RESTORATION ECOLOGY
The Journal of the Society for Ecological Restoration

RESEARCH ARTICLE

The contribution to forest conservation and restoration in Sweden of small, protected patches on private forest land

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In forest regions worldwide, the extent of industrial forestry footprint challenges biodiversity conservation and calls for advanced protection and ecological restoration. The conservation efficiency of protected areas needs to be improved, and forest ecosystems need to be set in a state that favors biodiversity, resilience, and provisioning of ecosystem services. Sweden hosts a large share of the European forests, with dominance of non-industrial forest ownership and extensive forestry footprint, hence with a strong need for expanded conservation, restoration, and multiple-use targets. Protection through voluntary Nature Conservation Agreements and regulated Biotope Protection Areas exists since the 1990s, supported by economic compensation to landowners. Across entire Sweden and all ecoregions, we assessed their abundance over a 30-year period, including forest types, restoration practices, rotation intervals, and selection of tree species. These nearly 14,000 patches covering over 70,000 ha are small with a median area of 3–4 ha and rarely larger than 20 ha. Their contribution is important, particularly in southern Sweden with low and fragmented forest cover distributed among many different owners. A decreasing trend in protection is alarming since these contribute to representative forest type across the forest landscape of Sweden. Active restoration dominates over passive set-asides; coniferous forest types are less represented than more rare forest types, many different tree species are favored, and different restoration practices occur, but with few dominating. While recognizing the important contribution, we find that the restoration practices are narrow and repetitive and that a greater diversification is needed to improve conservation and multiple-use targets of forests.

Key words: biodiversity, boreal, boreonemoral, ecological restoration, nemoral, private forest owners

Implications for Practice

- Small-sized Nature Conservation Agreements and Biotope Protection Areas on non-industrial private forestlands are critical components of Sweden's conservation and restoration agenda, but they require further expansion and development.
- Active restoration approaches, which dominate over passive ones, often contradict standard forestry practices by promoting multiple-tree species compositions and favoring rare tree species over common coniferous ones. These approaches provide essential examples of diversification in forests and forestry practices.
- However, current restoration practices remain narrow and repetitive, highlighting significant potential for further diversification and improvement.
- Nature Conservation Agreements and Biotope Protection Areas exemplify initiatives that deserve greater policy recognition and implementation. This is particularly relevant for value chains that acknowledge multiple forest ecosystem benefits and for advancing ecological restoration in forests.

Introduction

The contribution of small-sized protected patches to ensuring functional forest ecosystems and preserving biodiversity is often considered limited compared to larger areas (e.g. Fletcher et al. 2018; Timmers et al. 2022), as suggested by the theory of island biogeography (MacArthur & Wilson 1967). However, in many forested regions globally, long-term land use, fragmented land ownership, and extensive industrial forestry have resulted in significant habitat fragmentation and the loss of natural and near-natural forest habitats. This has left only small patches of high-conservation-value forests (Heino et al. 2015; Svensson et al. 2019; Sabatini et al. 2020). In such contexts, conservation planning increasingly depends on small-sized protected areas, which are recognized as highly valuable for

Author contributions: JS, AL-P, BGJ, NJS share first authorship; JS conceived the idea, scope, and context, coordinated the analyses and writing; AL-P compiled data, performed analyses, developed the illustrations; AL-P, BGJ, NJS participated in scope development, interpretation of results, writing, and revision.

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doi: 10.1111/rec.14390
Supporting information at:
http://onlinelibrary.wiley.com/doi/10.1111/rec.14390/suppinfo

biodiversity conservation and ecosystem services (Wintle et al. 2019; Fahrig 2020; Valdés et al. 2020; Riva et al. 2022).

To ensure ecosystem resilience, habitat connectivity, biodiversity, and the preservation of natural pools of ecosystem services, these small patches benefit from being connected within broader networks that include larger protected areas (Orlikowska et al. 2020; Strassburg et al. 2020). Such networks must be built not only on existing high-conservation-value forest patches but also through ecological rehabilitation and restoration to meet international and EU biodiversity goals, such as the Kunming-Montreal Global Biodiversity Framework (CBD 2022) and the EU Biodiversity Strategy (EC 2020). Consequently, ecological restoration has become a key element of sustainable forest and landscape planning (Chazdon et al. 2016; Besseau et al. 2018; Gutierrez et al. 2022).

Coherent and effective conservation planning poses particular challenges in areas dominated by private and fragmented forest ownership, as seen in many European countries (Tiebel et al. 2022). This is especially true in landscapes characterized by scattered, small forest patches interspersed with agricultural lands (Valdés et al. 2020) or plantation forests (Angelstam et al. 2020). Furthermore, conservation challenges are compounded by the multiple-use demands placed on forests (Knoke et al. 2017; Felton et al. 2020; Blattert et al. 2023), which, under extensive land use, highlight the need for restoration to enhance not just conservation but also ecosystem functionality and socio-economic benefits (Vallecillo et al. 2018; Svensson et al. 2023a).

European countries are accelerating efforts to implement the EU Nature Restoration Law (Bou Dagher Kharrat et al. 2023; EC 2024) and other major initiatives, such as the UN Decade on Ecosystem Restoration (UN 2019) and the CBD target to restore 30% of degraded ecosystems by 2030 (CBD 2022). In forest and forestry policies, restoration is essential for achieving landscape transformation, improving ecological functionality, enhancing conservation status, diversifying forest conditions, and increasing biodiversity and resilience (Halme et al. 2013). Restoration efforts are required at both stand-level and across broader landscapes, ecoregions, and distributions of native forest types (Svensson et al. 2023a).

The northern European forest landscape has undergone extensive transformation over the twentieth century (e.g. Pohjanmies et al. 2017). Large areas have been converted into plantation-like forests, leading to severe habitat fragmentation and the loss of both natural and socio-cultural capital (IPBES 2018; Fleishman et al. 2022; Sullivan et al. 2023; Tadesco et al. 2023). With 28 million hectares of forestlands (SLU 2023), Sweden accounts for approximately 12% of Europe's forests (Forest Europe 2020). Despite increased policy attention on forest conservation since the 1990s (Beland-Lindahl et al. 2017), the dominance of industrial forestry and rotation forestry models has left a significant anthropogenic footprint, undermining Sweden's ability to meet national, European, and international conservation and biodiversity goals (Angelstam et al. 2020; Swedish Forest Agency 2022).

As of 31 December 2022, 2.4 million hectares (9%) of Sweden's forestland was formally protected (Statistics Sweden 2023). However, the geographic distribution of these protected areas is uneven: 58% of the forestland in the mountain region is protected, compared to only 3–5% in the north boreal, south boreal, boreonemoral, and nemoral regions (Statistics Sweden 2023). Consequently, forest protection is heavily concentrated in subalpine habitat types, while forestlands outside the mountain region—comprising 95% of all commercially valuable forest (Statistics Sweden 2023)—require expanded protection to represent a broader range of forest types. Moreover, since forests outside the mountain region are predominantly under non-industrial private forest (NIPF) ownership (Statistics Sweden 2019), future protection efforts must increasingly involve NIPF land.

Nature Conservation Agreements (NCA) and Biotope Protection Areas (BPA) are formal forest protection instruments in Sweden, contributing to national, European, and global conservation agendas. NCAs are voluntary agreements, while BPAs are regulated and enforceable by the state (Statistics Sweden 2023). Both instruments are applied to NIPF land. According to official statistics (Swedish Forest Agency 2024), these instruments collectively protect 14,432 patches, covering a total of 74,773 ha, with average sizes of 7.2 ha (NCA) and 3.9 ha (BPA). Both instruments are based on the identification of Woodland Key Habitats (WKH; Statistics Sweden 2018), where structural features, historical context, physical conditions, and the presence of certain species indicate high conservation value (Timonen et al. 2010).

While some of these areas are set aside for natural development, others are actively managed through restoration practices. As such, NCAs and BPAs represent a national-scale approach to protection and ecological restoration, with specific management practices aimed at enhancing conservation value (cf. Riva et al. 2022), improving ecological functionality (cf. Brennan et al. 2022), broadening ecosystem services (cf. Peura et al. 2018), and restoring biotic and abiotic interactions in forest ecosystems.

In this study, we assessed the contribution of NCAs and BPAs to forest protection and restoration in Sweden over the 30 years these instruments have been in use. Our analysis focused on ecological aspects, including (1) the ecoregional distribution of NCAs and BPAs, (2) the types of protected forests, (3) the ecological restoration practices applied, (4) rotation intervals, and (5) favored versus disfavored tree species. Despite the longevity of NCAs and BPAs as formal instruments, their extent, restoration profiles, diversification potential, and overall contribution to forest conservation have not been comprehensively studied.

Our study aims to inform the scientific community, policymakers, landowners, and forest managers about the capacity of NCAs and BPAs as formal protection instruments within the broader context of forest restoration and conservation in Sweden. We highlight the opportunities for advancing restoration efforts to diversify forestry practices. Finally, we discuss the outcomes and potential of small-sized protection and restoration initiatives across a broad biophysical gradient, including the socio-economic aspects of NCAs as voluntary instruments compared to BPAs as stricter biodiversity protection tools. Our findings have implications for other countries and forest regions characterized by fragmented and diverse forest ownership.

Methods

Nature Conservation Agreements and Biotope Protection Areas

NCAs are voluntary agreements concerning forestland, established under the Swedish Land Code (1970), between a landowner and the State, represented by the Swedish Forest Agency (Statistics Sweden 2018). These agreements stipulate that the landowner, within a specified time period and in exchange for economic compensation, takes additional measures to protect nature conservation values beyond the legal requirements of the Swedish Forestry Act (Swedish Forest Agency 2023). The maximum duration for an NCA is 50 years, although shorter agreements are also available.

For a 50-year agreement, the standard economic compensation amounts to 60% of the merchantable value of the net standing wood biomass (i.e. the value after deducting estimated harvesting and logging costs). Shorter agreements receive proportionally lower compensation (Statistics Sweden 2018). The NCA instrument has also been applied to larger forest landscapes owned by state and private forest companies. For example, Sveaskog, the state forest company, has established 37 ecoparks under NCAs, ranging in size from 1100 to 22,000 ha (Bergman & Gustafsson 2020). These landscape-scale NCAs are not included in this study.

BPAs, on the other hand, are governed by strict regulations enforced by the state under the Environmental Code (1998). These regulations may involve expropriating the land or establishing formal decision-making authority over the management of aboveground vegetation. Typically, areas larger than approximately 20 ha are designated as nature reserves, while smaller areas qualify as BPAs. Landowners are compensated through a one-time payment, amounting to 125% of the reduced market value of the affected management unit (ownership property) (Statistics Sweden 2018).

Study Area

Sweden is predominantly covered by forestlands, accounting for 69% of the total land area (Statistics Sweden 2019). These forests span a biogeographical gradient, from the nemoral biome and habitat types in the south to boreal and subalpine forests in the north, reflecting pronounced biogeographic and socioeconomic differences. Scots pine (*Pinus sylvestris* L.) dominates the forest composition (40%), followed by Norway spruce (*Picea abies* [L.] H. Karts.) at 28%, mixed coniferous forests at 13%, and mixed coniferous and deciduous forests at 7% (Angelstam & Manton 2021). The latter includes approximately 1.1 million hectares of subalpine mountain birch (*Betula pubescens* ssp. czerepanovii Ehrh.) forests at the alpine treeline of the Scandinavian Mountain Range (Hedenås et al. 2016). Hardwood deciduous forests, primarily oak (*Quercus robur* L.) and beech (*Fagus sylvatica* L.), are more prevalent in the southern nemoral and boreonemoral regions.

On forestland suitable for commercial forestry—defined as areas capable of producing a wood biomass growth of at least 1 m^3/ha annually over a rotation period (SLU 2023)—NIPF owners are the dominant group, managing 48% of such land. They are followed by private forest companies (24%), the state and state-controlled companies (20%), and other private and public owners (8%) (Statistics Sweden 2019). NIPF land is primarily located in southern, central, and northeastern coastal areas of Sweden, where urban settlements are common, and the terrain consists of more fertile mineral soils (Statistics Sweden 2019; SLU 2023).

As a result, NIPF-owned land tends to be closer to forest industries and located on sites with higher productivity and biodiversity potential. The average wood biomass site production capacity on NIPF land is 6.3 m^3/ha per year, compared to the national average of 5.5 m^3/ha per year (SLU 2023). NIPF owners are consequently the primary suppliers of raw materials to Sweden's forest industry, contributing 61% of its total supply (SLU 2023). In 2022, there were 311,000 registered NIPF owners (physical persons) (Swedish Forest Agency 2024). These owners collectively managed 232,000 forest management units, with an average area of 34 ha and a median area of 12 ha (Swedish Forest Agency 2021). Notably, most management units are small, with 32% being ≤5 ha and 83% being ≤50 ha (Swedish Forest Agency 2024).

NIPF lands generally also include forests with a long and intensive land use history, characterized by open and semi-open conditions, livestock grazing, and small-scale forestry (Statistics Sweden 2019). Consequently, these forests may exhibit diverse and multifaceted conservation values, necessitating flexible conservation strategies and diversified active restoration practices.

We analyzed the distribution of NCAs and BPAs across Sweden within four ecoregions, following the classification by Statistics Sweden (2023). However, the mountain region was included within the north boreal and south boreal regions due to its limited forest area and the low abundance of NCAs and BPAs (Fig. 1). These four ecoregions broadly reflect Sweden's biogeographical gradient, as well as its patterns of land use, land cover, and landownership (Statistics Sweden 2019). This regional resolution allows for detailed analyses and results that support national reporting efforts.

Data and Analyses

The dataset includes all NCAs established from the first on 1 October 1993, and all BPAs established from the first on 28 February 1994, up to 26 June 2023. These data were extracted from a database provided by the Swedish Forest Agency, comprising a total of 13,779 objects covering 71,164 ha (Table 1). A significant proportion of the total protected area consists of productive forest—97% for BPAs and 90% for NCAs—that would otherwise be of interest for production forestry if not formally protected.

The dataset used in this study includes the following variables for all objects: polygon with centroid position (longitude, latitude), total area, forest area of potential interest for production forestry, agreement date, restoration practice area, type of

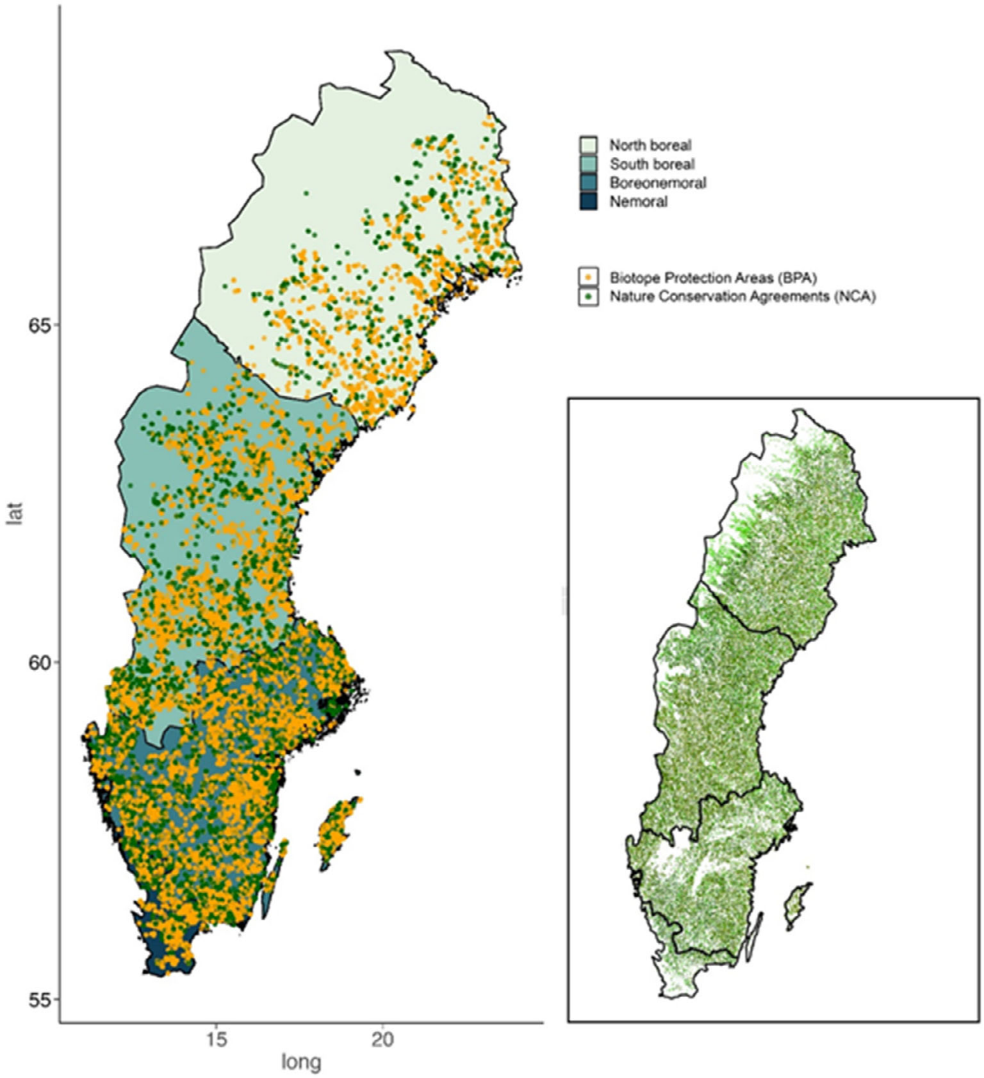

Figure 1. Spatial distribution of all Nature Conservation Agreements (established from 1 October 1993, shown in green) and all Biotope Protection Areas (established from 28 February 1994, shown in yellow) up to 6 June 2023, in Sweden. The map displays the four ecoregions used in this study, arranged from north to south with darker colors representing: North boreal, South boreal, Boreonemoral, and Nemoral. The inset map shows forest cover in Sweden (Swedish Environmental Protection Agency 2023).

restoration practice, target tree species, and return interval of restoration practice. Restoration practices encompass 30 distinct types, which were grouped into 13 categories: (1) Forest floor and hydrology, (2) Shrub layer, (3) Tree regeneration, (4) Tree age heterogeneity, (5) Removal of tree species, (6) Thinning from above, (7) Gap cutting, (8) Dead wood, (9) Prescribed

Table 1. Forest area (ha), protected forest area (ha), number of objects (No) and total area (ha) of Nature Conservation Agreements (NCA) and Biotope Protection Areas (BPA), presented per ecoregion and in total for Sweden. Data by the Swedish Forest agency. *Data from Statistics Sweden (2023). Statistics Sweden (2023) report 38,000 ha NCA and 31,900 ha BPA on forestland up to December 2022, that is, the total area provided here includes area up to June 2023 included a fraction of other land cover than forests.

	*Forest area**	*Protected forest area**	*NCA*		*BPA*	
	ha	*ha*	*No*	*ha*	*No*	*ha*
North boreal	8,740,400	1,564,300	591	5685	1042	4591
South boreal	10,300,500	514,200	1847	13,469	2756	11,314
Boreonemoral	6,909,100	277,000	2384	15,766	3811	14,218
Nemoral	957,900	42,800	457	3133	891	2988
Total	26,907,900	2,398,300	5279	38,053	8500	33,111

burning, (10) Forest edge, (11) Cultural and recreational values, (12) Other, and (13) Set aside (for free development).

The specific restoration types are detailed in Table S1. For the analysis of return intervals, only categories 3, 5, 6, 7, 8, and 9 were included, as these reflect forest stand management practices. Categories 1, 2, and 4 were excluded. Category 4 (tree age heterogeneity) was excluded because the data showed highly variable restoration goals within the forest area and across other land covers and structures. Additionally, a substantial portion of restoration under this category involved non-forest activities, such as re-creating pasture conditions or blocking ditches.

Analyses on favored and disfavored tree species focused only on categories 3, 5, and 6, where practices specifically target selected tree species. For favored tree species, subtypes within category 3 (tree-specific regeneration management) and category 6 (favor selected tree species and tree groups in the canopy layer) were analyzed, where restoration areas were defined for specific species.

Area calculations for restoration practices reflect overlap where different types of practices are planned on the same area. Consequently, while the areas are absolute for each type of practice, they cannot be totaled across multiple practices. Comparisons can, however, be made with areas set aside for natural, free development, where such overlap does not exist.

For complementary data on forest type (i.e. dominant tree species), we utilized publicly available National Land Cover Data (Nationella Marktäckedata [NMD]; Swedish Environmental Protection Agency 2023). This dataset classifies forest types at a 10 × 10 m resolution into eight categories based on either wet, organic, or dry mineral parent material substrata. For this study, we reclassified the NMD data into six categories: (1) pine forest, (2) spruce forest, (3) mixed coniferous forest, (4) mixed forest, (5) deciduous forest, and (6) deciduous hardwood forest. The "deciduous hardwood forest" category combines the NMD classifications "hardwood deciduous forest" and "hardwood deciduous forest with trivial deciduous forest." In the NMD dataset, pine, spruce, and deciduous forests are defined as having ≥70% of tree crown cover by those species. The NMD category "temporarily not forest" was excluded from this study.

All data compilation and analyses were conducted using R (R Core Team 2023) and QGIS (QGIS.org 2024).

Results

Since 1993, a total of 5279 NCAs have been established, covering 38,053 ha, and since 1994, 8500 BPAs have been established, covering 3311 ha (Fig. 2A). A sharp increase in the establishment of BPAs occurred toward the late 1990s and early 2000s, with most BPAs protected between 2000 and 2007. Similarly, the majority of NCAs were established between 2002 and 2009. However, the number of protected objects and total protected area has declined since 2006, while the average size of both NCAs and BPAs has increased significantly over time (Fig. S1). NCAs are generally larger than BPAs (Fig. 2B). The size distributions of both instruments show a concentration in smaller areas, typically up to 5 ha, with average sizes of 7 ha for NCAs and 4 ha for BPAs. Larger objects are rare, with the largest NCA measuring 221 ha and the largest BPA measuring 25 ha.

In terms of total forest area per ecoregion, NCAs and BPAs cover only small proportions: 0.07% (NCA) and 0.36% (BPA) in the north boreal ecoregion, and 0.33% (NCA) and 0.31% (BPA) in the nemoral ecoregion (Table 1). However, relative to the total protected forest area, the two instruments combined account for 0.7, 4.8, 10.8, and 14.3% of protected forests in the north boreal, south boreal, boreonemoral, and nemoral ecoregions, respectively.

Protection of deciduous hardwood forests is most prominent in the nemoral ecoregion, deciduous and pine forests dominate in the boreonemoral ecoregion, and pine and spruce forests dominate in the south and north boreal ecoregions (Table S2; Fig. 3), reflecting the prevalent forest types in these regions. Forests on wet, organic soils are generally rare. Across Sweden, pine forests (19,964 ha) and spruce forests (18,830 ha) are the most represented in NCAs and BPAs, followed by deciduous forests (11,888 ha), mixed forests (9522 ha), mixed coniferous forests (8060 ha), and deciduous hardwood forests (7447 ha).

The combined area under active restoration totals 40,579 ha, accounting for 57% of the total NCA and BPA area (Table S3; Fig. 4). Restoration practices within forest stands are dominated by tree species removal and thinning from above in the nemoral and boreonemoral ecoregions, with prescribed burning also playing a significant role in the south boreal ecoregion. In the north boreal ecoregion, prescribed burning is the most dominant practice. In total, tree species removal is applied on 9420 ha, and thinning from above on 8529 ha. Apart from cultural and recreational value restoration, particularly in the boreonemoral region, other restoration practices unrelated to trees are infrequent. The largest restoration category, however, is the area set aside for natural, free development, totaling 30,585 ha, which is especially dominant in the south and north boreal ecoregions.

For forest stand restoration management practices, the reoccurring time interval is predominantly between 1 and 5 years, except for prescribed burning, which is distributed more evenly across all time intervals (Table 2). Longer intervals of 30–50 years are rare for other activities.

Regarding restoration involving specific tree species selection, the results indicate that restoration practices favor diversity in tree species composition (Table S4; Fig. 5). In total, 24 different species are specifically selected to be favored in both the understory and regeneration stages, as well as in the canopy layer. However, a few species dominate, particularly Aspen (*Populus tremula* L.), birch (*Betula* sp.), oak, and pine in the canopy layer, and Aspen, birch, oak, pine, Rowan (*Sorbus aucuparia* L.), and willow (*Salix* sp.) in the understory. Of these, oak is restricted to the nemoral and boreonemoral ecoregions, while the other species occur across Sweden's forest landscapes. In contrast, Norway spruce is the most disfavored species, accounting for 95% of the area where tree removal is practiced. This includes both trees with a diameter greater than 15 cm at breast height (dbh) and understory regeneration (Table S5).

Discussion

Formally protected NCAs and BPAs on NIPF lands have contributed to the Swedish forest conservation agenda for 30 years,

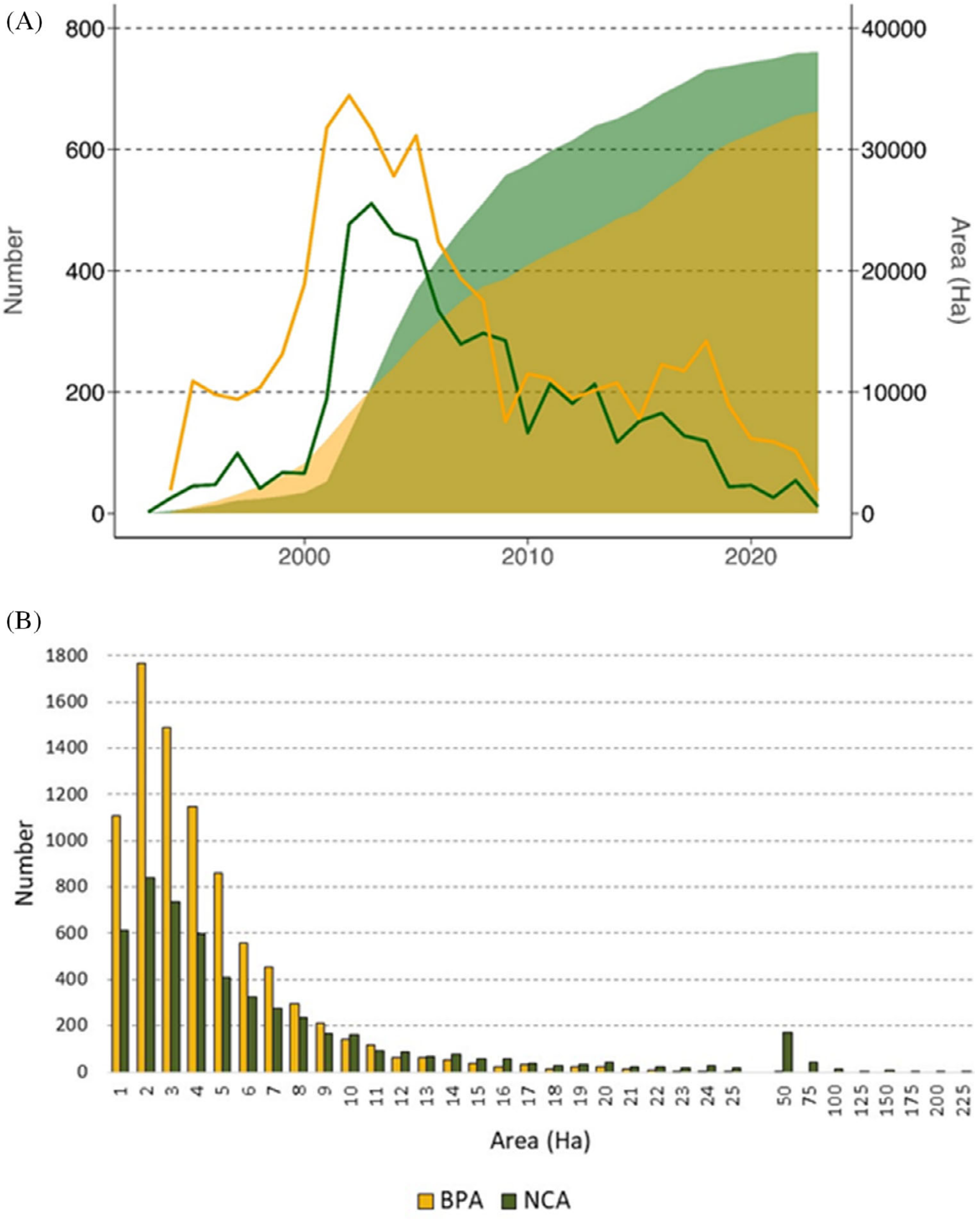

Figure 2. (A) Annual number and accumulated area of Nature Conservation Agreements (NCAs) and Biotope Protection Areas (BPAs) over time in Sweden. (B) Size distribution of NCAs and BPAs, grouped into 1 ha classes (maximum class value displayed on the axis) up to 24.1–25.0 ha, followed by broader classes: 25.1–50.0, 50.1–75.0 ha, etc. The mean, median, and standard deviation of NCA size are 7.2, 3.8, and 12.3 ha, respectively, while for BPAs, they are 3.9, 3.0, and 3.4 ha.

encompassing representative forest habitat types from the nemoral ecoregion in the south to the boreal and subalpine regions in the north. These areas complement larger protected areas, such as nature reserves, and contribute to the national conservation agenda. Although their total area is small relative to Sweden's vast forest cover, their role is significant, particularly in southern Sweden, where forest cover is proportionally lower, more fragmented, and distributed among many owners (Statistics Sweden 2019; SLU 2023).

The establishment of NCAs and BPAs increased substantially in frequency and area until 2006 but has since declined due to reduced governmental funding (Statistics Sweden 2018). Between 2020 and June 2023, only 137 NCAs (1178 ha) and 381 BPAs (2580 ha) were established. This decline persists despite an evident need to protect larger areas and more representative forest types, as highlighted by the Swedish Forest Agency's 2022 evaluation of Swedish forests' sustainability. Moreover, the imbalance in protected areas is stark, with limited coverage in forest landscapes below the Scandinavian Mountain Green Belt foothills (Svensson et al. 2020). This low and declining establishment of NCAs and BPAs in southern and northern coastal and

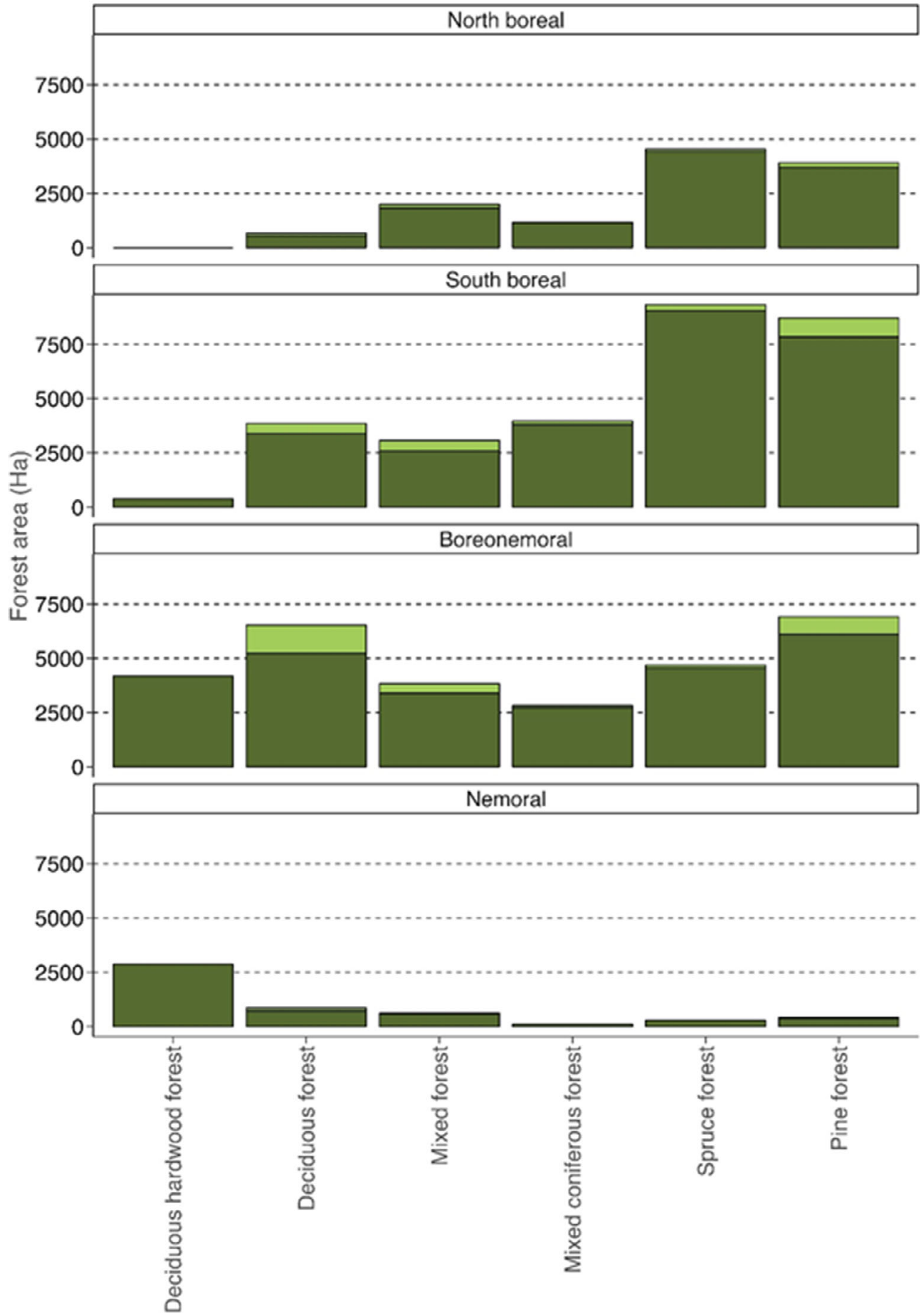

Figure 3. Total area (ha) of forest types within combined Nature Conservation Agreements and Biotope Protection Areas, presented by ecoregion in Sweden. Forests on wetland substrates are shown in light green, while forests not on wetland are displayed in dark green. Land cover data were sourced from the Swedish Environmental Protection Agency (2023).

inland forest landscapes, which are heavily transformed, is unfortunate (Bubnicki et al. 2024).

The inventory and registration of WKHs in Sweden were suspended in 2019 after an extended and heated debate, as the Swedish government withdrew funding (Hallberg-Sramek et al. 2020; Jakobsson et al. 2021). Reliable data, therefore, dates back several years but suggests that WKHs are substantially present on NIPF lands. As of 2015, approximately 61,200 WKHs covering 170,000 ha were reported outside forest company ownership (Wester & Engström 2016). Since NCAs and BPAs are based on WKH recognition, the suspension of the WKH inventory likely contributed

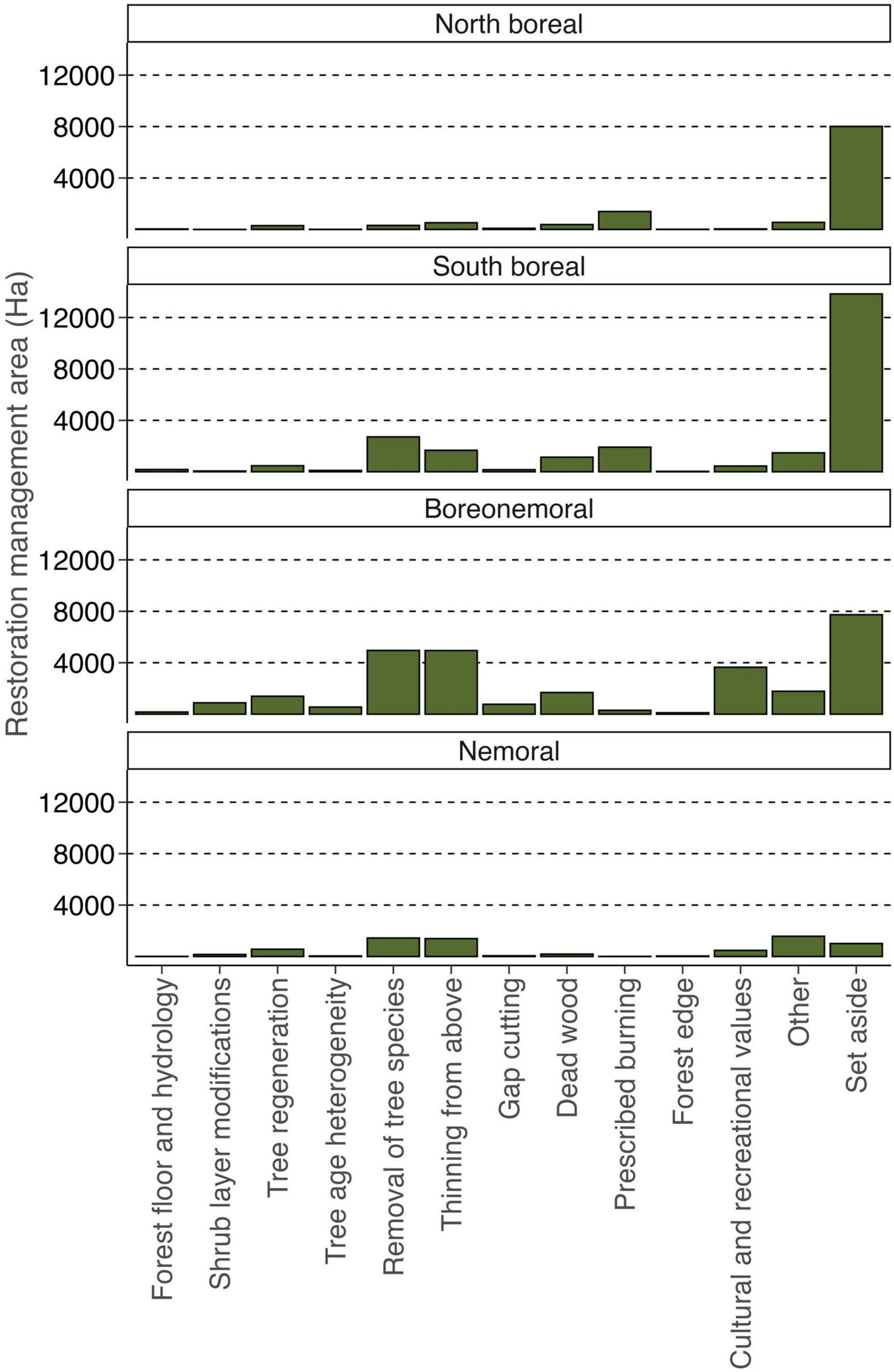

Figure 4. Area (ha) of restoration management practices within combined Nature Conservation Agreements and Biotope Protection Areas, presented by ecoregion in Sweden.

to the recent low levels of establishment and the continued loss of high-conservation-value forest patches due to clear-cutting or heavy thinning. The average clear-cut unit in Sweden is 3.6 ha (mean) and 2.2 ha (median) (Swedish Forest Agency 2024), which aligns with the size of most NCAs and BPAs.

Table 2. Proportion (%) of time interval (classes) between reoccurring restoration management practices. The calculations were based on forest area with different restoration management practices. A fraction (circa 8% in total and 1–2% per activity) of the area contains no data on time interval. These areas were considered in the totals of each activity; thus, the table does not sum to 100% horizontally.

	Time interval (year)			
	1–5	*5–10*	*10–30*	*30–50*
Tree regeneration	47	35	15	1
Removal of tree species	49	29	19	2
Thinning from above	50	30	17	1
Gap cutting	47	31	17	2
Dead wood	50	34	14	1
Prescribed burning	27	28	19	24

Our results demonstrate that NCAs and BPAs protect representative forest types, with deciduous hardwood forests dominating in the south and coniferous forests in the north. Compared with forest statistics (SLU 2023), NCAs and BPAs cover a higher proportion of deciduous forests (15.7 vs. 6.5%), deciduous hardwood forests (9.8 vs. 1.1%), and mixed forests (12.6 vs. 6.9%), while coniferous forests are underrepresented (62 vs. 82%). Thus, NCAs and BPAs are skewed toward protecting less abundant forest types.

Active restoration efforts account for 57% of the total NCA and BPA area, exceeding the area set aside for natural, free development (43%). This contrasts with earlier estimates, such as Wester and Engström (2016), who reported that only 13% of the WKH area required active restoration. Our results suggest that active restoration is often necessary even in WKHs to improve their ecological status. Restoration practices analyzed in this study align with the range of interventions known to support forest biodiversity (cf. Bernes et al. 2015). Passive restoration dominates in boreal ecoregions, where larger fragments of high-conservation-value forests exist (Bubnicki et al. 2024).

The time interval between active restoration interventions is generally short, typically up to 10 years for most practices, except prescribed burning, which occurs across intervals up to 50 years. Considering natural forest dynamics and disturbance regimes (Kuuluvainen & Aakala 2011; Berglund & Kuuluvainen 2021), practices like prescribed burning and creating

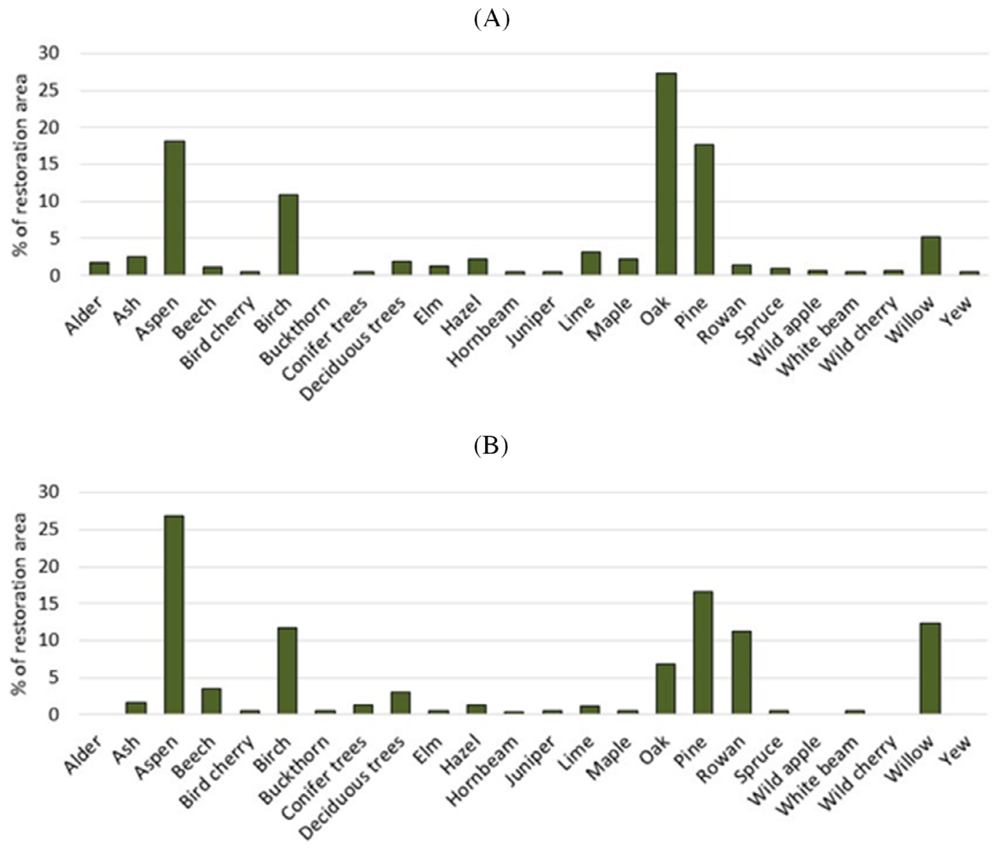

Figure 5. Favored tree and tall woody shrub species within canopy (A) and understory and regeneration layers (B), shown as a percentage of the total restoration area for all favored species. (A) Data are derived from the subtype Favor selected tree species and tree groups in canopy layer within the restoration type Thinning from above. Data are calculated for the subtype tree-specific regeneration management within the restoration type tree regeneration (see Table S1). Species with a contribution below 0.5% of the total area are not displayed in the diagram. Bars with no visible height indicate no recorded occurrence. Calculations were based on the registered area for each species relative to the total registered area for all species. Areas without registered species data were excluded. See Table S5 for detailed area data and Latin species names.

deadwood should occur at longer intervals, potentially exceeding 50 years. In contrast, interventions like thinning, small gap creation, and species-specific tree regeneration may require frequent repetition and should be planned, executed, and financed accordingly. Further research is needed to explore the optimal timing of restoration practices and their conservation effects, as no such data is currently available. This highlights the importance of adaptive restoration approaches with conservation-targeted actions, regular monitoring, and reporting.

Commercial forestry in Sweden is predominantly focused on Scots pine and Norway spruce, with birch, Aspen, introduced Lodgepole pine (*Pinus contorta*), oak, and beech contributing to a lesser extent (Svensson et al. 2023a). Spruce, pine, and Lodgepole pine account for 82% of forestlands under commercial forestry, with single-species spruce forests covering 27% (SLU 2023). Interestingly, our results show that spruce is the most disfavored tree species in both young plantation forests and older merchantable stands. Restoration, on the other hand, favors 24 tree and tall shrub species, emphasizing species with low or no commercial wood value but high ecological significance. Aspen (*Populus tremula*), birch (*Betula* sp.), oak, pine, Rowan (*Sorbus aucuparia*), and willow (*Salix* sp.) are the most favored species.

The applied restoration management in NCAs and BPAs is currently limited to a narrow range of practices. Given the natural variability in forest structure and dynamics across northern Europe (Esseen et al. 1997), there is immense potential to diversify restoration further. This diversification should consider land use history, ownership structures, climate change adaptation, emerging markets, and multiple-use demands (cf. Gann et al. 2019). Forestry on NIPF lands, like large-scale industrial forestry, is dominated by wood biomass yield and systematic rotation systems (Jonsson et al. 2019). However, these lands are also subject to other uses, such as reindeer husbandry by the Sami people in northern Sweden (Pape & Löffler 2012), recreation, tourism, and hunting (Neumann et al. 2022; Haukeland et al. 2023).

Emerging markets, including carbon and biodiversity credits (Iwarsson Wide 2022; Le et al. 2024), and alternative value chains suggest that forest governance and management must diversify (Knoke et al. 2017; Felton et al. 2020). Restoration should be integrated as a key component of future forest policy to secure biodiversity and ecosystem functionality while allowing the provision of multiple goods and services (Ferraro et al. 2013; Vallecillo et al. 2018; Svensson et al. 2023a).

NCAs, which are not limited to nature conservation (Statistics Sweden 2018), offer opportunities to protect additional values. As of 2023, only 15 NCAs (87 ha) have been established for non-nature conservation purposes (Swedish Forest Agency 2024). This underutilized potential warrants further exploration. The voluntary nature of NCAs, coupled with the ability to incorporate restoration within the stricter BPA framework, allows for alternative governance goals that may attract landowners, particularly if restoration aligns with management targets and offers economic benefits.

Finally, in regions with fragmented private land ownership, small protected areas can play a disproportionately significant role in biodiversity conservation and connectivity (Fahrig 2020; Brennan et al. 2022). Spatial planning that integrates small forest patches with targeted restoration can optimize ecological outcomes (Wang 2023). Future research should identify critical drivers, such as funding, political initiatives, and landowner willingness, to promote conservation over clear-cutting small forest patches. The experiences gained from NCAs and BPAs in Sweden provide valuable insights for forest restoration and conservation in similar contexts across Europe and beyond.

Acknowledgments

This study is part of the SUPERB: EU Horizon 2020 Research and Innovation Programme (SUPERB: Upscaling Forest Restoration—SUPERB [forest-restoration.eu]; Grant Agreement number 101036849). We acknowledge the assistance by G. Eriksson, Swedish Forest Agency, for compiling and providing the database with Nature Conservation Agreements and Biotope Protection Areas in Sweden.

LITERATURE CITED

Angelstam P, Manton M, Green M, Jonsson BG, Mikusiński G, Svensson J, Maria Sabatini F (2020) Sweden does not meet agreed national and international forest biodiversity targets: a call for adaptive landscape planning. Landscape and Urban Planning 202:103838. https://doi.org/10.1016/j.landurbplan.2020.103838

Angelstam P, Manton M (2021) Effects of forestry intensification and conservation on green infrastructures: A spatio-temporal evaluation in Sweden. Land 10:531. https://doi.org/10.3390/land10050531

Beland-Lindahl K, Sténs A, Sandström C, Johansson J, Lidskog R, Ranius T, Roberge J-M (2017) The Swedish forestry model: more of everything? Forest Policy and Economics 77:44–55. https://doi.org/10.1016/j.forpol.2015.10.012

Berglund H, Kuuluvainen T (2021) Representative boreal forest habitats in northern Europe, and a revised model for ecosystem management and biodiversity conservation. Ambio 50:1003–1017. https://doi.org/10.1007/s13280-020-01444-3

Bergman P, Gustafsson L (2020) Ecoparks – forest landscapes in Sweden with emphasis on biodiversity conservation and recreation. Pages 369–378. In: Krumm F, Schuck A, Rigling A (eds) 2020: how to balance forestry and biodiversity conservation – a view across Europe. European Forest Institute; Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmendorff. https://doi.org/10.16904/envidat.196

Bernes C, Jonsson BG, Junninen K, Lõhmus A, Macdonald E, Müller J, Sandström J (2015) What is the impact of active management on biodiversity in boreal and temperate forests set aside for conservation or restoration? A systematic map. Environmental Evidence 4:25. https://doi.org/10.1186/s13750-015-0050-7

Besseau P, Graham S, Christophersen T (eds) (2018) Restoring forests and landscapes: the key to a sustainable future. Global Partnership on Forest and Forest Landscape Restoration, Vienna, Austria. ISBN: 978-3-902762-97-9

Blattert C, Eyvindson K, Mönkkönen M, Raatikainen KJ, Triviño M, Duflot R (2023) Enhancing multifunctionality in European boreal forests: the potential role of triad landscape functional zoning. Journal of Environmental Management 348:119250. https://doi.org/10.1016/j.jenvman.2023.119250

Bou Dagher Kharrat M, Pötzelberger E, Nabuurs GJ, Bauhaus J, O'Hara J, Alberdi I, et al. (2023) SUPERB's policy recommendations for the EU nature restoration law. SUPERB – upscaling forest restoration. Policy brief, May 2023. https://bestlife2030.org/wp-content/uploads/IUCN_

BestLife2030_nature_restoration_law_policy_brief_EN.pdf (accessed 1 Mar 2024)

Brennan A, Naidoo R, Greenstreet L, Mahrabi Z, Ramankutty N, Kremen C (2022) Functional connectivity of the worlds' protected areas. Science 376:1101–1104. https://doi.org/10.1126/science.abl8974

Bubnicki JW, Angelstam P, Mikusiński G, Svensson J, Jonsson BG (2024) Mapping forests with different levels of naturalness using machine learning and landscape data mining. Communications Earth & Environment 5:196. https://doi.org/10.1038/s43247-024-01325-7

CBD (Convention of Biological Diversity) (2022) Kunming-Montreal global biodiversity framework. Convention of Biological Diversity Decision CBD/-COP/DEC/15/4 https://www.cbd.int/convention (accessed 1 Mar 2024).

Chazdon RL, Brancalion PHS, Laestadius L, Bennett-Curry A, Buckingham K, Kumar C, Moll-Rocek J, Vieira ICG, Wilson SJ (2016) When is a forest a forest? Forest concepts and definitions in the era of forest and landscape restoration. Ambio 45:538–550. https://doi.org/10.1007/s13280-016-0772-y

EC (European Commission) (2020) EU biodiversity strategy for 2030 – bringing nature back into our lives. European Commission 380, Brussels, Belgium

EC (European Commission) (2024) EU Nature Restoration Law, European Commission: the EU #NatureRestoration law. https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en (accessed 1 Mar 2024)

Environmental Code (1998) Miljöbalk, SFS 1998:808. Swedish Parliament Office. Miljöbalk (1998:808) Sveriges riksdag (in Swedish). https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/miljobalk-1998808_sfs-1998-808/ (accessed 1 Mar 2024)

Esseen P-A, Ehnström B, Ericson L, Sjöberg K (1997) Boreal forests. Ecological Bulletins 46:16–47. https://www.jstor.org/stable/20113207 (accessed 5 Feb 2025)

Fahrig L (2020) Why do several small patches hold more species than few large patches. Global Ecology and Biogeography 29:615–628. https://doi.org/10.1111/geb.13059

Felton A, Löfroth T, Angelstam P, Gustafsson L, Hjälten J, Felton AM, et al. (2020) Keeping pace with forestry: multi-scale conservation in a changing production forest matrix. Ambio 49:1050–1064. https://doi.org/10.1007/s13280-019-01248-0

Ferraro PJ, Hanauer MM, Miteva DA, Canavire-Bacarreza GJ, Pattanayak SK, Sims KR (2013) More strictly protected areas are not necessarily more protective: evidence from Bolivia, Costa Rica, Indonesia, and Thailand. Environmental Research Letters 8:025011. https://doi.org/10.1088/1748-9326/8/2/025011/meta

Fleishman F, Coleman E, Fisher H, Kashwan P, Pfeifer M, Ramprasad V, Solorzano CR, Veldman JW (2022) Restoration prioritization must be informed by marginalized people. Nature 607:E5–E6. https://doi.org/10.1038/s41586-022-04733-x

Fletcher RJ, Didham RK Jr, Banks-Leite C, Barlow J, Ewers RM, Rosindell J, et al. (2018) Is habitat fragmentation good for biodiversity? Biological Conservation 226:9–15. https://doi.org/10.1016/j.biocon.2018.07.022

Forest Europe (2020) State of Europe's forests 2020. UNECE. FAO. Ministerial Conference on the Protection of Forests in Europe. https://foresteurope.org/wp-content/uploads/2016/08/SoEF_2020.pdf (accessed 6 Mar 2024)

Gann GD, McDonald T, Walder B, Aronson J, Nelson CR, Jonson J, et al. (2019) International principles and standards for the practice of ecological restoration. Second edition. Restoration Ecology 27:S1–S46. https://doi.org/10.1111/rec.13035

Gutierrez V, Hallet JG, Ota L, Sterling E, Wilson SJ, Bodin B, et al. (2022) Forest and landscape restoration monitoring frameworks: how principled are they? Restoration Ecology 30:13572. https://doi.org/10.1111/rec.13572

Hallberg-Sramek I, Bjärstig T, Nordin A (2020) Framing woodland key habitats in the Swedish media – how has the framing changed over time? Scandinavian Journal of Forest Research 35:198–209. https://doi.org/10.1080/02827581.2020.1761444

Halme P, Allen KA, Aunins A, Bradshaw RHW, Brumelis G, Cada V, et al. (2013) Challenges of ecological restoration: lessons from forests in northern Europe. Biological Conservation 167:248–256. https://doi.org/10.1016/j.biocon.2013.08.029

Haukeland JV, Fredman P, Tyrväinen L, Siegrist D, Lindberg K (2023) Prospects for nature-based tourism: identifying trends with commercial potential. Journal of Ecotourism 1–18. https://doi.org/10.1080/14724049.2023.2178444

Hedenås H, Christensen P, Svensson J (2016) Changes in vegetation cover and composition in the Swedish mountain region. Environmental Monitoring and Assessment 188:452. https://doi.org/10.1007/s10661-016-5457-2

Heino M, Kummu M, Makkonen M, Mulligan M, Verburg PH, Jalava M, Räsänen TA (2015) Forest loss in protected areas and intact forest landscapes: a global analysis. PLoS One 10:e0138918. https://doi.org/10.1371/journal.pone.0138918

IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) (2018) In: Fischer M, Rounsevell M, Rando AT-M, Mader A, Church A, Elbakidze M, et al. (eds) Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for Europe and Central Asia of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES Secretariat, Bonn, Germany

Iwarsson Wide M (2022) Nya värdekedjor från skogen. Klimatkompensation och ekologisk kompensation. Skogforsk, Arbetsrapport, 1113–2022 (in Swedish). https://www.skogforsk.se/cd_20221123110846/contentassets/78d0b9f498e244f39db1488d88c9957d/arbetsrapport-1113_2022.pdf (accessed 5 Feb 2025)

Jakobsson R, Olofsson E, Ambrose-Oji B (2021) Stakeholder perceptions, management and impacts of forestry conflicts in southern Sweden. Scandinavian Journal of Forest Research 38:68–82. https://doi.org/10.1080/02827581.2020.1854341

Jonsson BG, Svensson J, Mikusiński G, Manton M, Angelstam P (2019) European Union's last intact forest landscape is at a value chain crossroad between multiple use and intensified wood production. Forests 10:564. https://doi.org/10.3390/f10070564

Knoke T, Messerer K, Paul C (2017) The role of economic diversification in forest ecosystem management. Current Forestry Reports 3:93–106. https://doi.org/10.1007/s40725-017-0054-3

Kuuluvainen T, Aakala T (2011) Natural forest dynamics in boreal Fennoscandia: a review and classification. Silva Fennica 45:823–841. https://doi.org/10.14214/sf.73

Le TAT, Vodden K, Wu J, Bullock SG (2024) Payments for ecosystem services programs: a global review of contributions towards sustainability. Heliyon 10:e22361. https://doi.org/10.1016/j.heliyon.2023.e22361

MacArthur RH, Wilson EO (1967) The theory of island biogeography. Princeton University Press, Princeton, NJ, USA

Neumann W, Levers C, Widemo F, Singh NJ, Cromsigt JPGM, Kuemmerle T (2022) Hunting as land use: understanding the spatial associations among hunting, agriculture, and forestry. Ecology and Society 27:2. https://doi.org/10.5751/ES-12882-270102

Orlikowska EH, Svensson J, Roberge J-M, Blicharska M, Mikusiński G (2020) Hit or miss? Evaluating the effectiveness of Natura 2000 for conservation of forest bird habitat in Sweden. Global Ecology and Conservation 22: e00939. https://doi.org/10.1016/j.gecco.2020.e00939

Pape R, Löffler J (2012) Climate change, land use conflicts, predation and ecological degradation as challenges for reindeer husbandry in northern Europe: what do we really know after half a century of research? Ambio 41:421–434. https://doi.org/10.1007/s13280-012-0257-6

Peura M, Burgas D, Eyvindson K, Repo A, Mönkkönen M (2018) Continuous cover forestry is a cost-efficient tool to increase multifunctionality of boreal production forests in Fennoscandia. Biological Conservation 217:104–112. https://doi.org/10.1016/j.biocon.2017.10.018

Pohjanmies T, Triviño M, Le Tortorec E, Mazziotta A, Snäll T, Mönkkönen M (2017) Impact of forestry on boreal forests: an ecosystem services perspective. Ambio 46:743–755. https://doi.org/10.1007/s13280-017-0919-5

QGIS.org (2024) QGIS geographic information system. QGIS Association. http://www.qgis.org (accessed 3 Oct 2024)

R Core Team (2023) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Version R 4.4.2 https://www.R-project.org/ (accessed 3 Oct 2023)

Riva F, Martin CJ, Millard K, Fahring L (2022) Loss of world's smallest forests. Global Change Biology 28:7164–7166. https://doi.org/10.1111/gcb.16449

Sabatini FM, Keeton WS, Lindner M, Svoboda M, Ververk PJ, Bauhaus J, et al. (2020) Protection gaps and restoration opportunities for primary forests in Europe. Diversity and Distributions 26:1646–1662. https://doi.org/10.1111/ddi.13158

SLU (Sveriges lantbruksuniversitet) (2023) Forest statistics 2023, official statistics of Sweden. Skogsdata 2023. Swedish University of Agricultural Sciences (in Swedish). https://internt.slu.se/globalassets/ew/org/centrb/rt/dokument/skogsdata/skogsdata_2023_webb.pdf (accessed 1 Sep 2023)

Statistics Sweden (2018) Biotope protection areas and nature conservation agreements on forest land in 2017 (Biotopskyddsområden och naturvårdsavtal på skogsmark). Official Statistics Sweden JO1402 SM 1801 (in Swedish). https://www.skogsstyrelsen.se/globalassets/statistik/statistiska-meddelanden/jo1402-statistiska-meddelanden-biotopskyddsomraden-och-naturvardsavtal-2017.pdf (accessed 5 Feb 2025)

Statistics Sweden (2019) Land use in Sweden. 7th ed. SCB Statistiska centralbyrån, SCB-Tryck, Örebro, Sweden ISBN: 978-91-618-1660-6 (in Swedish)

Statistics Sweden (2023) Protected nature 2022-12-31. MI 41 2022A01 (in Swedish). Statistics Sweden. ISSN: 1654-3947. www.scb.se (accessed 5 Feb 2025)

Strassburg BBN, Iribarrem A, Beyer HL, Coreido CL, Crouzeilles R, Jakovac CC, et al. (2020) Global priority areas for ecosystem restoration. Nature 586:724–729. https://doi.org/10.1038/s41586-020-2784-9

Sullivan AR, Karlsson E, Svensson D, Brindefalk B, Villegas JA, Mikko A, et al. (2023) Airborne eDNA captures three decades of ecosystem biodiversity. bioRxiv preprint, posted 11 Dec 2023. https://doi.org/10.1101/2023.12.06.569882

Svensson J, Andersson J, Sandström P, Mikusiński G, Jonsson BG (2019) Landscape trajectory of natural boreal forest loss as an impediment to green infrastructure. Conservation Biology 33:152–163. https://doi.org/10.1111/cobi.13148

Svensson J, Bubnicki JW, Jonsson BG, Andersson J, Mikusiński G (2020) Conservation significance of intact forest landscapes in the Scandinavian Mountains Green Belt. Landscape Ecology 35:2113–2131. https://doi.org/10.1007/s10980-020-01088-4

Svensson J, Mikusiński G, Bubnicki JW, Andersson J, Jonsson BG (2023) Boreal forest landscape restoration in the face of extensive forest fragmentation and loss. Pages 491–510. In: Girona MM, Morin H, Gaulthier S, Bergeron Y (eds) Sustainable forest management of the boreal forest in the face of climate change. Springer Nature, Cham, Switzerland

Swedish Environmental Protection Agency (2023) National Land Cover Database. Naturvårdsverket. Nationella Marktäckedata (NMD). https://www.naturvardsverket.se/ (accessed 3 Oct 2023)

Swedish Forest Agency (2021) JO1405. Factsheet. Forest properties and ownership structure 2021. Fastighets-och ägarstruktur i skogsbruket 2021 (in Swedish). https://www.skogsstyrelsen.se/globalassets/statistik/statistiska-meddelanden/jo1405-statistiska-meddelanden-fastighets--och-agarstruktur-i-skogsbruk-2020-uppdaterad20211013.pdf (accessed 13 Dec 2024)

Swedish Forest Agency (2022) Sustainable forests In-depthevaluation 2023. Report 2022:12 https://www.skogsstyrelsen.se/globalassets/om-oss/rapporter/rapporter-20222021202020192018/rapport-2022-12-sustainable-forests-in-depth-evaluation-2023-english-summary.pdf (accessed 1 May 2023)

Swedish Forest Agency (2023) Skogsvårdslagstiftningen Gällande regler 1 september 2022 (In Swedish). http://skogsstyrelsen.se/ (accessed 5 Feb 2025)

Swedish Forest Agency (2024) Statistics database. https://pxweb.skogsstyrelsen.se/pxweb/sv/ssd/ (accessed 7 Feb 2024)

Swedish Land Code (1970) Jordabalk, 1970:994. Swedish Parliament, Ministry of Justice: Jordabalk (1970:994). https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/jordabalk-1970994_sfs-1970-994/ (accessed 6 Mar 2024)

Tadesco AM, López-Cubillos S, Chazdon R, Rhodes JR, Archibald CL, Pétrez-Hämmerle K-V, et al. (2023) Beyond ecology: ecosystem restoration as a process for social-ecological transformation. Trends in Ecology & Evolution 38:643–653. https://doi.org/10.1016/j.tree.2023.02.007

Tiebel M, Mölder A, Plieninger T (2022) Conservation perspectives of small-scale private forest owners in Europe: a systematic review. Ambio 51: 836–848. https://doi.org/10.1007/s13280-021-01615-w

Timmers R, van Kuijk M, Verweij PA, Ghazoul J, Hautier Y, Laurance WF, et al. (2022) Conservation of birds in fragmented landscapes requires protected areas. Frontiers in Ecology and the Environment 20:361–369. https://doi.org/10.1002/fee.2485

Timonen J, Siitonen J, Gustafsson L, Kotiaho JS, Stokland JN, Sverdrup-Thygeson A (2010) Woodland key habitats in northern Europe: concepts, inventory and protection. Scandinavian Journal of Forest Research 25: 309–324. https://doi.org/10.1080/02827581.2010.497160

UN (United Nations) (2019) General Assembly of the United Nations. Distr. General, March 6, 2019. Resolution A/RES//#/284. United Nations Decade on Ecosystem Restoration (2021–2030). https://digitallibrary.un.org/record/3794317?v=pdf (accessed 1 May 2021)

Valdés A, Lenoir J, De Frenne P, Andrieu E, Brunet J, Charbriere O, et al. (2020) High ecosystem service delivery potential of small woodlands in agricultural landscapes. Journal of Applied Ecology 57:4–16. https://doi.org/10.1111/1365-2664.13537

Vallecillo S, Ploce C, Barbosa A, Castillo CP, Vandecasteele I, Rush G, Maes J (2018) Spatial alternatives for Green Infrastructure planning across the EU: an ecosystem service perspective. Landscape and Urban Planning 174:41–54. https://doi.org/10.1016/j.landurbplan.2018.03.001

Wang X (2023) Identification of restoration hotspots in landscape-scale green infrastructure planning based on model-predicted connectivity forests. Master thesis in Geographical Information Science nr 161. Department of Geography and Ecosystem Science. Centre for Geographical Information Systems, Lund University, Lund, Sweden.

Wester J, Engström A (2016) Nulägesbeskrivning om nyckelbiotoper. Skogsstyrelsen Rapport 7. Skogsstyrelsens böcker och broshyrer 551 83 Jönköping (In Swedish). http://skogsstyrelsen.se/ (accessed 5 Feb 2025)

Wintle BA, Kujala H, Whitehead A, Cameron A, Veloz S, Kukkala A, et al. (2019) Global synthesis of conservation studies reveals the importance of small habitat patches for biodiversity. Proceedings of the National Academy of Sciences U.S.A. 116:909–914. https://doi.org/10.1073/pnas.1813051115

Supporting Information

The following information may be found in the online version of this article:

Table S1. Restoration management types in the database include in total 30 different categories, where of 13 combined categories were constructed.
Table S2. Area (ha) of the six different forest types in all Nature Conservation Agreements and all Biotope Protection Areas.
Table S3. Area (ha) of the 13 different restoration management types in all Nature Conservation Agreements and all Biotope Protection Areas.
Table S4. Favored tree species in subtype tree-specific regeneration management.
Table S5. Disfavored species, extracted from restoration type Removal of tree species.
Figure S1. Predicted increase in total area (ha) of all Nature Conservation Agreements and all Biotope Protection Areas.

Coordinating Editor: Michael Perring

Received: 30 September, 2024; First decision: 8 December, 2024; Revised: 28 January, 2025; Accepted: 28 January, 2025