The role of natural forests, including primary forests and intact forest landscapes, in climate mitigation and limiting global warming to the Paris Agreement target of 1.5 °C

Griffith Climate Action Beacon Science Informing Policy Briefing Note 1/23

Authors

Prof Brendan Mackey[1], Dr Heather Keith[1], Dr Pat Norman[1] and Sonia Hugh[1,2]

1 Climate Action Beacon, Griffith University, Australia

2 Wild Heritage

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Contact: b.mackey@griffith.edu.au

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INTRODUCTION

This Science information Policy Briefing Note has been prepared for the United Nations Climate COP 28. This Briefing Note provides information on the contribution of natural forests, including primary forests and intact forest landscapes, to climate mitigation and meeting the Paris Agreement's long term temperature goal and intermediate targets as guided by science.

Protecting primary forests, including intact forest landscapes, and ecologically restoring degraded natural forests, is an essential mitigation action that needs to be implemented in parallel with achieving deep and rapid cuts in fossil fuel emissions. The Kunming-Montreal Global Biodiversity Framework Target 3 aims by 2030 for at least 30% of areas to be conserved through protected areas and Other Effective Area-based Conservation Measures (OECMs). In addition to their biodiversity value, natural forests, especially primary forests, because of their natural carbon sequestration and storage capacity, can make significant and irreplaceable contributions to climate mitigation and warrant being prioritised.

KEY FOREST ECOSYSTEM MITIGATION FACTS

The Global Stocktake Report[1] (September 2023) concluded that:

- More ambitious targets in Nationally Determined Contributions (NDCs) are needed to reduce global GHG emissions by 43% by 2030 and further by 60% by 2035 compared with 2019 levels and reach net zero CO_2 emissions by 2050 globally.
- The gap between the projected emissions levels in NDCs (excluding conditional elements) and the emission levels required to limit warming to 1.5 °C (with >50% likelihood) and achieving net zero emissions this century is estimated at 22.9 (21.3–27.9) Gt CO_2_eq over the period 2023-2030[2].
- For global emissions to peak before 2030, the conditional elements of the NDCs need to be implemented, which depends among other things on enhanced financial resources, technology transfer, technical cooperation, capacity-building support and the "absorptive capacity" of forests and other ecosystems.

The absorptive capacity of forests and other ecosystems referred to by the Global Stocktake Report is based on protecting them to avoid emissions from deforestation/degradation and maintain their natural sink capacity.

The Global Carbon Project[3] found that the total annual anthropogenic global fossil fuel CO_2 emissions in 2019 were 36.4 Gt CO_2 and in 2021 were 37.1 GtCO_2. Hence, emissions are continuing to rise, with increases of 0.23 Gt CO_2 per year. Research by Prof Nancy Harris and colleagues[4] estimated that over 2001-2019 global forests were a net carbon sink of −7.6 Gt CO_2e per year, reflecting the net balance between gross carbon removals of −15.6 Gt CO_2e per year and gross emissions from deforestation and other disturbances of 8.1 Gt CO_2e per year.

It follows that:

- If we continue to clear and degrade forests, then the current -7.6 sink will increasingly shrink and the mitigation gap widen.
- Ceasing deforestation and degradation would reduce global emissions by 8.1 Gt CO_2 per year.
- For the next seven years to 2030, this would generate an accumulated mitigation benefit of 56.7 Gt CO_2 which could contribute to filling the emission reduction gap identified by the Global Stocktake of 22.9 (21.3–27.9) Gt CO_2_eq over the period 2023-2030.
- The world would then be on the pathway that limits global warming to 1.5 °C.

Furthermore, the medium to long term mitigation benefit of primary forests comes from their accumulated ecosystem carbon stocks:

- These are larger, more stable and resilient than those in re-growth and degraded forests or plantations.
- Tropical forest currently store around 305.8 Gt C with around 149.9 Gt C stored in 5.5M km² of primary forests, 221.9 Gt C stored in 9.2M km² of mature and partially degraded forests, and 86 Gt C in 4.2M km² of degraded and regrowth tropical forests.
- Furthermore, tropical forests have ongoing sequestration rates of 1.72 – 4.77 Gt CO_2 per year, equivalent to 5–13% of annual global anthropogenic CO_2 emissions[5].

1. Technical dialogue of the first global stocktake. Synthesis report by the co-facilitators on the technical dialogue. UNFCCC. Secretariat https://unfccc.int/documents/631600
2. See Figure 8. Technical dialogue of the first global stocktake.
3. Global Carbon Project https://www.globalcarbonproject.org/carbonbudget/archive.htm#CB2019
4. Harris N. et al. (2021) *Nature Climate Change* 11, 234–240. https://doi.org/10.1038/s41558-020-00976-6; see Table 2 for details of how these values were calculated.
5. Mackey B. et al. (2020) Understanding the importance of primary tropical forest protection as a mitigation strategy. *Mitigation and Adaptation Strategies for Global Change* https://doi.org/10.1007/s11027-019-09891-4

IMPORTANCE OF PRIORITISING PROTECTION OF PRIMARY FORESTS

Not all forests are equal as they differ significantly in terms of the ecological condition and overall level of ecosystem integrity[6]. Furthermore, the characteristic biodiversity and ecosystem dynamics of forest ecosystems varies with biome and ecoregion[7]. Primary forest store the most carbon, have the highest level of biodiversity and ecosystem integrity, are more resilient and have greater adaptive capacity than regrowth and otherwise degraded forests. Appendix 1 provides an indicative comparison of the carbon and biodiversity attributes of tropical, temperate and boreal forests.

CURRENT FOREST ECOSYSTEM CARBON STOCKS

To provide further insight into the role of natural forests in climate mitigation we estimated forest carbon stocks using the best available Earth system data:

- European Space Agency Above Ground Living Biomass (AGLB) - these values for biomass dry weight were multiplied by 0.5 to provide an indicative estimate of biomass carbon; the data are provided at a 30m pixel resolution, however for this purpose we upscaled to 1km resolution and generated estimates of the mean, median, minimum and maximum values; **https://climate.esa.int/en/projects/biomass/about/**
- FAO GSOCmap global soil organic carbon map; **https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/global-soil-organic-carbon-map-gsocmap/en/**
- The results are shown in Figure 1. We have also made these data available through an Earth Engine App whereby users can navigate around the world and interrogate the spatial layers: **https://shughgriffith.users.earthengine.app/view/protectedareacarbonui**

We also analysed the AGLB carbon and soil carbon stocks found in the world's major forest ecosystems types as per the RESOLVE classification; **https://ecoregions.appspot.com/** and what percentage of each forest ecosystem type is found within a protected area (IUCN I-VI); World Database on Protected Areas; **https://developers.google.com/earth-engine/datasets/catalog/WCMC_WDPA_current_polygons**

The results are provided in Figure 2. Key results include:

- **18%**
  Percentage of global forest currently found within protected areas
- **646.061 Gt C**
  Total AGLB-carbon plus Soil-carbon
- **268.018 Gt C**
  Total AGLB-carbon
- **47.524 Gt C**
  AGLB-carbon currently in protected areas
- **99.731 Gt C**
  Total AGLB-carbon plus Soil-carbon in protected areas
- **220.495 Gt C**
  Currently unprotected forest AGLB-carbon
- **89.339 Gt C**
  AGLB-carbon if {protected areas + OECMs} increased to 30%
- **215.312 Gt C**
  AGLB-carbon plus Soil-carbon if {protected areas + OECMs} increased to 30%

Note that there are three important carbon pools missing from this analysis: below ground living biomass (tree roots); above ground dead biomass; and peat. Depending on the forest type, these pools can double the amount of stored ecosystem carbon[8,9].

6. Rogers B.M. et al. (2022) Using ecosystem integrity to maximize climate mitigation and minimize risk in international forest policy. *Front. For. Glob. Change*, Sec. Forest Management. https://doi.org/10.3389/ffgc.2022.929281
7. Mackey B. et al. (2015) Policy options for the world's primary forests in multilateral environmental agreements. *Conservation Letters* 8, 139–147. https://doi.org/10.1111/conl.12120
8. Bradshaw C. & Warkentin I. (2015). Global estimates of boreal forest carbon stocks and flux. *Global and Planetary Change*. https://doi.org/10.1016/j.gloplacha.2015.02.004
9. Keith K., Mackey B. & Lindenmayer D. (2009) Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests. *PNAS* 106, 11635-11640

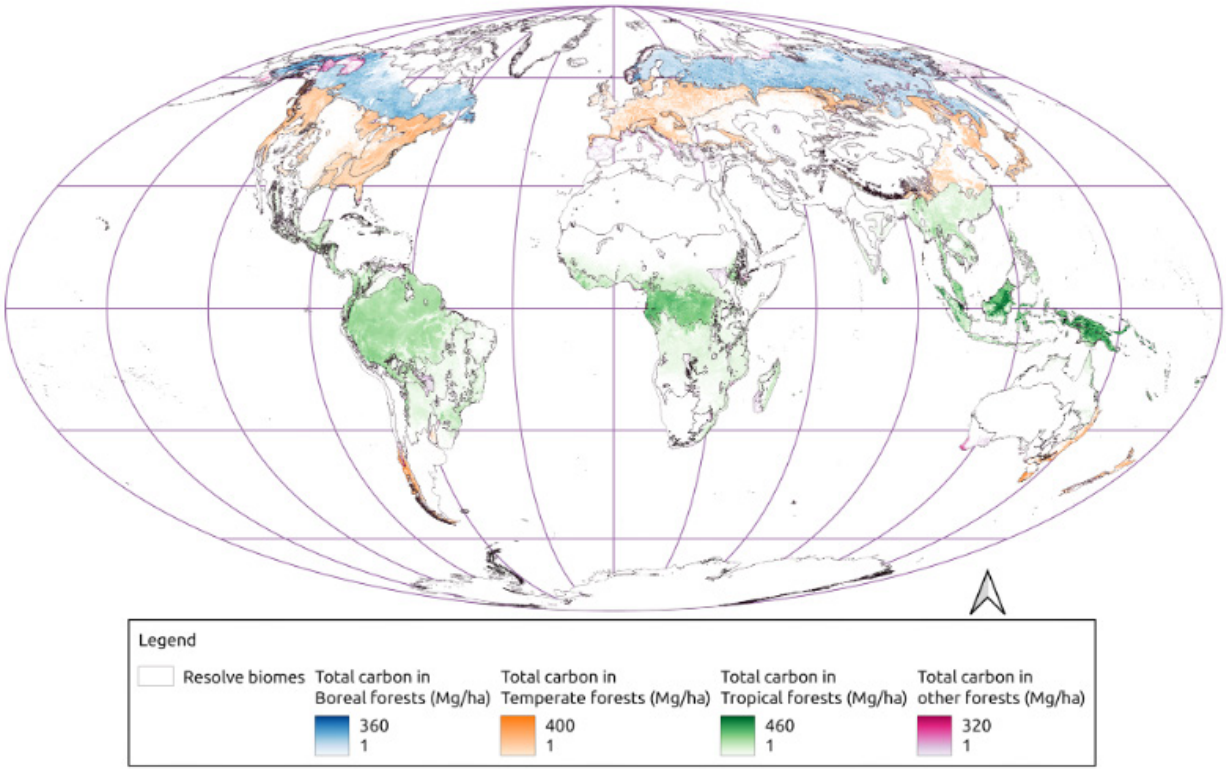


Figure 1. Distribution of forest carbon (Above Ground Living Biomass-carbon plus Soil-carbon at a 1km resolution. See text for details on data sources and methods.

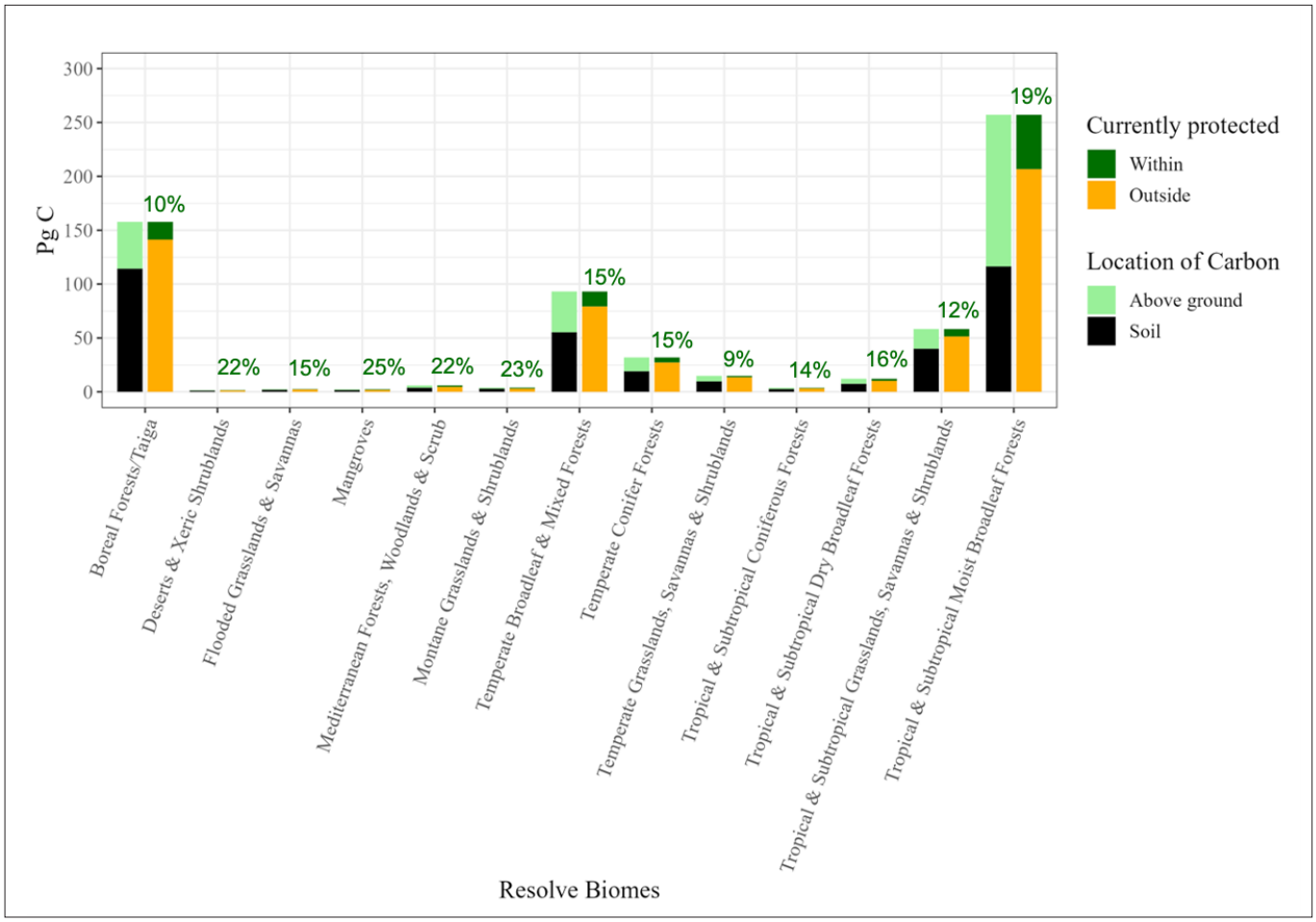
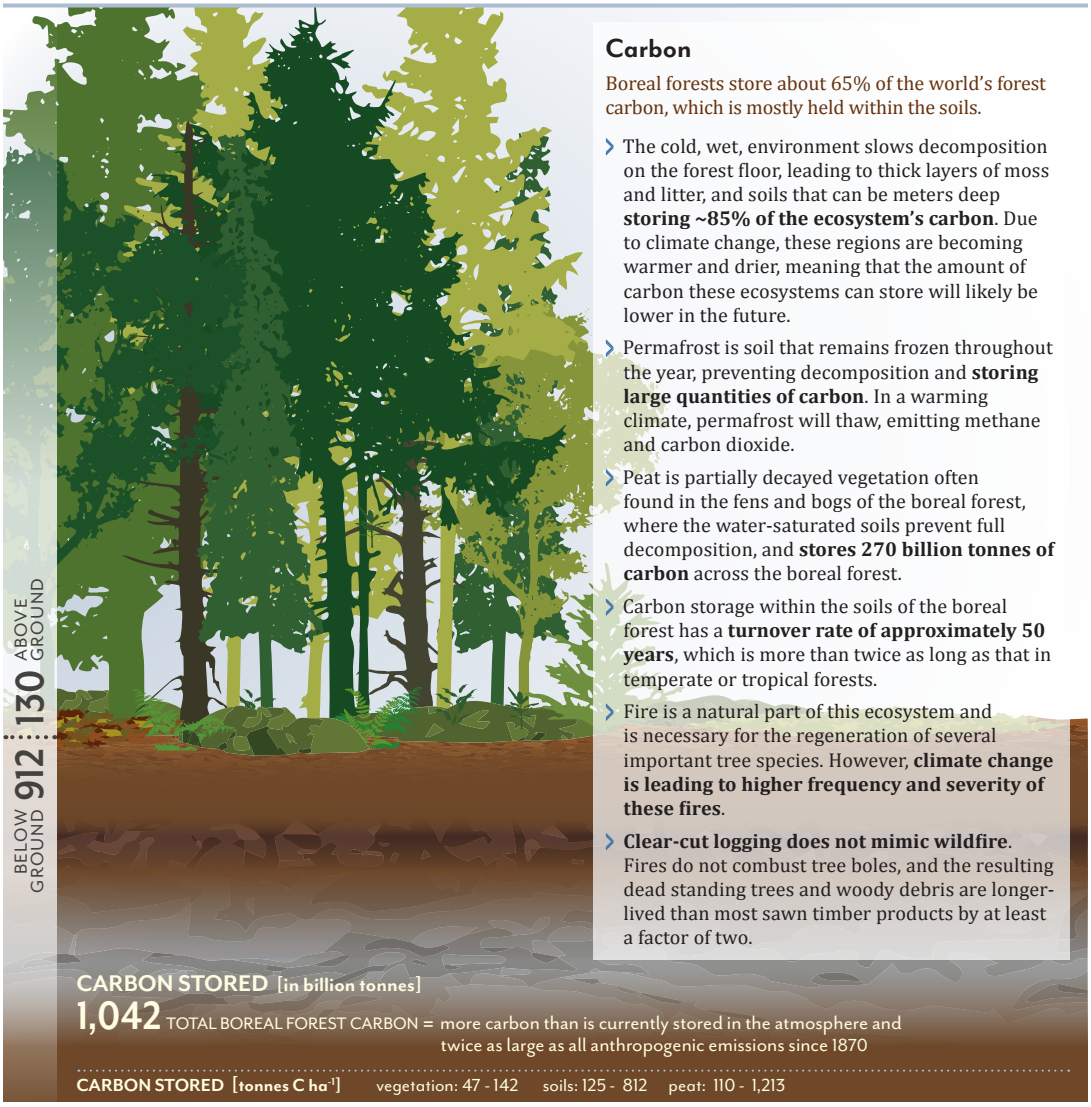


Figure 2. Estimates of the Above Ground Living Biomass-carbon and Soil-carbon in major forest types (biomes from RESOLVE ecoregions 2017) (left column). The percentage of each forest type found in Protected Areas IUCN categories I-VI. See text for further information on data sources and methods.

Appendix 1. Primary forest fact sheets. These fact sheets were developed in collaboration with colleagues from the Woodwell Climate Research Center, Frankfurt Zoological Society, Australian Rainforest Society, and GEOS Institute.

PRIMARY BOREAL FORESTS

PRIMARY BOREAL FORESTS PROVIDE CRITICAL STORES OF CARBON, BIODIVERSITY AND FRESHWATER



Carbon

Boreal forests store about 65% of the world's forest carbon, which is mostly held within the soils.

- The cold, wet, environment slows decomposition on the forest floor, leading to thick layers of moss and litter, and soils that can be meters deep **storing ~85% of the ecosystem's carbon**. Due to climate change, these regions are becoming warmer and drier, meaning that the amount of carbon these ecosystems can store will likely be lower in the future.
- Permafrost is soil that remains frozen throughout the year, preventing decomposition and **storing large quantities of carbon**. In a warming climate, permafrost will thaw, emitting methane and carbon dioxide.
- Peat is partially decayed vegetation often found in the fens and bogs of the boreal forest, where the water-saturated soils prevent full decomposition, and **stores 270 billion tonnes of carbon** across the boreal forest.
- Carbon storage within the soils of the boreal forest has a **turnover rate of approximately 50 years**, which is more than twice as long as that in temperate or tropical forests.
- Fire is a natural part of this ecosystem and is necessary for the regeneration of several important tree species. However, **climate change is leading to higher frequency and severity of these fires**.
- **Clear-cut logging does not mimic wildfire**. Fires do not combust tree boles, and the resulting dead standing trees and woody debris are longer-lived than most sawn timber products by at least a factor of two.

Boreal forests are home to 481 Million hectares of remaining primary forest, or 41% of the global total

Big, Old Trees

Large trees are critical to maintaining biodiversity, and are being lost due to harvesting and other anthropogenic impacts.

- Southern boreal forests typically have trees **15–30 m high**, while northern boreal forests have stunted trees usually **3–15 m high**.
- Old trees are **critical for the growth and abundance of epiphytic lichens** on their branches, which can decrease by a factor of 6 in managed forests.
- Old, dead trees, both standing and on the ground, **provide diverse habitats** that are important for many species of birds, fungi and insects.
- **Logging and other anthropogenic disturbances homogenize the landscape**, leading to an abundance of young forests and a scarcity of older forests, while removing much of the dead wood, and render the forest vulnerable to human-ignited fires.

Biodiversity

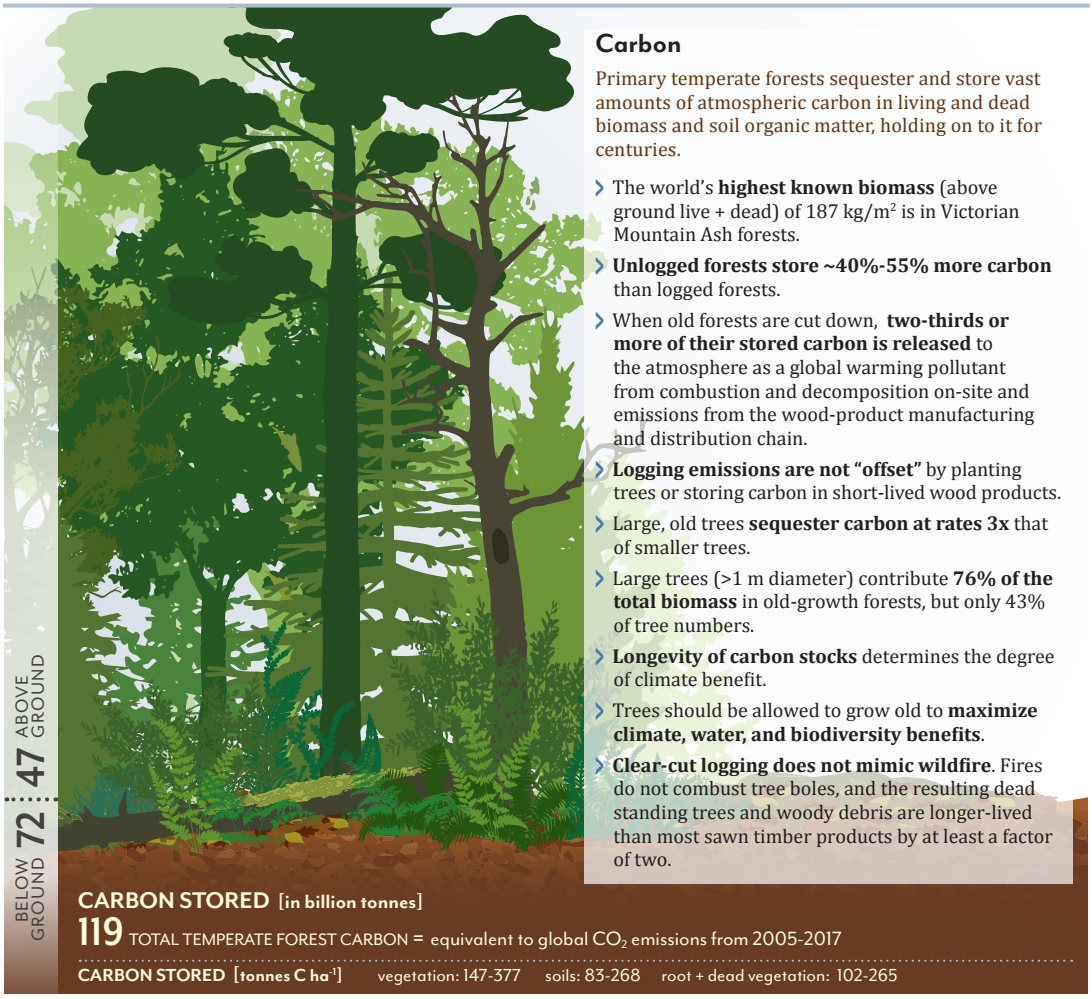
The diverse ecosystems, flora and fauna within the boreal forest, contribute to the ecosystem services this biome provides.

- **US$703 billion of services** per year in Canada alone.
- **60% of the world's remaining surface freshwater** is stored within the boreal forest, and the wetlands purify this water, filtering out contaminants.
- **Provides important breeding ground** for birds from further south, and important for almost half of all North America's bird species.
- **Maintaining biodiversity leads to higher levels of ecosystem services** such as carbon storage, berry production and game populations.
- **Many indigenous communities are dependent** on the ecological integrity of old growth boreal forests for medicinal plants, cultural practices and traditional livelihoods.
- These ecosystem services are likely **at risk under the warming climate**.

Woods Hole Research Center · Wild Heritage · IntAct International Action for Primary Forests · Griffith University · GEOS Institute · Australian Rainforest Conservation Society · Frankfurt Zoological Society

PRIMARY TEMPERATE FORESTS

HARBOR UNIQUE BIODIVERSITY AND ECOSYSTEM SERVICES, INCLUDING CLIMATE REGULATION



Carbon

Primary temperate forests sequester and store vast amounts of atmospheric carbon in living and dead biomass and soil organic matter, holding on to it for centuries.

- The world's **highest known biomass** (above ground live + dead) of 187 kg/m^2 is in Victorian Mountain Ash forests.
- **Unlogged forests store ~40%-55% more carbon** than logged forests.
- When old forests are cut down, **two-thirds or more of their stored carbon is released** to the atmosphere as a global warming pollutant from combustion and decomposition on-site and emissions from the wood-product manufacturing and distribution chain.
- **Logging emissions are not "offset"** by planting trees or storing carbon in short-lived wood products.
- Large, old trees **sequester carbon at rates 3x** that of smaller trees.
- Large trees (>1 m diameter) contribute **76% of the total biomass** in old-growth forests, but only 43% of tree numbers.
- **Longevity of carbon stocks** determines the degree of climate benefit.
- Trees should be allowed to grow old to **maximize climate, water, and biodiversity benefits**.
- **Clear-cut logging does not mimic wildfire**. Fires do not combust tree boles, and the resulting dead standing trees and woody debris are longer-lived than most sawn timber products by at least a factor of two.

Temperate forests are home to 108 Million hectares of remaining primary forest, or 9% of the global total, highlighting the urgency of protecting what's left

Big, Old Trees

Loss of big, old trees is a global concern as fewer of them, and the primary and intact forest landscapes that harbor them, remain due to logging and other threats.

- **Trees can tower to >100 meters** (coast redwood, mountain ash) with a base circumference of >9 meters (giant sequoia, New Zealand Kauri tree).
- **Trees can live for over a thousand years**, continuously accumulating and storing carbon, while helping to regulate the climate and hydrological cycle through forest-atmospheric feedbacks.
- Dead big trees provide **shade and moisture** for seedlings, **nest sites** for birds and mammals, serve as **biological legacies** jumpstarting forest renewal, and provide cultural and spiritual connections for people.
- Old forests, especially in floodplain areas, **buffer human communities** from floods and droughts.
- Old trees are **irreplaceable in human lifetimes** and need to be protected from logging.
- Old growth wet temperate forests are **far more resistant to drought and fire** than logged forests.

Biodiversity

Primary wet temperate forests (deciduous, evergreen, broadleaf, conifer, mixed) harbor diverse communities that experience distinct seasonal changes affecting productivity, ecosystem services, and migratory species, especially birds.

- Primary forests include both **exceptionally biodiverse and productive older forests and complex early seral forests** created by natural disturbance regimes ranging in frequency and intensity, including intense events that kill most of the trees in an area.
- **Lichen richness** is among the highest of any forested ecosystem.
- Forest carnivore assemblages and **complex food-web dynamics** are fully present and functional.
- **Keystone species**, like anadromous salmon, **connect terrestrial and marine environments** through nutrient cycling of spawned-out salmon carcasses.
- Small mammals feed on below-ground fungi, aiding in spore dispersal of mycorrhizae, which allow plants to **take up nutrients efficiently**.
- **Myriad ecosystem services** such as nutrient cycling, soil development, climate regulation, and water filtration .
- **Temperate forests cover roughly one-third of original extent** vs. 45-65% for tropical and boreal forests, respectively.

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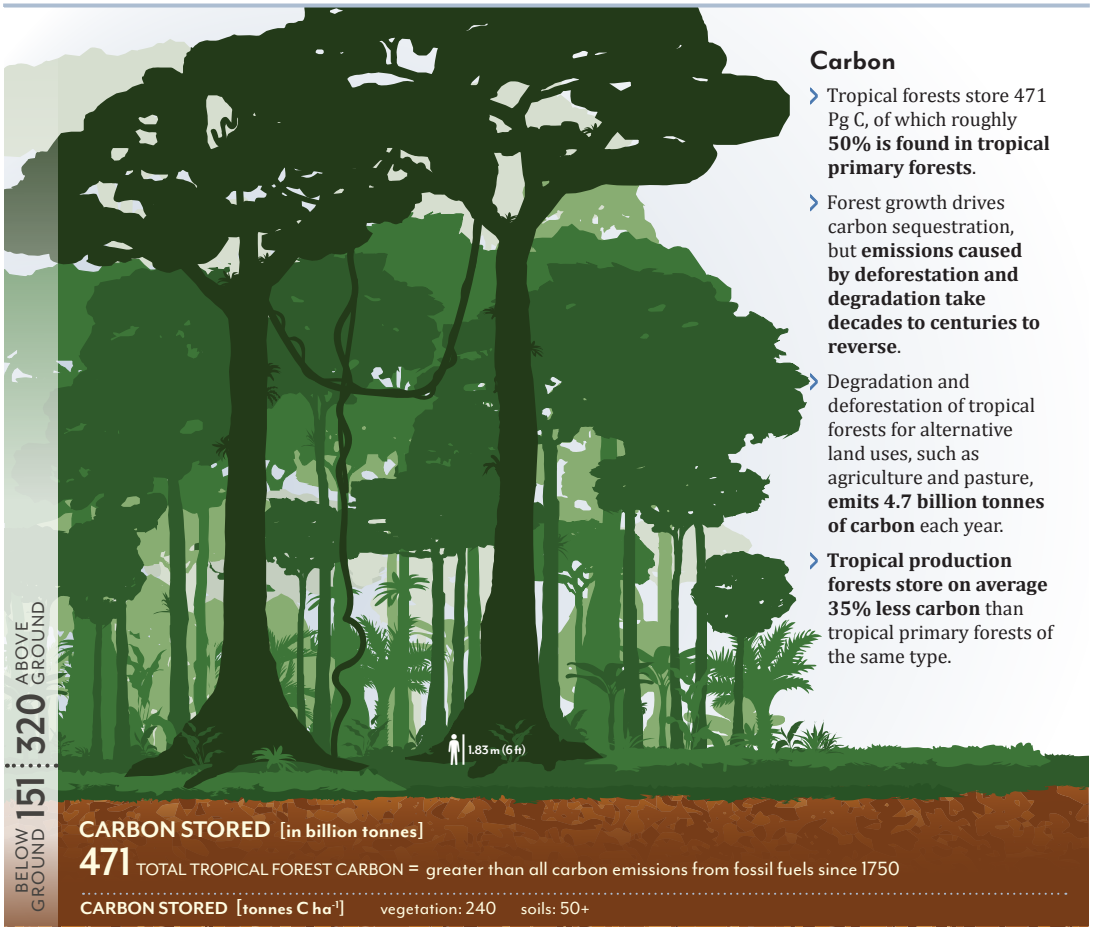
PRIMARY TROPICAL FORESTS

ECOSYSTEM INTEGRITY OF PRIMARY TROPICAL FORESTS IS CRITICAL FOR BIODIVERSITY AND CARBON



Carbon

- Tropical forests store 471 Pg C, of which roughly **50% is found in tropical primary forests**.
- Forest growth drives carbon sequestration, but **emissions caused by deforestation and degradation take decades to centuries to reverse**.
- Degradation and deforestation of tropical forests for alternative land uses, such as agriculture and pasture, **emits 4.7 billion tonnes of carbon** each year.
- **Tropical production forests store on average 35% less carbon** than tropical primary forests of the same type.

Tropical forests are home to 541 Million hectares of remaining primary forest, or 46% of the global total

Big, Old Trees

Big, old trees occur at low densities per hectare but are essential to the health of a primary tropical forest.

- **Store up to half of the biomass carbon** in a forest.
- **Live for centuries**, continuously accumulating carbon throughout their lifetimes.
- **Provide essential habitat for biodiversity acting as ecological anchors** within the food and community webs that are the processes producing forest resilience.
- **Create a stable forest interior environment** that is protected from extreme weather conditions.
- **Big trees need to be protected**—they are quickly destroyed by logging but take centuries to regrow.

Biodiversity

Native animals, plants, trees, fungi and microbes interact to create stable and enduring primary forests. Primary tropical forests are irreplaceable for biodiversity. They protect about two thirds of all terrestrial plant and animal species, many of which do not survive in degraded forests.

- **Mammal, bird, reptile and insect seed dispersers and pollinators** ensure trees, including long-lived, hardwood species, "replant themselves" and renew the forest.
- **Forest fauna and flora drive efficient nutrient and water cycles**, maintaining healthy forest growth.
- **The closed forest canopy creates an interior microclimate** sheltering the understory and maintaining moist, shady and cool conditions.
- **Water retained below the canopy** stimulates rapid and dense tree and other vegetation growth.
- **The canopy transpires water, driving convection**, which in turn can generate regional cloud cover and rainfall.
- **All of these attributes combine to create primary forest stability and resilience** to threats from diseases, invasive plants, feral animals, drought and fire.
- **These attributes also enhance ecosystem adaptive capacity** to climate change and other stress.

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