Climate-smart forestry case study: Finland

Peltola, Heli

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Chapter 11
Climate-Smart Forestry Case Study: Finland

Heli Peltola, Tero Heinonen, Jyrki Kangas, Ari Venäläinen, Jyri Seppälä, and Lauri Hetemäki

Abstract Finland is the most forested country in the EU – forests cover 74–86% of the land area, depending on the definition and source. Increasing carbon sequestration from the atmosphere, and by storing it in forests (trees and soil) will be one important part of the Finnish climate smart forestry strategy. However, just maximizing the carbon storage of forests may not be the best option in the long run, although it may provide the best climate-cooling benefits in the short term. This is because the increasing risks of large-scale natural disturbances may turn forests, at least partially, into carbon sources. The climate change adaptation and mitigation should therefore be considered simultaneously. Different adaptation and risk management actions will be needed in Finnish forests in the coming decades to increase forest resilience to multiple damage risks. This could be done, for example, by increasing the share of mixtures of conifers and broadleaves forests instead of monocultures. Yet, the CSF strategy should also include the production of wood-based products that act as long-term carbon storage and/or substitute for more GHG-emission-intensive materials and energy. Doing this in a way which also enhances biodiversity and sustainable provisioning of multiple ecosystem services, is a key. Moreover, increasing forest land – for example, by planting on abandoned or low-productivity agricultural land, especially on soils with a high peat content – would enhance climate change mitigation.

Keywords Forestry · Boreal forests · Climate change · Adaptation · Risk Management · Climate change mitigation ·

H. Peltola (✉) · T. Heinonen · J. Kangas
University of Eastern Finland, Joensuu, Finland
e-mail: heli.peltola@uef.fi

A. Venäläinen
Finnish Meteorological Institute, Helsinki, Finland

J. Seppälä
Finnish Environment Institute, Helsinki, Finland

L. Hetemäki
European Forest Institute, Joensuu, Finland

Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, Finland

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11.1 Finland's Forest Resources and Their Utilization

Finland is the most forested country in the EU, in terms of land area (Table 11.1). Depending on the definition of forest land, and the source, forests cover 74–86% of the land area. Finland's forests account for around 14% of the total EU27 forest land. The volume of growing stock and increments have almost doubled in the past five decades (Fig. 11.1; Finnish Forest Statistics 2019, 2020). Improved forest

Table 11.1 Overview of Finnish forest sector

Forest resources	
Area of forest land	26.3 million ha, of which 77% is productive and 10% poorly productive (the rest is unproductive land, forest roads, etc.)
Strictly protected forest area and biodiversity conservation areas in commercial forests	2.2 and 0.5 million ha
Total volume of growing stock	2482 Mm^3
Carbon storage of forest land	3200 Mt. CO_2-eq. in forest biomass and 14,000 Mt. CO_2-eq. in soil (most soil carbon in peatlands)
Net carbon sink of forest land	25.6 Mt CO_2-eq. in forest land in 2019, corresponding to 48% of total GHG emissions in Finland (additionally, 3.4 Mt CO_2-eq. in wood-based products, with estimated substitution impact of 27 Mt CO_2-eq.)
Average annual growth of growing stock	108 Mm^3 $year^{-1}$
Total volume of harvested roundwood	≈78 Mm^3 in 2018, this year being the all-time high
Total drain (harvested roundwood, logging residues and natural drain)	≈ 94 Mm^3 in 2018
Average growing stock volume on forest land (productive/poorly productive land)	119 m^3 ha^{-1}
Tree species composition	50% scots pine, 30% Norway spruce, 17% silver and downy birch, and 3% other broadleaves
Ownership	
Private	52%
State	35%
Companies	7%
Municipalities, parishes, funds, associations	6%
Economic contribution	
The value added in the forest sector	9 billion euros in 2019, 4.3% of the national economy
Employees in the Finnish forest sector	66,000 (forestry 26,000, forest industries 40,000) in 2019

Source: Finnish Forest Statistics (2019, 2020), Statistics Finland (2020)

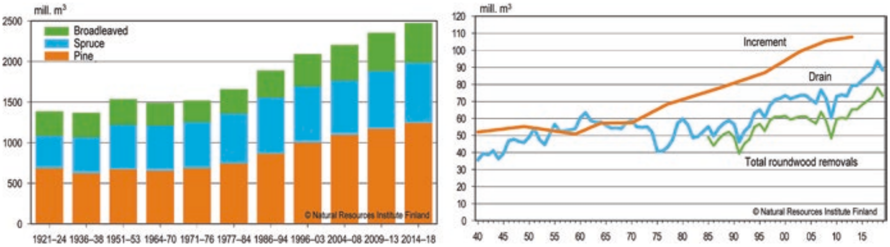

Fig. 11.1 Development of growing stock volume on forest land and poorly productive forest land, and total roundwood removals, increment and drain of the growing stock, in past decades in Finnish forests. (Sources: Finnish Forest Statistics 2019, 2020)

management practices have largely contributed to this change (Finnish Forest Statistics 2020). The forest growth has been increased through the ditching of peatlands, forest fertilization, maintaining higher growing stock (per hectare) in frequent thinnings, regeneration of poorly productive forests, and using improved forest regeneration methods and materials (seedlings and seeds), respectively. Additionally environmental change (e.g. climate change and nitrogen deposition) has contributed to this change (Henttonen et al. 2017). Another reason for this change is that annual wood removal in the last five decades, has been, on average, clearly less than the increment of the forests.

On the other hand, intensified forest management targeting for increased wood production has also affected harmfully forest biodiversity and the provisioning of some ecosystem services (Lehtonen et al. 2021). Also, the use of forest fertilization, and ditch network maintenance in peatland forests, have increased nutrient leaching and carbon emissions from the soil (Finér et al. 2020; Lehtonen et al. 2021). Until recently, the management of Finnish forests has been based, almost solely, on even-aged rotation forestry. However, interest among forest owners, professionals and general society in diversifying forest management practices and increasing provisioning of multiple ecosystem services has increased the attractiveness of uneven-aged management and mixed-species forestry (Díaz-Yáñez et al. 2020).

According to the National Resources Institute Finland, the maximum sustainable roundwood removal potential of Finnish forests, on land assigned for timber production, is 84 Mm^3 $year^{-1}$, on average, for 2015–2024. Annual wood removal in recent years has corresponded to an average of 75% of the total forest growth, which includes the growth of strictly protected forests and natural drainage (Fig. 11.1). This percentage is clearly higher for Finnish forests compared to the EU average, with Finland's forest sector having a relatively bigger role in the country's economy than is the case for any other EU country. Altogether, around 620,000 private forest owners sell about 80% of the Finnish forest industries' total domestic wood supply. Thus, the income generated by forestry is spread among a relatively large part of the population.

Besides the demand for wood production, there are increasingly high demands for forest-related recreation, tourism, biodiversity and forest carbon sinks. No forestry measures are allowed on 10% of the most strictly protected forested areas, which are mostly located in Northern Finland (Table 11.1). These forests are important for both recreation, tourism and biodiversity. Biodiversity is preserved in Southern Finland, in forests that are also used for wood production, through the government-funded Forest Biodiversity Programme (METSO, annual funding of 7–10 million euros). This targets forest owners, with the aim of increasing voluntary forest protection on their lands by 96,000 ha by 2025. Preserving and improving the biodiversity values of forests are also considered in the everyday management of commercial forests.

There are increasing EU and domestic pressures to increase the capacity of the forest carbon sink in Finland, such as the Green Deal and the updating of the land use, land-use change and forestry (LULUCF) regulation. According to the LULUCF regulation, for Finland, the reference level for a forest carbon sink with forest products is 29.4 million CO_2- equivalent (CO_2-eq.) tons in 2021–2025 (Suomen ilmastopaneeli 2021). However, the actual forest carbon sink can vary significantly from one year to the next, along with the annual harvesting levels (since the 1990s, these have been 17.5–47.4 Mt CO_2-eq., annually), which are largely affected by forest-industry business cycles. For example, in 2018 the forest carbon sink was clearly lower than in the previous and succeeding years, due to a higher total annual volume of harvested roundwood (Table 11.1). Given the various demands on Finnish forests, it is necessary to find a balance. Moreover, it is crucial to try to minimize the trade-offs and maximize the synergies between the different uses of forests. In this case-study, we analysed what the climate-smart forestry (CSF) approach could mean in the Finnish context in the coming decades.

11.2 Impacts of Changing Climate, Forest Management and Harvesting

11.2.1 Development of Forest Resources and Carbon Sinks

Compared to the reference period of 1981–2010, the annual mean temperature in Finland may increase by 1.9–5.6 °C and the mean annual precipitation by 6–18% by the 2080s under different GHG scenarios (i.e. Representative Concentration Pathways, RCPs) (Ruosteenoja et al. 2016). Forest growth is generally projected to increase significantly more in the northern boreal zone of Finland than in the southern boreal zone (Fig. 11.2), due to the differences in prevailing climatic conditions (e.g. temperature, precipitation) and forest structure (e.g. age and tree species composition) in these regions (Kellomäki et al. 2008). Overall, the increase in forest growth will come from birch (*Betula* spp.), in particular, but also Scots pine (*Pinus sylvestris*) (Kellomäki et al. 2018). For Norway spruce (*Picea abies*), the growing conditions may become suboptimal, especially in the southern boreal zone, along with increasing summer temperatures and drought.

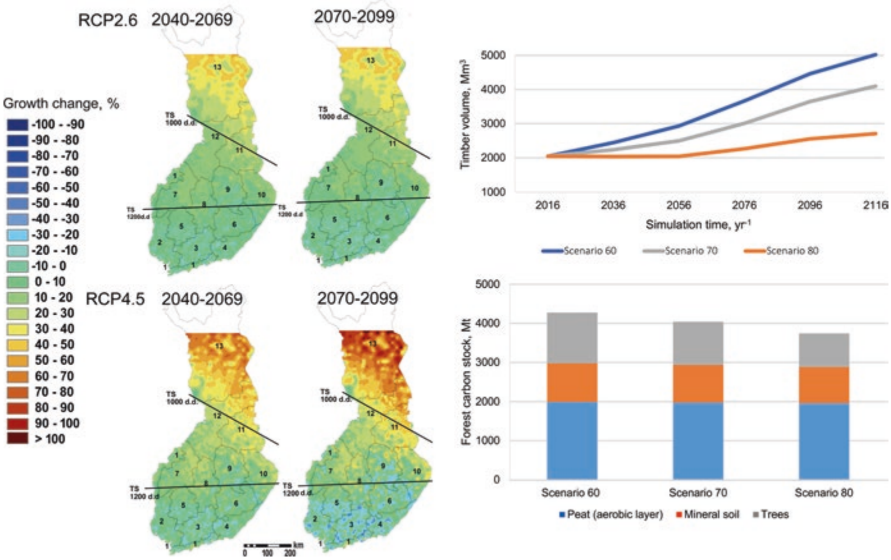

Fig. 11.2 Left: Spatial distribution of the percentage change in tree growth (diameter) in Finland over all tree species on upland (mineral) forest inventory plots, given separately for the coming two 30-year periods (2040–2069 and 2070–2099), under the RCP2.6 and RCP4.5 scenarios, compared to the period 1981–2010 (Kellomäki et al. 2018). If considering peatlands, the positive and negative impacts would be slightly stronger. The temperature sum lines across the country separate the southern (TS > 1200 d.d.), central (1000 d.d. < TS < 1200 d.d.), and northern (TS < 1000 d.d.) boreal regions. Right: Timber volume development (top) and average carbon stock in trees and soil (bottom) on forest land currently available for timber production in Finland in 2016–2116, with scenarios of 60-, 70- and 80-Mm^3 $year^{-1}$ timber cutting targets under the RCP2.6 scenario, with intensified forest management (data from Seppälä et al. 2019). The increasing abiotic and biotic damage risks under climate change were not considered in these scenario analyses

In addition to the severity of climate change, the intensity of forest management and harvesting will also affect the future development of Finnish forests, and consequently timber supply, the carbon sink and the balance of forestry (e.g. Hynynen et al. 2015; Heinonen et al. 2017, 2018). If assuming mild (RCP2.6) climate change and annual mean timber harvests of 60–80 Mm^3 $year^{-1}$, the average annual volume increment could be increased by 4.5–5.7 Mm^3 $year^{-1}$ in 2016–2116, and timber volume may reach 2.7–5.0 Bm^3 by 2116, on forest land currently available for timber production (Fig. 11.2), if increasing the use of forest fertilization and improved regeneration material (Heinonen et al. 2018).

Forest biomass contributes about 23–30% to the total carbon stock of forests (in trees and soil, including mineral soil and the aerobic layer of peat) (Fig. 11.2). Maintaining lower harvesting levels increases the carbon sink and the balance of forests (in trees and soil), but it decreases the carbon stock in wood-based products. Overall, the long-term carbon stock of wood-based products is small compared to that of forest biomass and soil. This is because a relatively small share of harvested wood is used in wood-based products with long-life cycles. In this sense, an increase in the wood harvesting level always results in less carbon being sink and a lower forestry carbon balance (including carbon in the forest and wood-based products), compared to a situation where wood harvesting is not increased in the coming few decades (Heinonen et al. 2017; Seppälä et al. 2019). On the other hand, a consideration of the substitution effects of wood-based products may change this forestry carbon balance, the magnitude of change depending on the production portfolio (Hurmekoski et al. 2020).

11.2.2 Abiotic and Biotic Disturbance Risks

Multiple abiotic and biotic disturbance risks to Finnish forests and forestry are expected to increase at different spatial and temporal scales, which may at least partially eliminate the positive effects of climate change on forest productivity and carbon sinks (Reyer et al. 2017). Warmer and wetter winters are expected to increase damage by windstorms, heavy snow loading and pathogens (e.g. *Heterobasidion* spp, root rot), while warmer and drier summer conditions are expected to increase insect pests (e.g. European spruce bark beetle, *Ips typographus*), droughts and forest fires, particularly in coniferous forests. The occurrence of different damaging agents (excluding snow extremes) is expected to increase, especially in southern and middle Finland (Mäkelä et al. 2014; Lehtonen et al. 2016a, b; Ruosteenoja et al. 2018; Venäläinen et al. 2020). A shortening of the soil frost period from late autumn to early spring will increase the wind damage risk, despite no great change in the wind regime (Lehtonen et al. 2019). Wind- and snow-damaged timber left in the forest will increase the amount of breeding material for bark beetles, an outbreak of which may, together with drought, further increase forest fire risk, through increased amounts of easily flammable deadwood. Attacks by *Heterobasidion* species may increase due to increasing tree injuries during harvesting in the unfrozen soil season (Honkaniemi et al. 2017). Wood decay will also increase the risk of wind damage due to poorer anchorage and stem resistance of trees.

11.3 Nexus for Adaptation, Resilience and Mitigation of Climate Change

11.3.1 Adaption to Climate Change and Risk Management

Different adaptation and risk management actions will be needed in Finnish forests in the coming decades in order to adapt appropriately to climate change and to increase forest resilience to multiple damage risks (Venäläinen et al. 2020). Possible adaptation and risk management actions evaluated in Finland, have so far considered almost solely even-aged forestry. However, some of these are also applicable to uneven-aged and mixed-species forestry.

In the southern boreal zone, a decrease in the cultivation of Norway spruce may be needed, particularly on forest sites with a relatively low water holding capacity, which are more suitable for Scots pine. Also, the potential for an increase in spring and summer droughts should be considered when planting seedlings or seeding in order to increase the success of forest regeneration. Additionally, by favouring growing mixtures of conifers and broadleaves (e.g. spruce and pine, spruce and birch, or pine and birch) instead of monocultures, forest resilience may be increased against multiple damage risks. Overall, timely precommercial thinning and more frequent or heavier commercial thinnings may also be needed in order to increase forest resilience and forest growth and to avoid an increase in natural mortality in stands that are too dense. A shortening of the rotation length may also be needed in order to increase forest resilience, especially for Norway spruce, which may be subject to multiple forest disturbance risks (e.g. wind damage, drought, European spruce bark beetle and *Heterobasidion* spp, root rot).

In planning and implementing thinnings and clearcuts, the increasing risks of wind damage should be considered, especially in the southern and central boreal zones, where strong winds will blow more frequently under unfrozen soil conditions (Laapas et al. 2019). Especially on high-risk areas, heavy thinnings should be avoided on the upwind edges of new clear cuts, and the creation of large height differences should be avoided between adjacent stands in the final harvesting, respectively (Heinonen et al. 2009). It is also recommended that forest fertilization is avoided at the same time as thinning in high-risk areas for wind and snow damage. Consequently, in the middle and northern boreal zones, timely precommercial and commercial thinning may increase the resilience of Scots pine and birch stands to snow damage. Also, the avoidance of forest fertilization on forest sites at high altitudes is suggested in order to decrease snow damage risks, regardless of tree species (> 200 m above sea-level). Timber damaged by wind and snow should also be harvested in a timely manner and transported out of the forest (also undamaged harvested timber) in order to avoid unnecessarily increasing the amount of breeding material for bark beetles. This also holds for bark-beetle-infested and *Heterobasidion*-infected trees.

Because climate change will induce multiple damage risks in Finnish forests and forestry, the probability of devastating cascading events is also projected to increase (Venäläinen et al. 2020). However, their severity may vary significantly at different spatial and temporal scales. Therefore, frequent adjustments to forest management practices in response to changing growing conditions will be required, in order to adapt to climate change and maintain forest resilience. This is also important from the climate change mitigation point of view because large-scale natural disturbances may act as significant carbon sources (Kauppi et al. 2018). Therefore, the multiple risks to forests need to be considered simultaneously in the planning and implementation of forest management. The flexible use of diverse management strategies, instead of one single management strategy (e.g. even-, uneven- and any-aged management) may help to ensure forest resilience and simultaneously provide multiple ecosystem services for society (Díaz-Yáñez et al. 2020).

11.3.2 Climate Change Mitigation

A forest-rich country like Finland can contribute to climate change mitigation especially by increasing carbon sequestration from the atmosphere, and by storing it in forests (trees and soil), but also by producing wood-based products that can act as long-term carbon storage and/or can substitute for more GHG-emission-intensive materials and energy (Hurmekoski et al. 2020). Whether the carbon sink of Finnish forests (and the forest sector) will remain at the current level or increase/decrease in the future will strongly depend on the intensity of forest management and harvesting related to wood demand in the coming decades (see Heinonen et al. 2017, 2018). The carbon sink will also be affected by the severity of climate change and natural disturbances (Venäläinen et al. 2020).

In order to increase the climate benefits of harvested wood, it should be increasingly used for products and fuels that will release fewer GHG emissions to the atmosphere than the fossil-based products and fuels it is substituted for (Hurmekoski et al. 2020). However, the substitution effects must be, on average, even doubled for additional wood harvest if, for example, 80 Mm^3 $year^{-1}$ is harvested annually instead of 60 Mm^3 $year^{-1}$ (in the coming 100 years) (Seppälä et al. 2019). This would be needed in order to compensate the lower carbon stocks of Finnish forests with increased harvest levels (Seppälä et al. 2019). On the other hand, lower harvesting levels in Finland would most likely increase harvesting in other countries. In the longer term, all sustainable uses of renewable wood that compensate for the use of fossil resources might be seen as remaining beneficial because we should be giving up using fossil resources as soon as possible, from the viewpoint of mitigating climate warming in the long term.

Forest growth will also decline, along with aging, which, together with a large volume of growing stock, could promote multiple natural disturbances and, consequently, carbon release into the atmosphere over the long term. Old-growth forests also sequestrate less carbon than younger forests, but they may offer significant carbon storage (Gundersen et al. 2021; Kellomäki et al. 2021). Forests also contribute to several other climate impacts, in addition to GHG emissions (e.g. albedo, biogenic aerosols, evaporation and surface roughness), which may be affected, directly or indirectly, through changes in forest cover and structure, and by the intensity of forest management and harvesting (Kalliokoski et al. 2020; Kellomäki et al. 2021). The opposing effects of changes in albedo and carbon stocks may also largely cancel each other in managed forests with little remaining net climate effect (Kellomäki et al. 2021). In short term, no management option may provide larger net climate benefits than even-aged or uneven-aged management, but increasing use of this option may require proper incentives such as compensation for lost harvest incomes for forest owners.

11.4 Climate-Smart Forestry Strategies and Policy Measures

Despite the important role of the Finnish forest sector in the national GHG balance, maximizing the carbon storage of forests may not be the best option in the long run, although it may provide the best climate-cooling benefits in the short term. This is because an increase in large-scale natural disturbances (e.g. storms, forest fires and European spruce bark beetle outbreaks) may turn forests, at least partially, into carbon sources that release large amounts of carbon into the atmosphere. Instead, in CSF, it is preferential to both increase the carbon stocks and sinks in forests, and increasingly use harvested wood for products and fuels, which will release fewer GHG emissions into the atmosphere, rather than the fossil-based products and fuels they are substituting for. At the same time, maintaining biodiversity and sustainably provisioning multiple ecosystem services should be ensured (Heinonen et al. 2017; Díaz-Yáñez et al. 2020).

Overall, living forest biomass and mineral soils (decaying organic matter and soil organic matter) remove carbon from the atmosphere (net carbon sink), and organic soils (peatlands) emit carbon (net carbon source) (Fig. 11.3). The harvesting level affects forest carbon storage and sinks more than forest management practices and ongoing climate change (Heinonen et al. 2017, 2018; Seppälä et al. 2019).

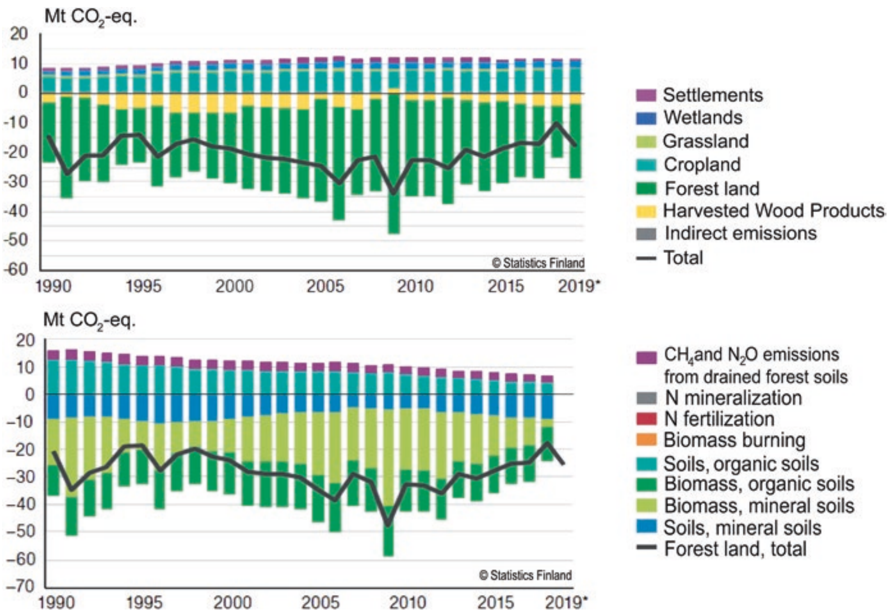

Fig. 11.3 Emissions (positive sign) and removals (negative sign) of Mt CO_2-eq. from different land-use categories (top) and forest land (bottom) in 1990–2019 in Finland (*partial estimation for 2019). (Source: Statistics Finland 2020)

However, forest carbon sinks and storage could be increased in even-aged forestry by increasing the use of improved forest regeneration material and forest fertilization, and by maintaining sufficient growing stock in thinnings (Lehtonen et al. 2021). Also, nutrient leaching and GHG emissions may be decreased on peatlands by maintaining a high enough soil water table level. This could be done by using uneven-aged forestry (especially selective cuttings) on suitable sites, and by avoiding unnecessary ditch network maintenance (Ojanen et al. 2019; Leppä et al. 2020a, b; Finér et al. 2020). This is necessary because a low soil water table will increase CO_2 emissions (Ojanen et al. 2019), and N_2O emissions, especially on fertile peatland sites (Minkkinen et al. 2020). On the other hand, CH_4 emissions may be notable on peatland sites with a high soil water table.

Increasing forest land – for example, by planting on abandoned or low-productivity agricultural land, especially on soils with a high peat content – would be a positive action when it comes to climate change mitigation. On the other hand, also decreasing the deforestation may be effective; currently, deforestation is occurring at a rate of about 10,000 ha, or 0.04% of the total forest area, annually (Kärkkäinen et al. 2019). Increasing the use of by-products for textiles and wood–plastic composites, in place of kraft pulp and biofuel, may also help to provide greater overall substitution credits compared to increasing the level of wood use for construction (Hurmekoski et al. 2020).

To conclude, forests and forest-based bioeconomy can contribute considerably to climate change mitigation in forested countries like Finland, through reducing GHGs in the atmosphere, especially by increasing the carbon sequestration and storage in forests, but also through carbon storage in wood-based products with long life-cycles and the substitution of fossil-intensive resources (Hurmekoski et al. 2020). However, at the same time, there is a pressure to both diversify forest management and increase the provisioning of versatile ecosystem services for society. The forest management implemented today strongly affects the future supply of different ecosystem services (Heinonen et al. 2017). Overall, CSF requires appropriate adaptations of forest management and utilization of forests under climate change, by taking account the multiple risks to forests and forestry. Different management strategies may be needed, depending on the region (and site) and time span, in order to ensure forest resilience and the simultaneous provisioning of multiple ecosystem services for society. This is important also from the climate change mitigation point of view.

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