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Trilemma of Nordic–Baltic Forestry—How to Implement UN Sustainable Development Goals

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Abstract: Forests are the dominant land cover in Nordic–Baltic countries, and forestry, the management of forests for improved ecosystem-service (ES) delivery, is an important contributor to sustainability. Forests and forestry support multiple United Nations Sustainability Goals (UN SDGs) and a number of EU policies, and can address conflicting environmental goals. Forests provide multiple ecosystem services and natural solutions, including wood and fibre production, food, clear and clean water and air, animal and plant habitats, soil formation, aesthetics, and cultural and social services. Carbon sequestered by growing trees is a key factor in the envisaged transition from a fossil-based to a biobased economy. Here, we highlight the possibilities of forest-based solutions to mitigate current and emerging societal challenges. We discuss forestry effects on forest ecosystems, focusing on the optimisation of ES delivery and the fulfilment of UN SDGs while counteracting unwanted effects. In particular, we highlight the trilemma of (i) increasing wood production to substitute raw fossil materials, (ii) increasing forest carbon storage capacity, and (iii) improving forest biodiversity and other ES delivery.

Keywords: United Nations Sustainable Development Goals; ecosystem services; forest; forestry; management practices; European Green Deal

1. Introduction

The Past and Today—Various Dimensions of the Northern Forest

The forest landscape in Nordic–Baltic countries, comprising Estonia, Finland, Latvia, Lithuania, Norway, and Sweden, is largely a 20th century creation of active management and governance aimed at optimising the economic value of forest production by increasing standing forest biomass. Today's forest landscape consists of a mosaic of stands of different ages, dominant tree species, productivity, and sizes (<1 to >100 ha) intermixed with semiopen and open land cover with low or no forest productivity (e.g., mires and bogs). There is also large diversity of forest owners ranging from the state to private individuals. Nordic–Baltic countries and their inhabitants derive economic, social, and environmental benefits from forests and forestry. Forestry has historically had a significant contribution to national and rural economies, and is still an important sector today. The development of a Nordic–Baltic forestry system mirrors the economic, environmental, and social development in the region, and forests play a significant role in the development of societal welfare. This societal welfare stems from activities ranging from global bioproduct mills to local sawmills and thermal power plants, and to local communities hunting, and picking berries and mushrooms.

Guiding principles for forestry are quite similar within the region, but with differences in the size, structure, and sectorial share of the national GDP. These differences are explained by the forest cover, terrain, and other sectors' development and share of the economy, among other factors. In addition to their economic importance, forests and woodlands provide other essential forest-ecosystem services [1–3]. Forest products are extracted and used in construction, paper and paperboard products, and in replacing fossil fuel and materials. However, production forestry interferes with biogeochemical cycles [4–6], changes hydrology [7,8], and affects biodiversity [9].

The Nordic–Baltic region encompasses a variety of climates, ranging from sub-Arctic in the north to nemoral in the south, with a more maritime climate along the Atlantic and the Baltic Sea coast, and a more continental climate in the east (Figure 1). Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst.), hardwood birches *(Betula pendula* (Roth.) and *Betula pubescens (Ehrh.))*, and aspen (*Populus tremula* L.), are the dominant tree species in the boreal forest zone in Finland, Norway, and northern Sweden. A range of broadleaf species, including beech (*Fagus sylvatica* L.), oak (*Quercus robur* L.), ash (*Fraxinus excelsior* L.), and alder (*Alnus glutinosa* L.) are common in the nemoral zone.

European cultural inheritance is largely related to forests, especially in Northern Europe, where forests are deeply rooted in cultural and belief systems. Many fairy tales and sagas are set in forests that are described as both dark and frightful places, and as a refuge for asylum and tranquillity [10]. Even today, when most of us live in cities and may have only limited contact with forests and rural areas, forests and trees make many essential and highly valued contributions to our well-being, e.g., recreational and outdoor activities.

During the last millennium, the ever-growing agrarian and industrial expansion, and the need for building material, firewood, and charcoal for mining and metal smelters led to a severe reduction in woodland coverage in Europe [11]. Forests historically provided construction material for housing, heating, and products such as charcoal, tar, resins, and potash, which are important material for industrial processes and shipbuilding. Humans actively use forests for food production, including livestock grazing and crop production (e.g., slash-and-burn agricultural farming). While the deforestation of midlatitude Europe accelerated over time, and woodland cover had reached its minimum prior to the Industrial Revolution, deforestation peaked in northern Europe during the 19th century [12]. Concerns about deforestation led to political actions supporting afforestation and intensifying forest growth, including the development of the world's first National Forest Inventories (NFIs) in Nordic countries about 100 years ago. Other restoration efforts that aimed to increase forest growth included applying different silvicultural practices, tree-breeding programmes, and peatland drainage. Approximately 1.5 million ha in Sweden and 4.7 million ha in Finland were drained, which increased available forest production areas, but also substantially impacted other land-cover types, habitats, biodiversity, ecosystem services, carbon loss, and ecosystem function [13–15].

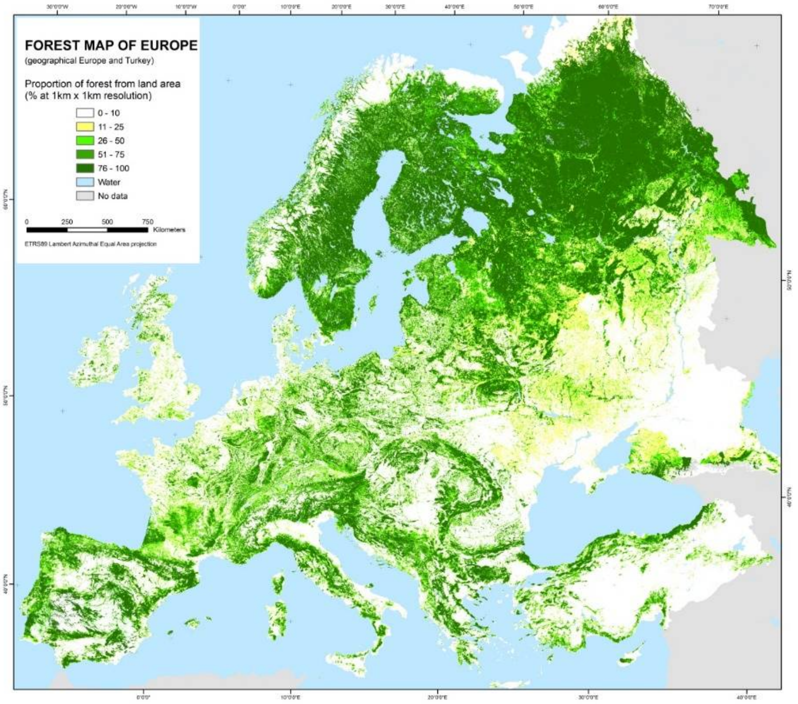

Figure 1. Forest map of Europe showing high proportion of forested area in Nordic and Baltic countries. With permission of the European Forest Institute [16–18].

During the past 100 years, standing volume increased by over 50% in the Nordic–Baltic region due to active forest management and favourable climatic conditions, and despite substantial logging during the same period. In boreal Sweden, for example, the total standing volume in the 1920s was 1.6×10^9 m^3; today, it is 3.6×10^9 m^3 [19], equivalent to a 111% increase. In Finland, the standing volume in 1990 was 1.9×10^9 m^3, and this increased to 2.5×10^9 m^3 (2018). At the same time, the total drain (removals and natural losses) of roundwood was 2.1×10^9 m^3, more than the whole standing volume in 1990 [20,21].

Forests regulate climate, buffering the effects of extreme temperatures and precipitation, and sustaining the water cycle [22,23]. They filter and purify both surface- and groundwater, and can mitigate floods and droughts. In cities, growing trees can contribute to cooling both with their shade and by transpiring water, in addition to improving air quality [24–26].

These multiple benefits and multiple use objectives are not intrinsically considered in forest planning. Forests can produce multiple and frequent benefits of goods and services, concurrently and from the same piece of land [27]. A recent study of northern Sweden showed that the demand for conservation, sociocultural, and economic land-use interests exceeds the available land area by 2 to 4 times [28].

Forestry and reindeer husbandry largely utilise overlapping areas; for example, in the reindeer-herding area in Sweden (160,000 km^2 around 55% of the Swedish land area), forestry and reindeer herding have had several confrontations [29]. In Finnish Lapland, forestry, reindeer herding, and tourism coexist in the same area that partly overlaps with Sápmi as the cultural region of the Sámi people, which creates difficulties between different land-use modes. As an example, reindeer herders and tourism entrepreneurs prefer continuous cover forest management, but the prevailing methods are based on stand-based even-aged forestry with final cuttings.

Biodiversity has decreased in many Nordic–Baltic forests due to a combination of historical habitat fragmentation and the logging of old growth stands. Replacing old growth stands, some of which are many centuries old, by conventional production forests fails to offer the same habitat complexity and diversity due to considerably shorter rotation lengths. Measures have been taken to help to reduce habitat fragmentation, and to maintain and create habitats by a combination of planned management and conservation. Intact forest landscapes were defined, e.g., in a recent mapping by Watson et al. [30], as larger (>500 km^2) mosaics of forests and natural open ecosystems. Intact forest landscapes include so-called primary forests, which show no or low influence of human activities or habitat fragmentation, but may contain the historical human influence of, e.g., preindustrial selective logging [31]. In northern Europe, large intact forest landscapes are only found on the Swedish side of the Scandinavian mountain range, the forest border area between Finland and Northwest Russia, and the Kola peninsula forest belt [32]. Elsewhere in the region, most forests were systematically transformed into plantation forests [33]. Intact forest landscapes and primary forests were lost, and the remaining patches are highly fragmented, with the effects of fragmentation even further pronounced when edge effects are considered [34].

Forest biodiversity is also threatened by the so-called "green shift". A global transition from an economy based on petrochemicals towards an economy that is sustainable, biobased, and circular is now underway with, e.g., the Paris Agreement, the European Green Deal [35], and the Renewable Energy Resources Act and Renewable Energy Directive. The economically, environmentally, and socially sustainable use of natural resources is the fundamental principle. Biobased innovation could, in this context, reduce dependence on fossil fuels, thereby making a positive contribution to meeting EU and UN climate goals. As a renewable natural resource, woody biomass can be valorised in innovative bioproducts alongside a range of conventional forest-industry products [36].

However, this also highlights what could best be described as a trilemma, with conflicting goals concerning biodiversity, carbon storage, and wood supply.

In this paper, we address and highlight some of the most critical aspects for a sustainable and advanced Nordic–Baltic forestry into the future in the context of some of the most relevant of the 17 UN SDGs, particularly SDG 12: responsible consumption and production, SDG 13: climate actions, and SDG 15: life on land. Further, we discuss the SDGs in the context of the European Green Deal. Our key message is that avenues into the future for sustainable forestry and a forest sector that contribute to societal development have to be sought out by addressing the conflicts risks, and integration and synergy opportunities among multiple, sometimes diverging, and even disparate high-level targets. Thus, a balancing act lies ahead. In this paper, we highlight how these three SDGs provide a perspective on a trilemma that needs to be explored and resolved to promote forestry, and forest and forest-landscape sustainability in a growing bioeconomy.

2. Sustainable Forest Management—SDG 12

Responsible production and consumption implies the need for sustainable forestry. However, the definitions of sustainable forestry include multiple subjective assessments and are consequently a moving target. Although forestry is generally orientated towards sustainability, sustainable forestry per se is as much of a matter of public perceptions of forest biology, ecology, hydrology, and woody-biomass production. Contreras-Hermosilla [27] argued that it is hard to agree on sustainability objectives and their relative importance, and thereby be able to assess whether a forest is sustainably managed or not.

Sustainable forest-production management is about understanding, planning, and balancing different goals and actions to achieve optimal ecosystem services to legitimate stakeholders, and avoid risks of negative environmental effects. This includes both combinable goals and spatially distributed functional landscape mosaics to achieve goals not possible to combine within acceptable limits. The complexity and lack of detailed knowledge concerning the side effects of management and actions show a common need for continuous monitoring to warn of both predicted and unpredicted environmental effects.

The forest-based bioeconomy can be defined as all economic activities that affect forest ecosystem services, ranging from forest biomass production to tourism, recreation, and nonwood products [37]. It is viewed as a way to mitigate climate change, which is best achieved within a balanced combination of ecosystems services [37,38]. This definition could be established on the pan-European or EU level, which would provide the basis for policy measures supporting economic activities and innovations related to the entire spectrum of forest ecosystem services.

Most forestry-derived bioenergy is currently produced as a secondary source, i.e., bark, black liquor, sawdust, and other byproducts from pulp- and sawmills. A minor fraction (e.g., in Sweden, 20%) of forestry-derived biofuel originates from branches and top residues from timber harvest. The extraction of forest biofuel from logging residues such as branches, twigs, tops, and needles (or leaves) has caused a fierce debate about sustainability from the perspectives forest production and forest protection, and for carbon balances [39,40].

Raising awareness of the need to manage forests for multiple potentially competing goals among landowners, foresters, and other decision makers is critical. Planning measures and natural solutions provide positive examples of ecological and spatial networks supporting endangered species, and improving resistance and recovery capacity for (i.e., response diversity) future ecosystem challenges [41].

3. Climate Actions—SDG 13

In addition to their potential for fossil-fuel substitution, forests and forestry have important roles to play in both climate mitigation and adaptation. Growing trees and other vegetation sequesters carbon. As a stand matures, more carbon is stored in the stems, stumps, and coarse roots. At the same time, decomposition increases, and there is a balance between growth and decomposition, meaning effectively no net CO_2 sequestration on the stand level [42,43]. As forests mature and age, carbon accumulates in understory vegetation, humus, and the upper soil layers. Net losses of sequestered carbon on the stand level can be caused by various kinds of calamities, e.g., insects, forest fires, and extreme weather. Old-growth stands with high levels of accumulated carbon thus also release high amounts of carbon if devastated by forest fires or storms [44,45].

Over the short term, harvesting returns carbon to the atmosphere through the use of extracted biomass and the decomposition of roots, branches, and soil organic matter. Site preparation, drainage, and soil scarification can exacerbate this problem. Initially, regenerated young forests may not accumulate carbon at rates equivalent to site capacity [46–48]. Middle-aged stands, typically 20–60 years old, in the region have fast growth and a high carbon uptake. As a stand matures, net carbon uptake decreases, although carbon could still accumulate in the soil. The total ecosystem carbon storage in forests varies by stand age, structure, soil type, species, site, bioclimatic conditions, and stand history. Many of these factors are included in integrated landscape-scale monitoring based on eddy-flux measurements [49,50].

Over the years, there has been a fierce debate of whether forestry and forest products are carbon-neutral [51]. Carbon calculations are largely dependent on how system boundaries are defined. Results based on single-stand or even single-tree calculations differ from landscape-scale calculations [52]. However, with balanced age distribution across larger geographic scales and a sufficiently large proportion of forest land set aside, forest function as a carbon sink can be maintained over the longer term. On the short term, given the needs to immediately reduce greenhouse-gas emissions and increase forest carbon storage, longer rotation periods could be considered [53,54]. On the stand level, total biomass production (and hence carbon storage) is highest if precommercial and commercial thinning is not performed, up to the stage when carbon release through natural decline and tree mortality exceeds the carbon uptake by living trees [55]. In upland forests, roughly half the carbon is stored above ground in tree trunks, branches, twigs, and needles or leaves [56–59]. The rest is stored below ground, which implies that forest soils are at least as important for carbon storage as above-ground vegetation. In addition, soil carbon is more recalcitrant toward disturbances [60].

Postharvest forestry activities also influence climate impact. Following the final felling, stand-level CO_2 emissions increase due to the decomposition of stumps, roots, and logging residues [61]. Carbon is also lost by the leaching of dissolved organic carbon (DOC) [62,63]. Soil scarification can increase the decomposition of soil organic matter, in particular in the humus layer [64]. On the other hand, soil scarification can increase carbon uptake by enhanced tree growth [65]. For carbon balance, an important factor is how fast the growth of the new stand counteracts soil CO_2 emissions. However, we have too many knowledge gaps to predict forest-management activities on soil carbon stocks with sufficient certainty to guide foresters, e.g., on soil preparation or nitrogen addition [64]. As these activities significantly improve tree growth, targeted research on the effects of forest-management actions on soil carbon storage is urgently needed.

4. Life on Land—SDG 15

Forestry and Habitat Maintenance

Nordic–Baltic forests harbour more than 25,000 known species of plants, animals, and fungi. There are about 2000 living forest species on average on the national red list of each Scandinavian country [66]. While forestry focuses on the active management of a handful of commercially important tree species, many other species are also affected. For example, in the Swedish Red List, as many as 1400 species are considered to be affected by clear felling [67].

Habitat loss and fragmentation are probably the most negative effects of forestry on flora and fauna. These processes usually involve several elements including habitat loss (decrease in total habitat area in a landscape), habitat isolation (e.g., increase in mean distance between habitat patches in a landscape), decrease in patch size, and increased edge effects [68,69]. The relative impact of these elements on biodiversity loss is still a matter of controversy [70–73].

Evaluating the impact of habitat loss and fragmentation on biodiversity is hugely more difficult when soil biodiversity is also considered, where we have numerous blind spots [74]. Planning, e.g., afforestation efforts to decrease habitat fragmentation, is not a simple issue, and local knowledge is needed, as the best methods might differ depending on landscape composition and location across elevation and geographical gradients in the region [75].

Stability, Resilience and Functional Diversity

Forestry practices that primarily focus on economically valuable species may, in combination with climate change, worsen forest ecosystem resilience. Forest management alters ecosystems and patterns of forest disturbances, and thereby natural ecosystem functions. Diversity in tree species, within and between stands, provides a higher range of options to respond to stresses and new environmental hazards. Furthermore, understanding the role of plant diversity, microorganisms, and other decomposers in successional trajectories, and the stability of secondary forests demands analysis of how these changes differ from changes in soil-organism diversity caused by more severe fires, wind throws, and pest outbreaks [76,77].

Ensuring species and habitat diversity is important for maintaining ecosystem resilience, especially under uncertainties associated with climate change [78]. It is, however, a paramount challenge for the forestry sector to offer enough suitable habitats to support viable populations of all species. Nature reserves, national parks, and voluntary set-aside forests offer such habitats and benefits. Forest certification standards and national legislations are partly directed towards creating and retaining habitats within the managed areas.

5. Discussion

Ecosystem resilience can be defined as the capacity over time for an ecosystem to resist external stress and disturbances or restore ecosystem structures and functioning to a predisturbance stable state [79]. Ecosystem resilience can have an antagonistic relationship with economic resilience, as the latter benefits from forestry-related forest disturbance (e.g., harvesting) as a source of income. This highlights the challenges in balancing multiple dimensions of sustainability in the forest landscape.

The bioeconomy, an economy that is based on renewable biological resources, such as forests and relies on sustainable biobased solutions, could, together with increased circularity, offer a way forward in building a more sustainable future [80,81]. This is particularly urgent in the societal transition to a fossil-free future. Circularity requires a new look at the economic model that we created, and rethinking the way we produce and consume. There is a plethora of new innovative biobased products that could replace fossil-based products, but these cannot currently compete in the marketplace due to the low price of fossil-based materials. Hence, new measures are needed to promote the use of more climate-friendly biobased materials.

Biological diversity defines the capacity of an ecosystem to adapt and evolve in a changing environment, and is therefore a prerequisite for a viable circular bioeconomy. By promoting a more holistic view on economic development, the circular bioeconomy could also contribute to protecting biodiversity and other important forest ecosystem services by replacing fossil products and contributing to climate mitigation. Given the uncertainty triggered by climate change, ensuring the diversity of species and conditions seems to be the most effective means to improve the resilience of the ecosystems [78].

Maintaining sustainable, climate-smart forestry is a balancing act among management strategies to meet conflicting goals. There is a challenge for the forestry sector to offer enough suitable habitats to support sufficient biodiversity to promote ecosystem resilience. Considering factors such as key habitats and biological legacies can create a conceptual frame to address forest regeneration, afforestation, and restoration efforts [82].

The magnitude and composition of Nordic–Baltic forests is the result of long-term investments in forest resources and economic benefits, and national priorities and governance that are generated by these investments. Ecosystem goods and services derived from healthy and functional forest ecosystem processes can contribute to social welfare [80] and economic wellbeing. Forests in Nordic–Baltic countries have provided ecosystem services and benefits throughout human history. These services have varied over time, but for more than a century, the benefits that contribute to income, employment, and social development have increased and developed.

Under the European Green Deal [35], a growth strategy that aims to transform the EU into a fair and prosperous society with a greener competitive economy, the European Commission adopted the EU Biodiversity Strategy 2030 in May 2020 [83]. To address biodiversity loss in the EU, the strategy aims to widen the network of protected areas and promote ecosystem restoration. In addition to the strict protection of primary and old-growth forests, forests and forest landscapes need to be ameliorated both qualitatively and quantitatively. Building on the biodiversity strategy, the Commission is preparing a new EU forest strategy during 2021. The key objectives include measures to increase absorption of CO_2, to reduce the incidence of forest fires, and to promote the bioeconomy in full respect for ecological principles favourable for biodiversity.

To achieve the objectives of the Green Deal policies, the measures must focus on both the protection and the use of forests. Management practices improving the quality and resilience in (all) multiple-use forests are key to both these objectives, and in providing products to circular and bioeconomy services (recreation, healthy products) and new business opportunities in line with the Green Deal. The sustainable re- and afforestation and restoration of degraded forests can contribute to carbon sequestration while also improving forest resilience and promoting the circular bioeconomy. A forest-based circular bioeconomy has great potential to contribute to the European Green Deal as part of a bundle of solutions.

6. Prospects

Promoting forestry, forest and forest landscape sustainability in a growing bioeconomy is arduous given the many actual, potentially diverging, and sometimes disparate high-level targets reflected in the UN Sustainable Development Goals [84]. Routes towards integration and synergy between different land-use modes and interests have to be mapped and promoted, whereas potential and real conflicts have to be acknowledged and avoided or mitigated [28]. Given the national and regional importance of the Nordic–Baltic forest sector, multiple challenges lie ahead to pave out future strategic and operational avenues.

In this paper, we explored and discussed a trilemma that originates from trying to simultaneously achieve SDGs 12, 13, and 15, and that encompasses some of the most challenging risks for conflict and opportunities for synergy and integration. Clearly, the current overlap of different present-day demands on forests and forest landscapes, as well as future expected and not yet defined demands, requires a wider acceptance of governance and management that acknowledges multifunctionality and is supported by evidence-based policies [85]. One example of this is the expanding renewable-energy sector. With the production and consumption of clean energy as a high-level global policy ambition [86], as reflected in SDG 13, the wind-power footprint on landscapes is becoming increasingly manifested [87–89]. The recent strategy for the sustainable development of wind power in Sweden [90] clearly defines the inland of northern Sweden as the focal area for new development, where production forestry is a dominating land use. Therefore, a substantial share of forest land for forest production and for meeting SDG 12 targets would transform to forest land used for energy production. Moreover, as wind power is commonly established on higher elevations where good wind conditions occur, the impact on the few remaining natural and near-natural forests with rich pools of biodiversity values (SDG 15) in such hinterland areas [32] must be expected, as well as pronounced visual, vibration, auditory, and light impact on landscape values, including human benefits and values [89].

Forests undeniably have great potential to substitute concrete or steel building materials and fossil-based raw materials or energy [90,91]. Wood used as construction material both offers long-term carbon storage and replaces materials with a much larger carbon footprint (e.g., concrete and steel). The sustainability of wood as an energy source is, however, debated. Here, the definitions and system boundaries for sustainability assessments affect the outcome. There is variation in national policies related to perceptions of the role of bioenergy in national climate strategies, but there have generally not been strong driving forces in forest policy to utilise forest biomass for energy. Where there were efforts for supporting the use of forest biomass as energy, such utilisation is generally recognised and supported for environmental and social reasons, as economic driving forces are considered to be weak, and profits minimal (see [92] and references therein). While the environmental sustainability of wood as an energy source is debated, there might be carbon benefits when replacing fossil fuels, but at the same time disadvantaging biodiversity [93].

Forests are the dominant land cover in the Nordic–Baltic countries and forestry. The management of forests for improved ecosystem-service (ES) delivery is an important contributor to sustainability. Forests provide multiple ecosystem services and natural solutions, including wood and fibre production, food, clear and clean water and air, animal and plant habitats, soil formation, aesthetics, and cultural and social services. A precursor to a successful transition to a biobased, circular economy is recognising the trilemma of (i) increasing wood production to substitute raw fossil materials, (ii) increasing forest carbon storage capacity, and (iii) improving forest biodiversity and ES delivery.

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