Chapter 19
Boreal Forest Landscape Restoration in the Face of Extensive Forest Fragmentation and Loss

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Abstract Historical conditions that provide a natural legacy for defining restoration targets are not applicable without adjusting these targets to expected future conditions. Prestoration approaches, defined as restoration that simultaneously considers past, present, and future conditions with a changing climate, are necessary to advance the protection of biodiversity and the provisioning of ecosystem services. Large areas of boreal forest landscapes are transformed and degraded by industrial forestry practices. With largely fragmented and too-small areas of remaining high conservation value forests, protection and preservation are insufficient and must be complemented by active restoration in the managed forest matrix. Successful forest landscape restoration incorporates varied spatiotemporal scales and resolutions to compose restoration routes that best reflect the expected future sustainability challenges as well as planning and governance frameworks.

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19.1 Introduction

In the face of climate change, the challenges for sustainable forest and landscape management become even more pronounced (Hlásny et al., 2017; Kremen & Merenlender, 2018). Forest landscapes characterized by the effects of long-term and intensive forest logging dominate vast areas in northern boreal Europe but are also increasingly common in all boreal regions (Curtis et al., 2018). In addition to extensive forest harvesting and other land-use impacts, a changing climate puts into place often unknown or difficult-to-predict trajectories of ecosystem response to disturbance (Kuuluvainen et al., 2017; Lindner et al., 2010; Scheffer et al., 2012). Forest fragmentation and loss are integrated with and respond to climate change through multiple unforeseeable feedback effects on forest conditions (e.g., Wang et al., 2020). Thus, the circumstances for biodiversity conservation, ecosystem service provisioning, as well as forestry and other land uses may differ markedly in the near future from the present and past circumstances (Frelich et al., 2020). Consequently, current and future landscape analysis and integrated planning oriented toward stand and landscape restoration are critical for maintaining viable and resilient boreal landscapes (Arts et al., 2017; Svensson et al., 2019a). Thus, climate adaptation and mitigation approaches must be integrated into green infrastructure planning, defined as a spatiotemporally functional planning framework for maintaining biodiversity and ecosystem services in landscapes affected by climate change and land use (Mikusiński et al., 2021; Stanturf, 2015).

There is much evidence for the loss of natural, near-natural, and intact forest landscapes and the associated negative consequences for biodiversity, ecosystem services, and other benefits to people (e.g., Potapov et al., 2017; Zanotti & Knowles, 2020). In Europe, most forest types have little to no remaining natural forests (Sabatini et al., 2020). Consequently, and recognized for example in the UN Decade on Ecosystem Restoration 2021–2030 (FAO, 2020) and the European Union Biodiversity Strategy for 2030 (EC, 2020), the current levels of protection, combined with often limited conservation functionality in the existing protected areas (Halme et al., 2013; Watson et al., 2014), are insufficient. Here we define limited functionality as areas that are too small and too fragmented to develop or maintain a favorable conservation status. Additionally, it is increasingly recognized that effective conservation of protected areas depends not only on the intrinsic values within these areas but also on the quality of the landscape matrix (Orlikowska et al., 2020; Ward et al., 2020). Thus, landscape restoration has a central role in green infrastructure planning.

New and innovative avenues need to be explored locally, nationally, and globally to preserve functional ecosystems for future generations. In addition to more and larger protected areas and greater consideration of nature conservation in standard forestry practices, active measures must include restoring forest patches and forest landscapes within sustainable management and governance strategies and plans (Mansourian, 2017; Stanturf et al., 2014). The preservation of forest ecosystem functions, biodiversity, and the naturally rich pools of ecosystem services and nature's contribution to people requires more active and progressive restoration approaches (IPBES, 2018).

Moreover, as land-use pressure is high and increasing from multiple, varying, and sometimes conflicting interests (Knoot et al., 2010; Svensson et al., 2020b), restoration must be oriented not only toward nature conservation values but also toward sociocultural and economic values associated with a broadening and diversifying of the forest landscape value chains (Jonsson et al., 2019; Stanturf, 2015). That is, restoration should aim at supporting a multifunctional forest use rather than a single-use orientation of a service or good, such as wood biomass for timber, pulpwood, or energy production.

In this chapter, we explore various aspects and routes forward for forest landscape restoration in the context of climate change. We benefit from recent research on Sweden's boreal and subalpine regions, which exemplifies a geographically broad case that harbors both generic and specific boreal characteristics. The study region encompasses around 27 million ha, of which 19 million ha is forest (Fig. 19.1; Mikusiński et al., 2021). Distinct gradients in historical and current land use provide representative examples of forest landscapes characterized by different biogeographical contexts and intensities of human exploitation. The loss of intact forest landscapes caused by the dominant systematic forest clear-cutting system has largely transformed forest landscapes across vast areas. The current Swedish Red List (Artdatabanken, 2020) encompasses 1,400 species listed as a direct and indirect consequence of this forestry approach. About 1,100 species of these listed species are found in northern Sweden. Only a narrow hinterland belt in the mountainous area, the *Scandinavian Mountains Green Belt*, can be considered intact (Fig. 19.2; Svensson et al., 2020a). The loss of natural forests, the geographically imbalanced conditions of the remaining intact forest landscapes in northern Sweden, and areas where landscape restoration is critically needed are illustrated in Fig. 19.1.

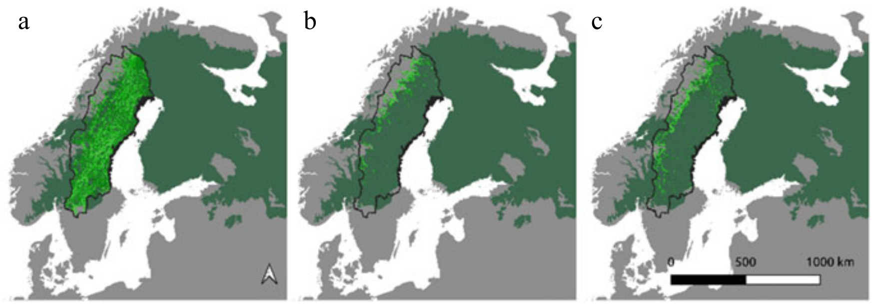

Fig. 19.1 Northern Sweden (*black delimiting line*) with the surrounding terrestrial areas (*gray shading*) and boreal biome (*dark green shading*) delimited; the illustrations show the structural connectivity of **a** all forest land, **b** protected forestland, and **c** remaining forestland not subjected to clear-cutting since the introduction of systematic forest clear-cutting in Sweden in the middle of the twentieth century (i.e., proxy continuity forests; see Svensson et al., 2019a). Connectivity was calculated using circuit theory (McRae et al., 2008), where structural connectivity implies that all forests are treated as a single entity, i.e., without separating the area into ecologically different forest types. Figure modified from Mikusiński et al. (2021), CC BY license

Fig. 19.2 Large areas of the mountain foothill forests are part of the Scandinavian Mountain*s* Green Belt (Svensson et al., 2020a) intact forest landscape; (*top*) Laxbäcken, Vilhelmina, overlooking the gradual change from coniferous-dominated forests to the broadleaf alpine tree line woodlands; (*bottom*) the landscape-scale mixture of forests, open mires and grasslands, and water bodies, toward the Marsfjället nature reserve. *Photo credits top* Jon Andersson, *bottom* Mikael Strömberg

19.2 Forest Landscape Restoration Approaches

Strategic planning at the landscape scale is critical for effectively securing representative aspects of biodiversity and forest ecosystem services (Mansourian et al., 2017). Restoration must simultaneously target different spatial scales, from individual trees to stands to landscapes. However, a landscape cannot be constrained by a single definition, as it is inherently context-dependent. For example, the term is used generically for defining a geographical area, for describing a spatial extent between *local* and *regional*, as an ecological term representing the spatiotemporal gradient in energy flow, nutrient cycling, and species interactions, and as a socioecological system in which different actors perceive and influence the spatial composition and functioning of various landscape elements. The term landscape may also refer to an older delineation of administrative units. Thus, any landscape approach is defined by the specific questions, species, habitats, and contexts being addressed.

Similar to the definition of landscape, its scale, i.e., the spatiotemporal extent of a landscape, is also conditioned by the habitat and species context. For forest areas, the extent should be sufficiently large to include an adequate range of different naturally occurring forest types and connected landscape elements that represent a relevant and practical scale for actors such as forest management planners or administrative authorities working with green infrastructure planning. In the context of boreal Europe, this normally translates into areas of a few tens of thousands of hectares. At a global scale, analyses of intact forest landscapes tend to address significantly larger areas and may include several hundreds of thousands of hectares (e.g., Potapov et al., 2017), i.e., the size perceived to encompass large-scale natural dynamics linked to disturbance regimes.

Forest landscape restoration encompasses a range of measures at various scales for numerous specific purposes (Chazdon et al., 2016) and with various specific measures and activities, such as restoration fire, the production of deadwood, and green tree retention. Below, we detail some of the more central terms, approaches and measures for boreal forests and forest landscape restoration (drawing from Mansourian, 2018), where, for the purpose of this chapter, we have clustered similar and related terms. In addition to various active measures that aid the development of forest habitats to improve biodiversity and resilience, passive strategies, allowing natural processes and dynamics to act, are optional or preferred in many situations.

Forest landscape restoration/ecological restoration: Traditionally, this approach relies on an understanding of historical landscape composition as a model for moving landscape structures closer to a historical baseline, often referring to a natural range of variability in terms of the extent of forest types and disturbance processes (Kuuluvainen et al., 2015; Pennanen, 2002). Thus, landscape restoration is a planning process rather than direct actions within individual stands, which include, for example, applying relevant data and the active participation of various landowners and decision-makers and planning according to given regulations and policies.

Prestoration: This approach is defined as restoration that simultaneously relies on past and present states that impact the present and future stages as expected by climate change while using as a starting point the species' need for suitable habitats (Butterfield et al., 2017; Mansourian, 2018). Prestoration aims to support biodiversity and ecosystem services given the anticipated effects, i.e., restoration with a target into an expected future given current knowledge and projections. Therefore, a central question is which tree species or genotypes should be planted or promoted for restoration to match the climatic conditions in 100 years or more (Halme et al., 2013; Kuuluvainen et al., 2017). Prestoration can be applied at the landscape scale and at the scale of specific stands and habitats; it should be explicitly sensitive to temporal dimensions, particularly for ecosystems that recover slowly such as the boreal forest.

Therefore, specific restoration actions can be performed in recently planted forest and during precommercial thinning and thinning stages and in the form of translocating biodiversity attributes such as snags and logs, i.e., ecological compensation approaches. The planting of tree species beyond their current distribution also forms part of this approach.

Habitat restoration/habitat reconstruction/rehabilitation: These measures include promoting structures and processes that have been lost through forestry or other land-use transformations of natural landscapes, normally within currently existing forest areas or landscapes dominated by forests. For boreal forests, measures include creating multilayered forest canopies, increasing volumes of deadwood, veteranization of living trees, reintroducing forest fires, and applying other stand- and tree-level measures. The veteranization of trees collectively includes measures that damage or affect living trees in ways that advance aging qualities, such as bark damage to create sap flow or cavity development. Measures also include the mitigation of degraded habitats by restoring soils through revitalizing or translocating soil biota, restoring hydrology through the blocking of ditches or restoring streams modified by timber floating, and establishing or replacing existing vegetation cover in forest edges and other transition zones. Habitat restoration, reconstruction, and rehabilitation can also be achieved through natural development, with or without minor active interventions, if conservation attributes and ecological processes have been maintained.

Reclamation/reconciliation/reallocation/reforestation/afforestation: These measures encompass the artificial planting or seeding of trees and the promotion of natural tree regeneration in areas that historically have been transformed from forests to other land cover types for longer or shorter time periods. The planting of a selected tree species can extend forest habitat areas and provide new habitat patches for associated species. This transformation of previously open areas to forest usually leads to decreases in values associated with open land cover, e.g., grassland biodiversity, landscape vistas, or farmland for food production. Thereby, explicit concern must be accounted for, e.g., natural or cultural values, and any potential trade-offs must be managed.

19.3 Dimensions in Forest Landscape Restoration

Except for historical slash-and-burn cultivation and wood for iron mining, which resulted in localized long and intense forest use that left extensive degraded areas (Angelstam et al., 2013), the transformation of boreal forests in northern Europe is relatively recent. Most transformation has occurred during the last two centuries with increasing intensity during the twentieth century. In particular, the systematic clear-cut rotation system—fully implemented after the mid-twentieth century—represented a shift from a continuous forest cover with multi-aged, multispecies stands to even-aged monocultural forests (Kuuluvainen et al., 2012). This shift has produced a severely fragmented landscape structure across vast areas of the boreal region. Only fragmented and small remnants of old and natural forests of high natural value are preserved (Fig. 19.3). With such a landscape configuration as a starting point for forest landscape restoration—with high conservation value forest only occupying a low share of the remaining forestlands—combined with the low growth rates of boreal trees and their limited dispersal capacities, restoration takes time and requires long-term planning.

A fully restored landscape should deliver the attributes of a naturally dynamic landscape, including living space for all native species, a full representation of different habitat types, and the presence of all-natural processes essential for ecosystem functioning. This restoration must also maintain natural disturbances to the extent possible, given societal risks with wildfires, for example. In boreal landscapes characterized by high levels of spatiotemporal randomness for the main natural disturbance agent, i.e., fire, extensive areas should be restored or protected to secure a continuous availability of all naturally occurring habitats. For example, Andrew et al. (2014) proposed that such a *minimum dynamic area* for the Canadian boreal forest should be at least 20,000 km^2. If wildfires are absent or occur too rarely or at a too-low intensity, as in Sweden because of effective long-term fire suppression, natural succession with broadleaf dominance is very rare and leads to a generically low abundance of broadleaf trees in the boreal tree species mixture (Bengtsson et al., 2000; Mikusiński et al., 2003). As a remedy, a forest management system based on mimicking natural disturbance regimes has been promoted for many years (e.g., Angelstam, 1998; Bergeron et al., 2002). However, the situation has not changed much despite such early promotion, as broadleaf species are not a central resource for the Swedish forest industry. Thus, aging broadleaf trees and stands remain critically rare in Swedish boreal landscapes (Mikusiński et al., 2021).

Old-growth forests are focal biodiversity nodes within boreal forest landscapes and have long been protected; in Sweden, however, their spatial distribution is highly skewed toward the northwestern mountain areas (Angelstam et al., 2020), i.e., the Scandinavian Mountains Green Belt. Protected forests are much less extensive in the other parts of the country. Achieving old-growth conditions in boreal forests after clear-cutting forestry or a major natural disturbance may take centuries (e.g., Hedwall & Mikusiński, 2015; Lilja et al., 2006).

Conservation planning tools that extend from the remaining ecological mainlands, i.e., geographically large nodes of intact forests and forest landscapes, must be used to embrace the temporal and spatial complexity of restoration in the boreal forest. This is particularly true from a green infrastructure perspective (Snäll et al., 2016) that supports the spread and migration of species into the surrounding landscape matrix (Mikusiński et al., 2007). Enhancing the functionality of the few remaining old-growth, primary or natural forest patches outside such mainlands and building the future green infrastructure pool, requires new protected areas having robust existing conservation values and also enhancing restoration efforts when the temporal transition to strong conservation conditions can be foreseen. Thus, in everyday forest-production landscapes where the transformation of natural conditions is substantial,

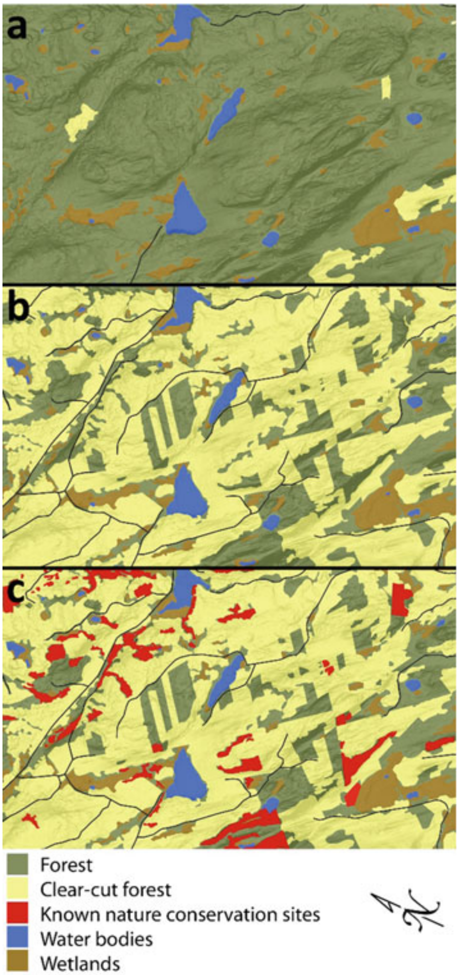

Fig. 19.3 Clear-cutting forestry was introduced at a large scale in northern Sweden in the mid-twentieth century; most forested areas have since been clear-cut. **a** Map of forest and clear-cut areas in 1958 and **b** 2016; **c** the locations of all known nature conservation areas, protected and not protected, are superimposed on the map to illustrate both the overlap and the remaining share of non-high-conservation value forests, as determined through inventories. The study area is situated 60 km west of the city of Umeå, east coast of northern Sweden, and covers about 3,000 ha. The area was previously 90% forested, whereas 72% was clear-cut by 2016. (see Svensson et al., 2019b)

restoration must become a natural part of landscape planning and include a broader spectrum of approaches and measures.

Boreal landscapes typically include land cover types other than forest, such as water bodies, open mires and grasslands, and subalpine environments. This heterogeneity represents a natural level of forest fragmentation in an intact dynamic landscape to which, in a broad sense, the associated forest species adapt. Thus, land cover types other than forests contribute significantly to landscape-level biodiversity and ecosystem services. The transition zones to forests, i.e., forest edges, are by themselves essential habitats for biodiversity and ecosystem services but also function as bridging elements (Harper et al., 2015). Consequently, effective restoration requires a holistic approach with integrated planning and policies across land cover types (Chazdon et al., 2017).

The current landscape configuration represents a natural, seminatural, or artificial land cover distribution that may be stable for a particular duration. However, a landscape may have had another configuration historically, where the land cover and the modifying agent that generated the configuration have left both natural and anthropogenic legacies. These legacies have relevance for the present state and premises for restoration. For example, northern Sweden is currently experiencing a loss of open habitats in rural areas and thus a loss in the biodiversity, cultural values, and ecosystem services associated with open habitats. The recent red list (Artdatabanken, 2020) includes around 1,400 species as direct and indirect consequences of the loss of open and semi-open landscapes being transformed into forests. Habitats with a certain value, for example providing rich winter grazing resources for ungulate species such as reindeer (*Rangifer tarandus*), may be replaced by dense, fast-growing forest stands (cf. Sandström et al., 2016). Many of these open habitats were naturally open in the distant past because of poor site conditions or were created by the active removal of forests to increase farmland. Over the last century, these areas transformed back to forest, either naturally or through silvicultural reforestation measures. Forests not currently being used for forestry, including other woodlands, sites having a low tree growth capacity and limited natural values, and single trees and tree groups in other land cover types, can connect spatially disrupted old-growth forest patches and decrease adverse effects from fragmentation. Thus, in landscape restoration, the land cover composition represents the first dimension that must be considered (Fig. 19.4).

The tree-age distribution of the forest represents the second dimension in landscape restoration. In managed forest landscapes, much of the old forest and forests composed of mixed-age assemblages have been transformed into young and middle-aged, fast-growing, and dense forests with management oriented toward wood biomass production. In northern Sweden, currently only 15% of all forests are 140 years or older, including forests that are of no interest to production forestry, i.e., mean annual wood biomass growth $\leq 1\ m^3 \cdot ha^{-1}$ over the rotation period. It should be noted, however, that 140-year-old forests often have not (yet) developed old-growth boreal characteristics; thus, *old* refers more to the forestry rotation cycle, i.e., stands at the final logging stage, than to a biologically significant status. With a focus on forest age, restoration activities can be directed toward a diversified and broader tree- and stand-age distribution on proportionally larger forest areas than at present. However, because boreal species are adapted to landscape compositions of low predictability and structure because of the stochasticity of the main large-scale disturbances, adequate trajectories of landscape and forest restoration must be promoted to attain a more varied forest-age distribution (Berglund & Kuuluvainen,

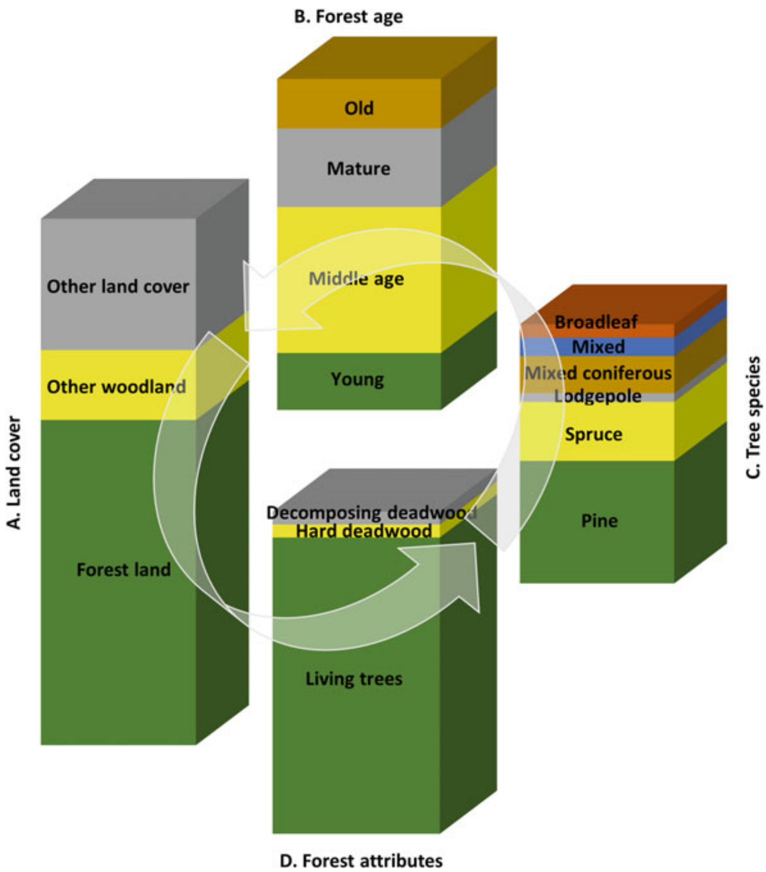

Fig. 19.4 Forest landscape restoration that considers four dimensions: land cover type, forest-age distribution, dominating tree species, and forest attributes; the illustration is derived from data of the Swedish National Forest Inventory for northern Sweden, roughly representing the boreal biome distribution (SLU 2020). **a** The distribution of forests (56%), other woodland areas (sparse and low growth), other land cover and land-use types (mainly alpine and open mires); **b** stand age based on data from all forests with young (≤20 years), middle-aged (21 to ≤ 0 years), mature (81 to ≤ 140 years), and old (≥140 years) forest; **c** stand-scale dominant (≥65%) tree species from data on forestry lands (productive, not formally protected) of Scots pine, Norway spruce, lodgepole pine, mixed coniferous, mixed, and broadleaf forest; **d** volume of living trees (m^2 basal area), hard (m^3) and decomposing deadwood (m^3) from all forests. The layer thickness in each bar is proportional to the abundance of the illustrated component. Dimension **a** is illustrated based on land surface area (27 million ha), dimensions **b** and **d** on forest land area (19 million ha), and dimension **c** on productive forest land (15 million ha). Here we apply data commonly recorded in national forest inventories and, hence, similar assessments can be made for other boreal regions

2021). From this perspective, it can be noted that regenerating young forests dominated by broadleaf trees can play a role as natural fire barriers and, accordingly, form part of the forest-age distribution at the landscape scale.

Dominant tree species represent a third landscape restoration dimension. Systematic clear-cutting forestry with a regular harvesting rotation has resulted in forest-stand monocultures. In northern Sweden, only 7% of forests are truly mixed, and only 5% are dominated by broadleaf species. Under natural conditions, succession, dynamics, and the various natural disturbances, ranging from small-scale treefalls to wind-felled stands to extensive burned regions, create tree species conglomerates that vary across time and space. From a site's disturbance dynamics and soil/bedrock conditions, different tree species naturally occur in a mosaic of stands having a single, few, or multiple species where the configuration can only be predicted at a very large scale (Pennanen, 2002). Clearly, restoration aiming for a more balanced and mixed tree species composition results in niche separation that supports broader pools of forest biodiversity and ecosystem services. Moreover, it provides prerequisites for diversified management strategies and innovative value chains.

The fourth dimension is exemplified by deadwood, representing a key biodiversity attribute, and other attributes typical of old-growth characteristics, i.e., multiple forest layers, old trees, horizontal heterogeneity, and broad substrate diversity. Deadwood is lacking in northern Swedish boreal forests but is slowly increasing, averaging presently around 8 $m^3 \cdot ha^-1$ (SLU, 2020). This quantity of deadwood is very low compared with natural conditions where deadwood volumes can be 50–80 $m^3 \cdot ha^{-1}$ for comparable forest types (Siitonen, 2001). Note, however, that an overall increase and general improvement of the ecosystem attributes that intrinsically support biodiversity and ecosystem services, e.g., deadwood as a colonizing substrate, the functionality of a given substrate in a specific site, are determined not only by site-intrinsic characteristics but also by characteristics in the surrounding habitats and landscapes.

19.4 Forest Landscape Prestoration to Mitigate Clear-Cutting Debt

The dominance of the rotation clear-cutting system has led the Swedish boreal forest landscape to lose most of its historical configuration. Outside the intact forest landscapes of the Scandinavian Mountains Green Belt, only fragments remain of forests that have never been subjected to clear-cutting. At the landscape scale, the dominance of young to middle-aged planted forests has led to a connectivity loss between the remaining old-growth patches. This resulting lack of connectedness between non-clear-cut forests represents a significant challenge, given that intact forest landscapes were historically dominated by older forests (Berglund & Kuuluvainen, 2021; Pennanen, 2002). As a parallel to the *extinction debt* related to species loss through habitat destruction (Hanski, 2000; Tilman et al., 1994), we may consider clear-cutting as the cause of a broader debt in terms of deteriorated or lost natural processes, structures, and other, not-yet-fully-known ecosystem changes. From this perspective, landscape restoration is required at much broader scales and higher rates than at present to manage and mitigate this debt.

However, for practical, economic, and climatic reasons, the target of landscape restoration cannot be to return to a pristine historical situation. Instead, what is needed is a careful consideration of those restoration measures able to provide components of natural forests that are sufficiently robust and resilient for any particular landscape given its natural settings, legacies of land use, and current socioeconomic situation. These considerations must then be placed and evaluated against climate change scenarios, i.e., restoration in the sense of prestoration. Thus, any restoration planning must consider climate change–driven biogeographical translocations and, therefore, include climate models as input data. The different available targets (Fig. 19.5) provide a gradient in segregating and integrating conservation goals (Bollmann et al., 2020), where some targets are relevant in areas primarily managed for biodiversity, i.e., protected areas, and other targets more suitable for mitigating adverse effects on natural values in more-or-less intensively managed forests. Regardless of the conservation goals, climate change will affect all forest types and their adaptative potential. Although historical knowledge of past natural conditions provides a critical reference state for species and biodiversity, we must now also address future conditions. Any prestoration targets for the future must include forms of *secondary natural forests* and novel, designed managed forests that ensure the full range of ecosystem services from the forest landscape (Bollmann et al., 2020).

Their remaining natural forests in boreal Sweden are, in most cases, restricted to the lower end of the site productivity gradient, i.e., mainly occurring on marginal lands (e.g., Andrew et al., 2014; Angelstam et al., 2020). Yet, these forests still provide crucial elements. Here, prestoration may complement nonintervention management and include promoting tree species that may be important biodiversity structures under future conditions and, if introduced, may prepare the ground for future range shifts of associated species. Prestoration in natural forests may also include the translocation of species to habitats outside their current distribution ranges.

For forests having been subject to a relatively limited impact from recent forestry, possible measures include habitat restoration through the veteranization of trees, prescribed fires, retention measures, and increased volumes of deadwood. When these measures are carefully applied and well placed at the landscape scale, they will also support landscape restoration and prestoration. The range of options for forests having a recent harvest history is likely to be greater, although the positive effects on biodiversity are delivered in a more distant future. A careful choice of tree species for regeneration and active measures to create structural and functional diversity in forests across broader spatial scales exemplifies different possible reforestation, rehabilitation, and habitat restoration measures.

Forested areas not used for commercial forestry can play a crucial role. These sites include woodlands in remote places, technically challenging sites such as steep slopes, and less fertile sites having a poor tree growth capacity. Such low-production forests often occur as islands or belts within productive forest landscapes. With

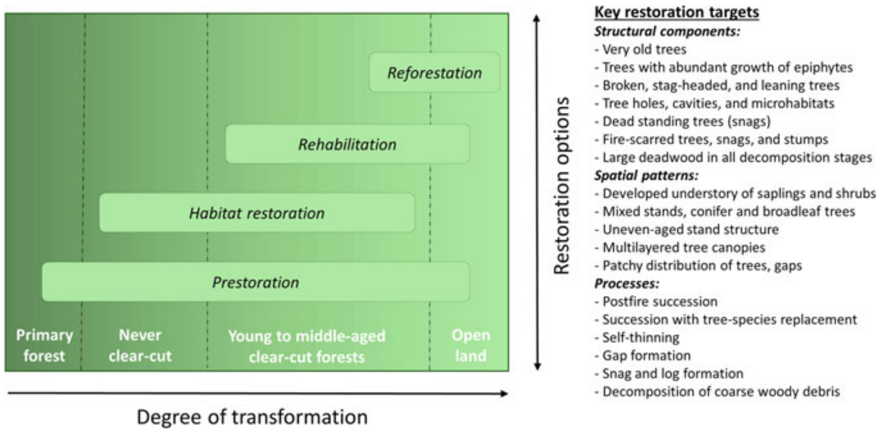

Fig. 19.5 A generic forest landscape composed of four categories of forests representing degrees of transformation: (1) primary forests with no or very limited human impact; (2) forests that have never been clear-cut; (3) young and middle-aged forests regenerated after clear-cutting; and (4) open lands that potentially could become forested through natural or silvicultural measures. The relative area of each category broadly reflects the current situation in Fennoscandian (Norway, Sweden, Finland) boreal forests. The figure exemplifies the most relevant type of restoration for each category that collectively represents landscape restoration opportunities if carefully planned at the landscape scale. The list (*right*) includes factors known to be essential for boreal forest biodiversity (after Esseen et al., 1997) and hence represent targets for restoration activities. Various types and groups of targets can be implemented at different degrees of transformation and at a range of spatiotemporal scales

careful consideration of the structures and habitats produced by these woodlands, it is possible to identify stepping-stone and corridor functions to improve landscape connectivity. Directed habitat restoration measures can enhance their functionality in cases where historical land use caused a loss of certain structures. From a prestoration perspective, it is also possible to increase structures beyond natural levels to compensate for the intensively managed forests in the surrounding areas.

19.5 Forest Landscape Restoration to Meet Global Sustainability and Conservation Targets

Sustainability, ecosystem services, and biodiversity are widely recognized on global agendas. The UN Sustainable Development Goals (SDG; FAO, 2020) and the Convention on Biological Diversity Aichi targets (CBD, 2010) have been paramount in setting this global policy agenda. The linkages between biodiversity and the fulfillment of the SDGs are apparent at multiple levels (Blicharska et al., 2019). Both the 2030 European Union Biodiversity Strategy (EC, 2020) and the new CBD framework further highlight the importance and challenges that humanity must consider moving from a net loss of natural values to a net gain. From this perspective, forest restoration and prestoration represent major opportunities given the high level of potential multifunctionality through these approaches, the inherent effects on biodiversity, and the generic applicability of measures and targets to local conditions and circumstances.

Intensive forest management has caused a loss of boreal biodiversity and reduced the provision of ecosystem services. Structurally and compositionally simplified forests and landscapes can only deliver some of the services essential for human well-being (e.g., Gamfeldt et al., 2013; Jonsson et al., 2020). Successful restoration of boreal forests and landscapes will, directly and indirectly, generate positive progress toward achieving several SDGs (Table 19.1). Whereas the positive impacts of restoration on biodiversity (SDGs 14 and 15) are obvious, the delivery of many other services, such as the securing of diverse food resources (SDG 2), health (SDG 3), clean water and energy (SDGs 6 and 7), and climate actions (SDG 13) are all, in some manner, linked to the successful restoration of vital forests (Table 19.1). Because achieving the full palette of services from forest environments that support multiple SDGs can be assumed to be impossible at the local level, diversification of management regimes at the broader landscape level has been advised (e.g., Felton et al., 2020; Triviňo et al., 2017). Unlike clear-cutting forestry, continuous cover forestry has a particular role in restoring multiple services within boreal landscapes (Eyvindson et al., 2021).

Restoration of boreal forests and landscapes clearly affects the ability to achieve Aichi Target 7 of sustainable forest management and Target 11 of setting aside 17% of all ecosystems for biodiversity conservation (CBD, 2010). The future management and conservation of forests in Sweden are currently at a crossroad between intensified wood production and multiple-use forests (Felton et al., 2020; Jonsson et al., 2019). Restoration aiming to improve a greater expanse of available habitat and securing their functional connectivity—along with safeguarding the long-term provision of these features within multiple-use forest landscapes—is a viable and successful means for achieving the Aichi targets.

19.6 Conclusions

Like the two-faced Roman god Janus, restoration must also look simultaneously in different directions. This reality means building on the historical understanding of species' habitat- and landscape-level requirements and considering climate change and future conditions, which we assume will differ substantially from the past and present. Thus, a relevant temporal resolution is necessary to reflect a slow ecosystem response where the net effects of restoration may lie far into the future. Spatial scaling is also necessary to reflect species' niches and behaviors in terms of movement,

Table 19.1 Examples of the benefits of forest landscape restoration in relation to 11 of the 17 UN Sustainable Development Goals, separated into the dimensions of the biosphere, society, and economy

SDG #	Biosphere	Society	Economy
1. No poverty	Increased pools of ecosystem services	Revitalize degenerated land for labor opportunities	Subsistence economy and multiple value chains
2. Zero hunger	Edible plants and hunting opportunities	Prevent erosion of agroforestry land	Subsistence economy and multiple value chains
3. Good health and well-being	Increased pools of ecosystem services	Forest medicinal plants, forests as de-stressing space	Ecotourism opportunities
4. Clean water and sanitation	Natural hydrological filtering of freshwater	Local freshwater accessibility	Local freshwater accessibility
5. Affordable and clean energy	Sustained growth of local bioenergy	Fossil-free neutral bioenergy production	Bio-economy options
6. Decent work and economic growth	Increased pools of ecosystem services	Rural development based on natural forest resources	Rural economy based on sustainable forestry and forest product processing
7. Sustainable cities and communities	Increasing green structures in urban and peri-urban areas	Accessibility to forest-based provisioning and cultural ecosystem services	Bio-based construction material of high quality
8. Responsible consumption and production	Sustainable forestry practices	Access to forest products based on sustainable use	Added market value from sustainably used forests
9. Climate action	Increased carbon storage in growing forests	Climate mitigation and offsetting	Payment for net carbon storage, fossil fuel substitution
10. Life below water	Ecological integrity of riparian and shoreline forestlands	Access to fresh and marine waters free from eutrophication	Revitalized aquatic systems with fish and other ecosystem services
11. Life on land	Improved habitats, biodiversity, ecosystem services	Provision of a full range of forest ecosystem services	Ecotourism opportunities, integrity of ecosystem functions and values

migration, and seasonal distribution patterns. Operating at a landscape scale is necessary, adding factors such as land cover types, landowners, policies, and decision-making. Restoration must target both natural forests and managed forests as important parts of the landscape, covering transformed and degraded landscapes. Boreal biodiversity and ecosystem services cannot be preserved solely through protecting the remaining high conservation value forests. An active restoration that mitigates fragmentation and the loss of intact forest landscapes and natural forest habitat values has a core role in integrated, green infrastructure–oriented landscape planning. Prestoration approaches, which acknowledge forest restoration across multiple spatiotemporal scales on the basis of past legacies and expected future situations, should be promoted and included within the governance and management of forests and forest landscapes.

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