Readiness of forest corporations for adaptation to biodiversity protection goals (RECORD)

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Content

1. Introduction

1.1. Background of the study

Forests and other wooded lands cover 182 million ha or about 43% of the total land area of EU-28 (EU-27 and the UK). They contribute to biodiversity conservation and forest product based bioeconomy while fulfilling important protective functions such as climate, soil and water protection (SoEF 2020). Sweden, Finland, Spain, France, Germany and Poland are the six EU Member States with the largest forest area that have economically important forest sectors. They account for two thirds of the EU forest area (Winkel and Sotirov 2016; Negre 2021, EUROSTAT 2021). Forest coverage varies however considerably from one Member State to another: while forests in Finland, Sweden and Slovenia cover more than 60% of the country, the equivalent figure is only 11% in the Netherlands and the United Kingdom (UK). Europe has many different forest types, reflecting its bio-geographical and climatic diversity, including, but not limited to boreal and alpine forests dominated by conifers, continental deciduous or mixed forests, Mediterranean deciduous forests (Negre 2021; EUROSTAT 2021; Krasovskiy et al. 2024).

Approximately 60% of European forests are privately owned where the remaining 40% of the forests are publicly owned; a clear Wester-Eastern private-public divide in forest ownership exists, however (Jonsson et al. 2024). While forest type distribution is shaped by climate, soil type, altitude and topography, the European forest frontier represents a mosaic landscape largely determined by human intervention. Only 4% of the European forested area are primary forests that have not been modified by human intervention, but their strict protection is not secured yet. Ca. 8% of European forests consist of fast-growing tree plantations. The remainder of ca. 88 % are 'semi-natural' managed forests largely shaped by human use and forestry operations for decades/centuries (Krasovskiy et al. 2024).

Some 25% of all EU-27 and UK's forests are designated as Natura 2000 sites but the majority of their nature conservation status remains inadequate or not satisfactory (Sotirov 2017, EEA 2020). The area of forests under Natura 2000 varies however significantly among the EU member states. It ranges from 6.4% in the UK (before Brexit), ca. 10% in Finland and Sweden and Latvia (below average) to ca. 18% in France and 25% in Germany (similar to average), and even to ca. 44% in Slovakia and Slovenia, and 53% in Bulgaria. On average ca. 18% of all forests in the old EU Member States are designated as Natura 2000 sites, and 35% in the new Member States (EC 2015).

Unlike in many parts of the world where deforestation due to agricultural expansion and illegal logging is still a major problem, the forest area in Europe has remained stable or increased as result of natural regrowth (mainly on abandoned agricultural lands) and (active) afforestation and reforestation activities (Negre 2021). However, pressures on forest ecosystems in Europe have increased lately. Climate change related impacts (e.g. drought, calamities, rainfalls, storms, wildfires) lead to changing site conditions and challenge species compositions, the frequency of hazardous incidents is growing noticeably and at the same time, wood demand and the net annual increment utilization rates increase (Forest Europe 2020), pointing towards regionally intensified forest management practices. The importance of Europe's multifunctional forests is undisputed (Mason et al. 2021), but a policy discussion questioning the role of intensive forest management systems is ongoing against the background of the future of forest ecosystems and the ambition to reach EU and national forest-related biodiversity conservation, climate protection and sustainable bio-economy policy objectives (Onida 2020; Sotirov et al. 2024).

The state of biodiversity in managed forests outside Natura 2000 sites or strictly protected areas, ca. 70% of all forests in the EU, remains disputed, marked by both positive and negative developments (Marchetti et al. 2017). For example, over the last few centuries, forests managed to varying degrees of intensity have replaced almost all of Europe's natural forests (Svensson et al. 2019; Maes et al. 2020). Currently, less than one third of all Europe's forests are uneven-aged, 30 % have only one tree species (mainly conifers), 51 % have only two to three tree species, and only 5 % of forests have six or more tree species (Forest Europe 2015 and 2020). The recently increasing use of forests as a source of renewable energy poses one of the major forest-related policy challenges. Current studies suggest that these harvesting activities lead to potentially a more than 20 % reduction in their capacity for carbon sequestration (Searchinger et al. 2018). Even the economic sustainability of current high timber harvesting levels in managed forests is subject to increasing scientific critique and debate (Ceccherrini et al. 2020; Palahi et al. 2021; Wernick et al. 2021; Ceccherrini et al. 2021; Seidl and Senf 2023). Regular timber use through clearcutting and other rotational harvesting (planned canopy openings) and salvage logging after climate change related forest disturbances (unplanned canopy openings) have increasingly reduced continuous forest cover on 68% of Europe's forest area (Seidl and Senf 2023).

Furthermore, the increased extraction of forest

products and intensified forestry practices have diverse impacts on the various habitats and species protected in the Natura 2000 network under the EU Birds and Habitats Directives. Ca. 85% of all forest habitat types included in the EU-wide Natura 2000 network of protected areas (which covers about 25% of all EU's forests) are found to be in 'poor' (54%) or 'bad' (31%) conservation status and many forest-dependent species declining in the period 2013-2018. Approximately 14 % of the assessments showed good conservation status (EC 2020; EEA 2020; Maes et al. 2020).

Forest biodiversity is particularly affected by the removal of old-growth forests, dead and dying trees, as well as by timber harvesting through intensive forestry including clear-cutting and other rotational harvesting methods and the plantation of monocultures (EEA 2020; Maes et al. 2020). Forestry is the dominant group of pressures reported for most of the Annex I forest types: it amounts to 50 % of all pressures for mixed forests, broadleaved deciduous and coniferous forests. For broadleaved evergreen forests, however, forestry accounts for only 20 % of the pressures. In particular, over 90 % of boreal forest habitat assessments show an unfavourable conservation status and worse trends than temperate and Mediterranean forests (Maes et al. 2020).

Intensive forestry practices are also among the largest pressure categories reported for species decline under the EU's Natura 2000 network of protected areas, affecting in particular arthropods, mammals, forest birds and non-vascular plants. Forest habitats are especially affected by the removal of dead and dying trees as well as by broader land use changes, such as conversion to monocultures or other forest types. Other habitat groups, e.g. grassland and heath habitats, are more significantly affected by ongoing afforestation dynamics in the EU, which decrease the area of open landscape structures (EEA 2020; Maes et al. 2020).

A particular concern is that the relatively short rotations employed have resulted in a lack of older stands and the rich habitats associated with features such as large trees, abundant deadwood, and an open stand structure. Such criticisms have been particularly strong in countries where plantation and/or planted forests are a major part of the forest area as in the UK and Ireland, or where natural forest stands have been gradually transformed towards a structure similar to a planted forest as in Scandinavia and parts of Central and Eastern Europe. As a result, there has been a growing perception and ensuing policy demands that conventional plantation silviculture based upon clear-felling may not be the most effective way of delivering multiple benefits, particularly in forests with high landscape, recreation, or conservation values (Bengtsson et al. 2000; Mason 2004; Puettmann et al. 2015; Mason et

al. 2021).

The EU LULUCF Regulation recognizes harvest intensity as "a core element of sustainable management practice" (Article 8(5)), but does not determine in detail how it should be defined. According to a recent EU study (Korosuo et al. 2021), the majority of Member States was found to define forest management activities expressed by rotation lengths, age or size thresholds, target species or cohort, and determination of timber harvest intensity. More importantly, this study notes that timber harvest volumes in the national forest reference levels (FRLs) are projected to increase in most Member States as compared to the reference period. The only exceptions are Belgium, Greece, the Netherlands and the United Kingdom, where the total harvest is projected to be slightly lower in the compliance period 2021-2025 as compared to the reference period 2000-2009. The FRLs project the total timber harvests in the EU to increase by around 16%. from ca. 510 Mm3 in the reference period 2000-2009 to ca. 600 Mm3 for the compliance period 2021-2025. The differences between Member States are notable ranging from more than 50% higher harvests in the FRL than in the reference period. as projected by Denmark, Croatia and Ireland, to a slight decrease projected by Belgium, Greece, the Netherlands and the United Kingdom between the reference period and the FRL. In numerical terms, the sum of the Member States' FRLs (EU-28) in the delegated act is a projected sink of -337 Mt CO_2 per year for the period 2021–2025 (Korosuo et al. 2021). This projection is about 18% lower than the sink of -413 Mt CO_2 y-1 reported by the EU 2019 GHG inventory on managed forest land for the period 2000-2009. This EU net forestry sink is smaller in 2021-2025 or 2026-2030 than during historical reference period 2000-2009 (EEA 2019).

If implemented in this way, forestry practices might lead to a net carbon loss that will be at odds with the EU's goals to maintain or enhance the carbon stored in standing forests, or to help conserve forest biodiversity (EEA 2019; Korosuo et al. 2021). They will allow increased timber harvesting equivalent to 80 million tons of CO_2 to be removed from forests and captured in harvested timber products and/or burnt in woody bioenergy (Nabuurs et al. 2018), but it would most likely jeopardize the environmental integrity of the EU's 2030 climate targets for 2030 and 2050 (FERN 2018; FERN et al. 2020).

In terms of socio-economic aspects, there were more than 1.8 million employees in the forest sector (i.e., working in forestry, wood manufacturing and paper industry) in EU-27 in 2023 (EUROSTAT 2024; cf. Forest Europe 2015). The forest sector employs about 1.1% of the total number of workers in Europe. In general, approximately 20% of the people employed in the overall sector work in forestry and timber harvesting, nearly 46% in wood manufac-

turing, and about 34% in the paper industry (EU-ROSTAT 2024; cf. Forest Europe 2020).

In forestry, there is about four employees per 1.000 hectares of forest. The labour intensity in forestry ranges from less than one person per 1.000 ha in some North European countries (Finland, Sweden) to more than 10 people per 1.000 ha in some Central-East European countries (e.g., Hungary, Slovakia). Employment in the forest sector has decreased by about 33% from 2000 to 2015 This reflects the increasing degree of mechanisation and the difficulty to access and harvest wood resources, but also the need for appropriate forest management (Forest Europe 2015; Forest Europe 2020).

In North and Central-West Europe, where forest productivity and mechanisation are high, the gross value added (GVA) per forestry worker exceeds 70 thousand EUR/year, whereas, in Southern and Eastern Europe, it remained below 45 thousand EUR/year in most countries. In wood manufacturing and paper industries, important regional differences subsist due to different industrial systems and varying labour costs. Forestry activities and wood manufacturing are often performed by small-scale enterprises. Self-employed people represent more than 15% of the workforce in these sectors and about 80% of the employees work in small and

medium enterprises. The paper industry sub-sector shows a different structure, with only a small share of self-employed persons (Forest Europe 2020).

The highest reductions occurred in South-East Europe (-44%) and Central-West Europe (–33%), mainly as a result of the reorganisation of the forestry activities and of the increase in productivity in the manufacturing sector. In Central-East Europe, employment in the forest sector started to decrease at the beginning of the millennium, mainly affecting forestry and wood manufacturing activities. In North Europe, the decline in the demand for printing paper combined with gains in productivity led to a restructuring of the pulp and paper industry, and a decrease in employment by 48.1% in this sub-sector (Forest Europe 2020).

After a decrease during the turn of the millennium, employment in forestry in EU-28 is now stabilizing in many countries and in some cases even increasing. This may be partly due to increasing demand for wood as a source of renewable material and energy, supporting countries in their efforts to reduce greenhouse gas emissions and in the transition to a sustainable, circular bioeconomy. The employment in wood industry in EU-28 is steadily decreasing (Forest Europe 2020).

1.2. Problem statement

According to the International Panel on Biodiversity and Ecosystem Services (IPBES) global scientific assessment report (IPBES 2019), land use (agriculture), land use change (e.g., deforestation, afforestation) and forestry (timber harvesting, reforestation) and wildfires, together with climate change, are among the key direct drivers of biodiversity loss and interlinked deforestation and forest degradation worldwide. These so called proximate factors are influenced by indirect drivers such as policy and legal changes, socio-economic developments, financial and business models, and technological innovations. The report points to different ways, through which companies through their business operations across supply chains can engage in biodiversity and climate positive transformation of economic sectors, including forestry and forest industry (IPBES 2019; Chan 2019).

The large forest industries in many European countries, including those based in Finland and Sweden, are powerful players at the EU and global levels. They have a strong influence on the domestic, European and international timber and forest product markets. Their market power, growing industry demand and global business operations can influence forest management practices, and vice versa. On the policy level, the economic power of large forest industries can exercise substantial influence on national and European legislation related to forests, carbon sinks and biodiversity conservation.

Thus far, largest forest industries have profiled themselves as leaders in sustainability through strategic communication and sustainability reporting. For example, a recent study of three big Finnish forest industries' own reporting from late 1990s to 2021 found that all of them named biodiversity loss as one of the most central environmental threats in Europe or globally in at least one of their sustainability reports as well as considered protection, preservation or safeguarding of biodiversity to be important and to form a core part of their sustainability work (Mäkelä and Halme 2025).

However, at home in many European and third countries including Finland and Sweden, the picture is more complex in the light of independent reporting showing evidence of forest biodiversity loss and the deterioration of carbon sinks in quality and quantity terms (see above). One possible explanation for this mismatch could be found in the expectation that the forestry sector measures sustainability mainly from an economic sustainability point of view. In this perspective, this is based on the so called "Annual Allowable Cut" (AAC), with the sole aim to keep timber removals at or slightly below the annual volume of timber regrowth in the concerned area of forest. According to official statistics, above 90% of the annual increment is harvested in Finland and Sweden, which is perceived to be within the limits of a sustainable forest management. This information is used by many commentators including policy advocates and some scientists to conclude that forest management in Europe, including in Finland and Sweden is sustainable because it does not exceed the (economically set) boundaries of sustainable timber harvest (Forest Europe 2020).

However, sustainable timber harvest is known to be a poor indicator of ecological and social sustainability aspects of forest management. The latter include biodiversity conservation, carbon sequestration, ecosystem stability, indigenous people rights, recreational needs, etc. Scientific and practical knowledge reveals that the sustainable yield criterion is not enough to secure effective forest biodiversity conservation, neither the thresholds are adequate since more than 75% use of the annual increment would have already negative ecological impacts (Naubuurs et al. 2024). Next to official statistics showing the decline of biodiversity, carbon and social aspects in Europe especially in Scandinavian forests (EEA 2020; Maes et al. 2020), voluntary sustainability reporting of forest industries also suggests that there is still a lot of work to be done to meet environmental (and social) objectives.

At the same time, the European Union and its member states (including Finland and Sweden) aim to walk the talk on global climate and biodiversity commitments. They have adopted and committed to several policies and initiatives to solve the intertwined problems of the climate, biodiversity and commodity supply crises. This mainly includes EU legislation and (non-legally binding) strategies, such as the the Birds and Habitats Directives, EU Nature Restoration Law, the EU LULUCF Regulation, the EU Renewable Energy Directive (REDD), the EU Taxonomy Regulation, the EU Regulation on deforestation-free supply chains replacing and building on the EU Timber Regulation, as well as the EU Biodiversity Strategy to 2030 and the EU Forest Strategy to 2030. Since the EU Green Deal, serving as their overall foundation, most of these policies request a profound socio-ecological change of economy in general, and in forest industries in particular (Sotirov et al. 2024).

1.3. Research questions

This puzzling situation raises a set of research questions with scientific and practical relevance:

Question 1: Based on what criteria can business performance be assessed as sustainable in relation to biodiversity performance and readiness?

Question 2: Who are the corporate leaders in the field of sustainable forest use in Europe?

Question 3: Are they ready to (fully) meet EU biodiversity forest policy objectives and regulations?

Question 4: Is the Scandinavian, and also the wider European forest industry ready for a transformative change towards socio-ecological sustainability?

Question 5: How well and fast are they adapting their business strategies with the global biodiversity and climate goals and related EU regulations?

To answer these research questions, there is a need to evaluate to what extent and how the major forest industry companies are incorporating EU legislation regulating environmentally-sound forestry and land use into their business strategy. For such an evaluation, relevant criteria need to be established, allowing to assess these business strategies against the rules and objectives of the EU policies. With a scientifically independent assessment, informed by solid and coherent criteria, plausible investigations of how well forest industry companies are adapting to the EU biodiversity and climate policy goals can be secured.

In this report, criteria, indicators and thresholds were developed that allow to assess whether and how leading forest companies are preparing for transformative changes in a context of climate and biodiversity crises and in view of implementing and complying with above listed forest related EU policies. In a second step, the assessment framework was applied to companies' self-reported biodiversity related corporate policies and performance.

Forest companies' self-reported sustainability practices remain a scarcely studied topic. In a recent literature overview, Mäkelä and Halme (2025) found 23 related studies of which only a few focused on biodiversity. The impact on biodiversity and environment of 13 big forest industries was studied based on their reporting by Lähtinen et al. (2016). However, they used the Global Reporting Initiative framework (GRI), a voluntary reporting tool for companies, to define indicators and assess what biodiversity and environmental impacts the companies reported and in what manner. A classification highlighting private forest companies' performance based on an analysis of 66 companies' sustainability reporting in light of GRI requirements was introduced by Toppinen et al. (2012). The study was not particularly focused on biodiversity though as biodiversity was considered only as one part of the assessment framework indicators among many others. Another study that included an assessment-based classification looked at the sustainability reporting practices of some of the European state forest management companies, but with focus on sustainable forestry assessed not only with ecological but also economic and social metrics (Liubachyna et al. 2017).

The study in hand seeks to combine a biodiversity-centered perspective on corporate sustainability reports with a performance assessment framework that is more applicable also to companies not following any specific voluntary guidelines in their reporting. Insights obtained from this exercise of developing and applying the assessment framework can be crucial for a meaningful engagement in evidence-based discussions in terms of current achievements of industry players and the needs for further business adaptations. This knowledge could also inform policy discussions about possibilities and limitations of the use of different tools to support biodiversity positive business transformation through public regulation (e.g., standards, subsidies), market rewards (e.g., price premiums, certification, payment for ecosystem services), and civil society recognition (e.g., "social license to operate", "blaming and shaming"). The underlying assumption of this theory of change is that supporting transformational downstream change in large forest industries will likely have significant effects, through market leverage, industry demand and social mobilisation, on the upper stream side of the supply chains, i.e. forest management by private and public forest owners.

2. Conceptual framework

2.1. Key terms and definitions

According to the Convention on Biological Diversity, "biological diversity", in short biodiversity, "means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (CBD 1992). Biodiversity gener¬ally consists of three components (Bollmann and Braunisch 2013; Naubuurs et al. 2024):

1. Compositional biodiversity:
this corresponds to the nature and number of the elements of biodiversity present in a given area. As regards compositional forest biodiversity, this includes the quality and quantity of tree species, tree species organisation, regeneration processes, removal of biomass etc.

2. Structural biodiversity:
this refers to the spatial arrangement and the dimensions of the elements that compose the ecosystem. As regards forest biodiversity, this includes spatial diversity (vertical diversity such as uneven-aged forests vs. even aged forests), horizontal diversity (from gaps to old growth); amounts and quality of deadwood.

3. Functional biodiversity:
corresponds to the way the system works including the role of each element and the interactions between species and habitats in a given ecosystem. In the forest biodiversity context, this includes high value conservation forests, old-growth and primary forests, and all related species that inter-act with these habitats such as fungi, soil nematodes, herbs, mosses, shrubs, insects, birds, and mammals.

In order to answer to questions about the readiness of forest industries in terms of positive forest biodiversity performance, there is a need for a clear assessment framework (known also as a "benchmark", "evaluation framework" etc.). In general, assessment frameworks are essential tools that help to measure success and progress towards achieving objectives By assessing, measuring and tracking progress, forest owners and managers as well as forest companies can identify areas for improvement, monitor their progress over time, and make evidence-based decisions to achieve their goals. Setting criteria, indicators and thresholds for forest sustainability in general and forest biodiversity in particular is complex, as the ecological functioning of a forest depends on the variety of regional, national or local circumstances. However, a set of common criteria and indicators with some variability in thresholds are developed and applied to discover both general regularities and particular context-specific variability (Linser and O'Hara 2019; Lier et al. 2021; Naubuurs et al. 2024).

Usually, an assessment framework consists of three key elements (Linser and O'Hara 2019; Lier et al. 2021; Naubuurs et al. 2024):

1. Criteria:
criteria relate to what is important to measure. Criteria define the essential topics that should be assessed. In EU and national policy and legal documents, this refers to the overarching policy objectives (e.g., biodiversity conservation, biodiversity restoration, achieving a good conservation status of habitats and/or species, biodiversity friendly and climate adapted and/or resilient forest management) (Hall 1993; Sotirov et al. 2024).

2. Indicators:
indicators relate to how to measure the topics of a criterion, and which elements cluster around which topics. Indicators may be specified in quantitative and/or qualitative terms. In EU and national policy and legal documents, specific indicators can be found (e.g., the indicators of forest biodiversity restoration in the EU's Nature Restoration Regulation, including amounts of lying and standing deadwood, uneven-aged forest, forest birds). Otherwise, many indicators can be derived from specific policy and legal targets, prescriptions and recommendations that are formulated in EU and national policy documents (Hall 1993; Sotirov et al. 2024). This can include policy targets such as avoiding clear-cuts, securing biodiversity friendly reforestation and afforestation, effective protection of old-growth forests, etc. as found in the EU Biodiversity Strategy, EU Forest Strategy, and related guidance documents)

3. Thresholds:
threshold is an amount, level, or limit on a scale which should not be reached or exceeded in case of undesired target (e.g., extinction, damage; dangerous concentration), or which should be reached in case of a desired target (e.g., increase of deadwood by % or m3/ha/year). Usually, thresholds are expressed in quantitative terms, but qualitative thresholds are also possible. Often, thresholds cannot be directly found in EU and national level policy documents, but in scientific and practical knowledge. Thresholds refer to policy settings (calibration of policy targets) that are (most often politically or scientifically agreed) values which should be reached (Hall 1993; Sotirov and Storch 2018).

2.2. Forest biodiversity assessment criteria, indicators and thresholds in the scientific literature

2.2.1. Compositional biodiversity

Promotion of biodiversity by natural regeneration
Effective forest regeneration after harvesting is fundamental to any concept of sustainable forest management. Methods of regeneration - that can be understood as thresholds - vary with objectives of forest management, forest type and harvesting and silvicultural systems. Most typical methods are artificial (reforestation by tree planting with seedlings or sowing, sometimes with non-native or site adapted tree species), natural (by juvenile native plants and coppice that have established naturally under dead, damaged or harvested trees), or mixed (artificial and natural over time or space) regeneration (McDermott et al. 2010). Key characteristic of close-to-nature forest management or ecological forestry is a priority given to natural regeneration (Schütz 2001; Schütz et al. 2012; Puettmann et al. 2015; Krumm et al. 2020; Larssen et al. 2022; Naubuurs et al. 2024).

Forest tree species diversity

According to the scientific and practical knowledge, the correlation between tree species richness and biodiversity is generally positive (Naubuurs et al. 2024). Increasing tree diversity is beneficial to a large number of species (Ampoorter et al. 2012; Gamfeldt et al. 2013; Zeller et al. 2023) and increases other crucial ecosystem services, such as productivity (Liang et al 2016) and resilience against climate induced forest damages, pests and diseases (Jactel and Brockerhoff 2007). The effects of increasing tree species numbers have different magnitudes in the different forest ecosystem types (Hardenbol et al. 2020). In a low tree species diversity ecosystem (like boreal or alpine forests), one additional species already makes a considerable positive contribution to enhancing biodiversity and ecosystem resilience. In a high tree species diversity ecosystem (like Mediterranean or lowland alluvial forests), the expected effects would be higher when a significant number of tree species are added. While there are some forest types where one or few tree species naturally tend to dominate (e.g., boreal or alpine forests), it is still sensible to aim for an increased number of tree species in all forest types (Ampoorter et al. 2021; Zeller et al. 2023). This differential magnitude of tree species diversity in different forest types can be conceived as critical thresholds.

Forest management intensity (Annual Allowable Cut/Sustained Yield)

Forest management intensity refers to the annual allowable cut (AAC) which is the volume of timber that may, or must, be harvested each year from a specified area. In managed forests intended to sustain wood production over time, the AAC cannot exceed the "sustained yield" of wood the forest is capable of producing. Consequently, the concept of sustained yield – which can be traced to what has been commonly referred to as the "German school", first promoted in the late 18th century in Prussia and Saxony, the birthplace of the (economic) "forest sustainability paradigm" (Winkel et al. 2011), of rational and scientific forest management – generally underlies the concept of AAC (Aplet et al. 1993; Johnson 1993; Scott 1998; McDermott et al. 2010). The appropriate thresholds and means to achieve sustained yield has been a subject of debates where the AAC calculation may be based on maximizing wood production from a given area of forest over minimum rotation period, or maintaining a minimum production level over the long term. When applied to mature semi-natural forests or old-growth forests, the former approach leads to substantial harvest volumes in the short term (usually by clear-cuts, shelter-wood and other rotational silvicultural methods), as standing forests are harvested, followed by "fall-down" in production before growth rates are ultimately maximized through the full establishment of younger, faster growing stands (e.g. usually by artificial reforestation, see above). For this reason, it has been termed the "liquidation-conversion" model of forest management (Wilson 1998; McDermott et al. 2010). In contrast, the latter approach – usually termed "non-declining even-flow" avoids the fall down effect by reducing harvest volumes in the short term to those that can be steadily sustained in the longer term (McDermott et al. 2010).

Forest management intensity is usually operationalized in terms of percentage of forest increment (growing stock) that is harvested. In the EU, as an average, it lies at ~75% (Forest Europe 2020), but with national differences and increasing recently to some 90%-95% in some Nordic countries where clear-cut forestry dominates, and with over 100% in Central and East European countries that applied salvage logging (another form of clearcutting) as response to bark beetle damages (Forest Europe 2020; Naubuurs et al. 2024). These high intensities will lead to decreasing stocks and thus the forest acting as a carbon source, often in line with biodiversity decline. Although Europe has built up large stocks of wood over the last seven decades, a very high level of harvesting and overharvesting can be seen as forest ecosystem degradation and biodiversity-harmful practice. In combination with some forest set-asides (see below), and given other increasing risks of climate related forest disturbances, a 75% felling intensity in managed forests is a defendable threshold for the whole forest area of a forest holding (Naubuurs et al. 2024). This threshold may be transgressed in exceptional cases for ecological reasons if the main objective is to convert poor forest stands (e.g., coppice forests) or forests affected by bark beetles after large disturbances into climate resilient and more biodiverse mixed forests. In this case, a clear commitment to close-to-nature forest management needs to exist to avoid intensive harvests and reforestation in disguise for climate adaptation (Larssen et al. 2022).

2.2.2 Structural biodiversity

Deadwood in managed forests
Retaining sufficient standing and lying deadwood in different decay stages in forest ecosystems can play an important role in conserving and restoring forest biodiversity since many species depend on deadwood for larval development, foraging, or nesting (Löfroth et al. 2023). Deadwood volume is one of the most documented biodiversity indicators to date (Naubuurs et al. 2024). Sufficient amounts of deadwood are considered especially relevant as regards the conservation of saproxylic beetles and wood-living fungi (Gao et al. 2015; Oettel et al. 2022), but also forest birds, bryophytes and vascular plants (Zeller et al. 2023). The correlation between deadwood volume (or other metrics such as number of dead trees) and biodiversity is generally positive (Kraus and Krumm 2013; Krumm et al. 2020). In their review, Müller and Butler (2010) analysed thresholds for deadwood and found peak values for species richness of several groups at 20-30 m3/ha

in boreal coniferous forests, 30-40 m3/ha in mixed mountain forests and 30-50 m3/ha in lowland oak-beech forests. Beyond these values, species richness does not increase further and hence these values can be used as thresholds to assess deadwood in managed forests (Naubuurs et al. 2024; Hering et al 2023).

While many European countries have observed increasing trends in the accumulation of deadwood in forest ecosystems (Forest Europe 2020), the deadwood volumes widely differ ranging from 1 m3/ha up to 28 m3/ha with an average of around 10 m3/ha. These volumes remain far lower than the conservation needs of species and the thresholds suggested by conservation biology knowledge, even in Natura 2000 forest protected areas (Winter et al. 2014; Sotirov 2017). Deadwood remains a crucial indicator for the health and diversity of forest ecosystems. At the same time, deadwood management has shown to be a controversial point of debate. Particularly Southern European countries fear an increase of forest fire outbreaks and intensities due to an increase of deadwood perceived as highly flammable woody biomass (Krumm et al. 2020). However, new research finds out that in most conditions deadwood is not significantly contributing to fire risk in Europe. Pieces of deadwood burn slowly and therefore contribute only little to fire intensity. Fine fuels such as branches and dead needles, attached to deadwood can have a significant effect on fire intensity. Salvage logging after a large-scale natural disturbance does not normally reduce the amount of fine fuels and may therefore not reduce fire risk (Larjavaara et al. 2023).

Close-to-nature forest management
Alternative methods of forest management to intensive forestry (clearcutting, shelterwood, reforestation) have been developed in parts of Europe for well over a century (Schütz 2001; Schütz et al. 2012). These methods can be subsumed under the term close-to-nature or continuous cover forestry. They are based on a set of five ecological silvicultural principles of ecological forest management that can be regarded as assessment thresholds: (i.) partial harvesting and avoidance of large clearcuts; (ii.) preferential use of natural regeneration and native tree species; (iii.) developing structural diversity and spatial variability within forests; (iv.) fostering mixed species forest stands and (v.) avoidance of intensive forestry operations such as soil cultivation, herbicide application and fertilizer input, and reliance on natural process such as self-thinning of seedlings and small saplings (Puettmann et al. 2015). Close-to-nature forest management serves as a push towards biodiversity restoration, biodiversity maintenance and enhancement and resilience to climate change induced damages (Krumm et al. 2020; Larsen et al. 2022).

In practice, the majority of EU countries do not prioritise close-to-nature forest management which is often practiced on 1-5% of the forest area with clearcutting and shelterwood forestry taking place on 90% or more of the area. Exceptions can be found in few countries such as Belgium, Germany, and Slovenia where continuous cover forest management takes place on 20-45% of the forest area. Overall, less than one third of all Europe's forests are uneven-aged, 30 % have only one tree species (mainly conifers), 51 % have only two to three tree species, and only 5 % of forests have six or more tree species (Forest Europe 2015 and 2020).

Avoidance of (large) clearcuts
Clearcutting is the most controversial forest harvesting practice because of its actual and perceived impacts on ecological and social forest ecosystem services and functions that compete with economic goods and services of timber production (McDermott et al. 2010). Clearcutting has attracted criticism on range of ecological (Franklin et al. 1999, Spence 2001; Lindenmeyer and Franklin 2003; Fedrowitz et al. 2014; Kohout et al. 2018), social (Bliss 2000) and economic (Stanbury et al. 1995; Bernstein and Cashore 1999; Knoke 2012; Tahvonen and Rämö 2016) grounds. The consequences of a larger clearcut, where larger areas of forest are systematically cleared, are generally severe from an ecological point of view. This "timber-centric" approach has

come in for increasing criticism in recent debates, because use of clearcutting can be damaging to a range of ecosystem services (Mason 2004). This includes a loss in quality and quantity of living biomass above ground (trees) and in the soil (roots, fungal webs, insects, microorganisms), biodiversity decline (e.g., loss of habitats and species depending on old growth forests, deadwood, continuous forest structures), disruptions in water cycles (e.g., water quality and quantity, water storage and groundwater recharge), soil degradation (e.g., reduction of vitality of soils, occurance of landslides and flooding), decline in carbon storage (e.g., removal of carbon stocks in standing forests and forest soils), reduction of landscape and recreational usage values (Lindenmayer and Franklin 2003; Luyssaert et al. 2008; Fedrowitz et al. 2014; Puetmann et al. 2015; Kohout et al. 2018; Bowd et al. 2019; Mayer et al. 2020; Mason et al. 2021). At the same time, some light-dependent animal or plant species might benefit from (smaller) clearcuts (SFV 2006). In a literature review as regards a large range of biodiversity indicators and many different taxonomic groups, Nolet et al. (2018) conclude that both uneven-aged and even-aged silviculture are needed to ensure a greater number of positive impacts.

The impacts of clearcuts are also very much dependent on the soil type and slope of the terrain; large clearcuts on steep slopes will lead to higher erosion risk. In larger clearcuts, the regulating function of the canopy is lost; leading to stronger temperature fluctuations and heat extremes. An enhanced soil carbon loss has been measured after clearcut, depending on soil and size of the cut up to 20-25 tonnes carbon per hectare (CO_2 emission of 75-90 tonnes CO_2 per hectare), and often increased leaching of nutrients (Den Ouden and Mohren 2020). Soil scarification and slash smashing

will enhance this. In the past, under boreal natural circumstances, large fires occurred, hence it is recommended to do harvesting as much as possible through thinnings or continuous cover forest management operations mimicing the natural (intermediate) disturbance regime (Aszalos et al. 2021).

The scientific literature shows that large-scale clear-cutting (> 2 ha) can be an obstacle to the biodiversity restoration of forest ecosystems for several reasons and shall largely be avoided (Pawson et al. 2006; Naubuurs et al. 2024). First, the substantial extraction of woody biomass through clearcutting as highly intensive forestry practice can lead to a depletion of both living and dead woody material (Rudolphi and Gustafsson 2007), which contradicts forest restoration efforts aimed at increasing the share of standing and lying deadwood for biodiversity protection and conservation. Second, clearcutting usually leads to monocultures and even aged forests which have lower biodiversity values. The shifts towards mixed and uneven-aged forest stands in (large-scale) clearcut areas can be challenging due to the relatively homogeneous site conditions, which may hinder the re-establishment of a diverse species mix with varying light and nutrient requirements (Torras and Saura 2008). Third, clearcut management can impact the nesting and breeding habitats of forest bird species that rely on the structural features provided by old trees with habitat structures (Müller et al. 2007). Fourth, clearcutting extensive forest areas can create a barrier to enhancing forest connectivity and, therefore, reduce the permeability of forest habitats to the movement of certain species (Popescu and Hunter 2011). Avoiding clearcuts or limiting clearcuts under 2 ha are recommended as appropriate quantitative biodiversity-friendly thresholds (Naubuurs et al. 2024, Sotirov et al. 2024).

2.2.3 Functional biodiversity

Primary and old-growth forests
Scientific and expert knowledge shows that primary, old-growth and unmanaged forests provide refuges for a large range of species, including rare species, and have proved to be more diverse and biodiversity supportive than managed forests (Paillet et al. 2010). Currently, less than 1% of Europe's forests can be assessed to be in a primary status and ca. 4% is the share of old-growth forests mainly concentrated in Scandinavia and South-Eastern Europe (Sabatini et al. 2018). Forest areas can be set asides to become natural forests over time where these forests will not be available for wood supply. However, due to the long history of human settlement and forest exploitation in Europe, not all forest set asides and protected forests show primeval or old-

growth characteristics (Paillet et al. 2015).
A strict protection status guarantees a slow recovery of natural forest features, and an increasing ca¬pacity to host biodiversity over time. However, the level to which a forest should be strictly protected, and the spatial distribution of natural forests over the landscape, to guarantee biodiversity conservation is still under debate. Further, mosaic landscapes containing open forest patches and strictly protected forests can host specif¬ic species (Bouget and Parmain 2016; Miklin et al. 2018).
Bouget and Parmain (2016) studied the influence of forest reserves area and configuration on the richness of saproxylic beetles in several landscapes in France and showed that, for lowland forests, the total bee¬tle richness increased with increasing cov-

er of forest reserves in the vicinity. They also show that 12%-20% of reserves within a total forest area increased richness and abundance in both managed forests and forest set asides. These results are in line with Schall et al. (2020) who show, for different sites in Germany, that a cer¬tain share of unmanaged forest is necessary to preserve species but only affects specialist forest species of bats, birds, spiders, true bugs and vascular plants. These groups are favoured by 10% of unmanaged forests in the landscape. From a policy point of view, these results tend to comply with the new EU Forest Strategy for 2030 to protect 30% of the land and sea, of which one third should be strictly protected with a special focus on remaining primeval and old-growth forests (EU 2021).

Strictly protected forest areas

Although biologists have long agreed that protected areas alone will be insufficient to conserve biodiversity (Hansen and DeFries 2007; McDermott et al. 2010), many also argue that protected areas are the cornerstone of biodiversity conservation strategies (Hoekstra et al. 2005; Brooks et al. 2006; McDermott et al. 2010). Consistent with this understanding, in 2004 the United Nations Convention on Biological Diversity (CBD) established a target to protect "at least 10% of each world's ecological regions by 2010" (Decision VII/28, CBD 2004; Schmitt et al. 2008). In 2022, the follow up Kunming-Montreal Global Biodiversity Framework under the CBD, defined a more ambitious target to ensure effective protected areas on at least 30% of terrestrial and inland water areas, and of marine and coastal areas, especially areas of particular importance for biodiversity and ecosystem functions and services (CBD/COP/DEC/15/4; CBD 2022).

The presence of legal protected areas status is important to achieve a range of functions such as providing habitats with minimal human presence (forests not available for timber harvesting) to places of recreation (reduced economic forest use) and to supporting traditional cultures and livelihoods (local timber use). Authors have found measurably lower deforestation and forest degradation rates across a variety of legally protected areas (Nepstad et al. 2006; Andam et al. 2008; Clark et al. 2008; McDermott et al. 2010). Scientific knowledge reviews also highlight the importance of protected areas as some taxonomic groups are negatively affected no matter the forest management approach used (Nolet et al. 2018).

Whatever the stated purpose, the part or total exclusion of extractive activities within designated natural areas plays a number of key roles in biodiversity conservation. These include maintaining species and ecosystems that require natural or near-natural conditions for survival, providing an

ark for threatened species whose surrounding habitats have been heavily disturbed and providing research opportunities for scientists and conservationists to learn lessons about natural processes and ecosystem adaptation. (McDermott et al. 2010). As shown above, a threshold of 10% of unmanaged forests is recommended to secure strictly protected forest areas that are not available for wood supply.

High Conservation Value forests

High Conservation Value (HCV) forests are areas of forest that hold exceptional ecological, social, or cultural significance. They are defined based on six key values: biodiversity (HCV1), landscape-level ecosystems (HCV2), ecosystems and habitats (HCV3), ecosystem services (HCV4), community needs (HCV5), and cultural values (HCV6). To designate HCV forests, thresholds are established to ensure their conservation. These thresholds typically include: Ecological Criteria: Presence of endangered species, intact ecosystems, or critical habitats. Landscape Considerations: Large, contiguous forest areas that maintain ecological processes. Ecosystem Services: Forests that regulate water supply, prevent erosion, or mitigate climate impacts. Community and Cultural Importance: Forests essential to local livelihoods or Indigenous traditions (FSC 2018; Munteanu et al. 2021).

The percentage of forest area designated as HCV forests depends on ecological, social, and regulatory contexts, but some general guidelines exist. For example, the Forest Stewardship Council (FSC) recommendations require the identification and protection of HCV forests but does not mandate a fixed percentage. The actual area designated as HCV varies based on the presence of high conservation values within the managed forest. In the European context dominated of semi-natural managed forests, HCV forests are often associated with rare, representative or endangered forest habitats and species protected under the EU-wide Natura 2000 network of special areas of conservation (SACs) and special protection areas (SPAs). Currently, Natura 2000 in forests in EU countries cover ca. 10-50% of all forests in a country, on average 25%, with shares of ca. 10-15% in Western/Northern Europe and ca. 15-30% in Eastern/Southern Europe (Sotirov 2017; EEA 2020). In large intact forest landscapes (in upper Boreal forests), a much higher proportion (e.g., 30%-50% or more) may be designated as HCV to maintain biodiversity and ecosystem services. Some conservation initiatives, like the 30x30 global target (protecting 30% of land and sea by 2030), may influence national HCV area allocations. Another example is the threshold under the Roundtable on Sustainable Palm Oil (RSPO) and other certification schemes. Typically, 10%-20% of a managed forest or a tree plantation may be set aside as HCV forests, depending on ecological assessments. In line with

the above, a threshold of ca. 12-20% of HCV forests can be suggested (Naubuurs et al. 2024).
the above, a threshold of ca. 12-20% of HCV forests can be suggested (Naubuurs et al. 2024).

Forest birds
Forest management practices and their impact on the diversity of forest structures from closed high forests to open woodlands areas is a critical influencing factor on the abundance and diversity of forest fauna, including forest birds (Basile et al. 2021). Therefore, the occurrence of common breeding forest bird species is frequently used as an important indicator to assess forest habitat structure and diversity such as under the regular reporting mechanism under the State of Forest Europe under Criterion 4: Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems – Indicator 4.10 (Marchetti et al. 2017). The official reporting suggests stable developments of common forest bird species during the last 37 years yet highlights a limited knowledge on the influencing factors on bird species abundance apart from forest management practices (Forest Europe, 2020). In general, forest bird data is often used as a key biodiversity indicator because it is based on extensive data sources and benefits from skills among professionals and volunteer networks (e.g., Jiguet et al. 2012). They may be also used as a direct indicator that would benefit from other measures, such as deadwood or tree-related microhabi¬tats enrichment (Burrascano et al. 2018; Paillet et al. 2018). It is hence recommended to not define a particular threshold but to use already existing forest bird indexes, lists etc. Hence, a qualitative threshold can set with any reference to forest bird species protection lists such as IUCN lists, CITES lists, BirdLife Important Bird Areas, Pan-European Common Bird Monitoring Scheme, Forest Europe Common Bird Indicator, SPAs (Special Protection Areas) under the Natura 2000 (Naubuurs et al. 2024).

2.3. Forest biodiversity assessment criteria, indicators and thresholds in EU policies and laws

Many of the aforementioned elements in the assessment framework (criteria, indicators and thresholds) relate to and can be found in several EU environmental forest policies and laws that need to be implemented on the national and subnational levels. According to the state-of-the art scientific literature (Winkel et al. 2013; Naubuurs et al. 2024; Sotirov et al. 2024), the most relevant EU policies and laws include:

- EU Biodiversity Strategy (EU-BS);
- EU Forest Strategy (EU-FS);
- EU Birds and Habitats Directives (Natura 2000)
- EU Nature Restoration Regulation (NRL)
- EU Timber Regulation (EUTR) and the EU Deforestation Regulation (EUDR);
- EU Renewable Energy Directive (RED);
- EU Land Use, Land-use Change, and Forestry (LULUCF) Regulation.
- EU Taxonomy Regulation.

EU Biodiversity Strategy for 2030
Under the European Green Deal (EGD) umbrella, Under the European Green Deal (EGD) umbrella, the Commission adopted the new EU Biodiversity Strategy to 2030 (EU-BS). European biodiversity is expected to be on a path of recovery by 2030 - for the benefit of people, the planet, and the economy. The Strategy contains a chapter on actions on forests, requiring the strict protection of all remaining EU primary and old-growth forests and increasing the forested area by planting at least 3 billion additional trees in the EU by 2030. It also aims at increasing the share of forest areas covered by management plans and developing guidelines on biodiversity-friendly practices on afforestation and closer-to-nature forestry. Furthermore, to counter the pressure of the increased demand for biomass on forests, the use of whole trees for energy production should be minimised, and bioenergy should focus primarily on wood waste and residues. Last, but not least, an EU Nature Restoration Plan will set legally binding conservation targets to restore degraded terrestrial (forest) eco-systems, landscapes, and forest-related water bodies, to enhance sustainable management and resilience. The Plan

demands measures to increase the quantity, quality and resilience of managed and protected forests in the EU-27. This refers to restoration measures such as biodiversity-friendly afforestation, reforestation and tree planting, closer-to-nature-forest management as a biodiversity-friendly practice, integration of biodiversity and restoration objectives in management plans of forest owners. The Plan also aims at creating jobs, reconciling economic activities (e.g., forestry) and biodiversity objectives, and ensuring long-term productivity and value of the natural capital (EC 2020).

The 2019 European Green Deal (EGD) deems forest protection in the EU is deemed as political priority in pursuing the new EU's climate (55% greenhouse gas emission reduction by 2030) and biodiversity (nature protection of 30% of the EU land area, incl. 10% under strict nature protection by 2030) policy objectives. The EGD, together with the EU Climate Law, the new EU Biodiversity and the new EU Forest Strategies call for a transformative process of change aiming at tackling the biodiversity and climate crisis in an integrated way. These EU policies recognise that forest ecosystems are under increasing pressure and call for action to improve the quantity and quality of the forests for the EU and its Member States to reach climate neutrality by 2050 and a healthy environment by 2030 (EC 2019).

EU Forest Strategy for 2030

As an initiative of the European Green Deal, and by building on the EU Biodiversity Strategy for 2030, the Commission adopted a new EU Forest Strategy to 2030 (EU-FES). The main objectives of the EU-FES are effective afforestation and forest preservation and restoration in Europe, to help to increase the absorption of CO2, reduce the incidence and extent of forest fires, and promote the sustainability of forest-based bio-economy in full respect for ecological principles favourable to biodiversity. It also aims to strictly and effectively protect all primary and old-growth forests in the EU. In addition, the EU-FES demands that clearcutting practices in the EU countries should be approached with caution, generally avoided and used only in duly justified cases, for example when necessary for environmental or ecosystem health reasons, and include environmental and ecosystem concerns (EC 2021). As such, the EU-BS and the EU-FES have developed a set of normative goals and policy-related arguments in favor of a EU policy approach of avoiding clearcutting and promoting close-to-nature forest management in Europe.

EU Birds and Habitats Directives (Natura 2000)

nature conservation law. The Nature Directives contain legally binding objectives and a com-mon legislative framework of nature protection stand-ards. They oblige EU Member States to ensure that species (ca. 500 bird species and a sub-set of additional 2.000 plant and animal species) and habitat types (ca. 230) are maintained at, or restored to, a favourable conservation status throughout their natural range within the EU. This target includes both a legal prohibition to avoid deterioration of, and a legal obligation to improve, the conservation status of species and habitats. More specifically, the EU Nature directives require Member States to designate, preserve, and where necessary restore, core sites for the protection of species and habitat types listed in Annex I and II of the Habitats Directive and Annex I of the Birds Directive, as well as for migratory birds. Collectively these sites form the EU-wide Natura 2000 network of protected areas. Member States must also establish a species protection regime for all wild European bird species and other endangered species listed in Annex IV and V of the Habitats Directive. This strict protection regime applies across the species' entire natural range in the EU, i.e. both inside and outside Natura 2000 sites (CEU 1992; Borrass et al. 2015; EC 2015; Sotirov 2017).

It is estimated that approximately 375,000 km² of forests are included in the Natura 2000 network. This represents around 50% of the total area in Natura 2000 and around 25% of the total forest area in the EU-27. The area of forests under Natura 2000 varies however significantly among the EU member states. It ranges from 6.4% in the UK (before Brexit), ca. 10% in Finland and Sweden and Latvia (below average) to ca. 18% in France and 25% in Germany (similar to average), and even to ca. 44% in Slovakia and Slovenia, and 53% in Bulgaria (above average). On average 18% of all forests in the old EU Member States are designated as Natura 2000 sites, and 35% in the new Member States (EC 2015).

The protection and management of all Natura 2000 sites, including al Natura 2000 forest sites designated under either directive is governed by Article 6 of the Habitats Directive. Member States must (1) establish the necessary conservation measures on each site, which correspond to the ecological requirements of the protected habitat types and species of EU importance present (Article 6.1); (2) take measures to avoid deterioration of the habitats, or any significant disturbance of the species for which the sites have been designated (Article 6.2); (3) introduce an assessment procedure for plans or projects not directly connected with or necessary to the management of the site that are likely to have a significant negative impact on a Natura 2000 site (Article 6.3 and 6.4) (CEU 1992; EC 2015; Sotirov 2017).

The EU Nature Directives do not list a specific set of forest management activities that are pro-hibited or required. However, specific examples for conserva-

tion measures (e.g., continuation of or transition to a close-to-nature forest management, forest restoration, forest set asides; increase the population of bird species in a forest site by 10% over 20 years; impact assessment of clearcutting and/or forest road building) can be demanded by Member States through statutory (e.g., national bylaw, Natura 2000 management plans), and/or financial (e.g., Natura 2000 forest contracts or subsidies). All legal provisions of the EU's Nature Directives apply to all forest management activities in Natura 2000 forests. This means that while there are no explicit and direct forest-specific rules in the EU Nature Directives, ecological practices for forest management within and outside Natura 2000 sites can be requested and enforced during practical application. EU guidance documents on Natura 2000 and Forests provide recommendations in this regard that are sometimes applied, and sometimes legally enforced, in implementation practice. For example, in order to reach conservation objectives the maintenance or restoration of some key features might be required. This includes close-to-nature forest management or strict forest protection that support forest-dependent species diversity as well as uneven-aged stands and appropriate quantities of deadwood in the form of microhabitats, preservation of a sufficient number of old and decaying trees maintenance of old and/or hollow trees (habitat trees), banning the use of pesticides and biocides, maintenance of root plates and stubs, and protection of forest edges (EC 2015; Sotirov 2017).

On the other hand, additional biodiversity-friendly planting or re-afforestation, the maintenance of open areas for natural regeneration, the removal of non-native tree species, selective thinning, the protection of the mineral soil layer may also be needed in some particular cases. In Natura 2000 forest sites where a species or habitat type maybe be in a favourable conservation status in a particular site precisely because of the way it has been managed up to now and, it is possible and important to ensure that the existing forest management practices are continued into the future as well (EC 2015; Sotirov 2017).

EU Nature Restoration Regulation (NRL)
After stakeholder consultation and political negotiations, the new EU Nature Restoration Regulation (Nature Restoration Law, in short NRL) was published on 24th of June 2024. The NRL directly regulates forests (e.g. Boreal, Temperate, Mediterranean, Macaronesian and Mountainous coniferous forests as referred to by codes in Annex I of the EU Habitats Directive-Directive 92/43/EEC) and other forest related habitats (e.g., forest related habitats such as rivers, lakes, alluvial and riparian including wet forests, dehesas and wooded meadows, alluvial/riparian forests, and others as referred to by

codes in Annex I of the EU Habitats Directive-Directive 92/43/EEC) in Natura 2000 network of protected areas or outside but listed in the Annexes of the EU Habitats and Birds Directives (Article 4(1) and (4), Annex I NRL). The NRL regulates also all managed forests outside Natura 2000 not included in Natura 2000 and not listed in the Annexes of the EU Habitats and Birds Directives (Article 12, Annex VI, NRL).

For forests in Natura 2000 network of protected areas, the NRL (Art. 4) stipulates legally binding restoration targets and obligations for Member States such as the implementation of restoration measures that are necessary to improve to good condition areas of habitat types listed in Annex I which are not in good condition, by 2030 on at least 30 % of the total area of all habitat types listed in Annex I that is not in good condition, as quantified in the national restoration plan referred to in Article 15; and by 2040 on at least 60 % and by 2050, on at least 90 % of the area of each group of habitat types listed in Annex I that is not in good condition, as quantified in the national restoration plan (referred to in Article 15 NRL). Member States shall also implement restoration measures for the terrestrial, coastal and freshwater habitats of the species listed in Annexes II, IV and V to Directive 92/43/EEC and of the terrestrial, coastal and freshwater habitats of wild birds falling within the scope of Directive 2009/147/EC. 'Restoration' means the process of actively or passively assisting the recovery of an ecosystem in order to improve its structure and functions, with the aim of conserving or enhancing biodiversity and ecosystem resilience, through improving an area of a habitat type to good condition, re-establishing favourable reference area, and improving a habitat of a species to sufficient quality and quantity in accordance with Article 4(1), (2) and (3) and Article 5(1), (2) and (3), and meeting the targets and fulfilling the obligations under Articles 8 to 12, including reaching satisfactory levels for the indicators referred to in Articles 8 to 12 (NRL Art. 3.3). 'Good condition' means, as regards an area of a habitat type, a state where the key characteristics of the habitat type, in particular its structure, functions and typical species or typical species composition reflect the high level of ecological integrity, stability and resilience necessary to ensure its long-term maintenance and thus contribute to reaching or maintaining favourable conservation status for a habitat, where the habitat type concerned is listed in Annex I to the EU Habitats Directive (NRL Art. 3.4.).

For managed forests outside Natura 2000 network of protected areas, the NRL (Art. 12) obliges the Member States to implement restoration measures necessary to enhance biodiversity of forest ecosystems, in addition to forests in Natura 2000 (see above), while taking into account the risks of forest fires. In particular, Member States shall achieve an increasing trend at national level of the common

forest bird index, as further specified in Annex VI, measured in the period from the date of entry into force of the Regulation until 31 December 2030, and every six years thereafter, until the satisfactory levels as set in accordance with Article 14(5) are reached. Member States shall also achieve an increasing trend at national level of at least six out of seven indicators for forest ecosystems, as further specified in Annex VI, chosen on the basis of their ability to demonstrate the enhancement of biodiversity of forest ecosystems within the Member State concerned. The seven indicators are (i.) standing deadwood; (ii.) lying deadwood; (iii.) share of forests with uneven-aged structure; (iv.) forest connectivity; (v.) stock of organic carbon; (vi.) share of forests dominated by native tree species; (vii.) tree species diversity. 'Native tree species' means a tree species occurring within its natural range, past or present, and dispersal potential, i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans. The trend shall be measured in the period from the date of entry into force of the Regulation until 31 December 2030, and every six years thereafter, until the satisfactory levels as set in accordance with Article 14(5) are reached.

EU Timber Regulation
As part of the EU's Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan, the European Parliament and the Council of the EU adopted the EU Timber Regulation (EUTR, Regulation 995/2010) in 2010, which is enforced by the European Commission and Member State authorities since March 2013. The EUTR is an EU environmental law that seeks to com-bat illegal logging and regulates trade in illegal timber and timber products along European and international supply chains from production to trade and consumption. The regulation applies to both EU-harvested and imported timber and timber products. The EUTR contains a legal ban that prohibits the placing of illegally logged timber and timber products on the EU market. Illegal logging is defined as the harvesting of timber in violation of the applicable laws of the country of harvest. Applicable legislation means the legislation in force in the country of harvest covering (1) rights to harvest timber within legally gazetted boundaries, (2) payments for harvest rights and timber including duties related to timber harvesting, (3) timber harvesting, including environmental and forest legislation including forest management and biodiversity conservation, where directly related to timber harvesting, (4) third parties' legal rights concerning use and tenure that are affected by timber harvesting, and (5) forest sector related trade and customs (EP and CEU 2010).

Economic operators such as forest owners, timber traders, forest industries, and retailers in the sense of the regulation are any natural or legal persons that place timber or timber prod-ucts on the internal EU market (from inside the EU and EEA) for the first time, for distribution or use in the course of a commercial activity. The EUTR also requires economic operators to exercise risk-based approach of due diligence when placing timber or timber products on the EU market. The due diligence system should first contain documentation of the operator's supply of timber and timber products placed on the market (description, trade name and type of product, common name of tree species; country or region or concession of harvest, quantity expressed in volume, weight or number of units; name and address of the supplier to the operator, name and address of the trader to whom the timber and timber products have been supplied; documents or other information indicating compliance of those timber and timber products with the applicable legislation). Second, it contains risk assessment in terms of assurance of compliance with applicable legislation (which may include certification or third party legality verification), prevalence of illegal harvesting in the country of harvest, the prevalence of armed conflict, sanctions imposed by the UN Security Council or the Council of the European Union on timber imports or exports, complexity of the supply chain of timber and timber products. Third, where the risk is assessed to be non-negligible, risk mitigation procedures must be applied to minimise effectively risk and which may include requiring additional information or documents and/or requiring third party verification (EP and CEU 2010; Sotirov et al. 2017).

In short, the EUTR can be used to request ecological forest management insofar as there is evidence that timber harvesting operations in a given EU country are carried out in violation of the applicable national forest and/or biodiversity laws. Under the EUTR, and with reference to the EU Nature Directives and applicable national biodiversity law, it would be illegal to practice timber production in protected forest areas (e.g., national parks, forest reserves, Natura 2000 sites) with general or specific timber use restrictions. It will be also illegal to overharvest forest ecosystems above annual allowable cut provisions and/or to foster timber production despite clearcutting bans (socio-ecological exemption may apply) where regulated by national forest law (Sotirov et al. 2024).

EU Deforestation Regulation
To close major regulatory gaps of not addressing agricultural expansion as direct and most important driver of deforestation, and timber logging as major driver of forest degradation, the EU institutions and Member States adopted the EU Deforestation Regulation (EUDR) in 2023 that will replace the EUTR. The

EUDR sets a conditional EU market ban on agricultural products such as cattle, cocoa, coffee, oil palm, and soya, as well as timber and rubber unless these commodities fulfill mandatory sustainability and legality standards. To meet the deforestation and degradation free standards, companies inside and outside Europe shall not produce and trade with food and timber commodities that are produced on deforested and degraded forest lands, regardless if this was legal under national law, and are not covered by a specified due diligence statement (Berning and Sotirov 2023; Berning and Sotirov 2024).

Deforestation means the conversion of forest to agricultural use, whether human-induced or not. Forest degradation means structural changes to forest cover, taking the form of the conversion of (a) primary forests or naturally regenerating forests into plantation forests or into other wooded land; or (b) primary forests into planted forests. Primary forest means naturally regenerated forest of native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. Naturally regenerating forest means forest predominantly composed of trees established through natural regeneration; it includes any of the following: (a) forests for which it is not possible to distinguish whether planted or naturally regenerated; (b) forests with a mix of naturally regenerated native tree species and planted or seeded trees, and where the naturally regenerated trees are expected to constitute the major part of the growing stock at stand maturity; (c) coppice from trees originally established through natural regeneration; (d) naturally regenerated trees of introduced species. Plantation means a planted forest that is intensively managed and meets, at planting and stand maturity, all the following criteria: one or two species, even age class, and regular spacing; it includes short rotation plantations for wood, fibre and energy, and excludes forests planted for protection or ecosystem restoration, as well as forests established through planting or seeding, which at stand maturity resemble or will resemble naturally regenerating forests. Planted forest means forest predominantly composed of trees established through planting and/or deliberate seeding, provided that the planted or seeded trees are expected to constitute more than 50 % of the growing stock at maturity; it includes coppice from trees that were originally planted or seeded (EUDR).

To comply with the legality standard, companies shall not produce or trade timber commodities that are not in compliance with the relevant producer countries' legislation. Relevant legislation of the country of production' means the laws applicable in the country of production concerning the legal status of the area of production in terms of (a) land use rights; (b) environmental protection; (c) forest-related rules, including forest manage-

ment and biodiversity conservation, where directly related to wood harvesting; (d) third parties' rights; (e) labour rights; (f) human rights protected under international law; (g) the principle of free, prior and informed consent (FPIC), including as set out in the UN Declaration on the Rights of Indigenous Peoples; (h) tax, anti-corruption, trade and customs regulations (EUDR; Berning and Sotirov 2023; Berning and Sotirov 2024).

EU LULUCF Regulation
Under the new EU climate law, Member States are obliged to ensure that accounted greenhouse gas (GHG) emissions from the Land Use, Land Use Change and Forestry (LULUCF) sector are balanced by at least an equivalent accounted removal of CO_2 from the atmosphere, known as the "no debt rule". In line with this, the EU LULUCF Regulation (Regulation 2018/841) on inclusion of GHG emissions and removals from LULUCF in the 2030 Climate and Energy Framework was adopted by the Council and the Parliament in 2018 (EP and CEU 2018; Sotirov et al. 2021).

The EU LULUCF Regulation establishes a legally binding EU environmental regulatory policy for accounting and monitoring how Member States deal with GHG emissions and removals from management practices in their forests during the compliance period 2021-2030 (Art. 8). In October 2020, the Commission amended the existing EU LULUCF Regulation with a delegated act setting forest reference levels (FRLs) that each country must apply between 2021 and 2025. The FRL is a projection of the net GHG emissions from managed forest land in 2021-2030, assuming that the forest management practices had continued similar to the practices in the reference period 2000-2009. A decrease in sink relative to the reference level is accounted as emissions. Specific national circumstances and practices, such as lower harvest intensity than usual or aging forests during the reference period, should be taken into account (Recital 23, Art 8.4). This way, the FRL provides a means to account for the impact of policy and forest management changes on the emissions and removals from forests, while factoring out the impact of age-related dynamics in the forests (Grassi and Pilli 2017; Korosuo et al. 2021). The EU LULUCF Regulation contains little regulatory standards with relevance for forest biodiversity conservation and restoration. Only Annex IV generally requests that the national Forest Reference Levels (FRLs) should be consistent with the objective of contributing to the conservation of biodiversity and the sustainable use of natural resources, as set out in the EU Forest Strategy (see above), Member States' national forest policies, and the EU Biodiversity Strategy (see above).

At the same time, FRLs allow for national flexibil-

ities where countries are allowed to use a limited amount of credits (280 Mt CO2) generated in the LULUCF sector to offset emissions in the Effort Sharing Decision; countries may also increase timber logging by 10%, but with a requirement to compensate in other sectors on EU level. This is expected to help farmers develop climate-smart agriculture practices and support forest managers through greater visibility for the climate benefits of wood products, which can store carbon sequestered from the atmosphere and substitute for emission-intensive materials (Grassi and Pilli 2017; Korosuo et al. 2021). LULUCF also permits carbon loss in standing forests (with high relevance for forest biodiversity conservation and restoration) at the expense of carbon gains in harvested timber products (with high relevance for timber production). Subject to national legal restrictions and forest management practices, countries are generally not discouraged by the EU LULUCF Regulation to increase harvesting in forests (e.g. by clearcutting). Intensive forestry in pristine or old-growth forests are not discouraged under the EU LULUCF Regulation either even if they are known to be important not only as long-term carbon stocks and ongoing carbon sinks, but also for their biodiversity and recreational values (Moomaw et al. 2020). So, intensive timber use (e.g. clearcutting) in managed forests and old-growth forests could be promoted to meet the EU LULUCF goals. This will be at odds with the normative goals of climate and biodiversity friendly forest management, and avoidance of clearcutting as stipulated in EU Green Deal (EC 2019), the EU Biodiversity Strategy (EC 2020b) and the EU Forest Strategy to 2030.

The national implementation of the LULUCF Regulation is still in the making and proves to be challenging due to complex technical rules, and recent practices of enhanced timber removal intensity, including larger clearcuts that should be reducing forest sinks in (most of) the EU countries (Ceccherini et al. 2020). The LULUCF Regulation recognizes harvest intensity as "a core element of sustainable management practice" (Article 8(5)). The majority of Member States was found to define forest management activities in the reference period expressed by rotation lengths, age or size thresholds, target species or cohort, and determination of timber harvest intensity. More importantly, timber harvest volumes in the FRLs are projected to increase in most Member States, when compared to the reference period (Korosuo et al. 2021). The only exceptions are Belgium, Greece, the Netherlands and the United Kingdom, where the total harvest is projected to be slightly lower in the compliance period 2021-2025, compared to the reference period 2000-2009. The FRLs project the total timber harvests in the EU to increase by ca. 16%. from ca. 510 Mm3 in the reference period 2000-2009 to ca. 600 Mm3 for the compliance period 2021-2025. The differences between Member States are notable ranging from

more than 50% higher harvests in the FRL than in the reference period projected by Denmark, Croatia and Ireland, to a slight decrease projected by Belgium, Greece, the Netherlands and the United Kingdom between the reference period and the FRL. In numerical terms, the sum of the Member States' FRLs (EU-28) in the delegated act is a projected sink of -337 Mt CO2 y-1 for the period 2021–2025 (Korosuo et al. 2021). This projection is about 18% lower than the sink of -413 Mt CO2 y-1 reported by the EU 2019 GHG inventory on managed forest land for the period 2000-2009 (EEA 2019). This EU net forestry sink is smaller in 2021-2025 or 2026-2030 than during historical reference period 2000-2009. If implemented in this way, forestry practices might lead to a net carbon loss that will be at odds with the EU's goals to maintain or enhance the carbon stored in standing forests, or to help conserve forest biodiversity (EEA 2019; Korosuo et al. 2021). They will allow increased timber harvesting equivalent to 80 million tons of CO2 to be removed from forests and captured in harvested timber products and/or burnt in woody bioenergy. This might help the forest sector to contribute to meeting the EU's and national climate mitigation goals (Nabuurs et al. 2018), but it would most likely jeopardize the environmental integrity of the EU's 2030 climate targets for 2030 and 2050 (FERN 2018; FERN et al. 2020).

EU Renewable Energy Directive (RED)

The EU's Renewable Energy Policy based on the EU's Renewable Energy Directive (RED I) and its recent revisions (called RED II and RED III), establishes a common EU policy and financial support framework for the use of energy from renewable sources, including from forest biomass, in order to limit greenhouse gas (GHG) emissions of the EU and its Member States (Directive 2009/28/EC, Directive 2018/2001). Member States have, among other things, to fulfil binding targets to increase the share of renewable energy, including from woody biomass, in their energy consumption and can use financial support of EU subsidies. The RED II establishes a legally binding 2030 renewable energy target for the EU of at least 32% of final energy consumption, with a clause for a possible upwards revision by 2023. As part of the EU's most recent "Fit for 55" package under the European Green Deal and EU Climate Law, the revised RED III seeks to contribute to the EU's goal of reducing GHG emissions to 55% of 1990 levels by 2030 (Camia et al. 2021).

Forestry is seen as the main source of biomass for energy and wood production in the EU-27. More robust accounting rules for forest management under the LULUCF Regulation (see above) are expected to provide a solid basis for the implementation of the RED III after 2020. This should address earlier broad criticism that GHG emissions from biomass in energy production were not accounted for under

the previous EU Renewable Energy Policy (RED I) (Sotirov et al. 2021).

According to the changes in the RED III, Member States would be no longer allowed to grant financial support for the felling of "high quality" roundwood such as forest biomass from saw logs and veneer logs to produce bio-energy. In analogy with the EUTR, the Commission would adopt a delegated act on how Member States should request economic operators (e.g., private and public forest owners, traders, bioenergy plants) to apply a risk-based approach to secure legal and sustainable production of bioenergy from woody biomass. The legality of harvesting operations should be secured when economic operators provide evidence of (a) the country of harvest, and, where applicable, the sub-national region where the forest biomass was harvested, including the sourcing area; and (b) the national or sub-national laws applicable to the area of harvest ensure compliance of harvesting with the due diligence system defined in article 6 of the EU Timber Regulation (Aggestam et al. 2017; Wolfslehner et al. 2020; Camia et al. 2021).

Forest biomass sustainability criteria and risk mitigation measures in the revised RED (Art. 29) request timber harvesting to prevent negative impacts on soil quality and biodiversity, avoid harvesting stumps and roots, avoid degradation of primary forests and old-growth forests or their conversion to plantation forest. Still, RED allows economic operators to harvest timber in compliance with maximum thresholds for large clear-cuts as defined in the country where the forest is located while encouraging locally and ecologically appropriate retention thresholds for deadwood extraction. In practice, a variety of clearcut related definitions and provisions in national policy and law, including absence of maximum clearcut size restriction or deadwood obligations could japordize the ability of RED II to support ecological forest management in the bioenergy use (Sotirov et al. 2024).

The EU RED requests timber harvesting for bioenergy use be carried out in compliance with requirements to use logging systems that minimise any adverse impact on soil quality, including soil compaction, and on biodiversity features and habitats. Forest sustainability criteria include also legal safeguards to ensure forest regeneration, by demonstrating that the applicable laws require natural or artificial regeneration, or a combination of both, aiming at the establishment of a new forest in the same area and within at least five years after the harvesting and that there is no biodiversity degradation in the regenerated forest area, including that primary forests and natural or semi-natural forests are not degraded to or replaced with plantation forests. Further safeguards are the effective protection of forest areas designated by international or national law, or by the relevant competent authority, for nature protection purposes, including areas being defined as wetlands and peatlands. The RED demands Member States to request from economic operators to ensure that harvest maintains or improves the forest's long-term production capacity. This includes ensuring that annual felled timber amounts do not exceed net annual increment (annual allowable cut) in the relevant sourcing area on average within the five-year period prior to the harvesting intervention, unless different amounts are duly justified in order to enhance the future production capacity of the forest; or because of "salvage logging" in documented events of forest pests, storms or other natural disturbances (Aggestam et al. 2017; Wolfslehner et al. 2020; Camia et al. 2021).

EU Taxonomy Regulation
EU Taxonomy Regulation (TR) aims to support sustainable business activities through a classification based on common set of criteria and indicators for investors, issuers, project promoters and policymaker. It formulates six environ¬mental objectives (EU 2020):

1) climate change mitigation
2) climate change adaptation
3) sustainable use and protection of water and marine resources
4) transition to a circular economy
5) pollution prevention and control
6) protection and restoration of biodiversity and ecosystems.

Forestry is one of 13 economic activities to be included and is addressed under the objectives of climate change mitigation, climate change adaptation and biodiversity protection and restoration. In addition, forestry is indirectly mentioned under horizontal "do-no-significant-harm" (DNSH) criteria of other objectives such as objective 4 (transition to a circular economy). The so-called Climate Delegated Act (CDA), applicable from January 2022, targets the first two objectives on climate change mitigation and adaptation (EU, 2021b). The remaining four objectives are part of the so-called Environmental Delegated Act (EDA), which is applicable from January 2024 (Begemann et al. 2023).

With regards to the biodiversity objective, the Taxonomy Regulation (EU, 2020) specifies in Article 15 the criteria for economic activities, such as forestry, that shall qualify as "contributing substantially to protecting, conserving or restoring biodiversity or to achieving the good condition of ecosystems, or to protecting ecosystems that are already in good condition". The forest related criteria include (Begemann et al. 2023; Naubuurs et al. 2024):

1) nature and biodiversity conservation, including

achieving favourable conservation status of natural and semi-natural habitats and species, or preventing their deterioration where they already have favourable conservation status, and protecting and restoring terrestrial, marine and other aquatic ecosystems in order to improve their condition and enhance their capacity to provide ecosystem services;

2) sustainable land use and management, including adequate protection of soil biodiversity, land degradation neutrality and the remediation of contaminated sites;

3) sustainable agricultural practices, including those that contribute to enhancing biodiversity or to halting or preventing the degradation of soils and other ecosystems, deforestation and habitat loss; or

4) sustainable forest management, including practices and uses of forests and forest land that contribute to enhancing or to halting or preventing degradation of deforestation and habitat loss.

According to the technical screening criteria (TSC), the biodiversity objective, including for forestry, should be in accordance with rele¬vant EU legislation and communications, such as the EU biodiversity strategy for 2030 (EU 2020). The final forestry TSC of the Climate Delegated Act comprise: (1) afforestation, (2) rehabilitation and restoration of for¬ests, including reforestation and natural forest regeneration after an extreme event, (3) forest management (intensity), and (4) conservation forestry.
For the Environmental Delegated Act, which targets the other four objectives, the "EU Platform on Sustainable Finance (PSF)" took up the work. Due to considerable disagreement among members of one of its subgroups that focused on agriculture, forestry and fishing, the forestry criteria with relevance to biodiversity were delayed at first and then published as part of a supplementary report in November 2022, including dissenting views on the 'forestry and logging' TSC for biodiversity and ecosystems. They were finally taken out from the final Environmental Delegated Act (Platform on Sustainable Finance 2022; Begemann et al. 2023).

3. Assessment framework

3.1. Criteria and indicators

Building on chapter 2, assessment framework for evaluating forest industries' readiness to implement forest biodiversity goals was derived. It is composed of 3 criteria and 10 indicators with corresponding (quantitative or qualitative) thresholds of forest biodiversity conservation and restoration. Table 1 summarizes the assessment framework and includes some exemplary sources from the scientific literature and EU policies/laws. Complete references can be found in chapter 2 above.

Table 1: Assessment framework of forest industries' readiness for forest biodiversity goals

Criteria	Indicators	Thresholds	Source
1.Compositional biodiversity	1.1. Promotion of biodiversity by natural regeneration	Yes (priority for natural regeneration) No (priority for artificial regeneration) Mixed (natural and artificial regeneration)	EU Nature Restoration Law, EU Taxonomy, partly EU Nature Directives Krum et al Naubuurs et al
	1.2. Forest tree species diversity	In low tree species diversity ecosystems (Boreal forests), one additional species makes a considerable positive difference for biodiversity, but better to aim for increased number of tree species	EU Biodiversity Strategy 2030, EU Forest Strategy 2030, EU Taxonomy Krum et al Naubuurs et al
	1.3. Forest management intensity (percentage of increment that is harvested)	Up to 75% felling intensity of the whole area of forest holding (more than 90% is the harvesting intensity in SE, FIN)	EU LULUCF Regulation McDermott et al Naubuurs et al

Criteria	Indicators	Thresholds	Source
2 Structural biodiversity	2.1. Conservation and restoration of standing and lying deadwood in managed forests	20-30 m3/ha in boreal coniferous forests, 30-40 m3/ha in mixed mountain forests, 30-50 m3 in lowland oak-beech forests	EU Nature Restoration Law, EU Taxonomy Müller et al Naubuurs et al
	2.2. Close to nature forest management (uneven aged forests)	At least 10 retention trees per hectar in managed forests Natural regeneration, no intensive machinery, no/minimal soil cultivation, no herbicides, little tree plantation (only)	PEFC Norway
	2.3. Avoidance of (large) clearcuts	Below 2 ha clearcuts or banned at all	EU Nature Restoration Law, EU Forest Strategy 2030, EU Biodiversity Strategy 2030 Schütz et al Puettnam et al
3. Functional biodiversity	3.1.Conservation of primary and old growth forests (forest area not available for wood supply)	10% of unmanaged forests (strictly protected areas)	EU Biodiversity Strategy, EU Forest Strategy 2030, partly EU Nature Directives, EU Taxonomy, EU Deforestation Regulation, EU Renewable Energy Directive (30% of all land and sea areas, incl. 10% strictly protected) Sabatini et al McDermott et al Müller et al Paillet et al Naubuurs et al
	3.2. Strictly protected forest areas (forest area not available for wood supply)	10% of unmanaged forests (strictly protected areas)	
	3.3. Protection and restoration of high value conservation forest ecosystems (Forest areas primary designed for conservation)	12-20% forest protected areas	
	3.4. Forest birds	Any reference to forest bird species protection lists such as IUCN list, CITES lists, BirdLife Important Bird Areas, Pan-European Common Bird Monitoring Scheme, Forest Europe Common Bird Indicator, SPAs (Special Protection Areas) under Natura 2000	EU Nature Restoration Law, EU Nature Directives, EU Taxonomy Marchetti et al Müller et al Naubuurs et al Paillet et al Schütz et al Puettnam et al

3.2. Assessment methodology

Approach to scoring
The assessment framework consists of 3 criteria and 10 indicators with corresponding thresholds (quantitative or qualitative). During the evaluation, each indicator was assigned a score according to the scoring rules and guidelines. Based on the individual indicator scores, the sum of scores for an indicator group (per criteria) was aggregated, and a company's total score was calculated as the sum of scores of all indicators and all criteria. This approach resulted in a score per indicator group / criteria as well as an overall score for each company, where the total score in the benchmark was set out of 100.

A set of guidelines for each indicator was prepared and used to score companies' readiness. Each indicator had a fixed scale by which the company received a score depending on the scoring rules. Scores have a 0-2 range: a score of 0 reflects no fulfilment, a score of 1 reflects partial fulfilment, and a score of 2 reflects a full fulfillment (Table 2). Each indicator is assessed against a set of predefined coding rules as defined below.

Table 2: Coding rules

Each indicator is limited to 2 points and broken into the following levels:
• **Met:** the company meets all the coding rules for a particular indicator (2 point)
• **Partially met:** the company meets some but not all coding rules for a particular indicator (1 points)
• **Not met:** the company does not meet any of the coding rules for a particular indicator (0 points).

Table 3: Scoring rules (with explanation)

1. Met (2 points): company can demonstrate with corporate policy, statements and evidence that it considers and meets indicators and their thresholds; this assessment would come with a clear and substantive language, and supportive evidence in corporate sustainability reports;

2. Partially met (1 point): company can demonstrate with corporate policy and statements that they consider indicators, but they cannot demonstrate with evidence that they consider or meet thresholds and indicators. This can be due to lacking corporate policies, statements or evidence; this comes in the form of general "wishful thinking" language or missing consideration of thresholds and lack of evidence in corporate sustainability reports;

3. Not met (0 points): company cannot demonstrate with corporate policy, statements and evidence that they consider or meet indicators and thresholds in corporate sustainability reports; the same applies if companies transgress thresholds even if they consider indicators; this usually comes with gaps and omissions in the corporate sustainability reports. Last but not least, if a company sets a corporate policy that goes against the states indicators and thresholds, this results in 0 score.

Overall ranking assessment formula:
10 indicators x 2 score points (maximum) = 20 points (maximum) x 5 (translation/multiplier factor) -> maximum 100 assessment points per company. A translation/multiplier factor (x 5) was introduced to normalize the assessment points at a scale of 100. This scale (from 0 to 100) was chosen as a more standard approach which offers better understanding and comparability of the results (instead of a scale from 0-20).

Approach to weighting
The 100% of the weight was equally divided among the 10 indicators. This is as all indicators (and criteria) are considered equally important for the forest systems transformation agenda towards biodiversity conservation and restoration. This also means that a company can achieve 10 points per indicator at maximum or total of 100 points. For companies that will be scored on all indicators, this means each indicator will weigh 10%. This will result in an overall score for each company, where the total score in the benchmark is out of 100.

Approach to data analysis
The main sources of information for the collection of information were companies' sustainability reports available at the time of assessment (June-December 2024). For all companies, publicly available sustainability reports were found and put into a common database. Usually, most of the sustainability reports analysed covered the business year 2023. Only few reports were dated from 2022. No report dated 2024 was available at the time of the assessment (June–December 2024). Upon request, a copy of the companies' sustainability reports can be provided.

Sustainability reports constitute a central source material for the assessment of companies' performance in environmental and ecological terms. They can be assumed to reflect the role of biodiversity in companies' modus operandi as biodiversity in the context of business is essentially linked to sustainability work (Mäkelä and Halme 2025). However, previous research has shown, not only generally but also regarding forest industry, that companies' sustainability reports tend to emphasize positive actions and successes while rarely dealing with challenges and problems or critically evaluating the real impacts of the biodiversity measures taken by the companies (Lähtinen et al. 2016; Blanco-Zaitegi 2022; Mäkelä and Halme 2025). These concerns have been taken into account in the design of the assessment framework as general value statements, without clear and matching evidence, do not yield full points.

The publicly available sustainability reports of the companies (abbreviated as "SR"= "Sustainability Report") were subject to desk research and content analysis informed by the assessment framework above. For all companies and each indicator, a detailed coding and summary assessment were prepared in the form of coding tables. The summary assessments with explanations are provided in chapter 3. Upon request, the detailed coding tables can be provided.

To allow for scientific integrity including transparency, reliability and replicability of the assessment results, two evaluators engaged in an inter-coder reliability and replicability checks. In particular, a random selection of 6 out of 16 (> 30% of the sample) sustainability reports were coded in parallel and independently by the two analysts, the results compared and discussed in a panel. A third expert acted as external reviewer and advisor to secure the overall validity of the assessments. Only after these pre-tests and calibrations, all reports were coded and analysed. In February 2025, the resulting results were then sent to all companies for their validation, feedback and comments in written. In addition to this, a video-call with interested and available companies was organized a couple of week later in order to obtain real-life validation and discuss the assessment results.

3.3. Units of analysis and data sources

As the study is interested in the whole European forest industry and its ability to adapt to the forest biodiversity goals as outlined in the scientific literature and EU laws/regulations, the aim has been to cover the industry as widely as possible. Therefore two main criteria have been used to select the companies: 1) the company needs to be headquartered in a EU member state or it should have significant activities in EU member states and the EU market and 2) the companies need to be with large operations to have market power that could influence the whole supply chain.

After systematic search, 16 companies were selected and assessed which represent the top companies in terms of turnover and business operations in the European and global marketplace. They represent different parts of the supply chains as it would have limited the choice unnecessarily if only one part of the supply chain had been chosen. Some of the companies produce only end products, like disposable paper products or hygienic paper, some of them produce cardboard and paper and some of them produce pulp, the basic raw material for end products. Some of the companies cover all parts of the supply chain, from owning the forest to producing pulp and finally producing end products.

Based on these criteria 16 companies were chosen, of which 14 are headquartered in a EU Member State and two outside EU but with significant EU market operations. Table 4 provides an overview of the 16 companies that were selected for the assessment:

Table 4: Overview of companies under study (in alphabetic order)

Company	Main products	Webpage
Ahlstrom (Finland)	Pulp/Paper/packaging	ahlstrom.com
Billerud Korsnäs (Sweden)	Pulp and paper	billerud.com
DS Smiths (UK)	Pulp/paper/packaging	dssmith.com
Essity (Sweden)	Tissue paper	essity.com
Holmen (Sweden)	Timber/pulp/paper	holmen.com
Huhtamaki (Finland)	Food packaging	huhtamaki.com
Metsä Group (Finland)	Timber/pulp/paper/tissue	metsagroup.com
Mondi (South Africa)	Pulp and paper	mondigroup.com
Navigator (Portugal)	Pulp and paper	thenavigatorcompany.com
Rottneros (Sweden)	Pulp	rottneros.com
Sappi (South Africa)	Pulp/paper/forestry	sappi.com
SCA Svenska Cellulosa Aktiebolaget (Sweden)	Timber/pulp/packaging	sca.com/en
Smurfit Kappa (Sweden)	Pulp/paper/packaging	smurfitkappa.com
Södra (Sweden)	Pulp/paper/forestry	sodra.com
StoraEnso (Finland and Sweden	Timber/pulp/paper/	storaenso.com/en
UPM (Finland)	Pulp/paper	upmpaper.com

4. Results

4.1. Company: Ahlström

Brief company's economic profile

Annual turnover

Ahlstrom's net sales for 2023 amounted to EUR 3.0 billion, with a comparable EBITDA of EUR 420 million.

Operational locations

Operations in 13 countries, with 37 plants and converting sites.

Key markets include:
- North America (42% of net sales)
- Europe (38%)
- Asia (13%)
- South America (6%)

Main products and services

Ahlstrom develops fiber-based specialty materials, focused on sustainability and innovation. Their key product offerings include:

- Filter media (air and liquid filtration, automotive filters, etc.)
- Packaging materials (e.g., food and consumer goods packaging, compostable and recyclable materials)
- Healthcare materials (medical fabrics, life science diagnostics)
- Building materials (nonwovens, glass fiber tissue, insulation papers)
- Technical materials (abrasive and tape backings, protective coatings)
- Specialized applications for sustainable packaging, electrification, and personalized healthcare.

Supply chain coverage

Ahlstrom's operations span multiple parts of the supply chain:

- Raw Material Procurement: Focused on sustainable sourcing of forest-based fibers (98% certified in 2023).
- Manufacturing: Includes production of specialty materials at 37 plants worldwide
- Processing and Innovation: Uses advanced technology for customized high-performance materials.
- Product End-Uses: In industries such as filtration, healthcare, packaging, construction, and technical solutions.

Forest ownerships and biomass sourcing strategies

Ahlstrom does not own forests directly but relies on sustainably sourced forest fibers for its operations. The company procures externally purchased natural fibers, with 98% of them certified under sustainable management standards like FSC™, PEFC™, and SFI™. These certifications ensure compliance with regulations like the EU Timber Regulation (EUTR) and the U.S. Lacey Act. Ahlstrom's goal is to achieve 100% certified fiber sourcing by 2030.

The report does not explicitly clarify the forest types (e.g., plantations, managed forests, or natural forests) from which Ahlstrom sources its fibers. However, the company emphasizes sustainable sourcing practices, with 98% of its externally purchased natural fibers certified under schemes like FSC™, PEFC™, and SFI™. These certifications generally aim to ensure responsible forest management, but the specifics of the forest types used are not detailed in the information provided.

Ahlström's Forest biodiversity readiness assessment

Total assessment score points: 6 points (out of 20 points)
Total ranking points: 30 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and/or data /evidence on the priority given to natural regeneration and not on artificial forest regeneration methods. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitment to certification (SR, p. 28). Certification standards may or may not request natural regeneration priority.

Indicator 1.2 Forest tree species diversity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data/evidence on tree species diversity. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitment to certification (SR, p. 28). Certification standards may or may not request forest tree species diversity.

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: No specific data /evidence on forest management intensity (ratio between annual timber harvest and forest growth/increment). General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitment to certification (SR, p. 28, SR, pp. 84–85). Certification standards request annual allowable cut (sustained yield).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific company's commitment deadwood in managed forests. No specific data / evidence on deadwood management (a lack of data / evidence on forest biodiversity).

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** Nno specific policy and data /evidence on close-to-nature forestry and/or uneven-aged forests. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place (SR, p. 28). SFM commitments and certification standards may not request uneven aged forests.

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific company's policy and data /evidence on avoiding (large) clearcutting across its supply chains. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place (SR, p. 28). SFM commitments and certification standards may or may not request avoidance of (large) clearcuts. General commitments for zero deforestation and zero forest degradation, including due diligence, in line with EU regulations.

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Basic company's policy that all forest fiber-based raw materials are purchased as sustainably certified or as a minimum controlled wood for sustainable forest management (SR, p. 28). Commitments to certification and EU deforestation-free and degradation-free regulations that request protection of old-growth forests. No specific data on primary and old growth forests.

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific policy and data / evidence on strictly protected forests (forest set asides). General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Basic company's policy that all forest fiber-based raw materials are purchased as sustainably certified or as a minimum controlled wood for sustainable forest management (SR, p. 28). Commitment to SFM and certification standards may or may not request forest set asides.

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data / evidence on HCV forests. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Basic company's policy that all forest fiber-based raw materials are purchased as sustainably certified or as a minimum controlled wood for sustainable forest management (SR, p. 28). Commitment to certification standards request HCV forests.

Indicator 3.4. Forest bird species protection
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific policy and data / evidence on forest birds. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Basic company's policy that all forest fiber-based raw materials are purchased as sustainably certified or as a minimum controlled wood for sustainable forest management (SR, p. 28). Commitment to SFM and certification standards may or may not request forest bird protection.

4.2. Company: Billerud

Brief company's economic profile

Annual turnover

Net Sales: Billerud's revenue for 2023 amounted to SEK 41.2 billion, showing a slight decline from 2022's SEK 42.6 billion.

Operational locations

- Operations span Europe (primarily Sweden and Finland) and North America (Michigan and Wisconsin).
- Customers are located in over 100 countries globally.

Main products and services

Billerud specializes in fiber-based and sustainable packaging materials:

- Liquid packaging board: 24% of sales.
- Graphic paper: 22%.
- Containerboard: 14%.
- Kraft and specialty paper: 14%.
- Sack paper: 8%.
- Cartonboard: 7%.
- Market pulp: 11%.

These products cater to food and beverage packaging, industrial applications, and printed communication.

Supply chain coverage

Billerud's operations encompass multiple areas:

- Raw Material Procurement: Sustainable sourcing of forest fibers.
- Production: Integrated mills producing pulp, paper, and packaging materials.
- End Products: Recyclable and biodegradable materials for a wide range of applications.

Forest wwnership

- Billerud owns approximately 318,000 hectares of forest land in Sweden.
- About 108,000 hectares are managed through group certification by smallholders under FSC® or PEFC standards.
- The company collaborates with forest owners in Norway and Sweden for long-term wood supply agreements

Forest types & sourcing

- Sweden (74%): Primarily managed forests.
- Other European countries: Including Norway, Finland, and the Baltics.
- North America: Michigan and Wisconsin, with a small portion (4%) from Canada.

Forest type details

- The focus is on sustainably managed forests certified under FSC® and PEFC.
- At least 10% of forest land is conserved for biodiversity and social purposes.

The company avoids:
- High-conservation-value forests.
- Illegally harvested wood.
- Genetically modified or converted forests

Billerud's Forest biodiversity readiness assessment

Total assessment score points: 10 points (out of 20 points)
Total ranking points: 50 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Billerud mentions both natural and artificial regeneration, including continuous cover forestry. Specific policies prioritizing natural regeneration are absent (Source: SR, p. 124).

Indicator 1.2 Forest tree species diversity
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Billerud promotes "Closer to Nature Forestry" to preserve natural forest structures and minimize soil disruption (Source: SR, p. 124).

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** General references to sustainable sourcing and operational biodiversity metrics are noted, but no specific mention of felling intensity percentages (Source: SR, p. 122).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Billerud leaves deadwood during felling and creates high stumps, but lacks direct policies (Source: SR, p. 124).

Indicator 2.2. Close-to-nature forest management
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Training and promotion of closer-to-nature practices are noted, aligning with EU Forest Strategy 2030 (Source: SR, p. 124).

Indicator 2.3. Avoidance of large clearcuts
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No direct data on clearcut size limitations, but sustainability practices are generally promoted by company's policy (Source: SR, p. 124).

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** General efforts for biodiversity conservation, but no specifics on unmanaged or old-growth forests (Source: SR, p. 125).

Indicator 3.2. Strictly protected forest areas
- **Indicator score:** 1 point (partly met)
- **Explanation:** No specific mention of 10% thresholds for unmanaged areas, but responsible sourcing practices are emphasized (Source: SR, pp. 108–109).

Indicator 3.3. Protection of high conservation value forests
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Clear measures to protect valuable habitats are documented (Source: SR, p. 125).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No data or thresholds on bird population protection (Source: SR, p. 125).

4.3. Company: DS Smith

Brief company's economic profile

Annual Turnover

- The report does not explicitly provide the company's annual turnover. According to newer sources, DS Smith revenue for the year ended 30 April, 2024 was 6.8 billion GBP.
- DS Smith is a multinational paper packaging company with headquarters in London, England.
- DS Smith is a major provider of sustainable packaging solutions with operations across Europe and North America, indicating a substantial revenue base.

Main products and services

DS Smith specializes in:

- Sustainable Packaging Solutions: Fiber-based packaging designed for recyclability and reuse.
- Recycling Services: Closed-loop systems for paper and cardboard.
- Paper Production: Using virgin and recycled fibers.

Key highlights include:
- Over 1.2 billion pieces of plastic avoided through fiber-based solutions since 2020/21.
- Products cater to sectors such as e-commerce, consumer goods, and industrial markets.

Forest Types and Fiber Sourcing

- The company sources wood fibers exclusively from managed forests.
- Utilizes virgin fibers certified for sustainability as the primary raw material.

Operational Locations

DS Smith operates in:

- Europe: Divided into Northern, Southern, and Eastern segments.
- North America: Focused on recycling and packaging.

Supply chain coverage

DS Smith's integrated business model covers:

- Sourcing: Primarily from managed forests with 100% recycled or chain-of-custody certified papers.
- Production: Operates 14 paper mills, with biodiversity programs at each site.
- Recycling: Circular economy operations, converting used materials into new products.
- End Products: Sustainable, recyclable packaging solutions.

Forest ownership

DS Smith does not directly own forests but emphasizes:

- Sustainable sourcing of virgin fibers only from managed forests.
- Strict adherence to international standards for sustainable forestry and the prevention of illegal deforestation.

DS Smith's Forest biodiversity readiness assessment

Total assessment score points: 11 points (out of 20 points)
Total ranking points: 55 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** A general corporate policy to protect and regenerate forests and biodiversity; no specific policy and/or data /evidence on the priority given to natural regeneration vs. artificial forest regeneration methods. General fiber supply chain commitments to timber use from sustainably managed forest. Commitment to certification (SR, pp. 49–53). Certification standards may or may not request natural regeneration priority.

Indicator 1.2 Forest tree species diversity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** A general corporate policy to protect and regenerate forests and biodiversity; no specific policy and/or data /evidence/ thresholds on forest tree species diversity. Gen-

eral fiber supply chain commitments to timber use from sustainably managed forest. Partnership with science on how to measure or quantify biodiversity. Commitment to certification (SR, pp. 49–53). Certification standards may or may not request natural regeneration priority.

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: General corporate policy/ commitments to sustainable forest management and forest certification in own forests and products. No specific data /evidence on forest management intensity (ratio between annual timber harvest and forest growth/increment). No information on timber use in relation to annual increment. Commitment to certification (SR, pp. 49–53). Certification standards request annual allowable cut (sustained yield).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific company's commitment or policy for deadwood in managed forests. No specific data / evidence on deadwood management (a lack of data / evidence on forest biodiversity). General commitment to protection of forests and biodiversity, sustainable forest management and use of certified fibre and certify its own forests (SR, pp. 49–53). Certification standards may or may not request deadwood in managed forests.

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data /evidence on close-to-nature forestry and/

or uneven-aged forests. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place; a general corporate policy to protect and regenerate forests and biodiversity (SR, pp. 49–53). This may or may not support close-to-nature forest management.

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific company's policy and data /evidence on avoiding (large) clearcutting across supply chains. General fiber supply chain commitments to ensure sustainable forest management and certified fiber production practices in place; general corporate policy to protect and regenerate forests and biodiversity (SR, pp. 49–53). SFM commitments and certification standards may or may not request avoidance of (large) clearcuts.

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: No specific company's policy and data /evidence on conservation of primary and old-growth forests. General fiber supply chain commitments to ensure sustainable forest management and certified fiber production practices in place; a general corporate policy to protect and regenerate forests and biodiversity (SR, pp. 49–53). SFM commitments and certification standards may or may not request the conservation of primary and old growth forests.

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific company's policy and data /evidence on strictly protected forest areas (forest set aside). General fiber supply chain commitments to ensure sustainable forest management and certified fiber production practices in place; a general corporate policy to protect and regenerate forests and biodiversity (SR, pp. 49–53). SFM commitments and certification standards may or may not request the strict protection of forest areas (forest set aside).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Specific policy and data / evidence on HCV forests and species with thresholds ranging between 11-35% of all habitats and/or species (in Portugal); HCV assessments and conservation management also in USA and Germany (SR, pp. 49–53).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Some information/evidence on assessing and protecting forest birds; but no specific policy and data / evidence on forest birds lists. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place; general policy on protecting and regenerating forest and biodiversity (SR, p. 49–53). Commitment to SFM and certification standards may or may not request forest bird protection.

4.4. Company: Essity

Brief company's economic profile

Annual turnover

Net Sales: Essity achieved SEK 147 billion in 2023, with an adjusted EBITA of SEK 18.9 billion, marking its highest profit ever.

Main products and services

Essity is a global leader in hygiene and health products, focusing on innovative and sustainable solutions. Key product categories include:

- Health & Medical: Incontinence products, wound care, and compression therapy.
- Consumer Goods: Feminine care, baby care, and consumer tissue.
- Professional Hygiene: Products for businesses, hospitals, and public spaces.

The company emphasizes sustainable materials and aims to address hygiene and health needs for people globally.

Forest types and fiber sourcing

- Essity sources fibers from sustainably managed forests, emphasizing biodiversity and responsible forest management.
- Commitment to alternative recycled fibers and materials to reduce raw material consumption and ensure long-term sustainability.

Operational locations

Essity operates in over 150 countries, with the majority of sales in:

- Europe (60%)
- North America (17%)
- Latin America (17%)
- Asia (2%)
- Other regions (4%).

Essity maintains a strong presence in both mature and emerging markets, prioritizing growth in East Asia, Latin America, and the U.S.

Supply chain coverage

Essity's operations span the entire value chain:

- Sourcing: Fresh wood-based fibers, with a strong commitment to sustainable forestry and zero net deforestation.
- Manufacturing: Innovation-focused production facilities, including new tissue-making processes that reduce CO_2 emissions and water usage.
- Products and Solutions: Emphasis on recycling and multi-use products, contributing to a circular economy.

Forest ownership

- Essity does not own forests but collaborates with partners to ensure sustainable fiber sourcing.
- All wood fibers are sustainably sourced, adhering to international certifications and zero net deforestation goals.

Essity's Forest biodiversity readiness assessment

Total assessment score points: 7 points (out of 20 points)

Total ranking points: 35 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Essity utilizes both natural and artificial forest management practices but lacks a detailed focus on prioritizing natural regeneration (Source: SR, pp. 67–69).

Indicator 1.2 Forest tree species diversity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** General commitment to sustainable fiber procurement is noted, but there is no explicit mention of promoting tree species diversity (Source: SR, pp. 67–69).

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: Essity highlights its adherence to certification standards but lacks specific data on felling intensity percentages (Source: SR, pp. 67–69).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Essity commits to general biodiversity improvement within its supply chain but does not specifically address deadwood restoration (Source: SR, pp. 67–69).

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Sustainable forestry practices are promoted, but there is no explicit mention of minimizing soil disturbance or machinery use (Source: SR, pp. 67–69).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 0 poins (not met)
- **Explanation/Source:** There is no specific mention of avoiding large clearcuts or size restrictions in the report (Source: SR, pp. 67-69).

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: General commitments to responsible fiber procurement and biodiversity are noted, but no specifics on primary or old-growth forest conservation (Source: SR, pp. 67–69).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 0 point (not met)
Explanation/Source: No explicit reference to strictly protected areas or 10% thresholds for unmanaged forests is included (Source: SR, pp. 67–69).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Essity participates in projects to monitor biodiversity but does not detail specific thresholds for high-value conservation areas (Source: SR, pp. 67–69).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** The report does not mention forest bird population thresholds or related data (Source: SR, pp. 67–69).

4.5. Company: Holmen

Brief company's economic profile

Annual turnover

Net Sales: SEK 22,795 million in 2023, with an operating profit of SEK 4,755 million

Main products and services

Holmen operates across several key areas. Holmen's strategy emphasizes climate-smart and sustainable materials:

- Forest: Sustainable forestry for timber and raw materials.
- Wood Products: Includes construction materials and engineered wood products like CLT and glulam.
- Paperboard: Premium paperboard for consumer packaging.
- Paper: Book and magazine paper, with new products for transport packaging.
- Renewable Energy: Hydro and wind power production on its land.

Forest types and fiber sourcing

- The majority of the forest land is managed forests, with sustainable practices certified by FSC® and PEFC®.
- Nature Conservation: 207,000 hectares of the total land are set aside for biodiversity.
- Holmen produces 45 million seedlings annually for reforestation, using tailored seeds to improve growth and resistance.

Operational locations

- Primarily in Sweden, with extensive land holdings totaling 1.3 million hectares, including productive forest land and industrial sites.
- Renewable energy projects and sawmills are also located near forest holdings for logistical efficiency.

Supply chain coverage

Holmen's operations encompass:

- Raw Material Sourcing: From its own managed forests and purchases from private forest owners.
- Processing: Industrial facilities process wood into products like paper, paperboard, and timber.
- End Use: Products cater to construction, packaging, and publishing industries, contributing to a circular economy.

Forest ownership

- Owns Forests: Holmen is one of Sweden's largest forest owners with 1.3 million hectares, of which over 1 million hectares are productive forest land.
- Forests are managed actively and sustainably, with reforestation and biodiversity

Holmen's Forest biodiversity readiness assessment

Total assessment score points: 10 points (out of 20 points)
Total ranking points: 50 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** Specific policy and/or data /evidence on the priority given to artificial forest regeneration methods. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitment to certification (SR, 12, p. 16, p. 38, p. 40, p. 78, p. 100). Certification standards may or may not request natural regeneration priority.

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data/evidence on tree species diversity. General corporate policy and indicators on volumes of standing timber from large broadleaves. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitment to certification (SR, p. 12, p. 16, p. 38, p. 40, p. 78, p. 100). Certification standards may or may not request forest tree species diversity.

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: Some (incomplete) data (without clear) thresholds on forest management intensity. Corporate policy on maximum sustained timber yield. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitment to certification (SR, p. 12, p. 16, p. 38, p. 40, p. 78, p. 100). Certification standards may request annual allowable cut (sustained yield).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific data and thresholds on deadwood, but corporate deadwood policy exists. General commitments to SFM and certification (SR, p. 12, p. 16, p. 38, p. 40, p. 78, p. 100). They may or may not request deadwood in managed forests.

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data /evidence on close-to-nature forestry and/or uneven-aged forests. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place (SR, p. 12, p. 16, p. 38, p. 40, p. 78, p. 100). SFM commitments and certification standards may or may not request uneven aged forests.

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 0 poins (not met)
- **Explanation/Source:** No corporate policy and data on avoiding clearcutting. General data on annual harvest in Sweden including clearcutting is presented in the report. General commitments on SFM and certification. (SR, p. 12, p. 16, p. 38, p. 40, p. 78, p. 100)

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 2 points (met)
- **Explanation/Source**: Corporate policy and data on the conservation of old growth forests meeting the thresholds (10%) exist (SR, p. 12, p. 16, p. 38, p. 40, p. 78, p. 100).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Corporate policy and data on strictly protected forest areas (forest set aside) exists, but data shows that thresholds are not met (8%) (SR, p. 12, p. 16, p. 38, p. 40, p. 78, p. 100).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Specific corporate policy on HCV forests exist and data confirms meeting the thresholds (18%). (SR, p. 12, p. 16, p. 38, p. 40, p. 78, p. 100).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific corporate policy and data on forest birds protection exist. General policy on nature conservation areas available, it may include forest birds protection (SR, p. 12, p. 16, p. 38, p. 40, p. 78, p. 100).

4.6. Company: Huhtamäki

Brief company's economic profile

Annual turnover

Net Sales: EUR 4.169 billion in 2023, with a decrease of 7% compared to 2022.

Main products and services

Huhtamaki provides sustainable packaging solutions with a focus on:

- Fiber Foodservice Packaging: Paperboard and molded fiber products for foodservice, quick service restaurants, and FMCG companies.
- Flexible Packaging: Lightweight packaging for food, beverages, pet food, healthcare, and retort pouches.
- Paper-based Packaging: For consumer goods, including folding cartons.
- Sustainability Innovation: Launch of recyclable mono-material flexible packaging solutions and circular product initiatives.

Forest types and fiber sourcing

- Focus on recycled fibers and virgin fibers from sustainably managed forests.
- Commitment to achieving 80% renewable or recycled materials in production by 2030.

Operational locations

- Operating Countries: 37 countries across Europe, Asia, Oceania, North America, South America, and the Middle East.
- Production Sites: 107 globally.

  Key geographic segments:

- North America: Largest contributor to sales, accounting for 35%.
- Flexible Packaging: 32% of net sales.
- Fiber Packaging: Expanding in regions like North America and South Africa.

Supply chain coverage

Huhtamaki covers multiple aspects of the supply chain:

- Sourcing: Relies on sustainably managed materials, with 98.7% of fiber from recycled or sustainably sourced materials.
- Manufacturing: Includes innovative production processes, such as fiber lid production in Germany and molded fiber products in South Africa.
- Distribution: Global network supporting circularity initiatives and innovation partnerships.

Forest ownership

- Huhtamaki does not own forests but emphasizes responsible sourcing:
- Fiber Sources: Mainly recycled and sustainably managed forests, ensuring minimal environmental impact.

Huhtamäki's Forest biodiversity readiness assessment

Total assessment score points: 5 points (out of 20 points)
Total ranking points: 25 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** The company is committed to zero deforestation and sourcing from sustainably managed forests, but specific practices prioritizing natural regeneration are not detailed (Source: SR, p. 168).

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 1 point (partly met)
- **Explanation/Source:** General commitments to sustainable sourcing and biodiversity are mentioned, but no explicit efforts to increase tree species diversity (Source: SR, p. 168).

Indicator 1.3. Forest management intensity
- **Indicator score:** 0 points (not met)
- **Explanation/Source**: No specific mention of deadwood conservation, but general biodiversity efforts are noted (Source: SR, p. 168).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific mention of deadwood conservation, but general biodiversity efforts are noted (Source: SR, p. 168).

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Sustainable practices, including certified wood sourcing, are emphasized, but specific close-to-nature techniques are not detailed (Source: SR, p. 168).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** There are no references to practices avoiding large clearcuts or limiting their size (Source: SR, p. 168).

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: Huhtamäki is committed to zero deforestation and conserving areas of high biodiversity value but lacks data on old-growth forests (Source: SR, p. 168).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** There is no specific reference to strictly protected forest areas or thresholds (Source: SR, p. 168).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** The company commits to zero deforestation but provides no detailed restoration targets or specific percentages (Source: SR, p. 168).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** The report does not address forest bird conservation efforts or thresholds (Source: SR, p. 168).

4.7. Company: Metsä

Brief company's economic profile

Annual turnover

Net Sales: EUR 6.98 billion in 2022, with a comparable operating result of EUR 1.276 billion.

Main products and services

Metsä Group specializes in sustainable, wood-based products and services across multiple business areas:

- Wood Supply and Forest Services: Sustainable forest management and timber trade.
- Wood Products: Includes sawn timber, Kerto® LVL, and plywood.
- Pulp and Bioproducts: Pulp, bioenergy, and other bioproducts like tall oil and turpentine.
- Paperboard: Folding boxboard and white kraftliner.
- Tissue and Greaseproof Papers: For hygiene and industrial use.

Forest types and fiber sourcing

Types of Forests:

- Primarily sources from managed forests certified under PEFC and FSC.
- Forests include a mix of pine, spruce, birch, and deciduous trees.
- A strong focus on biodiversity, with retention trees and biodiversity stumps left during harvesting.

Sourcing breakdown

- 85% of wood comes from Finland; the rest from Northern Europe.
- 89% of the wood used is certified, and all wood is traceable.

Operational locations

- Countries of Operation: Metsä Group operates 35 production sites in 8 countries, including Finland, Sweden, and other parts of Northern Europe.
- Main Markets: Europe, Asia, and North America.

Supply chain coverage

Metsä Group spans the entire forestry value chain:

- Forest Management: Supported by over 90,000 Finnish forest owners, who own approximately 5.3 million hectares of Finland's private forests.
- Manufacturing and Processing: Includes sawmills, paper mills, and integrated facilities.
- End Products: Delivered to 110 countries, supporting circular economy goals.

Forest ownership

- Own Forests: Through its cooperative members, Metsä Group has access to significant forest areas.
- However, the cooperative structure means forest ownership is distributed among its members rather than held centrally by the company.

Metsä's Forest biodiversity readiness assessment

Total assessment score points: 10 points (out of 20 points)
Total ranking points: 50 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** Specific corporate policy and/or data about priority given to artificial forest regeneration methods (planting and cultivation). General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitment to certification (SR, p. 9, p. 14, p. 19). Certification standards may or may not request natural regeneration priority.

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 2 points (met)
- **Explanation/Source:** Specific corporate policy and data/evidence on forest tree species diversity (mixed forests, birch and other broad-leave trees are mixed with spruce and pine). Commitment to certification.

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: General corporate policy on sustained yield ("We use wood from forests that grow more than they are used"). No specific data/evidence and thresholds on forest management intensity (ratio between annual timber harvest and forest growth/increment). Commitment to certification (SR, p. 9). Certification standards may request annual allowable cut (sustained yield).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Specific company's commitment and policy on deadwood in managed forests, mainly through retention trees at regeneration sites and four biodiversity stumps per ha in 90% of all harvesting sites (2030 targets, realized 90-95% in 2022). No specific data / evidence on meeting the deadwood management thresholds (20-30 m3/ha in Boreal forests) (SR, p. 14, p. 19).

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Specific corporate policy and data on continuous cover forestry on peatlands. No specific policy and data about other commercial forests. SFM and certification commitments, but they may or may not request uneven aged forests (SR, p. 15).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific company's policy and data /evidence on avoiding (large) clearcutting across its supply chains. Specific corporate policy on retention forestry, but no data showing the thresholds of avoiding (large) scale clearcuts (above 2 ha) are met. Corporate policy on planting after regeneration fellings hint to clearcut forestry dominance (SR, p. 9, p. 14, p. 19). SFM commitments and certification standards may or may not request avoidance of (large) clearcuts.

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: No corporate specific policy on the conservation of primary and old-growth forests. Specific reference to FSC/PEFC certification and/or related 5% of forest set asides in certified forests. The thresholds of 5% does not meet the threshold of 10%, no further evidence. (SR, p. 19).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific corporate policy and data / evidence on strictly protected forests (forest set asides). Certification standards (FSC) that the company commit to request at least 5% of forest set asides. FSC threshold does not meet the 10% threshold. No information and evidence how much forest is set aside.

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Specific corporate policy on HCV forests (protection of valuable nature) required by the FSC certification. In addition, corporate policy and funding support for biodiversity measures outside commercial forests (SR, p. 19). No information/evidence that the thresholds (12-20%) are met.

Indicator 3.4. Forest bird species protection
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data / evidence on forest birds. Specific policy based on recommendation to forest owners to protect threatened species, especially in herb-rich forests that are home of threatened species. Certification commitments (SR, p. 19). Commitment to SFM and certification standards may or may not request forest bird protection.

4.8. Company: Mondi

Brief company's economic profile

Annual turnover

Net Sales: €7.3 billion in 2023, with an Underlying EBITDA of €1.2 billion.

Main products and services

Mondi Group is a global leader in sustainable packaging and paper, with products spanning three core business units:

- Corrugated Packaging: Virgin containerboard and corrugated solutions for specialized end-use applications.
- Flexible Packaging: Kraft paper, paper bags, consumer flexibles, and hybrid packaging solutions.
- Uncoated Fine Paper: Printing and office paper for home, office, and professional use.

Key focus areas

- 85% of products are reusable, recyclable, or compostable, aiming for 100% by 2025.
- Innovative packaging solutions include sustainable alternatives like paper-based sleeves for Coca-Cola multipacks.

Forest types and fiber sourcing

Types of Forests:

- Managed plantations in South Africa and sourcing from managed forests in Europe.
- Strong focus on biodiversity, water stewardship, and resilient forests.

Sustainability Measures:
- Zero deforestation in wood supply.
- Collaboration with scientific organizations to promote climate-fit forests.
- Water and biodiversity assessments conducted at mills and forest sites.

Operational locations

Countries of Operation: Over 30 countries, with 100 production sites and major operations in Europe, North America, Africa, and Asia. Key countries include:

- Europe: Austria, Germany, Slovakia, Poland, and Sweden.
- North America: Canada and the USA.
- Africa: South Africa and Egypt.
- Asia: Production facilities in South-East Asia.

Supply chain coverage

Mondi operates across the entire value chain. Mondi Group is a leading sustainable packaging and paper producer with a fully integrated supply chain. It owns managed forests, ensures 100% responsible fiber sourcing, and emphasizes innovation and circular economy principles. Raw Material Sourcing:

- 100% of wood responsibly sourced, with 75% FSC™ or PEFC-certified fiber and the remainder meeting FSC Controlled Wood standards.
- 90% of wood sourced locally where mills are located.
- Approximately 1.3 million tonnes of paper recycled annually.

Production: Integrated pulp and paper mills supporting cost-competitive production and energy generation.

End Products: A broad portfolio of packaging and paper solutions, primarily delivered regionally but with global distribution.

Forest ownership

- Mondi owns sustainably managed forests in South Africa.
- Forest Area: approximately 255,000 hectares of forest land, which supports biodiversity and includes plantations certified by FSC and PEFC.

Mondi's Forest biodiversity readiness assessment

Total assessment score points: 10 points (out of 20 points)
Total ranking points: 50 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific corporate policy and/or data/evidence on a priority given to natural regeneration methods. A specific corporate policy on reforestation (planting) after final harvests (in both semi-natural forests and tree plantations). Specific corporate policy on natural vegetation to prevent plantations from fires (South Africa). General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitment to certification (SR, p. 60, p. 65; BD, p. 1–4). Certification standards may or may not request natural regeneration priority.

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data/evidence on tree species diversity. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. A specific policy on the management of invasive alien plant species and collaboration with research on biodiversity footprint (SR, pp. 64–65; BD, p. 1–4). Commitment to certification. Certification standards may or may not request forest tree species diversity.

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: No specific data/evidence on forest management intensity (ratio between annual timber harvest and forest growth/increment). General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitment to certification (SR, p. 27, p. 50, p. 62). Certification standards may request annual allowable cut (sustained yield), but there is no data about the (70%) AAC threshold.

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific company's commitment deadwood in managed forests. No specific data / evidence on deadwood management (a lack of data / evidence on forest biodiversity). Corporate policy on segregative nature protection, hence deadwood in managed forests (plantation) very unlikely.

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific policy and data /evidence on close-to-nature forestry and/or uneven-aged forests. Corporate policy on segregative nature protection, hence uneve-naged forest management in managed forests (plantations) very unlikely.

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific company's policy and data /evidence on avoiding (large) clearcutting across its supply chains. SFM commitments and certification standards may or may not request avoidance of (large) clearcuts. General commitments to zero deforestation and zero forest degradation, including due diligence, in line with EU regulations (SR, p. 60, p. 65; BD, p. 1–4).

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: No specific corporate policy on primary and old growth forests. No specific data/evidence about (10%) thresholds of primary and old growth forests. General corporate commitment to avoidance of controversial sources, including conversion of primary forests to plantations. General fiber supply chain commitments to ensure sustainable forest management and fiber production practices in place. Commitments to certification and EU deforestation-free and degradation-free regulations requesting protection of primary forests (SR, p. 90, p. 102; BD, p. 1–4).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 2 points (met)
- **Explanation/Source:** No specific corporate policy and data / evidence on (10% thresholds of) strictly protected forests (forest set asides). However, specific corporate policy on conservation area networks and conservation corridors outside the intensively managed plantation forestry (segregative approach at the landscape level with planted areas (for commercial harvesting), infrastructure (roads and buildings), and conservation areas (unplanted areas), incl. research partnership on biodiversity monitoring. Approximately 24% of landholdings (mainly grasslands and wetlands with a small portion consisting of woodland and natural forest ecosystems) are managed for conservation purposes (meeting the threshold). Further commitments include prevention of negative land conversion (grasslands into plantations), avoiding harm to protected areas and maintaining or improving the health of natural ecosystems. Two protected areas (mainly grasslands and wetlands) on Mondi's forestry landholdings in South Africa (SR, p. 64, p. 90, p. 102; BD, pp. 1–4).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data / evidence on (10% thresholds of) HCV forests. Commitment to certification standards may or may not request HCV forests. Specific corporate policy to maintain or enhance high conservation value areas (mainly grasslands and wetlands) and to manage other ecologically important areas to maintain ecological integrity. Specific identification of important biodiversity sites around the forestry operations. Biodiversity stewardship assessments and action plans for pulp and paper mills (but not for converting sites). Wood fibre procurement policy banning sources where critical biodiversity and important ecosystem values are threatened. Corporate policy to manage silviculture, harvesting and roads operations to reduce erosion (soil loss) and sedimentation risks to wetland and river ecosystems (SR, p. 64, p. 90; BD, pp. 1–4).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Corporate policy on forest bird protection somewhat unspecific, but corporate commitments in terms of habitats and species biodiversity inventories, IUCN Red lists and national conservation list species with habitats in areas affected by forestry operations. Evidence about (forest birds related) specific corporate policy with bans on sourcing from tropical tree species, species listed as protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), or the International Union for the Convention on Nature (IUCN), or wood from genetically modified trees. Commitment to SFM and certification standards may request forest bird protection (SR, p. 64, p. 65, p. 90; BD, p. 4).

4.9. Company: Navigator

Brief company's economic profile

Annual turnover

Net Sales: €1.953 billion in 2023.
EBITDA: €502 million, with an EBITDA margin of 26%.

Main products and services

Navigator specializes in sustainable, forest-based products:

- Pulp: Bleached eucalyptus pulp (BEKP), with 462,000 tons sold in 2023.
- Paper: A global leader in uncoated woodfree (UWF) printing and writing paper, with 1,131,000 tons sold in 2023.
- Packaging Solutions: Under the gKraft brand, focusing on sustainable packaging to replace fossil-based plastics.
- Tissue: Second-largest tissue producer in Iberia, with 165,000 tons annual capacity.
- Renewable Energy: Producing 76% of its energy from renewable sources, including biomass and solar power.

Forest types and fiber sourcing

Types of Forests Managed:

- Predominantly managed eucalyptus forests.
- 12.19% of the managed area designated as Conservation Interest Areas.
- Biodiversity Efforts: Protection of over 1,300 species of fauna and flora, with 4,420 hectares classified as protected habitats (Natura 2000).

Fiber Sourcing:

- 69% of wood from certified forests; 92.1% of wood suppliers with chain-of-custody certification.

Operational locations

Navigator manages forests in:

- Portugal: 107,871 hectares under certified management (FSC® and PEFC™).
- Spain and Mozambique: Additional forest management in Galicia, the Azores, and Mozambique.
- Export markets: Products shipped to 135 countries, with a significant presence in Europe and growing markets in North America and Asia.

Supply chain coverage

Navigator's vertically integrated business model covers:

- Forest Management: Sustainable eucalyptus plantations in Portugal and Mozambique.
- Production: High-efficiency mills in Portugal with advanced R&D facilities.
- End Products: Focus on circularity and sustainable innovation in pulp, paper, tissue, and packaging.

Forest ownership

Navigator manages but does not own forests outright, collaborating with landowners and promoting sustainable practices. Key initiatives are:

- Clube Produtores Florestais (Forestry Producers Club): Supporting local forest producers with best practices and certification.
- Fire prevention and biodiversity conservation efforts.

Navigator's Forest biodiversity readiness assessment

Total assessment score points: 11 points (out of 20 points)

Total ranking points: 55 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** The Zambujo Recover Project demonstrates a strong commitment to biodiversity through natural regeneration methods (Source: SR, p. 159, p. 205).

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 1 point (partly met)
- **Explanation/Source:** Efforts focus on increasing resilience by introducing species like holm oaks in some forest areas but lack a broad emphasis on species diversity (Source: SR, p. 355).

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: The company employs selective clearing and non-intensive methods to balance productivity and ecosystem health (Source: SR, p. 31).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Restoration work includes maintaining habitats that support deadwood conservation, benefiting insects, fungi, and small animals (Source: SR, p. 221).

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Practices include selective clearing and minimal soil cultivation, aligning with close-to-nature principles (Source: SR, p. 149).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Selective thinning is used, but explicit avoidance of large clearcuts is not detailed (Source: SR, p. 221).

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: Conservation efforts in protected habitats under Natura 2000 include converting eucalyptus areas to native species and focusing on rare ecosystems (Source: SR, p. 221).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Significant portions of managed forests are under strict protection as part of Natura 2000 Network habitats (Source: SR, p. 221).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Biodiversity conservation strategies are integrated into all managed holdings, with conservation areas defined during reforestation projects (Source: SR, p. 217).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 2 points (met)
- **Explanation/Source:** The company adheres to Habitats and Birds Directives and adjusts operations to avoid disrupting breeding cycles (Source: SR, p. 217).

4.10. Company: Rottneros

Brief company's economic profile

Annual turnover

Net Sales: SEK 2.755 billion in 2023, reflecting a decrease compared to 2022.

Main products and services

Rottneros specializes in market pulp and fiber-based packaging
market pulp:

- Chemical Sulphate Pulp: High-purity pulp used for filters, board, and specialized applications.
- CTMP (Chemi-Thermo-Mechanical Pulp): Used for board, tissue, and specialty papers.
- Fiber-Based Packaging:
- Fiber Trays: Sustainable solutions for food packaging, free of harmful chemicals.
- Renewable Energy Initiatives: Investments in tall oil and solar energy production.

Forest types and fiber sourcing

Types of Forests Sourced:

- Primarily managed forests with certifications ensuring sustainability.
- Rottneros emphasizes minimal environmental impact and uses renewable energy for production.
- Import Sourcing: Around 12% of pulp wood is imported, mainly from Latvia.

Operational locations

Facilities:

- Vallvik Mill (Sweden): Produces chemical sulphate pulp.
- Rottneros Mill (Sweden): Produces CTMP pulp.
- Packaging Operations (Sweden and Poland): Expanding capacity with a new factory in Poland.

Raw Material Sourcing:

- Sweden: Most wood is sourced locally, with some imports from the Baltics.

Supply chain coverage

Rottneros covers key parts of the pulp and packaging value chain:

- Forest Sourcing: Wood from spruce and pine, with a strong focus on traceability and sustainability.
- Pulp Production: High-efficiency production at Vallvik and Rottneros mills.
- Fiber-Based Packaging: Wet-formed fiber trays made from in-house pulp, primarily for food applications.

Forest ownership

Rottneros does not own forests but relies on sustainable sourcing:

- Wood is sourced from suppliers certified under FSC® or PEFC™ standards.
- Close relationships with private forest owners and associations in Sweden.

Rottneros's Forest biodiversity readiness assessment

Total assessment score points: 5 points (out of 20 points)
Total ranking points: 25 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and/or data /evidence on the priority given to natural regeneration and not on artificial forest regeneration methods. Commitment to sustainable forest management and CoC certification by FSC and PEFC (SR, p. 42). Certification standards may or may not request natural regeneration priority.

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data/evidence on tree species diversity. Commitment to sustainable forest management and CoC certification by FSC and PEFC (SR, p. 42). Certification standards may or may not request priority of forest tree species diversity.

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: No specific data /evidence on forest management intensity (ratio between annual timber harvest and forest growth/increment. Commitment to sustainable forest management and CoC certification by FSC and PEFC (SR, p. 42). Certification standards may request sustained yield but no thresholds for forest management intensity.

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific company's commitment deadwood in managed forests. No specific data / evidence on deadwood management (a lack of data / evidence on forest biodiversity). Commitment to certification standards (SR, p. 42) which may not request deadwood in managed forests.

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific policy and data /evidence on close-to-nature forestry and/or uneven-aged forests. Commitment to certification standards (SR, p. 42) which may not request uneven aged forests.

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific company's policy and data /evidence on avoiding (large) clearcutting across its supply chains. Commitments to certification (SR, p. 42) which may not request avoidance of (large) clearcuts.

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: No specific policy and/or data on the conservation primary and old growth forests. Certification commitments (SR, p. 42) which may request the conservation of primary and old-growth forests.

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific policy and data / evidence on strictly protected forests (forest set asides). Certification commitments (SR, p. 42) which may not request strictly protected forest areas or forest set asides.

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific policy and data / evidence on HCV forests. Certification commitments (SR, p. 42) which may request request the conservation of HCV forests.

Indicator 3.4. Forest bird species protection
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific policy and data / evidence on forest birds. Certification commitments (SR, p. 42) which may not request forest bird species protection in line with international indexes and lists.

4.11. Company: Sappi

Brief company's economic profile

Annual turnover

Net Sales: USD 7.7 billion for FY2023, with a focus on circular economy principles and sustainable innovation.

Main products and services

Sappi is a global provider of fiber-based materials and solutions, specializing in:

- Pulp Products:
- Dissolving pulp (Verve) used in textiles, pharmaceuticals, and foodstuffs.
- Paper pulp for printing and packaging applications.

- Graphic Papers:
- Coated and uncoated paper for publishing and printing industries.

- Packaging Papers:
- Sustainable, fiber-based alternatives to plastics.

- Specialty Papers:
- Used in niche markets for added value and differentiation.
- Biomaterials: Innovations like nanocellulose, lignosulfonates, and furfural for advanced applications.

Forest ownership

- Sappi owns 400,000 hectares of managed forests in South Africa.
- Forests are certified by FSC™ and PEFC™, ensuring sustainability and environmental stewardship.

Operational locations

Countries of Operation:

- Core operations in North America, Europe, and Southern Africa.
- Production facilities: 19 globally (including mills in South Africa and Europe).
- Sales offices in cities like Bogotá, Shanghai, Johannesburg, and Mexico City.
- Forest Holdings: 400,000 hectares of sustainably managed forests in South Africa.

Supply chain coverage

Sappi's vertically integrated business model spans:

- Forest Management: Focus on sustainability and biodiversity.
- Manufacturing: High-efficiency mills powered largely by bioenergy.
- Distribution: Strong regional networks to serve global customers.

Forest types and fiber sourcing

Types of Forests:

- Predominantly managed eucalyptus and pine plantations in Southern Africa.
- Specific areas reserved for conservation, biodiversity, and research initiatives.

Fiber Sourcing:

- 75% certified fiber globally, with a commitment to deforestation-free supply chains.
- Partnerships with suppliers to enhance sustainability in Europe and North America.

Sappi's Forest biodiversity readiness assessment

Total assessment score points: 9 points (out of 20 points)

Total ranking points: 45 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** The company prioritizes hybrid breeding and genetic selection but lacks evidence of promoting biodiversity through natural regeneration (Source: SR, p. 143).

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 1 point (partly met)
- **Explanation/Source:** Sappi actively maintains genetic diversity and tests new species to adapt to future challenges (Source: SR, p. 144).

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: Felling intensity is managed sustainably, with specific harvest metrics provided (Source: SR, p. 143).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** The report lacks specific data on deadwood conservation within managed forests.

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** Breeding practices aim to enhance resilience, but they may involve intensive forestry operations, and explicit close-to-nature management practices are not detailed (Source: SR, p. 144).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No measures or references to avoiding large clearcuts are provided in the report.

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: Conservation efforts include nature reserves as part of South Africa's Biodiversity Stewardship Programme, but details on old-growth forest preservation are lacking (Source: SR, p. 168).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Sappi protects critical ecological corridors within its nature reserves but falls short of the 10% unmanaged forest threshold (Source: SR, p. 168).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 2 points (met)
- **Explanation/Source:** The company aims to enhance biodiversity in important conservation areas (ICAs) by 10% by 2025 (Source: SR, p. 145).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** The report does not mention monitoring or conservation standards for forest bird populations.

4.12. Company: SCA

Brief company's economic profile

Annual turnover

Net Sales: SEK 20.4 billion in 2024.
Major contributors include forest operations, wood products, pulp, containerboard, and renewable energy.

Main products and services

SCA is centered on forest-based operations, including:

- Forest Products: Sustainable forest management, providing raw materials for other industries.
- Pulp: High-quality, sustainably sourced chemical and mechanical pulp.
- Containerboard: Renewable packaging solutions.
- Wood Products: Construction materials, including sawn timber.
- Renewable Energy: Wind energy, bioenergy, and fossil-free energy solutions.

Forest ownership

- SCA owns 2.7 million hectares of forest land, making it Europe's largest private forest owner.
- Forests are managed sustainably under FSC® and PEFC™ certifications.

Operational locations

- SCA primarily operates in Northern Sweden, with extensive forest holdings and production facilities.
- Key production units include sawmills, pulp mills, and containerboard facilities in Sweden.
- Renewable energy operations are integrated within forest areas.

Supply chain coverage

SCA controls its value chain, from sustainable forest management to final products:

- Forestry Management: Includes conservation parks and biodiversity-focused operations.
- Production: Manufacturing high-quality pulp, wood, and containerboard.
- Energy Production: Renewable energy generated from wind and bioenergy sources.
- Distribution: Regional and international markets for packaging and wood products.

Forest types and fiber sourcing

Forest Types:

- Primarily managed forests, with mixed-use areas for conservation and industrial forestry.
- Conservation parks: 5 key areas in Northern Sweden focusing on biodiversity.

Biodiversity Commitment:

- Dedicated to protecting habitats for over 203 identified species.
- Extensive biodiversity monitoring, focusing on indicators like deadwood and old-growth trees.

Fiber Sourcing:
- 100% of wood meets FSC® or PEFC™ standards, with 75% sourced from certified forests or using advanced retention methods.

SCA's Forest biodiversity readiness assessment

Total assessment score points: 12 points (out of 20 points)
Total ranking points: 60 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** Specific corporate policy and data/evidence on the priority given to artificial forest regeneration methods (planting with seedlings after final harvests). No policy and evidence exist on the priority for natural regeneration (SR, p. 20, p. 162).

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 0 points (not met)
- **Explanation/Source:** Specific corporate policy and data/evidence on planting introduced non-native tree species (contorta pine for climate adaptation). No policy or evidence on forest tree species diversity (SR, p. 151).

Indicator 1.3. Forest management intensity
- **Indicator score:** 2 points (met)
- **Explanation/Source**: Specific corporate policy and evidence on biodiversity friendly forest management intensity (ratio between annual timber harvest and forest growth/increment) with 70% threshold which is below the 75% one (SR p. 163, p. 165).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Specific company's policy on deadwood in managed forest; specific data / evidence on deadwood management (12,5 m3/ha) below the threshold (30-40 m3/ha in Boreal forests).

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Specific corporate policy on continuous cover forestry and low impact forestry (as forms of close-to-nature forestry and/or uneven-aged forests); still, there are not practiced across all managed forests (SR, p. 20, p. 36, p. 162).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** No specific company's policy and data /evidence on avoiding (large) clearcutting across its supply chains. Corporate policy and evidence on retention forestry that may or may not avoid large clearcuts below the threshold (2 ha) (SR, p. 163, p. 165).

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 2 points (met)
- **Explanation/Source**: Specific company policy on the conservation of primary and old-growth forests. Evidence showing thresholds is met (ca. 11,4% of old-growth forests). (SR, p. 165).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 1point (partly met)
- **Explanation/Source:** Specific corporate policy on strictly protected forests (forest set asides) including nature reserves, conservation parks etc. Evidence and data on forest set asides show that thresholds are not fully met (7% of productive forests or 5,4% of all forests in Sweden; 5% of forests in Baltics are 100% set aside). (SR, p. 22, p. 163).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Specific corporate policy on HCV forests. No evidence and data to show that the thresholds (12-20%) for set aside or protected HCV forests are met (SR, p. 34, p. 69, p. 162).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Specific corporate policy on forest birds. Evidence and data show that company refers to national and/or international species red lists, incl. forest birds (SR, p. 69, p. 162, pp. 164–165).

4.13. Company: Smurfit

Brief company's economic profile

Annual turnover

Net Sales: €11.3 billion in 2023, reflecting robust global operations in paper-based packaging.

Main products and services

Smurfit Kappa specializes in sustainable, paper-based packaging solutions:

- Packaging Solutions: Corrugated packaging, solid board, folding cartons, and bag-in-box solutions.
- Paper Products: Produces 7.7 million tonnes of paper and board annually, primarily for packaging.
- Recycling Services: Processes 7.7 million tonnes of post-consumer recovered paper annually.
- Forestry and Biodiversity: Owns and manages sustainable forest plantations.

Key innovations:

- Sustainable packaging alternatives to replace plastic.
- Award-winning circular packaging solutions, with a focus on reducing CO2 emissions and enhancing recycling.

Forest ownership

- Owns Forests: 68,000 hectares of FSC® and PEFC™ certified forest land globally, contributing to sustainable raw material sourcing.

Operational locations

- Countries of Operation: 36 countries across Europe, the Americas, and Africa.
- Facilities: 35 paper and board mills, 242 corrugated packaging plants, and 45 fiber sourcing operations.
- Approximately 47,000 employees globally.

Supply chain coverage

Smurfit Kappa operates a fully integrated value chain:

- Forestry: Sustainable management of 68,000 hectares of FSC® and PEFC™-certified forest land.
- Production: Paper mills produce containerboard and other packaging materials.
- Recycling: Provides recycling solutions for corrugated packaging and paper products.
- Customer Delivery: Manufactures 11.7 billion square meters of corrugated packaging annually.

Forest types and fiber sourcing

Forest Types:

- Managed plantations, focusing on sustainable forest management practices.
- Promotes biodiversity, conservation, and responsible fiber use.

Fiber Sourcing:
- 100% of sourced fibers are FSC® or PEFC™ certified, with a mix of virgin and recycled fibers.
- Emphasis on circularity through innovative fiber recovery and recycling systems.

Smurfit's Forest biodiversity readiness assessment

Total assessment score points: 9 points (out of 20 points)
Total ranking points: 45 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Smurfit Kappa promotes biodiversity through natural forest conservation but does not specify policies on prioritizing natural regeneration (Source: SR, p. 53).

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 1 point (partly met)
- **Explanation/Source:** Tree species diversity is supported through dedicated areas for native species, but explicit thresholds are not detailed (Source: SR, p. 53).

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: Low-impact commercial practices are emphasized, but specific felling intensity metrics are not provided (Source: SR, p. 53).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific metrics for deadwood conservation are noted.

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Close-to-nature practices focus on native species conservation and limited interventions, though specifics are lacking (Source: SR, p. 53).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** Clearcutting practices are not explicitly addressed in the report. So there is no specific company's policy and thresholds about regulating clearcuts.

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 2 points (met)
- **Explanation/Source**: Over 22,700 hectares of protected natural forests include primary and high-conservation value forests (Source: SR, p. 53).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Smurfit Kappa dedicates 22,700 hectares strictly for conservation and biodiversity purposes (Source: SR, p. 53).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** The company protects high-value ecosystems but does not provide specific thresholds for these areas (Source: SR, p. 54).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No specific corporate policy and data on forest bird conservation is provided.

4.14. Company: Södra

Brief company's economic profile

Annual turnover

Net Sales: SEK 33 billion in 2022.
Operating Profit: SEK 7.8 billion, a strong performance due to high demand for pulp and energy products.

Operational locations

- Sweden: Eight sawmills, three pulp mills, and several processing facilities.
- Key regions include Southern Sweden, where members collectively own and manage forests.

Main products and services

Södra is a cooperative organization integrating sustainable forestry with innovative wood-based products. While it does not own forests, its member-driven model supports biodiversity, renewable energy, and product innovation, positioning it as a leader in sustainability within the forestry sector.
Södra focuses on sustainable forestry and wood-based products, operating in five key areas:

- Pulp: A leading producer of paper and dissolving pulp, used in hygiene products, textiles (viscose, lyocell), and packaging.
- Wood Products: Structural timber for construction, including flooring, cladding, and high-rise buildings with cross-laminated timber (CLT).
- Liquid Bioproducts: Biomethanol, tall oil, and turpentine for industries like fuel, cleaning agents, and cosmetics.
- Energy: Green electricity, district heating, and biofuels derived from forest raw materials.
- Forestry Services: Advisory services and digital tools for members, focusing on sustainable forest management.

Supply chain coverage

Södra operates across the full forestry value chain:

- Forest Management: Provides sustainable forestry services for its 51,000 members.
- Production: Converts raw materials into timber, pulp, and bio-based products at its own mills.
- Distribution: Supplies renewable products to customers globally, focusing on circular economy principles.

Forest types and fiber sourcing

Forest Types:

- Primarily managed forests in Sweden, certified under FSC® and PEFC™.
- Significant emphasis on biodiversity, with voluntary conservation measures and set-asides for nature protection.

Fiber Sourcing:

- Sustainable practices ensure renewable raw material sourcing.
- Members' forests are a key source, with guidance provided for maintaining ecological balance and maximizing productivity.

Forest ownership

- Södra does not own forests directly, but its 51,000 members collectively manage over 2.8 million hectares of forest land.
- Members' forests contribute raw materials to Södra's industrial operations.

Södra's Forest biodiversity readiness assessment

Total assessment score points: 9 points (out of 20 points)

Total ranking points: 45 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Mixed regeneration practices are indicated, but there is no explicit prioritization of natural regeneration (Source: SR, p. 30).

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 1 point (partly met)
- **Explanation/Source:** Efforts to adapt tree species to climate change and promote diversity are noted but lack specific biodiversity metrics (Source: SR, p. 117).

Indicator 1.3. Forest management intensity
- **Indicator score:** 2 points (met)
- **Explanation/Source**: Sustainable harvest rates are detailed, with metrics provided for members' forests (Source: SR, p. 127).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Conservation efforts for forest residues as habitats for insects and fungi are documented but lack comprehensive metrics (Source: SR, p. 127).

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Practices include low-impact scarification and planting, but specific close-to-nature techniques are not fully elaborated (Source: SR, p. 30).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** There is no direct mention of policies or measures to avoid large clearcuts.

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 0 points (not met)
- **Explanation/Source**: General protection is discussed, but specific percentages or data on primary and old-growth forests are missing (Source: SR, p. 116).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Södra notes 89,000 hectares of formal site protection, covering 3.2% of productive forest land (Source: SR, p. 127).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Active restoration and conservation measures are in place, including voluntary set-asides (Source: SR, p. 127).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** The report does not include specific data on forest bird thresholds or conservation efforts.

4.15. Company: Stora Enso

Brief company's economic profile

Annual turnover

Net Sales: EUR 9.4 billion in 2023, down from EUR 11.7 billion in 2022.
Operational EBIT: EUR 3.6%, reflecting significant restructuring efforts and challenging market conditions.

Main products and services

Stora Enso specializes in renewable and circular products:

- Packaging Materials: Liquid packaging boards, food service boards, cartonboards, and containerboards.
- Packaging Solutions: Boxes, trays, and corrugated board solutions.
- Biomaterials: Pulp, lignin-based products, biobased chemicals, and wood foams.
- Wood Products: Timber, CLT (cross-laminated timber), and LVL (laminated veneer lumber) for construction.
- Forest Management: Sustainable wood sourcing and forest services.

Forest ownership

- Owns and Leases Forests: 2.02 million hectares globally, with forests primarily in Sweden and partnerships in Finland, Uruguay, Brazil, and China.
- Forest Valuation: EUR 8.7 billion, with advanced management practices to improve yield and biodiversity.

Operational locations

Regions: Europe, South America, Asia, and North America.

Key Facilities:
- Production units in 12 European countries and South America (Uruguay and Brazil).
- Major operations in Finland, Sweden, and Poland.
- Global Forest Holdings: 2.02 million hectares of forest land, including owned, leased, and joint ventures.

Supply chain coverage

Stora Enso controls a vertically integrated supply chain:

- Forest Management: Owns and leases forests, ensuring 36% of wood supply from internal sources.
- Production: Integrated mills for packaging, biomaterials, and wood products.
- Circularity and Innovation: Focus on recyclable and renewable materials, with 94% of products recyclable.

Forest types and fiber sourcing

Forest Types:

- Managed forests in Northern Europe.
- Eucalyptus plantations in South America and Asia.

Sustainability Certifications:

- 99% of forest areas certified under FSC® or PEFC™.
- Active efforts in biodiversity restoration, climate adaptation, and circular forestry.

Stora Enso's Forest biodiversity readiness assessment

Total assessment score points: 10 points (out of 20 points)
Total ranking points: 50 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Corporate policy/evidence on artificial regeneration (planting, tree breeding) in the most of the (spruce dominated) forest areas and policy/evidence on promotion of naturally regenerating broad-leaved trees (SR, p. 42).

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 2 points (met)
- **Explanation/Source:** Corporate policy and evidence about tree species diversity promotion (e.g., birch as native tree species in Nordic forests) (SR, p. 41–42).

Indicator 1.3. Forest management intensity
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: Corporate policy on sustained timber harvests, but the evidence (82% ratio) shows that the thresholds for biodiversity friendly forest use (up to 75%) are not met (SR, p. 16).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Corporate policy on deadwood management, but no evidence and data that show that thresholds (20-30 m3/ha) are met (SR, p. 41–42).

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No corporate policy and evidence on close-to-nature forest management (SR, p. 41–42).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** There is no corporate policies and evidence to avoid large clearcuts (SR, p. 41–42).

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source**: Specific policy and evidence on primary and old-growth forests in Brazil and Uruguay with evidence meeting the threshold (50%); General protection is discussed, but specific policy and data on the conservation of primary and old-growth forests are missing for Scandinavian forests; failure to meet conservation thresholds under EU Taxonomy Regulation (SR, p. 69, p. 118).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Corporate policy on voluntary or legally enforced forest set asides for Sweden and Finland. However, evidence shows that thresholds are not (fully) met (9,15% is below the 10% threshold) (SR, p. 69).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Corporate policy on high conservation value forests, including certification commitments and measures to improve specific valuable habitats exist; however, no evidence to show that thresholds (12-20%) are met (SR, p. 41).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Specific corporate policy on red-listed species protection (incl. on forest birds, including certification commitments exist. After some media and practical investigations about negative impacts of harvesting in bird nesting sites, corrective corporate actions and guidelines follow in line with certification procedures (SR, p. 41, p. 50).

4.16. Company: UPM

Brief company's economic profile

Annual turnover

UPM's total sales in 2023 amounted to EUR 10.5 billion, a decrease of 11% compared to the previous year.
Comparable EBIT (Earnings Before Interest and Taxes) was EUR 1,013 million, down 52% from 2022, reflecting market challenges.
The company maintains a strong balance sheet, with net debt/EBITDA at 1.55 and proposed a dividend of EUR 1.50 per share.

Main products and services

UPM operates in multiple sectors within the biomaterials industry:

- UPM Fibres: Pulp and timber products for packaging, tissue, hygiene, and paper industries.
- UPM Energy: CO2-free electricity production and trading, mainly in Finland.
- UPM Raflatac: Self-adhesive labels and graphic solutions.
- UPM Specialty Papers: Specialty papers for flexible packaging, labelling, and industrial uses.
- UPM Communication Papers: Graphic papers for publishing, home, and office use.
- UPM Plywood: WISA® plywood and veneer products for construction, transport, and shipbuilding.
- UPM Biorefining: Includes biofuels (wood-based diesel & naphtha), biochemicals (used in textiles, PET bottles, packaging, and cosmetics), biomedicals (nanocellulose for wound care and 3D bioprinting), and biocomposites (recycled composite materials).
- UPM Forest: Manages forests and supplies wood and biomass for its operations.

Operational locations

- UPM has 16,600 employees in 43 countries.
- 54 production plants globally.
- Largest investments in 2023 include Uruguay (pulp production), Finland (energy production), and Germany (biochemicals refinery).

Supply chain coverage

- UPM ensures 100% of its raw materials come from controlled sources
- 89% of total spend is covered by UPM's Supplier and Third-Party Code to ensure responsible sourcing.
- The company audited 95 suppliers and reviewed 890 contractor working conditions in 2023.

Forest types

- UPM focuses on planted eucalyptus forests in Uruguay for pulp production
- In Finland and Northern Europe, the company manages natural mixed forests, ensuring biodiversity and sustainability.
- The company protects 14,500 hectares of sensitive ecosystems in Uruguay, including grasslands, wetlands, and native forests.

Fibre sourcing

- UPM uses sustainably managed plantations and forests for fibre sourcing.
- Eucalyptus plantations in Uruguay provide the primary raw material for UPM's Paso de los Toros pulp mill.
- The company's forests are verified as carbon sinks, absorbing approximately -4.8 million tonnes of CO_2 equivalents annually.

Forest ownership

- UPM owns and manages large forest areas, primarily in Northern Europe and Uruguay.
- The company follows sustainable forestry practices, ensuring all wood is sourced responsibly.
- 87% of UPM's sourced fibre is certified, and the company aims for 100% certified sourcing in the future.

Key highlights of 2023

- UPM Paso de los Toros pulp mill in Uruguay started operations, increasing pulp capacity by over 50%.
- The Olkiluoto 3 nuclear power plant started production, increasing UPM Energy's CO_2-free electricity output by nearly 50%.
- Investments in biochemicals and biofuels: UPM's Leuna biochemicals refinery (Germany) is set to open by 2024, producing wood-based chemicals.
- The company achieved an AAA rating from MSCI ESG, ranking among the most sustainable companies globally.

UPM's Forest biodiversity readiness assessment

Total assessment score points: 12 points (out of 20 points)

Total ranking points: 60 points (out of 100 points)

Criterion 1. Compositional biodiversity

Indicator 1.1. Promotion of biodiversity by natural regeneration
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Corporate policy and evidence about mixed regeneration practices (natural regeneration and planting) are reported, particularly for Finland and Uruguay (SR, p. 25, pp. 82–83, pp. 84–85).

Indicator 1.2 Forest tree species diversity
- **Indicator Score:** 2 points (met)
- **Explanation/Source:** corporate policy and evidence about forest tree species diversity, e.g., increasing share of broad-leaved trees (e.g., birch) forests in Finland, and restoration of mixed species forests in the USA to improve biodiversity (SR, pp. 84–85).

Indicator 1.3. Forest management intensity
- **Indicator score:** 2 points (met)
- **Explanation/Source**: corporate policy and evidence on sustainable timber harvesting (61%) which meets the biodiversity friendly threshold (below 75%) (SR, pp. 82–83).

Criterion 2. Structural biodiversity

Indicator 2.1. Conservation and restoration of standing and lying deadwood in managed forests
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Corporate policy on deadwood management with self-reported evidence about increasing amounts of deadwood and tree retention, conservation and restoration, and enhancing habitats; However, no data and evidence to verify whether the thresholds (e.g., 20-30 m3/ha in Boreal forests) are met is provided (SR, pp. 84–85).

Indicator 2.2. Uneven aged forests (close-to-nature forest management)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** corporate policy and evidence that the company uses Smart Forestry™ techniques, which emphasize ecological classification and deadwood retention, especially in the USA. Company's forest management in Finland sometimes includes mixed forests management techniques that could align with close-to-nature forests. Still, clearcut forest management is reported (SR, pp. 83–85).

Indicator 2.3. Avoidance of (large) clearcuts
- **Indicator score:** 0 points (not met)
- **Explanation/Source:** No corporate policy to avoid (large) clearcuts and no evidence about this. Self-reported clearcutting practices (SR, pp. 83–85).

Criterion 3. Functional biodiversity

Indicator 3.1. Conservation of primary and old growth forests (forests not available for wood supply)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** General corporate policy and certification commitments on primary and old growth forests, especially in Uruguay. However, specific data on shares/thresholds on primary and old-growth forests are missing (SR, pp. 82–85).

Indicator 3.2. Strictly protected forest areas (forest set aside)
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Corporate policy on conserving strictly protected areas, including certification commitments. However, no evidence is provided on (10%) thresholds for strictly protected forests (Source: SR, pp. 82–85).

Indicator 3.3. Protection of high conservation value forests (primary designed for conservation)
- **Indicator score:** 2 points (met)
- **Explanation/Source:** Corporate policy and certification commitments on high-value conservation areas. Evidence shows that 15% of owned land are protected, focusing on HCV habitats like wetlands and natural forests; Thresholds (12-20%) are hence met (SR, pp. 82–83).

Indicator 3.4. Forest bird species protection
- **Indicator score:** 1 point (partly met)
- **Explanation/Source:** Corporate policy and certification commitments to actively monitor biodiversity, including bird species, as part of its forest action programs in collaboration with researchers. Planting of trees to support forest birds in Germany. The report does not include specific data on forest bird lists or indexes (SR, p. 83).

5. Discussion and conclusion

In this final section, we turn to the main research questions and provide answers based on a summary overview of the main findings and links to the state-of-the art knowledge.

5.1. Based on what criteria can business performance be assessed as sustainable in relation to environmental performance and readiness?

According to the International Panel on Biodiversity and Ecosystem Services (IPBES) global scientific assessment report (IPBES 2019), land use (agriculture), land use change (e.g., deforestation, afforestation) and forestry (timber harvesting, reforestation) and wildfires, together with climate change, are among the key direct drivers of biodiversity loss and inter-linked deforestation and forest degradation worldwide. These so-called proximate factors are influenced by indirect drivers such as policy and legal changes, socio-economic developments, financial and business models, and technological innovations. The report points to different ways, through which companies through their business operations across supply chains should and can engage in biodiversity and climate positive transformation of economic sectors, including forestry and forest industry (IPBES 2019; Chan 2019). However, the report does not provide suggestions how to assess the readiness of forest companies to adopt forest biodiversity conservation friendly goals.

The review of the scientific literature and the policy analysis of forest-related EU environmental laws and strategies shows that biodiversity related business performance of large forest industry companies can be assessed against a set of 3 criteria, 10 indicators and related (quantitative and qualitative) thresholds. The criteria encompass key compositional, structural and functional forest biodiversity aspects. Most indicators can be expressed and linked to different on-the-ground forest management and forest biodiversity conservation practices. The corresponding thresholds can be set at specific quantitative levels or qualitative features (e.g., for

useful review see Naubuurs et al. 2024).

In a Finnish context, the Harrinkari et al. (2025) study examines the evolution of sustainability goals in Finnish forest policy between 1990 and 2020, highlighting the interplay between timber extraction and biodiversity protection. The study finds that while sustainability has been incorporated into policy frameworks, the prioritization of timber extraction remains dominant, often at the expense of biodiversity and long-term ecosystem health.

Laakkonen (2023) suggest that the forest sector has a history of adapting to change and is incrementally shifting towards more sustainable, collaborative, and cross-sectoral value co-creation. However, challenges remain in fully integrating biodiversity protection goals into business models.

The criteria, indicators, and thresholds of biodiversity friendly forest management correspond to and can be found in the policy objectives, targets, instruments and settings of a range of forest related EU environmental policies and laws. The majority of the latter are formulated in the EU nature protection and biodiversity conservation policy domain, but they are also integrated in EU climate, bioenergy and sustainable finance policies and laws. Few forest specific EU strategies and laws regulating transnational supply chains in forest risk commodities also add to the basket of relevant and applicable policy and legal instruments (Winkel et al. 2013; Aggestam et al. 2017; Sotirov et al. 2021; Sotirov et al. 2024).

5.2. Which forest industry companies are leaders and laggards in meeting EU forest biodiversity policy objectives and regulations?

The cross-case comparison and synthesis of the individual companies' economic profiles (part A's) reveals three groups of companies' supply chain management models. The 16 companies under study fall somewhat evenly distributed under these three basic models (Table 5).

Type 1 refers to companies with fully integrated downstream and upstream supply chain operations

and full forest ownership coverage. They obtain timber/fibre from managing owned or leased forests, partly also from owned plantations, and partly from timber suppliers, whereas the biomass is processed in their own mills and then sold to the end-consumer in the marketplace. Examples from the analysed companies are Billerud, Holmen, Metsä, SCA, Södra, StoraEnso and UPM.

Type 2 includes companies with partial integration of supply chain operations. These companies usually do not own (primary or semi-natural) forests, but obtain wood/fibres from their own plantations and, mainly, from upstream external timber suppliers, which is all processed in their own mills and marketed to the end-consumer in the downstream supply chain. Examples hereof are Mondi, Navigator, Sappi, and Smurfit.

To type 3 encompasses downstream companies that do not own forests or plantations, buying wood/fibre from suppliers in the upstream supply chains. Here examples are Ahlstrom, DS Smith, Essity, Huhtamaki and Rottneros.

Table 5: Typology of companies' supply chain management models

Supply chain model	Fully integrated	Partly integrated	Not integrated
Supply chain focus	Downstream and upstream	Downstream and (some) upstream	Downstream mainly
Ownership types	Own forests, partly own plantations, own mills	No own forests, but own plantations, own mills	Do neither own forests nor plantations, own mills
Companies	Billerud, Holmen, Metsä, SCA, Södra, StoraEnso, UPM	Mondi, Navigator, Sappi, Smurfit	Ahlstrom, DS Smith, Essity, Huhtamaki, Rottneros

Based on a comparative comparison of the individual readiness assessments (part B), an overview of companies self-reported corporate commitments, policies and evidenced performance as regards biodiversity positive forest management in line with the evaluation framework is summarized in Table 6. Several key observations can be made based on these overview results, and in relation to translation of the numeric result¬s into a qualitative assessment (Table 7).

First of all, none of the companies was found to perform as a forest industry leader, ready to largely or fully meet forest biodiversity goals, as no company earned points to qualify for a "very positive" performance (80-100 points). Nor did any of the companies under study score "very poor" (0-20 points), which would indicate very low biodiversity related corporate commitment and performance. Only two companies (SCA and UPM) scored "good" (60-80 points). They can be regarded as having potential for advancing towards forest biodiversity readiness, but this is uncertain, as even these companies remain at the lower end of the "good" scale that is closer to the "fair" scale. About half of all companies, namely nine out of sixteen (Navigator, DS Smith, Billerud, Holmen, Metsä, Mondi, StoraEnso, Södra, Smurfit) earned between 45-55 points. Their readi-

ness for forest biodiversity goals can be interpreted as, at best, "fair" (40-59 points). The remaining five companies (Essity, Ahlstrom, Huhtamaki, Rottneros, Sappi) scored lower, between 25-35 points only ("poor"). This can be interpreted as a "poor" level of corporate readiness for forest biodiversity goals (20-39). None of the companies under study was found to score "very poor" (0-19 points).

Second, the company's supply chain management model (see Table 5) seems to provide some preliminary explanation for the degree of corporate readiness. There seems to be some correlation that can be defined as follows: the more a company controls fully integrated supply chain operations (e.g., by owning forests and producing biomass in the upstream and processes wood/fibre in its own mills in the downstream), the relatively better its forest biodiversity readiness will be. This could be explained with the potential fact that the company is more exposed to and more experienced with forest management and hence with forest biodiversity aspects in the upstream of the supply chain. However, the results show that even companies with fully or partly integrated supply chain management have not achieved advanced or full readiness for forest biodiversity policy goals. Hence, the supply chain model is neither the unique nor a sufficient

explanatory factor of corporate environmental sustainability performance. Another conclusion could be thattthese companies have more readily access to related information. Maybe this can support a due diligence approach under the EUTR/EUDR.

Inversely, the more a company manages non-integrated supply chains (by not owning forests or plantations, purchasing wood/fibre from external suppliers, and mainly owning mills in the downstream), the relatively poorer its biodiversity readiness will be. This could be explained with the distance to forest management operations in the upstream and the little exposition to and experience with forest biodiversity aspects. However, even companies not owning forests and further down the supply chain, bear a responsibility for forest biodiversity (in the supply upstream), as their influence forest management through their market behavior as regards purchase of timber-based products. If they do not have biodiversity positive procurement policies in place or do not meet indicators and thresholds with evidence, arguably, they do not contribute to biodiversity friendly forest management.

Table 6: Overview of companies' assessment results

Company	Compositional biodiversity			Structural biodiversity			Functional biodiversity				Assessment points	
	1.1.	1.2.	1.3.	2.1.	2.2.	2.3.	3.1.	3.2.	3.3.	3.4.	Total assessment (out of 20)	Total ranking (out of 100)
SCA	0	0	2	1	2	1	2	1	1	2	12	60
UPM	1	2	2	1	1	0	1	1	2	1	12	60
Navigator	1	1	1	1	1	1	1	1	1	2	11	55
DS Smith	1	1	1	1	1	1	1	1	2	1	11	55
Billerud	1	2	1	1	1	1	0	1	2	0	10	50
Holmen	0	1	1	1	1	0	2	1	2	1	10	50
Metsä	0	2	1	1	1	1	1	1	1	1	10	50
Mondi	1	1	1	0	0	1	1	2	1	2	10	50
StoraEnso	1	2	1	1	0	0	1	1	1	2	10	50
Södra	1	1	2	1	1	0	0	1	2	0	9	45
Smurfit	1	1	1	0	1	0	2	2	1	0	9	45
Essity	1	1	1	1	1	0	1	0	1	0	7	35
Sappi	0	1	1	0	0	0	1	1	2	0	6	30
Ahlström	1	1	1	0	0	1	1	0	1	0	6	30
Huhtamäki	1	1	0	0	1	0	1	0	1	0	5	25
Rottneros	1	1	1	0	0	0	1	0	1	0	5	25
Total all companies	12	19	18	10	12	7	17	14	22	12	n/a	n/a
Out of potential total	32	32	32	32	32	32	32	32	32	32	n/a	n/a

Table 7: Qualitative assessment framework

Score (out of 100)	Qualitative assessment	Description
80-100	Very good	Strong biodiversity commitment, aligned with best practices. "Leading the way"
60-79	Good	Solid biodiversity commitment with some areas for improvement. "Potential for advancing"
40-59	Fair	Some biodiversity commitment, but key gaps remain. "Fence sitting"
20-39	Poor	Limited action, lacks clear commitment with many gaps. "Lagging behind"
0-19	Very poor	No real biodiversity commitment and too many gaps. "Foot-dragging"

5.3. Is the forest industry based in Europe and beyond ready for a transformative change towards socio-ecological sustainability to meet global and EU biodiversity and climate policy objectives?

Looking at the aggregated assessment results (Table 6), one can draw a conclusion that major forest industry enterprises in Europe, and beyond, are not yet fully ready for a transformative change towards nature positive business practices. Table 6 also provides a clear indication as to the most urgent areas for improvement, needing the most attention and requiring significant shifts in business practices. These include "avoidance of (large) clearcuts" (indicator 2.3), "preference for natural regeneration" (indicator 1.1), "close-to-nature forest management" (indicator 2.2.), "strictly protected forest areas" (indicator 3.2.) and "forest birds protection" (indicator 3.4.). These are the performance indicators for management practices where companies, taken together, have scored lowest (between 7-14 points out of maximum 32) in view of the self-reported evidence assessed against the evaluation framework.

On the contrary, some good progress can be noticed for a few forest management and biodiversity conservation practices, such as the protection of HCV forests (indicator 3.3) and forest tree species diversity (indicator 1.2). For these indicators, companies have collectively earned higher number of assessment points (20-22 out of 32 points), but there is still further room for improvement. For the remaining two management practices such as "forest management intensity" (indicator 1.3.) and "conservation of old-growth and primary forests" (indicator 3.1), forest industry companies have collectively scored slightly above average (17-19 out of 32 points). Likewise, further progress as regards these important management practices is possible and needed.

Importantly, most companies under study were found to rely on market-driven third-party private regulation, such as forest certification, to meet forest sustainability and hence also biodiversity goals. Forest management and chain-of-custody certification under the PEFC (Programme for the

Endorsement of Forest Certification) and the FSC (Forest Stewardship Council) are frequently self-reported by the companies as the private instruments for private procurement of legal and sustainable wood/fibre products. The companies' emphasis on certifications as a central tool in achieving biodiversity goals corresponds with the findings of earlier studies on forest industries' self-reporting (Mäkelä and Halme 2025). The review of the analysis shows that not all companies clearly indicate the coverage of their supply chains with either PEFC or FSC or both certification standards. But, their participation in third party certification seems to have helped most companies put some forest biodiversity related policies and commitments in place.

Certification involves third party assessment of forest practices and supply chain operations according to a set of environmental (e.g., HCV forests, tree species diversity), social (e.g., respect of social and workers' rights) and economic (e.g., sustained yield) standards developed through multi-stakeholder processes. While they have gained a wide support in Europe, FSC and PEFC certification policies and standards are different, highly complex and dynamic depending on the national context. There is a broad agreement that PEFC is an industry-friendly and more flexible certification scheme that is dominated by the economic interests of non-state forest owners and state forest enterprises, forest industries with a tacit support by national forestry administrations. On the contrary, FSC is perceived as more strict and demanding certification scheme that is led by environmental, social and economic values and interests (McDermott et al. 2010; Sotirov et al. 2020; Wolff and Schweinle 2022).

Still, buying certified wood/fibre or getting forest management certificates or certificates of chains of custody is not always a guarantee for effective readiness to implement forest biodiversity goals. Important caveat of forest certification is that it is less independent since certification bodies and auditors are directly paid by the companies that seek certification. Many cases of inconsistent and ineffective certification are documented, leading some leading environmental and social groups to leave these schemes after questioning their legitimacy and sustainability (McDermott et al. 2010; Dieguez and Sotirov 2021; Wolff and Schweinle 2022). Participation in certification standards means that corporate responsibility for sustainability is outsourced to third parties such as certification bodies and private auditors, lowering the corporate environmental accountability and leading public institutions to not grant automatic recognition of certification as proof of legality or sustainability under EU law (Berning and Sotirov 2023; Berning and Sotirov 2024).

Scientific articles point to positive, neutral and mixed impacts of certification schemes on forest bi-

odiversity in Europe where most studies (85%) have analysed FSC certification and less so (15%) PEFC (Wolff and Schweinle 2022). Positive impacts include mainly cases of FSC certification, for example in terms of increased oak tree and shrub species diversity in conservation zones in Portugal, improved structural diversity of voluntary forest set asides in Sweden, increased number of biotope trees and deadwood in Estonia. Negative or mixed impacts were found in FSC certified forests as regards tree cover loss in primary forests due to large scale clear-cuts in the Boreal zone in Sweden, Finland and Norway, as well as in Lithuania (Blumröder et al. 2020).

Recent studies also show that PEFC and FSC are applied in Finland to set minimum requirements for landowners (private, public, and corporate) committed to certification, but the guidelines and practices vary significantly from case to case. Public landowners and large forest companies generally have more ambitious management goals and guidelines for green-tree retention than those required by PEFC certification criteria (Kaukonen et al. 2018). While both schemes state that retention trees are to be left permanently in the clearcut areas, research and data show the removal of retention trees was observed in almost every third of the cutting areas inspected, and harvesting was focused on large-diameter retention trees (Salomäki 2005; Kurttila and Hänninen 2006; Hänninen et al. 2008; Hänninen et al. 2010; Kuuluvainen et al. 2019). These authors conclude that the practice of tree retention in managed forests, set to safeguard some of the key structural, functional, and compositional diversity characteristics of forest ecosystems, currently lacks ecological credibility in both certified and non-certified forest in Finland. To attain tangible ecological effects on-the-ground, retention forestry in Scandinavia, including certification practices in this regard, these studies recommend they should urgently be developed to more efficiently safeguard biodiversity. In addition, the retention practices should be developed, using up-to-date ecological knowledge concerning species' habitat requirements, forest disturbance ecology, and legacy structures at multiple scales (Kuuluvainen et al. 2019).

From strategic policy and business perspectives, an important question is whether and how forest industries would transform their supply chains to meet biodiversity goals. A recent scientific study identifies three contrasting behavioral responses by forest industry companies in a likely "biodiversity first" scenario, where the aforementioned EU and national level biodiversity policy objectives and targets, and hence the biodiversity benchmark developed in this study would be prioritized (Sotirov et al. 2024). The first possible industry response includes relocation of larger forest-based industries of all or parts of production chains outside

the EU and/or scaling down industry production in the EU due to restrictions on wood supply, market availability of new wood qualities (hardwoods) and expected significant increase in production costs in the EU market. Another industry response could be a regional industry consolidation on the EU market, where mainly regionally and locally producing and sourcing industries of SME would survive and continue their business operations. These remaining regional SME would only be able to supply a smaller quantity of wood products, which would not cover the overall EU demand. The scarcity and changes in quality of the raw material (more hardwood than softwood) would lead to higher prices if consumer demand in the EU remains at today's level. The third possible industry response is likely to be an industry transformation by diversification and added value. Many European wood-based businesses might implement transformative change processes, which would entail the broadening and diversifying of products, focusing on new added-value products with increased quality and higher prices, made from a diversity of hardwood species. Industry transformation in Europe would embrace innovations in the forest-based bioeconomy, including nanotechnology, bio-based textiles, bio-based chemicals, etc. An important part of the transformation would be to shorten and decarbonize the wood value chains, by, for example, recycling products and using cascading systems that prioritise the material use of wood over bioenergy use. In order to mobilize wood from close-to-nature forest management (as opposed to intensive forestry methods widely used today), industries and business would offer a full service of sustainably harvesting, transport, and marketing of wood across properties to achieve economies of scale (Sotirov et al. 2024).

5.4. Limitations and directions for further research

This study comes with some methodological limitations. First, the main body of data was obtained from publicly available sustainability reports of the companies under study. As previous studies have concluded, there is variation between forest companies' sustainability reporting when it comes to, inter alia, depth and the extent of numeric descriptions (Sinclair and Walton 2003; Liubachyna et al. 2017). As such, the results reflect the state of individual corporate policies and evidence self-reported by the companies. There were limited possibilities to assess the on-the-ground or real performance of companies. Both self-reported biodiversity related corporate performance could meet or not daily and on-the-ground practices. Self-reported performance might be more or less ambitious than daily practices. The review of our results in light of the academic and practical knowledge has provided some useful hints in this regard.

Second, the study focused mainly on 16 largest forest companies, mainly headquartered in Scandinavia or in the UK, Portugal or South Africa. What is needed is a further analysis of other companies in the forest sector industry based in other European countries (e.g., France, Germany, Poland, Italy, Spain, Netherlands), including small and medium sized enterprises.

Third, there is a particular need for a systematic comparative analysis of the stringency and implementation of PEFC and FSC certification schemes across countries and assessment of their designed and operational impacts on forest biodiversity goals. For sure, a periodic assessment of corporate readiness for nature positive transformation of business operations across supply chains including possibilities to discuss and learn among companies, forest owners, environmental NGOs, and public regulators is highly recommendable for the near future.

The discussion of this study's result in the light of the reviewed scientific and practical knowledge begs a couple of key questions that need to be investigated in future research: what are the on-the-ground practices of companies (which is different from their corporate policies as self-reported in their sustainability reports)? Is there are gap between policies and on-the-ground/daily actions in the supply chain? What forest industry behavioral responses are expected to take place in the future?

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What forest industry behavioral responses are expected to take place in the future?

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Annexes

Annex 1: Individual assessment matrix (one per company)

Company (name)	Criteria (name)	Indicator (name)	Threshold (name)	Explanation (met=2; partially met=1; not met=0; with short explanatory text, see table 2)	Source (document, page number)
	1.	1.1.			
		1.2.			
		1.3.			
	2.	2.1.			
		2.2.			
		2.3.			
	3.	3.1.			
		3.2.			
		3.3.			
		3.4.			

Annex 2: Summary overview assessment table (with all companies)

Company (Name)	Assessment points (0-100)
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	
16.	