Industry note: Forests are key to climate change mitigation and sustainable development

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1 Introduction

Forests around the globe impact the climate through physical, chemical, and biological mechanisms that shape planetary energy balance, the water cycle, and atmospheric composition. These intricate and nonlinear interactions between forests and the atmosphere can either mitigate or intensify human-induced climate change (Bonan, 2008). Forests deliver essential ecosystem services [e.g., carbon (C) sequestration, biodiversity conservation, water regulation, and soil stabilisation (Wilson et al., 2017)]. The forest ecosystem contributes approximately 50% of terrestrial C storage and provides habitat for 80% of terrestrial species (e.g., animals and plants) and its ecosystem services are valued at over 100 trillion annually (Costanza et al., 2014).

Spanning around 4.1 billion hectares across tropical, temperate, and boreal regions, forests cover approximately 31% of the Earth's land surface. Over half of the world's forests are located in the Russian Federation, Brazil, Canada, the United States, and China (FAO, 2024). Forests play a crucial role in the global carbon cycle, contributing approximately 50% of terrestrial net primary production (Mitchard, 2018). They sequester substantial amounts of C annually, contributing to a residual terrestrial C sink of approximately 2.6 Pg C per year in the 1990s, equivalent to about 33% of emissions from fossil fuels and land-use changes (Denman, 2007). However, forests' low albedo, particularly in snow-covered areas, can increase solar heating and localised warming. Conversely, forests regulate the hydrological cycle through evapotranspiration, cooling the atmosphere by promoting cloud formation and precipitation (Bonan, 2008).

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Despite their critical importance, forests face growing threats from deforestation, land degradation, and climate change, which undermine their ability to provide ecosystem services and mitigate climate change. This industry note explores the current state of global forests, key challenges, opportunities, and strategies to enhance forest management for sustainable development under climate change.

2 The state of global forests

Forests are broadly categorised into tropical, temperate, and boreal forest types, each with unique ecological characteristics and economic contributions.

2.1 Tropical forests

Tropical forests are vital at local, regional, and global levels, contributing significantly to biodiversity conservation, the supply of livelihood resources (such as timber, fibre, fuelwood, and medicinal plants), and the provision of essential ecosystem services like climate regulation and C sequestration, all of which are crucial for human well-being (Bonan, 2008; Malhi, 2012). Tropical forests can be broadly classified into two main types: rainforests and monsoon (or seasonal) forests, both found near the equatorial region (mainly in South America). Monsoon forests, also referred to as mixed forests, are often located on the edges or within tropical rainforests, particularly in the southern and southeastern regions of Asia (Nair, 2004).

Despite their significance in human well-being, these forests face the highest deforestation rates and approximately 7.8 million hectares of tropical forests are lost annually (FAO, 2024). The Amazon alone absorbs 2.2 billion metric tons of CO_2 annually, but deforestation has reduced its C sequestration capacity by 17% over the past few decades (Lovejoy and Nobre, 2019). The relatively stable diel and seasonal temperature variations of tropical forests make them particularly sensitive to even minor temperature changes, significantly impacting plant and animal species composition and diversity (Brodie et al., 2012; De Frenne et al., 2021).

2.2 Temperate forests

Temperate forests are located in mid-latitude regions, situated between tropical and polar zones, approximately between 25° and 50° latitude north and south of the equator. These bioclimatic zones encompass around 766 million hectares, accounting for approximately 25% of the world's forested area (Pan et al., 2011; FAO, 2015). Temperate forests consist of deciduous, broadleaf, and coniferous evergreen trees and are distributed across North America, north-eastern Asia, western and eastern Europe, and Oceania. These forests are characterised by a temperate climate with 3–4 distinct seasons, each marked by specific temperature and precipitation patterns. Annual temperatures range from –40°C to 30°C, while precipitation varies significantly, ranging from 500 mm to 4,000 mm per year (Adams et al., 2019).

Temperate forests contribute about 17% of global net primary productivity, making them significant C sinks, especially in eastern North America, where they play a crucial role in mitigating global CO_2 emissions (Levin, 2013). These forests are also economically vital, as they generate over $300 billion of income annually from timber

sales (UNECE, 2022). Beyond their economic value, temperate forests provide essential ecosystem services, including water regulation, soil stabilisation, and recreational opportunities (McNulty, 2023).

2.3 Boreal forests

The boreal forest accounts for 30% of global forest cover, of which approximately 25% is natural. It spans Canada, Russia, and Scandinavia. Boreal forests store an estimated 1,500 gigatons of C, primarily in soils and in the permafrost, and represent 32% of global terrestrial C stocks (IPCC, 2022; Pan et al., 2011).

These forests are critical for the production of lumber and pulp and paper, with boreal regions supplying more than 33% of global lumber and 25% of pulp and paper exports (Mery et al., 2010). Despite tree harvesting practices, deforestation is generally avoided as harvested areas are regenerated, though species composition may change based on management practices (Ruckstuhl et al., 2008; Brandt et al., 2013). The boreal biome also plays a vital role in C sequestration, contributing ~20% of the global C sink attributed to forests (Gauthier et al., 2015).

Together, tropical, temperate, and boreal forests are integral to the Earth's ecological balance. Each type offers distinct contributions to C storage, biodiversity conservation, and ecosystem services, underscoring the need for their sustainable management to address global environmental challenges.

3 Key challenges for the forest industry

Forests are under mounting pressure from anthropogenic activities and environmental stressors, with deforestation and land use changes playing a pivotal role in affecting global forests. The world has lost 488 million hectares of forest cover since the turn of the century, equivalent to about 12% of global forest cover in 2000. Forest cover loss has been rising more recently, from 13.4 million hectares of forest cover loss in 2001 to 28.3 million hectares in 2023 (Hansen et al., 2013). Forestry, commodity-driven deforestation, wildfires, and shifting agriculture are the leading causes of forest cover loss (World Resource Institute, 2024). Tropical regions experience more forest cover loss related to agriculture, whereas boreal and temperate regions experience more loss from forestry and wildfire (Curtis et al., 2018). The annual rate of tropical forest cover loss nearly doubled from 6.7 million hectares in 2001 to 12.1 million hectares in 2023. Although Brazil and Indonesia experienced the largest area of forest cover loss in this century, these two countries have become less dominant as the rate of forest cover loss in all other tropical countries combined has increased by 142% since 2001 (World Resource Institute, 2024). Meanwhile, temperate and boreal forests have experienced 193 million hectares of gross forest cover loss since the turn of the century, with almost 99% of the loss related to temporary factors (forestry and wildfire). Canada, Russia, and the United States together make up 97% of forest cover loss related to wildfire and 67% of all loss related to forestry in temperate and boreal forests (World Resource Institute, 2024).

Climate change is another critical factor affecting forests. For example, rising temperatures, prolonged droughts, and erratic rainfall patterns intensify stress on forest ecosystems, particularly in boreal and tropical regions (Williams et al., 2013). For

example, droughts in the Amazon have led to a 30% decline in forest C uptake since 2000 (Phillips et al., 2009). Climate change will interact with forest disturbances, such as pathogens, insects, and fire, and will increasingly impact the geographic distribution, growth, and sustainability of the world's forest tree species. Outbreaks of forest diseases caused by native and introduced forest pathogens are predicted to become more frequent and intense as drought and other abiotic stressors are amplified under climate change (Sturrock et al., 2011).

4 Opportunities for sustainable forest management

A sustainable future for forestry promises good jobs, community and environmental benefits, and opportunities for future generations, and achieving this vision requires informed decision-making and the implementation of robust policies (Garrett et al., 2021). Sustainable forest management involves practices that ensure forests remain healthy, productive, and accessible for local communities and the society at large for generations, and thus, managing forests sustainably is vital to balancing ecological health and societal needs (Forest Stewardship Council International, 2024).

Key principles of sustainable forestry include adhering to local laws and maintaining certifications to ensure responsible forest management practices (Van Kooten et al., 2005). It involves defining clear tenure and use rights to avoid conflicts, preserving sacred or culturally significant forest areas, and allowing Indigenous communities to retain control of their lands unless they voluntarily delegate authority to other organisations (Forest Stewardship Council International, 2024). Sustainable forestry aims to balance resource use with societal demands while minimising environmental impact, which includes implementing management plans, regularly monitoring forest conditions, and maintaining high conservation value forests (Siry et al., 2005; Forest Stewardship Council International, 2024).

5 Conclusions

Forests are indispensable to maintaining Earth's ecological balance, climate stability, and biodiversity. Spanning tropical, temperate, and boreal regions, they provide critical ecosystem services, including C sequestration, water regulation, soil stabilisation, and cultural significance, while supporting 80% of terrestrial species and storing approximately 50% of terrestrial C. However, deforestation, climate change, and land-use changes threaten these vital ecosystems, reducing their capacity to mitigate global warming and maintain biodiversity.

To secure a sustainable future, it is essential to adopt robust policies and practices for sustainable forest management that balance ecological health with societal needs. This includes respecting Indigenous rights, adhering to local and international laws, and implementing measures to reduce deforestation and degradation. By addressing these challenges collaboratively, we can ensure the forest ecosystem can continue contributing to global C cycles and support the livelihoods and well-being of communities worldwide. Safeguarding forests is not merely an environmental imperative but a cornerstone for achieving global sustainability in the face of climate change.

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