FOREST MONITOR REPORT 2025

- A tool to monitor and protect EU's natural forest heritage

PROTECT THE FOREST

Report 2025:
FOREST MONITOR
- A tool to monitor and protect EU's
natural forest heritage

Authors
Jon Andersson, Viktor Säfve and Hainner Aparicio

Proofreading
Daniel Rutschman

Photos
The photographer's name appears next to each image.

Graphics
Jon Andersson, Hainner Aparicio and Viktor Säfve

Layout
Viktor Säfve

Acknowledgments:
We want to express our greatest appreciation to the Postcode Lottery Foundation, to Naturkompaniet and to our private donors! Humble thanks to our superbly competent consultant Mats Troeng for helping us to create a fast and easy-to-use map service! Thanks to Håkan Berglund at SLU for valuable comments on the chapter: Analysis of the "old forest" trends and underlying official statistics. A huge thank you to our patient and supportive families and to everyone who in various ways, via photos, inventories and knowledge contributed to the report and to Skogsmonitor.se

Cover photo:
Viktor Säfve

May 2025, report version 1.0

The report is produced by Protect the Forest 2025: www.skyddaskogen.se

This report has been produced with support from the Postcode Lottery Foundation

Skogsmonitor.se is run, developed and administered, via project funds from the Postcode Lottery Foundation (Postkodlotteriets stiftelse) and from private donations.

The 1.0 version of Skogsmonitor.se was made possible by project funding from Naturkompaniets Naturbonus 2020. Skogsmonitor's data is validated in sample areas in the forest landscape with funds from Naturkompaniets Naturbonus 2023.

TABLE OF CONTENTS

PREFACES

As spokesperson of Protect the Forest, I am incredibly proud of what we have accomplished in the Forest Monitor website. Five or ten years ago, this was a dream that we sometimes talked about: what if we could gather all the known valuable old forest in Sweden in one map? What if we could make a tool to show on a map, with clear boundaries, which forests have the highest conservation potential, the ones that we should prioritize in order to protect 30% of the productive forest land? This tool now exists: skogsmonitor.se.

It would not exist without the competence and drive of the project leads: Jon Andersson and Viktor Säfve. It is also not a coincidence that two of the Skogsmonitor employees have a background in research, because this is a technical project which has done scientific research. Among other things, this report explains our methods, and in the scientific spirit, we welcome scrutiny of our methods and results.

You may ask: why has a small non-profit environmental organization taken on this ambitious task? Shouldn't it have been done by a government authority, or perhaps by scientists at a university? To be fair, the Swedish Environmental Agency did commission an analysis of the forests of northern Sweden which have likely not been clear-cut (so-called continuity forests). But they never did such an analysis for southern Sweden. Such data has now been provided by our Forest Monitor website instead. The Swedish government, under pressure from the forestry industry, has lobbied against the EU Forest Monitoring Law, arguing that forest monitoring is too complicated and expensive. Well, we have proved them wrong on a shoestring budget.

Our website and our data now exists and is used daily by many people who want to know where in the landscape old forest is likely to be, whether it is threatened by logging, and whether someone has already been there and found rare or red-listed species. It can also be used for planning on a landscape level, a necessity in Sweden's fragmented forests.

This report contains, besides information on our methods, a background on why forest monitoring is needed, and uses our data to reveal trends and draw conclusions.
Happy reading!

Elin Götmark
spokesperson of Protect the Forest

Environmental legislation across the European Union is facing mounting pressure from a growing deregulatory agenda. Recent months have seen key elements of the EU Green Deal come under political attack—from efforts to weaken the Nature Restoration Law to resistance against the EU Deforestation Regulation. The proposed Forest Monitoring Law — a legislative effort to expand and standardize forest data collection across member states — is no exception.

Despite its practical and scientific rationale, the draft law is currently under heavy attack from some national governments and European parliamentarians, with many Swedish policymakers openly criticizing the law. This trend represents a broader retreat from science-based environmental policymaking at a moment when climate and biodiversity crises demand bold and coordinated action.

Data on forests across Europe is patchy, outdated and difficultly accessible. This year marks 5 years since the last State of Europe's forest report which provides a snapshot of various social, environmental, and economic figures on forests. However, it will not cover locations of Europe's primary and old-growth forets, a political goal outlined in the EU Forest Strategy for 2030. Despite their importance, such forests have been underrepresented in official Swedish datasets — especially in southern Sweden — and face continued degradation under current forestry practices.

Sweden, holding one of the EU's largest shares of forest land, is paradoxically both a direly needed guardian and a major driver of forest degradation.

It is in this context that the Forest Monitor report emerges as a crucial initiative that offers insight into what the Forest Monitoring Law could do for Sweden and the rest of Europe: to make forest information accurate, accessible, and actionable.

At the heart of Forest Monitor is Skogsmonitor.se, an open-access, map-based tool developed to locate, assess, and monitor older forests and continuity forests (of which old-growth forests is a sub category) across Sweden. Using a blend of satellite imagery, historical orthophotos, and machine learning, the project has identified extensive logging of these forests — full of life and critical for Indigenous Sàmi livlihoods —millions of hectares at risk, and large portions unprotected. The findings demonstrate both the utility and urgency of improved monitoring in the service of forests and those who depend on them.

It is a bottom-up, science-driven response to a political climate in which many politicians have resisted more stringent forest monitoring and protection efforts — often citing cost and complexity. Yet, this report demonstrates that with dedication and modest funding, highly credible and transparent forest data systems are possible.

As the EU Forest Monitoring Law faces dilution and undue criticism, Forest Monitor offers both a technical model and a political message. It shows that meaningful forest monitoring is entirely achievable — and that the real barrier is not technical capacity, but political will. This report urges policymakers to safeguard the ambition of the Forest Monitoring Law, and stands as proof that the EU has both the tools and the mandate to act — and must not back down.

Kelsey Perlman,
Forest and Climate Campaigner, FERN


Photo: Viktor Säve

THE FOREST MONITOR TEAM

JON ANDERSSON

Project manager and data developer at Protect the Forest´s web service Forest Monitor.

Jon Andersson is a GIS expert, forest expert, nature conservationist and PhD in biology.

Born and raised in Västerbotten. Even as a child he became interested in the forest and spent a lot of time there. After university studies with a focus on biology, he has dedicatedly worked with forest issues - in research, at authorities and as a consultant - and built up a solid knowledge of the state of the forest and the impact of forestry on biodiversity. Today works part-time at the organisation Protect the Forest, with forest mapping, and monitoring in the project Skogsmonitor.se, but also as an environmental consultant. Together with Viktor Säfve, Jon is the initiator of Forest Monitor.

VIKTOR SÄFVE

Project manager and communicator at Protect the Forest's web service Forest Monitor.

Co-founder of Protect the Forest. Works with forest ecology, forest monitoring, and has an interest in forest history and close-to-nature forest management. Works with ecosystem management and small-scale agroforestry projects.

Born and raised in Norrbotten. Lives and works together with his family on a forest garden farm in southern Närke. Is an experienced campaign leader, conservationist, educator, nature guide and garden enthusiast. Works part-time at the organisation Protect the Forest with issues related to the mapping of conservation value forests. Also works for his own family's company Åfallet Forest Garden with nature reserve management, lectures, guided tours, gardening and pedagogy. Together with Jon Andersson, Viktor is the initiator of Forest Monitor.

HAINNER APARICIO

Hainner is a GIS and remote sensing expert at Forest Monitor - Skogsmonitor.se

I am a believer that human development goes hand in hand with nature conservation! Born in the enchanting geography of Colombia, I have lived in Australia and Europe for the last 10 years. Here and there I have carried my studies as a Forest engineer, Natural resources manager & lately, a double MSc. In Forest Information Technology and Silviculture.

I have had the chance to apply IT to forest-related issues for several years. I am thankful to have experienced those years as a consultant/employee for private companies, governmental departments, and recently in research for Academia. From there my premise has never changed. #SaveTheForest.

MATS TROENG

Mats Troeng is, web service developer, support and consultant for Forest Monitor - Skogsmonitor.se

Mats is a civil engineer in information technology and has been programming since his early teens. Together with an interest in nature and outdoor life and a fascination for maps of all kinds, it has been inspiring for Mats to contribute to the technical machinery behind the display of Forest Monitor's map material on the web.


Photo: Viktor Säve

3. BRIEF INTRODUCTION

Forest Monitor is an online map service and a tool to monitor and protect the northern EU's natural heritage! Forest Monitor [Skogsmonitor.se] is a unique online map service that brings together important data and map layers of valuable forest habitats in one place. It also presents a new comprehensive mapping of potential older forests and continuity forests, in broad sense forests that have not undergone clear-cutting. The map layers show where there are, or could be, forests with high conservation values, but also social values and forests with large carbon stocks throughout Sweden.

The mapping of potential older forest and continuity forest (OFCF) has different degrees of accuracy and probability, and we are constantly striving to refine, adjust, validate and update our data to increase precision and accuracy.

The web-tool aims to facilitate the work with international and national environmental targets and various types of nature conservation, ecosystem management and climate initiatives. The map service creates better conditions for locating the forests that potentially contain the highest natural values, and the landscape sections where there are concentrations of potential older forests and continuity forests that may be or are forests with conservation values.

This is the basis for functional landscape planning, something that helps forest managers in their work with nature conservation. May it be individual forest owners, municipalities, forestry companies or authorities. They can all benefit from using our data.

Moreover, this is also a map service for outdoor activities and recreation, and for anyone who wants to explore the natural heritage of the north and wishes to enjoy the beauty and diversity of Sweden's most natural and magnificent forests.

Forest Monitor is an open and free map service. No one in Sweden has previously presented such a complete collection of open data on potential older forest and continuity forest that delimits forest stands with high conservation values.

Our goal

Sweden, one of the EU's most heavily forested countries, with 17.5 percent of the EU's total forest land area, is home to an important part of the EU's remaining natural forests. These forests are unique environments for biodiversity, with many species associated with old forests, dead wood and tree cover continuity and of different structures and substrates. Through their large carbon stocks in the soil and biomass, and their resilience to disturbance, these old forest remnants are also very important for the climate. Some of the forest-related environmental targets that have been set by the EU and the UN are now starting to reflect in the national legislations. To achieve these targets, however, current conservation value forests must be located and mapped. It is urgent!

Our map service, with delimitations of old forest and classifications according to available data sources, envisions how such data could look. We have collected data and developed this map service to present an overall picture of where in the landscape the most valuable forests are.

Furthermore, we aim to provide an overview of valuable concentrations of older forests, functional clusters of forests, and where the best locations for restoration can be found. Our map also contributes to making inventory efforts more effective, by delineating the areas with the greatest potential to harbor high conservation values.

Our vision

Our vision is that our map service, Forest Monitor, will grow and encompass other parts of Europe's forests, outside of Sweden. A mapping service where most of the natural heritage in the EU's forest are included. Our vision also includes the development of a fully automated interactive system, with planning tools, as well as relevant monitoring tools.

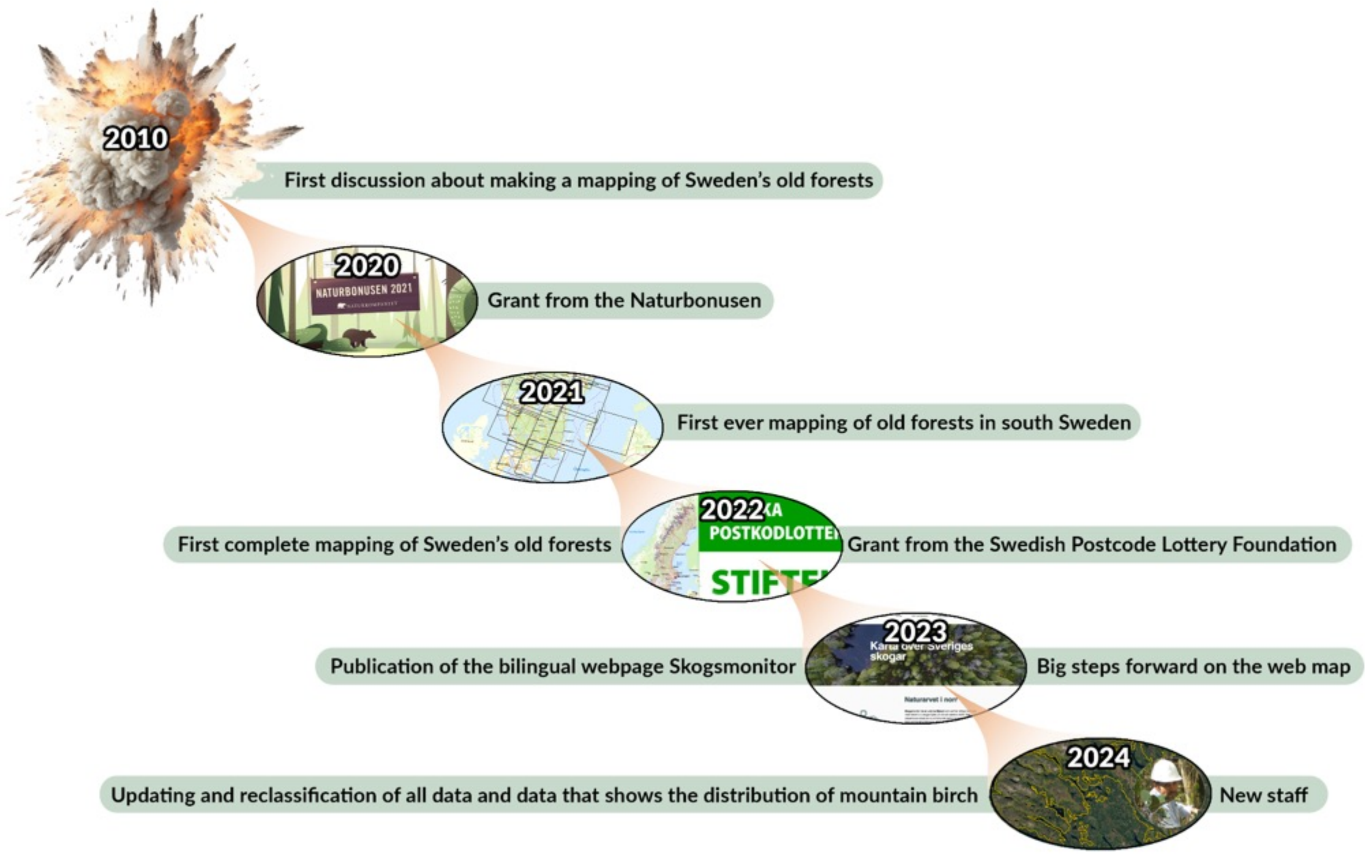


Figure 1. The most crucial steps in the history of Forest Monitor, which started with a sparking discussion in 2010 between Jon Andersson and Viktor Säfve. The grant from Naturbonusen in 2020 which enabled the analysis and creation of the first ever data on old forests for south Sweden. Our later grant from the Swedish Postcode Lottery Foundation paved the way for the web page, and other important steps is the ability to hire more staff members.

Mapping of continuity forests from a forest historical perspective

Clear-cutting as a forest management method has occurred, in parallel with selective logging methods, in southern Sweden and Bergslagen since the late 18th and during the 19th centuries. However, in most of Sweden, and particularly in northern Sweden (Norrland), clear-cutting became the main harvesting method after 1950, with mechanization. The same applies to some extent to Sweden's largest island, Gotland, where clear-cutting was probably introduced in the 1950s (Johansson & Petersson 2016).

For this reason, we have used and created data based on orthophotographs and satellite images that capture clear-cutting that has taken place since the 1950s. This is because an overwhelming majority of the forests in Norrland, and especially in northwestern Sweden, which were forests on the early orthophotographies, could be continuity forests according to the Swedish Forest Agency's current definition. As mentioned above, clear-cutting occurred, side by side with selective forestry practices, in the largest parts of southern Sweden (Svealand and Götaland). But forest history research shows that clear-cutting also occurred to some extent even before 1950, along the coast and in some local regions of Norrland (Lundmark et al. 2021). This means that the proportion of forest that existed before 1950, and which is older forest, to varying degrees has long continuity. However, it is in today's older forest, which was already forest on the oldest nationwide, open and available orthophotographs, that the forests with the highest conservation values are found, and this applies to the entire country.

Naturally and spontaneously regenerated forests dominated the landscape before the 1950s, although there were regional and local large-scale plantings and seed sowing before this period, especially in some areas of southern Sweden. According to professor emeritus Matts Lindbladh (2022), at Sweden's University of Agriculture sciences: *"Around 95% of all forest cultivation* (planting & sowing) *until today has taken place after the year 1950".*

This more or less coincides with mechanization and the total transition to clear-cut forest management. The fact that Forest Monitor is particularly interested in mapping forests that arose before the 1950s is, of course, also partly connected to this.

We focus on mapping OFCF. Continuity forests, seen from a land-use historical perspective, are concentrated mainly in northern Sweden, and especially north-western Sweden. But, Forest Monitor has mapped all potential older forest stands (including potential continuity forests) in southern Sweden, in order to delineate the forests that are the oldest in the landscape. Older forest is, not infrequently naturally regenerated also in the southern parts of Sweden and can have natural values linked to older forests and continuity. The older parts of the landscape also have the highest carbon stocks.

Forest Monitor's validation inventories in various landscapes from south to north, show that a not insignificant part of all forest mapped as OFCF via remote sensing are so-called "core areas" and forest with long continuity in northwestern Sweden (read more in the chapter on validation). This while the proportion of OFCF with natural values generally is lower, but still relatively high, in the southern parts of the country. On the other hand, the mapped area of OFCF is interesting for nature conservation and restoration throughout the country, as it constitutes the oldest parts of the forest landscape and the greatest potential to gain high natural values over time, so called restoration values.

Of course, not all forest land mapped with remote sensing as OFCF is forest with high conservation values. However, validations of the map layers from SEPA and Protect the Forest´s Forest Monitor service, show a high accuracy in finding OFCF that arose before the mechanization of clear-cut forestry in the 1950s.

Validations of the mapped area of probable continuity forest (SEPA definition, see page 77) show that most of the mapped area is continuity forest or older forests and estimates based on samples and on large field inventories indicates that a large part of these areas have natural and conservation values, or are so-called core areas and/or old-growth forests.

How large area of primary and old-growth forest outside strictly protected forest land is there in Sweden?

The Swedish Environmental Protection Agency´s (SEPA 2023) rough estimate:

- 2.2 – 2.8 million hectares of forest land.
- 1.5 – 1.8 million hectares of productive forest land in total.

Estimated overlap between primary and old-growth forest and map layer of probable continuity forest.

SEPA rough estimate:

- 50 – 80% overlap (northern Sweden).
- 40 - 70% overlap on productive forest land (northern Sweden).

The authorities assess that a relatively large part (approx. 50 – 80%) of these probable continuity forests is old-growth forest according to the current definition (EU-commission 2023).

Note! Furthermore, OFCF that cannot be classified as "old-growth" may have both conservation and restoration values and should not be felled. In order to reach national environmental targets and international conventions regarding biodiversity, nature restoration and climate mitigation, there is no room to harvest biomass from continuity forests in Sweden.

Conclusion: logging within the mapped area with OFCF means a high risk of degrading old-growth forest and destroying forest with conservation values. Protect the Forest's report from 2024: "The SCA - files" (Rutschman & Säfve 2024), shows that the forest industry giant SCA logs and plans to log many forests with conservation values and that the statistics in the report provide additional data that reinforces that the loggings are systematic.

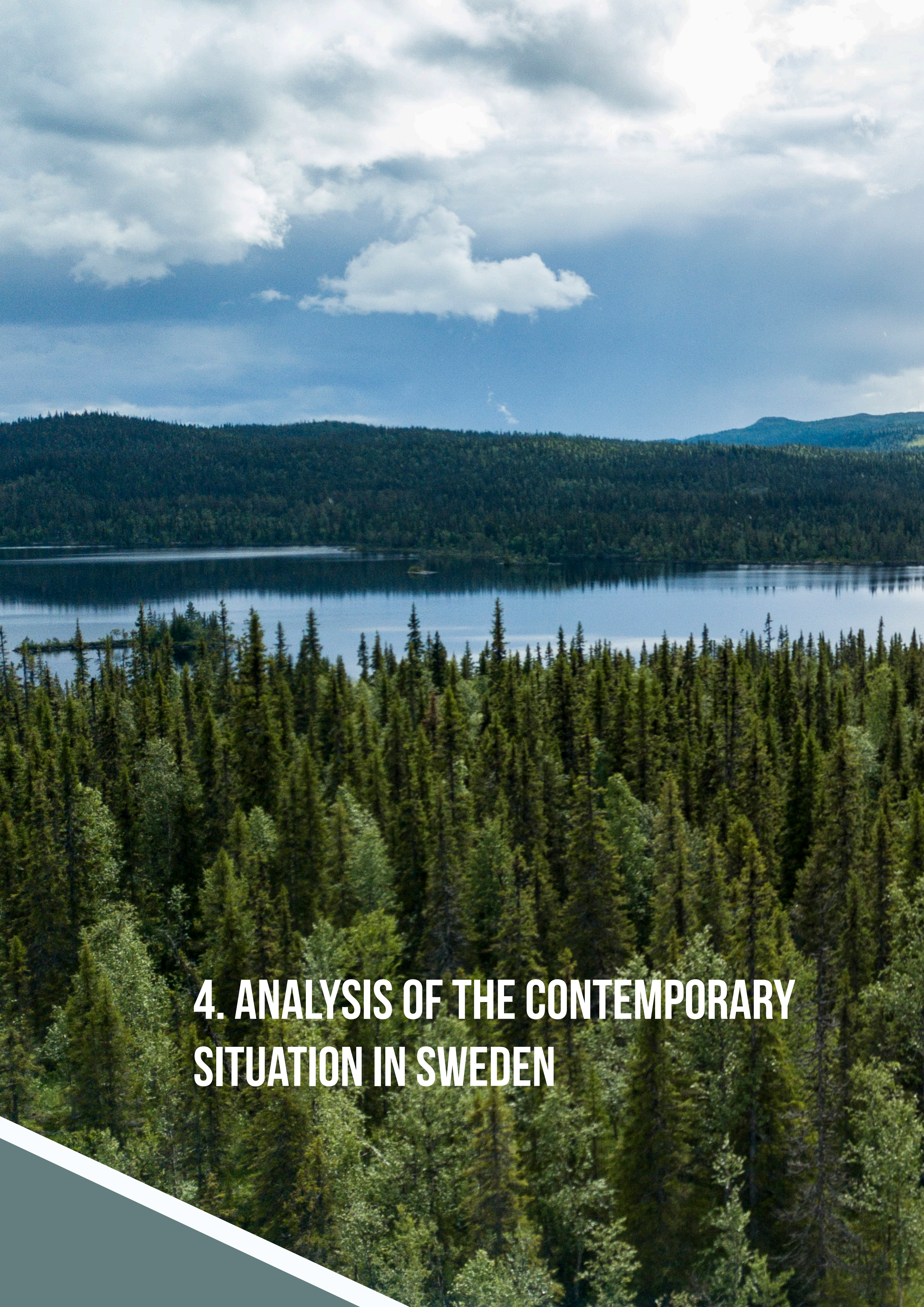
Photo: Björn Olin


Photo: Viktor Säfve


Photo: Anders Delin


Photo: Björn Olin


Photo: Viktor Säfve



4. ANALYSIS OF THE CONTEMPORARY SITUATION IN SWEDEN


Photo: Jon Andersson

ANALYSIS OF THE CONTEMPORARY SITUATION IN SWEDEN

Human induced climate change, loss of biodiversity (IPBES 2019) and weakened ecosystems are now threatening the very foundation of our civilization. Policy decisions made in the next few years will be critical. Halting the destruction and fragmentation of forest ecosystems as well as restoring and protecting the world's forests is fundamental; not the least in strengthening forest resilience (Thompson et al. 2009) during a period when the climate is projected to become increasingly volatile.

In a time when we would need to reduce emissions and to utilize every possible carbon sink (Luyssaert et al. 2008, Wardle et al. 2012, Clemmensen et al. 2013), and when we need to safeguard the current carbon storage (Besnard et al. 2018, Liao et al. 2010) the Swedish forestry industry continuously displaces large amounts of carbon from forests and into the atmosphere. The Swedish forestry model causes large greenhouse gas emissions (Vestin et al. 2020).

Researchers suggest that reduced logging levels may provide large climate benefits in the coming decades (Skytt et al. 2021). The time factor is crucial. The next few years may prove critical if we are to reach international climate targets and environmental goals, mitigate negative climate effects and avoid exceeding points of no return, reaching so-called "tipping points" (Armstrong et al. 2022).

The forest heritage in the North

Sweden harbors a significant part of the EU's natural heritage, and estimations suggest that the country has the largest area of continuity forest within the EU (Höjer 2023). The Swedish forest landscape is diverse and contains several forest habitat types defined in the EU's Habitats Directive, whereof Western taiga (habitat type 9010) is the most commonly occurring. However, only a minuscule part of Sweden's forests reach favorable conservation status. Proper Western taiga, with primary- and old-growth forests characteristics and naturally regenerated continuity forests is becoming increasingly scarce due to forestry.

Due to historical deforestation in southern Sweden, the Fennoscandian hemiboreal natural old broad-leaved deciduous- and beech forests are very reduced in size and logging is still going on in these forests. The forests covering the foothills of the Scandes mountains (**Figure 2**) is sometimes referred to as the Scandinavian Mountains Green Belt (the SMGB). The SMGB is largely situated within the borders of Sweden and is a unique natural heritage from a European as well as international perspective (Svensson et al. 2020). The still unprotected forests in Sweden, with conservation values, are critical to maintain biodiversity, protect ecosystem functions and contribute to climate change mitigation.

Sweden's forests are in peril

Assessments made by the Swedish Forest Agency, the SFA (2023), and the Swedish Environmental Protection Agency, the SEPA (2022, 2024) on the environmental quality objective Living Forests [Levande Skogar] shows an ever down-spiraling and unsatisfactory ecological condition.

The assessments conclude that in recent years, despite alleged efforts to improve the ecological status of Swedish forest ecosystems, the trend is negative. Moreover, according to the SFA (2023), 14 out of 15 forest habitat types listed under the Habitats Directive do not reach a favorable conservation status, and the conservation status for 10 out of 11 woodland-living priority species of invertebrates is "bad", with the remaining one listed as "inadequate".

Moreover 2,249 forest-dwelling species are red listed in Sweden according to the Swedish Species In-

Figure 2. Aerial image of the transition from northern boreal coniferous forest to the baren alpine meadows. Photo: Jon Andersson

formation Center (SSIC) at the Swedish University of Agricultural Sciences, the SLU. Approximately 1,400 red-listed species are strongly negatively affected by logging (SSIC 2020). An assessment from 2022 shows that out of the threatened forest living species, close to 400 are directly negatively affected by clear-cutting (Ottosson 2022). Most investigations to measure the state of the forest ecosystem concludes an alarming situation for biodiversity and ecosystem health in Sweden.

The urgency of the situation cannot be stressed enough. With today's rapid logging rate, scenarios and estimates made by researchers (Ahlström et al. 2022), authorities (Larsson 2011, SFA 2015) and experts indicate that most of Sweden's remaining continuity forests and old conservation values forests, outside protected areas, will be lost within approximately a few decades.

Sweden's government aims to cut down on forest protection

Despite the dire forest situation, the right-wing Swedish government installed in 2022, sharply reduced the budget for nature protection and downgraded many climate initiatives set by previous governments (DN 2022).

Today we label Sweden as a "high-risk country" to trade forest products with, and both the EU, forestry, industry and the Swedish government must take drastic measures to turn this situation around. There are three main reasons why Sweden is a high-risk country:

- The Swedish Forestry Act and forestry certifications like the PEFC and the FSC cannot guarantee its customers that the products do not come from forest degradation and from forests with conservation values.

- The current forest management negatively affects the Sámi reindeer husbandry.

- The Swedish government pursues a policy hostile to nature conservation at the EU level.

The Sámi culture and the forest

The Sámi's reindeer husbandry culture is dependent on the forest for their survival. The forest provides shelter, food and materials for Sámi handicrafts. One of the major threats to Sámi culture is the loss of habitat due to direct or indirect impacts from competing land use.

Commercial forestry is one of those. Especially the on-going clear-cutting and methods such as soil scarification and the use of fertilizers aggravate the condition for reindeer husbandry. It destroys ground lichen habitats, the primary food resource for the reindeer. In an article published in 2016, researchers found that during a period of 60 years, about 70% of the lichen rich forests that are crucial for reindeer husbandry were lost (Sandström et al. 2016).

Forestry also has a negative impact on tree living pendulous lichens, which is the second most important food resource for the reindeer. Pendulous lichens are much more common in old forests than young production stands (Dettki & Esseen 2003, Esseen et al. 2021). Also, forestry and its infrastructure have significantly reduced the area of old spruce forest, which can give shade to the reindeer during hot waves and relief from stinging insects.

The right to Free, Prior and Informed consent (FPIC) by the Sámi people is a prerequisite to ensure respectful harvest conditions that protect traditional subsistence living but also biodiversity and ecosystems. How this works in reality has been questioned (Stockholm Environmental Institute 2024 & Greenpeace/Renskog 2025).

Some advice for future Swedish politicians

By referring to the aforementioned facts about the negative impact of Swedish forestry, we here give future politicians with hopefully more broad-sighted agendas and a larger interest in future generations, three obvious reasons to restrict the Swedish forestry industry:

- Despite the Swedish Forestry Act and the alleged good of labeling forest products with sustainability certifications like the FSC and the PEFC, there is no guarantee their customers aren't sustaining large-scale forest degradation and accelerating destruction of forests with conservation values.

Photo: Viktor Säfve/Helifilm.com

● The Swedish forest industry seems to have completely forgotten about the Sámi reindeer husbandry. Despite continuous protests from the Sámi community, the forestry industry has destroyed about 70% of the lichen rich forests that are crucial for reindeer husbandry during the last 60 years.

● The Swedish forest industry's way of battling the climate crisis is dubious. If their intentions were pure, why do they then lack the interest in listening to well-published researchers who have found that clearcut forestry may worsen the climate situation and that reduced harvest levels provide large climate benefits coming decades? If they were as interested as they say they are, they wouldn't run aggressive campaigns to unilaterally promote more clearcut forestry and stand in public media ranting about increased harvest levels.

Right now, tens of thousands of hectares of forest is notified for final felling (planned to be clear-cut), within our mapped area of forest with confirmed high conservation values or probable conservation values! Nevertheless, this is an underestimation, as the mapping does not contain classification of all the known high natural and conservation value forests within the layer of OFCF.

Considering the overwhelming evidence that the current Swedish forestry is harmful to the ecosystem and the Sámi, and most probably worsen the climate situation, it is a disgrace that the Swedish government is fighting to defend this so-called green industry and the Swedish forestry model.

This raises concerns about the aggressive forestry lobbying and how forestry representatives have managed to wriggle their way all the way into the very heart of decision making. Scientists warn that Sweden threatens European biodiversity (Chapron 2022) as our leaders act and cooperate with other nations to weaken or stop important EU-level legislative initiatives.

Figure 3. Swedish forestry model - loggings of older forest with a low-level of retention patches and singel trees left om the clear-cuts.

Is our forestry sustainable?

According to the Helsinki resolution, sustainable forest management (SFM) is:

"The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems."

It is clear that the forestry methods used in the Nordic countries, on multiple points strongly deviate from this description. Maybe we should ask ourselves why we haven't yet, despite grand international resolutions, shifted to a sustainable way of managing forests. The only possible answer is that the current business as usual is considered more profitable in the short run for the forest industry than sustainable forestry and that the industry is disproportionately influential on policy making. Our politicians are letting this go on and many voters cannot see the difference between sustainable forestry and the current unsustainable destruction of forests.

The Swedish forestry model

The Swedish forestry model (the SWFM) is promoted as a success story, now promising both climate change mitigation and the safeguarding of biodiversity and living ecosystems. But is this really a sane image of this forestry model?

Few people who hear about the SWFM understand its essence. It can be best described as "tree-farming". Older forests are clear-cut, usually with a low-level of retention patches and single trees left on the clear-cut (**Figure 3**). Then the soil is often scarified. The most common regeneration method is plantations with pre-grown seedlings. After a few years the stand is pre-commercially thinned and later the stand is again thinned. When the trees are considered harvestable, at around 45 - 100 years of age, the stand is clear-cut again.

The impact of the SWFM is not limited to Sweden. It has implications for the rest of the world as well. Some of the world's and the EU's largest forestry, hygiene, paper, furniture and wood companies such as SCA, Holmen, Stora Enso, Sveaskog, IKEA and Essity, all originate from or have their base in Sweden. Some of these companies source wood and pulp and operate in many parts of the world, thus spreading the Swedish forestry model around the globe. There are many other large international companies who uses wood and pulp from the Swedish forest industry too.

In times of climate change, the forest industry claims to hold the magic wand, aka wood. Swedish forestry representatives are praising the use of wood in everything from disposable articles, packaging and makeup, to fuel for an ever-expanding transport sector. To push this narrative, the forest industry spends millions on advertising, public relations and lobbying to present their products and raw materials as the solution for the green transition. The forest industry portrays Sweden as a country with vast and inexhaustible resources of wood. Their representatives and Swedish parliament members have celebrated the SWFM as the role model of forestry, which they claim has transformed Sweden from "a more or less deforested nation" a hundred years ago to a rich forested nation today. But can we really say that planted monocultures of pine or spruce is forests? According to the forest industry the answer is of course a resounding yes. But is a forest something more than just trees?

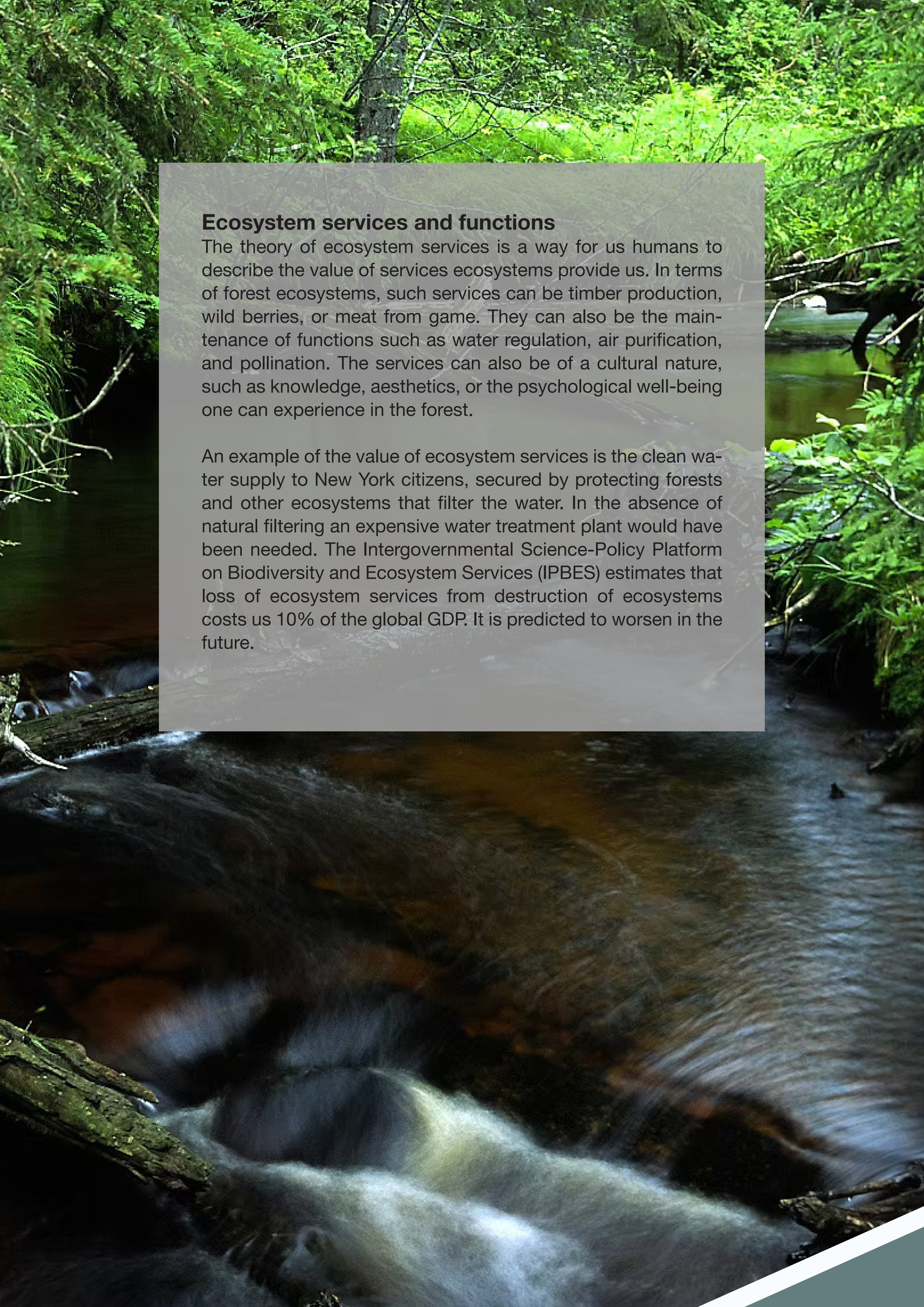
According to the narrative, Swedish forestry is generally balancing economic and environmental targets. The promise to plant two to three trees for each tree that is felled is given as a proof that Swedish forests become increasingly richer. The slogan "for more than 100 years Sweden has been planting more trees than it cuts down" has spread. Some, like the Swedish Forest Industries Federation take it one step further. They claim that *"The forest industry is making biodiversity possible"*. So, without forestry there would be no forest species? In many ways it resembles a religion.

Multiple-use and Ecosystem functions

Old forests do not only harbor a rich biodiversity. They also store large amounts of carbon and are vital for a wide range of ecosystem functions. They are also important for the multiple-use of the ecosystem services of forest such as recreation, wild berry production, ecotourism and much more. Wood production, which is many times raised above other ecosystem services, is thus only one of many others which are essential for our existence. Therefore, increased protection and restoration of forests and a transformation to more sustainable forestry methods are not only important tools for climate mitigation and biodiversity. It is also an economic investment.

By reckless, large-scale usage of the SWFM, Sweden has converted the majority of a living forest ecosystem into a fragmented forest landscape with managed tree stands and tree plantations. To halt and reverse this process, a transformation of today's intensive forestry into close-to-nature forest management is fundamental. Furthermore, to strengthen biodiversity and ecosystems, and to also increase resilience and build on carbon storage to combat climate change, it is necessary to restore forests. Moreover, future wood products must be made more climate friendly than today's.

Photo: Stig Björk



Ecosystem services and functions

The theory of ecosystem services is a way for us humans to describe the value of services ecosystems provide us. In terms of forest ecosystems, such services can be timber production, wild berries, or meat from game. They can also be the maintenance of functions such as water regulation, air purification, and pollination. The services can also be of a cultural nature, such as knowledge, aesthetics, or the psychological well-being one can experience in the forest.

An example of the value of ecosystem services is the clean water supply to New York citizens, secured by protecting forests and other ecosystems that filter the water. In the absence of natural filtering an expensive water treatment plant would have been needed. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) estimates that loss of ecosystem services from destruction of ecosystems costs us 10% of the global GDP. It is predicted to worsen in the future.

5. EXPLORING THE MAP SERVICE

EXPLORING THE MAP SERVICE

When you explore the map, you can turn different layers on and off. These can be found at the top right corner of the map. You can zoom in and out and scroll around on the map. You can write, draw and make measurements, as well as share and export customized maps. You can also draw shapes around areas of interest, and find information about species by clicking a specific button, which will open a window with findings of registered nature conservation species. There is also a function that tracks your location when you are out in forests, which comes in handy when navigating on various field surveys. The map service can be used on a computer, smartphone, or tablet. Forest Monitor's map layer of OFCF and mountain birch forests, in addition to the free web service, is also available as a WMS-service, with paid subscription.

Let's explore the map service!

Icons on the upper left corner

If we start from the top right corner in **Figure 4** to the left, we find a direct link to skogsmonitor.se, and 4 clickable icons and below a zoom control. The first icon from the left allows you to create a link to your current position: "Link to selected position on map" that can be copied and sent to a friend. The next icon from the left enables an export function so that you can download the current geographical extent as GeoTIFF, PDF or PNG. When downloading GeoTIFF for use in an external mapping application, be aware that Skogsmonitor uses the Web Mercator projection and not SWEREF99.

The third icon shows findings registered on the Swedish species observation system Artportalen – an open database run by Artdatabanken, the Species Information Center at SLU.

Select an area using the drawing tools on the right side of the map (**Figure 5**), then click this button to display the species findings for the selected area.

The magnifying glass on the far right of this menu allows you to search by the name of a village, a town, city, or by ID on the specific felling notification number (A XXXX-XXXX).

The icons on the upper right

At the top you will find a measuring tool that measures both distance and area (**Figure 6**).

Then you will find different shapes you can use to draw on the map (also used to delimit your searches for species findings). You will also find a text icon for making notes on the map.

At the bottom there is a trash can where you can delete measurements etc.

Overview map in the lower left corner.

Down on the left you will find a inset map (**Figur 7**).

The main menu on the right

On your right (**Figure 8**) you will find the main menu and various background map options. Here you can also switch between English and Swedish and see the coordinates of the current cursor location in decimal degrees.

The layers can be turned on and off. Three of the layers, the four background maps, Old forests & continuity forests 2.0 and Logged old forests & continuity forests have a slider that allows you to adjust the individual opacity. To get information about each layer, you can click on the grey expression mark to the right of each layer (**Table 1**).

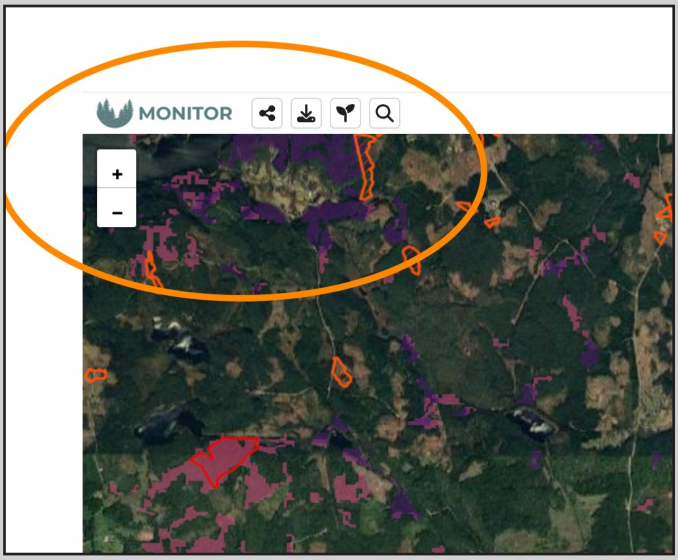


Figure 4. Icons on the upper left corner.

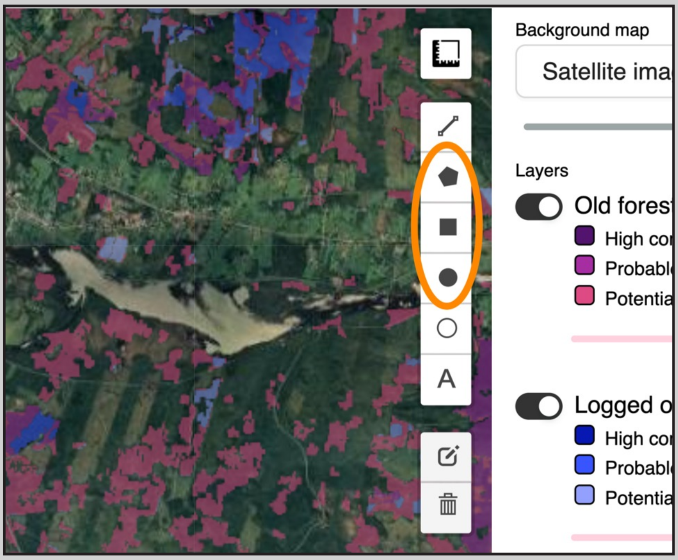


Figure 5. The drawing tools on the right side.

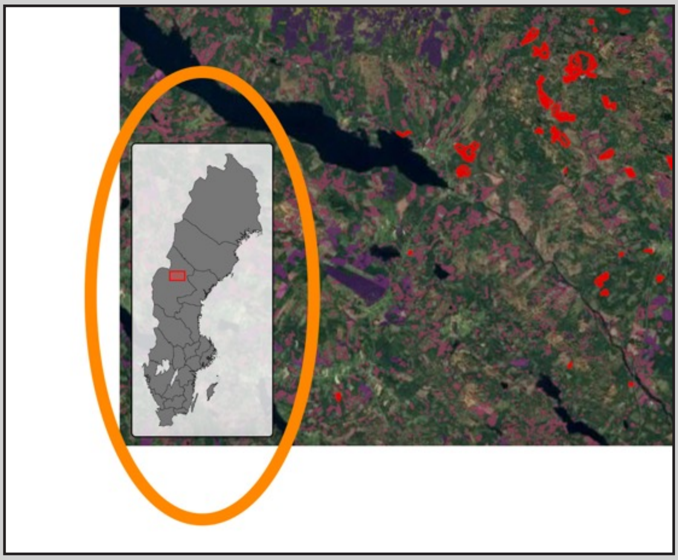


Figure 7. Location map.

Figure 6. The measuring & drawing tools.

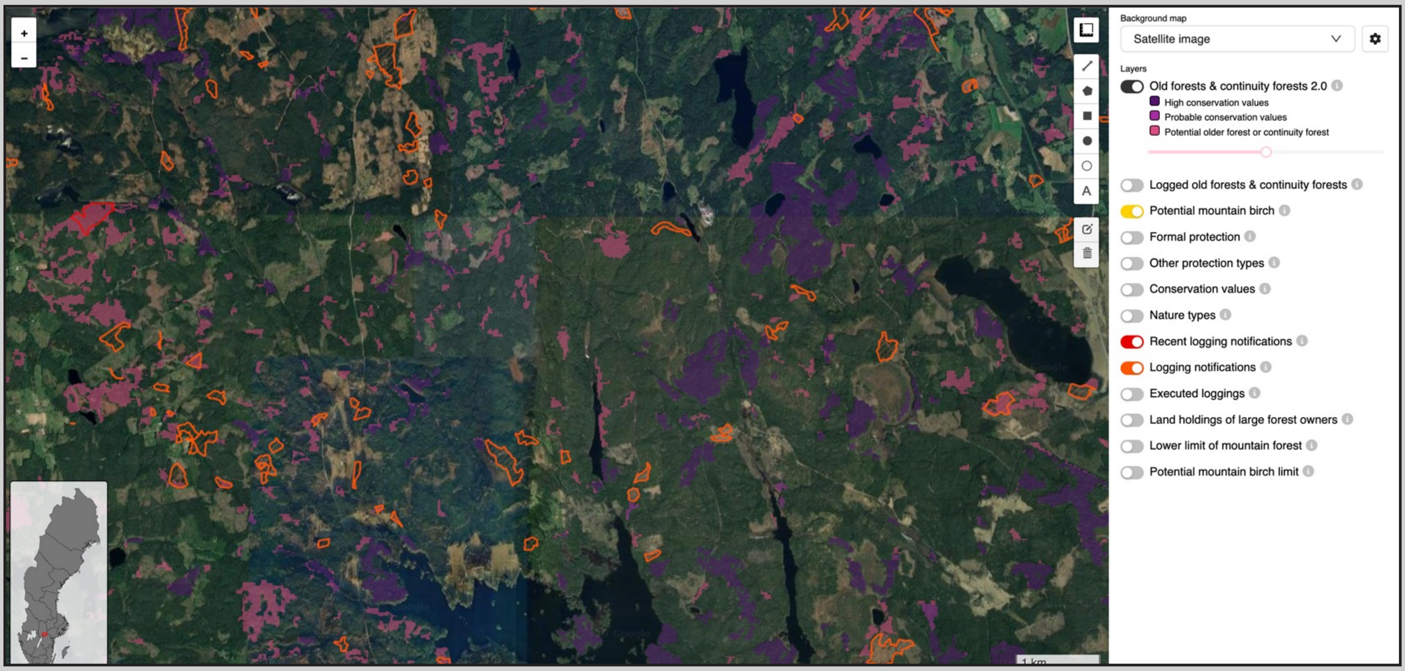


Figure 8. The main menu.

Table 1: Layers:	Content and description:
Background maps	You can choose between the following background maps: • Lantmäteriet's topographic web map, where you can see place names in Swedish, contour lines, roads, etc. • Google maps satellite map • Lantmäteriet's Historical aerial photograph, 1960 • Lantmäteriet's Historical aerial photograph, 1975
Old forests & continuity forests 2.0	This layer contains potential continuity forest and older forest identified via remote sensing, as well as areas (High conservation values & Probable conservation values) that various open source data and inventories have shown to have high natural values (inventory & open source data) or probable conservation values (species data and open geodata). The remote analysis shows forest areas that have probably not been clear-cut since the 1950s and are therefore potential older forest or continuity forest depending on land use history and which region the analysis was carried out in. Version 2.0 of this layer is based on a hybrid between open data from the Swedish Environmental Protection Agency (Dalarna, Värmland and the counties in Norrland) and Forest Monitor's own remote analysis (counties in the rest of the Svealand and Götaland). The processing and classification is done by Forest Monitor. This layer will be improved and updated for the entire country. ***High conservation values:*** Areas within the remote analysis that open data (field inventory is usually the basis) confirm have high conservation values, as well as older forest and continuity forest within formally protected nature. ***Probable conservation values***: Areas within the remote analysis with potential older forest and continuity forest where in all or parts of a polygon there are probably conservation values or high conservation values, based on public and open source data such as species finds and geodata. ***Potential old-growth forest or continuity forest*** (the rest): Remote sensing based on AI, classification, and change detection analysis, which shows forest that has likely not been clear-cut since the 1950s and is therefore potential older forest, old-growth forest and/or continuity forest depending on land use history and which region the analysis was performed. This part of the layer probably contains a large amount of unknown areas of forest with high conservation values.
Logged old forests & continuity forests	This layer shows forests from the layer "Old forests & continuity forests" that have been logged since the beginning of 2022. Note that these are just recently logged old forests and continuity forests (incl. potential) and that most of the logging in this kind of forests were made before the publication of Forest monitor (skogsmonitor.se). In some places, narrow strips of harvested "Old forests & continuity forests" are visible. This is often because the boundaries in this layer do not always correspond to reality and that logging that has taken place right next to these boundaries sometimes intersects the data layer but not the old forest out in reality. Seen over the entire forest landscape, Swedish forestry has already logged most of the old forest with high conservation values in the country, and the process is still ongoing.
Potential mountain birch	Modelled, potential occurrence of mountain birch. Mountain birch forest is not currently interesting for large-scale forest production and is therefore not threatened in the same way as the rest of the forest land. It is therefore important to separate it from the rest of the forest landscape.

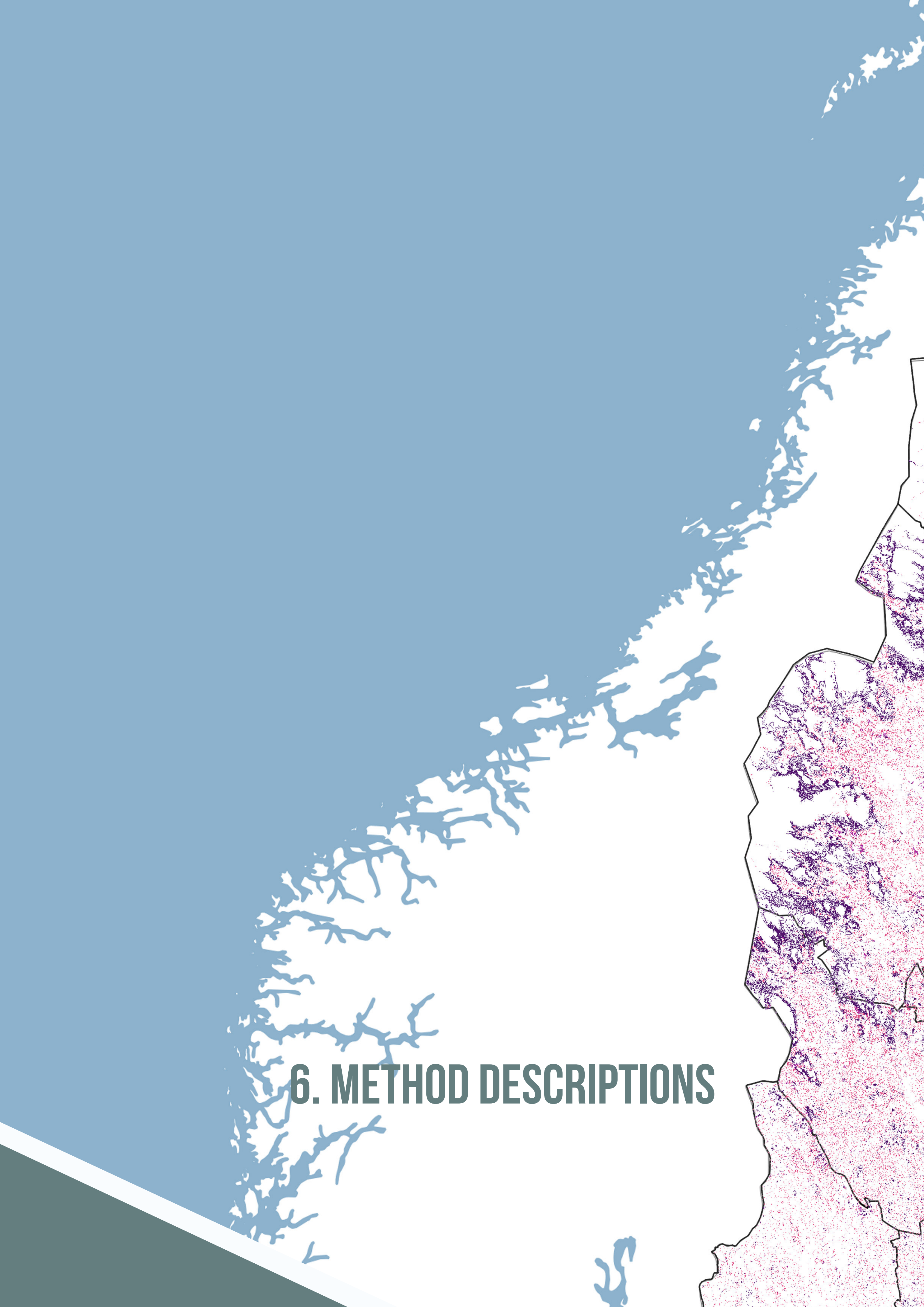
Table 1: Layers:	Content and description:
Formal protection	**National parks** The purpose of a national park is to 'preserve a larger contiguous area of a certain landscape type in its natural state or in an essentially unchanged condition' (from the Environmental Code). The state owns all land in a national park. The national parks must consist of representative landscape types that are preserved in their natural state, but they must also be scenic or unique environments that can provide natural experiences. Sweden has 30 national parks. **Nature reserves** The county administrative boards and municipalities can form nature reserves according to the Environmental Code. Nature reserves are formed 'with the aim of preserving biological diversity, caring for and preserving valuable natural habitats or meeting the need for areas for outdoor activities. An area that is needed to protect, restore or create valuable natural environments or habitats for species worthy of protection may also be declared a nature reserve.' (from the Environmental Code). Sweden has roughly 5,100 nature reserves. **Forest biotope protection areas** Biotope protection areas are used to preserve smaller habitats for nationally threatened species and small nature types worthy of protection in the forest or agricultural landscape. Forest biotope protection areas are managed by the Swedish Forest Agency. **Other biotope protection areas** Biotope protection areas are smaller areas of land and water that provide habitats for endangered animal and plant species, or that are especially worth protecting. Biotope protection areas are normally not larger than 20 hectares. Municipalities and county administrations can establish biotope protection areas. **Nature conservation agreements** A nature conservation agreement is signed between the property owner and the Swedish Environmental Protection Agency or a county administrative board as contracting party for the state. A nature conservation agreement is a civil law agreement. The property owner and the state or a municipality agree on a certain financial compensation for the property owner in return for the latter refraining from, for example, forestry. Nature conservation agreements can be concluded both for areas that depend on management to preserve the natural and conservation values and for such areas where the natural values benefit the most from free development. The contract period can vary between 1 and 50 years. The Swedish Forest Agency and the Swedish Environmental Protection Agency jointly guide how to proceed. **Nature conservation agreements, other**
Nature types	**The national wetland inventory** Objects of the Wetland Inventory (VMI). The data contains the boundary of the VMI object (surface), a center point and an ID (LOID). Scale 1:250,000. At the Swedish level (1:6,400,000) and down to 1:250,000, only inventories > 1000 HA are shown. Under 1:250,000, all inventoried wetland areas are shown, regardless of size. NOTE: Data for Jämtland and Skåne counties have some errors, so for use in these counties it may be better to search for data via the county board's GIS portal. **SFA swamp forests** Collective name for all forested wetlands. 3 types, swamp/wetland forest, moist forest and coastal forest. The bog forest can be divided into marsh forest and bog forest. The moist forest is divided into overflow forest and other moist forest.

Table 1: Layers:	Content and description:
Other protection types	**Natura 2000 The Birds directive** In 1979, the EU member states decided to introduce special rules for the protection of birds, the Bird directive (directive 79/409/EEC). The Birds directive affects a total of 200 bird species that occur in the member states. There are 66 of them in Sweden. Each member state must partly take measures that are necessary to maintain bird species in viable populations (for example, regulate bird hunting) and partly take special measures for bird species that are listed in Annex 1 of the directive. Among other things, special protection areas must be identified. The protection can also be about restoring habitats for the birds. The directive contains several rules that govern the countries' possibilities to hunt and trade in birds. **Nature 2000, Habitats directive** The Habitats Directive (Directive 92/43/EEC) was introduced in 1992. It deals with habitats and species groups other than birds. The term habitat is used very broadly and includes geological formations as well as biotopes and plant communities. The species groups in the directive are mammals, including wolves, some seals and bat species, amphibians such as bell frogs, some fish species, molluscs such as river pearl mussels, some vascular plants and mosses. Lichens, fungi and algae are not included in the directive. A total of over 170 nature types are listed in Annex 1 to the habitat directive, of which 88 are found in Sweden. Each member state must propose areas of community interest with affected nature types (appendix 1), including species that are mentioned (appendix 2) and ensure that the necessary measures are taken in the areas to preserve the habitats of the species so that they can survive in viable populations and that the nature types are preserved in the long term. For both habitat and bird directive areas, the member state must ensure that the Natura 2000 areas receive the care they need and monitor that their natural values are preserved so that the condition of the habitat types and species concerned remains favorable. The different nature types in the directive are defined in the EU Commission's interpretation manual (Interpretation Manual). Based on it, the Swedish Environmental Protection Agency has produced the book Swedish nature types.
Other protection types	**Nature memorials** Most of the natural monuments are established through older decisions and with the support of previous nature conservation legislation. Most of them consist of trees that are particularly worthy of protection, e.g. giant oaks. Other items are big blocks. Even smaller areas, such as habitats for unusual plants or small islets, occur among the natural monuments. Natural monuments can be both areas and points. **Nature conservation areas** Before the Environmental Code came into force, the County Administrative Board or the municipality could set aside nature conservation areas with the support of the Nature Conservation Act. The form of protection was weaker than the nature reserves and was not allowed to prevent ongoing land use, such as forestry. Most nature conservation areas were established to protect the landscape, especially in coastal areas, or to maintain the management of hay meadows and pastures. Some municipalities have used the form of protection to guard popular outdoor areas. Since the Environmental Code came into force, the possibility of creating new nature conservation areas has ended. But nature conservation areas that have already been established remain and, according to the Environmental Code, must now be considered nature reserves.

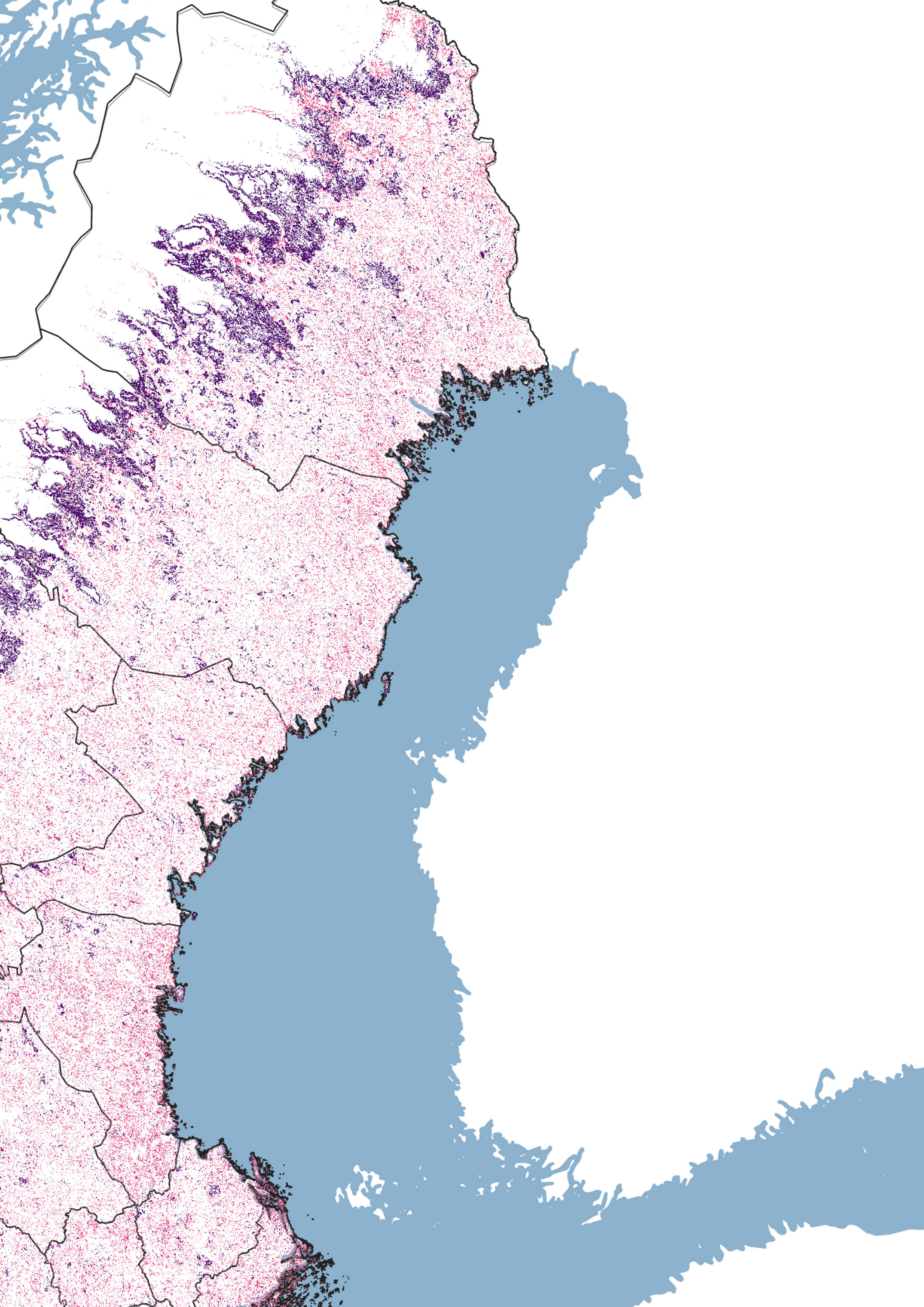
Table 1: Layers:	Content and description:
Other protection types	**Animal and plant protection areas** It is possible to protect, for example, nesting birds or seal colonies by prohibiting access to an area during certain months of the year. Most of the more than 1,000 animal protection areas that exist today are located on coasts or lakes and have been added to protect seabirds or seals. **Cultural reserves** With the support of the Environmental Code, municipalities or county boards can protect valuable cultural landscape areas as cultural reserves. They can be set up on state as well as municipal or private land. **Scenic protection areas** Scenic protection areas is an older form of protection (which was established with the support of Section 19 of the Nature Conservation Act) and a concept that is not found in the Environmental Code. It is gradually being replaced with other forms of protection, but until these are in place, the regulations in the landscape protection areas apply. Special regulations have been drawn up for each landscape image protection. The protection regulates buildings, roads and other facilities that can have a negative effect on the landscape. It does not regulate forestry and agriculture. The county administrative boards handle landscape image protection. Contact the respective county board if further information is requested. **Interim prohibition areas** The conservation values of an area can be protected pending a decision on a nature reserve. The county administrative board or the municipality can issue a temporary ban on taking measures that could damage the values they want to protect. Examples of measures that may conflict with the purpose of a proposed nature reserve are logging.
Conservation values	**SFA woodland key habitats** A Woodland key habitat is a forest area which, from an overall assessment of the biotope's structure, species content, history and physical environment, today has very great significance for the forest's flora and fauna. There are or can be expected to be red-listed species in the area. **Forestry's woodland key habitats** Large forest owner's like forest companies was mandated to map and register woodland key habitats on their own properties. The companies that are part of Large forest owner's woodland key habitats are Sveaskog, SCA, Holmen Skog, the State Property Agency, several parts of the Swedish church forests, Gävle and Karlstad municipalities and parts of what was previously owned by Bergvik Skog AB. **SFA conservation values** During the inventory of woodland key habitats, other objects was also registered that have natural values, without reaching the same quality as a woodland key habitat. The result is used for advice and planning efforts for nature conservation. **State conservation value forests** Map layer showing state forests with conservation value and primeval forests. Inventory of forests on state land with natural values that justify the formation of nature reserves. The inventory was carried out by the County Administrative Boards following the Environmental Protection Agency's instructions on behalf of the Government. The inventory was finally reported in 2004.

Table 1: Layers:	Content and description:
Recent logging notifications	Logging notifications that were handed in less than 6 weeks ago. This is the time window when the Swedish Forest Agency can evaluate whether the felling notification follows the legislation, or if nature or culture consideration needs to be adjusted.
Logging notifications	Logging notifications that are older than 6 weeks, that passed the time limitation when the Swedish Forest Agency has the chance to evaluate whether the felling notification follows the legislation.
Executed loggings	Logged areas according to change detection in satellite images.
Land holdings of large forest owners	Companies with over 100,000 hectares of forest Municipalities and regions The Swedish Environmental Protection Agency National Property Board Other (e.g. trading companies, limited partnerships, commons, the church) Other limited companies with over 1,000 hectares of forest Other government agencies and authorities The data describes the property holdings of large forest owners. The layer contains geographically defined properties owned by landowners with a holding of more than 1000 hectares of forest if they are part of one of the owner categories. Private owners (individuals) are not included. The layer is based on information from the property register (assessment information and digital register map) and the Swedish Environmental Protection Agency's property information (FIDOS). The basis can be used for general planning and regional statistics. Connections between assessed land owner and individual properties in the map may be missing, which is why the basis should not be used to search for or contact interested property owners, in which case a more thorough property investigation is needed.
Lower limit of mountain forest	West of this border, a permit is required for logging.
Potential mountain birch limit	Limit for modelled, potential occurrence of mountain birch. Mountain birch forest is not currently interesting for large-scale forest production and is therefore not threatened in the same way as the rest of the forest land. It is therefore important to separate it from the rest of the forest landscape.

Photo: Viktor Säfve



6. METHOD DESCRIPTIONS



METHOD DESCRIPTIONS

We used various retrospective remote sensing and machine learning techniques to create Forest Monitor's data. By using a combination of, on the one hand, existing open data on conservation and natural values collected in the field by authorities, researchers, municipalities and non-profit nature conservation organizations, and on the other hand, data modeling of species occurrences, we then classified the OFCFs into three non-overlapping classes. For data validation, we used, among other sources, organized field inventories to survey large reference areas of entire landscape sections. In this report we present the validation from the field inventories.

We used a classification scheme that depended on whether conservation values could be confirmed in a specific forest patch. If conservation values were mapped during previous field visits the forest was assigned to conservation class 1, *high conservation values.* If forest patches were otherwise validated with i.e. supplementary assessments, we assigned them to class 2, *probable conservation values.* Remaining forest patches, that could not be assigned to any of the two first classes were assigned to class 3, *potentially older forest or continuity forest*, or proxy continuity forests (for class 3, see Svensson et al. 2018 for a description of proxy continuity forest). A thorough description of these classes is presented in the chapter *Classification of conservation values in forest fragments.*

Only a fraction of the forest landscape has been visited in the field by i.e. authorities and non-profit organizations, and hence there are limitations of the open-source data we used to classify our data. Consequently, the areas in class 1, *high conservation values* and class 2, *probable conservation values* in the OFCFs show an underestimation of the real coverage of forest in these two classes. Therefore, the third category, class 3, contain significant areas of forest with high conservation values (class 1 and 2). The location of these conservation values are however currently unknown to us.

Since the launch of the first version of the OFCF-data there has been one national-covering update of the three classifications. Note that this update didn't change the area, the shape nor the size of mapped forest fragments. Only the classifications. Thus, it is now called "Old forests & continuity forests 2.0" (OFCF 2.0). Regarding the overall mapping of the delimitation and area of OFCFs, our data currently presents an overestimation of the real area in some parts of the country. Particularly this is true for southern Sweden and Gävleborg county, where most of the data hasn't been updated. More about the specifics on this topic is addressed in the coming chapters.

First mapping of old forest in southern Sweden

Our mapping of OFCFs for the southern half of Sweden has entirely been developed by Forest Monitor. However, the forestry history in Sweden varies greatly. Forestry has been going on for much longer in southern Sweden than in the northern parts of the country. Thus, when we talk about the relative accuracy of our mapping of OFCFs, the chosen retrospective analysis methods, that reach back to the mid-1950s, cannot fully capture events that took place beyond the 70-year time window between today and the mid-1950s. Our data shows older forests that haven't been felled during the most recent period with intensive clear-cutting, which was the completely dominant method from the 1950s and onward. We hereafter call historical data the 1960s batch and the 1975 batch. The mapping also excludes forest patches that are smaller than 0.5 hectares. Altogether, this means that certain forest fragments of OFCFs are not included in our mapping. For an overview of the data acquisition years and the distribution of data over time in the historical ortophoto batches from the 1960s through the 1970s, see **Figur 9**.

The coverage of certain forms of deciduous forest with conservation values is also under-mapped. The updated mapping of Kalmar and Örebro county is slightly better, in this respect (**Figure 10**). This is our first version, and in some parts of the landscape there is an over-mapping of older forest. This is due to, i.e., limitations in methodology. Especially the use of grey-scale historical orthophotos was difficult. Other inaccuracies may also occur due to limitations related to satellite data analysis. Clear-cuts can also have been missed in the data on recent loggings by the Swedish Forest Agency. We are currently working with an improved methodology and will hopefully present new, more precise data during 2025.

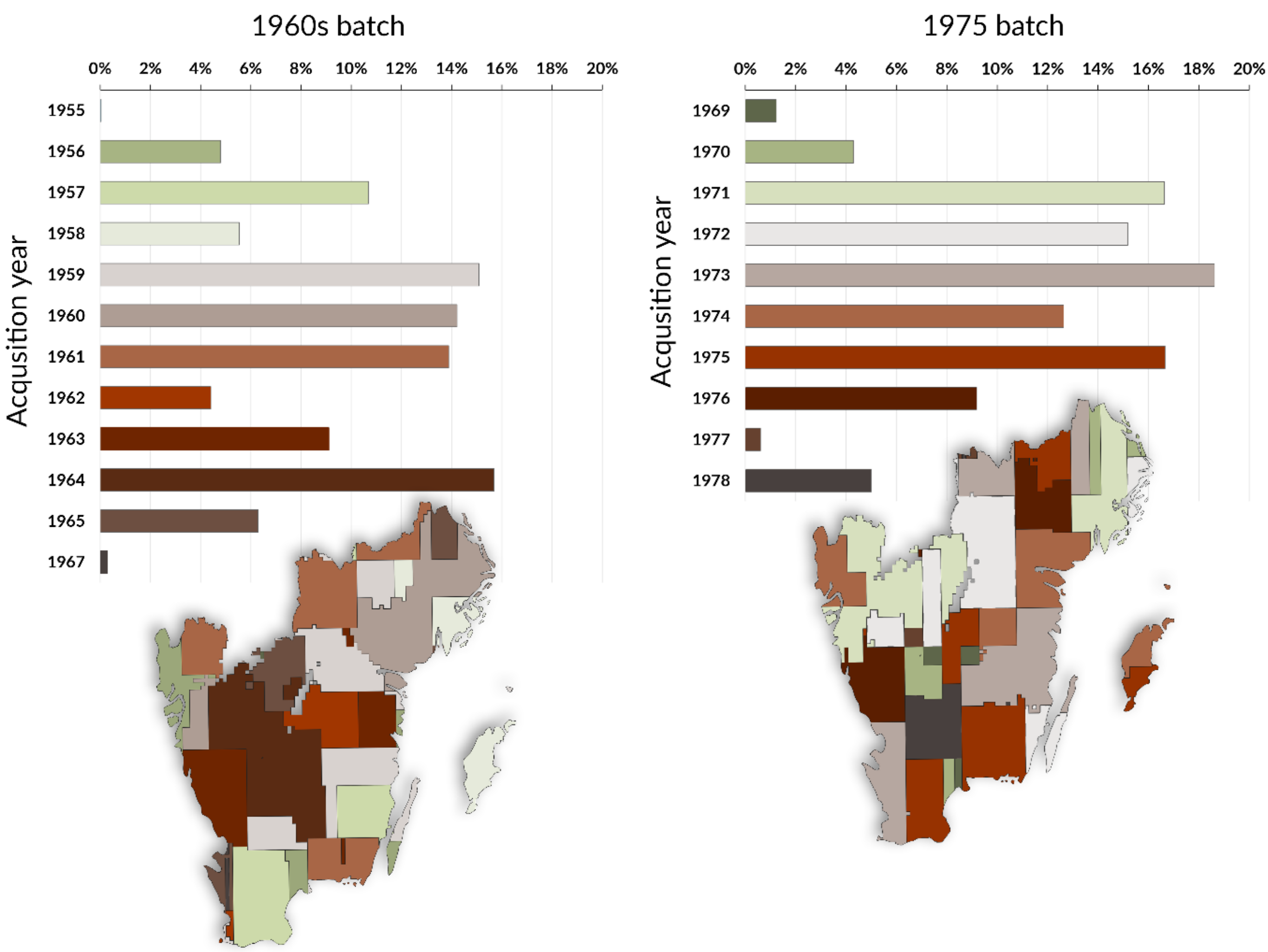


Figure 9. The data acquisition years and the data distribution over time in the 1960s batch and the 1975 batch.

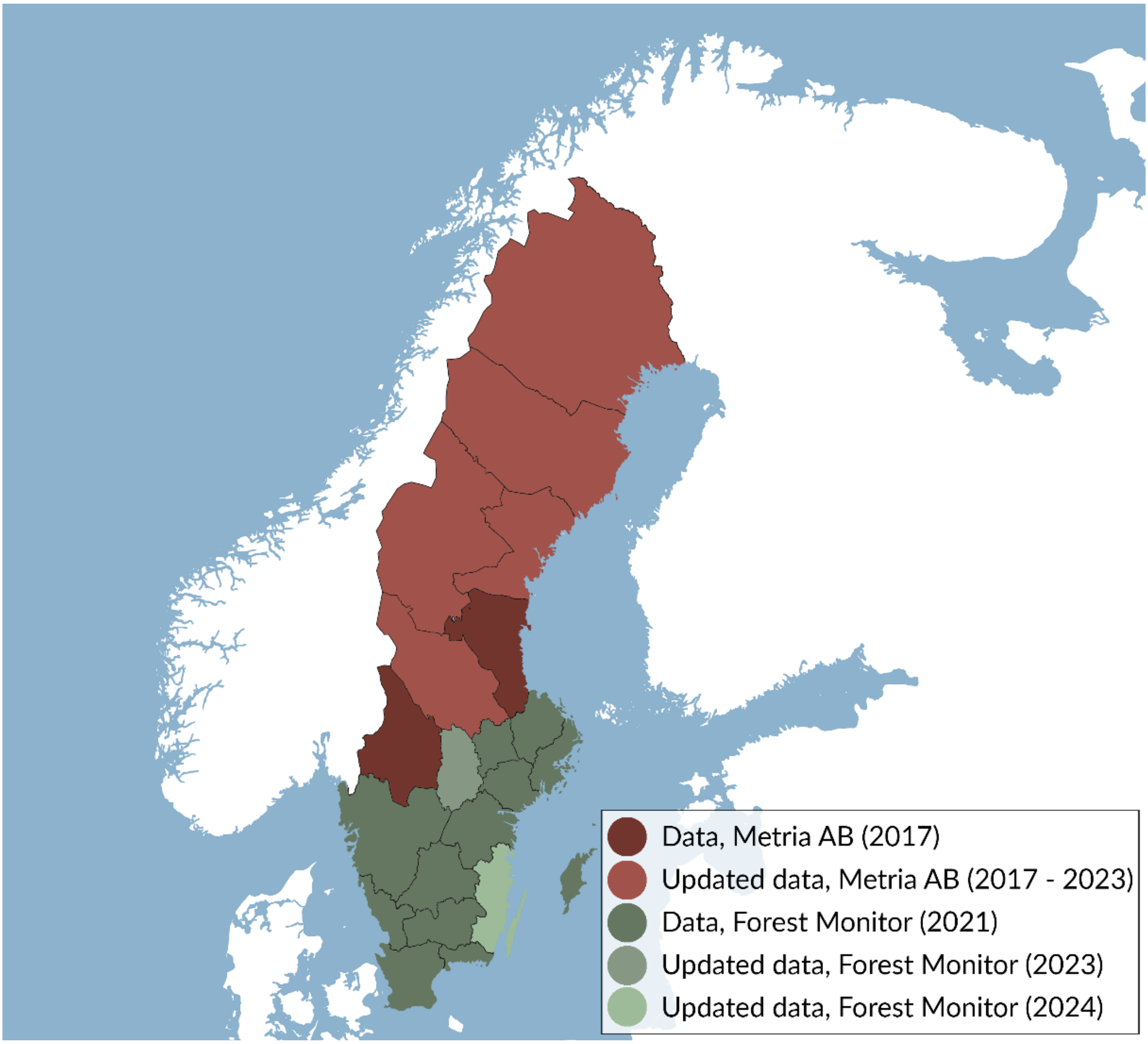


Figure 10. A map of Sweden's 21 counties and the count-wise distribution of the five data sources from Metria AB and Forest Monitor. Updates have been made to both the data from Metria AB and to the data from Forest Monitor.

Dalarna and Värmland counties and the Norrland region

The mapping of OFCFs for the northern half of Sweden are based on the Swedish Environmental Protection Agency's remote sensing project that was created between the years 2016 – 2023. For a thorough description of the methodology used by Metria AB, we refer to the methodology described in Ahlkrona, et al. (2017a).

Note that for the counties Norrbotten, Västerbotten, Jämtland, Dalarna and Västernorrland, data has been updated by visual inspection and thus have a higher accuracy (for details we refer to Ahlcrona, 2017b; and Metria, 2019, 2021, 2023a, 2023b). The data for the counties Gävleborg and Värmland were not updated and shows lower accuracy at the moment. The data for Värmland has, however, been processed by the County Administrative Board in Värmland, and probably has slightly higher precision than Gävleborg County. The data layers from Metria AB have been modified to suit our web mapping service, and then in their entirety classified according to the three aforementioned conservation classes.

Until we have done our own analysis over the rest of Svealand and the Norrland region, the Swedish Environmental Protection Agency's mapping will continue to be the foundation to the delimitation of OFCFs in these parts of the country.

How did we create the data in Forest Monitor?

The sole purpose of Forest Monitors's mapping was to detect clear-cutting made from approximately the mid-1950s through the 1970s until the 2020s in the southern Swedish counties Stockholm, Uppsala, Södermanland, Östergötland, Jönköping, Kronoberg, Kalmar, Gotland, Blekinge, Skåne, Halland, Västra Götaland, Värmland, Örebro, and Västmanland (**Figure 10**).

The delimitation of the mapped OFCF-data in Forest Monitor is created by using a variety of remote sensing techniques. Remote sensing is a collective name for methods and processes aiming to detect and monitor the physical characteristics of an area by measuring its reflected and/or emitted radiation. Data can be collected by satellite or any form of aircraft. The data in Forest Monitor is created by analyzing both satellite data (1980s until present) and data collected by airborne cameras (appr. mid-1950s to late 1970s), the 1960s batch and the 1975 batch. The specific remote sensing techniques used to obtain information were *change detection* and *image classification*. These techniques will be discussed more in depth later in the text.

The mapping and delimitation of clearcuts is based on a merger of the following analyses and auxiliary data sources:

- Change detection analysis of Landsat satellite images acquired from the mid-1980s until the 2020s, to detect clear-cuts (temporary forest loss) and rapidly growing forest (rapid forest gain). In our analysis, we assume that temporary forest loss is mainly due to clear cutting and/or heavy thinning. Likewise, we assume rapid forest growth to be due to the fast regeneration of plants and younger forests after clear cutting.

- Classification of bright areas in historical orthophoto mosaics (approximately 1950s and late 1970s). We assume that bright areas (only on forest land) are mainly about 1 - 5-year-old clear cuts or other land that was not covered with trees on the data acquisition date.

- Data on resent logging [Utförd avverkning] from the Swedish Forest Agency (2025).

- Data on temporary non-forested areas [Tillfälligt ej skog] in the National Land Cover Database NMD (The Swedish Environmental Protection Agency, 2024a).

- Data on forest land in the National Land Cover Database NMD, additional data on forest productive or non-productive forest land (The Swedish Environmental Protection Agency, 2020).

Change detection and classification of Landsat satellite data

Change detection is a common application of remote sensing technology. It is a methodology used to detect the changes of specific features within one, or as in our case, multiple consecutive image-captures on various points in time. Change detection provides the spatial distribution of features and gives qualitative and quantitative information of changes in, for example, forests.

In the realm of change detection, multi-band remote sensing images are usually used because they provide the opportunity to analyze various features on the ground depending on the reflection from e.g. vegetation, water or from the ground, each with their own specific spectral signatures. The change detection methods of multi-spectral remote sensing imagery can be divided into three main methodologies: the image subtraction method, the image ratio method, and the method of change detection after classification. We used the image subtraction method.

We used the Landsat TM & ETM spectral bands 4,5,7, and the Landsat OLI bands 5,6,7 spectral bands, that are reasonably consistent between the three satellite missions. We used principal component analysis (PCA) at each point in time and picked the first principal component for analysis.

All analyses were preceded by thorough preparation of all data. As a first step, cloud free images had to be searched for and compiled into overlapping image stacks. With image stack, we here mean five completely or partially cloud free images taken between the mid-1980s and the 2020s. We downloaded data from the open database service Earth Explorer provided by the United States Geographical Survey, USGS (2020). In this database, it is possible to search images based on specific satellite missions, the cloud coverage percentage (0 - 100%) and data acquisition dates. It is also possible to get a quick overview of the entire series of images which eases the search. Once a completely cloud free image stack acquired from the mid-1980s until the 2020s was found and downloaded, it was possible to mask the data so that clouds were completely avoided. In some cases, the procedure had to be repeated to fill gaps in the image stacks where smaller patches of clouds covered the ground. For a complete view of the entire patchwork of the 14 cloud free image stacks we used in the analysis see **Figure 11**.

After compiling the 14 cloud free image stacks, we stretched the band length of each image pair taken at time point t ($t_1 - t_2$, $t_2 - t_3$ etc.) to equal length (8-

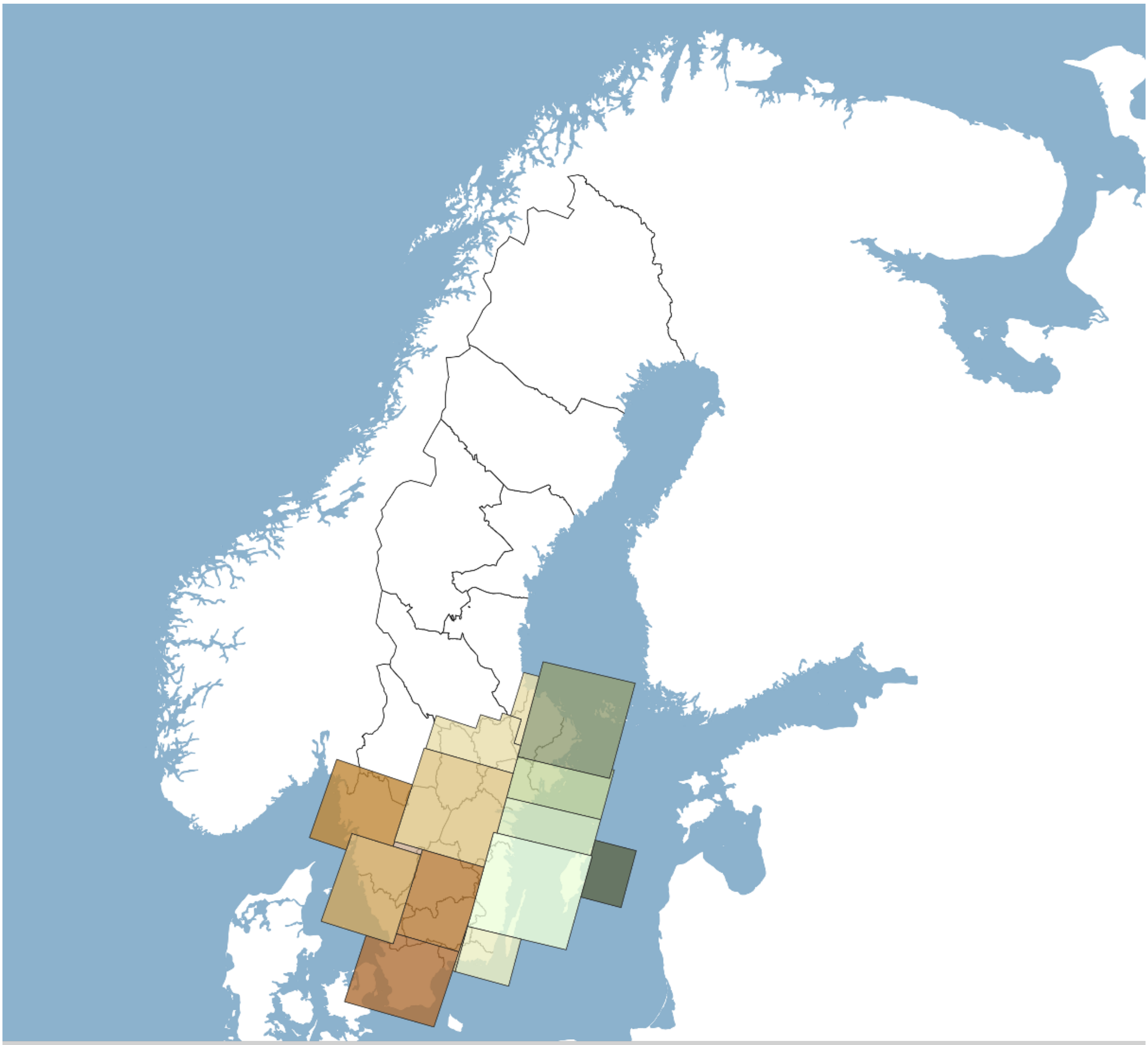


Figure 11. A map of Sweden and the location of the 14 cloud free image stacks created for the change detection analysis. Note that two of the image stacks are very small, and therefore not easy to see in this image.

Clear-cut by the FSC-certified company Stora Enso/Bergvik skog, in Ljusnarsberg municipality, Örebro county. One of many fellings detected as loss using change detection analysis. Photo: Olli Manninen bit data with 256 possible values, 0 - 255) and we conducted histogram matching. We then used the image subtraction method by subtracting the 8-bit value of corresponding pixels of an image acquired at one point in time (t_1) by an after image acquired at a later point in time (t_2). After subtraction, the changed region and unchanged region were determined by selecting the appropriate threshold values of gray of the resulting subtraction-image.

The formula for subtraction analysis of pixel-wise change, *Dx* is:

$$Dx_{ij}^{k} = X_{ij}^{k}\,(t_2) - X_{ij}^{k}\,(t_1) + C$$

Where ij are pixel coordinates, *k* for the band, in our case the first principal component of three bands, *xk ij* (t_1) for the pixel (*ij*) value of k-band image, t_1, t_2… for the time of the first and the second image,

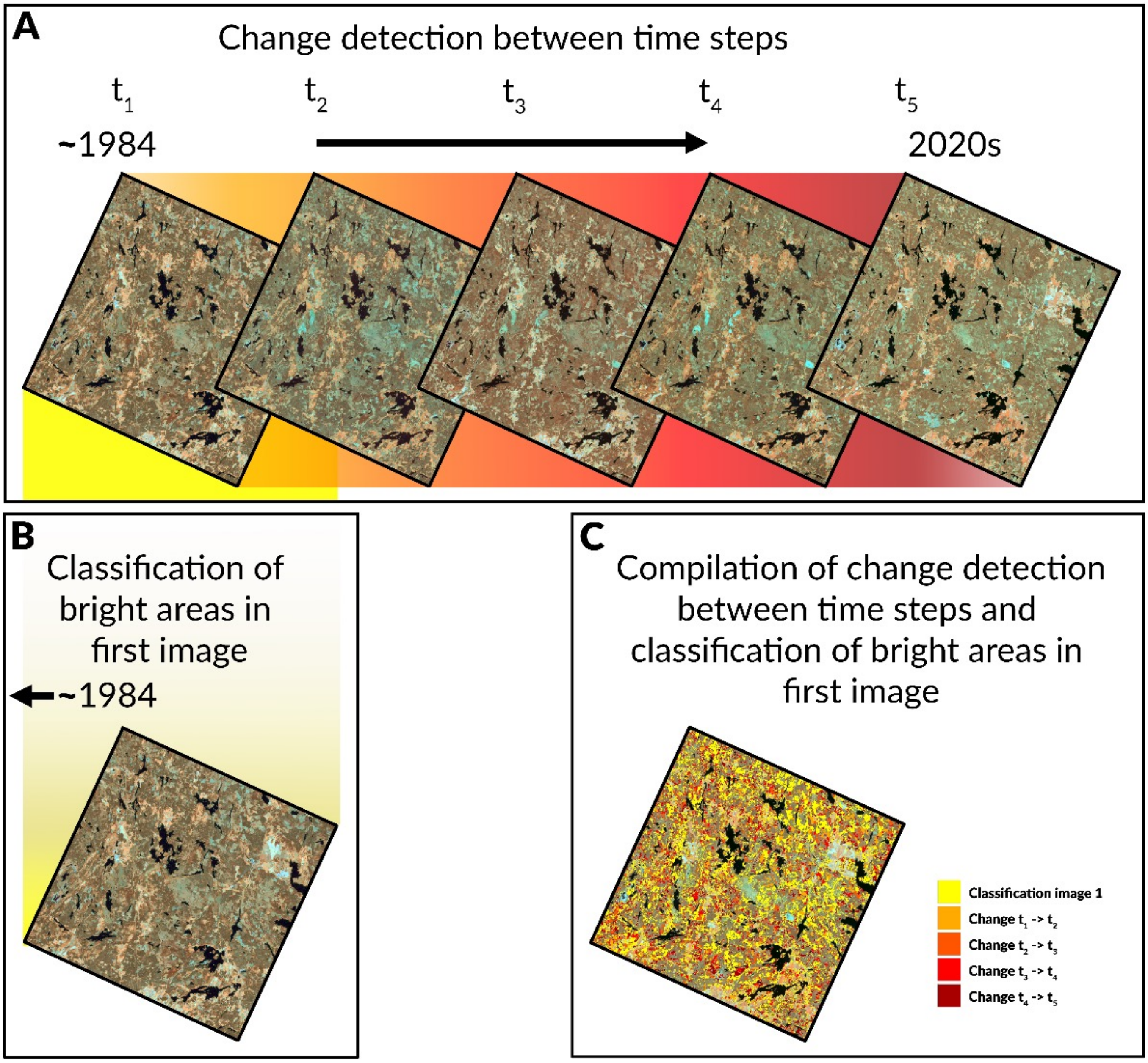


Figure 12. The steps taken to extract information on clear-cutting in the Landsat images, acquired from the mid-1980s until the 2020s. In A, an example of satellite images acquired at five different points in time, starting from the mid-1980s until the 2020s. The analysis captures change between two images at a time (t_1 and t_2, t_2 and t_3 etc.) until all four time steps have been analyzed. In B, the classification of bright areas in the first image, and in C a compilation of all captured changes from A, and the classification of bright areas made in B. Note that the classification procedure in B, contrary to the change detection analysis, not only captures logging made on the image acquisition year, but also logging made several years before that year.

the second and the third image, and so on (Shaoging & Lu 2008), see **Figure 12A**. C is the threshold. We used standard deviations (one std away from the mean) as a threshold for positive or negative change or no change when the subtraction result was below the threshold.

To detect bright areas (**Figure 12AB**) in the first image (t_1) in each image stack, we used ISO-cluster classification (Ball et al.1965) with seven classes and carried out a visual inspection of each image to determine the optimal number of ISO-cluster classes. All detected changes between image pairs in the stack, t_1 to t_2… t_5, and the classified bright areas were then compiled into one single mapping of change and bright areas (**Figure 12C**).

Classification of bright areas in historical orthophoto mosaics

The mapping of bright areas in historical orthophoto mosaics was done in a similar way to the classification of bright areas in the first image in the satellite image stacks. However, with a few differences. To begin with, the historical orthophoto mosaics (the 1960s batch and the 1975 batch) were organized into data units with large variation in brightness. Making an analysis of small bright areas, such as new clear-cuts, on the entire mosaic for southern Sweden simultaneously would therefore cause some problems. The difference in brightness between data units would render it impossible to detect local bright areas caused by e.g. logging.

Therefore, we first separated the orthophoto mosaic into smaller units, hereafter "data blocks", as shown in **Figure 13**. From there we could start to work on finding the smaller bright areas caused by e.g. clear cutting.

After making this initial breakdown of the data

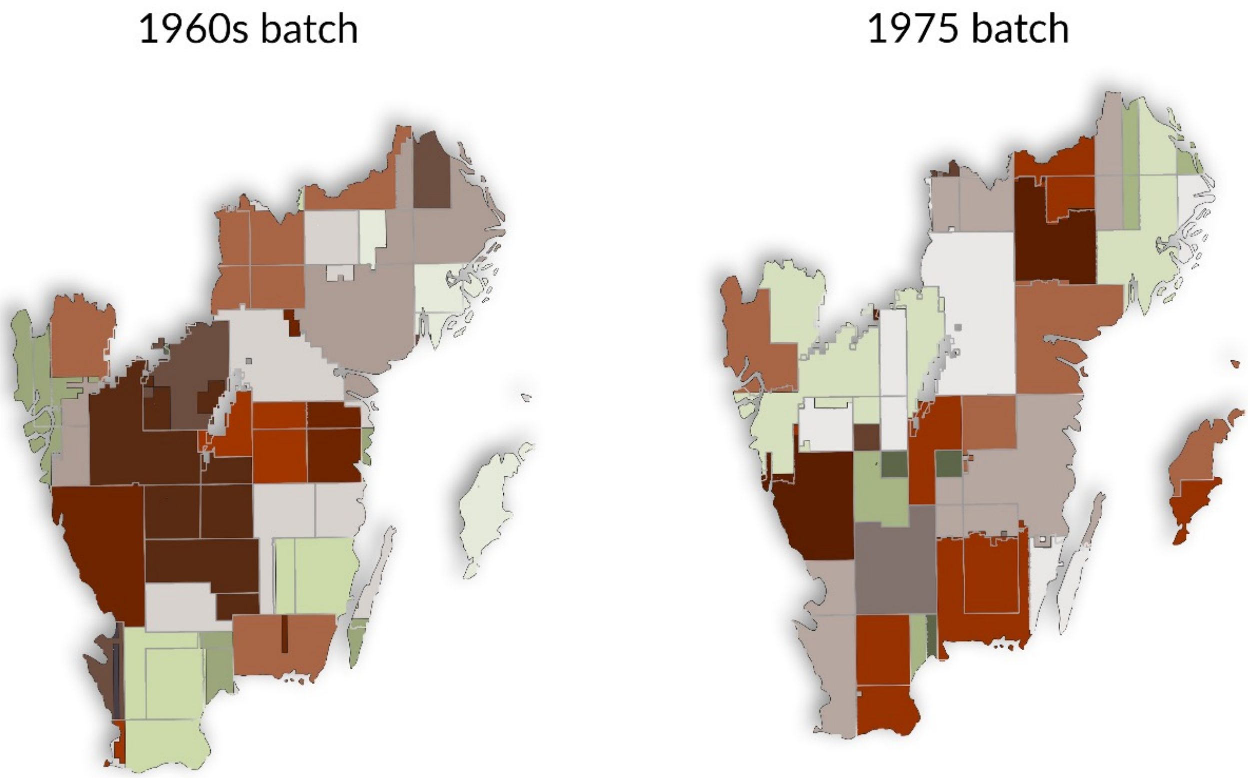


Figure 13. The data distribution in the 1960s batch and the 1975 batch and the location of the data blocks (white borders) used in the classification of bright areas in orthophotos. The size of the data blocks differs greatly both in size within each mapping period and in location between the two mapping periods. Note that the delimitation of the data blocks sometime differs from the acquisition years. This is because the mosaicking process has not always followed the acquisition years.

(**Figure 14A**), we began working on the individual data blocks. Now yet another problem was discovered. The brightness within the data blocks showed differences due to the mosaicking process. Clear banding artifacts were found following the southward to northward direction of the original flight paths (**Figure 14B**).

Again, making an analysis of the neatly broken-down data blocks would cause severe banding in the classification of bright areas in the result. To solve this issue, we started by down-sampling the original 0.5-meter raster to 10 meters. Since lakes, built-up areas and farmland were not the target of our analysis, we then proceeded with masking out all non-forest land. After this, we used a filter to smooth the data, so that larger brighter (or darker) patterns would appear more clearly and so that they

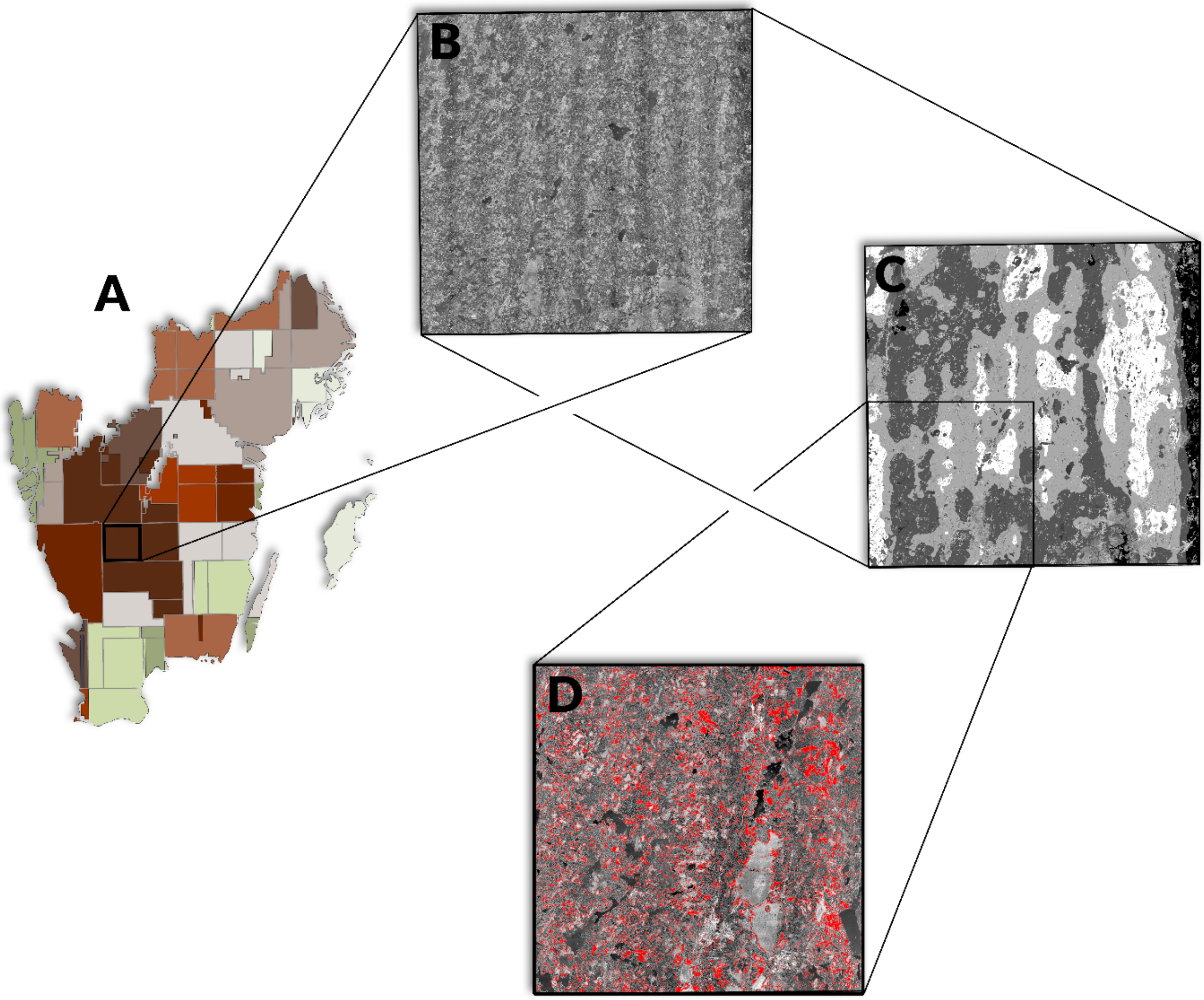


Figure 14. A schematic description of the process of finding bright areas in historical ortophotos. In A is a map of southern Sweden with one of the 46 data blocks from the 1960s batch highlighted. In B is the original historical orthophoto of the data block. As it can be seen, the photo is not homogeneous in light, and there are dark streaks going from south to north. In C the photo is divided into four light classes which then could be used for breaking up the data block into separate analysis units. In D is the ready-made result from both the 1960s batch and the 1975 batch, showing the mapped bright areas in red superimposed on the 1975 batch data block. Note that bright areas on farmland and built-up areas are not mapped as bright areas since the analysis was only made on forest land.

could be split into even smaller units.

The smoothed image was then divided into 3 – 4 classes by again using ISO-clustering classification (**Figure 14C**). The classes were separated and used as masks to divide the original down-sampled, 10-meter data blocks into separate analysis units, hereafter light classes. The remaining part of the analysis was identical to the analysis of bright areas in the first image in the change detection image stacks.

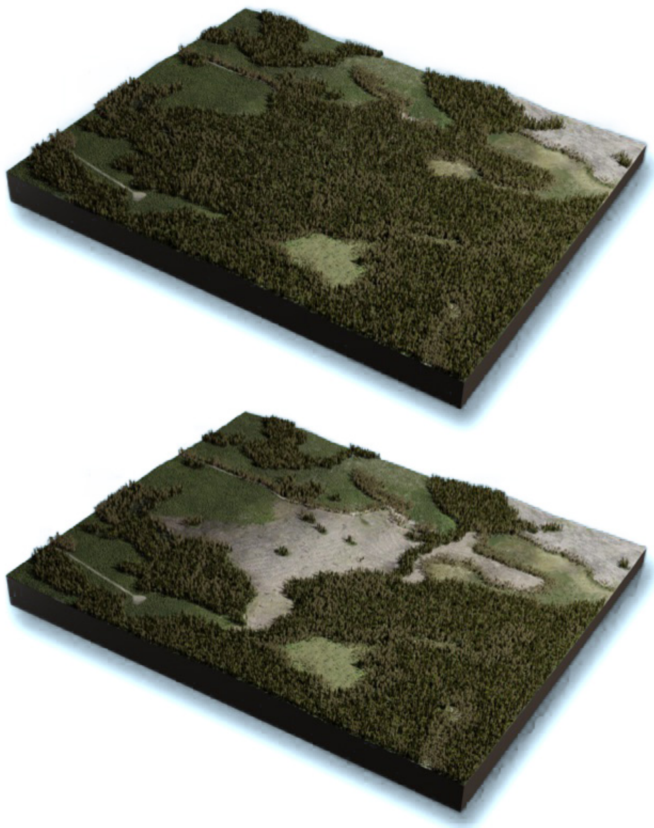
In the final step, we merged all the results into one raster with 10-meter resolution. We then again used the National Land Cover Data, NMD, additional data on forest land to mask out detected bright areas from the forest land. In the final steps we used data on recent logging from the Swedish Forest Agency to mask out further clear cuttings made since 2003. The merged result was then vectorized and generalized by using smoothing algorithms (function smoother in R among others). We also deleted floating pixels, smaller islands and small holes in larger fragments.

Updating of classification in historical orthophotos

In two of the southern counties, Örebro and Kalmar, the analysis of bright areas in historical orthophotos has been updated with new methods. Örebro was updated in 2023 and Kalmar in 2024, revisit **Figure 10**. The preparation of the data basically followed the same routine as in the first analysis made in 2021 with the difference that data blocks were divided into six individual light classes instead of four.

The classification procedure was changed. Instead of using standard ISO-clustering classification, we used Ilastik, which is an open-source image classification and segmentation tool (Sommer et al. 2011). Ilastik is mainly used in medicine. It uses machine learning algorithms to easily segment, classify, track and count, among other things, human cells or other experimental data. Nevertheless, Ilastik is not a tool for geographical data, which introduced some problems.

In this analysis, each of the six light classes were uploaded to Ilastik and the training was set up in two training classes: 1. forested areas, and 2. non-forested areas such as recent clear-cuts and other open areas. To ease the interpretation of the result, which could not be scrutinized directly in Ilastik, we established a file-connection between Ilastik and QGIS 3.3 by uploading the geographical information for each brightness class to QGIS. In this way we could easily update QGIS to see the “on-the-fly” generation of classifications in Ilastik appear together with other relevant data. The last step, to merge and generalize the data, was made in the same way as in our first analysis made in 2021. However, for Örebro county, we used only productive forest land for masking.



3D model showing loss of forest.

Classification of conservation values in forest fragments

The final step of creating the nation covering data layer (now OFCF 2.0) was made by using a compilation of several auxiliary data sources. As previously mentioned, the classification constitutes three non-overlapping classes in decreasing order of predicted conservation value:

1. *High conservation values*
2. *Probable conservation values*
3. *Potential older forest or continuity forest*

The two first categories were made by using overlapping information, with the original result from our change detection and classification, and also from Metria AB's data as basic delimitation. The last class, *Potential older forest or continuity* forest is based on remote sensing only, and hence, as previously mentioned, there can be considerable uncertainty in terms of conservation value. For a thorough review on validation, see the chapter *Validation of Forest Monitor's data*.

Starting with the highest conservation class 1, *High conservation values*, the auxiliary data we used for classification were:

- Formal protection of forests, national parks, nature reserves etc.
- Animal and plant protection areas.
- Woodland key biotopes delimited by the Swedish Forest Agency.
- Woodland key biotopes delimited by large forestry companies.
- Nature values registered by the Swedish Forest Agency.
- Open inventory results from County Administrative Boards.
- Inventory data from NGOs.
- Forest value core areas by the Swedish Environmental Protection Agency.

Before proceeding to the next step, the data in class 1 were removed from the rest of the data. For creating class 2, we used data from the SSIC (2024) open data base [Artdatabanken], which currently holds information on about 61 million records of species found in Sweden. However, to reduce computational power needed to do the analysis, and to narrow down the search to relevant species, we only used data on species of conservation concern (Swedish Forest Agency, 2023). These species are red listed species, indicator species determined by the Swedish Forest Agency, and legally protected species of Sweden. For a complete guide to the selected species groups and the database searches refer to **Table 2**. More about red listed species can be found in the chapter *Species of conservation concern inside OFCFs*

We aimed to make the analysis reflect not only the presence of individual species of various conservation concern, but also to be able to consider and prioritize areas with high diversity of species. To do this, we created a simple algorithm that both summarizes species finds in an area and weighs species depending on the current conservation value. Species that are considered more threatened got higher weight than more common species in lower red list categories and so on. Below, **Table 3** with the ranking categories used in the algorithm.

Note that any values with a similar difference in "weight" could have been used here, and that we don't suggest that these specific weights are definitive. In the analysis of conservation values of individual forest fragments dependent on species finds, the highest species conservation category was always used in the algorithm. If a species was both red listed in the category Vulnerable, VU (weight 12) and at the same time legally protected (weight 1), the conservation value remained 12 and so on.

To finally be able to determine whether there were enough species finds to classify an individual forest fragment as class 2, we had to set a threshold value. The reasoning here is that even the presence of one very uncommon red listed species, like a species in the red list category critically endangered CR (weight 24), is not a guarantee that the forest has high conservation values. Even if this single uncommon species is found twice or even thrice. If, however, there are two of these very rare species found in the same forest fragment, then with a weight of 96 ((24 + 24) x 2), one could guess that there is something unusual with the characteristics of this forest. We would then want to highlight this by putting it in class 2, *Probable conservation values*.

Table 2. The main species groups, the parameters, the selection of parameters and the number of taxa used in the analysis. Note that there were overlaps in the lists and hence the final list constituted a slightly lower number of taxa than seen after just summarizing the lists.

Main groups	Parameters	Selection	Number of taxa
Red listed species	Organism group	All but birds	1,676
Red listed species	Red listing categories	EX, RE, CR, EN, VU, NT	
Red listed species	Landscape type (alternative)	Forest (Only show species where the landscape is important)	
Red listed species	Effects (negative)	Clear cutting	
Red listed species	Risk factors	All but "Extreme fluctuations"	
Action program	Organism group	All but birds	102
Action program	Type	Not started, under production, established, under revision	
Action program	Landscape type (alternative)	Forest (Only show species where the landscape is important)	
Action program	Effects (negative)	Clear cutting	
Action program	Risk factors	All but "Extreme fluctuations"	
Birds	Organism group	Only birds	18
Birds	Birds	Prioritized in SvL	
Birds	Landscape type (alternative)	Forest (Only show species where the landscape is important)	
Birds	Effects (negative)	Clear cutting	
Birds	Risk factors	All but "Extreme fluctuations"	
Legal protection	Organism group	All but birds	63
Legal protection	Legally protected species	The Species Protection Ordinance	
Legal protection	Landscape type (alternative)	Forest (Only show species where the landscape is important)	
Legal protection	Effects (negative)	Clear cutting	
Legal protection	Risk factors	All but "Extreme fluctuations"	
Indicator species	Indicator species defined by the SFA – complete list, Version 2023-1	All species but the moss *Tortella tortuosa* s.lat.	344
		Taxa in lists	2,203
		Taxa in lists, without overlap	**2,041**

Table 3. The ranking of conservation values depends on weight with species classified as threatened (red list categories CR, EN and VU) with the highest weight and the nearly threatened (NT) slightly lower. Other species were harder to weigh according to vulnerability and were hence given the same weight.

Conservation category	Weight
Red list category CR	24
Red list category EN	24
Red list category VU	12
Red list category NT	6
Indicator species	1
Legally protected species	1
Bird species prioritized in SvL	1
Species in action program	1


Photo: Jon Andersson

But what happens if there is a large number finds of species with low weights, like many finds of indicator species? Couldn't this also be a sign that the forest has some conservation values? Well, since these species are usually more common than the threatened red listed ones, they should appear more plentiful and in larger variation. Here is an example: If we found one species in the red list category nearly threatened NT, three different indicator species and one legally protected species, which is not unlikely in a forest with high conservation values. It could surely be a sign that the forest has some conservation value. The aforementioned species finds yield a weight of 50 ((6 + 1 + 1 +1 +1) x 5). But if we went to another forest fragment the next day and made 20 observations of one single indicator species, it would still only yield a weight 20 (1 x 20).

For the classification of forest fragments into class 2, *probable conservation values* or class 3, *potentially older forest or continuity forest*, or proxy continuity forests, we used the following function to calculate the conservation value per forest patch, *CVp*:

$$CVp = D \cdot \sum_{i=1}^{n} Ki$$

Where D is the total number of species in the forest patch and n is the total number of species finds in the forest patch. *Ki* is the summary of the weights according to the conservation category in **Table 3** of the *i-th* individual.

To capture these differences, and to give higher weight to a diversity of species rather than to a repeated strain of observations of the same, we set the determinant threshold to 40.

$$FVp = \begin{cases} positive, & if\ FVp \geq 40 \\ negative, & if\ FVp < 40 \end{cases}$$

After all, one of the first things we learn in ecology class is that the observation of many species is the decisive factor in finding places with high biodiversity.

After feeling rather satisfied with the developed classification system of forest fragments, we soon ran into yet another problem. What happens when a forest fragment is very large, and the finds of species are concentrated to one corner of the fragment. Is it really a good idea to determine the conservation value of a 20-hectare forest fragment based on species of concern found in a two-hectare corner of the forest? The answer has to be no.

To handle this issue, we realized that we needed to break down the forest fragments into smaller units. There are of course many ways to achieve this, however, since species are usually confined to a specific forest type, it seemed appropriate to also divide the forest fragments into forest types before doing the classification with species finds.

We therefore used the forest types from the National Land Cover Database (NMD) (The Swedish Environmental Protection Agency, 2020) to break down large forest fragments into smaller units. However, we soon found that using all the 14 forest types in NMD would split the forest fragments into too small fragments. Therefore, we organized the forest types from NMD into three new groups, see **Table 4** below.

We classified the forest fragments according to the following three basic rules:

- Fragments with an area ≥ 0.5 hectares but < 10 hectares were not split up and were classified directly with the species weight algorithm

- Fragments with an area ≥ 10 hectares were split up with the three NMD forest type groups and then classified with the species weight algorithm

- Remaining fragments with an area < 0.5 hectares were not classified with the species weight algorithm

All analyses were carried out in R and ArcMap. In most cases, the data was first prepared in ArcMap 10 and in QGIS 3. All Database tasks were conducted in Microsoft Access. All data were re-projected to Pseudo Mercator (ESPG 3857) which is the projection used in Forest Monitors web map.

Table 4. Grouping of the 14 forest types in the National Landcover Database, NMD and the original raster pixel classification values from the database. We used both the forest types found on wetlands and outside wetlands.

Groups and forest types	**Original NMD pixel values**
Group 1 (Pine forests)	
Pine forest	111, 121
Group 2 (spruce forests and mixed coniferous forests)	
Spruce forest	112, 122
Mixed coniferous forest	113, 123
Group 3 (Mixed forest and trivial deciduous forest)	
Mixed forest	114, 124
Trivial deciduous forest	115, 125
Mixed deciduous forest	117, 127
Deciduous forest	116, 126

Mapping of mountain birch

The tree species mountain birch (Betula ssp. czerepanovii) is not used in commercial forestry and in Sweden, subarctic forests with mountain birch is the only Nature 2000 habitat type (9040) that reaches favorable conservation status (SEPA 2020). Forest Monitor is a tool that, among other things, tracks the loss of forests with high conservation value. But since there is no overarching threat from forestry to the vast mountain birch forests along the Scandes range, we wanted to exclude these birch forests from the OFCFs. The latter is under constant threat from forestry, mountain birch forest is not.

The potential distribution patterns of mountain birch in Sweden

The study area covers the western parts of the counties Norrbotten, Västerbotten, Västernorrland, Jämtland, Gävleborg, and Dalarna, the parts of Sweden where mountain birch has been reported historically. As with most tree species, the distribution of mountain birch might be influenced by multiple factors. Information on local and regional conditions was hence needed.

We set out to build a model that described the outer border of the distribution patterns of this tree species. With this delimitation, we then wanted to extract the specific growth places from a second data source. For this we decided to use the National Land Cover Database, NMD, which unfortunately doesn't distinguish between the various species of trivial deciduous trees. However, at elevations where we usually find mountain birch, birches are the overwhelmingly most common deciduous tree species. In theory, by using a delimitation of the distribution of mountain birch, sorting out mountain birch from all other deciduous trees in the NMD, would be possible.

Mountain birch is a tree species with very specific distribution patterns. It thrives mainly in the space between the coniferous forest and the tree limit, on high altitude. At lower altitude it is outcompeted by conifers and at higher altitude it cannot survive because of climatic limitations. We therefore determined elevation to be one of the main factors in explaining the distribution patterns.

Our mapping of mountain birch is far from being the first, fortunately. We found several data sources with partial mappings of mountain birch to be very useful for modelling. As temperature might be an important variable too, we searched for such data to add to the model. We found the cell resolution to be too coarse to account for microclimatic factors that influence the finer details of the distribution. Hence, we decided not to use this data. In **Table 5** below, the specific data sources that were used to build the model.

Methodological approach

This section describes the methods used for the identification and validation of mountain birch limits and locations. We describe the pre-processing steps, the modelling and the post production steps. In the end of this chapter, we present a workflow chart which provides insight into the steps we used (See **Figure 20** in the end of this chapter.). We started by georeferencing the 17 scanned high-resolution maps from "the vegetation map of the Swedish montane region", see **Figure 15**. Then we extracted the classification "Mountain birch" from the geo-referenced raster dada by using Ilastik, the Support Vector Machine Classifier (SVM).

Table 5. Data sources that were used to model the distribution delimitation for mountain birch.

Data name	Data description	Data distributor	Purpose
The vegetation map of the Swedish montane region. [Vegetationskarta över svenska fjällen]	Vegetation mapping of the Swedish montane region for the counties Norrbotten, Västerbotten and Jämtland. Maps Produced by Ulf Von Sydow. Department of physical geography, Stockholm University, Sweden at the request of the Swedish Environment Protection Board.	Available as 17 individual paper maps only.	Modelling of distribution
Continuous Habitat Type Mapping of Protected Areas, KNAS6	A nationally homogeneous habitat type classification of protected areas. The KNAS mapping covers nature reserves, national parks, nature conservation areas and Natura 2000 areas. It is used as a basis for strategies and practical nature conservation work, as well as for national and international reporting.	Swedish Environmental Protection Agency.	Modelling of distribution
European Digital Elevation Model	Digital elevation Model (DEM) over Europe from the GMES RDA project (EU-DEM, resolution 1 arcsec) - version 1	European Environment Agency.	Modelling of distribution
National Land Cover Database 2018, NMD	Base mapping in 25 thematic classes in three hierarchical levels. Mapping is in raster format with 10-meter resolution and with a minimum mapping unit down to 0.01 hectares.	The Swedish Environmental Protection Agency.	Specific growth places within the modelled delimitation of the distribution of mountain birch.

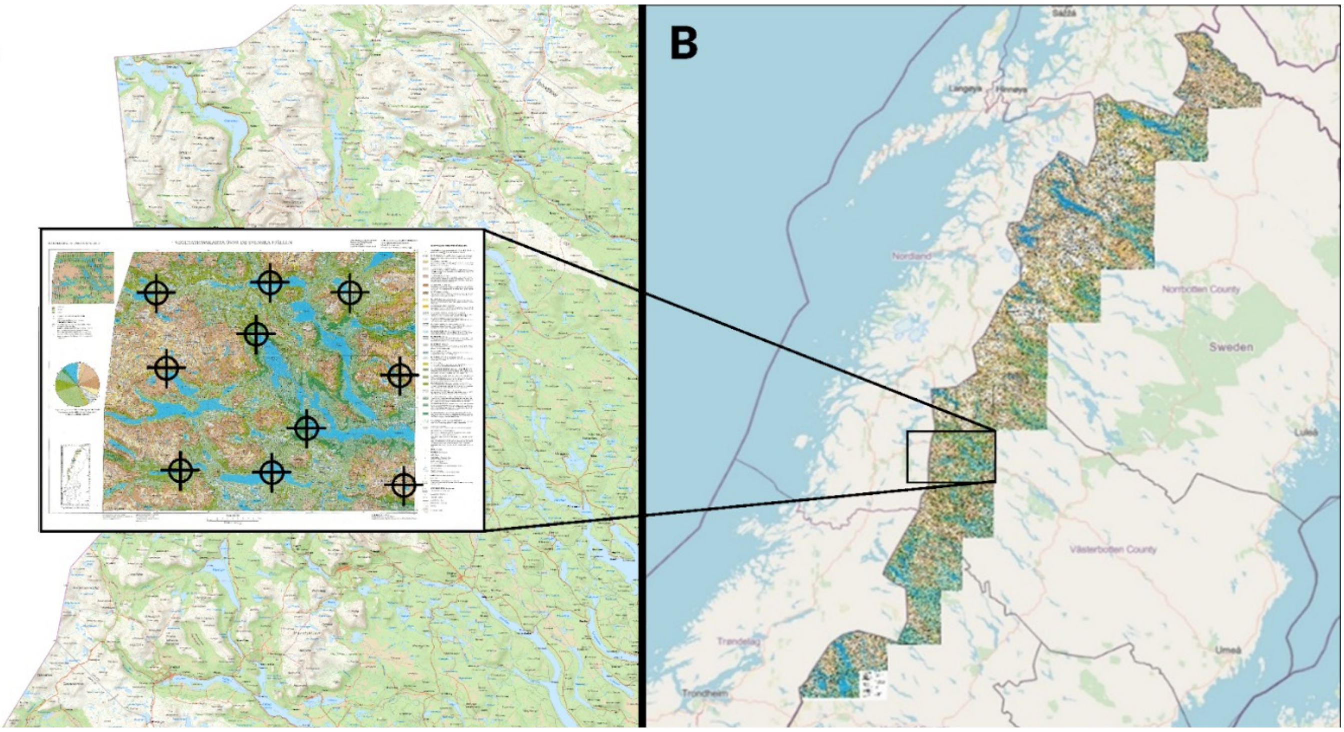


Figure 15. The geo-referencing process. In A, one of the 17 single frames with 10 referencing locations depicted as crosshairs. In B, the location of the single frame in A together with the complete mosaic.

An example of the segmentation and extraction procedure and its result can be seen in **Figure 16**. From the data layer Continuous Habitat Type Mapping of Protected Areas, KNAS6, that covers formally protected areas, we extracted only the mapping of Mountain birch forest. We used all available tiles from KNAS6.

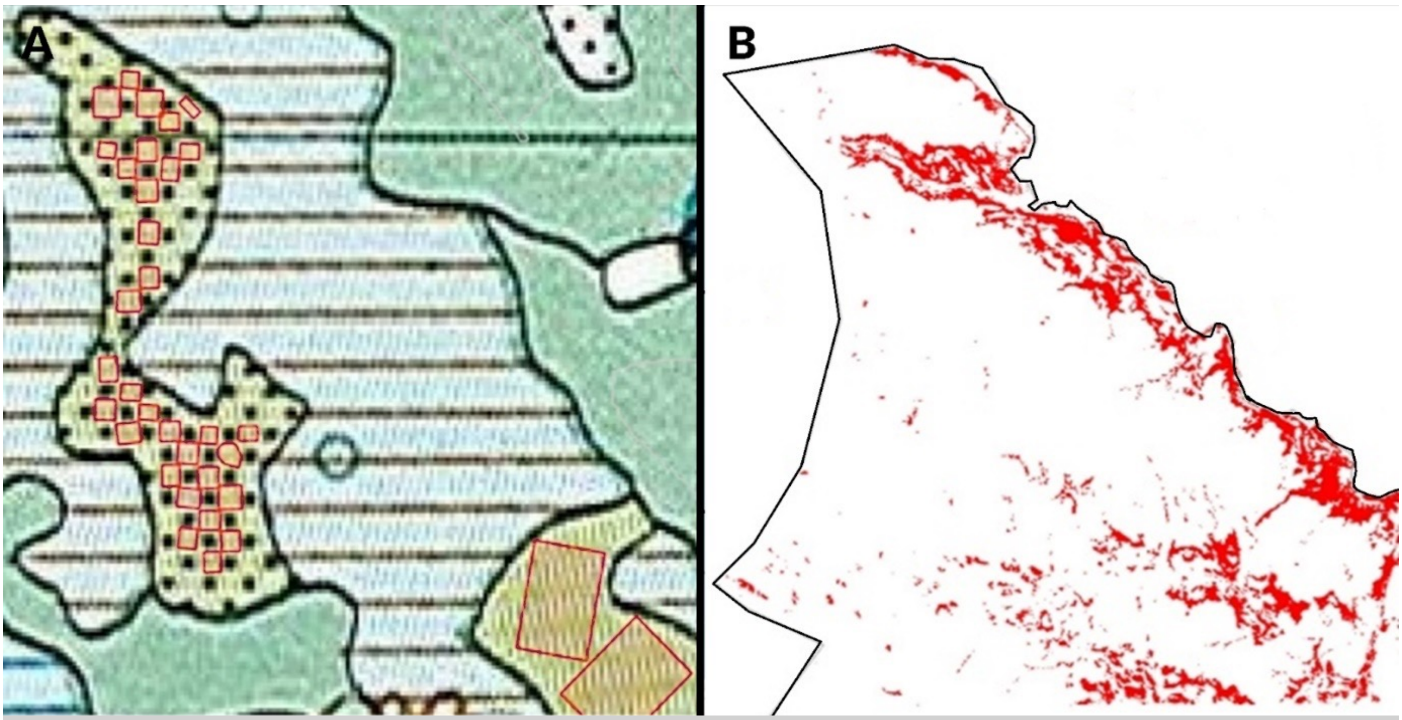


Figure 16. Segmentation and extraction of Mountain birch pixels from the old vegetation maps. In A, the training procedure, to teach the software to recognize the color and the pattern of mountain birch (red squares) in the old vegetation maps. In B, an example of the result from the machine learning procedure (SVM). The areas of classified mountain birch are colored red.

Defining the delimitation of the distribution of mountain birch

To build our model, we created six "subset areas" approximately equally distributed, starting in the farthest north of the country and ending in the southernmost known range of mountain birch. We then used a point grid to extract data from the old vegetation map and from the KNAS6 data. For each grid point, we also extracted the elevation from the *European Digital Elevation Model* along with their respective coordinates.

As expected, the occurrence of mountain birch showed clear elevation gradient in both latitude and longitude. The extracted elevations in the northernmost subset area showed significant differences in comparison to the coordinates in the southern subsets. A similar pattern, but on shorter scale, was observed in the eastward to westward direction.

To capture the variability in the occurrence of mountain birch in both latitude and longitude, we started by fitting polynomial functions to the elevations in the subset data sets. We then combined the models to produce a dummy raster. The dummy raster was applied to the original elevation data to produce a model for predicting the occurrence of mountain birch, see **Figure 17**. The fitting of the limit delineated using the resulting raster showed an R2 = 0.98 in relationship to the validation data. (*vegetation map of the Swedish mountain region* and *KNAS6*).

By using the resulting elevation dummy raster, we could then find a threshold for the distribution of mountain birch throughout the entire area. This was done by using a simple conditional calculation. The result was then reclassified, see **Figure 18**.

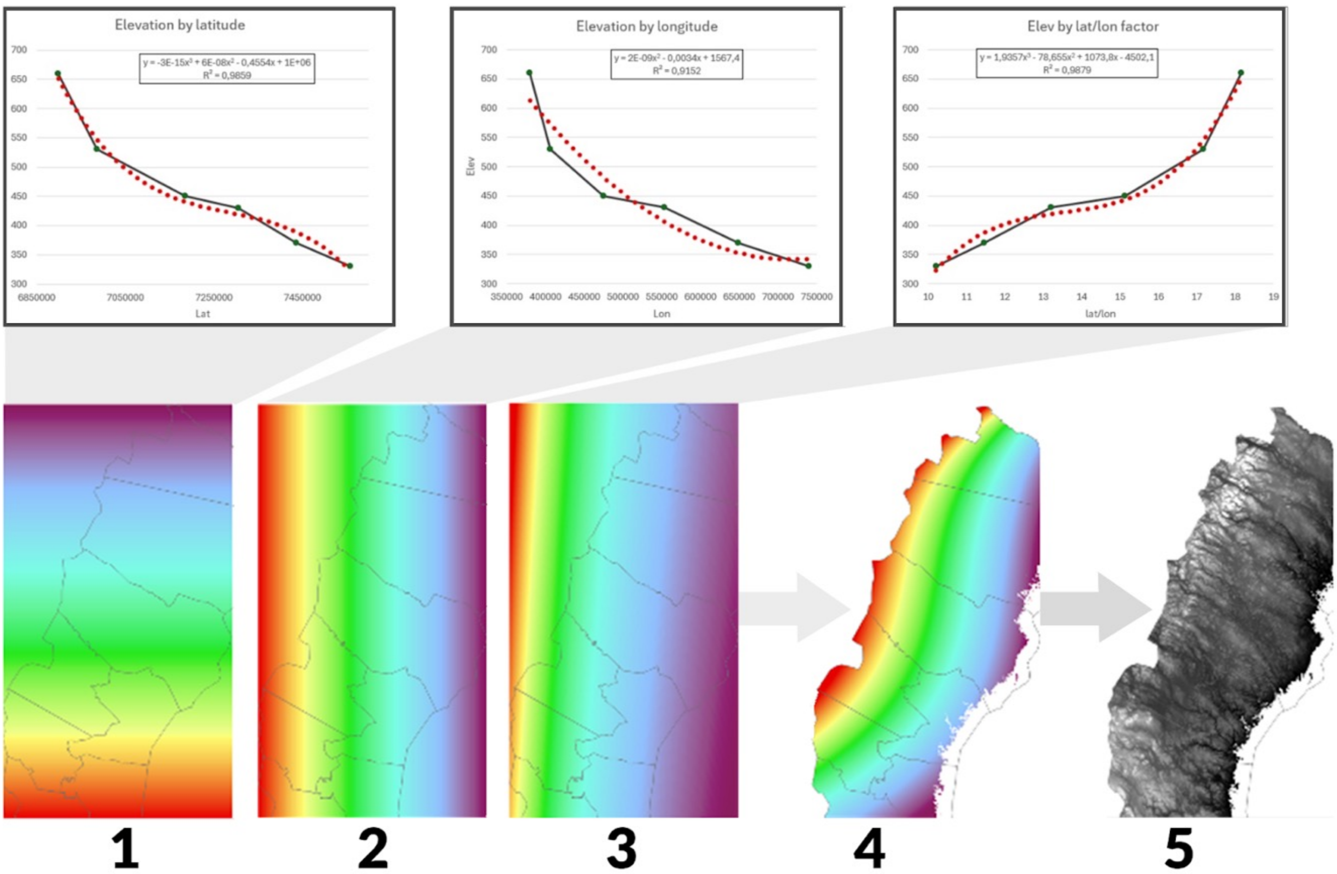


Figure 17. The steps taken to produce a dummy raster for correcting the digital elevation model (DEM). The first step was to find the best fitting function to predict the broad occurrence patterns dependent on elevation and latitude, and elevation longitude (1 - 2), and the combination of both (3). The model from step 3 was then applied to a raster that combined both latitude and longitude to produce a dummy raster (4). The dummy raster was then applied to the original DEM (5)

Figure 18. The first result of the conditional classification of the distribution of mountain birch.

Modelling of limit line of Mountain birch eastward patches

After looking at the initial model we soon realized that we failed to capture the changes in distribution in the eastward to westward direction. There were too many and too large mountain birch “patches” to the east of the main distribution. Also, the model didn’t fit the validation data from the vegetation map of *the Swedish montane region* and *KNAS6* in these places. It was clear that other factors than elevation alone were important for the distribution in these areas.

To solve this mismatch, a specific analysis was carried out on the patches located to the east of the main occurrence. We hence constructed a variable threshold to classify and render pixels from the polynomial function so that they would change according to the distance of the main occurrence. In this way, patches of pixels near to the main mountain birch occurrence in the west would have a threshold close to the one used for the original model but slightly more restrictive. The farther away from the main occurrence, the more restrictive threshold. After this procedure, the result matched significantly better with the validation data.
In **Figure 19** the result of the calculation of the patches using variable thresholds and a comparison between the original result and the new one. We then used the updated delimitation of the distribution of mountain birch to extract trivial deciduous forests from the NMD.

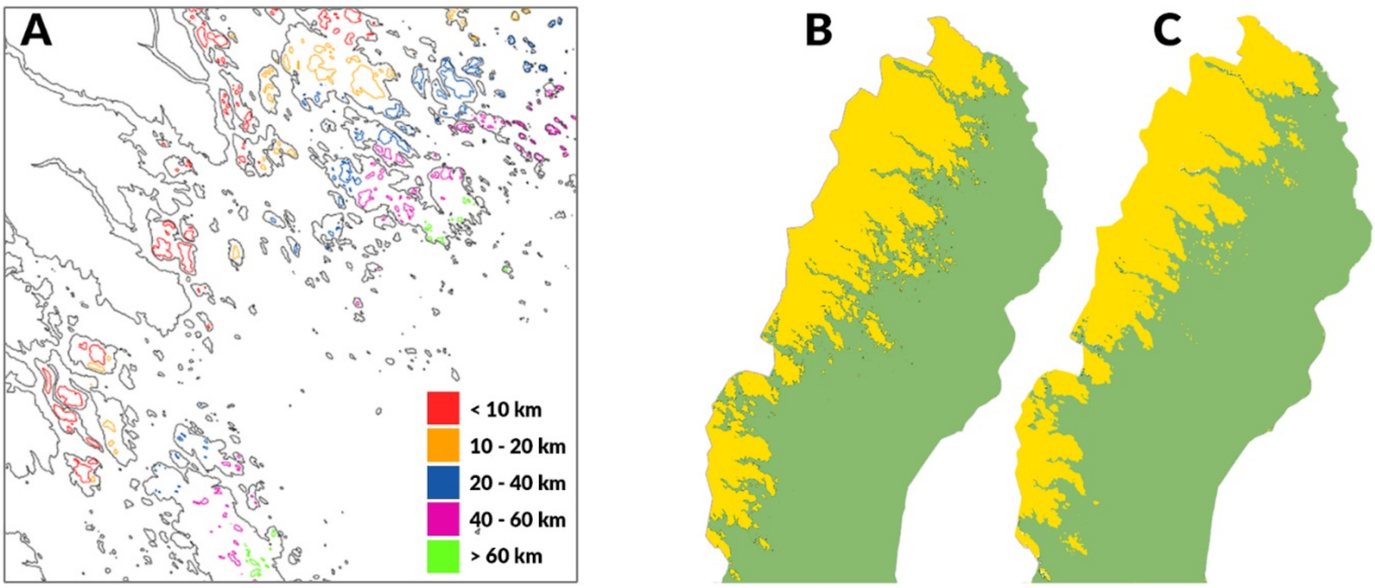


Figure 19. In A, a comparison of the original modelled eastmost delimitation of mountain birch (black lines) and the result from using variable thresholds to detect occurrence patterns while going from the main occurrence in the west and eastwards. In B, the original modelled eastmost delimitation of mountain birch and in C the final reduced version.

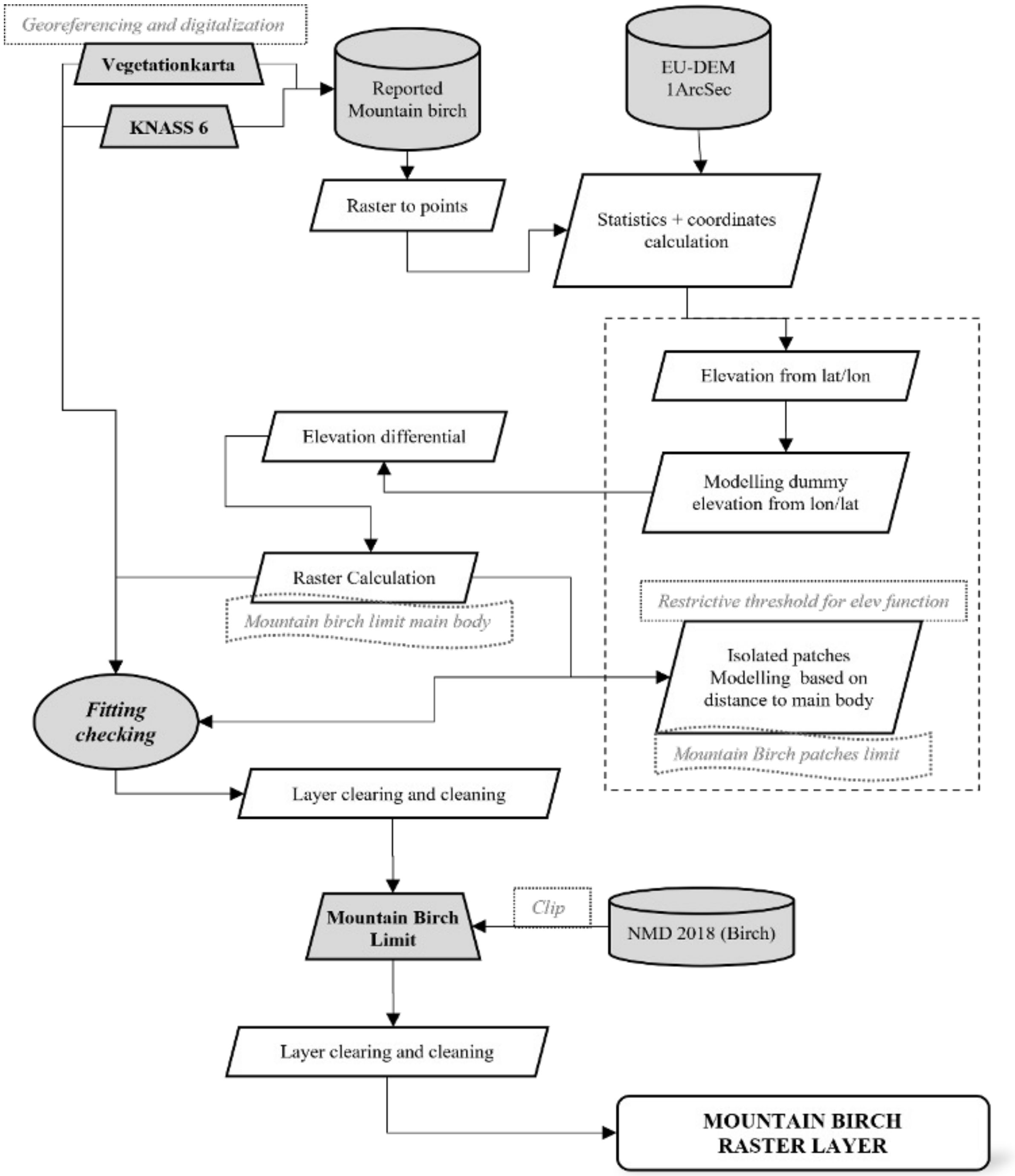


Figure 20. Workflow chart.

Photo: Jon Andersson

7. VALIDATION OF FOREST MONITOR'S DATA

Photo: Viktor Säfve

VALIDATION OF FOREST MONITOR'S DATA

Our mapping consists both of data based on field inventories with comparably high precision and data based only on remote sensing techniques used on satellite imagery and on aerial images. To be clear, our data on OFCFs created with the remote sensing analysis contains various types of errors, not one kind. To begin with, both clear cuts and young managed forests are sometimes incorrectly mapped as potential older forest or continuity forest, especially in those parts of the country where the data is not updated (revisit **Figure 10**).

Moreover, subtle imperfections like wrongly delimitated forest patches or missing small fragments of old forest are certainly an issue. The delimitation error rises from limitations in the resolution in our data sources. Rough source data causes delimitation errors in the output. Landsat data that has a resolution of 30 meters is an issue. And even though the historical orthophotos we used did have an astonishing resolution of up to 50 centimeters, we needed to down-sample this data to 10 meters to run the analysis. Shadows that are cast from the tree canopy and over an open area like a clear cut will also cause delimitation errors as the dark of shadows may be interpreted as forest. Altogether, these things cause the borders of our OFCF-patches to differ from reality.

But despite varying degrees of over- and under mapping, and delimitation errors, a large percentage of the mapping is correct even in the counties where no updates of the data have been conducted. Our validations show a surprisingly high degree of accuracy for areas that have only been mapped with remote sensing. Therefore, we consider our OFCF-data to be useful for locating older forests and continuity forests.

The field inventory

The field inventory was made by using a semi-randomized design to study the OFCFs. We started by selecting a county. In each county we choose a 10,000-hectare study landscape (mean size 10,003 ha ± 6.9 std). We have so far surveyed seven such landscapes, two each in Kalmar, Örebro and Västerbotten counties, and one in Norrbotten county, see **Table 6** and **Figure 22**. Well worth noting here is that the data for Västerbotten and Norrbotten counties were created the same way as in the Forest Monitor's data for Kalmar county, and hence none of the data created by Metria AB was analyzed in this survey.

Since we only survey within our mapped forest fragments, our field inventory is a survey that captures only over-mapping, in this case wrongfully mapped patches of young forest as being true OFCFs. For the same reason it cannot capture under-mapping, wrongfully mapped OFCFs as young, non-OFCFs. This would have required field inventories of forest outside our mapping.

Inside each study landscape, we aimed to survey an area of 1,000 hectares. We selected, by starting with the largest OFCF-fragment inside the study landscape to successively smaller ones, an area that corresponded to the target area of 1,000 hectares (mean size 1,016 ha ± 18.2 std) see **Table 6**. The reason for choosing the largest OFCF-fragments for the survey was solely due to the logistic aspects of the survey. An inventory of a few large forest fragments takes less time than to survey many small, even if the total area of the small fragments is the same. Traveling time between locations is of the essence.

The survey itself was made by using a methodology used by the County Administrative Board in Västerbotten county. This methodology is used by the authority to find and delimit high conservation forests that could be of interest in their work with formal protection, the basis for establishing new nature reserves, national parks and biotope protection areas.

The methodology is fairly simple: A well-trained field ecologist visits the forest and records the presence of key elements like the amount of standing and laying dead wood, the presence of old trees and other important forest structures. Another important

Table 6. Basic information about the seven study landscapes. Note here that the inventoried area sometimes is larger than the planned area. This is because of delimitation errors in the mapping of OFCFs and reality. In study landscapes 1 and 2, we surveyed only about half of the area that was originally planned for inventory.

Study landscape # (county)	Total area (ha)	Forest land (productive) (ha)	Planned for inventory (inventoried) (ha)
1 (Kalmar)	10,007	8,890 (8,352)	982 (451)
2 (Kalmar)	10,007	8,419 (7,708)	1,015 (216)
3 (Örebro)	10,008	6,727 (6,137)	1,015 (1,254)
4 (Örebro)	10,008	8,387 (7,329)	1,037 (1,139)
5† (Västerbotten)	9,991	7,650 (6,955)	1,027 (936)
6† (Västerbotten)	10,003	6,802 (6,158)	1,006 (901)
7† (Norrbotten)	9,995	7,103 (6,796)	1,031 (1,114)

† - survey on updated data from Forest Monitor

part is to assess the local forest history. All field ecologists who worked on our project was familiar with this methodology and they also underwent a short introduction and some also a field calibration.

Whether the forest has been clear cut after the introduction of clear cutting in the 1950s or only selectively logged prior to this period is an important question. This is because our mapping reaches approximately back to this point in time. Hence, if the field ecologist found him or herself standing in a young forest stand regenerated after clear cutting during the 1960s our mapping would be wrong.

They also checked if the forest bore marks from previous forest fires and could thus be self-generated after a disturbance event etc. Also, last but not least, what is the degree of forest "naturalness", no stumps or many? Based on these observations of the forest, the field ecologist makes a final judgement of the forest's ability to sustain populations of species of conservation concern. If the answer is yes, the forest is placed in one of the four different conservation categories listed below:

- Value core area 1, (CV1) virgin forest (exceedingly rare and usually very small)
- Value core area 2, (CV2) forest with high conservation value
- Value core area 3, (CV3) forest with some conservation value (common)
- Non-conservation value forest (NCV) forest that doesn't reach category CV3

For real life examples of how these four categories of forest may look, see **Figure 21**. Apart from doing the survey of the forest structures, the field ecologist also made records of species of conservation concern. For a description of these species, revisit **Table 2**. Species finds, however, did never alone determine the ranking of forests in the three conservation categories listed above. The species findings and the proportion of mapped OFCFs in the four aforementioned categories from study landscapes 1 – 7 are presented in the chapter Species of conservation concern inside OFCFs further down in the text.

We want to remind the reader that no field ecologist can recognize the full list of species of conservation concern in Sweden or elsewhere. Nor do we claim to base our validation on the full list of species and perfect estimations of dead wood volume, forest age, history etc. Nevertheless, the methodology captures the essence of natural values in a forest, something even the most meticulous plot surveys can fail to accomplish. Lastly, the methodology is apparently good enough for our Swedish authorities and it has been widely and successfully used for decades to find forest with high conservation values throughout the country.

Is the mapping of OFCFs correct or not?

The answer to this question, based on the results from our surveys of the OFCF-mapping in southern Sweden, is that it varies depending on what we are looking for. The answer to the main question, if ac-

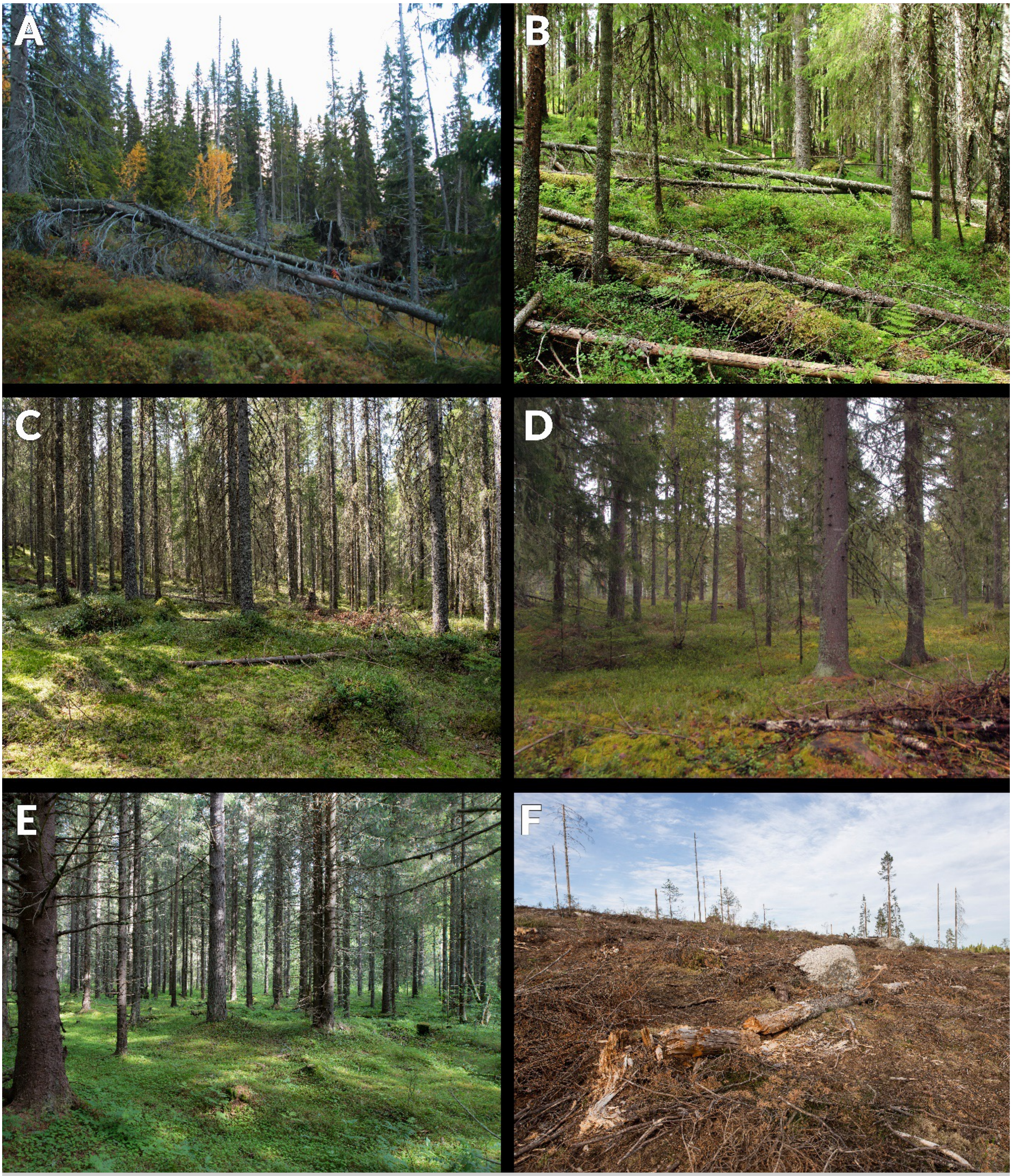


Figure 21. Examples of the different forest types that have occurred during the field inventories. In A, virgin forest devoid of signs of previous forestry, value core area 1 (CV1). In B high conservation value forest in the category value core area 2 (CV2). In C, an example of a forest in the category value core area 3 (CV3). In D a correctly mapped OFCF that didn't reach category value conservation area 3 and was hence placed in the category non-conservation value forest (NCV). In E, a wrongly mapped OFCF that is only about 50 years old, and in F recently logged OFCF.

curacy of the actual mapping is satisfactory, the answer is in most cases yes. In study landscapes 1, 2, 3 and 4 located in Kalmar and Örebro counties, the proportion of correctly mapped OFCFs was 98% and 94% respectively. In study landscapes 5 and 6 in Västerbotten county and in study landscape 7 in Norrbotten county the corresponding figures were 90%, 81% and 85% respectively, see Figure UP.

For the accuracy of the data created by Metria AB, for northern Sweden, we refer to Ahlcrona (2017b) and Metria (2019, 2021, 2023a, 2023b). They state that for Västernorrland, Jämtland, Västerbotten and Norrbotten counties, the likelihood of the mapped forest having an age over 70 years is about 90%. For Gävleborg and Dalarna counties, they report a corresponding proportion of about 80%.

These errors show that the degree of exaggeration of the proportions of mapped OFCFs in each of the landscapes studied is quite low. But we again want to remind the reader that our inventory is not made to detect the under-mapping of OFCFs. Thus, the over-mapping we detected may be balanced by the possible under-mapping outside the OFCF-mapping.

According to Sweden's official statistics on old forest, defined as forest with mean stand age exceeding 140 years in the boreal region and exceeding 120 years in the boreonemoral and nemoral regions, in 2020 about 10.3% of the productive forest land consisted of such old forests (Swedish Forest Inventory, 2025). Nevertheless, with our mapping we detect forests that are significantly younger, and thus they should constitute a larger share of the forest land. Moreover, the Swedish Forest Inventory (2025), reports that about 25.3 percent of the trees in their study plots on productive forest land and outside protected areas, has a basal area weighed mean age that exceeds 80 years, see Ducey & A. Kershaw Jr (2023) for an explanation of this measure. But since we cannot fully reach 80 years back in time our mapped forests should still constitute a larger share of the forest land.

Most forests in our mapping exclude formally protected areas, and hence these figures could be comparable with the SFIs reported 25.3 percent despite our inclusion of non-productive forest land which constitutes a minor part of the forest land. Comparing our mapping that reaches about 60 to 70 years back in time with the SFAs data from their plot survey with trees older than 80 years, tells us that we are close, but that our data may suffer from some degree of under-mapping.

Despite the detected over-mapping and possible under-mapping, our interpretation is that only about 25 – 30 percent of the forest in the study landscapes constitutes forest that hasn't been clearcut within the time frame of our analysis. When it comes to the conservation values in these old forests, there is more to read further down in the text.

In the SSIC-report The State of the Forest – Red Listed Species in a Nordic Perspective from 2011, the author Artur Larsson writes:

"Sweden's forest landscape is being transformed from pristine or extensively managed forests with great biological diversity to biologically more monotonous production forests. These forests do not get very old (before being clear-cut again/our remark) and are less varied in tree age, tree species and structures (they also contain smaller amounts of dead wood). This changes the conditions for the forest's plants, fungi and animals. Some benefit, but significantly more are disadvantaged."

and

"Since 1950, approx. 60% of Sweden's productive forest land has been clear-cut and converted to production forests. In addition to this, comes clear-cuts from further back in time."

If we add to the question whether mapped OFCFs have conservation values enough to qualify in one of the three categories core area 1 – 3, well, then we must dig a bit deeper. On average, the proportion of correctly mapped OFCFs that reached conservation values enough to qualify in the any of the categories core area 1 – 3 was 55% (max 76%, min 37%). In study landscapes 2, and 7 we found the highest proportion of core areas, 72% and 76% respectively. Study landscape 2 is in an area where the Swedish forestry company Sveaskog have many set-asides, the Hornsö Ekopark. Study landscape 7 lays further to the west where we also expected to detect more forests with high conservation values.

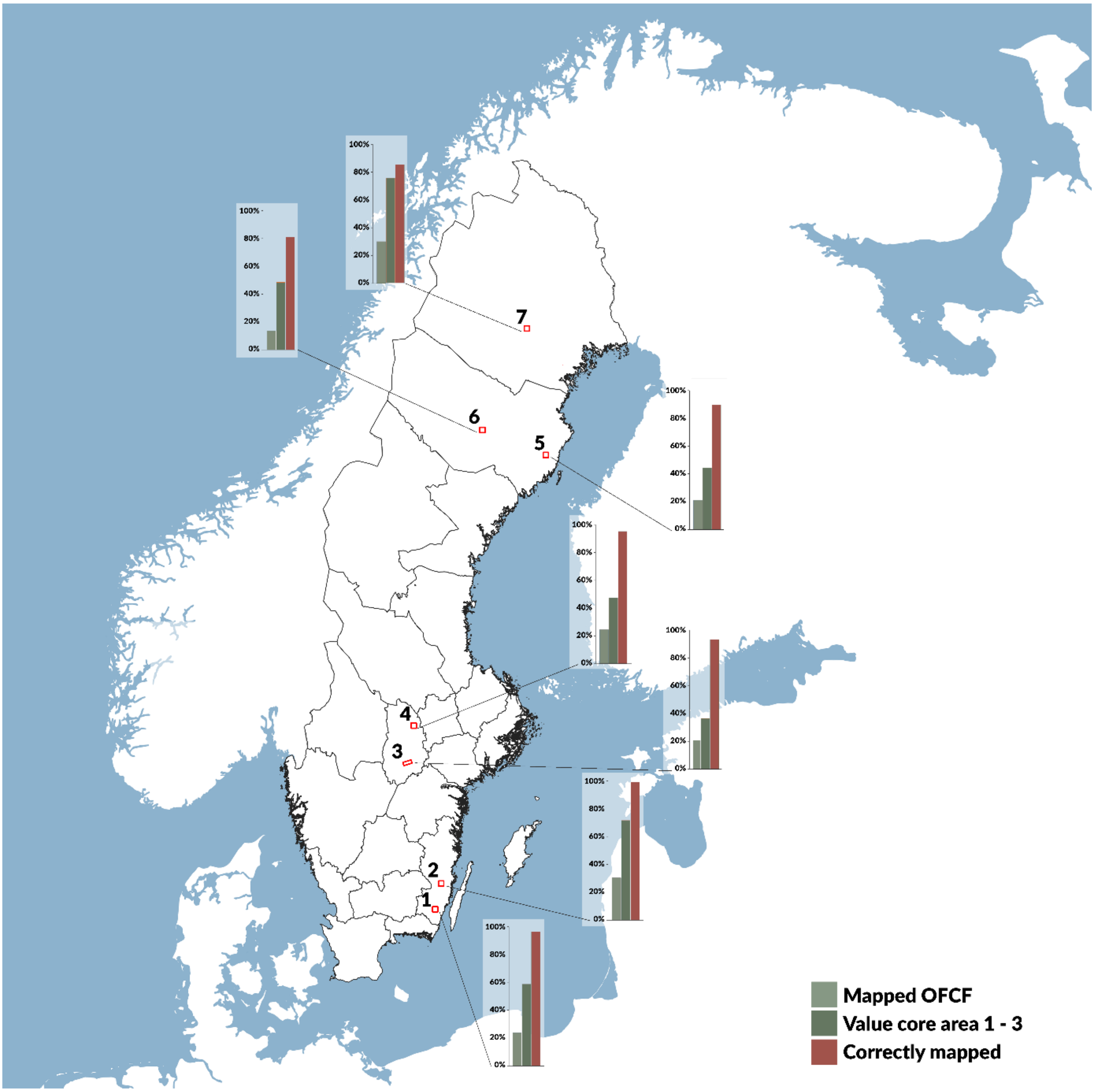


Figure 22. A map of Scandinavia, with Sweden and the location of the seven study landscapes inside the four Swedish counties Kalmar (1 & 2), Örebro (3 & 4), Västerbotten (5 & 6) and Norrbotten (7). The barplots give information on the proportion of, per study landscape, proportion of the forest landscape that was mapped as OFCFs, the proportion of surveyed OFCFs that was determined value core area 1 – 3, and the proportion of correctly mapped OFCF.

Species of conservation concern inside OFCFs

As previously mentioned, our field ecologists recorded findings of species of conservation concern while doing the field inventories inside the OFCFs. In this section we will discuss the species findings made in the four study landscapes made in the southern part of Sweden, study landscapes 1 – 4. We do not consider this part of the data collection to be validation data. However, findings of many species of conservation concern inside the correctly mapped OFCFs gives some support that the mapping has successfully captured the parts of forests where rarer species find refuge. Especially if the wrongly mapped forests lack these species. We will discuss our findings on this topic in the coming chapter.

Species of conservation concern

The International Union for Conservation of Nature's Red List of Threatened Species, also known as the IUCN Red List (IUCN 2025), is the world's most comprehensive information source on the global extinction risk status of animal, fungi and plant species. The IUCN Red List has assessments of the relative risk that various species have of becoming extinct on national and global levels. The risk is evaluated according to criteria from the International Union for Conservation of Nature.

In Sweden, the Swedish Species Information Center is responsible for the national red list. About 2,000 forest-dwelling species are red listed. According to SSIC (2024a), approximately 1,400 red-listed species are strongly negatively affected by logging. A recent assessment shows that out of the threatened forest living species, 394 are directly negatively affected by clear-cutting (SSIC 2024b). For an overview of the red list categories, see **Figure 23**.

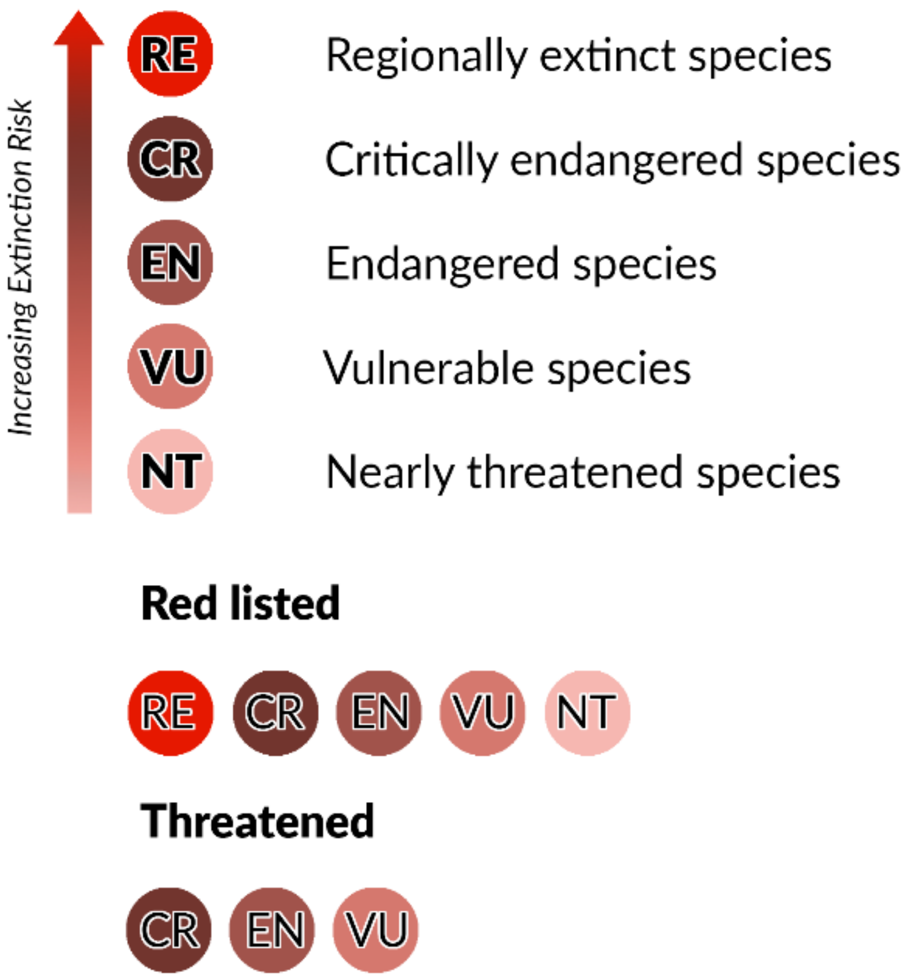


Figure 23. The categories in the national red list.


Photo: Jon Andersson

Photo: Jon Andersson

Apart from the species listed under one of the red list categories, there are other species of conservation concern. The SFA have made a list of species that also includes species that indicate either the occurrence of other rare species or habitats that are threatened by forestry. These species are not necessarily red listed. The important thing here is that they indicate presence of conservation values, species or habitats. They can also be uncommon species, but usually not to the degree that they deserve to be the red listed. Hence, they are not yet considered severely threatened by forestry, but the presence of multiple species on this list doesn't usually come without the occurrence of red listed species. We hereafter refer to these species as indicator species [signalarter]. For a full list, see the Swedish Forest Agency (2023).

Another category of species that are usually referred to as species of conservation concern are species that are protected under Swedish law, species listed in the Swedish Species Protection Regulation (2007:845) (The Swedish Parliament, 2007). As with the SFAs indicator species, these species are not necessarily red-listed, although some are. However, many are rare, and they are protected according to law. Usually, it means protection against the destruction and killing of the species itself as well as the destruction of the habitats they occupy. For some vertebrates, this law can be quite far-reaching while for many sessile species of plants and fungi it is less extensive.

The last category we will mention here are bird species that are listed by the SFA as prioritized bird species in the Swedish Forestry Act. They write that in habitats and on substrates where priority bird species occur damage resulting from forestry measures shall be prevented or limited. These bird species are marked with N and n in Appendix 1 to the Species Protection Regulation (2007:845) or are categorized as CR, EN, VU or NT in the national red list, see **Figure 23**.

Are species of conservation concern spread out randomly in the forest landscape?

The result from dividing the mapped and surveyed OFCFs into different categories depending on the detected conservation value, reveals that even though forests are old, they may not necessarily meet the criteria of being a core area, as defined by the County Administrative Board.
About 54% of the correctly mapped OFCFs in study landscape 1 - 4 met the criteria and were placed in one of the three core area categories. As expected, a very small fraction constituted core areas class 1, virgin forests (about 4%). These forests are rare throughout the mapped area.

In total, we made 815 findingss of species of conservation concern in the correctly mapped OFCF (on 3,034 ha). Out of these, only 108 findings (about 13%) were made in non-conservation value forests (on 1,423 ha). If we only consider the wrongly mapped OFCFs, forests younger than 60 – 70 years, there were 2 finds (on 129 ha). None of the species found in the latter were among the threatened species, see **Figure 23**. Although, most of the non-conservation value forests, NCV were correctly mapped OFCFs, species of conservation concern were still highly over-represented in the three classes of core areas, CV1 – CV3, see **Figure 24, B & C.**

Here, let's stop for a while and think about these numbers. It is not so strange that we found much more of the species of conservation concern in the OFCFs with core value areas than in the non-conservation value forests, someone may add. However, if we look at the density of this kind of species, we find that it is nearly six times as high in the OFCFs with core areas than in non-conservation value forests.

Moreover, in a study by Dahlberg (2011) investigating the abundance of species of conservation concern, the result showed a significantly higher abundance of such species in old forests than on clear cuts, precommercial thinning and in thinning stands. Our result confirms that the occurrence of species of conservation concern is much lower in non-conservation value forests. This is deeply worrying.

The results from our inventory prove that old forests with high conservation values, to a significant degree, can be mapped with remote sensing. Our results also suggest that the combination of remote sensing and the comparably simple methodology used by the Swedish County Administrative Boards, captures the health of the ecological system in forests. There is, however, nothing that says that other field survey methodologies wouldn't be useful in performing this kind of assessment.

In Sweden, there is an ongoing discussion about whether the red list is really capturing anything else than conservationists' own interest in protecting more forest. And naturally, the forestry industry are the ones who are most interested in downplaying the validity of the red list, and with it all methodologies that are used to measure the ecological health of ecosystems.

It seems that some Swedish forestry representatives, without the blink of the eye, disregard decades of research on the effects of forestry on biodiversity, that has proven forestry to be the main culprit in the demise of many forest living species. Regarding this matter, we honestly appreciate the lively discussion on this topic. But in this case, is it not better to just admit that "the Earth is round, not flat"? The SWFM-way of doing forestry is very harmful, indeed.

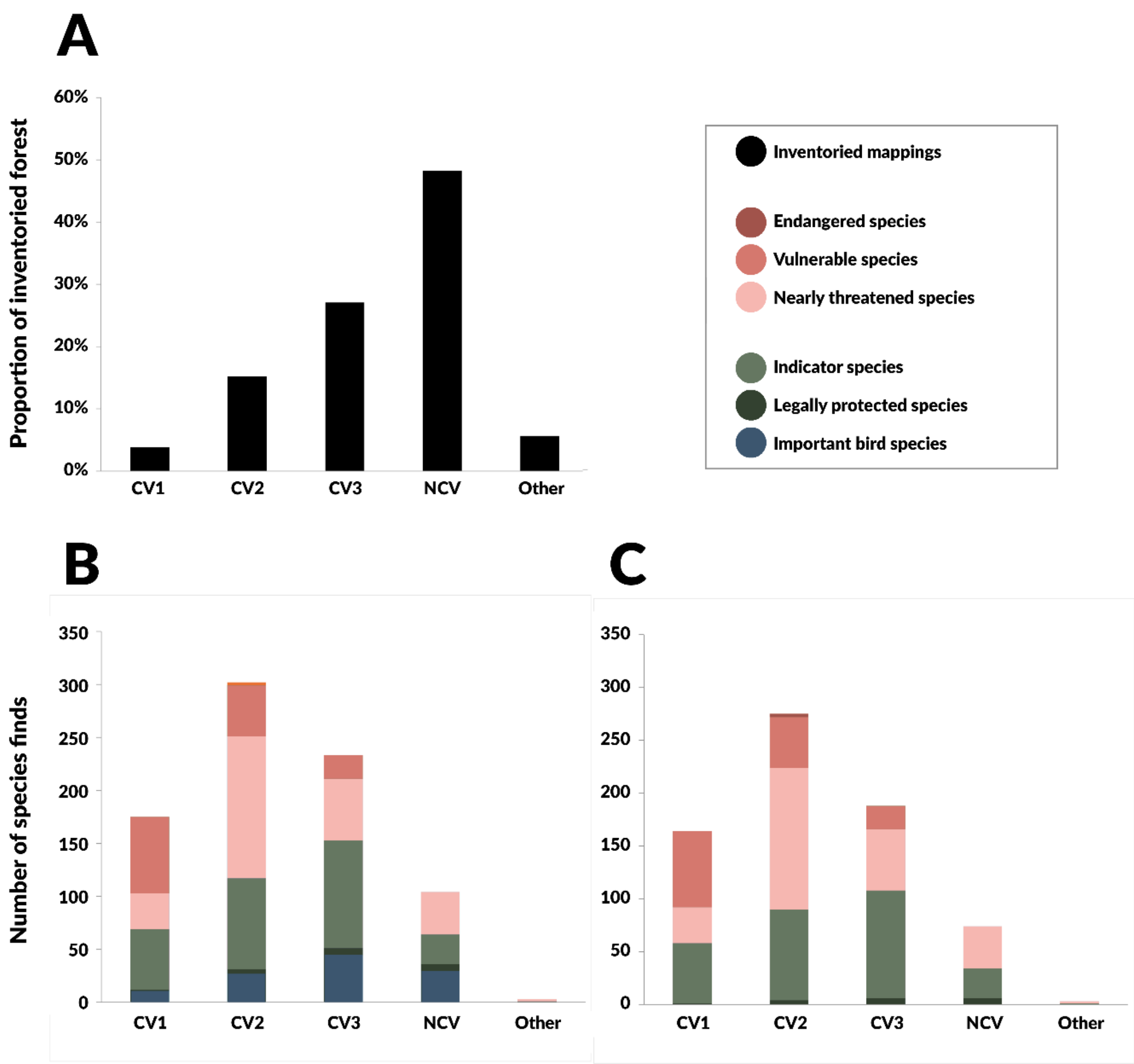


Figure 24. In A the proportion of the inventoried mappings presented in the five different conservation value categories CV1 - CV3 forests, non-conservation value forests (NCV) and other forest types, usually very low productive impediments. In B the number of all species findings made in the five different conservation classes, and in C, the frequently discussed orchid Northern Rattlesnake Plantain (VU) and bird species of conservation concern were removed from the data. Note that no species in the red list category critically endangered were found.

8. FOREST MONITOR - MONITORING THE LOSS AND THE THREAT TO OFCFS

Photo: Olli Manninen

Forest Monitor - Monitoring the loss and the threat to OFCFs

Forest Monitor enables environmental monitoring of forests in the three different classes *high conservation values* and *probable conservation values*, and all *potential older forest and continuity forest* in the map service's map layer. That is, our statistics only apply to the mapped and known OFCFs. Undermapping occurs.

We can both present data on the proportion of the three different classes that are currently notified for final felling (planned to be clear-cut), and how much of the different categories have been lost since we created and uploaded the data.

On our web service, we provide statistics on the forest in the three classes inside and outside formally protected areas.

Unprotected and formally protected OFCFs

An overlap analysis between formal protection land and the mapped OFCFs show the following:

Table 7. The forest area in each of the three classes found inside formally protected areas.

OFCF classes	Area
Class 1 ***High conservation values***	1,528,812 ha
Class 2 ***Probable conservation values***	6,783 ha
Class 3 ***Potential older forest or continuity forest***	33,010 ha
	Total: 1,568,605 ha

Table 8. The forest area in each of the three classes found outside formally protected areas.

OFCF classes	Area
Class 1 ***High conservation values***	1,096,512 ha
Class 2 ***Probable conservation values***	373,567 ha
Class 3 ***Potential older forest or continuity forest***	4,399,594 ha
	Total: 5,869,673 ha

What is the proportion of the unprotected OFCFs in class 3 that have conservation values?

The simple answer is that we don't know. However, it is reasonable to assume that class 3 contains a large proportion of core areas with conservation value forest. This assumption is based on the knowledge we have about the proportion of core areas (forest with conservation values) in our field-visited validation landscapes, and based on SEPA rough estimates on the overlap between probable continuity forests and old-growth forest.

SEPA states in a report from (2023) that:

"The authorities' assess that the area of old-growth forest [naturskog]...that lies outside strictly protected areas amounts to between 2.2 and 2.8 million

hectares of forest land. From this area, 1.5–1.8 million hectares are estimated to be on productive forest land.”

And:

“...a relatively large portion (approximately 40–70%) of the area with probable forest continuity on productive forest land is assessed to consist of old-growth (naturskog) *according to the current definition.”*

Note! SEPA’s definition of probable continuity forest should not be confused with Forest Monitors OFCF class 3. However, since the layers in northern Sweden largely overlap, SEPA’s rough estimate still gives an indication that there are large areas of unknown conservation value forest within OFCFs.

Executed loggings within OFCFs

Below are statistics showing the loss of OFCFs in the various classes since the data was created, updated and published on skogsmonitor.se:

Table 9. Area of logged forest in the in the three classes.

OFCF classes	Area logged
Class 1 ***High conservation values***	27,853 ha
Class 2 ***Probable conservation values***	36,391 ha
Class 3 ***Potential older forest or continuity forest***	625,501 ha

Logging notification statistics March 2025

By using the SFA’s data layer of current logging notifications and measuring how large the overlap is with the three classes of OFCFs, we can produce statistics on how much is currently notified for logging. This data is updated each month.

Right now (2025-03-01), tens of thousands of hectares of forest are notified for final felling (planned to be clear-cut), within the mapped area of OFCF with high conservation values or probable conservation values! However, as the current version of our mapping does not contain all known natural and high conservation values, we fear that the area of forest in classes 1 and 2 is

Table 10a. The forest area notified for logging in two of three classes.

OFCF classes	Area of current logging notifications
Class 1 ***High conservation values***	44,637 ha
Class 2 ***Probable conservation values***	19,096 ha
	Total: 63,733 ha

a major underestimation. This is because forests in class 3 (**Table 10b**), until now, contains an unknown proportion of high conservation values and hence are not included in the statistics presented in **Table 10a**. And as a consequence, there is also a gross underestimation of the total area of forest with conservation values that is notified for final felling.

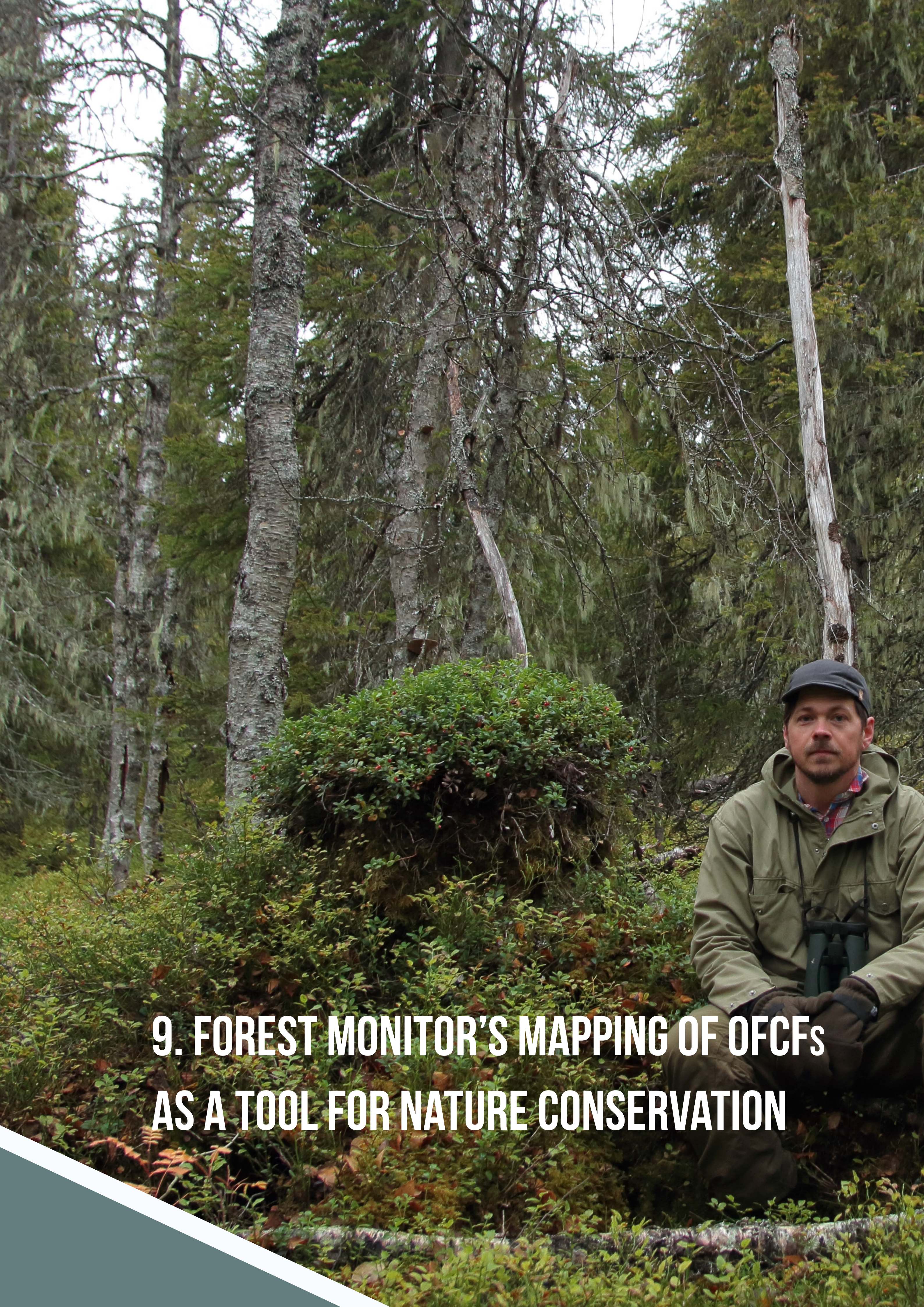
The SEPA's rough estimates, based on field inventories from the County Administrative Boards, indicate that 40 – 70 percent of the productive forest land within probable continuity forest in the Norrland counties is old-growth forests (naturskog/forest with high conservation values). This in turn means that there is a risk that a not insignificant part of the 256,473 hectares of class 3 forests that are currently notified for logging may have conservation values, because these forests are not formally protected, or included in the open data of land owners' voluntary set-asides.

Table 10b. The forest area notified for logging in OFCF class 3.

OFCF class	Area of current logging notifications
Class 3 *Potential older forest or continuity forest*	256,473 ha

Note! It is important to point out that notifications for final felling in subalpine primary and old-growth forest are also used by landowners to pressure the authorities to get economical compensation in case they are not granted permission to clear-cut the forest. This practice has been put in system. This means that a certain part of the notifications in the subalpine forests, where additional legislation applies, will ultimately not be clear-cut.

Photo: Björn Olin



9. FOREST MONITOR’S MAPPING OF OFCFs AS A TOOL FOR NATURE CONSERVATION


Photo: Jon Andersson

FOREST MONITOR'S MAPPING OF OFCFs AS A TOOL FOR NATURE CONSERVATION

Ecosystem services and green infrastructure

In this report, we mainly talk about nature protection for biodiversity and the functioning of ecosystems for the sake of nature itself. The theory of ecosystem services, on the other hand, focuses on ecosystems and species as tools and goods for the benefit of human civilizations and the economy. Such services include, for example, water purification, improving air quality, providing space for recreation, as well as helping with climate mitigation and adaptation. Although the theory sets human needs in focus, there is no way we can weaken the health of nature and at the same time reap the goods from our ecosystems. The equation works only in one direction.

One way of sustaining the production of ecosystem services is to build *"a strategically planned network of natural and semi-natural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services, while also enhancing biodiversity"*, a so-called green infrastructure (European commission, 2025). This network of green (land) and blue (water) spaces improves the quality of the environment, the condition and connectivity of natural areas, as well as improving citizens' health and quality of life. Developing green infrastructure can also support a green economy and create job opportunities.

Connectivity, functionality and representativeness

When we talk about the functionality of forest landscapes, we often think about species survival and dispersal related to the distance, proportion and size of suitable habitats. Together with the area between the targeted habitat – the landscape matrix as it usually called – these factors are interlinked.

We can visualize species dispersal by imagining a large room with any number of people trying to send a message from one side of the room to the other by whispering. The more people in the room, the easier it will be to send the message. On the contrary, if there are very few people in the room, it will be virtually impossible as the sound of a whisper can only be heard at a certain distance, see **Figure 25 A & B**. In the same way, species dispersal will be difficult if preferred habitats are fragmented and only occupies a small part of the landscape. Distances will be too long for successful dispersal and colonization to take place. In this explanation model, the distance between suitable habitats and the proportion of these are inseparable. Low proportion of habitats leads to long distances between them.

If we add to this the size of habitats, it becomes more problematic. We again visit the same room, but now with fewer people. However, this time we imagine that people can whisper a bit louder. And if the people send loud whispers, the message can easily be sent from one side of the room to the other. If, however, they can only send silent whispers, even a good number of people will not guarantee successful transferring of the message, see **Figure 25 C & D**. Likewise, a landscape with large (or with high quality) fragments, that support viable sub-populations of species, will better sustain the dispersal of species than a landscape with small fragments where only a few individuals of the same species can survive.

Also, remember that different species' dispersal capacities vary greatly, which affects the species-wise effect on populations from fragmentation. Note here also that a higher number of individuals will not increase the maximum dispersal distance of a species. It will only increase the number of attempts and hence also the number of successful colonization events of adjacent habitat fragments.

We have now ventured into the realm of connectivity. Connectivity is the ability for species to move between suitable habitat patches. This is vastly important for sustaining species and hence ecosystems. Habitat fragmentation has immediate and long-lasting negative effects on populations of species. Infrastructure and increased development cut off migration routes so that species are losing the ability to move, migrate, and disperse across landscapes. But if we compare ecosystems, connectivity may look different. It can be undeveloped habitat corridors that connect key habitats or wildlife crossings, the safe passages that are built as bridges over major roadways. In the coming chapters, we will mainly focus on forest connectivity. However, the theories on connectivity do apply to any type of habitat that experiences fragmentation.

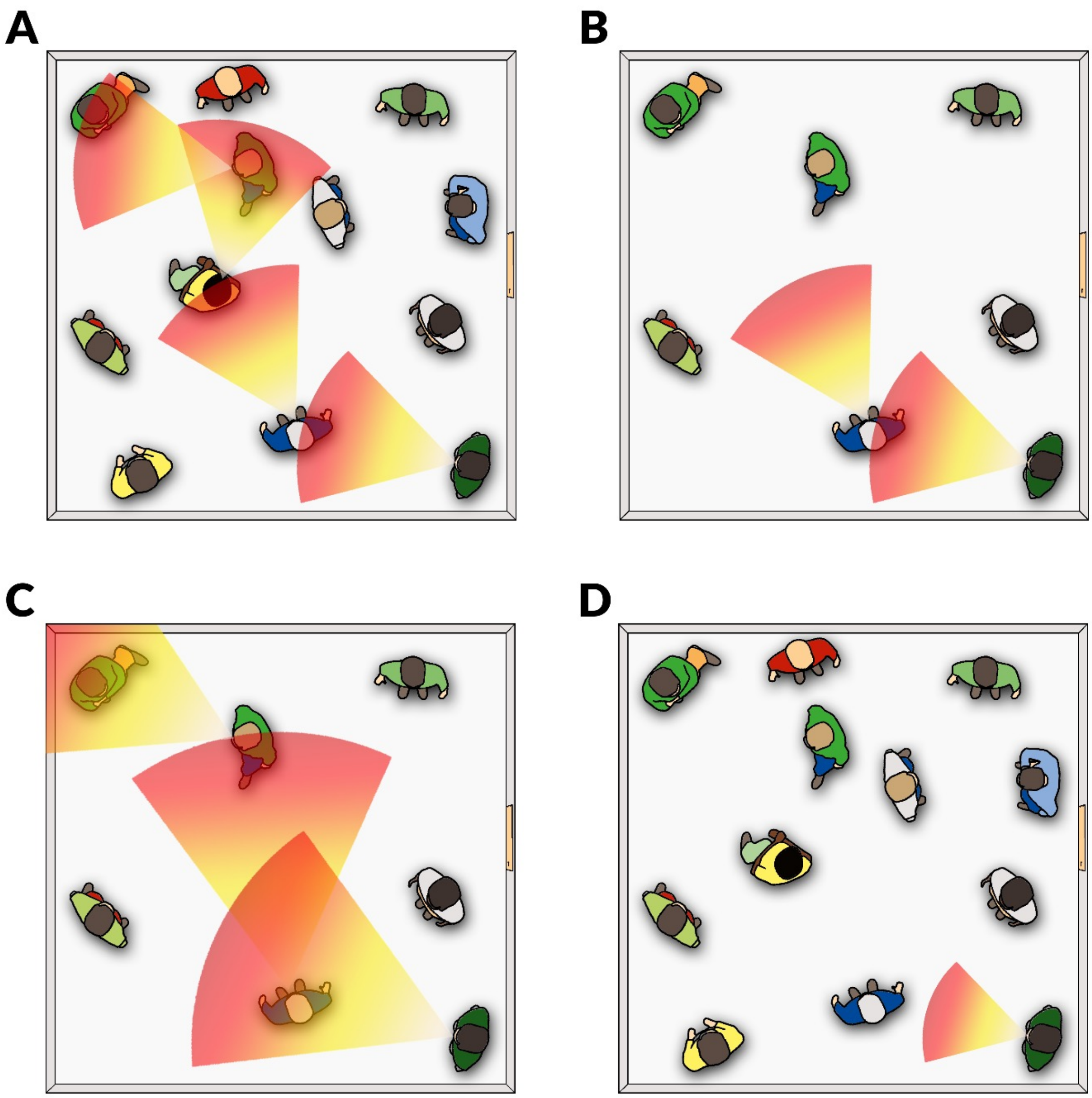


Figure 25. A simplified sketch of the effect of fragmentation. In A, there are enough people in the room so that the person in the lower left corner can pass the message by whispering to the next and further across the room to the person in the upper right corner. In B there are too few people to successfully pass the message. In C, people are whispering slightly louder, and hence the message can be passed despite the low number of people in the room. In D, the person whispers too silently, and hence the message cannot be passed even though there are many in the room.

The Convention on Biological Diversity, CBD (2025) emphasize functionality, connectivity and representativeness in the work with forest protection. When it comes to the CBD's 30-percent target on protection of land, water and seas they state that especially areas of "particular importance for biodiversity and ecosystem functions and services" must be protected. Moreover, they state that these protected areas should be "effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures".

This message is supported by a scientific study by Angelstam et al. (2020) that highlights that ignoring the importance of representativeness and forest connectivity is likely to exaggerate the functionality of green infrastructure. It is therefore unwise to include, for example, forest impediments like tree-covered bogs or wooded rocky outcrops in the protection statistics for productive forest land. Low-productive forests do, because of their inherent shortage of resources, sustain a fewer number of species (Hämläinen et al. 2018, but see Jönsson & Snäll. 2019). Moreover, due to their low productivity, impediments are not usually targeted in forestry. For the same reason, it is also unwise to protect many small, exposed forest-slits along waterways or small tree patches on clear cuts and weigh them equally important as large nature reserves. Due to their differences in the proportion of core areas (Ruete et al. 2017), they are not at all comparable.

To summarize, the preservation of forest biodiversity will not be reached by only adding quantitative figures, like the inclusion of forest land that's not currently under pressure from forestry operations or small "SWFM-leftovers". Since productive forest produces higher biodiversity per unit area (Hämäläinen et al. 2018), and are subject to logging, these forests are also the ones in most urgent need of protection. Finally, without proper mapping of representative forests, that constitute the most important pieces in the puzzle, it will be very difficult to achieve the target, to build a green infrastructure for species and to boost the provision of ecosystem services.


Photo: Stig Björk

CBD and the Kunming-Montreal Global Biodiversity Framework 2030-Targets

Scientists state that (Angelstam et al. 2020): Sweden does not meet agreed national and international forest biodiversity targets. Sweden was far from reaching the Aichi targets within the CBD by 2020, and is even further from reaching the current, more ambitious targets that were put forward under the Kunming-Montreal Global Biodiversity Framework.

Scientists state that (Dinerstein et al. 2019): “Protected areas are the cornerstone of biodiversity conservation, and studies document that well-managed reserves are far more effective in safeguarding biodiversity than are other forms of land use”, and that: “Opportunities to address both climate change and the extinction crisis are time bound. ”.

The current, and for forest biodiversity relevant, targets for 2030, as part of the United Nations Convention on Biological Diversity (CBD), are:

> **Target 1:** Ensure that all areas are under participatory, integrated and biodiversity inclusive spatial planning and/or effective management processes addressing land- and sea use change, to bring the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity, close to zero by 2030, while respecting the rights of indigenous peoples and local communities.
>
> **Target 2:** Ensure that by 2030 at least 30 per cent of areas of degraded terrestrial, inland water, and marine and coastal ecosystems are under effective restoration, in order to enhance biodiversity and ecosystem functions and services, ecological integrity and connectivity.
>
> **Target 3:** Ensure and enable that by 2030 at least 30 per cent of terrestrial and inland water areas, and of marine and coastal areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures, recognizing indigenous and traditional territories, where applicable, and integrated into wider landscapes, seascapes and the ocean, while ensuring that any sustainable use, where appropriate in such areas, is fully consistent with conservation outcomes, recognizing and respecting the rights of indigenous peoples and local communities, including over their traditional territories.
>
> **Target 4:** Ensure urgent management actions to halt human induced extinction of known threatened species and for the recovery and conservation of species, in particular threatened species, to significantly reduce extinction risk, as well as to maintain and restore the genetic diversity within and between populations of native, wild and domesticated species to maintain their adaptive potential, including through in situ and ex situ conservation and sustainable management practices, and effectively manage human-wildlife interactions to minimize human-wildlife conflict for coexistence.
>
> **Target 10:** Ensure that areas under agriculture, aquaculture, fisheries and forestry are managed sustainably, in particular through the sustainable use of biodiversity, including through a substantial increase of the application of biodiversity friendly practices, such as sustainable intensification, agroecological and other innovative approaches, contributing to the resilience and long-term efficiency and productivity of these production systems, and to food security, conserving and restoring biodiversity and maintaining nature’s contributions to people, including ecosystem functions and services.
>
> **Target 11:** Restore, maintain and enhance nature’s contributions to people, including ecosystem functions and services, such as the regulation of air, water and climate, soil health, pollination and reduction of disease risk, as well as protection from natural hazards and disasters, through nature-based solutions and/or ecosystem-based approaches for the benefit of all people and nature.

International, national targets, strategies, laws and directives

The EU biodiversity strategy
The following commitments in the EU biodiversity strategy (European Commission 2020) are related to forest and forest protection:

1. Legally protect a minimum of 30% of the EU's land area and 30% of the EU's sea area and integrate eco-logical corridors, as part of a true Trans-European Nature Network.

2. Strictly protect at least a third of the EU's protected areas, including all remaining EU primary and old-growth forests.

3. Effectively manage all protected areas, defining clear conservation objectives and measures, and moni-toring them appropriately.

The EU Nature Directives
The EU Birds and Habitats directives (European Commission 2015), known as the Nature Directives, form the cornerstones of the EU's nature protection policy. The two directives imply that several species and habitat types are covered by a common system of protection, with requirements of regular monitoring and reporting.

The overall objective is to ensure that protected species and designated habitat types are maintained, or restored to a favourable conservation status throughout their natural range within the EU.

Sweden's reporting on the ecological status on forest habitats according to the EU Habitats Directive, shows an overall unfavourable conservation status. Out of 15 forest habitat types, 13 are estimated to have inadequate or unfavourable conservation status in all regions where they occur. Only in the alpine region, two forest habitat types are classified as having a favourable conservation status.

The EU Commission has presented guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests in order to "provide practical guidance to national policy- and decision-makers that will allow them to effectively identify and protect remaining primary and old- growth forest in the EU."

The EU's RED III, the Renewable Energy Directive, has special rules connected to primary and old-growth.

The EU has adopted a law, the EUDR. However, it is not implemented in the member states, and Euractiv.com reported that: "The European Commission has proposed a one-year extension to the transition period for enforcing the EU's anti-deforestation regulation (EUDR), following months of pressure from member states, trade partners, and stakeholders.".

The deforestation and forest degradation regulation, [VS1] has special rules for primeval forests and naturally regenerated forests (Official Journal of the European Union 2023).

The EU habitat types classes, for example Western taiga, in the Habitat directive overlap to a large extent with old-growth and old forest with conservation values.

Favourable conservation status
Favourable Conservation Status describes the situation in which a habitat or species is thriving throughout its natural range and is expected to continue to thrive in the future. It includes all occurrences of a habitat or species, both those in the wider environment and those in protected areas.

The concept is used in the EU Habitats Directive. The official definition for a species is that "conservation status will be 'favourable' when: 1) population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, 2) the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and 3) there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis."

The official definition for a habitat types is that “the conservation status of a natural habitat will be taken as ‘favourable’ when: 1) its natural range and areas it covers within that range are stable or increasing, 2) the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and 3) the conservation status of its typical species is favourable.”.

National environmental targets
The national environmental quality objective “Living Forests” (Levande skogar) states: “The value of forests and forest land for biological production must be protected, at the same time as biological diversity and cultural heritage and recreational assets are safeguarded.”

The objective specifies, for example:
“The biodiversity of forests is preserved in all natural geographical regions and species have the opportunity to spread within their natural range as a part of a green infrastructure.”

“Habitats and naturally occurring species associated with forest areas have a favourable conservation status and sufficient genetic variation within and between populations.”

An in-depth assessment of Sustainable Forests carried out by the Swedish Forest Agency shows that “Sustainable Forests has not been achieved and will not be achieved with existing policy instruments and measures. Developments in the forest environment are negative”.

Formal protection is a crucial means to reach national objectives and international environmental targets. It can be in the form of nature reserves, national parks, smaller biotope protection areas, or legally binding agreements with landowners. As of end of 2023 Sweden has protected:

9.2 % of the forest land (with impediments or so called low-productive forest included).
6.1 % of the productive forest land.
3,7 % of the productive forest land below the montane forests.

Most of the protected forest (over half) is thus located near the mountains. A further 5 % is voluntarily set aside. The set asides lack formal protection and are defined as: “Conservation measure with limited duration”. There is a lack of knowledge about the set aside areas quality, location and long term protection.

Forest connectivity in Sweden

Our mapping of OFCFs in Sweden provide, among other things, a unique opportunity to make large-scale analyses of connectivity. In this section we will present the first ever generalized visualization of the current forest connectivity situation in Sweden. We will now start by briefly explaining the tools we used and how this analysis was carried out.

We used the open-source connectivity analysis toolset inside Circuitscape 4.0. and ran the software inside Julia Programming Language 1.10.5. (Anantharaman et al. 2019). Circuitscape is a connectivity analysis software package which adopts electronic circuit theory to predict and visualize, for instance movement patterns in animal populations across heterogeneous landscapes (Li et al. 2023 and Chen et al. 2023)

Our data covers the entire forest land in Sweden, about 27.9 M hectares. As previously described, our data is made up of two different sources, and both data sources are updated (revisit the chapter on *Method descriptions* for details). Consequently, the data is not homogeneous throughout the country and the result of the connectivity analysis on the entire dataset would likely suffer from these differences.

To reduce the effect of the beforementioned differences, and to ease interpretation of the result, we chose to make a comparison between the connectivity in formally protected areas (mostly forests in the class *High conservation values*) and all the OFCFs in the classes *High conservation values* and *Probable conservation values*. We determined that this reduction of the full dataset by removing the least accurate class *Potential older forest or continuity forest*, and the division of the data would smooth out the inherent differences in the source data sets. Furthermore, this comparison enabled the visualization of the potential loss of forest connectivity if Sweden fails to protect the still unprotected areas with high conservation forests, and forests with known indication of high conservation values.

Data preparation and analysis

Sheer size can cause problems in analyses and in these cases the choice of data resolution becomes very important. Thus, for our analysis of forest connectivity on national level, we reduced the resolution from our native 30-meter pixel size to 250 meters.

Our analysis aimed to investigate connectivity patterns for the entire country. With few changes, we followed the methodology explained in Svensson et al. (2020). This methodology does not require a selection of a focal species and that doesn't depend on the placement of source and destination nodes (see Koen 2014 for an example). We also used cumulative current density (CCD) to measure connectivity which estimates for each pixel of the resistance surface raster.

As previously described, we wanted to make a comparison between formally protected OFCFs and OFCFs in both conservation value classes *High conservation values* and *Probable conservation values*. We started by dropping the third class, *Potential older forest or continuity forest*. Then we extracted remaining OFCFs with the delimitation of formally pro-tected areas. Finally, for both data sets, OFCFs inside formally protected areas (OFCF1) and for all OFCFs but the class *Potential older forest or continuity forest* (OFCF2), we merged the two conservation value classes and then assigned each OFCF-patch with the resistance value 1 and the surrounding landscape matrix, including other habitat types, with the resistance value 100.

We estimated the current flow between all pairs of 254 focal nodes (32,131 combinations) randomly placed along the perimeter of a buffer around the Swedish forest landscape, fol-lowing the approach by Koen et al. (2014) and Svensson et al. (2020). To reduce the size of the full raster, however, we reduced the buffer from 50 km to 25 km in our analysis.

The resistance map of the OFCF2-data, with a higher number of patches, had roughly 16,7 M nodes. The OFCF1-data had slightly fewer. To speed up calculations in both analyses, we hence used multi-threading with 16 processes in parallel which significantly reduced the processing time from about a week to a few days. This procedure was also tried with 32 and 64 processes in parallel, but for whatever reason it caused the software to crash repeatedly.

What happens if Sweden fail to protect its old forests?

To begin with, let's remember that the field inventory detected to a varying degree high conservation values in class 3, *Potential older forest or continuity forest* that are not included in this connectivity analysis. Therefore, regarding the interpretation of the result, based only on OFCFs in classes 1, *High conservation values* and 2, *Probable conservation values*, we acknowledge the fact that it underestimates the true connectivity in the old forests in Sweden.

We detected, yet unbroken old forest connectivity from northern Värmland county in the south to the border of Finland in the north, a stretch nearly 1,000 km long. From this long chain of large forest massifs, extend branches toward the east into the exceedingly fragmented forests of the inner and coastal regions of eastern Sweden. In the eastern part of northern Sweden, in the south and along the western coast, the connectivity between old forests fragments is generally poor (**Figure 26**). In the result from the study Svensson et al. (2020), there was clear band of older forests reaching from the main assembly of high connectivity forests in the west towards the coastal areas and along the coast in the east. This is not seen in our result, however. Here, recall that the data in our analysis, which is basically the same as in Svensson et al. (2020), is first reduced from the updating by Metria AB and then again reduced before analysis by removing the mountain birch and a part of the dataset that is less accurate. Exceptions can be seen in Stockholm county and in the western parts of Västra Götaland county where large areas of rocky, low productive forests can be found. Also, the closeness to heavily populated areas around Stockholm city leaves visible traces in the species records we use to classify our data. Many people equals many species records. Stockholm county, with 6.1% formally protected productive forest land (the Svealand region average is about 4.7%), has the most formally protected forest in southern Sweden.

For many it may be tempting to discredit this result because the analysis is based on remote sensing of satellite images and analysis of historical orthophotos. We have not used any data from, for example, the Swedish Forest Inventory, the SFI to guide the result. Despite this, the general pattern is consistent with what has been reported previously about old forests (>160 years old) in Sweden (SFI, 2017). Here, note that our mapping of old forests capture also forests that are significantly younger. Still, by to some extent, including forests that are younger in the analysis, the result highlights yet the fact that most of the Swedish forest landscape is severely affected by forest fragmentation and that much of it is very young.


Photo: Jon Andersson


Photo: Jon Andersson

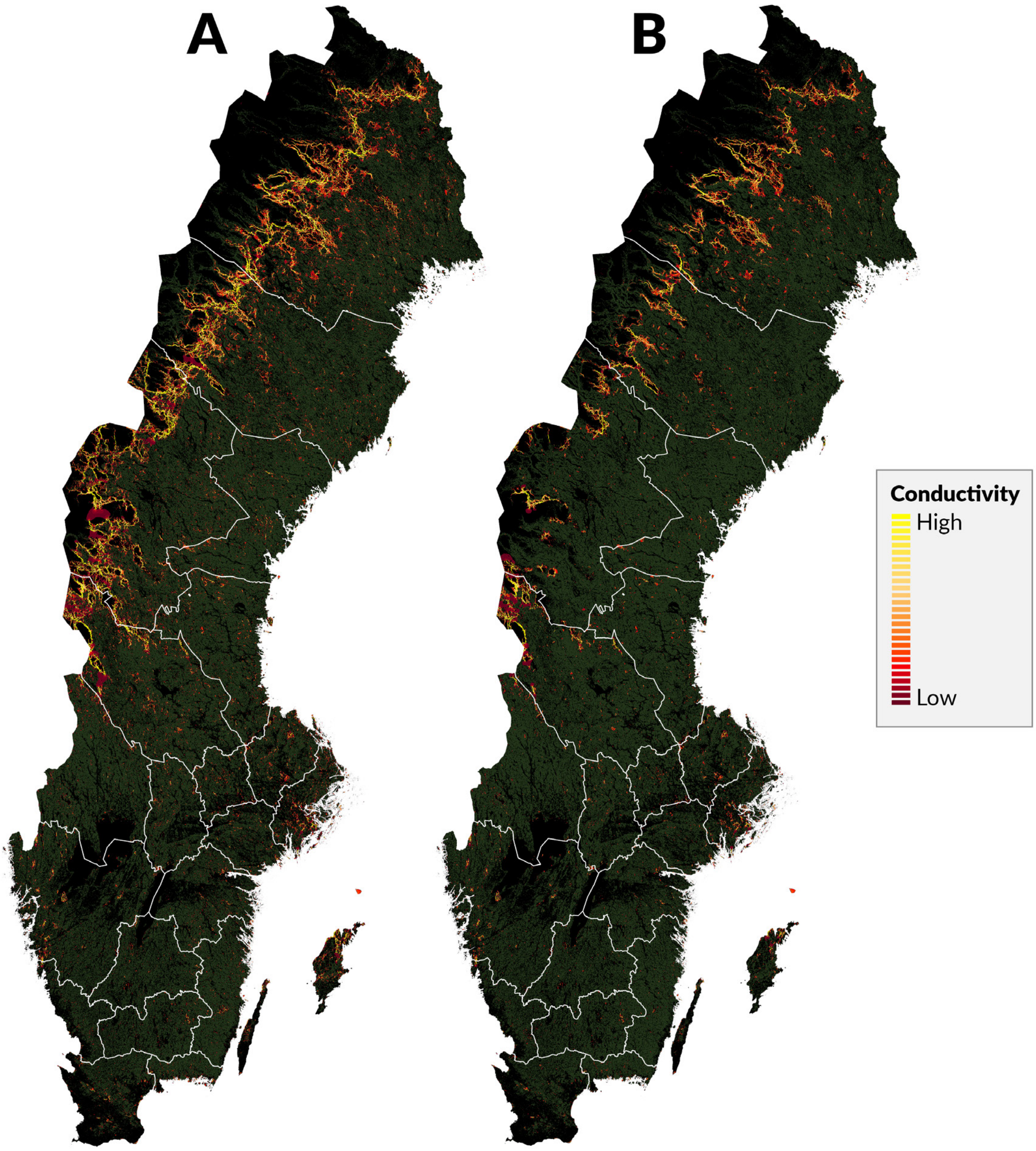


Figure 26. Result from the connectivity analysis of A, all OFCF in classes 1 and 2, and in B, only formally protected OFCF in class 1, presented as conductivity across the landscape. High values (yellow) indicate high conductivity and good connectivity between forest patches. Low values (red) indicate low conductivity and poor connectivity between forest patches. The Swedish forest land is colored dark green and black is other habitat types; mires, lakes and other. Losing forests with known and probable conservation values would drastically weaken forest connectivity, especially in western Sweden.

Green infrastructure planning

We will here present an example of how to build the green infrastructure the EU-commission is talking about, “a strategically planned network of natural and semi-natural areas…”, and so on. When we think about a network, it is usually a set of data hubs or nodes that are connected with lines or cables to transfer the information. Better cables will ease data transfer while bad cables will do the opposite.

Similarly, a patchwork of old forests with species assemblages that cannot live outside such patches, will have to use some sort of network to disperse and colonize new patches. Alternatively, the patches are close enough for species to jump over via propagules – seeds, spores or larvae – to adjacent patches, see also the whisper example in **Figure 25**). Nevertheless, for many species, the level of fragmentation has passed beyond the limit of their inherent dispersal ability. Their subpopulations become increasingly isolated and vulnerable.

In Sweden, there is no law that prevents logging close to watercourses, wetlands and lakes. The environmental clauses in the Swedish Forest Act are largely voluntary and rests strongly on the motto “freedom under responsibility”. In the pamphlet named “consideration to water” by the SFA (2014), there are many lively depictions of how forestry should best comply with the weak legislation. The forestry’s consideration of water varies greatly, unfortunately. According to the EU´s Water Framework Directive (WFD, 2000/60/EC) all waters within the EU should experience no further degradation and achieve good ecological and chemical status by 2027.

Forests that are in the vicinity of lakes, water courses and wetlands are collectively called riparian forests. In Sweden, about 3% of all forest lays within 25 meters from streams and lakes, and an additional 8.3% around mires (Lind 1998). Riparian forests have proven to be comparably species-rich, Pielech (2021), and the management practices in these forests have important implications for water quality and biodiversity (Gundersen et al. 2010; Renouf & Harding 2015). Among many other things, riparian forests can also better sustain recovery of bryophytes, Dynesius et al. (2009), and they generally produce larger volumes of dead wood, Oettel et al. (2022). Moreover, riparian forests are relatively easy to find and map.

In the examples we present here, of a possible way to create green infrastructure, we have decided to add a 50-meter buffer along all wetlands in the Swedish Wetland Survey, that were determined to have conservation values class 1 – 3, but not class 4 with low conservation values. We also added water courses from the Water Information System Sweden in classes 1 – 3, but not class 4 with waters in unsatisfactory condition. Lastly, we added a 50-meter forest buffer around all the larger lakes. Note that in Sweden, many lakes and rivers are surrounded by farmland as the soils around waters are usually the richest. In our example we don’t suggest converting farmland into forest to build forest buffers.

In the example presented in this section, we aimed to construct an infrastructure to counteract fragmentation and at the same time both protect and amplify natural values in other habitat types than forests, such as waters and wetlands. We hence started by adding selections of waterways and wetlands as well as all larger lakes to our OFCF-data (see **Table 11** for a full list).

Table 11. Data that was used to build green infrastructure between remaining old forest fragments.

Name	Description	Source data
OFCFs	All three classes	Forest Monitor
Lakes	50-meter forest buffer around lakes	Topografi 50, the Swedish Geological Survey
Large courses	50-meter forest buffer along large water courses	Topografi 50, the Swedish Geological Survey
Watercourses in WISS	50-meter forest buffer along watercourses registered in WISS, classes 1 - 3 but not class 4	Water Information System Sweden, WISS [VISS]
Wetlands	50-meter forest buffer around wetlands found inside the delimitations in the National Wetland Survey, classes 1 - 3 but not class 4	The Swedish Wetland Survey, SWS [VMI]

The resulting rasters are presented in **Figure 27**.

We present the current situation with all three OFCF classes as a starting point from which we can choose to either continue with business as usual, further fragmenting the forest landscape, or protect, set aside and restore more and build functional green infrastructure. We predict that the first forests among the OFCFs to be clear cut are in class 3, the Potential older forest or continuity forest (**Figure 27 A-1 & B-1**) because they are not systematically surveyed in the field by authorities and are hence easy targets for forestry.

We predict that the second most likely forests to be clear cut are the OFCFs in class 2, Probable conservation values which are also to a high degree not field surveyed by authorities. However, since there are usually registered findings of species of conservation concern in these forests they have higher chances to remain un-cut. After the last step in the fragmentation process, when only OFCFs in class 1, High conservation values remain (**Figure 27 A-2 & B-2**), we will probably have reached a point of no return. Too many species will have become locally extinct for us to be able to restore the system to its original state without using exceedingly expensive reintroduction schemes.

We here suggest an alternative pathway, where we by protecting the remaining old forests and by adding buffers in crucial parts of the forest landscape (**Figure 27 A+1 & B+1**), can both halt the ongoing fragmentation process and at the same time reinforce and sustain biodiversity in water and in wetland edges. If we assume that the relation between the distance and the proportion of forest land next to water courses and wetlands is linear, our suggestion will add about 6% and 16.6% of the forest land respectively to forest protection. However, recall the result from our field survey, that on average 42% of the OFCFs did not reach conservation values enough to qualify as value core areas in categories 1 – 3. These forests could either be used for restoration or be logged with appropriate methods without clear cutting.


Photo: Jon Andersson

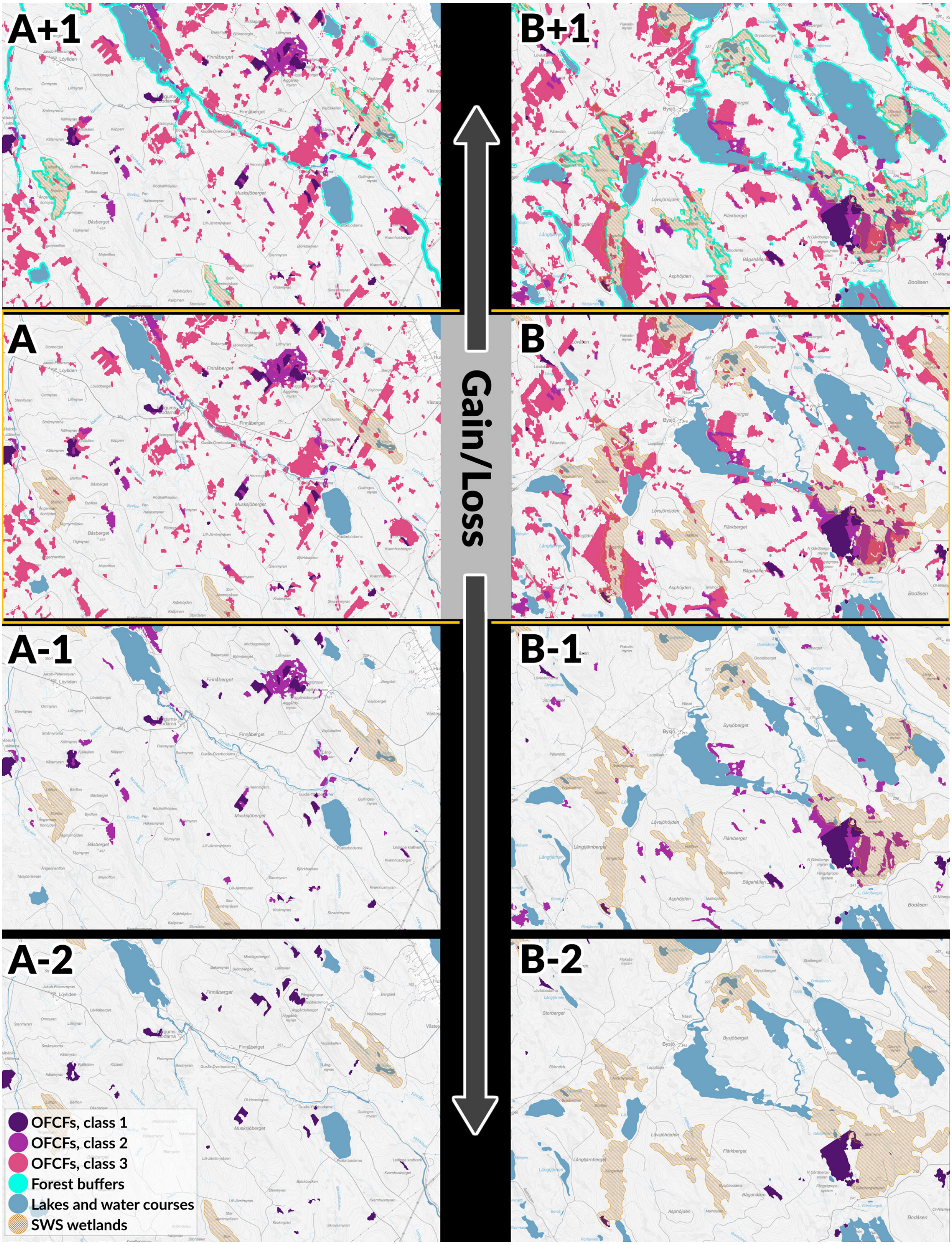


Figure 27. A series of examples in two landscape sections to visualize the outcome of choosing either to protect and reinforce (Gain) two forest landscapes or to continue destroying them with the SWFM (Loss). In both land-scape A and B, (second to top), by protecting the existing old forest and counteract fragmentation by introducing forest buffers around valuable waterways, the lakes and SWS wetlands, we will gain connectivity (A+1 & B+1). If, however, we fail to protect the core areas and other old forests (A-1 & B–1) as well as forests where we currently know from field inventories that conservation values are high, the level of fragmentation of conservation value forest will be monumental (A-2 & B-2). Unfortunately, with today's direction, this is where we're heading.

The last outpost

As we have already discussed, after millennia of human activity, most of the EU outside Scandinavia, is a patchwork of crop fields, tree plantations and settlements. Natural forests are rare. And although Scandinavia is still largely covered by forest, most of Sweden's, Norway's and Finland's forests are heavily managed by clear-cutting forestry. Natural-like forests are mainly found in steep terrain and low-productive areas, where logging has been difficult or unprofitable, and where farming is impossible. Consequently, pristine forests, seemingly untouched by humans, remain only in comparably small patches unevenly tossed out across the EU.

But this was not always the case. A large proportion of the European continent was once covered in broad-leafed, and mixed forests, broken only by meadows and savannah-like fields, mountain ranges and huge wetlands. The latter has been drained and converted to farmland. The old-growth forests of the past are now typically confined to nature reserves and national parks as hazy memories of long-forgotten European nature mystique. However, in the northern most corner of the EU, a large unbroken belt of old-growth forest remains which until this day is still largely intact – the last outpost of the EU: the Scandinavian Mountain Green Belt. The EU member states cover roughly 4,476,000 square kilometers or 44% of Europe's total area. In this vast area resides 6 out of a total of 14 different world biomes. Four out of the six biomes found in the EU constitute different types of forest. Biomes are large communities of plants and wildlife that are adapted to specific climate types, from cold arctic Tundra up north through the coniferous Taiga and Temperate broad-leafed forests in central Europe to the dry Mediterranean forests and Temperate grasslands in the southeast.

Forest definitions

On the European Commission's web page (2021a), it reads "forests and other wooded land cover more than 40 % of Europe, making it one of the most forest-rich regions in the world". But is the EU really covered in forest, and if so, what is the condition of these forests after centuries of human impact?

Well, let us start with a definition of the word "forest". The United Nation's Food and Agriculture Organization, FAO gave it a try in (2001). They defined forest as a piece of land "covering more than 0.5 hectares with trees higher than 5 m and a canopy cover of more than 10%, or trees able to reach these thresholds in situ". Sweden, one of the EU's most heavily forested countries, however has its own definition of the productive part of the forest land. The definition states that "productive forest land should produce on average at least one m^3 of timber per hectare and year" (SLU 2021), or else it is simply termed "impediment". These so-called impediments are usually low productive and useless for timber production, revisit the chapter Forest monitor's mapping of OFCFs as a tool for nature conservation for more info.

The weakness in these definitions is that they only consider tree growth and production potential in a defined area. They leave out other valuable aspects of forests such as forest biodiversity and the continuity of habitats. Hence, to answer our question about whether the EU is a forest-rich region, we need to broaden these definitions, to encompass all organisms that can be found in a specific biome. Natura 2000 is a network of protected nature, spanning across Europe. Its main goal is to sustain the long-term survival of Europe's most valuable and threatened species and their habitats (European Commission 2021b). All EU-states are therefore instructed to identify and delimit representative areas to fulfill this goal. To define specific habitats that make up the network, the European Commission has set up a list of 91 different habitat types, each with its own definition. These definitions include typical habitat characteristics and typical species. Let us call it a measure of "naturalness".

Here is an example to clarify: habitat type number 6120, Xeric sand calcareous grasslands. For the novice this would probably look like a dry meadow, a patch of dry grassland. But it isn't that easy. The habitat description for this specific grassland type says that there should be a dry and somewhat disturbed soil layer with a semi-open vegetation cover and patches of calcareous, more or less humus-free, nutrient-poor and well-drained, sandy soils. And on it goes. For this grassland to fulfill the definition it also needs some of the 23 different typical species, whereof four are beetles. So, this "dry meadow" is actually much more complicated than first anticipated. And remember, this was the easy one. Now, what If we chose something a little bit more difficult, like number 9010, Western taiga? For this habitat type there is a list of 134 typical species and the habitat description covers a whole page.

One may argue that this is overambitious but then bear in mind that the species list for Western taiga, still only encompasses a tiny fraction of the total number of species found in this ecosystem, the taiga. To qualify as a habitat type in the Habitats Directive is, as you can see, not easy. This kind of definitions also stands in stark contrast to the above-mentioned, the FAOs and the Swedish definitions of forest, that mostly aim to quantify production potential and tree biomass etc.

The condition of forests in the EU

By using the more comprehensive definitions, like the Habitats Directive's, one can draw conclusions about the current health of forests valuable not only for European forestry companies, but also for the preservation of biodiversity. The European Environment Agency (2020) has used such data to evaluate the conservation status of habitat types listed in the Habitats Directive. **Figure 28 A** shows the conservation status of the EU's forest habitats in 2015, ten years ago. Forest habitats with favorable conservation status could then only be found in a few places within the EU. Sadly, in most parts of the EU, forest habitats were in unfavorable condition, based on this data. The notion that the EU is a region largely covered in lush forests is therefore open to debate.

If we leave out the condition of forest habitats, then what about the actual forest cover – was there more forest in the past? From the data on historical forest cover modelled by Kaplan et al. (2009) we can get an idea. The comparison made in this study between bronze age forest conditions, 1000 BC, and 2,850 years later, in the mid-1900 century, is astonishing, see **Figure 28 B & C**. Although much of the EU's forests were already affected by human settlement and forest clearing in 1000 BC, whatever happened over the 3,000 years that followed had a profound impact on forests. The forest cover in the 1850s (B) is a mere fraction of the original, bronze age forest cover (C). If we add the information about the present conservation status of the EU's forest habitats (**Figure 28 A**), one can see that not only do extraordinarily little forest area remain.

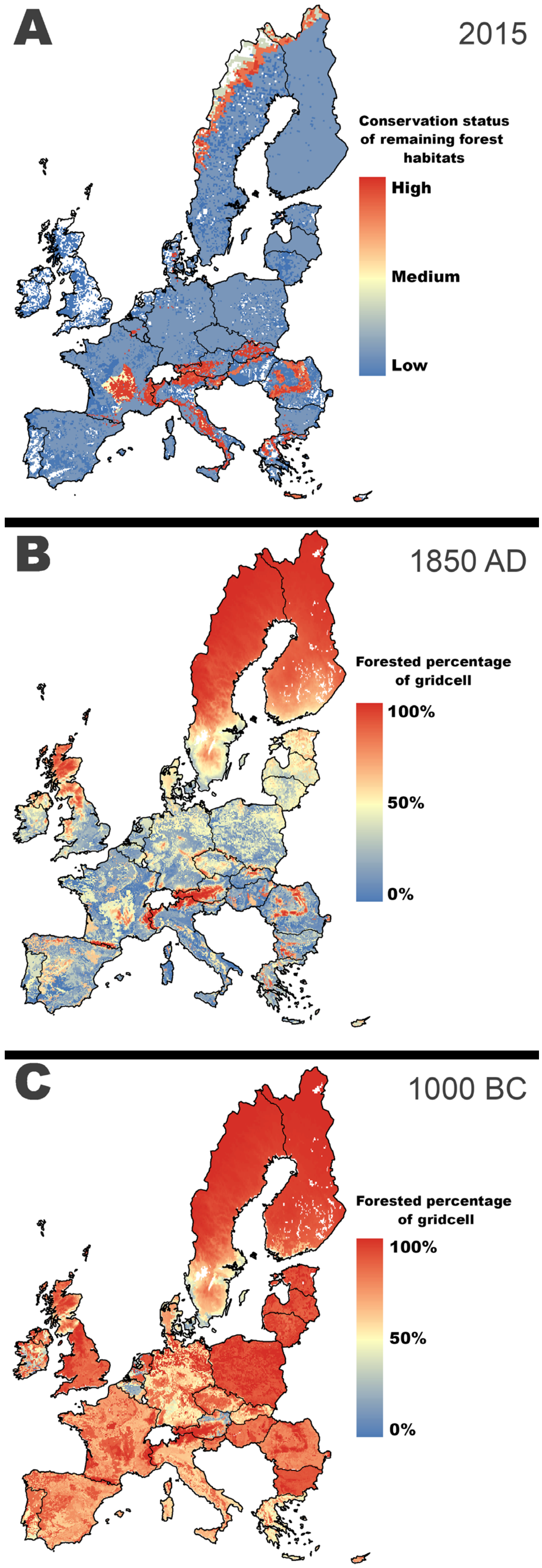


Figure 28.

The islands of remaining forest habitats are in extremely poor condition. A recent study by Sabatini et al. (2018) showed that untouched primary forests only constitute about 0.7% of Europe's remaining forest cover and out of these remnant patches only 46% are strictly protected against exploitation.
The fact that only remnants of the EU's forests are left may not come as a big surprise to people living in most parts of the EU, where population density is high, and little forest remains. But what about places where most of the forest cover persists, but with poor conservation status, like Sweden and Finland? You may wonder what happened there, and why is a large portion of the foothill-forest of Scandinavia still in comparably good condition? Read about this in the next chapter.

Next page: Continental Europe's forests are often fragmented and only a few primary forests remain in the lowlands. The picture shows a fragment of old-growth forest that remains in the mountains of Austria.
Photo: Viktor Säfve


Photo: Viktor Säfve


Photo: Jon Andersson

The Scandinavian Mountains Green Belt
- forests in hard-to-reach places, outlook

Near the Scandes, the mountain range running north-south in Scandinavia, there is a more than 800 km long belt of montane (or subalpine) forest, relatively untouched by forestry. It is an area with concentrations of primary and old-growth forests. This landscape is a very valuable natural heritage and could be called the Amazon of Scandinavia. Scientists delineated the Scandinavian Mountains Green Belt as the largest intact forest landscape within the European Union (SLU 2020).

It is largely situated within the borders of Sweden, and is a unique natural heritage from a European as well as international perspective. About half of these intact mountain forests still lack strict protection, and some wood from forestry within the Green Belt still potentially ends up in the supply chains of certified forest companies.

In May 2024 the Swedish Radio reported that over 6,000 hectares, of the internationally valuable natural forests in the Scandinavian Mountains Green Belt has been cut down in just four years (SR 2024). SCA is one of the two biggest loggers in the area according to the report.

In the 19th and early 20th centuries, timber was floated down the rivers to Sweden's east coast, and the western mountainous areas were difficult to log and to extract timber from. Even today, they are less accessible, which is why this forest belt has remained. 58,7 % of the montane forest (both productive and low-productive) is formally protected today. According to the Forestry Act, logging of high conservation value montane forests is not permitted. Despite this, in 2021 approximately 30 per cent of the applications for logging in this area were permitted. In order to protect biodiversity and maintain ecological processes, this north-south corridor, where species will be able to migrate to escape a

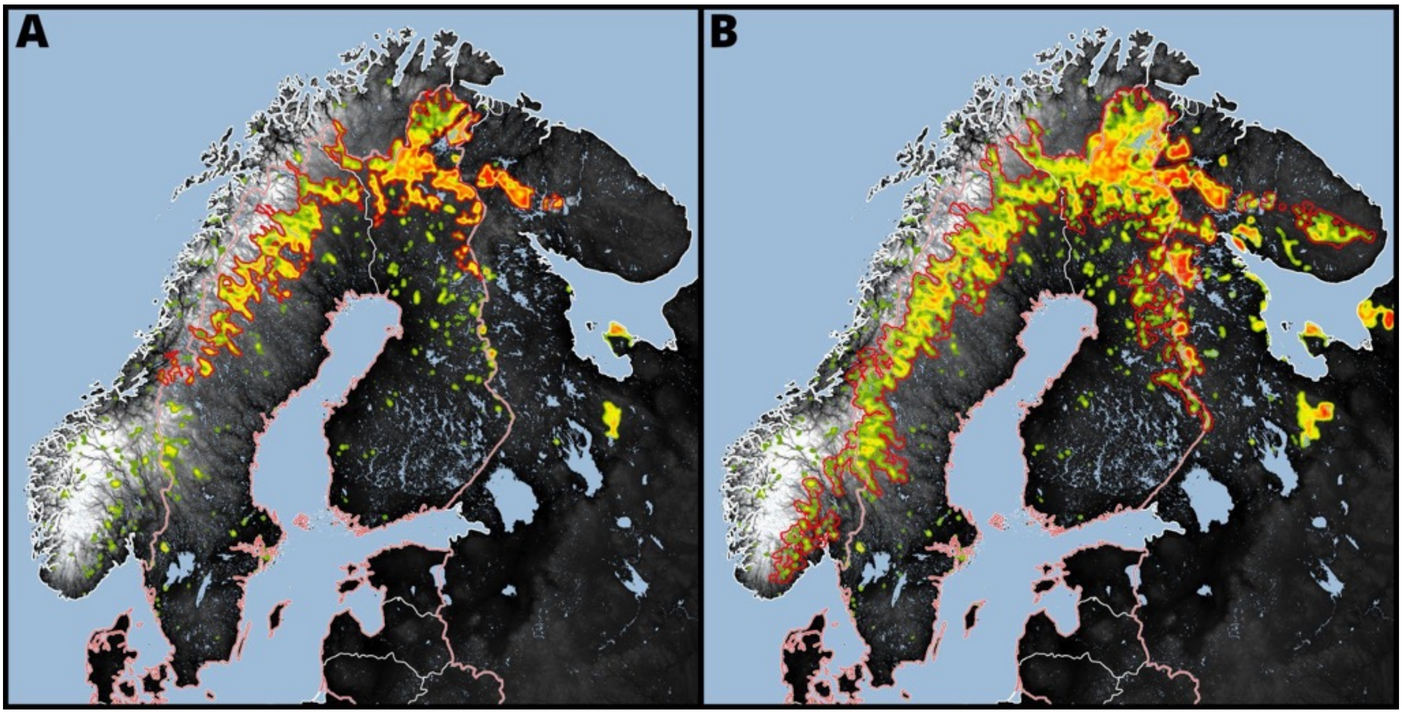


Figure 29. These maps show the extension of the Scandinavian Mountains Green Belt based on a concentration analysis. There is, however, a quite big difference in the size of the delimited area depending on how much of the high conservation value forest we include in the analysis. In A the concentration analysis is made purely on the presence of protected forests, forests in national parks, nature reserves and other protected areas. In B, on the other hand, all the old forests with high conservation values, independent of protection status, are included in the analysis. This shows clearly that the loss of yet unprotected high conservation value forests could lead to a disaster for large-scale forest connectivity in western Scandinavia and eastern Finland.

warmer climate, must be preserved. Scientists state that: “the Scandinavian Mountains Green Belt is a key entity supporting ecological legacies, boreal biodiversity and ecosystem services, resilience and adaptive capacity, which needs to be safeguarded for the future.”.

The SEPA has mapped over 500,000 hectares of productive forest land with very high conservation values within or in close proximity to the border of subalpine forest. A government investigation (SOU 2020) suggests that: “...approximately 500,000-525,000 hectares of productive forest land, in the large contiguous natural forests within and in close proximity to the border of subalpine forest,…, long-term preservation must be ensured”. This is motivated by, among other things the need: “...to preserve biological diversity at the highest level, ecosystem diversity”. Today, however, there are no government decisions for the protection of all this internationally valuable forest, nor are there any sufficient funds to back up this statement.

10. ANALYSIS OF THE “OLD FOREST” TRENDS AND UNDERLYING STATISTICS

Photo: Viktor Sätve

ANALYSIS OF THE "OLD FOREST" TRENDS AND UNDERLYING OFFICIAL STATISTICS

The trend for old forest in Sweden and regulations, laws and environmental targets

Old-growth forests and continuity forests (often overlapping) are species-rich habitats with a very long ecological delivery time. These habitats once dominated the forest landscape of Europe and the Nordics. But today fragmented islands remain, here and there in the Swedish landscape, below the Scandinavian Mountain Green belt. This is one of the main reasons why many species linked to dead wood, continuity of trees or linked to old trees and other ecological qualities, have been put on the national red list. Either they have ended up on the red list because they were more common, but their habitat is noticeably decreasing, or because they are rare and therefore extra vulnerable.

Old-growth forests and other older forests with conservation values are valuable both for biodiversity, as carbon stocks and sinks, and for preserving functional forest ecosystems, because they have the highest levels of most ecosystem services (Jonsson et al 2020). Therefore, there are both national targets and international environmental targets, regulations and directives, which have been specially instituted and committed, in order to preserve these precious habitats.

In the EU Biodiversity Strategy there is a commitment to strictly protect all remaining primary and old-growth forests in the EU.

"Old forest" and "old-growth forest"

Old forest is one of the Swedish national environmental target indicators for the environmental target Living Forests [Levande skogar].

The Swedish Parliament has decided on 16 environmental quality targets. For the environmental target Living Forests, the SFA has the overall responsibility. During the 20th century, the area of old forest was greatly reduced. Old forest is therefore considered an important indicator. The definition of "old forest" is that such forests should have an average stand age that is over 140 years in northern Sweden, and over 120 years in southern Sweden.

Hereafter, the concept of average stand age appears in the report. By this we mean basal area-weighted average stand age, but abbreviate it average stand age.

To measure the trend for "old forest", data from the plot survey from the National Forest Inventory database is used.

In the last 3 decades, the National Forest Inventory has shown an increased area of old forest in Sweden. This at the same time as the clear-cutting of old forest and continuity forests remains high.

In this chapter we will explain why this statistical increase is a so-called statistical mirage, which does not reflect the trend for habitat and species linked to old-growth-, continuity-, nor Western taiga forest well, but is unsuitable as a decisive follow-up method and indicator. We will explain why we see this statistical apparent increase. The question is how can we get less "real" old forest with long continuity for each logging, while the statistics appears to show the opposite?

Summary of the analysis.

The main reasons why we see a statistical increase in forest within the statistical definition "old forest" are that:

1. Already older forest stands and natural forests with long continuity, so called continuity forests, and forests with old-growth characteristics, get an increased stand age and grow into the definition of "old forest", and this at a faster rate than the clear-cutting of statistically old forest takes

place. This applies to both forests outside the nature conservation areas, and forests that lack formal protection, but are voluntarily set-asides by different forest owners. The area of older forest with conservation values and long continuity will continue to decrease with each logging. However, this will only be seen in the statistics following the “old forest” trend, when the parallel trends meet.

2. There is a net loss of naturally dynamic forests, continuity forests and natural forest-like older forests (old-growth), which have an average stand age below the definition, which is then not seen as a loss of statistical “old forest”. For example, loggings and loss of continuity forests and old-growth forests with a stand age of less than 140 years in northern Sweden, will not be detected as a loss of statistical “old forest”.

Even if the statistical mirage concerning statistical definition of “old forest” shows increased stand age, at the same time statistics from NFI show that the average age of the entire managed productive forest area continues to decrease.

Why, then, did we see a sharp reduction in forest with a stand age of more than 140 years throughout the 20th century, until the mid-1990s, when we reached an all-time low?

Our hypothesis is simple:
Especially after 1950, clear-cutting is behind the reduction of statistical “old forest”. But both selective logging and clear-cutting before 1950, also had a large effect.

Before clear-cutting took off, reduced average stand age on a landscape level was a result of a combination of loggings and selective fellings, often of the oldest large-diameter trees in old-growth forest in the 19th century, and at the beginning of the 20th century. This resulted both in a reduced average stand age in the old-growth forests, and in an ingrowth of younger trees in the gaps, which had an effect on the stand age for a long time to come, see **Figure 30** for a historical reminder.

The statistical increase, based on sample plots from NFI, that has taken place since the mid-1990s is due to, in addition to the above explanations: The average age has increased in the remaining older forests and continuity forests, due to the fact that a long time has passed since the last disturbance in the form of wild fire or anthropogenic disturbances such as clear-cutting or selective logging. This resulted in increased stand age, in forests that have not been affected by intensive management.

Figure 30. Pine regeneration in selectively felled old-growth forest, on a southern slope, Västerbotten, Degerfors. The picture was taken in 1914. The young trees in the gaps will later in the 20th century affect the average age of this forest stand. Source: SLU’s media archive.

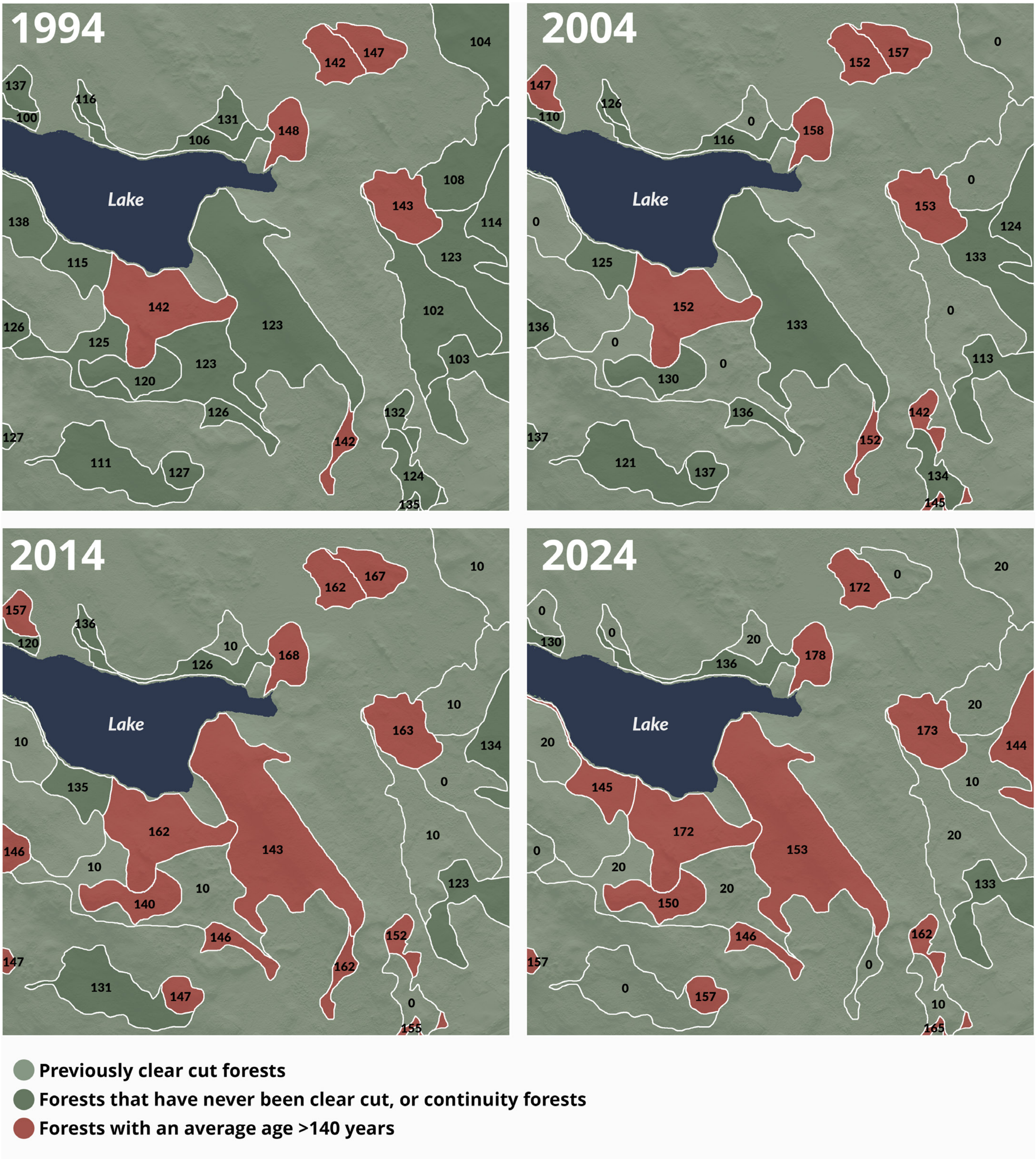


Figure 31. A schematic map series that visualizes the problem with using an average age as a criteria for measuring the area of “old forest” over time. The area of forest with an average stand age >140 years shows a steady increase from 1994 to 2024 while at the same time the area of forest that has never been clear cut before, sensu lato continuity forest, shrinks. Despite the fact that accumulation of structures that are crucial for the occurrence of late successional species increases over time, there is no scientific proof that such species suddenly colonize when the mean age of a forest stand reaches 140 years. Clear-cutting and habitat loss, on the other hand, is a decisive factor for their disappearance.

Stand age alone is not a good measure of natural or high conservation values in primary or old-growth, or continuity forest, or other forests important for biodiversity. And the assessment of stand age does not include trees that are significantly older than the dominant tree layer, so-called overstory trees or hold-over trees [överståndare] (the oldest trees).

A natural forest that is uneven-aged can easily have an increased stand age by felling the younger trees in the stand, and only saving the oldest. Conversely, the stand age can decrease if only the oldest trees are felled. Both of these measures are negative for the dynamic processes, and structural diversity in the forest and have a negative impact on nature conservation and biodiversity.

If instead you take a normal Swedish thinning of all trees in an even-aged production stand or plantation, of say 50 years, then nothing happens at all to the average age. This is one of the many reasons why average stand age should not have too much weight as an indicator or criteria in terms of monitoring, mapping, definitions or protection of primary and old-growth forest, or other forests with high conservation values. In **Figure 31** on the previous page, we visualize the effect of using a strict average age limit to determine the area of "old forest".

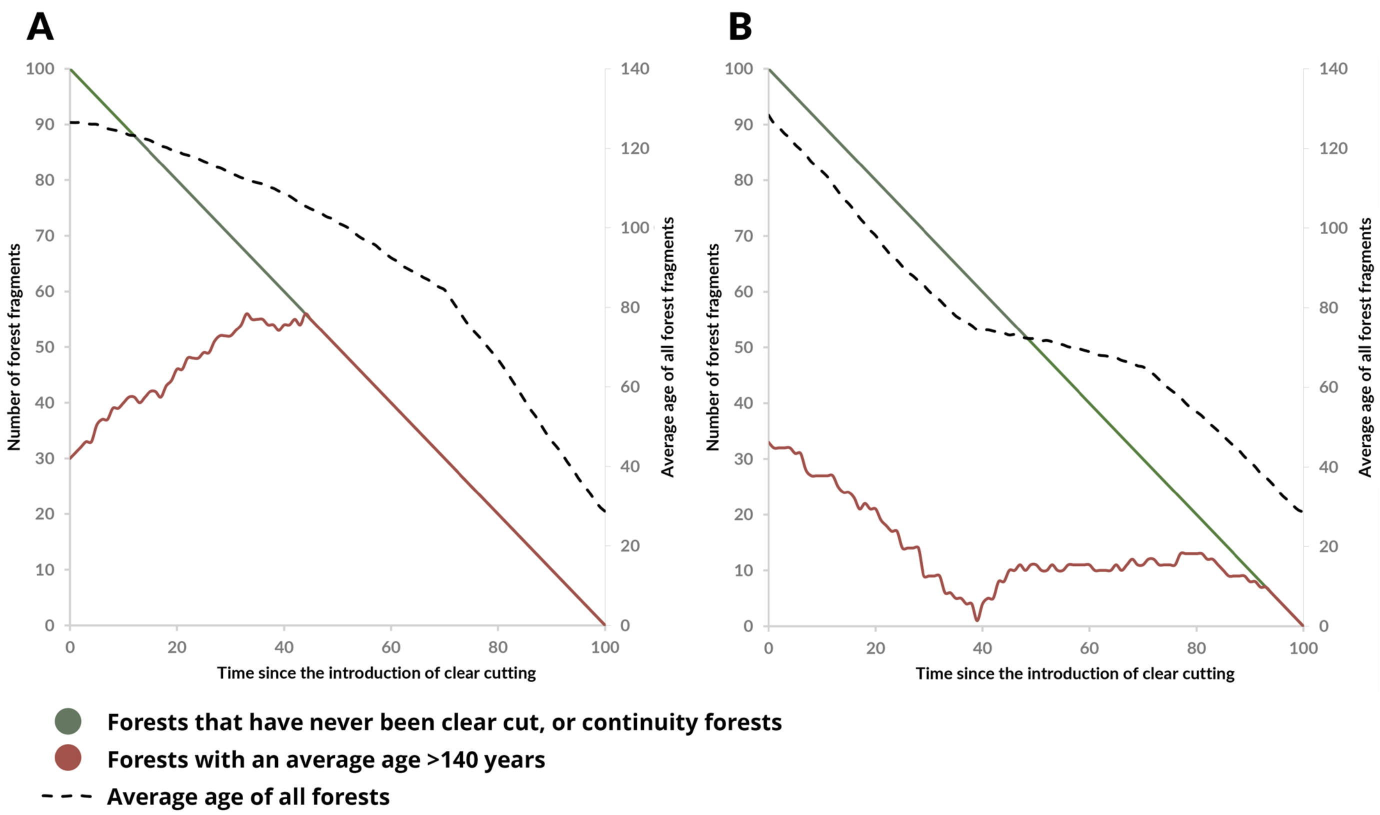


Figure 32. Two different scenarios with 100 forest fragments with equal sizes and start-ages varying between 95 to 160 years. In both scenarios, 1 fragment is harvested every year during a 100-year period. In A the age of each fragment increases by one year every year. In B the age of each fragment is decreasing with 0.5 years every year the first 40 years and after that the age increases with one year every year as in A. In both scenarios, the fragments are harvested a second time after 70 years to simulate rotation forestry. Note that the average age adheres to the right axis in both graph A and B. When all the remaining forests that have never been clear cut before reach the average age of 140 years, the area of such forests will decline with each clear-cutting event.

The annual clear-cutting/logging of statistical "old forest" in Sweden varies between approximately 20,000 and 40,000 hectares during the period 1985–2020 (SLU 2023).

We can conclude that older forests, which have not previously been clear-cut, i.e. continuity forest, have only decreased during this period, and cannot be recreated in a few decades.

But, as long as there is a large enough area of older forests that can increase their average stand age and tip over into "old forest", and this at a higher rate than the loss of already "old forest", it will look like a statistical increase. However, behind this statistical mirage lies the fact that the biologically old forests, with long continuity that originates from before the great clear-cut era, will decrease with each felling. For each felling we see a loss of valuable habitat, a loss, that an increased stand age within already old stands cannot compensate for.

We visualize this process in **Figure 32** on the previous page by using two different models. If we assume that continuity forests are a finite resource, we can use a simple model to visualize the process under which continuity forests within a certain age span disappear, and why forests with an average age above a certain age threshold (140 years) can increase during a certain period, until all remaining older forests pass that specific age limit. Note, however, that in the models no forests with an age under 95 years reach the lower age limit within the starting age span of 95 to 160 years. Although the allowed forest age at final felling may vary between 45 to 100 years in Sweden, the number of second-generation forests (forests that have once been clear cut) that reaches 95 years before the second final felling, is small. In the model, we make the reasonable assumption that plantations and production forests that have been clear-cut will be clear-cut again in the future, and will not have time to become old before they are cut down again.
In the second model, historical natural and anthropogenic disturbances (such as selective logging) have affected the average stand age in continuity forests, in the way that forest above 140 years old decreases for a while. Over time, nevertheless, the average age of these forests increases, so that many of them eventually reach above the 140-year threshold.

The Swedish National Forest Inventory writes about this phenomenon in a fact sheet (Nilsson et.al 2013), freely translated into English:

"However, it should be clear that an indicator of this kind (old forest) does not show the whole picture...For while the area of "old forest" according to the environmental objective has increased, the area of forest in the age class below the age limit for "old forest" has decreased. The area of older forests...has therefore not increased, but rather decreased.".

The forestry's environmental policies and the changes in environmental policy in Sweden in the 1990s are usually pointed out as the reason for the "increase" in the statistical old forest. However, in order to analyze the role of forestry in terms of trends for species and habitats that are linked to old forest, one must, as we have done in this chapter, see these statistics in relation to the whole picture. One must compare the condition of the forest today with historical levels of old forest, and one must compare today's levels with the minimum threshold levels that research, and environmental targets have set.

Seen in the light of this, we have a negative trend for ecosystems and species linked to old forest. We have much less old forest today than before the exploitation of the forests, and we have protected much less forest than international environmental targets require. In addition, to understand how forestry has affected indicators such as old forest, dead wood and deciduous forest, different scenario models must be set up, simulating how different indicators would be affected by different levels of forestry and management. If the forest industry had not clear-cut tens of thousands of hectares of old-growth forest and continuity forest every year since the 1990s, the situation for old forest and dead wood would have been much more positive than it is today.

Stand age measured as basal area-weighted average age
To determine a stand age for the Swedish National Forest Inventories sample areas, a basal area-weighted average age is used where the average height is at least 7 meters, otherwise as arithmetic mean age for main trunks/saplings. Stand age in this context corresponds to "area-weighted average age", which means that the age of large trees is given greater weight than the age of small trees when calculating average age. Stand age is expressed as total age of living trees in the dominant tree layer, not the actual age of the forest in terms of continuity. The assessment does not include small undergrowth tree saplings or trees that are significantly older than the dominant tree layer, so-called overstory trees or hold-over trees [överståndare] (the oldest trees). In this context, the sample area refers to an area with a radius of 20 meters from the center of the sample area. The fact that not only the area where the tree is measured constitutes a reference area (10 or 7 m radius) is because the age of the larger area better describes the average age of the stand. If only the measured area were to constitute a reference area, the probability is greater that a deviating part within the stand will be described. The stand age cannot be measured, as this would mean determining the age of all trees in the 20-meter area, but is assessed. Age-determined sample trees are used to support the assessment, and in cases where the area lacks sample trees, at least two representative trees at breast height are age-determined (SLU 2001 & SLU 2023).

The presentation in **Figure 33 A - C**, highlights three main problems with using average stand age limits to determine relevant thresholds for "old forest" and how the combination of such limits on the one hand, and the period limitations on the other can easily be cherry picked to advertise predetermined outcomes.

Also, we want to remind the reader that the mean age of a forest stand has limited bearing on the ecological values of forests without adding information on species occurrences, structures and continuity of ecological elements like tree cover and dead wood.

Remember throughout this section that it is a well-known fact that making good progress from low starting points is easy. Here we will show astonishing examples.

The first problem is of course to find a relevant age-threshold, the threshold when "normal" forests turn into so-called "old forests". If we look at **Figure 33 A** and **33 B** one should note that half of the formally protected forest area is below an average stand age of 160 years, which should make anyone who wants to use exceedingly high age-thresholds to find ecologically relevant forests hesitate. Here,

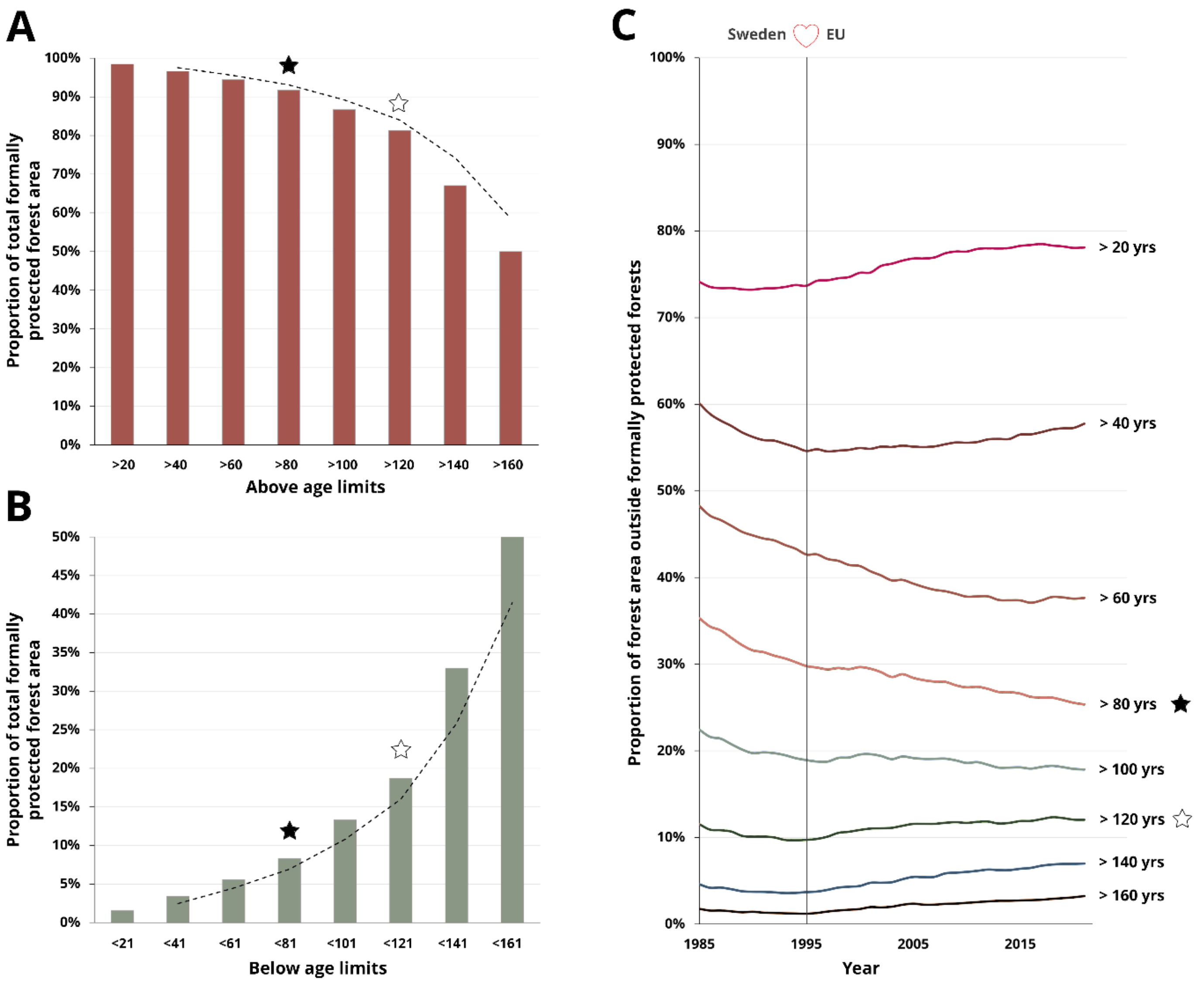


Figure 33. In A and B, the proportion of forest ages in formally protected areas divided into eight different age limitations. In A, proportions above limitations and in B proportions below limitations. The filled star in all panels denotes the age limitation relevant to the mapping of OFCFs the open star denotes a possible age limitation relevant to the majority average age limit in protected forests. In C, the proportion of the same age limitation as in A measured over time from 1985 through 2021. The year 1995, when Sweden joined the EU, is highlighted in C.

read on page 114, about the Swedish government's recent proposed definition of old-growth forests as a forest with an average stand age above 180 years.

If we move on to the next problem, which is finding relevant thresholds for change over time, it gets even worse. In our mapping of OFCFs, we determine forests that haven't been logged since about the 1950s – 1960s to have higher probabilities to harbor natural and conservation values, and rare or red-listed species. According to our surveys this seems to be the case. These forests have an age that corresponds in some sense to the average stand age limit of forests over 80 years, as they originate from the time before the mechanization of forestry in the 1950s. However, we realize that forests with an average age of about 80 years may still lack high conservation values. Hence, if we chose to infer ecologically relevant forests by age limits, this specific age limit may cause over-estimation of such forests. If we want to follow the well-forgotten and utterly under-used precautionary principle in The Swedish Environmental Code (s 2, 3§), arguing for lower age limitations is also better.

Increased or decreased area of older forest and continuity forest since 1995?

Representatives of landowner rights organizations and the Swedish forest industry often communicate that Sweden has more "old forest" today, than in 1995, when Sweden joined the EU.

But, the truth is that older forests and continuity forests (often multi-ages and multi-layered) with an average stand age of over 80 years have steadily decreased since 1995 (see **Figure 33 C**). However, some older forests and continuity forests have had an increased average stand age, which has caused parts of the older forest over 80-120 years to "move into" the part of the older forests and continuity forests that have an average stand age over 120-160 years. But, at the same time, the total area of older forest and continuity forest has decreased, both through logging, and through movement within different categories of average stand age. Note that the area of forest over 80 years has been reduced drastically since 1985 and even since 1995 when Sweden joined the EU. When we move to forest with ages over 120 years, we find little change since 1985, but a slight increase since 1995.

And here we arrive to the third problem, which is finding a relevant starting point, or "reference year" as we may call it. The Swedish government is promoting the year 1995, when Sweden entered the EU as the reference year to report the condition of Swedish forests to the EU. This reference year may seem relevant from a legislative perspective, but from an ecological point of view it completely lacks relevance.

And here is why. Neither did the forest suddenly sprout from nowhere in 1995, nor did the disruptive influences on forest ecosystems from forestry begin in 1995. The Swedish boreal and hemiboreal forest ecosystem is thousands of years old. And forestry, even if we only include the most recent history with the usage of the SWFM, has been around in large scale since at least the 1950s.

Now let's see what 1995 as a reference year has to offer. To begin with, the proportion of forests that fall within the category "harvestable" (Average in Sweden is 99 years) has decreased (forests with an average stand age over 80 years old decreased with 13% or by 5% points, see **Figure 33 C**). If we include forests with an average stand age older than 100 years, we can also see a slight decrease.

If jumping up one step, and including only forests over 120 years old, then we find a slight increase in such forests since 1995 (forests over 120 years old increased with 26% or by 2% points, see **Figure 33 C**). If we also include preceding years back to 1985, this positive trend is erased. Also remember that the minimum forest age of 120 years is the lower limit for "old forest" in southern Sweden.

Trends in older forest outside formally protected areas according to 2022 boundaries.

In 1995, there were 4,354,000 hectares of OFCF with an average age between 81-120 years and 2,109,000 hectares of OFCF with an average age over 121 years (SLU 2025). The latest figures from the National Forest Inventory from 2021 show the following figures: 2,942,000 hectares of OFCF with an average age between 81-120 years and 2,661,000 hectares with an average age over 121 years. If you combine the figures for all older forests, you see that in 1995 there were 6,463,000 hectares of older forests and continuity forests with a basal area-weighted average stand age of over 81 years, in 2021 the figure was 5,603,000 hectares.

This means that, despite a continuous ingrowth of younger stands into the 81+ year category, we have seen a decrease of 860,000 hectares, due to logging, of forests with a basal area-weighted average stand age over 81 years since entry into the EU in the mid-1990s. This statistical decrease testifies to a negative trend for species associated with habitats with long forest continuity and older forests. This is even though statistics from the SFI don´t say everything.

And by now we have made our way into the minuscule and rare part of the forest land that reached the average stand age 140 years, the limit that constitute the lower limit for "old forest" in northern Sweden. Here we find an astonishing increase of about 93%. However, the percentage point difference is only about 3% since 1995. The age limit for old forest that has now been conjured up by the Swedish government is a staggering average stand age of 180 years. Without having any data to support it, our estimate is that these very old forests have increased a little bit too, since they are almost non-existent. Forests with an average stand age of over 180 years are so rare that they are not even reported in the age classes set by the SFI.

In the end, what it might come down to is what different stakeholders aim to do with the result. Do we want to estimate the occurrence of old ecologically important forests, or do we want to keep forests available for clear-cut forestry? According to our results, setting a comparably low age limit gives us the chance to evaluate forests and infer ecological values by field inspections before logging. Contemporary Swedish forest policies, unfortunately, seem to opt for high average age limitations, and ignore the fact that it will harm the forest ecosystem.

The proactive management strategy we propose may seem very tedious. But with proper guidance from authorities, where the forest manager must make field visits before logging to confirm that no high natural values will be spoiled, there is no need for immediate large-scale survey campaigns. It becomes a task done piece by piece. If we, as the Swedish government suggest, use very high age limits, we are putting large areas of high conservation forests in peril.

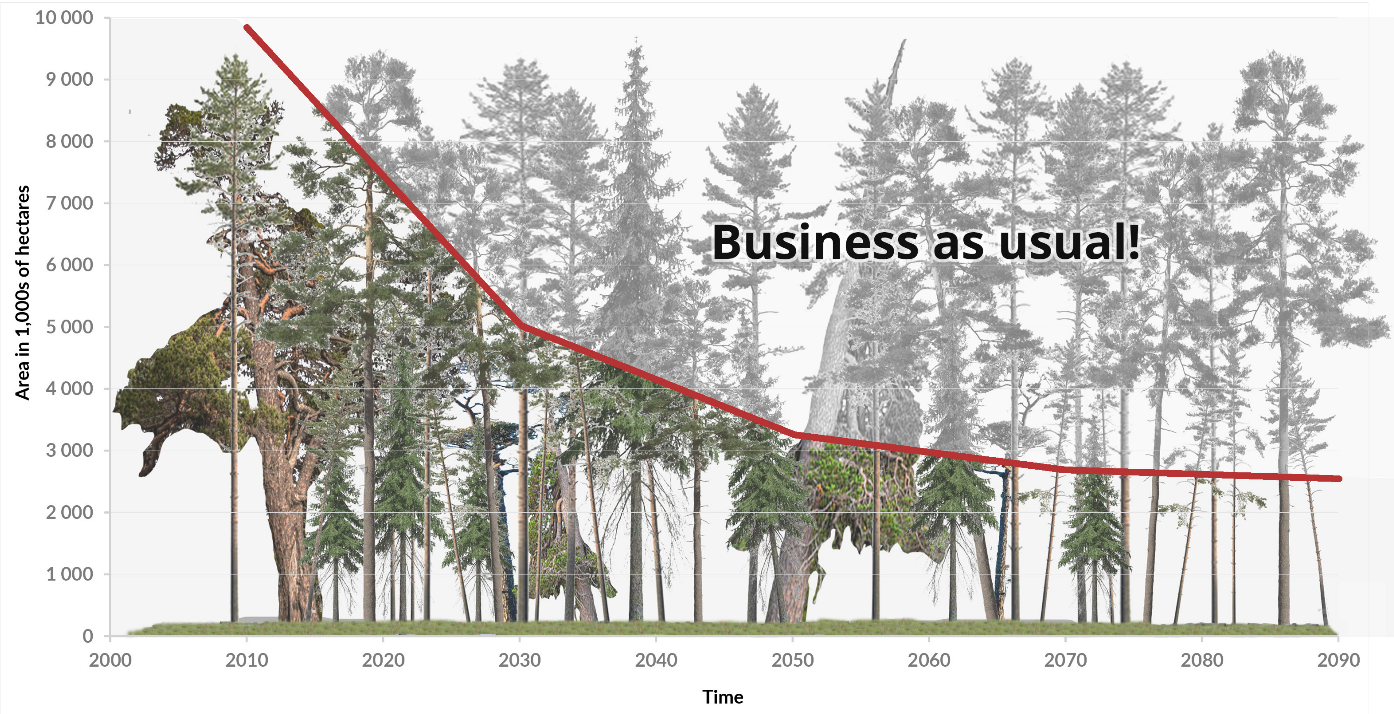


Figure 34. The change since 2010 in the area of productive forest land that has not been clear-cut after the 1950s, including continuity forests and the modelled future development of such forests if forestry continues in the same way as today. Based on figure 2.30. from the report SKA15, Swedish Forest Agency 2015.

Photo: Viktor Säfve

Discussion on Swedish implementation and lobbying to weaken or stop protection of old-growth forest at both EU and national level.

According to assessments, Sweden has the EU's largest area of continuity forests, but also unprotected primary and old-growth forests.

In December 2023 the two governmental authorities, the SFA) and the SEPA issued a report in which they estimate the area of primary and old-growth forests [Urskog och naturskog] in Sweden.

It clearly shows that Sweden:

A) Holds, and has great responsibility, for a large part of the EU's natural heritage of primary and old-growth forests.

B) Are far from protecting this internationally important natural heritage.

In the report they write, among other things: "The authorities' assessment is that the area of old-growth forest [naturskog]…that lies outside strictly protected areas amounts to between 2.2 and 2.8 million hectares of forest land. Of that area, 1.5–1.8 million hectares are estimated to be on productive forest land.".

We at Forest Monitor, Protect the Forest, believe that the authorities' assessments are quite reasonable regarding parts of the country, while we believe that there may be underestimates of the area of old-growth in, for example, southern Sweden. This is because they do not have the same data material for southern Sweden as for the northern parts of the country.

The forest industries are certainly trying to influence the Swedish government and relevant authorities to reevaluate their assessments and the government has shown clear tendencies to try to control the interpretation of the terms primary forest and old-growth forest in an industry-loyal manner, with intention to minimizing the mapped area, identified and protected as primary and old-growth. This is to maximize the area that can be used by the forestry industry.

Appropriation directions from the Swedish government has been sent to the SFA (Regeringen 2023). The task itself was unfortunately contradictory and contains the totally unscientific criteria that primary- and old-growth forest is to be defined by: "very high stand age (mainly 180 years or older)".

This is a typical example of political manipulation. The government request the SFA to reformulate the criteria for primary forests and old-growth forest based on a single parameter such as an exceedingly high average stand age. Here, instead of letting experts and researchers make assessments and come up with fact-based criteria, the government tries to bypass the very framework of the EU-assignment, by adding made-up criteria based on bad guessing and misinterpretation, which will likely lead to a reduction of the area originally classified as primary and old-growth in the aforementioned SEPA-report. Unfortunately, this government assignment was carried out more or less without the protests that could be expected from the authorities' experts. The Swedish authorities, the SFA (which was primarily responsible) and the SEPA, which participated in the process, have now presented a report in which, in accordance with the directives from the government, they propose unscientific and unrealistic criteria for the definition of old forest, which, among other things, contain a main criteria for northern Sweden with an avarage stand age of 180 years (SFA 2024).

Old-growth forests are generally unevenly aged and contain everything from newly sprouted small trees to really old trees. Some of the EU's most untouched spruce forests have an (basal area-weighted average stand age) stand age of well under 180 years. This means that even the crown jewels among primary- and old-growth forests would not be defined as old forest if stand age among trees is considered a decisive factor.

A very high stand age (180 years or older) is a highly unreasonable, contradictory and unscientific criterion. There seems to have been an unfortunate mix-up between the EU Commission's proposed definition (European commission 2023) that highlights "the presence of old trees", with basal area-weighted average stand age. Also note that the government added the word "high" before occurrence, which is not in the EU document. The stand age cannot be used to measure the presence of uneven-aged, naturally regenerated old-growth forest with long continuity, so-called continuity forests (often these overlap with the concept of old-growth natural forest/old-growth forest/primeval forest). This is forests that have never been clear-cut, or old-growth forests (for example in southern Sweden) where historical logging was carried out so far back that the forests have acquired natural forest-like structures and can still be classified as “old-growth”. Continuity forest usually has an significantly longer continuity and stand history than, for example, 180 years, but at the same time a average stand age that is significantly lower than 180 years. For example, an older study of one of Sweden’s finest primeval spruce forests with old-growth character, revealed that it had a stand age well under 180 years (Löfgren 2024). This is because in old-growth forests we often find a variety of young trees and tree ages that extend all the way up to very old trees, to dead trees. There may also have been natural disturbances (or historically extensive land use whose traces have gradually disappeared) affecting the average stand age.

A continuity forest or old-growth forest may have an average age of the trees in a stand under 120 years, but even so there may be a tree and deadwood continuity of hundreds or thousands of years and trees over 200 years old in the stand. Good examples of this can be found in internationally and from an EU perspective unique sub-alpine (and adjacent) primary and old-growth forests. That is, the forest has an “age” of more than 180 years, but a average stand age within delimited stands of less than 180 years.

Stand age is a central concept used in rotation-forestry management. The SNFI also measure tree ages at breast height and not the total age of trees. Average age of trees in stands cannot, however, be used as criteria for old-growth forests, to assess whether they are worth protecting – it is more relevant in rotation, clear-cut based forest management. This is a generally recognized position that even advocates of clear-cut forest management, and outspoken nature conservation critics agree with. A known forester and SLU-researcher wrote this on the social media platform X in 2023, regarding this issue: *“Average stand age is a central concept in rotation forestry. It completely lacks relevance…for unmanaged forests…*”.

According to the National Forest Inventory´s data on age distribution, approx. 0.72 million hectares, or 3% of the productive forest land, outside formally protected areas, consists of forest over 161 years old in stand age. The proportion of productive forest land with a stand age over 180 years is of course even lower. Now compare those figures with the lower figure in the range of 1.5 - 1.8 million hectares (of old-Growth forest), the earlier estimate made by the authorities. Here a big mistake has obviously been made by the government. Basal area-weighted average age, the continuity of a forest, and the oldest age of individual trees in a stand are completely different things. This must be noted!

The forest industry is trying to influence the Swedish government and relevant authorities to reevaluate their assessments of the area of primary and old-growth forest. The government has shown clear tendencies to try to control the interpretation of the concepts and criteria, with the intention of minimizing the mapped area identified as primary- and old-growth forest. This, partly to influence which forests are affected by the Renewable Directive III, REDIII, and other laws and targets, and partly to minimize the area that must be given strict protection. This to maximize the area that can be used by the forest industry.

Unfortunately, the problems associated with using average age of stands as a criteria or environmental target indicator, do not stop there. Sweden’s reporting to the EU regarding the trends for nature type-classified forest habitats is also affected. One of the decisive criteria for different habitat types is again the stand age. There is a template for this, where the stand age varies depending on local production potential, habitat type, region and tree height (Gardfjell & Hagner 2019). But, unfortunately, the result will be the same. When using the SNFI:s stand age data from sample plots to measure trends for species and habitats, it gets it wrong.

In the draft report from the SLU (2022), the authors concludes that:
“NFI’s stand-age criterion varies with local timber production potential, but it is always 20 or 40 years higher than the lowest recommended age of clear cutting in forestry. It therefore become strongly decisive in the classification of plots into habitat types”.

Despite the loss of old continuity forest with conservation values, an area that decreases with each felling, changes in the stand age in sample plots make it look like the trend is stable or even positive.

That forests with hundreds or thousands of years of continuity and old trees could increase with each clear-cut would defy the laws of physics. Nevertheless, statistics from the SNFI show that the area of old forest continues to increase from an all-time low in the 1990s. In part, the statistical increase is due to a conceptual confusion. Partly it depends on what we define as a statistical mirage.

To put it simply:
It is a much greater loss for biodiversity associated with natural forests with long continuity and long ecological delivery time, to fell a continuity forest with an average stand age below 140 years, than the "conservation gain" of an already old forest growing over the threshold value criteria from 139 to 140 years (northern Sweden), and thus being statistically classified as an "old forest".


Photo: Björn Olin

11. LAND USE AND FOREST HISTORY

Photo: Viktor Säfve/Hellfilm.com

LAND USE AND FOREST HISTORY

An overview

This is a description of Europe's, and particularly Sweden's interesting and diverse forest and land use history. Here, among many other things, we want to explain why Sweden, and especially north-western Sweden, holds such a large part of the EU's remaining natural forest legacy.

Sweden is an oblong country, stretching 1,572 kilometers from Smygehuk in the south to Treriksröset in the north, from mountains in the west to coastal lands in the east, from beech forests in southern Sweden, to mountain birch and conifers forest along the mountain range in the west. This means that the forest types and tree species composition, land use history and the ecology of forests differ greatly, depending on the region of the country. To speak about Sweden's forest and land use history in general terms is therefore risky and it usually leads to large misunderstandings (Emanuelsson 1997).

Forest and land use history in Europe is hugely diversified, both in terms of the degree of impact, type of land-use, and the timescale used. Deforestation, and transformation of natural forest into agricultural land, and large-scale exploitation of the forest ecosystems happened many centuries or millennia ago in large parts of the continental EU. In northwestern Sweden, Finnish Lapland, and some remote mountain regions in Europe, on the other hand, the exploitation of forests has a more recent history. In any case, this is true in terms of industrial and large-scale forest use.

The forest area among EU member states is unevenly distributed, and it is mainly in the north and north-east of the EU that forests really dominate the landscapes. The degree of urbanization, population density, the colonization patterns, the type of ownership, and climatic and ground or soil conditions, as well as accessibility are all factors that have played an important part in how the forest has developed in the northern parts of the EU (Emanuelsson 1997).

This is also one of the reasons why Sweden is considered to have the EU's largest remaining area of naturally regenerated forests, forests that has so far escaped clear-cutting. We call them continuity forests, and they are important parts of the EU's remaining natural dynamic forests, like primary and old-growth forest.

In the coming chapters, we will bring you back to the very beginning of Sweden's forests.

Early post-glacial forest history

With only about 10,000 years since the last large ice sheets disappeared from northern Sweden, the country's forest history is relatively short. Nevertheless, the forest-dwelling species and the forest ecosystems, which have developed through evolution, have taken eons to form. As an example, various forms of spruce (*Picea*) have existed for millions of years (Lockwood et al 2013).

During the coldest period of the last ice age, roughly 20,000 years ago, however, Norway spruce was pushed back to the central East European plain. It is an area that today roughly corresponds to European Russia, Ukraine and Belarus. In Belarus there have been discoveries of macrofossils like pieces of wood, and cones from spruce a little bit over 22,000 years old (Lindbladh 2021).

There are exciting research findings about pockets of trees that grew in northern Europe even during the ice age. Studies have found that trees probably survived in small ice-free refugia, that existed on early ice-free mountain peaks (nunataks) at different locations in the Scandes during the Late Glacial (Kullman 2008). Forest history, in Sweden, begins at the end of the last ice age about 10,000 years ago.

The ice retreated gradually, so that Skåne was ice-free around 12,000 BC, Central Sweden around 8,000 BC and Norrland around 7,000 – 6,000 BC. The first period after the ice melted was characterized by tundra vegetation (Olsson & Pettersson 1993). Gradually the trees and many other forest-living species colonized. Birch was the very first tree species, followed by pine, aspen, and rowan (SLU 2024). Some norway spruce grow in small ice-free refugia (Kullman 2008). The first colonizing humans, that probably followed the slowly retracting ice sheet, lived in small hunter-gatherer societies.

Between 8,000 – 5,000 BC the tree species oak, ash, elm, linden and maple came to Sweden (SLU 2024 & SkogsSverige 2025). The climate became warmer and between 6,000 – 3,000 BC, broadleaf trees thrived much farther up north in the country than today. But as the climate again cooled, spruce expanded into many new areas. A large front of spruce probably also came into Sweden from the northeast 3,000 – 4,000 years ago (Lindbladh 2021). Around 2,500 BC, the tree species beech and hornbeam migrated in from the south (SLU 2024 & SkogsSverige 2025).

With the trees came associated species of bryophytes, insects and fungi, and many of them co-evolved with the tree species. Some specialized in a specific tree species, or a specific type of deadwood, others were generalists. The native species of our forest ecosystems are adapted to natural dynamics and disturbance regimes, and they have evolved in, and are associated with self-regulating and organizing forest ecosystems.

The way the forest industry of today is managing our forests, with industrial tree stands, plantations and managed forest landscapes is completely out of step with the life history of many forest species. Some species seem to cope with the enormous landscape transformation caused by modern forestry. Sadly, many don't. Hence their populations are declining and becoming increasingly isolated and threatened by local and national extinction.

It seems to be a strong correlation between species diversity and the time since colonization and the geographical spread of individual tree species. Tree species that colonized early after the ice age and now have large geographical distributions seems to harbor large numbers of associated species. An example of this is the Norway spruce. The SSIC estimates that 1,100 species are associated with this very common conifer (Sundberg et al 2019).

Sweden only has about 40 native tree species which according to the SSIC form the backbone of the country's biodiversity. Further they say that Norway spruce stands out as an important host plant. It has the highest number of associated species (SSIC 2019). According to the same source of information, Scots pine comes second with an impressive 920 associated species and the common oak with 880 species.

Present vegetation patterns

Today, Sweden can roughly be divided into four vegetation zones: the nemoral, the boreonemoral, the boreal zones and the alpine zone (**Figure 35**). The nemoral zone covers the southwest coast, the county Skåne, and parts of Blekinge and Öland counties. It largely corresponds to the continental biogeographic region. This part of Sweden is also the most affected by historical deforestation. The remaining natural forests in this area mainly consist of deciduous broadleaf tree species such as beech and oak. It forms the northern extension of the large central European broadleaf forest that once existed. The northern limitation of the nemoral vegetation zone roughly coincides with the assumed natural southern border of the Norway spruce (**Figure 35**). However, Norway spruce has since long been planted much farther south than this natural limitation.

In the boreonemoral zone Norway spruce and Scots

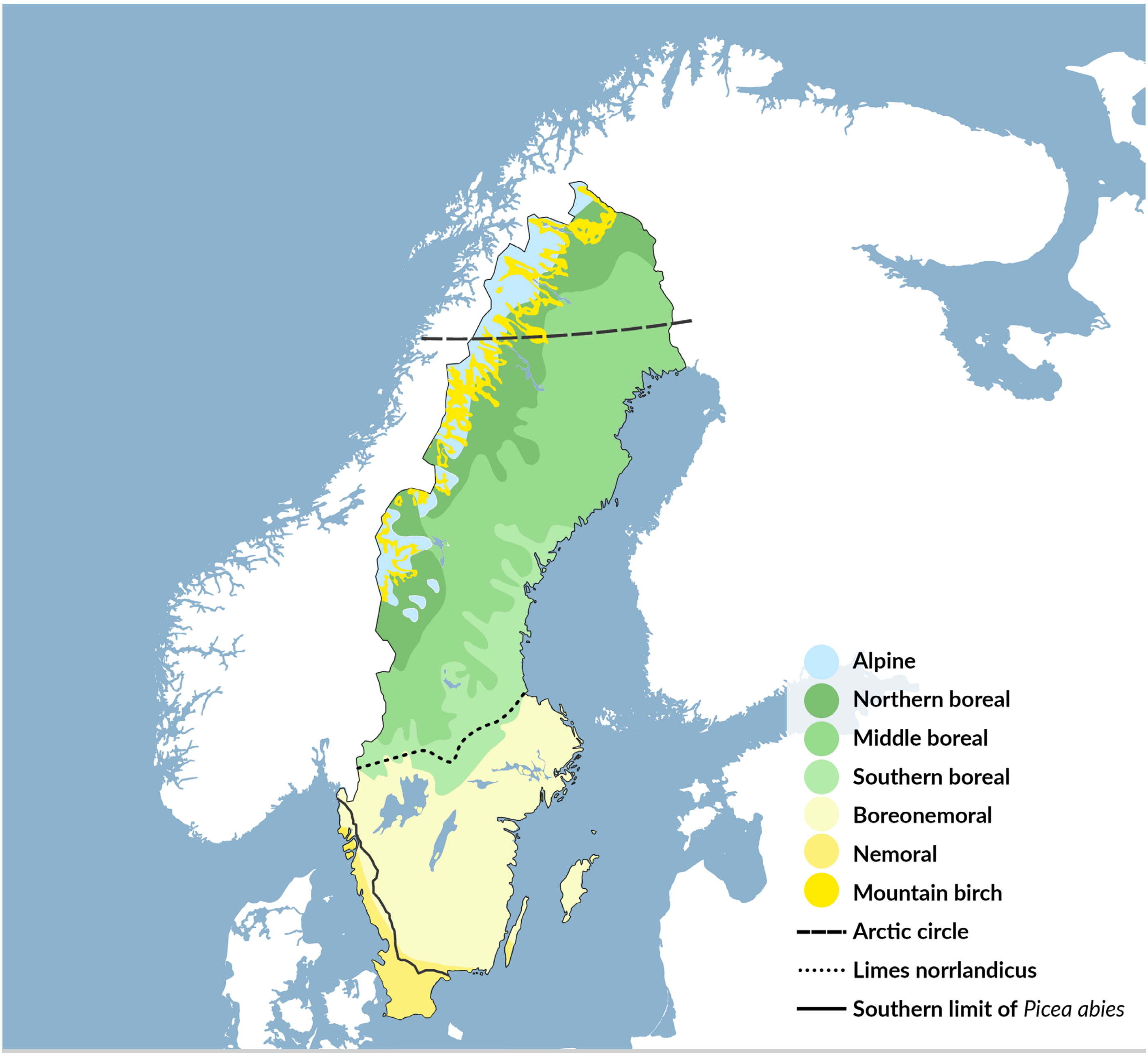
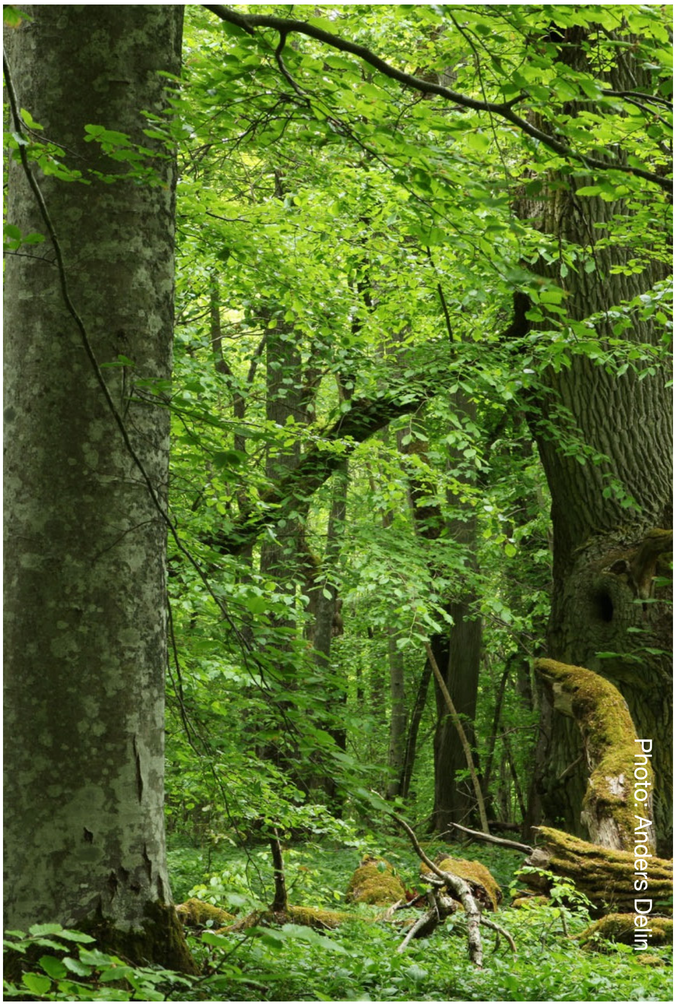


Figure 35. Vegetation zones according to Gustafsson & Ahlén 1996 with addition of a rough delimitation of the distribution of mountain birch in Sweden from Högbom 1906. The southern limit of Picea abies in Sweden from Caudullo et al. 2017.



pine dominate. It is usually seen as the southern-most expanse of coniferous forests in Sweden. Even here, however, broad-leaf trees cover larger patches. These outcrops with broad-leafed forests usually coincides with calcareous or clayey soils.

The Norwegian and Swedish boreal zone, often divided into three zones (**Figure 35**), forms the west-most Scandinavian branch of the great taiga belt that circles the earth from eastern Canada through Russia and into Scandinavia. These forests are dominated by various species of conifers. In Scandinavian boreal forests there is also a rich element of birch, aspen, willow, alder and rowan. All with their unique diversity of associated species. An exception to the conifer dominated forest of the Swedish taiga is the large areas of mountain birch forest along the Scandes range (**Figure 35**). Deciduous trees may also completely dominate for some time in the early succession after severe fires or storms. There are also wet forest types where alder and birch dominate or are an important component in the tree species mix.

The forests of boreal Sweden, that expanded into the area after the last ice age, has formed a complex, species-rich, structurally and naturally dynamic, self-regulating ecosystem. Over millennia, the forest has been shaped by natural disturbance regimes such as fire, flooding, storm cuts, grazing and the early low-intensive, pre-industrial anthropogenic utilization of the forests. In these forests, small- and medium scale disturbance regimes with gap dynamics and cohort dynamics dominated. Stand replacing fires and storms was however more rare (Kuuluvainen & Aakala 2011).

The border between the boreal zones in the north and the boreonemoral zone in the south is called Limes norrlandicus or the Biological northern border [Biologiska Norrlandsgränsen] (**Figure 35**). This border is characterized by the slowly decreasing incidence of species like oak.

The forest ecosystem before industrial logging and modern forest management

What did Swedish forests look like before they were affected by intensive industrial forestry? Even if the tree species colonized Sweden only some thousand years ago, they are, as previously mentioned, adapted to the natural conditions present much further back in time. For example, Europe's deciduous forests used to be home to a variety of large herbivores, such as the European bison, aurochs (Bos primigenius) and wild horses, which affected the forest through their browsing and grazing. The boreal forest was also strongly marked and affected by fire in the past. Much more so than today (Niklasson & Granström 2000).

During the Mesolithic period, people who lived in a hunter-gatherer culture mainly affected the forest indirectly by reducing the populations of large herbivores. They probably also used fire, for example, to improve game grazing. Later on, some of the megafauna became extinct or greatly reduced, such as the European forest bison, also known as the wisent. This, while other species such as the aurochs (considered to be the wild ancestor of modern domestic cattle), probably disappeared as a result of a combination of hunting and domestication (Upadhyay et al. 2017). Further on, when man began to keep domesticated cattle, the domesticated animals, to some extent, took over grazing in the Swedish-forest.

In southern Sweden, about 6,000 years ago, humans started growing emmer wheat on small fields that were cleared in the forest (Lundström 2018). When agriculture spread out, the land in southern Sweden was organized into holdings and open fields, probably already several thousand years ago. The domesticated animals grazed in the open fields and forests. The villages were located on the enclosures, which were fenced to keep the animals out. On the holdings there were also fields and hay meadows, where people grew winter fodder for the animals (Olsson & Pettersson 1993). The domesticated animals voraciously ate saplings of linden, forest elm, ash and maple, and therefore these fields became largely devoid of old individuals of these tree species. They were instead found in the owners' leafy meadows, where they were used for gathering leaves (hamling) for the animals' winter feed. It was common for the rangelands to be burned to improve grazing.


Photo: Viktor Säfve


Photo: Sebastian Kirppu


Photo: Jakob Wallin

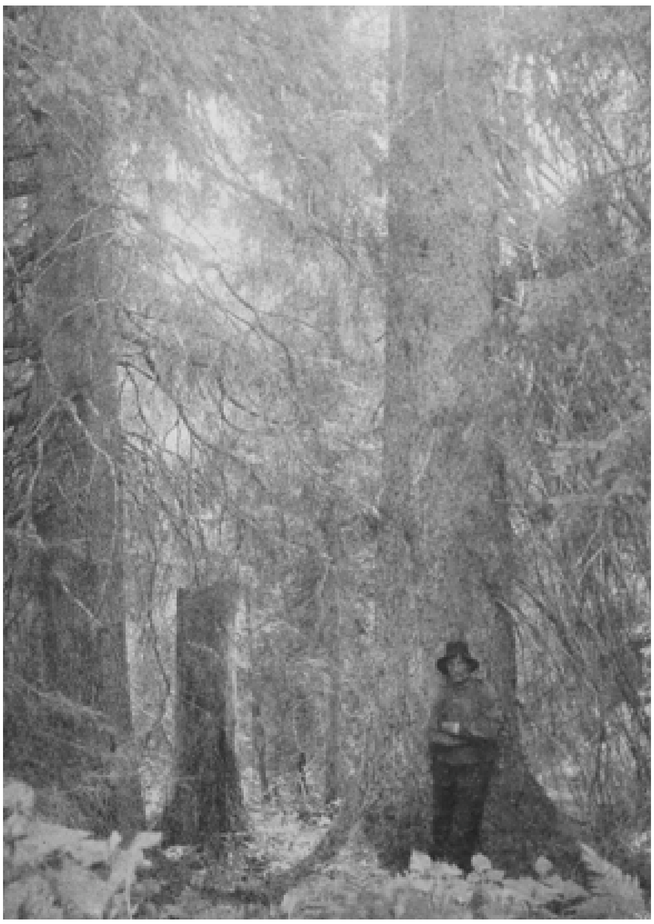
The dawn of forestry

During the Swedish Middle Ages, generally considered to span between the 1050s to the early 1500s, the human use of land increased due to population growth. However, the population development and pressure on forests during the Middle Ages was not linear, but affected regionally, for example by the Black Death. Areas that were deforested before the Black Death, for example in Bohuslän, were reforested due to the Black Death, which drastically reduced the preasure on forest resources (Vilov & Kewenter 1995). A law against the logging of beech and oak was introduced by the Swedish crown during the 16th century in order to provide a long-term supply of wood for shipbuilding. The legislation and regulations for oak and beech were changed in the 18th and 19th centuries, opening up for felling. Many old oaks and beeches were felled (Holmberg 2005).

How did forestry then develop? In a region called Bergslagen, forests had been utilized for charcoal production for centuries. During the 16th-18th centuries, metal and tar were large export products in Sweden. By using charcoal in the smelting plants, metal could be extracted from the mined ore. However, it is a myth that Bergslagen would have been almost entirely deforested during this period. The reasoning is absurd since the mines and industry needed a steady supply of charcoal and other products and materials from the forest during an extensive period of time. Studies from parts of this region, which are based on documented data on forest conditions, show that the forest landscapes in this region were by no means without forest resources during the period (Backström & Östlund 2013).

The myth of total deforestation in Bergslagen probably spread at the time because of the competition for easily accessible forests. And hence historians today have found "evidence" in old historical records of overlogging and local deforestation. In the 19th century, demand also arose for sawn wood products from Europe, and later also for paper. In order to reach the vast forests further up in Norrland, rivers were modified for timber floating. The dawn of the 19th century timber frontier can be seen in **Figure 36.**

The expansion of the industries along the coast in northern Sweden, and the corporatization of large areas of forest land in northern Sweden, has left clear marks on the forest's ownership structure. In Norrland, a larger share of the forest is owned by companies than by private individuals compared to southern Sweden. Since northern Norrland was much more sparsely populated than southern Sweden, the forests there were relatively unaffected by man and there were large areas of natural forest left. The history of land use and the development of the forest in northern Sweden, and especially in northwestern Sweden, will be discussed in more detail later in this chapter.



Previous pages: Primary old-growth sub-alpine spruce forest in 1912, Jämtland. Photo: L. Larsson

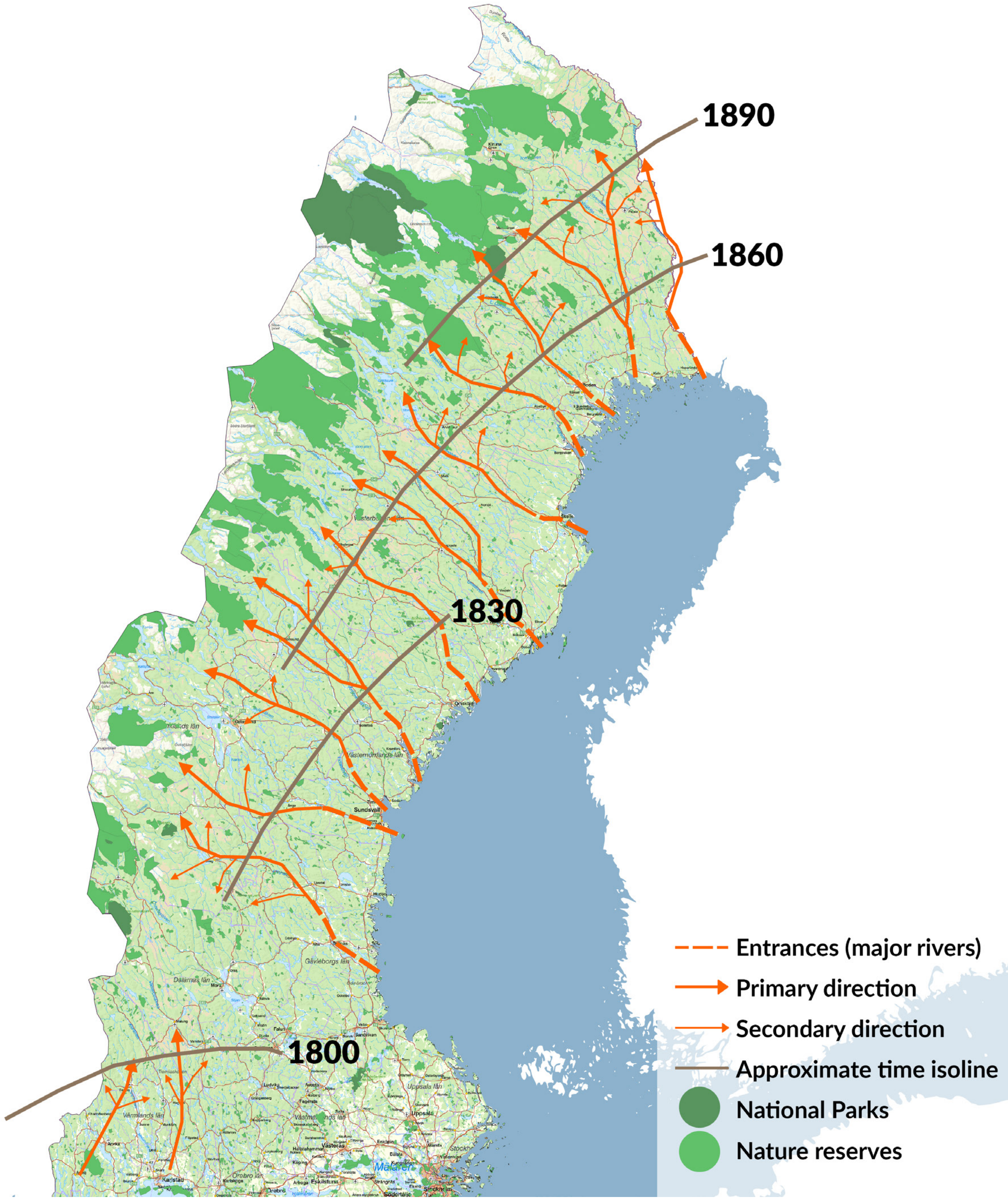


Figure 36. Map of central-northern Sweden. The map depicts the timing and direction of the timber frontier during the 19th century. The map also shows the location and extension of national parks and nature reserves as of July 2024. Adaption of figure in Östlund & Norstedt 2021.

Photo source: Leif Öster

Photo source: SLU, Forest Library's image archive.


Photo: Viktor Säfve


Photo: Viktor Säfve

"Same same, but different"

Representatives from the forest industries and landowners' organizations tend to argue that because humans have affected the Nordic forest ecosystems since the ice age there is no harm in using management methods like clear-cutting. However, this fact is by no means a good argument against the protection and restoration of valuable nature and carbon rich forests important for biodiversity, climate, ecosystem functions and/or for protection of the cultural heritage. There is a huge difference between, for example, small-scale, diverse and extensive, pre-industrial forest use in northwestern Sweden and modern mechanized forest management with 15,000 kg harvesters and enormous industries (see **Table 12**). To claim that the pre-industrial human impact on the forest is "same same, but different" as today's industrial exploitation, is like saying that a toy train is equally useful for public transport as a real train because both of them run on rails.

It is true that in Fennoscandia a large part of the forests have been used in different ways for several centuries. There are however typical gradients, whereof the most obvious is that southern forests to a much larger extent have been used and transformed for agricultural purposes, including slash-and-burn cultivation that impacted the forests for centuries or even millennia.

Previous pages: "Same, same but different". Mechanized forestry and industrial exploitation cannot be compared to the impact and use of the forest in ancient times. Top left, soil scarification, photo source: Leif Öster, top right: pine plantion, photo: Viktor Säfve, bottom left, Removing bark with hand tools, photo: SLU's media archive, bottom right , primeval forest that has not been affected by forestry, photo: Viktor Säfve

Table 12. Modified version of table by Lars Östlund professor in forest history (Östlund 2022)

Humans and the forest in the north boreal region of Sweden before the 19th century	Humans and the forest in the north boreal region of Sweden after the 1950s
Few people per square kilometer	More people per square kilometer who also consume much more per person.
Large roadless forests and few roads	An increasingly expanded network of forest roads.
Low-intensity and extensive forest use; firewood, grazing (burning), wood tar, pot ash, fences and charcoal in limited areas.	Large-scale Industrial use and large-scale export. Highly intensive and mechanized industrial forest exploitation; pulp wood, timber and energy.
Simple technique - fire and axe.	Advanced technology - use of heavy and large forest machines for logging operations, soil scarification etc., and trucks transporting timber. – Intensive methods are or have been used during this period such as manipulation of waterways, use of herbicides and insecticides, large-scale clear-cutting, establishment of tree plantations, soil scarification, ditching etc.
Natural tree species mix.	Production stands were one or two tree species dominates.

Photo source: Leif Öster


Photo source: Leif Öster

Figure 37. Old-growth spruce forest photographed in 1914 in Jämtland, Eltnäs and Hillersberg. The old natural spruce forest was selectively logged in about 1900. Note that dead trees and trees with smaller dimensions have been left. If a previously selectively logged natural forest like this is left untouched from forestry, and allowed to self-restore, it would have very high natural values today in 2025, 125 years later. Not because of the historical selective logging, but in spite of it. Photo source: SLU, Forest Library's image archive.

From old-growth forests and natural forest landscapes to tree plantations and industrial forest use in Boreal Sweden

Again, it is important to point out, and repeat that the boreal part of the EU, and what is called northern Sweden (Norrland), has a much more recent exploitation history, in form of industrial large-scale forestry and industry, than, for example, southern Sweden, or for that matter parts of the central and southern EU. Forest use in north-western Sweden in the pre-industrial era was much more low-intensive which meant that old natural forest dominated the landscape, despite anthropogenic presence. Of course, there were people who used the boreal forests before the industrial era, but these areas were very sparsely populated and the use and influence took place with means and simple technology such as fire and ax (see **Table 12**). The main pre-industrial use of the northern forests was for firewood. The Sami have used the forests for reindeer husbandry and multiple-use for a long period. Other forms in which the forest was used were as pasture for, for example, cows, goats, horses and sheep. Linked to different forms of grazing, the forest floors were also often burned to benefit the grazing. There was also production of pine tar, potash, and in some limited areas of the north, charcoal production. Charcoal production was not something that occurred across the entire boreal region at this time, but a local or regional phenomenon (Östlund 2022).

Forestry in boreal Sweden from the 1830s to the beginning of the 20th century – the timber front.

The large demand and consumption of timber in central Europe resulted in more large-scale use, and increased selective logging. The beginning of the industrial use of large diameter timber in the old-growth forest of the north, made its entrance about 1830, and continued until about 1900 and a bit into the 20th century (Östlund & Norstedt 2021). Something that resulted in a huge expansion of sawmills along the coast of Norrland. To transport the timber from the vast inland forest areas, the rivers were used to float the logs down to the sawmills and related industries.

The timber front's exploitation of the forests, via selective felling of mainly the largest trees, was a crude exploitation. The trees were felled with an axe (and later with hand saws), then dragged by horse and then, as previously mentioned, floated to the sawmills on the coast. At the beginning of the progress of the timber front, the hunt was focused on the largest and oldest pines, but then as the larger trees became increasingly rare, interest also increased in spruce and trees of smaller dimensions. After a large part of the larger trees were felled, the rest of the trees in the old natural forests were left behind, at the timber front. What remained were selectively logged but naturally regenerated continuity forests and old-growth forests, often with a large amount of dead wood, and with a natural genetic diversity, as well as a long continuity of ecological qualities. In addition to many conifers being left behind, deciduous trees, dead wood, but also entire stands of low productive forest, hard-to-access forest etc. were also left behind. Many of these forests, which were historically exploited natural forests, are the forests in which we today find high natural values. They are the continuity forests, the old-growth and near natural forests that are important in contemporary forest protection. Not because of the timber front in the 19th century, but in spite of it.

Many of today's old-growth forests and the continuity forests with high natural values, outside the vast primary and old-growth forests in the Scandinavian mountains green belt (and fragments in other parts of Sweden), are forests that historically to some degree underwent selective logging. Some of these forests have then had 70 - 150 years and more to regenerate some of the naturalness that were lost, both in terms of standing wood volume, carbon storage and valuable structures and natural processes.

This is of course provided that they have not to a considerable extent been affected by modern commercial forest management. These natural and near-natural dynamic old-growth forests are often multi-storaged and contain tree ages ranging from small and young trees up to hundreds of years old trees. They also contain structures like standing and laying dead wood in various stages of decomposition. Hence these forests, regardless of the historical selective cuttings, live up to the EU Commission's proposed definition of old-growth forest, and fit the description: "signs of former human activities may be visible, but they gradually disappear or are too limited to significantly disturb natural processes".

Historically pine-dominated, and selectively logged old-growth forests, outside the scattered fragments of primary forest , and below the Scandinavian mountain Green belt forests, however, are often missing one important component. This crucial feature is the presence of the oldest generation of pines. And this gap is not so surprising considering the time it takes to recreate such an ancient component in a forest. In the few cases they are still standing, they today reach staggering ages of up to 400-600 years (some even older). However, sparsely scattered groups of old pines may still be found, provided that historically pine was a substantial element in the forest.

Historically, Sweden's montane forests, the subalpine forests along the Scandinavian mountain range, were also partially exposed to selective logging. Still, the selective logging made during the timber front period did not reach everywhere and did not hit equally in all places. In fact, the timber front never reached some of the most remote and hard-to-reach parts. Furthermore, in many of these remote parts, the cycles of selective logging events are fewer and have left the forests more intact. This together with the fact that the Swedish forestry model has not yet affected this landscape very much is the main reason why Sweden has the EU's largest landscapes of more or less intact, and relatively untouched natural forests (SLU 2020).

We repeat: Forests that historically, and to a varying degree and scale, were affected by selective logging, can at the same time be old-growth high conservation value forests. From both an EU perspective and from a Swedish perspective, these forests have a comparably long continuity of ecological qualities, and they are many times containing "primeval forest legacies". These forests exhibit a unique biological diversity linked to slow-regenerating habitats with a very long ecological delivery time.

The final blow

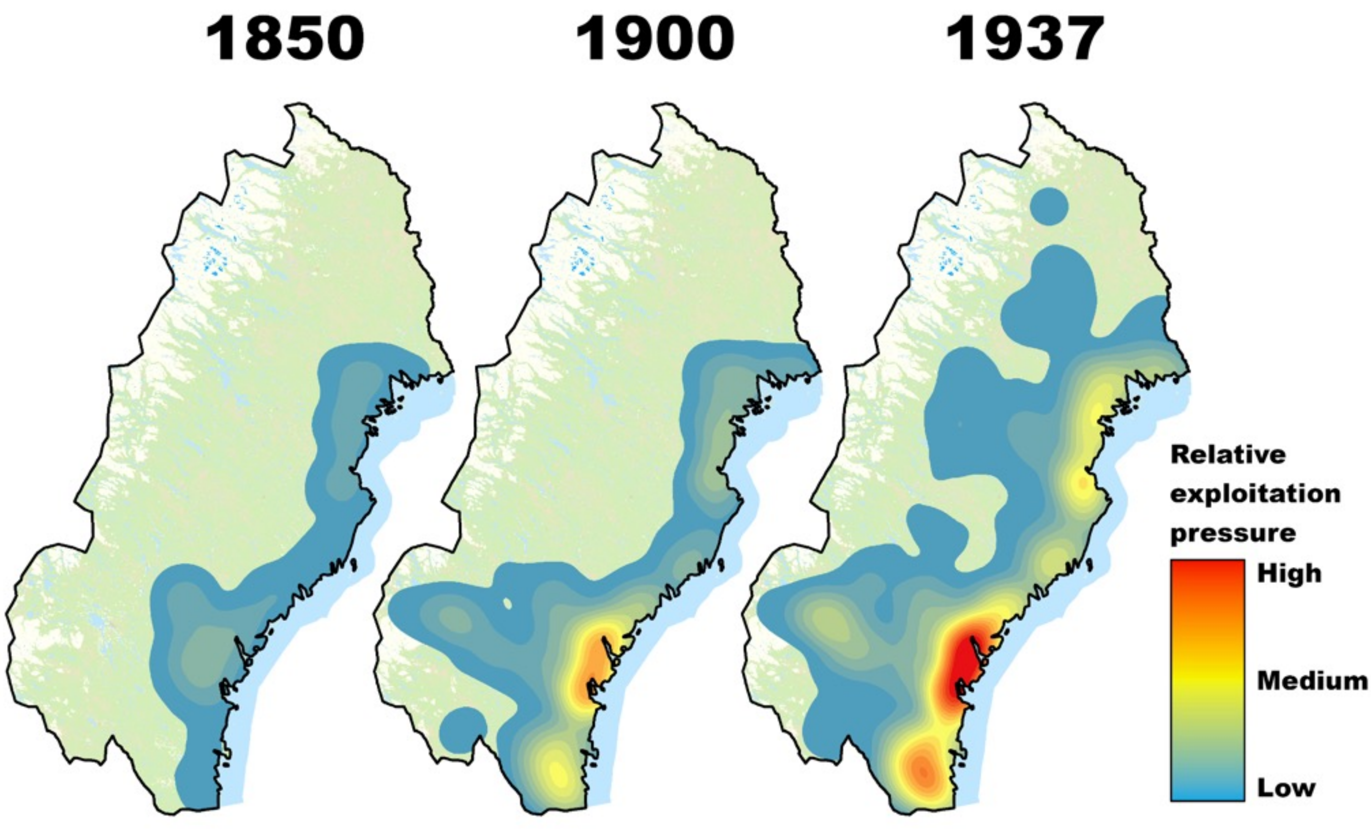
A substantial part of this natural forest heritage is now threatened by a final blow - clear-cutting management and a modern wave of selective logging promoted by the new "closer to nature forestry". Forestry will result in both a weakening of these ecosystems, and/or a break in continuity. Moreover there is imminent risk for further destruction of the irreplaceable primeval forest legacies that has persisted through time despite waves of forestry. Many valuable cultural sites and values that are linked to the natural forests are in peril. This will lead to the final transformation, a trivialized forest landscape with production stands and plantations. The organization Protect the Forest has shown that, for example, forest companies such as the FSC-certified SCA (Svenska Cellulosa), systematically clear-cuts old-growth and continuity forests with conservation values. In a case study, they felled very old natural forest with trees as old as 370 years!

Another threat is that the forest owner uses the "Trojan horse", and goes in with forest machines and does an extensive selective or so-called alternative felling, and crosses the entire forest with heavy machines, and in this way negatively affects the structure and noticeably reduces the natural values of the forest.

We believe that both the Swedish government and Swedish forest managers and forest industry representatives have shown both obstruction, when it comes to preserving this unique natural heritage, and an enormous domestic blindness, when it comes to understanding how unique it is within the EU, with forests with the same degree of naturalness and ecological continuity. These forests are both unique and extremely important to preserve. Countries like Italy and Spain lost large parts of their ancient forests a long time ago, with major negative consequences for biodiversity and vital ecosystem functions. But this is hardly a good argument for why Sweden and the Swedish forestry industry should continue to cut down unique old-growth and continuity forests in 2025. Today, the science and knowledge about the value of natural forests is in place, and it is pure obstruction and madness to cut down and degrade these unique ecosystems.

Rough pattern of the timber front

An analysis of the accumulated concentration of sawmills along the coast of Norrland from the 1850s to the 1940s (See **Figure 38** below) showed a non-uniform timber front moving from the coast and inland towards the alpine forest along the Scandinavian mountain range. With the total transition from selective logging to clear-cut forestry in the 1950s and the extensive logging the following 60 – 70 years, a large part the northern Swedish forest land has once been clearcut. This estimation of logging excluded the actual logging, since there are no continuous and nation wide mappings of these historical events. Nevertheless, the presence of sawmills gives strong evidence of logging in the surrounding landscape.



Figur 38. A depiction of the timber front moving from the Swedish east coast towards the Scandinavian mountain range between 1850 until 1937. The relative exploitation pressure is based on the accumulated number of sawmills in the area. Data from Wik. H. 1950. Norra Sveriges sågverksindustri från mitten av 1800 till 1937. Geographica Nr 21.

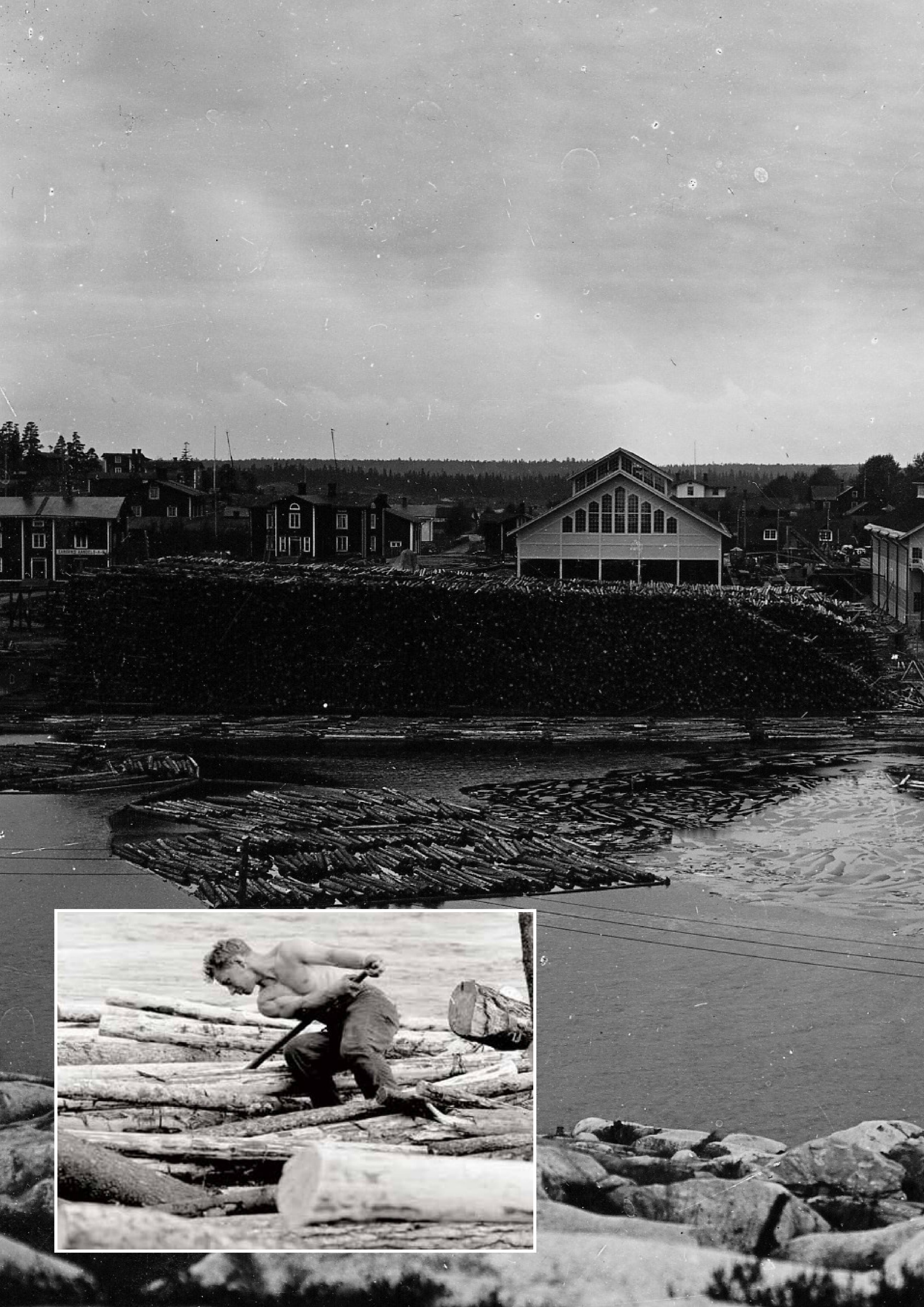


Photo source: SLU, Forest Library's image archive.

Modern forestry in Norrland 1900-2024

Sweden got a new forestry act in 1903. This law is considered to be the first modern forestry act in Sweden (Enander 2000). In many ways it is a reaction to the extensive exploitation of natural forests in the 19th century. The purpose of this production-oriented legislation was for the industry to plan for the future, and to ensure the regeneration of new stands that would secure the supply of raw material for the future industry.

At the same time, German forest management ideas gained more and more attention in Sweden. These novel ideas, which were developed by German foresters at the end of the 18th century, were aimed to promote a more technical approach to conducting forestry. The theory was that the forest land should be treated as a crop field and not a self-regulating and self-organizing natural ecosystem, i.e. the natural forest. This came in sharp contrast to previous management practices which aimed to remove individual trees or tree groups. In Sweden, these new ideals slowly evolved into the idea that the forest land could be used as an area for tree farming.

The forest land became divided into different treatment areas, with the aim to homogenize forests and to produce the same tree species in the same age classes separated into delimited compartments, so called stands. Then the different stands could more easily be managed by completely removing the tree layer in never ending cycles, rotation forestry or clear-cutting. After the removal of a stand by using clear-cutting, some land was prepared via controlled fires. Trees were then regenerated via manual or natural seeding or by planting of seedlings. Draining of forest land, so called forest ditching became increasingly common to increase the wood-producing area. This was also subsidized by the Swedish State. Vast areas of wet forests were drained during this time. Ideas about plant selection in nurseries evolved and management methods such as pre-commercial thinning and thinning to manipulate the regenerating stands to grow faster were parts of the modern forestry research at the time.

During the end of the 19th century, there were probably mainly experimental areas with clear-cutting as management method in the boreal region. Furthermore in the first half of the 20th century, there was clearcutting in experiments between 1910-1930, and in some smaller parts of the boreal region, parallel with more large-scale applied selective felling in old natural forest. In the 1950s clear-cutting took over, and has been completely dominant ever since. A minor study has indicated that clear-cutting occurred in one eastern part (near forest industries) of the boreal region as early as the beginning of the 20th century (Lundmark et al. 2021). While in other parts of the boreal region, in the northwest, clear-cutting was probably introduced as common practice, on a large scale as late as in the 1950s - 1960s.

Forestry was greatly intensified after the 1950s, with the mechanization of forestry and the use of herbicides and insecticides. Mechanization resulted in less need for manpower and thus fewer forest workers, who were replaced by more and more efficient machines. In conjunction with the large-scale, almost complete transition from selective logging to clearcutting and tree-farming forestry. With the mechanization that transpired in the 1950s, came also the large-scale use of herbicides, an era that lasted until the end of the 1970s, early 1980s. More than 700,000 hectares of forest land were sprayed with agent orange (hormoslyr), to defoliate and kill deciduous trees (Östlund et al. 2021). This is because these were considered to compete with the industrially valuable conifers. The use of herbicides of course resulted in various negative environmental effects that affected both humans and nature. The loss of deciduous forest and trees and related biological diversity that followed is still a problem in some areas after 40 years.

The new brutal methods led to major protests and the birth of today's modern forest protection movement. The protests started out in forest villages, among locals, forest workers, cultural workers and environmentalists, and were initially protests against the spraying with agent orange (hormoslyr) and against the enormous clear-cuts, sometimes approaching 1,000 hectares in size. Later this movement came to include the forests ecological values and issues related to the environment, climate, social and cultural considerations and biodiversity. Researchers conclude that: *"the use of herbicides in forestry in Sweden was done on a very large*

Photo: Viktor Säfve

Photo source: Leif Öster

Photo source: Leif Öster

Photo source: Leif Öster

scale in the period 1948–1984" (Östlund et al. 2021), but mechanized large-scale forestry with clear-cutting, and conversion of naturally regenerated old-growth forests and other near natural forests, to planted stands (or seed-cultivated) continues today.

Since the Swedish forestry act of 1993, that states equal importance for and balance between economy and the environment, however, a non-scientific based low-level nature consideration is left on the clear-cuts. The clear-cuts are usually significantly smaller than the largest were between 1950-1990, before the 1993 forestry act. Nevertheless, huge clearcuts, with sizes of up to 30-40 hectares (and sometimes much bigger) are still today quite common in the northern Swedish forest landscape.

This is especially true on forest land managed by the State or by other large privately owned forestry companies. Also when large clear-cuts are created "edge to edge", for several years, the result is enormous scars in the forest landscape where the adjacent clear-cuts of sometimes hundreds of hectares spread out. However, the annual logging rate of about one percent has stayed the same even after 1993, thus it is rather questionable whether today's clear-cuts are smaller only due to increased nature consideration and due to pressure from the environmental movement and the market? Another reason that is just as likely is simply that the pockets of old forests that are logged today are often smaller, and they remain in a much more fragmented forest landscape than in the past. This in turn would naturally lead to a decreasing size of the clear-cuts. When the young production stands and plantations that were established on giant clearcuts in the 1950s to the 1990s are later logged, it is likely that the size of individual clear-cuts will increase again.

It is also important to acknowledge the fact that clear-cutting made today in the remaining small patches of forests with high natural and conservation values, is most probable significantly worse than when old forests were felled in the 1950s. This is simply because there is far fewer old continuity forests left today than there were in the 1950s.

The naturally regenerated natural and near-natural forests are also much more fragmented today than for example 70 years ago. And species linked to a continuity of wood, may it be certain qualities of dead wood, the bark of old trees or related to micro-climatic factors, they were surrounded by entire landscapes with concentrations of such qualities. According to the Swedish Forest Inventory's data from 2021 (5-year central average), about 80 percent of Sweden's forests, outside the formally protected areas, has an average stand age under 100 years (SFI 2024). This can only mean catastrophe for the species that need features that take centuries to develop in forests. So, in an experiment where we imagine that clear-cutting is conducted in a natural-like forest landscape at various points in time, like in 1950, 1980, and in the 2000s, one would expect a decreasing colonization rate for such species over time due to the continuous loss of habitat and fragmentation. The Swedish Red List of Threatened Species gives indirect support for this theory.

Sadly, many of the remnants of natural forest and old-growth forest, are surrounded by plantations of young trees in various stages of age after clearcutting. This means that the continued and reckless logging that takes place in forests with high conservation values, has an extremely negative effect on the forest landscape at large.

Clear-cuts in Ljusdal municipality during the 1990s. Photo: Anders Delin 1993


Photo: Jon Andersson

Land of the Sámi

The northern boreal forest is the land of the indigenous Sámi people. The Sámi people have lived with the land and the natural forests landscapes, and used it for hunting, fishing, gathering, fire wood, buildings, handcrafts or for reindeer husbandry, as natural grazing areas.

Colonial Sweden has over the centuries in various ways suppressed the Sámi and violated the rights of the indigenous people and negatively affected their lands. Both through mining, massive road networks, hydroelectric plants that manipulated rivers and water systems. But, not least through forestry and in modern times the construction of large wind power plants that disturb reindeer husbandry. For an example of how the forestry road network has expanded on mainly Sami lands, see **Figure 39**.

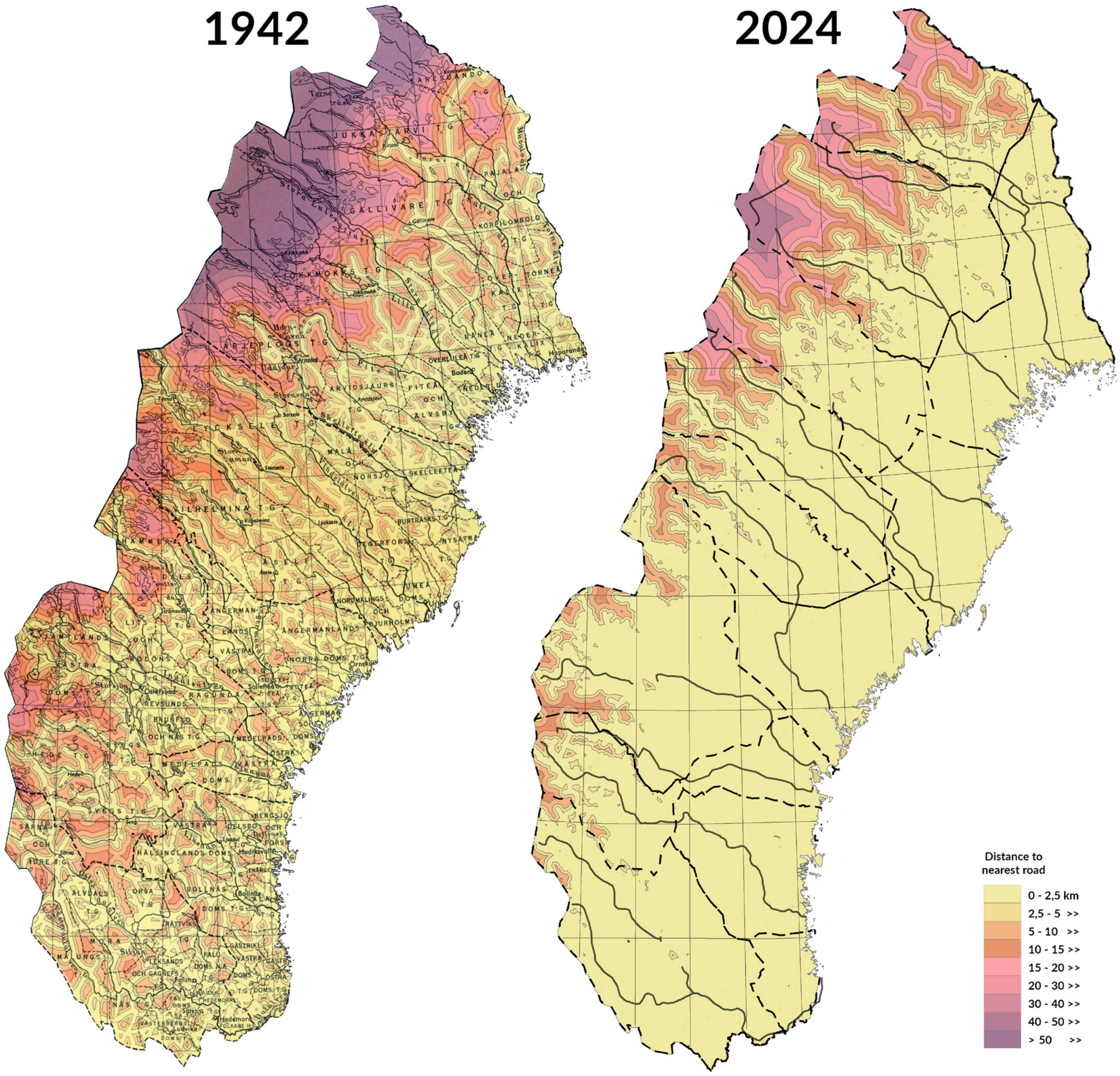


Figure 39. The change in distance to nearest road between 1942, before the introduction of large-scale clear cutting forestry, and today, in 2024. The area largely coincides with the Sámi lands in Northern Sweden. The 1942 map, Geografiska Förbundet i Stockholm 1942, red. Lundqvist. Norrland - Natur, befolkning och näringar and the 2024 map is made by doing the same analysis by using the present road data base as in-data. Note that place names, which are presented in the 1942 map, are missing in the 2024 map.

Cultural history and forestry

Natural forests and old-growth forests are often the richest bearers of cultural history in boreal Sweden. This may sound contradictory, but it is nevertheless true (Olsson. A. & Pettersson. B. 1993, Östlund et al. 1997, Lundqvist et al. 2015).

It is, on the other hand, logical. This is due to, for example, the fact that the indigenous people, the Sámi, have left traces behind since time immemorial, traces that are often erased by clear-cutting with heavy machinery and during soil scarification.

This applies both to traces after traditional Sámi bark harvesting on old pines, trapping systems, sacred places, traces of ancient fireplaces etc.

When you walk in a really old forest in the Swedish part of Sápmi, the land of the Sámi, on forest land that has not been subjected to mechanical soil scarification, or run over by forestry machines, you often find the most untouched traces of the past and of the taiga ancestors. Cultural treasures that must be protected.

However, modern forestry has had a strong negative impact on cultural and ancient remains in Sweden's forests, and not only in Sápmi. Many cultural and ancient remains are affected in varying degrees. This despite increased ambitions in recent decades to take into account the culture treasures (Palmbo & Backman 2023).

Professor of forest history Lars Östlund, shows an ancient pine in primeval forest, with traces of old Sami bark harvesting. Photo: Viktor Säfve

Discussion: The inverted landscape

- How did the forest landscape look like before the history of modern industrial forestry and forest exploitation in the boreal region of Sweden?

"The history of the boreal forest of Scandinavia (Sweden) is characterized by very low human population density and relatively late impact by modern forestry. The coniferous boreal forest has changed dramatically since the late 19th century, which, in turn, has resulted in loss of biodiversity."

/Lars Östlund, Professor in forest history

The fact is that today we have an inverted forest landscape in Sweden, where what was common in the historical natural forest landscape (and in contemporary natural forest landscapes and tracts), is unusual today. At the same time what was unusual in natural forest landscapes, has now become common (see table 13). Today, managed young even-aged stands, created after an anthropogenic stand-replacing disturbance (clear-cutting), dominate, while multi-layered old forests are uncommon. The opposite situation applied before industrial forestry took off.

It is neither far-fetched nor strange that many species have been displaced, disadvantaged, or threatened in today's industrial forest landscape. Species that have co-evolved, coexisted and adapted to the conditions, dynamic processes and structural diversity associated with natural forest, with negligible human impact.

Historical data and studies based on historical documents, records, maps and assessments, show that there was much, much more old forest, large and old trees, and dead wood, than in today's landscape. In a fact sheet from SLU from the late 1990s, Lars Östlund, professor of forest history and forester Anna-Lena Axelsson writes that:

"In 1914, when the first comprehensive forest assessment was carried out on the Royal Domänverket (now state owned forest company Sveaskog/our comment) forest holdings in Lycksele, 83 percent was covered by multi-layered forest. Trees older than 150 years were found in 85 percent of all stands."

Old-growth forest, large amounts of dead wood and old trees dominated the northern Swedish, and mid boreal forest landscape before industrial exploitation, and were found all over the landscape, not just in small fragments. Different studies show that old multi-storeyed forest dominated the landscapes (Östlund, Zackrisson & Axelsson 1997, Linder & Östlund 1998, Axelsson & Östlund 2001), comprising about 70–95% of the total forest area in this region in the 19th century, and that the forests contained trees that were very old, such as pines with an age of 400 – 600 years, which had survived many forest fires. Studies from Finnish natural forests show similar results and indications in forest landscapes with a low or negligible human impact (from forestry).

The disturbance regimes and dynamics that shaped the historical and natural forests and forest landscapes of northern EU were far more complex and diverse than what previously was the narrative. The researcher and forest ecologist Timo Kuuluvainen describes this clearly in a review paper (Kuuluvainen 2009):

"In particular, the generalization that the boreal forest is regulated by fierce stand-replacing disturbances, leading to the dominance of even-aged stand successions, has been disproved. However, this misconception has, until now, been repeated and used to legitimize the dominant practice of clear-cutting as a nature-based way to manage the forest. The practical conclusion of this review paper is that the dominating forest management model in North European boreal forests, which is based on the clear-cut harvesting of timber and growing of even-aged stands, is in contradiction with the variable and complex characteristics of the disturbance-succession cycle observed in naturally dynamic forests with negligible human impact."

Forest ecology research from natural forests in Fennoscandia has shown that there is a great variety of different dynamics, successions and processes, but also different disturbance regimes.

Researchers Per Angelstam and Timo Kuuluvainen (2004) made a simplified and rough division of these into: (1) small-scale tree mortality inducing gap dynamics, (2) partial, low-severity stand-scale disturbances inducing tree age-cohort dynamics, and (3) high-severity, stand-replacing disturbances inducing even-aged dynamics.

The forest history studies agree well with a review paper (Kuuluvainen & Aakala 2011) on forest dynamics and natural disturbance regimes showing that around >80 percent of the Nordic natural forest landscapes consisted of forests with complex mosaics with medium and small-scale disturbances. So-called gap- and cohort dynamics dominated, while only around 20 percent of the forests had more intensive, stand-replacing disturbance regimes, like intense wildfires that created even-aged stands, with a lot of dead wood.

These studies and assessments of the historical boreal forest condition agree well with contemporary studies of boreal natural forest landscapes, and with, for example, more rough estimates and low-resolution estimates from the mid-19th century, such as Crown Prince Karl's forest map (**Figure 41 A & B**) of the Swedish forest condition. In the 19th century, Sweden's boreal forests contained one of Europe's largest forest resources of large old trees and old forests. It is these ancient, centuries-accumulated timber volumes that were the reason why investors from the continent built large sawmill industries along the east coast in northern Sweden, and floated timber down to these sawmills.

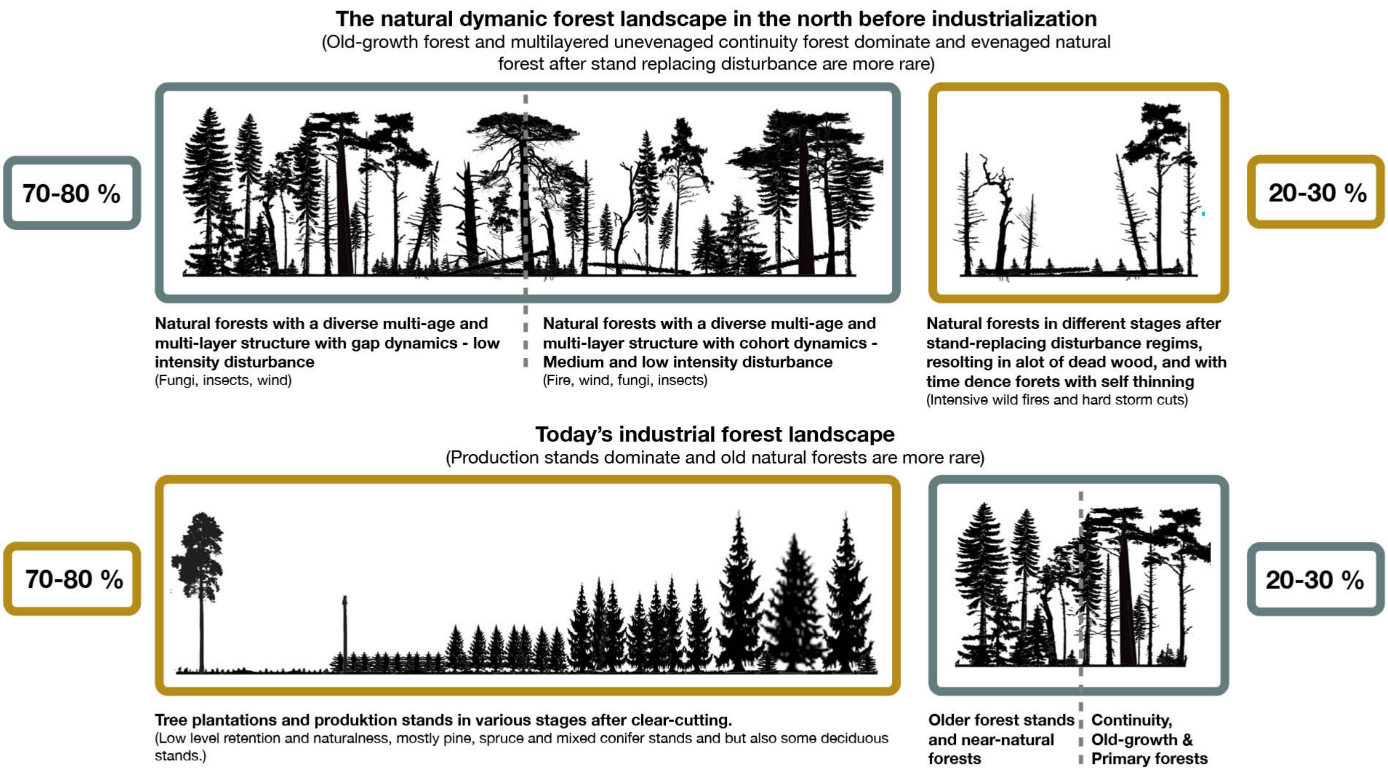


Figure 40. This graphic is based on forest history (Östlund et al. 1997, Linder & Östlund 1998, Axelsson & Östlund 2001) and forest ecology research (Kuuluvainen & Aakala 2011, Berglund & Kuuluvainen 2021) on contemporary and historical natural forest landscapes in the Nordics, as well as data from Skogsmonitor.se and the Swedish National Forest Inventory.

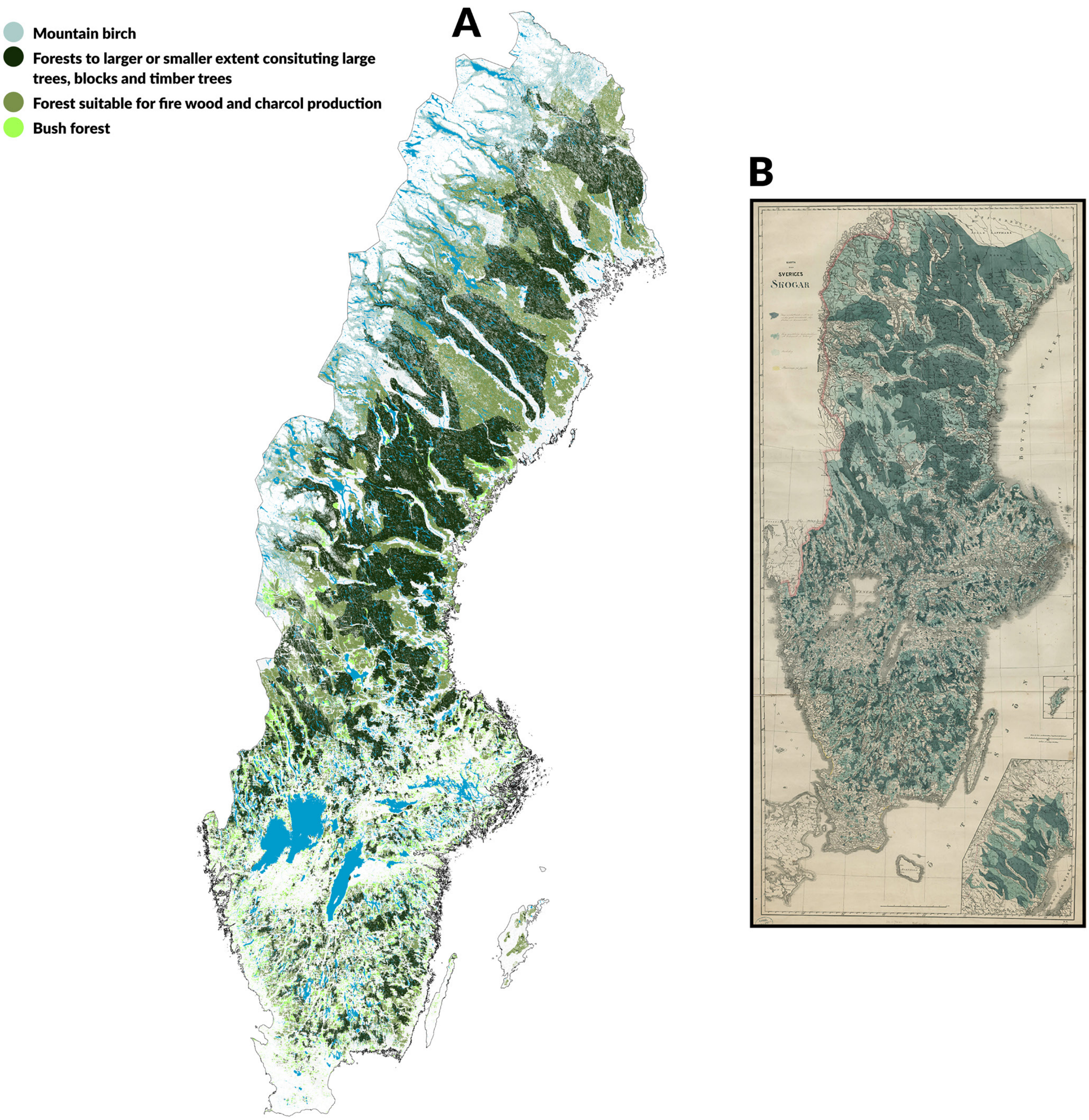


Figure 41. The first nation covering mapping of Swedish forests made by Crown Prince Carl in 1846. **A** is a refined and joined version of the original map in **B.** The mapping is based on local and regional testimonies collected about the state of the forest and is a rough estimate. Dark green color shows forests with "large trees, blocks and timbre trees", and is probably to a large extent old-growth forests and primary forests. It is highly probable that even the many of the lighter green fields at this time were natural forests, but which due to various reasons were assessed to have a low proportion of coarse timber trees. It can be due to everything from wild and controlled fires, storms, grazing of domestic animals, storms and human use of the forest for firewood, timber, house and fence construction, manufacture of potash and tar, and locally and regionally, production of charcoal and boat building etc.




Table 13. Some major differences between natural forest and today's industrial silviculture landscape (Modified version of table after Bleckert & Petersson 1997).

The historical natural forest landscape	Today's Swedish industrial landscape
Powerful spring rivers with flooded forests.	Many forests without natural water impact. Major impact on the forest waters via ditching, hydropower plants and dams, forest road networks, manipulation of streams and rivers, for historical timber transport, leakage of heavy metals from transport wounds, and due to lack or absence of buffer zones, etc.
Natural relationship between pioneer and secondary trees, and natural dynamics. Natural spontaneous regeneration of trees.	Unnatural order of succession and dynamics. For example, spruce monocultures planted on clearcuts.Today planting dominates as regeneration method.
Big grazers affect the forest.	Fewer species of natural grazing animals.
Continuity of biological qualities.	Temporary biological qualities.
Large amount of dead wood, with great diversity.	Small amount of dead wood, with smaller diversity.
Plenty of giant and old trees.	Giant trees are almost absent in production stands.
Landscapes dominated by old-growth forests and multilayered forests.	Old-growth forests fragmented with a relatively small area remaining below the Scandinavian Mountain Green bealt. Even-aged stands, which are often not multilayered or uneven aged.
Natural fire dynamics.	Unnatural fire dynamics.
Wild fires often.	Suppression of wildfires.
Fires in naturally dynamic forest landscapes, with intact wetland forest types and fire barriers.	Fires in industrial forests, where ditching of wet forest types, the lack of deciduous forest, dense production stands, and climate change affect the course of the fire.
Natural tree species mix.	Production stands were one or two tree species dominates.
Old broad leaf forests on productive soil types.	Agricultural land without trees.

Pictures on page 149:
Although the pictures are not from 1846, but from the first half of the 20th century, one can imagine that the timber forests on Crown Prince Carl's map are similar to those in the pictures. Top right: Primary forest on block-rich land, in Dalarna County, Hamra, Top left: Primary forest in Västerbotten, Bottom right: Primary forest in Norrbotten, Lapland, Gällivare, Bottom left: Primary forests in Dalarna. Source: SLU, Forest Library's media archive.

More forests today than ever?

Forestry representatives have claimed that Sweden was almost deforested in the 1850s (SR 2017), and that today we “have more forest in Sweden than ever”. However, this is a very strange and contradictory historiography, which falls on its own absurdity. Why would the sawmill industry have flourished in the second half of the 19th century if there was nothing to fell and saw?

Other actors, like the landowner association LRF, go even further and claim that: *“We have more old forest in Sweden today than 100 years ago.”*

Many people probably think that a forest is a collection of trees. But, can we really say that a managed monoculture of pine, lodge-pole pine or spruce planted in rows is a forest? Or is a forest something more than just raw material that can be measured in cubic meters? Trees can be planted, but not a natural old-growth forest. The forest industries often claim that we have doubled the amount of forest in Sweden. The forestry industry’s timeline seems to begin in the 1920s. At that time, after many decades of intensive forestry, the National forest inventories started to collect forest statistics, when the standing volume of forest in the country was lower than before due to all the felling of large diameter trees that went into building up the sawmill industry, and due to other types of land use. Therefore, the industry usually claims that we have never had as much forest as now, with the implication that it is no problem to fell more, and that it is the forestry industry’s merit that we have so much “forest”.

This is probably wrong no matter how you measure it. But, even if one measures as they do in standing volume of living trees, their claim is still likely to be wrong (Östlund 2013 and Linder & Östlund 1992).

Despite the increased volume of timber since the 1920s, we may still today have less standing volume of timber in the north of Sweden (Norrland) than before the 1850s, and that despite the fact that the frequency of wild forest fires was much, much higher historically, despite extensive forest grazing of domesticated animals in the 19th century forest landscapes, and despite a lot of former anthropogenically started fires to improve grazing in the forest, and despite other forms of forest use etc (see **Figure 42**).

However, it is important to remember that the estimates from the 19th century are based on a different type of data than those that come from the National forest inventory from 1920 and onwards. Historical data and estimates, not infrequently measured in other ways, and in some cases, for example, low-diameter trees were excluded.

It must be remembered that the amount of carbon and the volume of dead and living trees is much, much higher in an undisturbed old natural forest, compared to what is found in a clear-cut, in a young, or in a middle-aged production stand. This means that a old forest of today, with a negligible human impact, have much higher wood and carbon stocks than the average in the managed industrial forest landscape.

There is a difference between the standing volume historically and the standing volume today. Today, the stands of trees, or the so-called forests, and their structure, are completely different. Now a significant part of the volume is in remaining but fragmented parts of old natural forests and near-natural continuity forests that were not previously clear-cut, (and have not been managed nor burned for a long time), and in younger uniform dense and dark industrial stands of trees. Back then, in the 1850s, and beyond, a large part of the volume in boreal Sweden, was in old large trees, which stood in varied old continuity forests.

If one excludes plantations and heavily managed industrial stands of trees, then the truth is that Sweden has less real natural dynamic forest today than ever, or at least since Sweden was completely forested after the last ice age.

Photos on page 153: There is a difference between "forest" and forest. The upper picture shows a spruce plantation, which in Sweden is classified as "forest", and the lower a natural spruce forest in the same area. The forest industries' slogan: "more forest than ever" is misleading, to say the least.
Photos: Viktor Säfve

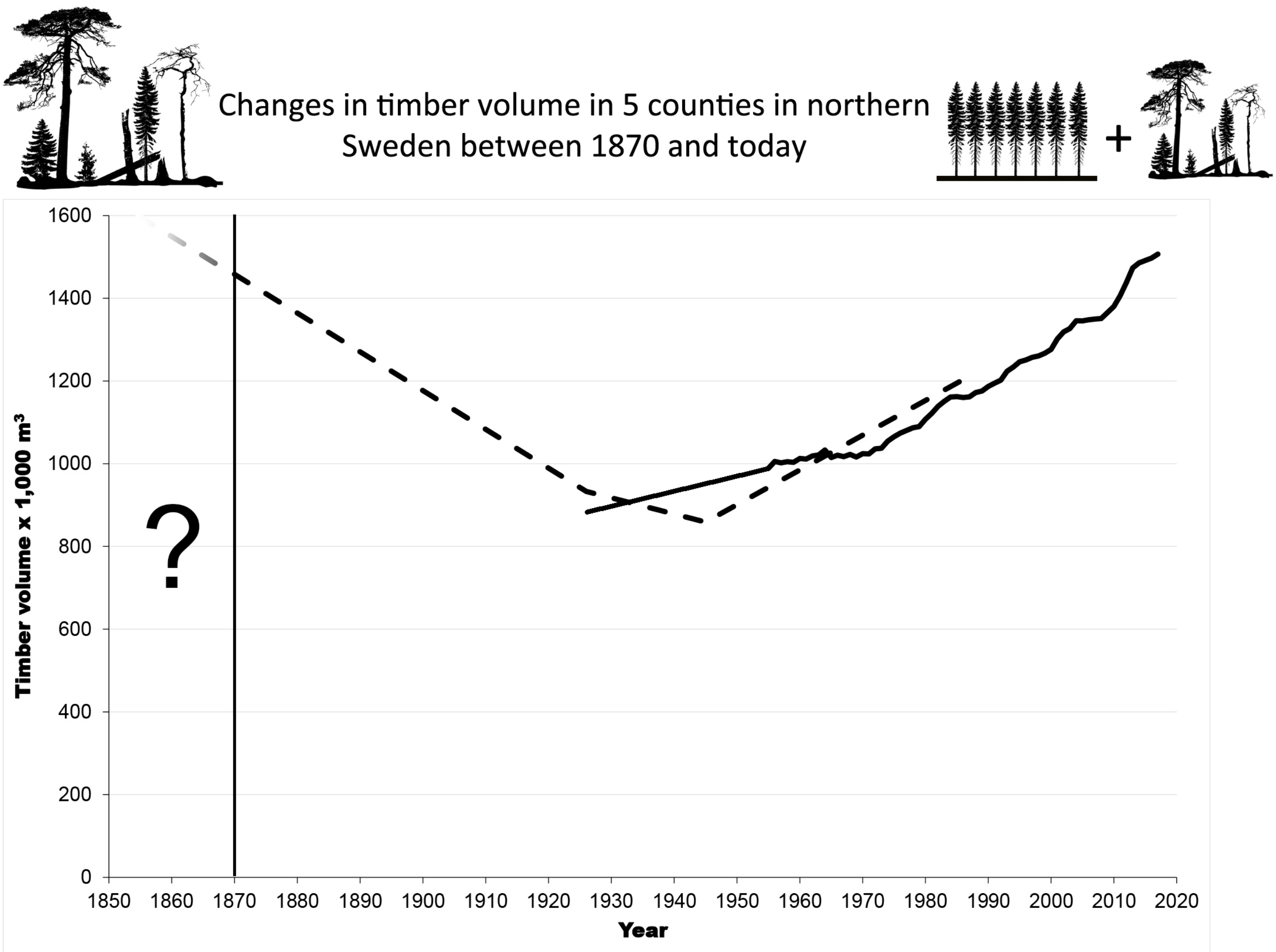


Figure 42. Despite the increased volume of timber since the 1920s to 40s, we may still today have less a standing volume of timber in north Sweden (Norrland) than before the 1850s, and that despite the fact that the frequency of wild forest fires was much, much higher historically, despite extensive forest grazing of domesticated animals in the 19th century forest landscapes, and despite a lot of former anthropogenically started fires to improve grazing in the forest, and despite other forms of forest use etc. It should also be added that the volume of dead wood was much higher in historical natural forests than in today's production stands, which means that the total carbon stock and volume of tree biomass was much larger historically. Source: Older data/Lars Östlund combined with data from The Swedish National Forest Inventory.


Photo: Viktor Säfe


Photo: Viktor Säfe

12. The Swedish forest vision for 2030

The Swedishforestvision.org is an appeal and a vision for Swedish forests supported by over 260 researchers, Sami organizations and more than 60 environmental organizations that together represent millions of committed members.

Protect EU's natural heritage in the North!

Our demands to Sweden and our vision for the Swedish forest are:

1. Implement an immediate logging moratorium in all forests with identified conservation values.

These include (1) old-growth and primary forests and verified continuity forests (2) woodland key habitats and other forests with documented high conservation values (designated in municipal plans, via SIS-standard, or similar), (3) areas classified by the Swedish Environmental Protection Agency (SEPA) as core areas which are of great importance for plants and animals, (4) pendulous lichen-rich forest important for the Sámi community, and (5) all unprotected forest habitat types protected under the Habitats Directive. These five categories may in many cases overlap. Even though there is a lack of comprehensive data on all existing areas with high conservation value, the moratorium can be implemented immediately for the known areas using today's knowledge. A moratorium would secure all known conservation value forest until strict protection is in place.

2. Protect and restore forests in line with EU species and habitats directives, biodiversity- and forest strategy and the CBD-framework by 2030.

In line with the EU biodiversity strategy, EU directives and international agreements, at least 30 percent of the productive forest land should be protected, especially areas of particular importance for biodiversity and ecosystem functions and services. They need to be ecologically representative, well-connected, and equitably governed systems of protected areas. Today, only about 6 percent of the Swedish productive forest has long-term, quality assured and transparent protection; however, the productive forest land hosts the most diverse nature types and provides habitats for the majority of the red listed forest species. The target must be achieved by 2030 and be well-distributed across the different forest regions. To achieve a functional protection of 30 percent, significant restoration efforts are required for large areas.

- All forests with identified conservation values must be protected. The protection needs to be transparent, long-term, and based on the preservation of large, coherent forests of high quality. Protected areas should include all remaining primary and old-growth forests and all other forests with conservation values.

- Also, all forests mapped with remote sensing as potential continuity forest or forest with conservation values must be mapped in the field by SEPA. Where the field surveys confirm conservation or restoration values the area should be protected from logging. - Sweden's state-owned forest should be used as one of several tools to meet the target of protection.

- In addition to protection, to enhance biodiversity, ecosystem functions and services, ecological integrity, and connectivity in the forest landscape, there are major restoration needs.

Efforts should be made to target degraded forests and those forest types which have the highest need for restoration. Successful restoration efforts would result in an increase of the protected areas.

3. Protect the Scandinavian Mountains Green Belt.

The belt of subalpine and montane forest with conservation values along the Swedish mountains must be preserved in its entirety. This is one of the few remaining large European intact forest landscapes and a unique opportunity to protect entire resilient ecosystems at landscape level. It is a key tool for retaining boreal biodiversity, ecological legacies, ecosystem services, adaptive capacity and resilience, which need to be safeguarded for the future.

4. Transform forestry to a close-to-nature management model.

Forestry needs to transform from today's dominating methods with clear-cutting and tree plantations, to a close-to-nature forest management. The transition must start immediately, with clear, time-bound targets, knowledge-sharing hubs and capacity building, and economic incentives for landowners. A close-to-nature forest management seeks to work with and protect the natural processes; promoting a self-organized ecosystem that fosters heterogeneity, biodiversity, resilience and adaptive capacity. It will improve the ability for forestry to preserve biodiversity, maintain and restore resilient forests, adapt to climate change and continue to deliver various ecosystem services well within the planetary boundaries. A shift to close-to-nature forestry is well in line with both the EU forest strategy and the proposed EU nature restoration law. Introducing close-to-nature forest management does not reduce the current need for forest protection. No forestry, regardless of forestry method, should therefore be carried out in conservation value forests that need urgent protection.

5. Constrain wood use within planetary boundaries.

In the current environmental crisis, the government needs to ensure that consumption and production of biomass are constrained by planetary boundaries. About 80 % of Sweden´s harvested biomass is used for short-lived products such as bioenergy, cardboard and paper. In addition, paper and pulp products are very energy-intensive to make: the forest industry is responsible for almost half of Sweden´s industrial energy use. Already, the demand for wood products far exceeds supply and the need to constrain and for prioritization is urgent. It is important to be explicit on how wood products are promoted through policy: Long-lived products must be prioritized before short-lived and disposable. Short-lived products and bioenergy from forest biomass must not be subsidized. The circularity of wood products, incentivizing re-use, and recycling need to increase drastically. The production needs to be energy efficient. To properly achieve a circular economy Sweden needs to implement the cascading principle, as pointed out in the EU Forest Strategy.


Photo: Stig Björk


Photo: Stig Björk

13. DEFINITIONS AND DICTIONARY

Biodiversity
Biodiversity is the total variety of life on earth, or in a smaller area. One measure of biodiversity is a count of species, but one may also examine the diversity above species level, and the genetic diversity within species. Another aspect is the different ways in which species may combine to form ecosystems, and whether the species present are generalist species common in large areas, or rare, specialist species. Biodiversity has arisen through many millions of years of evolution. Much of biodiversity is invisible to us, such as single-celled organisms or the rich web of life in the soil, and yet, it is vital for the processes that ensure our survival.

According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES 2019): “Biodiversity – the diversity within species, between species and of ecosystems – is declining faster than at any time in human history,” and “Nature across most of the globe has now been significantly altered by multiple human drivers, with the great majority of indicators of ecosystems and biodiversity showing rapid decline.”.

Carbon storage and carbon sinks
A carbon stock (or storage) is the amount of carbon which is contained in some system, for example the sea, a forest, or a building. A carbon sink is a system which currently takes up carbon. A carbon source, conversely, emits carbon.

Studies show that tree plantations, in general, store less carbon than the former old natural forest, regardless of geographic region (Liao, Luo, Fang & Li 2010).

An old forest has a large carbon stock. Besides the trees, large amounts of carbon are stored in the soil, enhanced by the fungal networks (Clemmensen et al. 2013). Disturbances such as fires or storms may affect the amounts of carbon in an old forest, but undisturbed, it may continue to build up carbon for centuries (Wardle et al. 2012). Studies have shown that old-growth forests both store a lot of carbon (Simon Besnard et al 2018), and can be large carbon sinks (Luyssaert et al. 2008).

An appeal signed by more than 500 scientists addressed to the EU underlines the importance of understanding the difference between carbon debt, carbon stocks and carbon flows: “Forests are important for mitigating climate change…because of the amount of carbon that is already stored in living biomass, dead biomass and, particularly in boreal forests, in soil.”. They also write: “Harvesting reduces the amount of stored carbon and therefore increases the amount of carbon dioxide in the atmosphere. Any claim to the contrary is simply wrong...”, and: “All carbon uptake in managed forest is therefore a payback of the historical carbon debt.”.

Clear-cuts, logging levels and CO2 emissions
Research shows that reduced logging levels provide large climate benefits coming decades (Skytt et al 2021). The time factor is important - the next few years will be critical, if we are to reach international climate- and environmental targets, mitigate negative climate effects and avoid exceeding so-called “tipping points”.

The most effective way to mitigate climate change is to avoid emissions of carbon (Mackey et al. 2013), and to preserve and enhance the natural carbon stocks and carbon sinks. Emissions must be rapidly reduced from both fossil and biogenic sources.

Clearcutting emits large amounts of greenhouse gases (Vestin et al. 2020).

Scientists and experts points out that we cannot wait for the trees that replace the forests being clear-cut today to grow back and rebind all the carbon. Exceeding 1.5°C global warming could trigger multiple climate tipping points (Armstrong et al. 2022). Planetary boundaries have already been overstepped (Rockström, J., Steffen, W., Noone, K. et al. 2009).

Close-to-nature forest management

The EU's forest strategy for 2030 clearly states (European commission 2021) that forest management systems like clear-cutting should only be used in duly justified cases since it affects above ground biodiversity, and causes the loss of carbon in the roots and part of the carbon in the soil.

The clear-cut and planting model, and the industrial tree stand forest landscape that is the result of this management, is according to a forest ecologist (Kuuluvainen 2009): "in contradiction with the variable and complex characteristics of the disturbance-succession cycle observed in naturally dynamic forests with negligible human impact".

Also, the forest ecologist stated that: "In particular, the generalization that the boreal forest is regulated by fierce stand-replacing disturbances, leading to the dominance of even-aged stand successions, has been disproved. However, this misconception has, until now, been repeated and used to legitimize the dominant practice of clear-cutting as a nature-based way to manage the forest."

To tackle negative climate effects, biodiversity loss in forest landscapes, and increase resilience and resistance, there is an urgent need for a transition to a forest management model based on: "naturally emerging self-organized ecosystem dynamics that foster heterogeneity, biodiversity, resilience and adaptive capacity."

Following the general principles for a Close-to-nature forest management, all forest management must meet following guidelines:

- Use unmanaged forests with a natural dynamic, shaped by natural processes and disturbance regimes, as reference areas. Management methods should be adapted to the natural forest dynamics so that, to the greatest extent possible, natural processes create a heterogeneous forest landscape. Reference areas can show if forestry is moving towards or away from an increased natural dynamic development in the managed forests. A Close-to-nature forest management should be as close to the reference areas as possible, while extraction of valuable timber and other values from the forest is possible.

- Preserve and restore natural processes and functions of forest ecosystems. To ensure a resilient forest landscape, natural processes and functions of ecosystems must be preserved. These are, in many cases, regulating and supporting ecosystem services such as biogeochemical cycles as well as climate and water regulation.

- Preserve and restore structural complexity of forest ecosystems. Forestry practices must ensure sufficient nature consideration to preserve and restore structures, such as the amount and type of dead wood, old trees and wetlands.

- Preserve and restore natural tree species composition and diversity of forest ecosystems, both at a stand- and landscape scale. Trees form the basis of forest ecosystems by directly providing habitats and affecting biophysical conditions. Therefore, forestry should only use native tree species that, as far as possible, are naturally regenerated.

- Apply a landscape perspective. Planning should be done at a forest stand level as well as at a landscape level to ensure connectivity and to preserve and restore the natural variation in the forest landscape.

- Be based on best, and adapted to, new knowledge and experiences. Forestry should continuously be adapted to new research findings as well as practical experience.

Continuity forest
Continuity forest is defined by the Swedish Forest Agency (SFA 2011) as: “A forest that has natural values whose occurrence is explained by the fact that for a long time there have been suitable forest habitats and substrates in this particular forest or in its vicinity“.

The definition includes forests that have never been clear-cut and includes the majority of all forests (particularly in the northwest of Sweden) generated before clear-cutting was introduced as common practice, and on a large scale.

Continuity forests are found within several different forest habitat types but dominate within western taiga, wooded bog and mountain birch forest.

Many species are associated with continuity forests, and these forests have a unique biological diversity. The Swedish Species Information Center at the Swedish University of Agricultural Sciences states that (SSIC 2020): “Lack of continuity forests, i.e. forests that have never been clear-cut, is one of the main reasons why forest-dwelling species are listed on the Red List.” and that: “In order to reverse the trend of declining populations, unprotected forest environments, with habitats for red-listed species, need to be preserved in the long term throughout the country.”.

Core areas
A core area [värdekärna] is a mapped forest area with high conservation values of major significance for the flora and fauna (SEPA 2024). Core areas vary in size, from small forest stands to areas of several hundred hectares. WKH and other areas with conservation values are included. A core area can also be a forest area that is not classified as a WKH, but which has one or more of the characteristics of forests with high conservation values.

Old-growth forest
The European commissions staff working document “Commission Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests”, states that (EU-commission 2023):

‘A forest stand or area consisting of native tree species that have developed, predominantly through natural processes, structures and dynamics normally associated with late-seral developmental phases in primary or undisturbed forests of the same type. Signs of former human activities may be visible, but they are gradually disappearing or too limited to significantly disturb natural processes.’

Explanatory notes:

1. This definition includes forest stands that originate not only from natural regeneration, but also from planted or sown native tree species (provided that they meet the rest of the definition).
2. This definition includes forest stands where indigenous peoples engage in traditional forest stewardship activities that otherwise meet the definition.
3. This definition includes forest stands with visible signs of abiotic damages (e.g. storms, snow, droughts and fires) and biotic damage (e.g. from insects and diseases) that meet the definition (see the third additional note in Section 2.4).
4. Forests with visible signs of past human activity are not excluded from the definition of old-growth forests, unless the magnitude of the impact of the activity is such as to prevent the forest stand from counting as old-growth (see Section 3.2).
5. Old-growth forest stands do not include stands for which there is evidence that they are under active productive management. This includes low-intensity silvicultural regimes and coppicing.
6. Some key characteristics of old-growth forest stands are:

• they contain structural features and dynamics such as natural regeneration, gap dynamics, large and diverse dead wood, structural complexity, and the presence of old trees, or trees reaching senescent stage and tree-related microhabitats.
• they have acquired these structural features and dynamics through several decades of natural development without significant human intervention

Pendulous lichen-rich forest

Pendulous lichen-rich forests are often characterized by a significant amount of hanging tree lichens and older trees. The forests are often multi-layered and usually dominated by spruce, but in northernmost Sweden also by pine. Entire stands of older pendulous lichen-rich forests are today relatively uncommon, especially below the mountain forest.

For several species including lichens, insects and resident birds, these forests are very important. In the winter, the semi-domesticated reindeer kept by the Sámi need to eat lichen to survive. The tree hanging lichens are especially important in the winter when reindeer, due to ice crust, cannot dig through the snow to reach the lichen on the ground.

Productive and low-productive forest

A Swedish forest is designated as productive if the annual timber growth is more than 1 cubic meter per hectare. Low-productive or unproductive forest often consists of wetlands or rocky ground sparsely covered with trees, or slow growing forest near the treeline in the mountains. Forestry is permitted in the productive forest, whereas large-scale forestry is not allowed in the low-productive forest. According to the Forestry Act (SFA 2023): "Logging, forest management measures and fertilizing may not take place on forest impediments (low-productive forest land) that are larger than 0.1 hectares. Single trees may, however, be felled if it does not change the character of the natural environment.".

Woodland key habitats (WKH)

According to the Swedish Forest Agency, WKHs are forest areas that, by an overall assessment of its ecological structure, species content, forest history and physical environment has a high importance for the forest's flora and fauna today, and harbor or can be expected to harbor red-listed species (SFA 2020).

WKHs were systematically mapped and registered by the Swedish Forest Agency and by the large forest companies during the 1990's and early 2000's. They were also registered when encountered in connection to authority supervision. There are still many undetected WKHs and further systematic inventories are needed.

WKHs do not have any legal protection, but within the voluntary forest certification FSC, they are prohibited to be logged. According to a recent governmental decision the Swedish Forest Agency no longer maps and registers new WKHs. Recently WKHs have begun to be de-registered, following demands by land-owners and forest companies.

14. SOURCES

Brief introduction

European Commission. 2023. Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests. https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2023)62&lang=en (visited 25-03-19)

Höjer. O., Eriksson. A., Wennberg. S. & Wester. J. 2023. Urskogar och naturskogar – Sammanställning av underlag och bedömning av arealer Kunskapsunderlag till Miljömålsberedningen. https://www.sou.gov.se/contentassets/e66f5e3eaaed43ddb8ae786a452eed39/underlagsrapport-urskogar-och-naturskogar---kunskapsunderlag.pdf

Johansson. B. G. & Petersson. J. (red.). 2016. Gotlands flora band 1. SBF-förlaget & Gotlands Botaniska Förening. Uppsala.

Lindblad. M. 2022. A newcomer to the forest - how the spruce conquered Sweden. Webinar lecture by Professor Matts Lindblad, Department of South Swedish Forest Science, SLU 25 Jan 2022. Organizer: Forest History Society, Department of South Swedish Forest Science and Faculty of Forest Science, SLU.

Lundmark. H., Östlund. L. & Josefsson. T. 2021. Continuity forest or second-generation forest? Historic aerial photos provide evidence of early clear-cutting in northern Sweden. Silva Fennica. https://doi.org/10.14214/sf.10460

Rutschman. D. & Säfve. V. 2024. Protect the Forest Report: SCA-FILES "500 single mistakes". https://scafiles.skyddaskogen.se/

Analysis of the contemporary situation in Sweden

Ahlström. A., Canadell. J. G. & Metcalfe. D. B. 2022. Widespread unquantified conversion of old boreal forests to plantations. Earth's Future. https://doi.org/10.1029/2022EF003221

Armstrong. D. I., Staal. A., Abrams. J. F., Winkelmann. R., Sakschewski. B., Loriani. S., Fetzer. I., Cornell. S. E., Rockström. J. & Lenton. T. M. 2022. Exceeding 1.5°C global warming could trigger multiple climate tipping points. Science. https://www.science.org/doi/10.1126/science.abn7950

Besnard. S., Carvalhais. N., Arain. M. A., Black. A., de Bruin. S., Buchmann. N., Cescatti. A., Chen. J., Clevers. J. G. P. W. & Desai. A. 2018. Quantifying the effect of forest age in annual net forest carbon balance. Environmental Research Letters. DOI 10.1088/1748-9326/aaeaeb

Chapron. G. 2022. Sweden threatens European biodiversity. Science. https://www.science.org/doi/10.1126/science.adf2714

Dagens Nyheter. 2022. Forskare: Budgeten är ett dråpslag mot miljön på bred front. https://www.dn.se/sverige/forskare-budgeten-ar-ett-drapslag-mot-miljon-pa-bred-front/ (visited 25-03-19)
Dettki. H. & Esseen. P-A. 2003. Modelling long-term effects of forest management on epiphytic lichens in northern Sweden. Forest Ecology and Management. https://doi.org/10.1016/S0378-1127(02)00131-7

Clemmensen. K. E., Bahr. A., Ovaskainen. O., Dahlberg. A., Wallander. H., Stenlid. J., Finlay. R. D., Wardle.

D. A. & Lindhal. B. D. 2013. Roots and Associated Fungi Drive Long-Term Carbon Sequestration in Boreal Forest. Science. https://www.science.org/doi/10.1126/science.1231923

Eriksson. A., Snäll. T., Harrison. P. 2015. Skogliga Konsekvensanalyser. Analys av miljöförhållanden – SKA 15. Rapport 11. Skogsstyrelsen. Jönköping.
https://www.skogsstyrelsen.se/globalassets/statistik/skogliga-konsekvensanalyser/analys-av-miljoforhallanden-ska-rapport-11-2015.pdf

Esseen. P-A., Ekström. M., Grafström. A., Jonsson. B-G., Palmqvist. K., Westerlund. B. & Ståhl. G. 2021. Multiple drivers of large- scale lichen decline in boreal forest canopies. Global Change Biology. https://doi.org/10.1111/gcb.16128

Höjer. O. 2023. Översikt kring kontinuitetsskogar och naturskogar i boreal region. PM 2023-05-16. Swedish Environmental Protection Agency. https://www.naturvardsverket.se/48cc10/contentassets/9639737013004819b9d71fe5800e932f/oversikt-kring-kontinuitetsskogar-och-naturskogar-i-boreal-region-16-maj-2023-webb.pdf (visited 25-03-19)

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). 2019. Global assessment report of the Intergovernmental Science – Policy Platform on Biodiversity and Ecosystem Services, Brondízio. E.S., Settele. J., Díaz. S., Ngo. H.T. (ed.s). IPBES secretariat, Bonn, Germany, ISBN: 978-3-947851-20-1

Liao. C., Luo. Y., Fang. C. & Li. B. 2010. Ecosystem Carbon Stock Influenced by Plantation Practice: Implications for Planting Forests as a Measure of Climate Change Mitigation. PLoS ONE. https://doi.org/10.1371/journal.pone.0010867

Luyssaert. S., Schulze. E-D., Börner. A., Knohl. A., Hessenmöller. D., Law. B.E. Ciais. P. & Brace. J. 2008. Old-growth forests as global carbon sinks. Nature. https://doi.org/10.1038/nature07276

Ottosson. E. 2022. Skogliga arter som hotas av modernt skogsbruk – Sammanställning av nationellt och regionalt hotade och utgångna skogliga arter. https://media.wwf.se/uploads/2022/09/skogliga-arter-som-hotas-av-trakthyggesskogsbruk.pdf (visited 25-03-19)

Sandström. P., Cory. N., Svensson. J., Hedenås. H., Jougda. L. & Borchert. N. 2016. On the decline of ground lichen forests in the Swedish boreal landscape: Implications for reindeer husbandry and sustainable forest management. Ambio. https://doi.org/10.1007/s13280-015-0759-0

Skytt. T., Englund. G. & Jonsson. B-G. 2021. Climate mitigation forestry – temporal trade-offs. Environmental Research Letters. DOI 10.1088/1748-9326/ac30fa

Stockholm Environmental Institute (SEI). 2024. EU's Critical Raw Materials Act fails to protect Sámi rights – here's how to strengthen it. https://www.sei.org/perspectives/eus-critical-raw-materials-act-sami-rights-protection/ (visited 25-01-04)

Greenpeace/Renskog. 2025. Rapport: Kampen om renskogarna.
https://www.greenpeace.org/static/planet4-sweden-stateless/2025/03/f8a29df4-kampen-om-renskogarna-greenpeace-och-renskog.pdf

Svensson. J., Bubnicki. J., Jonsson. B-G., Andersson. J. & Mikusiński. G. 2020. Conservation significance of intact forest landscapes in the Scandinavian Mountains Green Belt. Landscape Ecology. https://doi.org/10.1007/s10980-020-01088-4

Swedish Environmental Protection Agency (SEPA). 2022. Miljömålen, Årlig uppföljning av Sveriges nationella miljömål 2022 – Med fokus på statliga insatser. Rapport 7033. ISBN 978-91-620-7033-5

Swedish Environmental Protection Agency (SEPA). 2024. Årlig uppföljning av Sveriges nationella miljömål 2024 - Med fokus på statliga insatser. Skrivelse 2024-03-28. https://www.naturvardsverket.se/4960d4/globalassets/om-miljoarbetet/sveriges-miljomal/miljomalen-arlig-uppfoljning-2024.pdf (visited 25-01-04)

Swedish Forest Agency (SFA). 2023. Levande skogar. Fördjupad utvärdering 2023. Rapport 2022/12. https://www.skogsstyrelsen.se/globalassets/om-oss/rapporter/rapporter-20222021202020192018/rapport-2022-12-levande-skogar---fordjupad-utvardering-2023.pdf (visited 2025-01-04)

Swedish Species Information Centre (SSIC). 2024. Sammanfattning Rödlista 2020. https://www.slu.se/artdatabanken/rodlistning/Sammanfattning-rodlista-2020/ (visited 25-03-19)

Thompson. I., Mackey. B., McNulty. S. & Mosseler. A. 2009. Forest Resilience, Biodiversity, and Climate Change. A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43, 67 pages.

Vestin. P., Mölder. M., Kljun. N., Cai. Z., Hasan. A., Holst. J., Klemedtsson. L. & Lindroth, A. 2020. Impacts of Clear-Cutting of a Boreal Forest on Carbon Dioxide, Methane and Nitrous Oxide Fluxes. Forests. https://doi.org/10.3390/f11090961

Wardle. D.A., Jonsson. M., Bansal. S., Bardgett. R.D., Gundale. M.J. & Metcalfe, D.B. 2012. Linking vegetation change, carbon sequestration and biodiversity: insights from island ecosystems in a long-term natural experiment. Journal of Ecology. https://doi.org/10.1111/j.1365-2745.2011.01907.x

Method descriptions

Ahlkrona. E., Giljam. & C., Wennberg. S. 2017a. Kartering av kontinuitetsskog i boreal region. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Automatiserad_Kskogskartering_2015_BorealRegion/Sammanfattning_Kartering_av_kontinuitetsskog_boreal_region.pdf (visited 25-03-19)

Ahlkrona. E., Giljam. C., Kesketalo. C., Klein. J. & Naumov. V. 2017b. Preciserad kartering av kontinuitetsskog i Västernorrlands län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2016_Y/Precisera%20karteringen%20av%20kontinuitetsskog%20Vasternorrlands%20lan.pdf (visited 25-03-19)

Ball. G. H. & D. J. Hall. 1965. A Novel Method of Data Analysis and Pattern Classification. Menlo Park, California: Stanford Research Institute.

Metria AB. 2019. Preciserad kartering av kontinuitetsskog i Jämtlands län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2017_Z/Preciserad%20karteringen%20av%20Kskog%20Jamtland.pdf (visited 25-03-19)

Metria AB. 2021. Preciserad kartering av kontinuitetsskog i Västerbottens län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2018_AC/Preciserad_kartering_av_kontinuitetsskog_i_Vasterbotten_lan.pdf (visited 25-03-19)

Metria AB. 2023a. Preciserad kartering av kontinuitetsskog i Dalarnas län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2022_W/Preciserad_kartering_av_kontinuitetsskog_i_Dalarnas_lan.pdf (visited 25-03-19)

Metria AB. 2023b. Preciserad kartering av kontinuitetsskog i Norrbottens län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2022_BD/Preciserad_kartering_av_kontinuitetsskog_i_Norrbottens_lan.pdf (visited 25-03-19)

Shaoging. Z. & Lu. X. 2008. The comparative study of three methods of remote sensing image change detection. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B7. Beijing. https://www.isprs.org/proceedings/xxxvii/congress/7_pdf/10_ths-18/12.pdf (visited 25-03-19)

Sommer. C., Straehle. C., Koethe. U. & Hamprecht. F. A. 2011. "Ilastik: Interactive learning and segmentation toolkit". 2011 IEEE International Symposium on Biomedical Imaging: From Nano to Macro. pp. 230–33. doi:10.1109/ISBI.2011.5872394. ISBN 978-1-4244-4127-3. S2CID 206949135.

Swedish Forest Agency. 2023. The SFA's indicator Species – a complete list, version 2023-1 [Skogsstyrelsens signalarter – en komplett förteckning, version 2023-1]. Skogsstyrelsen. Jönköping. https://www.skogsstyrelsen.se/globalassets/miljo-och-klimat/nyckelbitoper/skogsstyrelsens-signalarter---version2023-1.pdf (visited 25-03-19)

Swedish Forest Agency (SFA). 2025. Recent logging [Utförd avverkningar] – Produktbeskrivning. https://www.skogsstyrelsen.se/globalassets/sjalvservice/karttjanster/geodatatjanster/produktbeskrivningar/utforda-avverkningar---produktbeskrivning.pdf (visited 25-03-19)

Swedish Environmental Protection Agency (SEPA). 2024a. National Land Cover Database [Basskikt], NMD. https://geodata.naturvardsverket.se/nedladdning/marktacke/NMD2023/NMD2023_Produktbeskrivning_Basskikt_NMD2023_v01.pdf (visited 25-03-19)

Swedish Environmental Protection Agency (SEPA). 2024b. National Land Cover Database [Produktivitet], NMD. https://geodata.naturvardsverket.se/nedladdning/marktacke/NMD2018/NMD_Produktbeskrivning_tillaggsskikt_Produktivitet.pdf (visited 25-03-19)

Swedish Species Information Centre (SSIC). 2024. Species Observations. https://www.slu.se/en/slu-swedish-species-information-centre/species-observations/ (visited 25-03-19)

USGS, 2021. Earth Explorer. https://earthexplorer.usgs.gov/ (accessed 24-12-17)

Validation of Forest Monitor's data

Ahlkrona. E., Giljam. C., Kesketalo. C., Klein. J. & Naumov. V. 2017b. Preciserad kartering av kontinuitetsskog i Västernorrlands län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2016_Y/Precisera%20karteringen%20av%20kontinuitetsskog%20Vasternorrlands%20lan.pdf (visited 25-03-19)

Ducey. M & A Kershaw Jr. J. 2023. Alternative expressions for stand diameter in complex forests. Forest Ecosystems. https://doi.org/10.1016/j.fecs.2023.100114

Dahlberg. A. 2011. Kontinuitetsskogar och hyggesfritt skogsbruk – Slutrapport för delprojekt naturvärden. Rapport 7. Skogsstyrelsens förlag. Jönköping. https://cdn.abicart.com/shop/9098/art51/10768251-68e6a3-1837.pdf (visited 25-03-19)
International Union for Conservation of Nature (IUCN). 2025. IUCN Red List of Threatened Species. https://

iucn.org/resources/conservation-tool/iucn-red-list-threatened-species (visited 25-01-12)

Larsson. A. (red). 2011. Tillståndet i skogen – Rödlistade arter i ett nordiskt perspektiv. ArtDatabanken Rapporterar 9. ArtDatabanken SLU. Uppsala.
https://www.slu.se/artdatabanken/publikationer/tillstandet-i-skogen/

International Union for Conservation of Nature (IUCN). 2025. IUCN Red List of Threatened Species. https://iucn.org/resources/conservation-tool/iucn-red-list-threatened-species (visited 25-01-12)

Metria AB. 2019. Preciserad kartering av kontinuitetsskog i Jämtlands län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2017_Z/Preciserad%20karteringen%20av%20Kskog%20Jamtland.pdf (visited 25-03-19)

Metria AB. 2021. Preciserad kartering av kontinuitetsskog i Västerbottens län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2018_AC/Preciserad_kartering_av_kontinuitetsskog_i_Vasterbotten_lan.pdf (visited 25-03-19)

Metria AB. 2023a. Preciserad kartering av kontinuitetsskog i Dalarnas län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2022_W/Preciserad_kartering_av_kontinuitetsskog_i_Dalarnas_lan.pdf (visited 25-03-19)

Metria AB. 2023b. Preciserad kartering av kontinuitetsskog i Norrbottens län. Metria AB på uppdrag av Naturvårdsverket. https://geodata.naturvardsverket.se/nedladdning/Kartering_av_kontinuitetsskog/Preciserad_kskog_2022_BD/Preciserad_kartering_av_kontinuitetsskog_i_Norrbottens_lan.pdf (visited 25-03-19)

Swedish Forest Inventory (SFI). 2025. Taxweb. https://taxwebb.slu.se/ (visited 24-12-12)

Swedish Forest Agency (SFA). 2023. The SFA's indicator Species – a complete list, version 2023-1 [Skogsstyrelsens signalarter – en komplett förteckning, version 2023-1]. Skogsstyrelsen. Jönköping. https://www.skogsstyrelsen.se/globalassets/miljo-och-klimat/nyckelbitoper/skogsstyrelsens-signalarter---version2023-1.pdf (visited 25-03-19)

Swedish Parliament. 2007. The Swedish Species Protection Regulation (2007:845) [Artskyddsförordning (2007:845)].

Swedish Species Information Center (SSIC). 2024a. Summary of the Swedish Red List 2020 [Sammanfattning Rödlista 2020]. https://www.slu.se/artdatabanken/rodlistning/Sammanfattning-rodlista-2020/ (visited 25-01-12)

Swedish Species Information Center (SSIC). 2024b. Many forest-dwelling species are threatened by clear cutting forestry [Många skogslevande arter hotas av trakthyggesbruk]. https://www.slu.se/artdatabanken/arter-och-natur/Dagens-natur/manga-skogslevande-arter-hotas-av-trakthyggesbruk/ (visited 25-01-12)

Forest monitor's mapping of OFCFs as a tool in nature conservation

Anantharaman. R., Hall. K., Shah. V.B. & Edelman. A. 2019. Circuitscape in Julia: High Performance Connectivity Modelling to Support Conservation Decisions. Proceedings of JuliaCon. https://juliacon.github.io/proceedings-papers/jcon.00058/10.21105.jcon.00058.pdf

Angelstam. P., Manton. M., Green. M., Jonsson. B-G., Mikusiński. G., Svensson. J. & Sabatini F. M. 2020. Sweden does not meet agreed national and international forest biodiversity targets: A call for adaptive landscape planning. Landscape and Urban Planning. https://doi.org/10.1016/j.landurbplan.2020.103838

Chen. X., Kang. B., Li. M., Du. Z., Zhang. L. & Li. H. 2023. Identification of priority areas for territorial ecological conservation and restoration based on ecological networks: A case study of Tianjin City, China. Ecological Indicators. https://doi.org/10.1016/j.ecolind.2022.109809

Convention on Biological Diversity (CBD). 2025. 2030 Targets (with Guidance Notes). https://www.cbd.int/gbf/targets (visited 25-03-19)

Dinerstein. E., Vynne. C., Sala. E., Joshi. A. R., Fernando. S., Lovejoy. T. E., Mayorga. J., Olson. S., Asner. G. P. & Wikramanayake. E. 2019. A Global Deal For Nature: Guiding principles, milestones, and targets. Science Advances. https://doi.org/10.1126/sciadv.aaw2869

Dynesius. M., Hylander. K. & Nilsson. C. 2009. High resilience of bryophyte assemblages in streamside compared to upland forests. Ecology. https://doi.org/10.1890/07-1822.1

European Commission. 2025. Green infrastructure - Promoting the use of green infrastructure in all EU policies, to help restore nature and boost biodiversity. https://environment.ec.europa.eu/topics/nature-and-biodiversity/green-infrastructure_en (visited 25-03-19)

European Union. 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. https://eur-lex.europa.eu/eli/dir/2000/60/oj (visited 2025-01-17)

Gundersen. P., Laurén. A., Finér. L., Ring. E., Koivusalo. H., Saetersdal. M., Weslien. J. O., Sigurdsson. B. D., Högbom. L., Laine. J. & Hansen. K. 2010. Environmental services provided from riparian forests in the Nordic countries. Ambio. https://doi.org/10.1007/s13280-010-0073-9

Hämäläinen. A., Strengbom. J. & Ranius. T. 2018. Conservation value of low-productivity forests measured as the amount and diversity of dead wood and saproxylic beetles. Ecological applications, 28: 1011-1019. https://doi.org/10.1002/eap.1705

Jönsson. M., & Snäll. T. 2020. Ecosystem service multifunctionality of low-productivity forests and implications for conservation and management. Journal of Applied Ecology. https://doi.org/10.1111/1365-2664.13569

Koen. E. L., Bowman. J., Sadowski. C. & Walpole. A. A. 2014. Landscape connectivity for wildlife: development and validation of multispecies linkage maps. Methods in Ecological Evolution. https://doi.org/10.1111/2041-210X.12197

Li. Y., Liu. W., Feng Q., Zhu. M., Yang. L., Zhang. J. & Yin. X. 2023. The role of land use change in affecting ecosystem services and the ecological security pattern of the Hexi Regions, Northwest China. Science of The Total Environment. https://doi.org/10.1016/j.scitotenv.2022.158940

Lind. T. 1998. Quantifying the area of edge zones in Swedish forest to assess the impact of nature conservation on timber yields. Annual report [Årsrapport]. Department of Forest Resource Management. https://pub.epsilon.slu.se/8857/1/lind_t_120410.pdf (visited 2025-01-17)

Oettel. J., Braun. M., Sallmannshofer. M., de Groot. M., Schueler. S., Virgillito. C., Westergren. M., Božič. G., Nagy. L., Stojnić. S. & Lapin. K. 2022. River distance, stand basal area, and climatic conditions are the main drivers influencing lying deadwood in riparian forests. Forest Ecology and Management. https://doi.

org/10.1016/j.foreco.2022.120415

Pielech. R. 2021. Plant species richness in riparian forests: Comparison to other forest ecosystems, longitudinal patterns, role of rare species and topographic factors. Forest Ecology and Management. https://doi.org/10.1016/j.foreco.2021.119400

Renouf. K. & Harding, J. S. 2015. Characterising riparian buffer zones of an agriculturally modified landscape. New Zealand Journal of Marine and Freshwater Research. https://doi.org/10.1080/00288330.2015.1013475

Ruete, A., Snäll, T., Jonsson, B.G. & Jönsson, M. 2017. Contrasting long-term effects of transient anthropogenic edges and forest fragment size on generalist and specialist deadwood-dwelling fungi. Journal of Applied Ecology. https://doi.org/10.1111/1365-2664.12835

Statens Offentliga Utredningar (SOU). 2020. Stärkt äganderätt, flexibla skyddsformer och naturvård i skogen. ISBN 978-91-38-25121-8

Svensson. J., Bubnicki. J. W., Jonsson. B-G., Andersson, J. & Mikusiński. G. 2020. Conservation significance of intact forest landscapes in the Scandinavian mountains green belt. Landscape Ecology. https://doi.org/10.1007/s10980-020-01088-4

Swedish Forest Agency. 2014. Consideration to water [Hänsyn vid vatten]. https://www.skogsstyrelsen.se/globalassets/mer-om-skog/malbilder-for-god-miljohansyn/malbilder-kantzoner-mot-sjoar-och-vattendrag/hansyn-till-vatten-alla-faktablad-samlade-i-en-pdf.pdf (visited 2025-01-17)

Swedish University of Agricultural Sciences (SLU). 2020. Great conservation value of the Scandinavian Mountains Green Belt. Newsletter.
https://www.slu.se/en/ew-news/2020/9/great-conservation-value-of-the-scandinavian-mountains-green-belt/

SR 2024: Unprotected old-growth forests along the Swedish mountains are being felled at a fast pace, Swedish Radio News reports.
https://www.sverigesradio.se/artikel/ancient-swedish-forests-cut-down-at-fast-pace

Analysis of the "old forest" trends and underlying statistics

SR 2024: Unprotected old-growth forests along the Swedish mountains are being felled at a fast pace, Swedish Radio News reports.
https://www.sverigesradio.se/artikel/ancient-swedish-forests-cut-down-at-fast-pace

Micael Jonsson et al 2020 Environ. Res. Lett. 15 0940a8
Stand age and climate influence forest ecosystem service delivery and multifunctionality
DOI 10.1088/1748-9326/abaf1c

SLU 2023: Skogsdata 2023: https://www.slu.se/globalassets/ew/org/centrb/rt/dokument/skogsdata/skogsdata_2023_webb.pdf

Nilsson et.al 2013, SLU, Skogsdata 2013: https://pub.epsilon.slu.se/10812/9/nilsson_et_al_130923.pdf

SLU 2001: Skogsdata 2001: 3. Tema: Skogens ålder.
https://www.slu.se/globalassets/ew/org/centrb/rt/dokument/skogsdata/skogdata_2001_tema.pdf

SLU 2025: Riksskogstaxeringen - TaxWebb (visited March 2025):
https://taxwebb.slu.se/_layouts/15/SLU.SharePoint.TaxWebb/SLUWopiFrame.aspx?id=E6087E4E-A951-42DE-A679-9C6A364F2F14&action=view

Regeringen 2023: Regleringsbrev för budgetåret 2024 avseende Skogsstyrelsen
https://www.esv.se/statsliggaren/regleringsbrev/Index?rbId=24087

SFA 2024: Underlag för kostnadseffektivt genomförande av förnybartdirektivet – slutredovisning Rapport 2024/09 Regeringsuppdrag
https://www.skogsstyrelsen.se/globalassets/om-oss/rapporter/rapporter-2024/rapport-2024-09-underlag-for-kostnadseffektivt-genomforande-av-fornybartdirektivet.pdf

European Commission. 2023. Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests. https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2023)62&lang=en (visited 25-03-19)

Löfgren 2024. Written comment from Rolf Löfgren 2024, former employee at SEPA.

Gardfjell & Hagner. 2019. SLU: Instruktion för Habitatinventering i NILS och THUF, 2019 Version 2019-06-19. https://www.slu.se/globalassets/ew/org/centrb/nils/publikationer/2019/habitatkompendium_nilsthuf_2019.pdf

SLU 2022: DRAFT REPORT V1.0: Ecological conditions in Western taiga (9010) - inventory methods used in Sweden

Land use and forest history

Backström. B. G. & Östlund. L. 2013. En bruksskogs historia - Finspångs Bruk under 300 år.
Future Forests, SLU. ISBN: 978-91-637-4166-1

Caudullo. C., Giovann. T. & de Rigo. D. 2016. Picea abies in Europe: distribution, habitat, usage and threats. In: San-Miguel-Ayanz. J., de Rigo, D., Caudullo, G., Houston Durrant, T. & Mauri. A. (eds.). European Atlas of Forest Tree Species. pp. 114-116. Luxembourg. Publication Office of the European Union.

Emanuelsson. U. 1997. Människan och skogen. Reds. Östlund L. Svenskt skogslandskap i ett europeiskt perspektiv. Kungl. Skogs- och Lantbruksakademien, Nordiska museet och Sveriges lantbruksuniversitet. Nordiska museets förlag. Stockholm.

Enander. K-G. 2000. Riksdagsdebatten 1903 om vår första nationella skogsvårdslag.
https://skogshistoria.se/wp-content/uploads/2018/03/%C3%85rsskrift-2000-s-71-82-K-G-Enander-Riksdagsdebatten-1903.pdf (visited 2025-03-19)

Gustafsson. L. & Ahlén. I. 1996. Växter och djur. Sveriges Nationalatlas.

Högbom. A. G. 1906. Norrland: Naturbeskrifning. pp. 448. Almqvist & Wiksell

Kullman. L. 2008. Early postglacial appearance of tree species in northern Scandinavia: review and perspective. Quaternary Science Reviews. https://doi.org/10.1016/j.quascirev.2008.09.004.

SLU 2024. Vegetationshistoria: https://www.slu.se/institutioner/mark-miljo/miljoanalys/markinfo/standort/vegetation2/vegetationshistoria/

SkogsSverige 2025. Svenska Träd: https://www.skogen.se/svenska-trad/(visited 2025.05.05)

Kuuluvainen. T & Aakala. T. 2011. Natural forest dynamics in boreal Fennoscandia: A review and classification. Silva Fennica. https://doi.org/10.14214/sf.73

Lindbladh. M. 2021. En nykomling i skogen - så erövrade granen Sverige. pp. 200. Hirschfeld Förlag.

Sundberg, S., Carlberg, T., Sandström, J. & Thor, G. (red.) 2019. Värdväxters betydelse för andra organismer – med fokus på vedartade värdväxter. ArtDatabanken Rapporterar 22. ArtDatabanken SLU, Uppsala. https://www.slu.se/artdatabanken/publikationer/vardvaxters-betydelse-for-andra-organismer-med-fokus-pa-vedartade-vardvaxter/

Lockwood et al 2013. A new phylogeny for the genus Picea from plastid, mitochondrial, and nuclear sequences. Molecular Phylogenetics and Evolution. https://doi.org/10.1016/j.ympev.2013.07.004

Lundmark. H., Östlund. L. & Josefsson. T. 2021. Continuity forest or second-generation forest? Historic aerial photos provide evidence of early clear-cutting in northern Sweden. Silva Fennica. https://doi.org/10.14214/sf.10460

Lundqvist. R., Mogren. M., Regnéll. J. & Welinder. S. 2015. Att skriva ett landskap. Vallkullornas och karlars trädristningar i Dalarna. Nordic Journal of Settlement History and Built Heritage. pp. 57–71. ISSN 0349–2834 ISSN. https://uu.diva-portal.org/smash/get/diva2:1533760/FULLTEXT01.pdf (visited 2025-03-19)

Olsson. A. & Pettersson. B. 1993. Kulturmiljövård i skogen: att känna och bevara våra kulturminnen. Skogsstyrelsen. Riksantikvarieämbetet. ISBN 9188462056

Palmbo. F. & Backman. B. 2023. Skogsbrukets påverkan på våra kulturmiljöer. https://kulturmiljonorrbotten.com/2023/11/10/skogsbrukets-paverkan-pa-vara-kulturmiljoer/ (visited 2025-02)

Swedish National Forest Inventory (SNFI). 2024. Taxweb. https://taxwebb.slu.se/ (visited 2024-12-12)

Swedish Species Information Centre (SSCI). 2019. Värdväxters betydelse för andra organismer – med fokus på vedartade värdväxter. Reds. Sundberg. S., Carlberg. T., Sandström. J. & Thor. G. Swedish Species Information Centre. Uppsala.

Niklasson. M., Granström. A. 2000. Ecology: Numbers and sizes of fires: Long-term spatially explicit fire history in a Swedish boreal landscape. Ecology. https://doi.org/10.1890/0012-9658(2000)081[1484:NASOFL]2.0.CO;2

Upadhyay, M., Chen, W., Lenstra, J. et al. Genetic origin, admixture and population history of aurochs (Bos primigenius) and primitive European cattle. Heredity 118, 169–176 (2017). https://doi.org/10.1038/hdy.2016.79

Lundström, M. 2018. Exploring Fennoscandian agricultural history through genetic analysis of aged crop materials. Linköping Studies in Science and Technology, Dissertation No. 1959 ISSN: 0345-7524 ISBN: 978-91-7685-194-4. https://www.diva-portal.org/smash/get/diva2:1261340/FULLTEXT01.pdf

Vilov. A., Kewenter. P. 1995: Skogshistoria i Göteborgs och Bohuslän. https://pub.epsilon.slu.se/4251/1/Avilov_A_Kewenter_P_1995.pdf

Holmberg. L-E. 2005. Skogsstyrelsen, rapport 5, 2005: Skogshistoria år från år 1177-2005 – Skogspolitiska beslut och andra viktiga händelser i omvärlden som påverkat Skogsvårdsorganisationens arbete. https://shop.skogsstyrelsen.se/shop/9098/art87/4646087-1abef6-1735.pdf

Östlund. L., Zackrisson. O. & Axelsson. A-L. 1997. The history and transformation of a Scandinavian boreal forest landscape since the 19th century. Canadian Journal of Forest Research. https://doi.org/10.1139/x97-070

Östlund. L. 2022: From old-growth forests to industrial plantations in northern Sweden: forest history, reference conditions and ecosystem-based management for the future. Lecture given at The Boreal Eco-Forestry Online Conference 2022.

Östlund, L., Laestander, S., Aurell, G. & Hörnberg. G. 2021. The war on deciduous forest: Large-scale herbicide treatment in the Swedish boreal forest 1948 to 1984. Ambio. https://doi.org/10.1007/s13280-021-01660-5

Östlund. L. & Norstedt. G. 2021. Preservation of the cultural legacy of the indigenous Sami in northern forest reserves – Present shortcomings and future possibilities. Forest Ecology and Management. https://doi.org/10.1016/j.foreco.2021.119726

Swedish University of Agricultural Sciences (SLU). 2020. Great conservation value of the Scandinavian Mountains Green Belt. Newsletter.
https://www.slu.se/en/ew-news/2020/9/great-conservation-value-of-the-scandinavian-mountains-green-belt/

Angelstam. P. & Kuuluvainen. T. 2004. Boreal forest disturbance regimes, successional dynamics and landscape structures: A European perspective. Ecological Bulletins. pp. 117-136. Oikos Editorial Office.

Axelsson. A-L. & Östlund. L. 2001. Retrospective gap analysis in a Swedish boreal forest landscape using historical data. Forest Ecology and Management. https://doi.org/10.1016/S0378-1127(00)00470-9

Berglund. H. & Kuuluvainen, T. 2021. Representative boreal forest habitats in northern Europe, and a revised model for ecosystem management and biodiversity conservation. Ambio. https://doi.org/10.1007/s13280-020-01444-3

Bleckert. S. & Petersson. R. 1997. Liv i skogen. Södra skogsägarna. Växjö. ISBN 9789197141437

European Commission. 2021a. Forests. https://ec.europa.eu/environment/forests/index_en.htm (accessed 2021-03-15)

European Commission. 2021b. Nature 2000. https://ec.europa.eu/environment/nature/natura2000/index_en.htm (accessed 2021-03-15)

European Environment Agency. 2020. Conservation status of habitat types and species. Article 17 - 2020 spatial data. https://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec-2 (accessed 2021-03-15)

Food and Agriculture Organization of the United Nations, FAO. 2001. Global Forest Resources Assessment 2000 - Main report. Food and Agriculture Organization of the United Nations. pp. 365.

Kaplan. J. O., Krumhardt. K. M. & Zimmermann. N. 2009. The prehistoric and preindustrial deforestation of Europe. Quaternary Science Reviews. https://doi.org/10.1016/j.quascirev.2009.09.028

Kuuluvainen, T. & Aakala. T. 2011. Natural forest dynamics in boreal Fennoscandia: A review and classification. Silva Fennica. https://doi.org/10.14214/sf.73

Linder, P. & Östlund. L. 1998. Structural changes in three mid-boreal Swedish forest landscapes. Biological Conservation. https://doi.org/10.1016/S0006-3207(97)00168-7

Linder. P. & Östlund. L. 1992. Förändringar i norra Sveriges skogar 1870-1991. Svensk Botanisk Tidskrift. pp. 199-215. Lund. ISSN 0039-646X.
https://slunik.slu.se/kursfiler/SG0179/20064.1819/Linder_o_Ostlund_-_SBT_1992.pdf

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P., Kassem, K.R. 2001. Terrestrial Ecoregions of the World: A New Map of Life on Earth. Bioscience. https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

Swedish Radio (SR). 2017. Sveaskog in SR: "...ur ett historiskt perspektiv så hade vi nästan avskogat Sverige på 1850-talet". https://sverigesradio.se/sida/avsnitt/970209?programid=4058 (Starts after 19.00 min)

Swedish University of Agricultural Sciences (SLU). 2021. Productive forest land. https://www.slu.se/en/Collaborative-Centres-and-Projects/the-swedish-national-forest-inventory/forest-statistics/forest-statistics/productive-forest-land/ (accessed 2021-03-15)
Östlund. L. 2013. https://skogshistoria.se/tidender-artiklar/det-fanns-mycket-virke-i-skogen-ocksa-forr/

Östlund. L., Zackrisson. O. & Axelsson. A-L. 1997. The history and transformation of a Scandinavian boreal forest landscape since the 19th century. Canadian Journal of Forest Research. https://doi.org/10.1139/x97-070

Definitions and dictionary

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). 2019. Global assessment report of the Intergovernmental Science – Policy Platform on Biodiversity and Ecosystem Services, Brondízio. E.S., Settele. J., Díaz. S., Ngo. H.T. (ed.s). IPBES secretariat, Bonn, Germany, ISBN: 978-3-947851-20-1

Liao. C., Luo. Y., Fang. C. & Li. B. 2010. Ecosystem Carbon Stock Influenced by Plantation Practice: Implications for Planting Forests as a Measure of Climate Change Mitigation. PLoS ONE. https://doi.org/10.1371/journal.pone.0010867

Clemmensen. K. E., Bahr. A., Ovaskainen. O., Dahlberg. A., Wallander. H., Stenlid. J., Finlay. R. D., Wardle. D. A. & Lindhal. B. D. 2013. Roots and Associated Fungi Drive Long-Term Carbon Sequestration in Boreal Forest. Science. https://www.science.org/doi/10.1126/science.1231923

Wardle. D.A., Jonsson. M., Bansal. S., Bardgett. R.D., Gundale. M.J. & Metcalfe, D.B. 2012. Linking vegetation change, carbon sequestration and biodiversity: insights from island ecosystems in a long-term natural experiment. Journal of Ecology. https://doi.org/10.1111/j.1365-2745.2011.01907.x

Besnard. S., Carvalhais. N., Arain. M. A., Black. A., de Bruin. S., Buchmann. N., Cescatti. A., Chen. J., Clevers. J. G. P. W. & Desai. A. 2018. Quantifying the effect of forest age in annual net forest carbon balance. Environmental Research Letters. DOI 10.1088/1748-9326/aaeaeb
Luyssaert. S., Schulze. E-D., Börner. A., Knohl. A., Hessenmöller. D., Law. B.E. Ciais. P. & Brace. J. 2008. Old-growth forests as global carbon sinks. Nature. https://doi.org/10.1038/nature07276

Skytt. T., Englund. G. & Jonsson. B-G. 2021. Climate mitigation forestry – temporal trade-offs. Environmental Research Letters. DOI 10.1088/1748-9326/ac30fa

Mackey, B., Prentice, I., Steffen, W. et al. Untangling the confusion around land carbon science and climate change mitigation policy. Nature Clim Change 3, 552–557 (2013). https://doi.org/10.1038/nclimate1804

Vestin. P., Mölder. M., Kljun. N., Cai. Z., Hasan. A., Holst. J., Klemedtsson. L. & Lindroth, A. 2020. Impacts of Clear-Cutting of a Boreal Forest on Carbon Dioxide, Methane and Nitrous Oxide Fluxes. Forests. https://doi.org/10.3390/f11090961

Armstrong. D. I., Staal. A., Abrams. J. F., Winkelmann. R., Sakschewski. B., Loriani. S., Fetzer. I., Cornell. S. E., Rockström. J. & Lenton. T. M. 2022. Exceeding 1.5°C global warming could trigger multiple climate tipping points. Science. https://www.science.org/doi/10.1126/science.abn7950

Rockström, J., Steffen, W., Noone, K. et al. A safe operating space for humanity. Nature 461, 472–475 (2009). https://doi.org/10.1038/461472a

European Commission 2021: New EU Forest Strategy for 2030
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0572

Kuuluvainen. T. 2009. Forest management and biodiversity conservation based on natural ecosystem dynamics in northern Europe: the complexity challenge. Ambio. https://doi.org/10.1579/08-A-490.1

Dahlberg. A. 2011. Kontinuitetsskogar och hyggesfritt skogsbruk. Slutrapport för delprojekt naturvärden. Skogsstyrelsen 7 • 2011.
https://shop.skogsstyrelsen.se/shop/9098/art51/10768251-68e6a3-1837.pdf

Swedish Species Information Centre (SSIC). 2024. Sammanfattning Rödlista 2020. https://www.slu.se/artdatabanken/rodlistning/Sammanfattning-rodlista-2020/ (visited 25-03-19)

SEPA 2024: Olika typer av skog med höga naturvärden.
https://www.naturvardsverket.se/amnesomraden/skyddad-natur/bevara-hoga-naturvarden-och-fa-ersattning/olika-typer-av-skog-med-hoga-naturvarden/

European Commission. 2023. Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests. https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2023)62&lang=en (visited 25-03-19)

SFA. 2023. Skogsvårdslagstiftningen gällande regler 1 september 2022.
https://www.skogsstyrelsen.se/globalassets/lag-och-tillsyn/skogsvardslagen/skogsvardslagstiftningen-2022.pdf

SFA. 2020. Handbok Nyckelbiotopsinventering.
https://www.skogsstyrelsen.se/globalassets/miljo-och-klimat/nyckelbitoper/handbok-nyckelbiotopsinventering.pdf

PROTECT THE FOREST

www.skyddaskogen.se

SVENSKA POSTKODLOTTERIETS STIFTELSE

This report has been produced with support from the Postcode Lottery Foundation

Skogsmonitor.se is run, developed and administered, via project funds from the Postcode Lottery Foundation (Postkodlotteriets stiftelse) and from private donations.

The 1.0 version of Skogsmonitor.se was made possible by project funding from Naturkompaniets Naturbonus 2020. Skogsmonitor's data is validated in sample areas in the forest landscape with funds from Naturkompaniets Naturbonus 2023.

CONTACT US

skogsmonitor@skyddaskogen.se

www.skogsmonitor.se