156], which confirms that it is more appropriate to adapt the riparian zone according to the desired function than to use a fixed width. A wide buffer zone on all watercourses would therefore result in unnecessarily large production losses for forestry. Riparian zones should fulfil the requirements for good status under the Water Regulation. The requirement is that no more than 15 percent of the watercourse's immediate vicinity and slope may

[147] Gustafsson et al. 2010.
[148] Aubry et al. 2009.
[149] Kuglerova et al. 2020.
[150] Jyväsjärvi et al. 2020.
[151] Swedish Forest Agency. 2023b.
[152] Sweeney and Newbold. 2014.
[153] Marczak et al. 2010.
[154] Selonen and Kotiaho. 2013.
[155] Jyväsjärvi et al. 2020.
[156] Chellaiah and Kuglerova. 2021.

have no riparian zone[157]. Forestry management along watercourses can also mimic natural disturbances, for example through careful exploitation felling to increase foliage, layering and light penetration. Larger disturbances can be mimicked in drier areas, where trees are harvested down to the water's edge to increase the proportion of deciduous trees.

Another measure to strengthen biodiversity that needs to be implemented on a larger scale is the preservation and re-creation of species-rich edge environments, especially between forest and agricultural land[158]. Half of the forest edges in Sweden are characterised by sharp boundaries between landuse types and have no ecotone at all[159].

Environmental considerations are also important in continuous cover forestry, and natural and cultural values must always be taken into account when harvesting[160]. Although the objectives for good environmental stewardship are designed for even-aged retention forestry, the same type of measures are needed in continuous cover forestry. In addition, measures to favour light-demanding trees and light-demanding dead wood may be needed in, for example, thinning forests. Environmental considerations may be more difficult to discern in forests subjected to continuous cover forestry, and the retained trees may need to be labelled in order to ensure their persistence over time.

EU Commission guidelines

According to the European Commission's guidelines for closer-to-nature forest management, intensive management measures should be avoided when extracting timber and great consideration should be given to soil, water and other valuable environments. Small-scale felling should be preferred, i.e. exploitation and gap felling. The gaps should be a maximum of 0.2-0.5 ha. The European Commission's guidelines contain no recommendation for environmental consideration levels, other than for dead wood (see chapter 2.5.5.).

The boreal application states that closer-to-nature forest management should be based on forest management practices that are adapted to forest type and local conditions, maintain forest biodiversity, promote forest resilience and provide various ecosystem services. Good examples of current forestry practices should be strengthened and adapted to climate change. Retention forestry in combination with prescribed burning or controlled burning on clear-cuts can be used especially in dry and less fertile sites. Shelterwood or gap felling can be used as a more gentle harvesting option and to favour light-demanding species. The boreal application also describes that the current levels of environmental consideration in retention forestry are not sufficient. Retention patches and trees should be permanent and contribute to the preservation of key structures and elements in the forest, as well as biodiversity, especially red-listed species that are dependent on dead wood and old trees. Environmental consideration levels should be based on science.

[157] Swedish Agency for Marine and Water Management. 2019.
[158] Swedish Board of Agriculture. 2018.
[159] Swedish University of Agricultural Sciences. 2015.
[160] Swedish Forest Agency. 2021a.

Assessment

The Swedish Environmental Protection Agency and the Swedish Forest Agency believe that closer-to-nature forest management should focus on being more gentle, more small-scale and more varied than current forestry. The long-term goal is for multi-aged forests to dominate the landscape. Clearings in closer-to-nature forest management should mimic small or medium-sized natural disturbances caused by fire, storms, beavers or insect outbreaks. Closer-to-nature forest management encompasses both adapted even-aged retention forestry, continuous cover forestry methods and certain historical management practices such as coppice forestry. Adapted even-aged retention forestry refers to limitations in the size of the clear-cuts and requirements for greater environmental consideration than in today's forestry.

In closer-to-nature forestry, the use of management methods without clear-cutting, i.e. without gaps larger than 0.25 ha, should gradually increase. The gaps should be adapted to the prevailing conditions and to the desired type of regeneration and can be of varying shapes and sizes. In areas that are managed with adapted even-aged retention forestry, clear-cuts may not exceed two hectares in Götaland and four hectares in the rest of the country. To avoid creating large clear-cuts edge to edge, a new clear-cut should not be created until the adjacent forest has reached 2.5 metres at the earliest. An exception is salvage harvesting after natural disturbances, i.e. when large clearings are created in forest areas that have been extensively damaged. Continuity forests, i.e. forests that have not been clear-cut, are managed using only continuous cover forestry methods without clear-cutting. Forests with an old-growth character are not harvested.

The Swedish Environmental Protection Agency and the Swedish Forest Agency also believe that greater environmental consideration is required in closer-to-nature forest management. Even-aged retention forestry as part of closer-to-nature forest management requires a high degree of environmental consideration to meet the needs of forest species, to preserve ecosystem services and to mimic the effects of natural disturbances. Environmental consideration in even-aged retention forestry and continuous cover forestry should be based on the objectives for good environmental consideration. In the case of even-aged retention forestry, 20 percent of the area should also be left as environmental consideration. The consideration is planned so that large bare areas are avoided, and tree continuity is preserved within the stand. The environmental consideration must be permanent over time. All areas set aside for nature conservation within the felling area, i.e. also voluntary set-asides of less than one hectare, or less than 0.5 hectares for broadleaf forests, are counted as consideration.

Functional riparian zones along watercourses shall be left in all forestry operations. In even-aged retention forestry, an average edge zone of 15 metres on each side of the watercourse must be left over the felling area. No more than 15 per cent of the watercourse may have no buffer zone. Great emphasis is placed on preserving outflow areas and areas important for biodiversity. The width is otherwise adapted to the conditions at the site. Ecotones between forest and agricultural land must be preserved or restored during forestry operations. They should be rich in deciduous trees and at least ten metres wide.

Dead wood is discussed in chapter 3.1.5.

2.5.3 Minimise other management measures

Fertilisation

In Sweden, forest soil fertilisation may be carried out to a limited extent to increase forest production[161]. Where and how the forest may be fertilised is described in the regulations and general advice in §30 of the Forestry Act (1979: 429). The availability of nutrients, and particularly nitrogen, is a strongly limiting factor for forest growth, making nitrogen fertilisation an effective method of increasing growth. A normal application of 150 kilograms of nitrogen per hectare results in an increase in growth of 13 to 20 forest cubic metres per hectare within ten years[162] . In 2022, 9 900 hectares were fertilised, which is 77% lower than the previous year when 42 700 hectares were fertilised. This can be explained by high fertiliser prices caused by the war in Ukraine[163]. Over the last 20 years, the fertilised area has varied between 13 800 hectares and 80 400 hectares per year.

Forest fertilisation affects, among other things, the composition of natural vegetation and can cause nutrient leakage to lakes and rivers[164]. Nitrogen fertilisation also negatively affects lichen growth, and thus reindeer grazing. There are restrictions in the form of protection zones and land exempted from fertilisation, partly to reduce the impact on watercourses and sensitive environments.

Ditching, ditch clearing and remedial drainage

New ditching (land drainage) with the aim of increasing forest production is currently permitted in northern but not in large parts of southern Sweden and central Sweden. A large area of forest land has been drained at some point[165] (see Chapter 2.3.2). Clearing of vegetation and silt may be carried out in old ditches to maintain the function of the ditch and is usually done in connection with final felling. Remedial drainage may be carried out in connection with final felling to enable regeneration on land that risks becoming swamped by felling. Both ditch clearing and remedial drainage are subject to mandatory consultation. Ditch clearing and remedial drainage can cause sludge and nutrient transport to watercourses.

In order to reduce the environmental impact, continuous cover forestry methods and/or shelterwood can be an alternative to ditch clearing and remedial drainage. In the case of ditch cleaning or remedial drainage, sufficient consideration must always be given to environmental values, as described in the forest sector's common objectives for ditch cleaning and remedial drainage [166].

[161] Swedish Forest Agency. 2014.
[162] Swedish Forest Agency. 2014.
[163] Swedish Forest Agency. 2022c.
[164] Swedish Forest Agency. 2014.
[165] Skogskunskap. 2023.
[166] Swedish Forest Agency. 2019b.

Logging residues and ash recycling

Removal of branches and tops (logging residues) as forest fuel after final felling may be carried out in certain areas[167]. The extraction of forest fuel contributes to the fulfilment of the national environmental quality objective "Limited climate impact", but can have a negative impact on the fulfilment of other environmental quality objectives such as "Only natural acidification" and "A rich plant and animal life". Natural and cultural values must be considered in all measures. If necessary, compensatory measures must be taken to ensure that damage does not occur to the forest soil's nutrient balance and buffering capacity. Extraction should not take place on land with high nature values, such as stands with a rich flora, or in nature conservation areas unless the extraction of logging residues is positive for the nature values. Nor should logging residue extraction take place in forests rich in pendulous lichens which are valuable to reindeer husbandry. To protect species that live on dead wood, at least 20 per cent of the logging residues should be left in clearings and dead wood over ten centimetres should be left in the stand. Extraction should only target the most common tree species in the landscape.

Ash recycling can compensate for the nutrients removed during forest fuel extraction, to favour long-term productive capacity and counteract acidification[168] . The ash contains no nitrogen but can affect the soil's content of heavy metals and organic environmental toxins. Ash recycling is subject to authorisation. The ash's content of heavy metals and nutrients must be tested before spreading.

Stump harvesting

Removing stumps to increase biomass extraction means more intensive utilisation of the forest with greater impact on, for example, soil, water, biodiversity and outdoor life[169] . Stump harvesting is allowed in some cases, but its application is very limited.

EU Commission guidelines

According to the European Commission's guidelines on closer-to-nature forest management, organic fertiliser can be used to a limited extent in closer-to-nature forest management to improve tree health and soil nutrient imbalances. The regional application does not mention fertilisation.

Assessment

The assessment of the Swedish Environmental Protection Agency and the Swedish Forestry Agency is that nitrogen fertilisation or ditching is not permitted in closer-to-nature forestry in Sweden. Clearing of existing ditches can be carried out with great consideration for environmental effects downstream in accordance with the objectives of good environmental consideration. In the first instance, alternatives to remedial drainage and ditching should be used, such as shelterwood and adapted felling.

Extraction of logging residues can be done with regard to natural and cultural values if enough dead wood is left in the stand (see chapter 2.5.5). At least 20

[167] Swedish Forest Agency. 2019c.
[168] Swedish Forest Agency. 2019c.
[169] Swedish Forest Agency. 2009a.

percent of branches and tops and dead wood over 10 centimetres are left in the stand. Stump harvesting is not allowed. Ash recycling can be carried out to compensate for nutrient loss in connection with logging residue extraction.

2.5.4 Conserving and restoring soil and water ecosystems

Forestry operations affect soil and water in a variety of ways. Soil scarification is currently carried out on about 87 percent of the area reported for final felling[170] . Soil scarification can lead to an increased risk of erosion, as well as transport of organic material, nutrients and heavy metals from soil to water.

Driving in forest land

Driving with heavy machinery can cause, among other things, erosion and compaction that can affect the root growth of remaining trees[171]. Driving over watercourses can lead to damage to streambeds and soil and create water obstacles for fish and other aquatic organisms. The forestry sector's common objectives for good environmental practice contain objectives for consideration when driving in forest land and crossing watercourses, with the aim of reducing the negative impact of driving on land and water[172] .

Ecologically functional border zones

A key measure for consideration of soil and water is to leave ecologically functional buffer zones along lakes and watercourses. The Swedish Forest Agency's monitoring of consideration has shown that one third of the water edges in the monitoring programme had no buffer zones at all. The forestry sector's objectives for good environmental consideration also provide guidance for the design of edge zones. In Sweden, a fixed width of the buffer zone is not used. Rather, the width of the zone is allowed to vary, so that wider buffer zones are left, for example, where there are biotopes requiring consideration or outflow areas for water along the watercourse. Along other stretches, the buffer zones are allowed to be narrower, if the functions that are important for the water (e.g. shading and supply of food and dead wood) can be maintained (see chapter 2.5.2).

Consideration of mycorrhizal fungi

Even-aged retention forestry is unfavourable to mycorrhizal fungi that live in symbiosis with the roots of the trees, and the occurrence of fungi after felling is dependent on the presence of trees left as consideration and tree-bearing forest edges. Species numbers and diversity of fungi in older pine forests gradually decrease with distance from the trees/forest edge[173]. Fruiting bodies can form up to 10 metres from the trees, but at that distance the diversity of fungal mycelium is severely limited. Mycelium has been found up to 25 metres from standing trees, but the distance varies depending on the species and environmental conditions. Even-aged forestry has a very large impact on mycorrhizal communities, and studies show that it can take 50 to 90 years after felling before species richness

[170] Swedish Forest Agency. 2023e.
[171] Magnusson. 2015.
[172] Swedish Forest Agency. 2023b.
[173] Sterkenburg et al. 2019.

and diversity starts to resemble that of older forests[174] . The sensitivity and ability to recolonise after final felling varies depending on the fungal species.

Continuous cover forest management that maintains high tree continuity is one way to conserve mycorrhizal diversity in older forests[175] . Retention trees left in even- aged retention forestry can also conserve mycorrhizal species, but to conserve rarer species, many retention trees need to be left. More trees left increases the likelihood that the particular tree or trees to which the fungus is attached will survive. A study from a pine forest in Effaråsen showed that the diversity of mycorrhiza was almost intact when 50 per cent of the trees were left and the distance to the nearest retention tree did not exceed 5 metres[176] . Exactly what levels of consideration are sufficient cannot be answered today, but the more trees that are retained, the greater the likelihood that more mycorrhizal species will survive, and that the mycorrhizal community will be less affected.

EU Commission guidelines

According to the European Commission's guidelines on closer-to-nature forest management, the condition of the soil is crucial to the condition of the forest and to the role of the forest in harbouring biodiversity and mitigating climate change. Diversity of fungi is fundamental to forest health and vice versa. Ploughing and tillage affect fungal and soil health, and forest resilience. Negative impacts must be avoided by using techniques that have the least possible impact. Preserving the quantity and quality of aquatic ecosystems makes it possible to reduce the impact of drought on surrounding ecosystems and human activity. Riparian forests are an important part of watercourse dynamics and play an important role in providing multiple ecosystem services. In the boreal application, soil damage must be prevented during felling and great consideration must be given to natural and cultural values. Soil scarification should only be used in exceptional cases.

Assessment

The Swedish Forest Agency and the Environmental Protection Agency believe that ecologically functional buffer zones along lakes and watercourses are central to closer-to-nature forest management. For those areas that currently lack functional buffer zones, restoration or re-creation is required. In connection with lakes and watercourses, there must always be a zone that is exempt from driving and soil scarification (see chapter 2.5.2).

Driving damage and soil compaction must be minimised in connection with harvesting. The planning and execution of driving must therefore be carried out carefully. In sensitive areas, driving may only take place on frozen ground or in dry summer conditions. Skid trails and base roads need to be carefully planned and covered with slash were needed. Passages over watercourses are avoided in the first instance by choosing an alternative logging route. If a crossing is necessary, the measure is adapted to minimise the impact on the aquatic environment, for example by using timber bridges and log mats.

[174] Lindahl et al. 2021.
[175] Rosenvald & Löhmus. 2008.
[176] Djupström et al. 2022.

In sensitive areas, forest management should be adapted to prevent erosion, landslides and mudflows. For example, storm-resistant stands with stratification and multiple tree species should be favoured.

To preserve the diversity of mycorrhizal fungi in areas with an abundance of red-listed species, continuous cover forestry methods that preserve tree continuity are used. Forest biodiversity hot spots are not harvested but left as set-asides or nature consideration areas. Retention trees are left scattered in the stand. Nature value trees and old trees are prioritised as retention trees. No, or gentle, soil scarification is carried out.

2.5.5 Conserving and creating dead wood

The availability and quality of dead wood is a very important factor for forest-living species[177]. The amount of dead wood is significantly lower in today's managed forests than in a natural landscape, although the volume of dead wood has increased by 25 percent since the mid-1990s[178]. About half of the forest-dwelling red-listed species are dependent on dead wood. Many specialised species require wood of different qualities, for example dead wood from slow-growing trees, fire-killed and charred wood or hollow trees with wood mould[179] . The amount of dead wood is often significantly higher in natural forests that have not been managed on a large scale, in riparian forests and along watercourses[180] . The volume of dead wood on productive forestland, outside formally protected areas and voluntary set-asides, is about 9.8 cubic metres per hectare[181] . The available dead wood is of low quality and is dominated by small-diameter dead wood in early stages of decomposition and there is little variation in terms of tree species, diameter and degree of decomposition.[182]

Thresholds for dead wood that meet the requirements of forest species are significantly higher than current levels. Thresholds are estimated to be approximately 20-30 cubic metres per hectare in boreal forests, 30-40 cubic metres per hectare in mixed coniferous forests close to mountains and 30-50 cubic metres per hectare in broadleaf forests with oak and beech[183]. The thresholds are derived from studies in nature reserves or other areas with high nature values where there is high-quality wood, for example from slow-growing trees and deciduous trees, in contrast to today's production forests.

Active creation of dead and dying wood

In order to increase the quantity and quality of dead wood in the forest landscape, dead wood can be created through conservation management in nature conservation areas or in connection with forestry measures, for example by creating high stumps, stripping the trees' bark, or by making use of small scale prescribed burns on individual trees to create charred wood[184]. Dense groups of

[177] Esseen et al. 1997.
[178] Jonsson et al. 2016.
[179] Swedish Forest Agency. 2022a.
[180] Esseen et al. 1997.
[181] Swedish University of Agricultural Sciences. 2023.
[182] Jonsson et al. 2016.
[183] Müller and Büetler. 2010.
[184] Swedish Forest Agency. 2023f.

deciduous trees can also be left untouched to favour the creation of dead wood through self-thinning. The active nature conservation measures can be implemented in retention areas to reduce production losses and to ensure that the trees or wood are retained also during the following silvicultural treatments. Consideration should be given to the risk of damage from, for example, spruce bark beetle infestation. Larger amounts of dead wood can be concentrated in nature conservation set-asides, provided they exist in the landscape, and in retention areas in the production forest.

Consideration of dead wood

To preserve existing dead wood, lying dead wood can be marked before driving with a machine. All mechanised driving is done with great care so as not to damage the dead wood.

EU Commission guidelines

According to the European Commission's guidelines, sufficient dead wood for species' needs should be left, including wood in various stages of decay, standing and dying wood and hollow trees. The volume, density and location of dead wood is determined with consideration to fire safety, insect pests and outdoor recreation. The boreal application states that dead wood levels should be increased by leaving dying and dead trees as nature consideration and by actively creating dead wood, for example through the creation of high stumps.

Assessment

The Swedish Environmental Protection Agency and the Swedish Forest Agency assess that the quality and volume of dead and dying wood needs to increase in the forest landscape in order to eventually reach biodiversity thresholds in different regions. Proposed thresholds at landscape level are around 20-30 cubic metres per hectare in boreal forest, around 30-40 cubic metres per hectare in mixed coniferous forest in mountainous areas and around 30-50 cubic metres per hectare in broadleaf forest. At stand level, there should be at least five cubic metres of dead wood per hectare in conifer-dominated stands and at least ten cubic metres per hectare in mixed stands and deciduous stands. In landscapes with few formally protected areas and voluntary set-asides, larger volumes of dead wood are required in production forests. Dead and dying wood is actively created in all forestry operations.

The amount of dead coniferous wood in production forests should not exceed the maximum volume per hectare of fresh coniferous wood per year stated in the Forestry Act. To reduce the risk of spruce bark beetle infestation, dead wood can be created from deciduous trees, and dead wood from conifers can be created successively on several occasions. All mechanised driving in forest land is done with great care so as not to damage existing dead wood.

2.5.6 Nature conservation set-asides

The Biodiversity Strategy aims to have 30% of the EU's land and sea area legally protected by 2030, with 10% of the EU's land area strictly protected, including all remaining pristine and old-growth forests. The percentage of protection should be

representative within each biogeographic zone[185] . Research shows similar threshold levels (20-30%) of suitable habitat in the landscape for the conservation of many forest species (see also chapter 2.3).

Formal and voluntary set-asides

In Sweden, formal protection and voluntary nature conservation set-asides are important components of the current Swedish model for nature conservation in forestry, together with the environmental considerations that must be implemented during forestry operations to preserve biological, cultural-historical and social values[186, 187] . Today, 8.9 percent of the total forest land is formally protected and 4.9 percent is voluntarily set-aside by forest owners[188] . 61 percent of the formally protected forest land is located in the mountainous region (alpine zone).

The FSC and PEFC certification standards require at least five per cent of the productive forest land to be voluntarily set-aside, and FSC certification also requires that at least another five per cent of the productive forest land area be managed with long-term conservation and development of natural and/or social values as the primary objective[189,190]. According to the national strategy for the formal protection of forests, which is currently being revised, core forest areas for biodiversity (forests with high natural values) are to be prioritised in the protection of forests and weighed together with the needs of outdoor recreation, cultural heritage management, reindeer husbandry and various social interests[191]. There are also regional strategies for forest protection at the county level.

To best contribute to biodiversity and national and regional strategies, the choice of voluntary set-asides should follow similar priorities. This means that core forest areas for biodiversity are prioritised over forest areas with currently low natural values. The set-asides are primarily located in landscape units with high biodiversity values[192] , other designated areas with high nature values, or in the vicinity of existing formally protected areas. The set-asides consist of prioritised forest types. In some cases, set-asides can also be prioritised with the aim to strengthen the green infrastructure, for example in designated corridors in regional action plans for green infrastructure.

Nature conservation management

Conservation management to preserve or restore natural values in formally protected areas and voluntarily set-aside areas is needed to meet the habitat needs of threatened forest species. There is a great need for nature conservation management. The need for nature conservation management is described, for example, in the *Prioritised Action Framework* (PAF) for Sweden's Natura 2000 sites and in the Swedish Forest Agency's inventory of the need for management in nature conservation agreements and habitat protection areas managed by the

[185] European Commission. 2023b.
[186] KSLA. 2009.
[187] Lindahl et al. 2017.
[188] Statistics Sweden. 2022.
[189] PEFC. 2017.
[190] FSC. 2020.
[191] Swedish Environmental Protection Agency & Swedish Forest Agency. 2017.
[192] Landscape sections with particularly high ecological conservation values

Agency[193]. Prescribed burning is particularly important in the boreal landscape, which is characterised by fire disturbance and hosts species that are both fire-dependent and fire-favoured. Wildfires are expected to increase in a changing climate. They can contribute to the conservation of fire-dependent and fire-favoured species through nature conservation set-asides or by conserving substrates such as dead trees and dead charred wood in retention areas.

EU Commission guidelines

According to the European Commission's guidelines, voluntary set-asides constitute a tool to support closer-to-nature forestry and to integrate biodiversity conservation into forest management. Voluntary set-aside should be designated in areas of high biodiversity importance. This applies to areas where, for example, IUCN red-listed species and nationally threatened species are found. They should also aim to maintain a diversity of habitats and networks between habitats. The boreal application states that voluntary set-asides are important for preserving areas with high nature values, including woodland key habitats and other value cores. They are of great importance for rare and specialised species and can be crucial for creating interconnected habitats (green infrastructure).

Assessment

The Swedish Environmental Protection Agency and the Swedish Forest Agency believe that formally protected areas and voluntary set-asides are important elements in preserving biodiversity in the forest landscape and a complement to closer-to-nature forest management. In combination with measures in production forests, nature conservation set-asides should have the aim and ambition of achieving the objectives of the EU biodiversity strategy for 2030. For the set-asides to provide the greatest benefit for biodiversity, high nature values at stand and landscape level should be prioritised for protection. Core forest areas for biodiversity and habitats of conservation concern should be completely excluded from forestry. The selection of set-asides should primarily follow national and regional strategies for forest protection. Nature conservation management should be carried out in nature conservation set-asides to preserve biodiversity, in accordance with the national strategy for nature and culture conservation management of tree-bearing land managed for nature conservation purposes[194] .

2.5.7 Species conservation

Action programmes for threatened species

Action programmes for threatened species and habitats and their implementation are important for species conservation. They contribute to the national environmental quality objective "A rich plant and animal life"[195]. The action programmes have been put in place for species that have been assessed as needing special measures and that cannot be conserved solely through area protection or other measures. Collaboration across landowner boundaries is often required to meet the needs of the species, and most of the work takes place outside protected areas. The practical work arising from the action programme is run by the county administrative boards in collaboration with various stakeholders. Examples of

[193] Swedish Forest Agency. 2021b.
[194] Swedish Environmental Protection Agency and Swedish Forest Agency. 2023.
[195] Swedish Environmental Protection Agency. 2023b.

action programmes involving forests are 'Fire insects in boreal forests', 'White-backed woodpecker' and 'the long-horned beetle *Plagionotus detritus'*.

Knowledge of species and adaptation of forestry measures

To preserve red-listed and protected species in connection with forestry operations, the forest owner must be aware of which species are present in the area and what consideration they require. The government assignment on species protection in the forest, which was reported in September 2023, highlights the need to work preventively with species that are protected under the Species Protection Act[196]. In the first instance, forest management should be adapted to the protected species so that no prohibited impact occurs. This can be done by taking sufficient environmental consideration, retaining a functional nesting site or avoiding measures during the period when protected species are sensitive to disturbance. Sometimes more extensive measures are required or the forestry operation is avoided altogether.

EU Commission guidelines

In the European Commission's guidelines for closer-to-nature forest management, species conservation is included as a key measure but is not described further. The boreal application describes the need for nature conservation set-asides and prescribed burning of nature conservation set-asides and clearcuts to conserve fire-dependent species, as well as the need for sufficient environmental consideration to conserve threatened and red-listed species.

Assessment

The Swedish Environmental Protection Agency and the Swedish Forest Agency believe that knowledge of and consideration for species of conservation concern and their habitats need to increase in closer-to-nature forestry. Collaboration on action programmes for threatened species should be used to conserve species in closer-to-nature forestry. Forest owners should be aware of the occurrence of protected and red-listed species on their land and make sufficient adaptations to avoid damaging them.

2.5.8 Responsible ungulate management

Ungulates are an important component of biodiversity, and in general, moderate browsing pressure has a positive impact on biodiversity[197]. Locally, browsing pressure can be high and cause significant forest damage and inhibit the establishment of biologically important deciduous trees[198]. Browsing of pine mainly results in large production losses in forestry, while browsing of rowan, aspen, goat-willow and oak has a negative impact on biodiversity associated with these species.

Swedish wildlife management should be based on the species' role in ecosystems, where management should endeavour to achieve densities that provide the best overall benefit from various ecosystem services such as hunting, outdoor recreation and biodiversity[199]. At the same time, dense game populations cause

[196] Swedish Forest Agency and Swedish Environmental Protection Agency. 2023b.
[197] Swedish Environmental Protection Agency. 2019a.
[198] Swedish Forest Agency. 2023g.
[199] Swedish Environmental Protection Agency. 2022a.

damage to agriculture and forestry, among other things, and wildlife management has a responsibility to help limit this damage. Ungulates moves across property boundaries, and a landscape perspective on both ungulate management and forage-adapted forest management is therefore necessary to deal with the problem of browsing damage.

Active wildlife management and adapted forest management

To reduce damage from ungulate browsing and increase tree diversity, especially of deciduous trees, in areas with high browsing pressure, ungulate populations can be regulated by active wildlife management. Forest management can also be adapted to increase forage availability, for example by increasing the proportion of deciduous trees and widening buffer zones and ecotones.

Fencing and anti-browsing protection products

To increase the proportion of deciduous trees in areas with high ungulate browsing pressure, fencing can be used. Southern broadleaf forests are particularly vulnerable to wildlife grazing, and fencing is often required to bring up a regeneration of broadleaved trees. Fencing of broadleaved trees on production land is eligible for support through the Swedish Forest Agency's broadleaf support programme. The use of approved anti-browsing protection products can be another way of favouring deciduous trees and reducing production losses from ungulate browsing.

EU Commission guidelines

The European Commission's guidelines to closer-to-nature forest management describe that ungulate management is important to address, as it greatly affects forest regeneration. To protect seedlings from browsing, fencing, regulation of ungulate populations or preventive management measures can be applied. In the boreal application, it is emphasised that ungulates are an important component of Europe's boreal forests. When browsing pressure is high, countermeasures such as hunting, repellents, and fencing of young forest stands are necessary. Balanced wildlife management needs to take into account both economic and ecological factors.

Assessment

The Swedish Environmental Protection Agency and the Swedish Forest Agency believe that in closer-to-nature forest management, ungulates should be managed from the various perspectives of wildlife management: conservation of wildlife species, utilisation of wildlife as a resource and limitation of damage and undesirable consequences of wildlife.

Active ungulate management is needed to balance wildlife populations with respect to forage availability and damage levels. At the same time, forest management should be adapted to increase the amount of forage. To increase the presence of rowan, aspen, goat-willow and oak, fencing of young deciduous stands or individual trees can be applied. Authorised wildlife protection products can be used in some cases to benefit rowan, aspen, goat-willow and oak and reduce production losses.

2.5.9 Landscape planning

After almost 200 years of commercial forestry, the Swedish forest landscape is heavily dominated by managed forests, and the remaining forests with high nature values mainly occur as isolated fragments. In addition to the loss of natural forest areas, this means that connectivity between habitats is poor and there are major deficiencies in the forest landscape's green infrastructure[200] .

Landscape planning is an effective tool for strengthening natural values, creating coherent habitats and increasing variation in the forest landscape[201] . Landscape planning is also a basis for sustainable forest development, where the forest, its values and users are viewed as a whole. Landscape planning is also fundamental to the EU's biodiversity and green infrastructure strategies. The European Landscape Convention emphasises that the landscape is a common asset and responsibility, where ecological, social, cultural, environmental and economic values meet.

Landscape planning is based on knowledge of where there are high nature values in the landscape and where various initiatives will be most beneficial. There are several existing bases for landscape planning. The county administrative boards' regional action plans for green infrastructure focus both on challenges and proposals for concrete measures in various areas of intervention for green infrastructure and have identified high-value landscapes for most counties. The Environmental Protection Agency has carried out a mapping exercise that shows the presence of continuity forests and natural forests at the forest patch level. The mapping can be used by various stakeholders as a knowledge and planning basis at both strategic and operational levels to preserve and take account of valuable forests for biodiversity, reindeer husbandry and outdoor life.

SLU's Species Occurrence System with known species occurrences, the forest sector objectives for good environmental practice and various open forestry data can serve as a basis for landscape planning. The objectives for good environmental consideration provide guidance on how environmental consideration can be adapted to the natural values on the site, such as care-demanding habitats, trees with natural values, dead wood and edge zones along watercourses and wetlands. The Swedish Forest Agency and the Swedish Environmental Protection Agency have an ongoing government assignment to develop digital geographical knowledge databases on natural and cultural environment values, which was reported in June 2023 and which may constitute an important basis for landscape planning[202] . There are also various open map services that show natural values or the likelihood of natural values in forests[203, 204, 205] .

In Sweden there are several good examples of landscape planning with the aim of preserving and strengthening natural values in a landscape, such as Sveaskog's

[200] Jonsson et al. 2022.
[201] Swedish Environmental Protection Agency. 2019b.
[202] Swedish Forest Agency & Swedish Environmental Protection Agency. 2023a.
[203] Swedish Environmental Protection Agency. 2023c.
[204] Bubnicki et al. 2023.
[205] Swedish Forest Agency. 2023h.

ecoparks, which are large contiguous landscapes of at least 500 hectares where at least half the productive area is set aside for nature conservation and future management is described in an ecopark plan. The stands' target classes and levels of environmental consideration are regulated in a nature conservation agreement with the Swedish Forest Agency that is valid for 50 years. Landscape planning of conservation set-asides has also been applied in various ways in forestry, for example through green forestry plans in private forestry, and ecological landscape planning among FSC-certified large forest owners.

Formally protected areas and voluntary set-asides of areas with high nature values are an important part of preserving important habitats and creating a green infrastructure in the forest landscape; they are discussed in section 2.5.6.

EU Commission guidelines

According to the European Commission's guidelines, closer-to-nature forest management must take into account three scales: tree, stand and landscape level. In the boreal application, the landscape perspective is described as critical in closer-to-nature forest management. Structures and substrates, cultural and nature conservation areas, roads, distribution of measures in time and space, conditions for red-listed species and greater connectivity in the landscape are included. Landscape-adapted management can often be more easily carried out by larger forest owners. Open data and collaboration with authorities and other forest owners can make it easier for small forest owners.

Assessment

The Swedish Environmental Protection Agency and the Swedish Forest Agency consider that the landscape perspective should be taken into account when planning measures in closer-to-nature forest management.

The proportion of uneven-aged forest stands should increase in the landscape by 2030 and account for at least two-thirds of the landscape by 2050. This will be achieved by increasing the use of continuous cover forestry and adaptation of retention forestry. The proportion of deciduous trees will increase in the landscape in the continental and boreal zones.

Active nature conservation to maintain and strengthen the natural values in the landscape should be applied in connection with production measures, such as the creation of dead wood and resinous wood, clearing to support deciduous trees and the creation of forest-edge environments rich in bushes and deciduous trees. The active measures can preferably be carried out in retention areas to reduce the impact on forestry.

In reindeer grazing areas, felling is planned so that a continuity of ground and pendulous lichens is maintained over time in the landscape. Forest roads should be planned from a landscape perspective to reduce fragmentation of the forest landscape.

Large landowners always plan forestry measures from a landscape perspective. One approach should be for larger forest owners to eventually have a forestry plan or equivalent that is adapted to closer-to-nature forest management and is based on

the landscape perspective. Voluntary set-asides, environmental considerations, distribution of forestry measures in time and space and the creation of a functional green infrastructure for species of conservation concern should be included in the planning. Smaller forest owners take advantage of information and/or counselling on natural values at landscape level.

In this report, "landscape" refers to large contiguous areas. A landscape may, for example, consist of catchment areas or sub-catchment areas, high-value landscape or ecoparks. For smaller forest owners, the landscape division can be based on management units, where known natural values in the surrounding landscape are considered in planning.

2.5.10 Adaptations to reindeer husbandry

Connectivity between lichen-rich forests

Increased connectivity of old forests is of great importance for Sami culture and reindeer husbandry. Improved connectivity of lichen-rich old forests can be achieved through closer-to-nature forest management and other similar management practices. This would make it easier for reindeers to move across continuous pastures and potentially also increase the availability of arboreal lichens in the forest.

The sharp decline of lichens is a major threat to the survival of reindeer husbandry. Lichens are crucial to the survival of reindeers and, by extension, Sami culture. Lichen-rich forests have declined by an estimated 70 percent over a period of 60 years[206] . Reindeer lichens (*Cladonia* spp.) are often found in older forests on sandy and dry soils. Reindeers also eat beard lichens, *Bryoria*-lichens and other pendulous lichens that often thrive in older forests. In young, even-aged stands, both types of lichens are often absent. This is due to changes in soil conditions as a result of soil scarification, emerging dark young forest and the fact that pendulous lichens need to spread into the new growing forest again if all the trees were harvested at the same time, which takes time.

Adapting forest management to reindeer husbandry

Lodgepole pine creates migration barriers for reindeer and the new growing stands are generally far too dark for reindeer lichens to thrive. The factors that affect reindeer and, by extension, the Sami's ability to practise reindeer husbandry are a combination of various types of migration barriers, the reduction and fragmentation of land rich in ground lichens, the cumulative effects of various land-use activities in the landscape and the effects of climate change. Closer-to-nature forest management should be adapted to contribute to an improved situation for reindeer husbandry, both at stand and landscape level. See also chapter 2.5.4 in the Swedish version of the report.

EU Commission guidelines

The boreal application of the European Commission's guidelines highlights that a continuous dialogue between the Sami population and forest owners is crucial in closer-to-nature forest management. Consultation and cooperation with the Sami population on measures that may have a direct impact on them according to the

[206] Sandström et al. 2016.

principle of 'Free Prior Informed Consent' (FPIC[207]) is a key to preserving traditional lifestyles, biodiversity and ecosystems. See also chapter 2.4.

Assessment

The Swedish Environmental Protection Agency and the Swedish Forest Agency consider that closer-to-nature forestry in the reindeer husbandry area should be planned from a landscape perspective and take great account of the needs of the Sami people and reindeer husbandry. When planning management measures that affect reindeer husbandry in the reindeer husbandry area, collaboration with the Sami village concerned is offered according to FPIC. Connectivity between lichen-rich forests important for reindeer grazing and for the movement and herding of reindeer is preserved and increased. No regeneration takes place with lodgepole pine. Existing lodgepole pine stands in the reindeer husbandry area are eventually converted to a more natural state.

Nature consideration and forestry methods are adapted to reindeer husbandry, which involves retaining trees with pendulous lichens, creating lighter, more open forests to favour ground lichens through thinning or gap felling, aiming for sparser stands after clearing and thinning, and avoiding or carrying out gentle soil scarification on lichen-rich areas (the government commission "The State leads the way" discusses what forestry adapted to reindeer husbandry could entail[208]). Gentle intermittent (patchy) or targeted soil scarification is applied on lichen-rich land and soil scarification is avoided completely on lichen-rich areas. Older lichen-rich lands are managed with small-scale forestry. If they constitute care-demanding habitats, they should be set aside as retention patches or voluntary set-asides. Consideration is given to culturally important Sami sites and cultural remains.

[207] FAO. 2016.
[208] Swedish Forest Agency. 2023i.

3 Proposed definition of closer-to-nature forest management in a Swedish context

3.1 Suggested definition

The Swedish Environmental Protection Agency and the Swedish Forest Agency propose the following definition:

Closer-to-nature forest management mimics natural disturbance processes, creates diverse forests and strengthens the environmental values of the forest landscape. Management is based on a landscape perspective and includes adapted even-aged retention forestry, continuous cover forestry and certain historical forms of forest management.

The aim of closer-to-nature forest management is to strengthen the role of forests in sustainable development. Biomass extraction from forests should be done in a way that is gentle on nature. Forest management should mainly mimic a combination of small and medium-sized disturbances caused by fire, grazing, insect outbreaks, fungal attacks, wind and hydrological disturbances. Small- and medium-scale disturbances include gap and cohort dynamics (repeated disturbances that create distinct cohorts of trees). Large-scale disturbances include stand-replacing disturbances. Forest history must be taken into account when choosing a measure.

The aim is to conduct economically viable forest management that (1) ensures a long-term supply of products and services from the forest; (2) increases the diversity of the landscape with a greater proportion of mixed and mixed-aged forests; (3) preserves and enhances biodiversity in the forest landscape; (4) increases the resilience of forests to damage and climate change.

The definition applies to the whole of Sweden with some regional adjustments to the alpine, boreal and continental regions according to the division in the European Commission's guidelines. The emphasis is mainly on the boreal region since this region covers the largest area of Sweden. Adapted even-aged retention forestry means, among other things, limited clearcut size and increased environmental consideration.

The definition is concretised in ten key measures based on the European Commission's guidelines, which have been adapted to a Swedish context based on the assessments in Chapter 2.5. For all key measures, a *direction (increase or decrease)* towards closer-to-nature forest management is presented. In cases where the Swedish Environmental Protection Agency and the Swedish Forest Agency have judged that the documentation is sufficient, we also specify numerical levels or objectives. These are based on current knowledge, research and expert judgement, and may change if the evidence changes.

3.1.1 Promoting natural regeneration

- Increased proportion of stands that are naturally regenerated through the use of shelterwood, seed trees, selection cutting or gap felling on sites with favourable conditions.

Direction	
Natural regeneration	↑
Tree species composition	↑
Deciduous forest/trees	↑
Soil scarification	↓

- Natural regeneration is supplemented, if necessary, by planting to achieve an approved regeneration according to the Forestry Act, to favour climate adaptation, or to increase the tree species mix.

- When planting or sowing is applied, a mix of 30 percent naturally regenerated trees over the rotation period should be the goal where suitable conditions exist. A mix of tree species that is natural for the site and that takes into account the likely effects of climate change should be an objective.

- Mixed forests and an increased proportion of deciduous trees are promoted through regeneration and management measures.

- When planting or sowing, different seed sources should be used and provenances of seed and planting material can be moved to strengthen climate adaptation.

- Regeneration with non-native tree species can be allowed to strengthen the climate adaptation of forests. This may involve strengthening forest resilience and maintaining its productive capacity. Effects on both biodiversity and forest production should be carefully analysed before application.

- Invasive species are controlled to prevent their spread. Species at high risk of becoming invasive are recognised to take measures to prevent their spread.

- Gentle soil scarification with great consideration for various environmental values is carried out in stands where it is required to achieve an approved regeneration according to the Forestry Act. To facilitate rejuvenation, soil scarification should not cause greater soil impact than necessary.

- During soil scarification, special consideration must be given to dead wood, watercourses, ground lichens in reindeer grazing areas, the presence of red-listed soil fungi, erosion and landslide risk, forests with a rich biological cultural heritage and recreational areas.

3.1.2 Ensuring sustainable logging

Direction	
Continuous cover forestry	↑
Adapted rotation forestry	↑
Environmental consideration	↑
Biological cultural heritage	↑
Clear-cut size	↓

- In areas managed with adapted even-aged retention forestry, clearcuts may be taken up to a maximum of two hectares in Götaland and four hectares in the rest of the country. An exception is salvage harvesting after major natural disturbances, i.e. larger clearings can be created in forest areas that have suffered extensive damage.

- Environmental consideration in the case of adapted even-aged retention forestry and continuous cover forestry must be based on the Forestry Act and the objectives for good environmental consideration. When applying adapted even-aged retention forestry, at least 20 percent of the area must also be left as environmental consideration. Consideration is planned so that large bare areas are avoided and high nature values and tree continuity are preserved. The clearcuts must not be contiguous; there must be a forest stand or low-productive forest in between. The consideration must be permanent over time.

- Forests with continuity values, i.e. forests resulting from natural regeneration and often with elements of older trees and dead wood in various stages of decomposition, should only be managed using continuous cover forestry methods.

- Forest areas with a rich biological cultural heritage, resulting from, for example, forest grazing, haymaking and tree pollarding (pruning of all branches at regular intervals of between 3 and 20 years), are predominantly managed using continuous cover forestry methods. Particular attention is paid to the combination of social, cultural and biological values.

- Functional riparian zones along watercourses shall be left in all forestry operations. In the case of adapted even-aged retention forestry, an average buffer zone of at least 15 metres on each side of the watercourse shall be left over the felling area. No more than 15 percent of the watercourse may have no buffer zone.

- Ecotone habitats between forest and agricultural land should be preserved or restored during forestry operations. The ecotones should be rich in deciduous trees and flowering shrubs, and should be at least ten metres wide.

3.1.3 Minimise other management measures

Direction	
Ditch cleaning	↓
Logging residue outtake	↓
Ash recycling	↓
Ditching	X
Stump harvesting	X
Nitrogen fertilisation	X

- Nitrogen fertilisation or ditching is not allowed. Ash recycling can be carried out to compensate for nutrient losses from the extraction of logging residues.

- Clearing of existing ditches should be carried out with great consideration for downstream environmental effects according to the objective of good environmental practice. Alternative methods to ditch clearing with shelterwood should always be considered.

- Logging residue extraction can be done with consideration to natural and cultural values, and when enough dead wood has been left in the stand (see chapter 3.1.5). At least 20 percent of branches and tops and all dead wood over ten centimetres should be left in the stand. Stump harvesting is not allowed.

3.1.4 Conserving and restoring soil and water ecosystems

Direction	
Edge zones towards water	↑
Retention trees	↑
Soil damage	↓

- Driving damage from forest machines should always be minimised during harvesting. In sensitive areas, driving may only take place on frozen ground or in dry summer conditions.

- In areas with an abundance of red-listed mycorrhizal fungi, continuous cover forestry methods that preserve tree continuity shall be applied. Species diversity hot spots are not harvested. Retention trees are left scattered in the stand. Trees with high value for nature conservation and old trees are primarily retained as consideration trees.

- In the vicinity of lakes and watercourses, there should always be a zone free from driving and soil scarification.

3.1.5 Preserving and creating dead wood

Direction	
Dead and dying wood	↑

- Dead or dying wood is created during forestry operations to increase the quantity or quality of dead wood.

- At the stand level, there should be at least five cubic metres of dead wood per hectare in conifer-dominated stands and at least ten cubic metres per hectare in mixed and deciduous stands. Consideration is given to the risk of damage such as spruce bark beetle infestation.

- At the landscape level, dead wood should eventually occur in volumes corresponding to threshold amounts in different regions, including nature conservation set-asides and low-productive forest. This means around 20-30 cubic metres per hectare in boreal forests, around 30-40 cubic metres per hectare in mixed coniferous forests in the mountains and around 30-50 cubic metres per hectare in broadleaf forests.

- All mechanised driving is done with great care so as not to damage existing dead wood.

3.1.6 Nature conservation set-asides

- Formally protected areas and voluntary set-asides should be seen as important complements to closer-to-nature forest management, but they are not included in the definition. Voluntary set-asides of less than one hectare, or less than 0.5 hectares for broadleaf forests, within the harvested area are counted as environmental consideration.

3.1.7 Species conservation

Direction	
Species conservation	↑
Awareness of species	↑

- The action programmes for endangered species should be used for collaboration across landowner boundaries on species conservation in closer-to-nature forest management.

- The forest owner must be aware of the occurrence of species of conservation concern on their land and make sufficient adaptations to protected and red-listed species during forestry operations so that they are not harmed.

3.1.8 Responsible ungulate management

Direction	
Rowan, aspen, willow and oak	↑
Deciduous trees	↑

- Ungulates should be a natural part of the forest ecosystem. In areas with high browsing pressure and high levels of damage, ungulate populations may need to be adapted to the level of damage and forage availability. At the same time, forest management may need to be adapted to increase the amount of forage.

- Deciduous trees should be favoured in all forestry measures. To increase the presence of rowan, aspen, willow and oak, fencing of young deciduous stands or individual trees can be applied.

- Authorised anti-browsing protection products can be used in some cases to benefit rowan, aspen, willow and oak and reduce production losses.

3.1.9 Landscape planning

Direction	
Fragmentation	↓
Connectivity	↑
Uneven-aged forest	↑
Adapted forest management plan	↑

In this report, the term landscape refers to large contiguous areas. A landscape can, for example, consist of catchment areas or sub-catchment areas, high-value landscapes or ecoparks. For smaller forest owners, the landscape division can be based on utilisation units, where known natural values in the surrounding landscape are taken into account in planning.

- Increase the proportion of multi-aged forest stands in the landscape by 2030 by using more small-scale practices that maintain tree continuity. By 2050, multi-aged forest stands should cover at least two-thirds of the

landscape. Increase the proportion of deciduous trees in the continental and boreal regions.

- In reindeer grazing areas, felling should be planned so that a continuity of ground and pendulous lichens is maintained over time in the landscape.

- Large landowners must plan forestry measures from a landscape perspective, including voluntary set-asides, environmental considerations, planning of measures over time and the creation of green infrastructure.

- Small forest owners should receive information and/or counselling on nature values at the landscape level.

- Larger forest owners should eventually have a forest management plan or equivalent that is adapted to closer-to-nature forest management and is based on the landscape perspective. In forestry planning, well-connected habitats for different species should be sought by applying a combination of nature conservation set-asides, adapted even-aged retention forestry, environmental considerations, and small-scale forest management methods. Forest roads should be planned from a landscape perspective to reduce fragmentation of the forest landscape.

3.1.10 Adaptations to reindeer husbandry

Direction	
Lichen rich forest	↑
Connectivity of lichen rich forest	↑
Adaptation of forest management	↑
Lodgepole pine	↓

- Landscape planning in the reindeer husbandry area that takes into account different forms of land use must be based on the needs of the Sami people and reindeer husbandry.

- Connectivity between lichen-rich forests that are important for reindeer grazing, movement and herding of reindeer should be preserved and increased.

- No regeneration takes place with lodgepole pine. Existing lodgepole pine stands in the reindeer husbandry area will eventually be converted to a more natural state.

- Consideration and forestry methods must be adapted to reindeer husbandry, and older lichen-rich areas are managed with small-scale forestry. When planning management measures that affect reindeer husbandry in the reindeer husbandry area, collaboration with the Sami village concerned is offered through free, prior and informed consent (FPIC). Gentle intermittent or targeted soil scarification should be applied on lichen-rich land and scarification should be completely avoided on lichen-rich patches.

- Consideration shall be given to culturally important Sami sites and cultural remains.

3.1.11 Choice of terminology

In the consultations with the forest sector, there were several suggestions to use a different Swedish term than ”naturnära skogsbruk”. The main argument has been that the term should better reflect a direction, i.e. something we are working to achieve by practising closer-to-nature forest management, rather than a strict objective. The same direction is indicated by the r in *closer-to-nature forest management* in the report produced by the *European Forest Institute*. The authorities have analysed three Swedish terms: *naturnära-*, *naturanpassat-* samt *naturligare skogsbruk*. These indicate a direction, are easy to understand, are linked to natural dynamics and to the European Commission’s *closer-to-nature forest management.* Other proposed terms are *naturvänligare-*, *naturnärmare-*, *ekologiskt skogsbruk* and the acronym *CNF*.

The authorities have also taken support from the Language Council (terminologists), who use a terminological method to explore terms and how they can be described. In this way, in addition to considering the experts’ use of language, we have also included perspectives from the more general understanding of Swedish and the Swedish language system. The terminologists’ analysis shows that the term *naturnära skogsbruk* for the English *closer-to-nature forestry* is not entirely appropriate as the term is already used for the very similar concept of *close-to-nature forestry*.

The Swedish Language Council's proposal for a Swedish equivalent of *closer-to-nature forestry* is *naturlig skog-anpassning*. This is in line with names for other concepts that deal with measures to adapt existing activities to specific circumstances, such as *klimatanpassning* (measures to manage the effects of existing climate change and to prepare for future climate change).

The Language Council has also proposed a definition for *naturlig skog-anpassning*: “adaptation of forest management to mimic natural forest processes and ecosystem and to protect biodiversity”.

The Swedish translation of the EU Forestry Strategy translates close-to-nature forestry into *naturnära skogsbruk*. The European Commission has recently informed the Swedish Forest Agency and the Swedish Environmental Protection Agency that their guidance is being translated. The translation of *closer-to-nature forest management* will then be *naturnära skogsbruk*. To make the concept easy to understand and implement, we conclude that the Swedish term should primarily correspond to the translation of the EU Commission.

Assessment

The Swedish Environmental Protection Agency and the Swedish Forest Agency believe that the concept of *naturnära skogsbruk* should be retained for the time being because it has already been established, is easy to understand and the link to *closer-to-nature forest management* is relatively strong. However, clarity on how the term is used is always needed to minimise the risk of confusion. A change of concept can of course be discussed in a continued process.

4 Overall impact assessment of closer-to-nature forest management

Closer-to-nature forest management is based on a voluntary approach and the definition contains flexibility regarding selection of management methods and how to approach management. When applying landscape planning, private forest owners should be able to base their planning on the unit of use and their own use should not be affected by how neighbouring landowners choose to use their land.

To create functional and varied landscapes, a significant part of the landscape must be managed with closer-to-nature forest management. The future certification for closer-to-nature forest management being developed by the European Commission will probably provide a framework for how closer-to-nature forest management is to be implemented in Sweden. A likely direction is that forest owners' entire holdings, at least in the long term, should be managed with closer-to-nature forest management, as this gives the greatest effect at landscape level. However, there are major differences among forest owners. Greater demands may need to be placed on large forest owners in terms of landscape planning, who have more resources for this. Individual/smaller forest owners otherwise risk being disproportionately affected by how the forest in the surrounding landscape is managed.

4.1 Societal benefits

Biodiversity and many ecosystem services can significantly benefit from closer-to-nature forest management compared to the current even-aged retention forestry being practiced in Sweden, and thus contribute to achieving Sweden's environmental objectives and the UN's sustainability goals. Today, however, the production of biomass is the primary source of income for most forest owners and closer-to-nature forest management can result in lower growth and longer rotation periods, and lead to a reduced supply of raw materials such as timber, pulpwood and firewood.

A definition of closer-to-nature forestry, if applied in Swedish forestry, could therefore mean a more socio-economically profitable distribution of resources compared with the current situation. Maximum efficiency is achieved if appropriate closer-to-nature forest management methods are applied where they create the greatest social value. For the overall effect, the economic valuation of the non-monetary benefits is crucial, as is the size of the area that will be managed with closer-to-nature forest management and how the remaining areas will be managed.

4.2 Incentives to practise closer-to-nature forest management

One difficulty is that there is currently no compensation for loss of income when converting to closer-to-nature forest management. The European Commission's guidelines describe various mechanisms that could be used to support closer-to-nature forest management: regional development funds, LIFE programmes, state aid in the forestry and agricultural sector and the CAP. Other possibilities could be that the market or citizens compensate forest owners, for example in the form

of a market-driven compensation system. The government authorities see that other incentives may also be needed to increase the proportion of closer-to-nature forestry, such as counselling.

Closer-to-nature forestry may involve some additional costs for the forest owner, for example through increased requirements for environmental considerations at felling or restrictions on the amount of timber that can be harvested, linked to forestry practices with less harvesting over a long period of time. However, this type of forestry can also be profitable in other ways, because it involves lower investment costs (machinery), forest management measures such as soil scarification, planting and clearing[209] , and there are good opportunities to produce quality timber with higher timber prices.

Closer-to-nature forestry is in many ways suitable for forest owners, large and small, who are interested in making their forests resistant to damage and infestations due to climate change. There is also an interest among many forest owners to practise small-scale, low-impact forestry and to make forests more varied, more pleasant to visit and better for biodiversity. It may, however, be easier for private forest owners to achieve profitability with small-scale harvesting/continuous cover forestry than for forestry companies. Multiple use is also in many ways more suitable for private forest owners than for forestry companies. On the other hand, the number of individual forest owners is falling, i.e. the average forest owner owns more forest land today than before. Self-employment is declining and ownership by non-residents is increasing. Large-scale forestry, on the other hand, has the resources and better conditions for landscape-adapted management, but few incentives to carry out closer-to-nature forest management. The ownership structure also differs greatly between southern and northern Sweden.

Creating climate resilience in the forest is a prerequisite for being able to conduct long-term forestry in a way that is sustainable for both the forest and society. Closer-to-nature forest management increases the forest's resistance to disturbances and reduces the risk of the forest being severely affected by, for example, storms, fires and insect damages. The fact that closer-to-nature forestry aims to increase the variation in the landscape provides a greater opportunity for adaptive management (the ability to adjust forestry more quickly) in the event of new conditions due to the changing climate. For example, there may be new insect damages that require a rapid conversion to other tree species, which is possible in a mixed forest, in order to maintain production. In this way, long-term profitability can be positively affected.

4.3 Knowledge of closer-to-nature forest management

Compared to current forestry, closer-to-nature forest management involves a greater variety of forestry practices. Research results pertaining to such practices are scarce, especially for long timelines. There are uncertainties about how different practices affect biodiversity, forest production, carbon sequestration and

[209] Jentzen et al. 2021.

resilience. Other knowledge gaps concern which forestry practices work best in different parts of the country and for different ecosystem services.

Closer-to-nature forest management means that a larger area is left as consideration when harvesting the forest, which leads to a reduction in the harvest potential. This means a reduced carbon sink and reduced opportunities for substitution. Selective harvesting can lead to some negative effect on tree growth, which has been linked to the felling of large and vital trees[210] . At the same time, other studies indicate that selective logging has the potential to avoid post-harvest emissions from a clear-cut[211, 212,] and that increased landscape diversity creates more resilient forests and thus more stable carbon stocks[213] .

[210] Bianchi et al. 2020.
[211] Lindroth et al. 2018.
[212] Vestin et al. 2020.
[213] Messier et al. 2022.

5 Explanation of terms

Business model: A business model explains how an organisation creates value for its target customers by describing the company's offering, customer segments, activities, costs and revenues.

Selection system: A way of managing the forest by thinning so that the forest is fully layered after felling. This means that the forest contains trees in many size classes and felling is mainly done of the larger trees.

Externalities: An external effect (or externality) occurs when an economic transaction affects the benefits of third parties. Externalities can be both positive and negative.

Ecosystem service: All products and services provided by ecosystems to humans that contribute to our well-being and quality of life. These services are categorised as supporting, provisioning, regulating and cultural ecosystem services.

Alien species means a living specimen of a species, subspecies or lower taxonomic unit of animals, plants, fungi or micro-organisms introduced outside its natural range, including all parts, gametes, seeds, eggs and reproductive bodies of those species, as well as hybrids, varieties or breeds capable of surviving and subsequently reproducing (taken from Regulation (EU) No 1143/2014 of the European Parliament and of the Council)

Protected species: Species or organisms that are legally protected from disturbance. The protected species are listed in the Species Protection law (SFS 2007:845).

Green infrastructure: Ecologically functional networks of habitats that contribute to the conservation of biodiversity and the promotion of socially important ecosystem services throughout the landscape.

Sustainable forest management: Sustainable forest management means the management and use of forest lands in a manner and at a rate that maintains their biodiversity, productive capacity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions at local, national and global level and that does not cause damage to other ecosystems.

Sustainable development: A common definition is that used in the Brundtland Commission's report 'Our Common Future', which states that it is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept is central to the Sustainable Development Goals (SDGs) included in the 2030 Agenda framework, adopted by UN member states in 2015. They are based on three integrated dimensions of sustainable development: ecological, social and economic sustainability.

Intermittent soil scarification: Soil scarification prior to planting or seeding, where patches or piles are created at specific distances and the land in between is

left untouched. The method results in less soil impact than so-called continuous soil scarification (soil scarification in continuous strips).

Invasive alien species: Species that have been moved by humans from their original environment and begin to spread rapidly in their new surroundings, causing serious damage to ecosystems, infrastructure or human health and resulting in high costs to society and individuals. Soil preparation for planting or sowing, where patches or piles are created at specific distances and the land between them is left untouched. This method produces less soil impact than continuous land preparation (land preparation in continuous strips). Pile driving and patch land preparation are examples of intermittent land preparation; harrowing is an example of continuous land preparation.

Bark scarification: Stripping the bark of pine trees to obtain resin or resinous wood.

Climate adaptation in forestry: Implementing measures that increase the ability of forests to recover or resist various disturbances.

Connectivity: The possibility for animals, plants, sediments and organic matter to move and disperse in nature.

Cohort dynamics: Repeated disturbances that create distinct age cohorts of trees.

Continuous cover forest: Forest area that has been covered with trees for a long time and has not been subjected to final harvest.

Continuous cover forestry: In this report, the term is used on the basis of the FSC definition and means a practice with the aim of keeping the land continuously covered with trees and where the practice maintains or develops forest stratification (FSC Sweden 2020).

Gap dynamics: Phenomenon in more or less natural (untouched) forests, where small gaps are created by the death of trees or felling by the wind. There, seedlings of one or more tree species are given the opportunity to develop.

Gap cutting: This method involves cutting gaps in forests that have reached the minimum age for final felling according to the Forestry Act. As regeneration is established through self-rejuvenation, seeding or planting, the gaps are expanded until the stand is regenerated. This means that the regeneration phase lasts for a longer period of time, often around 15-40 years.

Marginal benefit to society: The marginal benefit to society is the total benefit society receives from the consumption or production of an additional unit of a good or service, which includes not only the private benefit but also external benefits or spillover effects that affect society at large.

Market failure: The concept of market *failure is* used to explain situations where individual decisions by market actors lead to inefficient allocation and prioritisation of resources. An example of market failure is environmental problems. Since market failures lead to resources not being allocated and

prioritised optimally to create the greatest social benefit and result in efficiency losses, they are reasons for the state to intervene in the market through various forms of policy instruments. This is to steer towards a more efficient allocation of resources that generates a greater benefit to society. Market failure also describes situations where different actors lack the incentive to solve the environmental problem themselves, while at the same time leading to costs for a third party.

Natural disturbances: Dynamic processes that occur in nature at regular or random intervals and have shaped the ecosystem. These include disturbances caused by, for example, landslides, storms, fire, insect outbreaks, grazing, extreme drought and flooding. Small- and medium-scale disturbances in forests include gap and cohort dynamics (repeated disturbances that create distinct cohorts of trees), while large-scale disturbances include stand-replacing disturbances.

Nature conservation species: A collective term for signal species, red-listed species and protected species that are particularly worthy of protection or indicate areas with high nature values.

Uneven-aged forest: Forest where the trees are of different ages. According to the definition of the Swedish National Forest Inventory, a forest stand is classified as fairly even-aged if at least 80 percent of the volume is within an age interval of 20 years and completely even-aged if 95 percent of the volume is within an age interval of 5 years. Other stands are classified as uneven-aged. In the case of multi-layered stands, this refers to the layer that determines the felling class.

Exploitation felling: Felling of individual trees without thinning of intermediate sections, mainly through target diameter/dimensional felling, but also single tree selection harvest. Often the harvesting is focused on trees with special desired characteristics.

Resilience: The ability to maintain basic functions in the face of disruption or change.

Red-listed species: Species classified as Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Nationally Extinct (RE) or Data Deficient (DD) based on an assessment of the risk of extinction. The national Red List is updated every five years by the Swedish Species Information Centre at SLU.

Signal species: Site-level nature value indicators, which are not red-listed but are useful in practice for locating and distinguishing areas of high nature value.

Forest nature conservation hot spot: A forest nature conservation hot spot is a continuous forest area deemed to be of great importance for fauna and flora and/or for a prioritised forest type. For a full definition see the national strategy for formal protection of forests (“*skogsbiologisk värdekärna”)*[214] .

[214] Swedish Environmental Protection Agency and Swedish Forest Agency. 2017.

Forest management system: Also referred to as forestry practice. An intended model for how a forest stand is to be managed, harvested and replaced with new forest. See even-aged retention forestry and selection system.

Shelter tree method: A forest management method within the forest management system of retention forestry. The method aims to rejuvenate the forest with seed from shelter trees and means that the old forest is thinned so that after felling the stand no longer fulfils the Forestry Act's requirement of closeness in paragraph 10, but not so much that it is classified as bare ground.

Storm resistance: A measure of how a tree or forest is expected to withstand wind without falling. Storm resistance can be affected by, for example, forest thinning.

Disturbance: Event that significantly affects the structure of an ecosystem, plant community or population and changes the conditions for its development.

Even-aged retention forestry: A form of rotational forestry practice with distinct phases where the forest undergoes a distinct regeneration phase by means of planting, sowing or natural regeneration, followed by a young forest and growth phase and then harvested and replaced by a new stand. Retention trees and nature consideration areas (retention patches and buffer zones) are left on the clearcut.

Forest hot spot: A continuous forest area that has been assessed by the county administrative board as being of great importance for fauna and flora and/or for a prioritised forest type.

Value tract: A landscape section with particularly high ecological conservation values. A value tract has a particularly high density of hot spots (and/or value elements) for animal and plant life, including biologically important structures, functions and processes than is found in the surrounding landscape.

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Annex 1 - Summary of the results of the consultations

Summary of consultations within the government's assignment on continuous cover forestry and closer-to-nature forest management.

The Swedish Forest Agency and the Swedish Environmental Protection Agency have been commissioned by the government to develop the conditions for continuous cover forestry and to propose a definition of closer-to-nature forest management. The assignment must be reported no later than 15 December 2023.

The Swedish Forest Agency and the Swedish Environmental Protection Agency will jointly develop the conditions for, and analyse and describe any obstacles to continuous cover forestry and compile knowledge about these methods based on science and practical experience in dialogue with relevant stakeholders.

The authorities will also compile knowledge on innovation work and business models with regard to continuous cover forestry.

The Swedish Forest Agency and the Swedish Environmental Protection Agency shall also propose a definition of closer-to-nature forestry that takes into account the balanced objectives on production and environment and, in relevant parts and, if appropriate, takes into account the proposal for guidelines on closer-to-nature forest management currently being developed by the European Commission under the new EU Forest Strategy for 2030 (COM (2021) 572).

As part of this work, digital consultations were held in February 2023 with representatives from various authorities, organisations and companies. A total of nine consultation sessions were held with the participants grouped into eight stakeholder groups and one wrap-up session. A total of 65 representatives from 40 authorities, companies and organisations participated. The purpose of the consultations was to obtain views on the various parts of the government assignment as support for further work. The questions asked were:

1. What experience do you have of continuous cover forestry and what thoughts do you have about what it means in practice?

2. What obstacles do you see in order to increase the application of continuous cover forestry/use of continuous cover forestry methods?

3. What changes would you like to see to develop the conditions for continuous cover forestry?

4. Which methods do you see as the most interesting to develop in continuous cover forestry? Justify why.

5. Business models - What business models would you like to see developed in order to make continuous cover forestry methods more economically interesting for individual forest owners and larger forest owners?

6. What is most important in designing a definition for closer-to-nature forest management in Sweden? Justify - why?

7. Which forestry practices do you consider to be part of the concept of closer-to-nature forest management?

8. If there is time: Is there anything you want to add that did not come up during the discussion?

The consultations were documented using notes of what was said (Ref. SKS: 2022/3845; Ref. NV-06790-22). Below is a summary of the consultations.

Continuous cover forestry

1. What experience do you have of continuous cover forestry and what thoughts do you have about what it means in practice?

Several advantages of the method were emphasised in the consultation meetings. Many highlight the possibility of increased consideration for the natural environment, but also that it promotes experience values, cultural environments including specialised timber production, nature tourism and outdoor life. Less continuous efforts as well as pride and increased status of forestry activities were also emphasised. Reindeer husbandry was often said to coincide with nature conservation interests, but not always.

Several disadvantages and uncertainties were also highlighted in relation to continuous cover forestry. The production perspective of continuous cover forestry was highlighted by several, either as an uncertainty or that it results in more expensive felling than retention forestry. The problem of reduced growth linked to the climate issue and carbon sequestration was also emphasised. There was also experience of it being more difficult to practise continuous cover forestry in the northern part of Sweden, where historical experience is poor, which has led to a difference in attitude compared to southern Sweden.

Knowledge and skills were felt to be lacking in terms of operational knowledge, the effects of conversion from retention forestry and knowledge based on monitoring, where monitoring of continuous cover forest management is currently felt to be lacking. It was stated that there are too few studies today concerning continuous cover forestry and that better growth models are needed and that enough people practice continuous cover forestry. Only then would the operational scale be large enough to get a better grasp of how the method can be optimised.

Some believe that continuous cover forestry is not at all perceived as relevant and important in comparison with closer-to-nature forest management. The definition of continuous cover forestry is considered to be broad, focusing mainly on experiential values. Others feel that the difference between continuous cover forestry and closer-to-nature forest management is unclear, as well as how these relate to effects in nature.

2. What obstacles do you see in order to increase the application of continuous cover forestry/use of continuous cover forestry methods?

In the consultations, many different stakeholders stated that forestry in Sweden has long been shaped by the industry's need for raw materials. This has meant that training, legislation and machine development have been adapted to the conditions of retention forestry. This is perceived by several of the stakeholders as a major obstacle in the transition from retention forestry to continuous cover forestry. On the whole, some stakeholders emphasise that continuous cover forestry is more demanding in terms of management, entails a greater risk of damage and greater economic uncertainty.

Many of the stakeholders emphasise the economic uncertainty of continuous cover forestry, and that the industry and the market are not adapted to the timber produced by continuous cover forestry. Today, several stakeholders see that there is no opportunity to utilise the raw material created by this management method, such as overgrown trees or certain tree species. Business models for continuous cover forestry are unclear, and there is a lack of support for conversion through, for example, certification systems and state remuneration or compensation.

With regard to management, the machinery, for example, is highlighted as an obstacle in a conversion, where today's machines are designed for more large-scale retention forestry, they need to be used more often in continuous cover forestry and would cause greater driving damage.

One obstacle raised by a stakeholder is also the perceived risk of losing control of their forest as a consequence if the natural values and the forest are transferred from a production purpose to being subject to area protection.

It was also emphasised that there is a lack of knowledge about several aspects of continuous cover forestry, both in research and among entrepreneurs, for example. The need for knowledge about the effects and consequences of climate impact and carbon sequestration, reduced logging residue extraction, fewer by-products, damage by spruce bark beetle and root rot, yields and business models, and which areas would be suitable for continuous cover forestry were highlighted.

Several stakeholders express the view that the definition of continuous cover forestry should also include nature conservation management in set-aside areas.

It is perceived to have been difficult to obtain sufficient and good advice on continuous cover forestry. It is felt that there is a lack of practical advice from the Swedish Forest Agency, and that the advice that is available is biased and governed by the forest industry's demand for biomass.

Several stakeholders also highlighted norms and attitudes as an obstacle to continuous cover forestry. Today's forestry and education programmes are based on the idea that the forest should supply an industry. Continuous cover forestry was said to be perceived as a threat and that attitudes are reinforced. Historically poor experiences of selection systems and traditions of even-aged retention forestry were also highlighted.

3. What changes would you like to see to develop the conditions for continuous cover forestry?

Several emphasise the need for financial incentives to encourage forest owners and other stakeholders to opt for continuous cover forestry. Some proposals include conversion aid, financial contributions in the form of tax rebates for more expensive felling methods, paid training for machine contractors, payment for carbon storage or compensation for the use of forest roads. Forms of compensation for encroachment are requested, and several people point to measures to avoid losing access to their forest if it becomes older and more species-rich. Others see the importance of the market being prepared to pay for timber from continuous cover forestry. However, some stakeholders emphasise that the state should not interfere with the market and the timber produced. The certification systems are highlighted as a possible development to support continuous cover forestry methods.

It was highlighted that there is a need to develop value chains with entrepreneurs who can utilise valuable timber, where quality is more important than volume. New machines and soil scarification methods also need to be developed. Someone highlighted the possibility of measuring ecosystem services and being able to quantify them in order to be able to show the benefits of continuous cover forestry - then there may be interest from external financiers.

Research organisations highlight the importance of a long-term approach and clear signals, where a major research programme may be appropriate to include as many aspects as possible and where practice and knowledge generation can take place simultaneously. Analyses and knowledge bases that also cover economics and forest damage risks are emphasised as important. For example, a changing climate is highlighted as an argument in favour of more continuous cover forestry, but that this should be verified through research and tests. The need to test continuous cover methods on a large scale is emphasised, where the state is considered to be able to take the lead. The public sector can also take the lead through public procurement by requesting building materials produced through alternative forestry.

There is a need for more factual advice to forest owners on continuous cover forestry methods and economic conditions, at a concrete level based on the forest owner's conditions. Some stakeholders see an opportunity to integrate contiuous cover forestry methods into all forestry training programmes so that all stakeholders have knowledge and understand alternative forestry methods.

It is also emphasised that the legislation needs to be reviewed, for example regarding the relaxation of the requirement for reforestation. In forestry planning, the need was highlighted for a review of the classification of stands based entirely on retention forestry.

Several also emphasise that the EU has greater pressure on the Member States on this issue now, and that this will require Sweden to change its position on this issue. Policy development is considered important for creating goals that actors can work towards.

4. Which methods do you see as the most interesting to develop in continuous cover forestry? Justify why.

The majority of stakeholders emphasise the need to take into account different perspectives such as social values, natural values, the local conditions at the site and the forest owner's objectives and needs. Conditions differ greatly wherever you are in the country. This means that different methods are more suitable than others in some forests, which is why it is considered important to have a wide range of management methods. Instead of continuous cover forestry methods, some would prefer to use terms such as alternative methods or variation-rich, ecosystem-based, holistic and close-to-nature forest management.

Someone sees that it would be better not to start from different methods, but rather to talk about the intensity of management.

Several forest owners are in favour of continuing to develop methods such as selection system, selective thinning, shelterwood, and specifically pine shelterwood forestry, exploatation felling, strip felling and gap cutting. However, some emphasise that selective thinning is already established and is not a problem today.

It is emphasised that there is also a need to look at the methods used when removing trees, how they affect driving damage, lack of dead wood, the preservation of old trees, and so on. Some see the importance of increasing knowledge about and the possibility of continuous cover forestry methods in specifically birch and pine forests.

Some highlight the need to take into account reindeer husbandry in the north of the country and outdoor recreation in the south when developing methods,

5. Business models - What business models would you like to see developed in order to make continuous cover forestry methods more economically interesting for individual forest owners and larger forest owners?

Several elements of what could be included in a business model were highlighted in the consultations. Many came back to state compensation of various kinds as part of the solution, for example when adapting management due to the presence of certain species. Some consider this to be particularly important in areas where continuous cover forestry is favoured but where there are no high nature values. Someone highlighted that an approach to the CAP could enable investment support for conversion. The development of business models for agriculture and forestry as a whole was also highlighted, as they are interrelated for many landowners. There was a proposal that the state could create a fund to which income from a certain proportion of the timber sold goes. These funds could then be used to provide compensation to those who want to preserve natural values. This was highlighted as a solution to follow the 'polluter pays' principle.

However, someone emphasised that the state should not work with business models that go beyond the state's responsibility. Another person also emphasised the importance of market models without government subsidies. It was also highlighted that a lot is happening now and that market models will come, with

the example of biodiversity credits being highlighted and that the demand for timber from continuous cover forestry methods probably already exists. Some mentioned that assortments other than pulpwood would have to become drivers of the market and thus production. Other participants emphasised that the market would have to adapt prices to supply and demand, with the cost being passed on to consumers.

Some pointed out that there may be other values that affect the business model than those purely linked to the market, such as recreation and outdoor life. For example, a municipal landowner who wants to adapt urban forestry.

A developed forest management plan was considered to be a form of stockpiling and in the future, targeted orders could be placed (at tree level) from different actors. Forest management could then become more market-driven.

Certification or labelling of continuous cover forestry was mentioned several times as an opportunity linked to business models and pricing. However, it was also highlighted that it takes time before serious certification models have an impact.

There were problems with the system of carbon credits linked to climate work, where continous cover forestry was considered to be counterproductive. But also the need to link business models with the aim of limiting climate impact with continuous cover forestry.

The possibility of multiple use, which can be favoured by continuous cover forestry, was also highlighted with the example of ground lease income through nature tourism and reindeer husbandry. It was emphasised that it depends on the conditions that exist and is therefore difficult to make a general statement about this. It was emphasised that there are relatively few forest owners who engage in multiple use, and that most of them see continuous cover forestry as an opportunity to reduce the risk of their activities.

The need for networks for small-scale forest owners was highlighted to facilitate, for example, marketing, small sawmills and other synergies.

Closer-to-nature forestry

The consultations carried out within the framework of the government assignment show that there are both similarities and differences in how stakeholders view a definition of closer-to-nature forest management and how it should be formulated. Several emphasise that the concept of "*closer-to-nature*" is new, rather diffuse and relatively unknown in the forestry sector at the time of the consultation. It is also unclear what a future certification will look like. There is a consensus that the definition should be based on the function and objectives of closer-to-nature forest management, and not on which forestry methods are appropriate. The definition should be based on current knowledge and research, be adapted to Swedish conditions, be applicable and work throughout the country.

Most believe that some form of retention forestry should be included. Several stakeholders believe that closer-to-nature forest management in Sweden should

include "our" way of managing the forest, primarily through retention forestry, but with certain adjustments. This could include, for example, better site adaptation, more consideration and creation of new dead wood, reduction of driving damage and limitation of the use of non-native tree species, such as lodgepole pine. Others emphasise the importance of forest management based on small-scale disturbance dynamics and increased rotation times, for example based on what the landscape looked like 150 years ago. Although the methods should not be the focus, there is a demand for a greater breadth of methods that provide increased variation. It is important not to equate continuous cover forestry with closer-to-nature forest management.

Another aspect that many raise is the landscape perspective, but probably with slightly different starting points. It may be to favour the variation in the landscape, to reduce the area of clear-cuts or to use co-planning for reindeer husbandry based on landscape ecology principles. One starting point may be how much biomass can be harvested without reducing biodiversity in the landscape. Several also emphasise that climate change needs to be taken into account. Many believe that fertilisation should not be possible in closer-to-nature forest management. However, planting can be included on the basis that a changing climate can change the conditions for certain tree species. There may then be advantages in using improved plant material that is better adapted to the prevailing climate and it is pointed out that Sweden has a good breeding programme for genetic variation and that half of the pollen in seed plantations generally comes from outside, from wind flows. Many believe that natural regeneration methods need to be increased, but that soil preparation and planting are needed on land that is difficult to regenerate. The sharp decline in natural regeneration means that there is a risk that knowledge disappear. Seed trees also have an important function in maintaining mycorrhiza, which requires tree continuity.

Opinions in the sector are divided on how well Sweden's definition should follow the European Commission's guidelines. There is strong concern among some stakeholders that the guidelines will impair the opportunities for our Nordic forestry and that forest growth will be reduced. Others believe that the definition should follow the European Commission's guidance and that this could enable a major change in our forestry practices that increases the resilience of our forests and biodiversity. Others argue that instead of introducing a new term 'closer to nature', we should focus on achieving sustainable forest management. Some have mentioned the possibility that closer-to-nature forestry could be included in the work on the nature restoration law.

Annex 2 - Participating organisations and stakeholders

Participating stakeholders and organisations in dialogues, consultations, workshops and surveys.

1. Association for Ecological Forestry Certification (AEFC)
2. Billerud Skog AB
3. Birdlife Sweden
4. Ekoskog
5. Swedish Energy Agency
6. Finnatorps såg AB
7. FORMAS
8. FSC
9. Fältbiologerna
10. City of Gothenburg
11. University of Gothenburg
12. Hembygdsförbundet
13. Holmen Skog AB
14. Komatsu Forest AB
15. Kopparfors Skogar AB
16. Lassas byggnadsvård AB
17. Linnaeus University
18. LRF Skogsägarna
19. Lund University
20. Jämtland County Administrative Board
21. Kronoberg County Administrative Board
22. Mellanskog Forest Owners' Association
23. Mid Sweden University
24. Moelven AB
25. Naturnära skogsbruk in Tiveden
26. Naturturismföretagen
27. Norra Skog Skogsägarförening
28. PEFC
29. Plockhugget AB
30. Swedish National Heritage Board
31. The Sami Parliament
32. SCA Skog AB
33. Skogens mångbruk
34. Skogforsk
35. Skogsindustrierna
36. Skogskvinnorna Värmland
37. Skogssällskapet
38. Skogstekniska klustret
39. Skydda skogen
40. Swedish University of Agriculture Sciences
41. Spillkråkan
42. The National Property Board
43. Stockholm University
44. Stora Enso Forest
45. Sveaskog
46. Church of Sweden
47. The Swedish Society for Nature Conservation
48. Svenska Samernas Riksförbund (SSR)
49. Sveriges allmänningsskogars förbund
50. Sveriges häradsallmänningsförbund
51. Sveriges jordägareförbund
52. Södra Skogsägarna
53. University of Quebec
54. th University of Freiburg
55. Uppsala University
56. Vinnova
57. WWF