Food and Agriculture
Organization of the
United Nations

Bridging nature and climate through protection of primary forests with high ecological integrity

FAO technical brief

Bridging nature and climate through protection of primary forests with high ecological integrity

FAO technical brief

Kate Dooley,
Amy E. Duchelle,
José Carlos Fernandez-Ugalde,
Sheila Wertz-Kanounnikoff,
Axelle Boulay,
Antoine Libert-Amico,
Anne Branthomme,
Serena Fortuna,
Anssi Pekkarinen

Food and Agriculture Organization of the United Nations
Rome, 2024

Required citation:
Dooley, K., Duchelle, A.E., Fernandez-Ugalde, J.C., Wertz-Kanounnikoff, S., Boulay, A., Libert-Amico, A., Branthomme, A., Fortuna, S. and Pekkarinen, A. 2024. *Bridging nature and climate through protection of primary forests with high ecological integrity - FAO technical brief*. Rome, FAO. https://doi.org/10.4060/cd1733en

Cover photograph: Aerial view of the Amazon Rainforest, near Manaus, the capital of the Brazilian state of Amazonas, Brazil., © CIAT/Neil Palmer

Contents

INTRODUCTION

Primary forests[1], which comprise less than one-third of the world's remaining forests (around 1.11 billion ha), are where the majority of the world's terrestrial biodiversity is found (FAO, 2020a). They also comprise the largest proportion of terrestrial carbon stocks with the total ecosystem carbon stored in primary tropical forests calculated at 141-159 Gt C (gigatonnes of carbon) (Mackey *et al.*, 2020). Furthermore, the world's tropical primary forests are the customary homelands of Indigenous Peoples who continue to play a critical role in their protection and conservation management (Garnett *et al*., 2018; Ricketts *et al*., 2010). Yet primary forests continue to be lost at a rate of more than one million ha per year (FAO, 2020a). This technical brief focuses on the important role of primary forests in meeting climate and biodiversity goals. It also explains science-based principles relevant to policy pathways for protecting, restoring, and sustainably managing these forests.

Existing policies and funding mechanisms insufficiently prioritize the protection of primary forests. Despite the climate change mitigation potential of primary forests and their importance for adaptation, less than five percent of climate finance is used to support forest conservation (Barber *et al*., 2020). The situation is particularly challenging for countries or jurisdictions with large areas of primary forests. Policy and financial incentives for protection of primary forests should be mobilized before clear or immediate threats are apparent.

Forest protection and restoration are the most effective climate mitigation actions in the land sector (IPCC, 2022a), but forests do more for the climate than store and sequester carbon. Scientific evidence highlights the dramatic global cooling effect of forests through evapotranspiration and via their physical structure and chemistry. When taking these biophysical effects into account, it is estimated that tropical forest conservation could provide 20-40 percent greater global cooling than previously thought (Lawrence *et al*., 2022; Seymour *et al*., 2022). This extra global climate change mitigation is complemented by the ability of forests to regulate rainfall and stabilize local climate, helping minimize extreme weather and making forests essential for climate change adaptation and resilience (Lawrence *et al*., 2022; Seymour *et al*., 2022). Furthermore, the biodiversity values of primary forests serve as a key "adaptation services", alongside other important ecosystem services. Future agricultural productivity, especially in the tropics, depends on the climate regulatory functions that forests provide (Lawrence *et al*., 2014). Undervaluing the multiple benefits of primary forests can lead to deforestation and degradation of high integrity ecosystems, adversely impacting local livelihoods, biodiversity and the global climate.

[1] Primary forests are defined by FAO as naturally regenerating forests of native tree species where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed (including forests where Indigenous Peoples and local communities engage in traditional forest stewardship and management/use activities that meet this definition) (FAO, 2023). More details about the existing definitions of primary forest and related concepts, such as intact and old-growth, have been further documented in Mackey *et al.* (2020).

Key messages:

- **Primary forest conservation is imperative for meeting climate and biodiversity goals.** Primary forests serve as vital carbon sinks and provide a host of biodiversity benefits and other ecosystem services that help enhance the adaptive capacity and resilience of people and ecosystems.
- The critical **urgency of protecting primary forests should be further prioritized in existing policies and funding mechanisms**, and in particular carbon trading mechanisms, which focus on carbon fluxes rather than stocks. The benefits of primary forests for climate regulation and cooling go beyond carbon.
- **Joint climate and biodiversity action to protect primary forests is needed at all levels** and can be bolstered by the goals of the Paris Agreement and the Kunming-Montreal Global Biodiversity Framework.
- A significant share of primary forest is outside any formal protection status. Effective conservation of primary forests will require **integrated landscape approaches and innovative solutions** to manage trade-offs and promote the essential regulatory services provided by primary forests for agricultural production.
- **Recognition of secure tenure rights for local communities and Indigenous Peoples** – **and compensation and support** for their role in protecting forests and ecosystem services – must be priorities.

PROTECTING PRIMARY FORESTS IS CRITICAL FOR TACKLING CLIMATE CHANGE AND BIODIVERSITY LOSS

Forests play an outsize role in both climate mitigation and adaptation. The role of forest ecosystems in the carbon cycle is critical for climate stabilization. Forests are part of the natural land carbon sink that absorbs a large share of emitted carbon dioxide, thereby helping to keep warming much lower than it would be in the absence of this natural sink effect (Mackey, 2020). The biophysical structure of forests interacts with the atmosphere and cools the planet through evapotranspiration and other biophysical processes (Lawrence *et al*., 2022). In fact, without forests, the world today would be 0.5°C warmer than it is now (Lawrence *et al*., 2022), leading us beyond the Paris Agreement commitment[2] of maintaining global temperatures within a safe operating space for the planet and humanity.

The world's remaining primary forests are of particular importance in these processes, supporting an exceptional confluence of globally significant environmental and social values compared to forests that have been degraded by human activities. These include biodiversity, carbon sequestration and storage, water provision, Indigenous Peoples' cultures, and the maintenance of human health (Watson *et al*., 2018). All of these qualities underpin higher levels of ecosystem integrity in primary forests, which in turn lends greater stability and resilience to the carbon stored in these ecosystems (Keith *et al*., 2021). Any further loss or degradation of the world's remaining primary forests would exacerbate climate change effects through both the carbon emissions and the decline of this crucial and under-appreciated carbon sink. Maintaining and restoring the ecological integrity of primary forests is therefore an urgent priority for current global efforts to halt the ongoing biodiversity crisis, slow rapid climate change, and achieve sustainability goals (Watson *et al*., 2018).

Primary forests are crucial to the goals of multiple international conventions and declarations. The Paris Agreement, which aims to limit warming to 1.5°C, recognizes the critical role of forests and other ecosystems in carbon sequestration and storage in Article 5, with the first global stocktake decision emphasizing the importance of "enhanced efforts towards halting and reversing deforestation and forest degradation by 2030"[3]. The Kunming-Montreal Global Biodiversity Framework aims to slow the loss of ecosystems of high ecological integrity, protect 30 percent of ecosystems and restore 30 percent of degraded areas by 2030, while recognizing and respecting the rights of Indigenous Peoples and local communities. There is the potential to use these agreements to prioritize the crucial qualities of primary forests that contribute most to achieving the specific goals of both preventing dangerous warming and conserving biodiversity and natural ecosystems. Many monitoring and incentive frameworks, however, do not prioritise the unique characteristics of primary forests, focusing for example, on forest extent but not condition (Watson *et al*., 2018). The current framework of carbon accounting rules and policy incentives under the Paris Agreement focuses on carbon fluxes instead of stocks, which risks incentivising tree planting over protecting existing carbon stocks in primary forests. Classification systems for forests do not include characteristics representing ecological condition which is crucial for maintaining biodiversity (Keith *et al*., 2021). Conservation of primary forests must be prioritised in efforts to combat climate change and reverse biodiversity loss; it is insufficient to

---

[2] The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. It entered into force on 4 November 2016.

[3] FCCC/PA/CMA/2023/16/Add.1: Decision 1/CMA.5

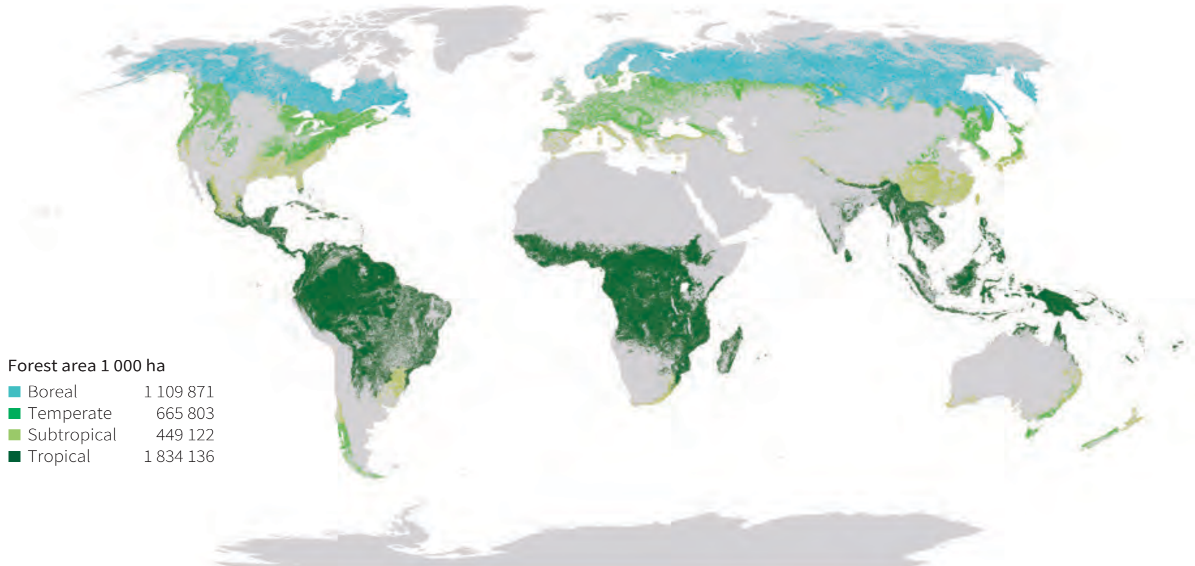
treat all forests as equal regardless of their condition (Mackey, 2020).

Primary forests' characteristics and extent

In primary forests, forest composition, structure and function are dominated by natural ecological and evolutionary processes, including natural disturbance regimes (FAO, 2020b; Mackey, 2020). They are also under the stewardship of Indigenous and local communities living traditional lifestyles that conserve and sustainably use biological diversity (CBD, 2010). Therefore, it is the intensity and impact of human activity, rather than the presence of people per se, that matters most to the conservation of a primary forest (Kormos, 2018). Primary forests represent the highest level of ecosystem integrity along a continuum that reflects the impacts of human activities – from minimal to severe. Thus, the carbon stored in primary forests, with higher levels of ecological integrity than degraded ecosystems, is more stable and resilient, providing resistance to threats that are increasing with climate change such as pests, disease, drought, floods and fire (Keith *et al*., 2021).

Primary forests can be classified into four broad biomes – tropical, subtropical, temperate, and boreal. Forty-five percent of the world's forests are in the tropical domain, followed by the boreal (27 percent), temperate (16 percent) and subtropical (11 percent) domains (FAO, 2020a). Carbon storage follows different patterns across these different forest biomes. For example, 60 percent of the carbon found in boreal forests is in belowground carbon stocks (INTACT, 2020).

Figure 1. The global distribution of forests, by climatic domain (FAO, 2020a)



The global forest area in 2020 was estimated at 4.06 billion ha, which is 31 percent of the total land area (FAO, 2020a). Less than one-third of these remaining forests (around 1.11 billion ha) were reported to be primary forests, and they are being lost at a rate of more than one million ha per year (with a decline of 81 million ha in the 30 years from 1990 to 2020 (FAO, 2020a)). The total ecosystem carbon in primary tropical forests has been calculated at 141-159 Gt C (Mackey *et al*., 2020). These figures underscore the urgent need for effective measures to ensure their conservation and sustainable use. Approximately 23 percent of primary forests are deemed to have reached their threshold for abrupt decline (Forzieri *et al*., 2022). Forest degradation, where forests remain standing, is understood as a human-caused reduction in the ecosystem integrity of the forest, which impacts the composition, structure, function and productivity of the ecosystem, resulting in reduced ecosystem resilience (Keith *et al*., 2021). The sensitivity of forest ecosystems to climatic variations, such as changes in temperature and precipitation patterns, and the consequent potential for altered forest composition is also well documented (Seidl *et al*., 2020; Wang *et al*., 2019). Higher ecosystem integrity in primary forests reduces the risk profiles of these forests to carbon loss and increases the ecosystem services and benefits provided (Rogers *et al*., 2022).

A hierarchy of first protecting, then restoring and then managing land for climate mitigation and sustaining ecosystem services reflects the unique characteristics of primary forests (Rogers *et al*., 2022) noting that there are limits to "restoring" primary forests. Avoiding forest loss and protecting primary forests must be the first priority in combatting the climate and biodiversity crises, not only to keep emissions out of the atmosphere now, but also to maximise ecosystem integrity and biodiversity protection (Mackey, 2020). The next priority is to enhance the restoration of degraded natural forests, following conservation principles to buffer and increase connectivity between primary forest patches (Rogers *et al*., 2022). Improving forest management and reforming plantation management and establishment practices have a role to play by reducing pressure on and increasing the protection of primary and degraded natural forests. Protection, restoration and improved management of forests are not mutually exclusive; in planning and practice, these actions can be highly complementary (Cook-Patton *et al*., 2021). Importantly, all three pathways can help boost agricultural productivity and food security through the essential ecosystem services that forests provide.

However, the economic value of standing forests, including primary forests, is typically lower than alternative land uses. Furthermore, some climate change mitigation responses that compete for land and land-based resources can pose risks – the scale of which largely depends on the type of land management activity undertaken and the context in which it is deployed (IPCC, 2022a). For example, promoting bioenergy and fast-growing plantations for carbon sequestration can drive the loss of primary forests through direct conversion or increasing competition for agricultural land (Dooley *et al*., 2022a). Focusing land-based mitigation efforts on forest conservation and ecosystem restoration can improve both ecological values and contribute to staying within the 1.5°C temperature limit when coupled with phasing out of emissions from other sectors (Dooley *et al*., 2022b). This shows the importance of protecting existing primary forests, as well as restoring degraded natural forests and other ecosystems, to build back their ecological integrity.

Current incentives for protecting primary forests

Conserving primary forests constitutes an effective and efficient solution to climate change by retaining carbon stored in forests; preventing the emissions of forest carbon stocks to the atmosphere; and providing cooling benefits at multiple scales through a series of biophysical processes described below. Policy and financial incentives for protecting forests has increasingly come to focus on REDD+[4] in developing countries. REDD+ can contribute to immediate emission reductions, but what about forests that are not at immediate or evident threat of deforestation and degradation? Countries with a high percentage of forest cover and relatively low rates of deforestation include Belize, Costa Rica, Gabon, Guyana, and Papua New Guinea, as well as some subnational jurisdictions in Brazil, Colombia, and Indonesia, among others. These countries face economic pressures to exploit their natural resources, including forests, as a means of generating revenue and supporting their economies. This can lead to unsustainable logging, agricultural expansion, and infrastructure development that threatens forest ecosystems.

The rationale behind frameworks such as REDD+ is that emission reductions are estimated by comparing actual emissions against reference levels presented by countries. Emission baselines provide an estimate of emissions likely to occur in the absence of policies and measures to mitigate them, also known as the "business-as-usual" scenario against which mitigation outcomes can be measured. Most countries have opted for simple historical averages to define their reference level (FAO, 2020b). However, a particular case where historical averages underestimate future forest loss is that of countries or jurisdictions with relatively high forest cover and low deforestation, which include significant areas of primary forests. From the perspective of the forest transition curve theory (Mather, 1992), regions with initial high forest cover and low deforestation would face increased deforestation in the future as economic development progresses. In these cases, the use of historical averages as the business-as-usual scenario would underestimate the likely higher future pressures on forests.

Estimating such adjustments is quite challenging, as it requires accounting for the scale and effect of future development needs and population pressures, among other factors, and there is a concern that countries may have incentives to unduly inflate their adjustments. There are no standardized methods to assess forest transitions. Current allowable adjustments under various financing windows and standards include arbitrary criteria to define which countries can apply upward adjustments and an upper limit to the scale of the adjustments in the name of conservativeness. As a result, significant primary forest areas facing latent threats will not be accounted for in incentive mechanisms. An additional challenge is scale, since most criteria to allow upward adjustments are applied at the national scale, whereas the forest transition may also be applicable at subnational scales.

---

[4] REDD+ stands for Reducing Emissions from Deforestation and forest Degradation, plus the sustainable management of forests and the conservation and enhancement of forest carbon stocks, in developing countries.

Indigenous Peoples as forest stewards

Evidence shows that Indigenous Peoples with secure land rights vastly outperform both governments and private landholders in preventing deforestation, conserving biodiversity, and producing food sustainably (Garnett *et al*., 2018; Fa *et al*., 2020; FAO-FILAC 2021; Townsend *et al*., 2020). Secure tenure rights for Indigenous Peoples and forest-proximate communities results in lower rates of deforestation and soil degradation and better protection of the biodiversity and ecosystem functions upon which these communities depend (Blackman & Veit, 2018).

Clear tenure rights empower communities to make long-term decisions about their land (Meyfroidt *et al*., 2022). When people have legal rights and a stake in the land, they are more likely to invest in its conservation and to implement sustainable agricultural practices. This includes techniques like agroforestry, crop rotation, and agroecological approaches that maintain soil fertility and structure. Secure tenure allows Indigenous Peoples to steward the land based on traditional practices and knowledge, with intricate knowledge of their local ecosystems (Rights and Resources Initiative, 2020). This can include measures to safeguard critical habitats, conserve native species, and prevent destructive activities like illegal logging or poaching. Clear and secure land rights can help reduce conflicts over land and resources (Meyfroidt *et al*., 2022).

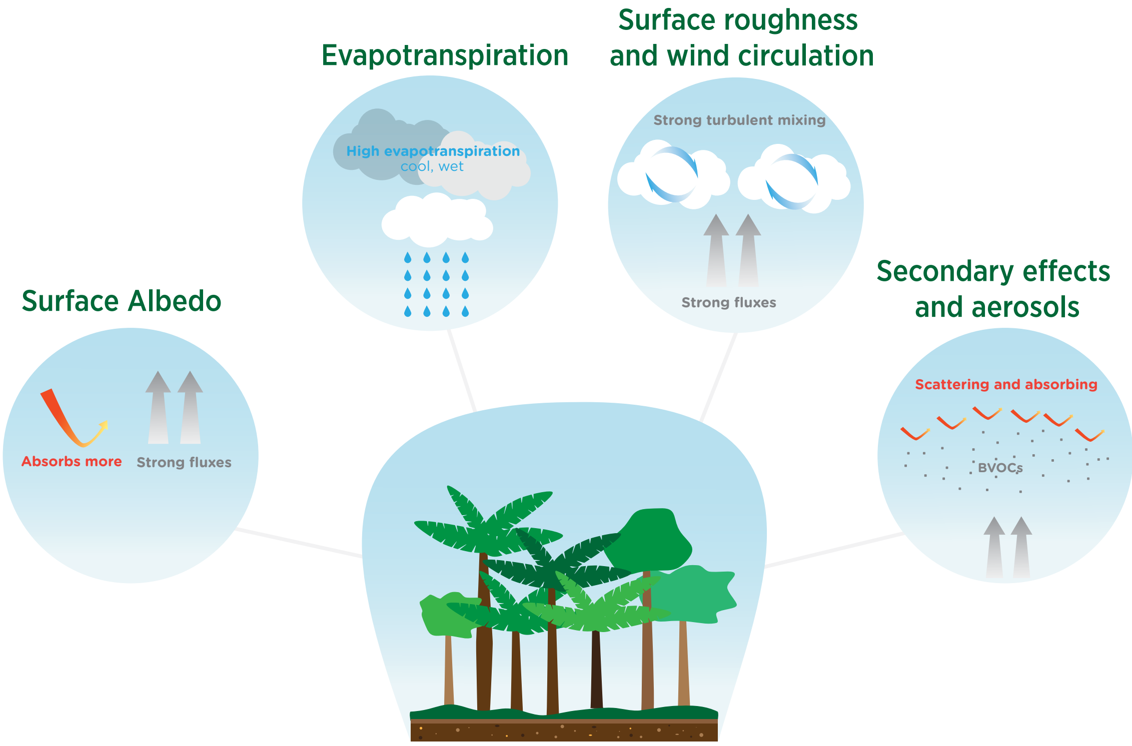
Primary forest conservation could also be supported through the recognition of Other Effective Area-based Conservation Measures (OECMs). Protected and conserved areas, including OECMs, are key to achieving Target 3 of the Kunming-Montreal Global Biodiversity Framework to effectively conserve 30 percent of land area by 2030. Securing local tenure rights has been shown to be lower cost than government managed protected areas (Ding *et al*., 2016). Local tenure security can also reduce conflict (Tauli-Corpuz *et al*., 2018). Furthermore, securing tenure rights can contribute to several of the Sustainable Development Goals (SDGs). Many countries are providing for the recognition of community tenure rights inside protected areas (e.g. Australia, Brazil, Colombia, Ecuador, India, Peru, the Philippines, South Africa and the United States of America) (Rights and Resources Initiative, 2015), and some OECMs also recognize local rights in order to permit sustainable use while producing positive conservation outcomes (FAO, 2020b). One example of this is in Namibia, where the community-based approach to wildlife management grants community institutions organized into conservancies legal rights to use and benefit from wildlife on their lands, resulting in income generation as well as increases in numbers and diversity of native fauna (FAO, 2020b).


© CIFOR/Icaro Cooke Vieira

PRIMARY FORESTS PROVIDE COOLING BENEFITS BEYOND CARBON

The climate benefits of primary forests go well beyond carbon sequestration and storage. A growing body of evidence suggests that forests, across multiple climatic biomes, have a significant impact on global climate stability, by interacting with the atmosphere in many ways other than through the global carbon cycle (Hasler *et al*., 2023; Lawrence *et al*., 2022; Li *et al*., 2023; Smith *et al*., 2023). The role of forests in climate policy has so far focused on the need to enhance carbon sequestration into forests and protect and maintain existing carbon stocks in forests. Beyond carbon flows and stocks, forests influence global and local temperatures and rainfall patterns through four main biophysical processes: albedo, evapotranspiration, surface roughness and aerosols. These four processes all affect the amount and forms of water and energy transfer between land, the biosphere (living organisms), and the atmosphere (Seymour *et al*., 2022; Figure 2).

Figure 2. Biophysical processes in forests that impact climate (adapted from Wolosin & Harris, 2018 and Seymour *et al.* 2022)



Surface albedo refers to the light absorbing or reflecting capacity of the planet's surface. Forests, with their dark green surfaces absorb a larger fraction of incoming solar energy than lighter surfaces, such as croplands, grasslands, or snow. This dark surface area means forests *increase* radiative forcing – or warming. The albedo effect has been extensively mapped and understood for boreal forest biomes. However, new research shows an even greater proportion of net negative climate areas in arid biomes, meaning that the carbon storage benefit of restoring tree cover in arid zones can be offset by increased albedo (Hasler *et al*., 2023). The effect varies across the landscape, and accounting for albedo based on global mapping efforts can help to deploy restoration of tree cover for maximum climate benefit (Hasler *et al*., 2023).

Forests also convert incoming solar energy into water vapour through evapotranspiration, meaning that forests play a critical role in rainfall regulation. These benefits have been found to vary with seasons and topography, with upland sites having increased evapotranspiration rates and decreased warming impacts compared to deforestation at lowland sites (Bulusu *et al*., 2023; Zeng *et al*., 2021). Rainfall decreases in deforested areas, which can lead to further forest die-back and a feedback effect (Seymour *et al*., 2022). The physical structure of a forest also influences the climate, by creating turbulence that mixes surface air with air in the low atmosphere. The loss of forests can increase wind speeds leading to further drying and warming. Forests also impact the climate through secondary effects – namely aerosols that interact to generate cloud formation – which in turn increases albedo, causing more of the sun's energy to be reflected into space with a cooling effect. The cooling effects of additional cloud formation from forests can offset some of the warming from forests' low albedo (Duveiller *et al*., 2021; Seymour *et al*., 2022).

Deforestation exerts a profound impact on crucial forest biophysical processes, with far-reaching consequences for climate stability. These effects reverberate across the global, regional, and local scales. On a global scale, the repercussions of tropical deforestation extend beyond carbon emissions alone, potentially contributing to global warming by an estimated 20-40 percent more than initially estimated (Lawrence *et al*., 2022; Seymour *et al*., 2022). The net climate influence of forests, whether cooling or warming, hinges on their geographical location. Tropical forests, when factoring in biophysical effects, emerge as significant contributors to global cooling, with evidence from the across the tropics (Smith *et al*., 2023). This underscores the pivotal role tropical forests play in climate regulation.

At the regional level, deforestation has the potential to disrupt precipitation patterns downwind, exerting implications for rainfall patterns even across international borders (Seymour *et al*., 2022). Deforestation at larger scales has a more pronounced effect on precipitation, with pan-tropical satellite datasets showing that forest loss caused reductions in precipitation at scales greater than 50 km (Smith *et al*., 2023). Deforestation in the Brazilian Amazon has been shown to have a discernible impact on rainfall in neighbouring countries like Bolivia, Uruguay, Paraguay, and Argentina (Seymour *et al*., 2022). This perturbation in precipitation can escalate the risk of drought, posing threats to food and water security and underscores the important role of tropical forest conservation to support regional climate resilience.

On the local scale, deforestation can lead to a notable elevation in local average and extreme temperatures. While the overall impact of greenhouse warming may have been modest, some local communities experiencing the loss of forests' cooling effects have witnessed the hottest part of the day soaring more than 7.6°C above average temperatures. Localized temperature surges have been observed in deforested areas, compounding the effects of global greenhouse warming, intensifying heat stress on both human populations and vital agricultural and livestock resources (Seymour *et al*., 2022). Reducing local air pollution tends to enhance the biophysical cooling effect from forests at mid-low latitudes, with the enhanced cooling potential most strongly observed in China (Ge *et al*., 2023).

This understanding of the net effects of forest cover loss in increasing radiative forcing highlights that to realize the full climate benefits of forests must be integrated into mitigation and adaptation policies and strategies.

Appreciating the cooling effects of primary forests can also help to understand the limitations of greenhouse gas (GHG)-centric incentive schemes for forest protection, specifically for forest-dependent communities in tropical regions. These groups are custodians of a substantial portion of the world's forest carbon (Rights and Resources Initiative, 2018). Carbon crediting systems do not account for tropical forests' biophysical climate effects, meaning they undervalue the climate benefits of conserving large areas of tropical forests (Seymour *et al*., 2022; Su *et al*., 2023). Undervaluing these forests puts them at further risk of deforestation by limiting available funding, threatening the global climate while increasing the negative local impacts of deforestation on the very communities that have the best track record of preventing deforestation. These negative impacts include higher local average and extreme temperatures, increasing the risk of heat stress to forest-adjacent communities and their agricultural systems. Governance and financing strategies that recognise and incentive the non-carbon benefits are needed to ensure the full climate benefits of forests are maintained.

RESILIENT FORESTS SUPPORT LOCAL ADAPTATION

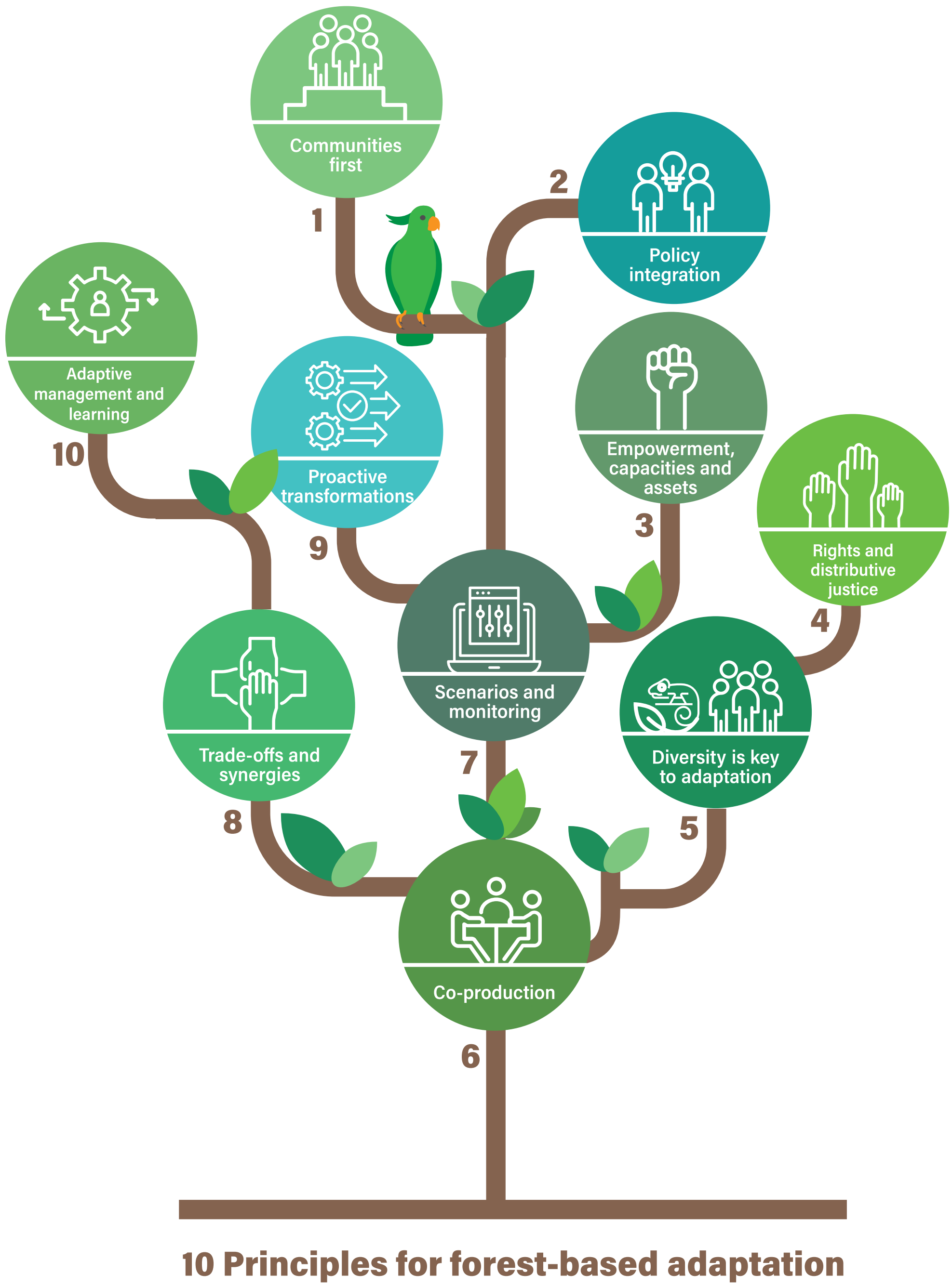
While tropical forests contribute to climate regulation, global climate change is impacting forest ecosystems (Artaxo *et al*., 2022). Primary forests are essential to climate adaptation efforts, but the vulnerability of forest ecosystems to climate change also needs to be considered in climate actions (Forzieri *et al.*, 2022). Recent research indicates that "climate change is enhancing the cooling effect of forests in the short term, underscoring the importance of protecting natural, diverse forest ecosystems in the face of rising global temperatures that threaten ecosystems, human health, and food production" (Smith *et al*., 2023; Verbiest *et al*., 2023).

The Intergovernmental Panel on Climate Change (IPCC) recognises forest-based adaptation as an important strategy for enhancing the adaptive capacity and resilience of people and forests (IPCC 2022b). Forests provide a multitude of ecosystem services that often are hard to quantify and have significant spatial variation. These benefits often go unrecognized and are not centered in policy responses, valued in GHG-centric incentive schemes, or included in evaluations of the costs and benefits of extractive activities versus protecting and restoring forest ecosystems (Keith *et al*., 2021). In addition to the cooling benefits described in the previous section, the biodiversity values of primary forests serve as key "adaptation services", with research describing important synergies with protecting large trees for climate mitigation, biodiversity, and forest resilience goals (Mildrexler *et al*., 2023). The ongoing provision of the quantity and quality of all ecosystem services, including global climate regulation through the retention of carbon stocks, is directly linked to the integrity of forest ecosystems. Activities that result in deforestation and degradation reduce ecosystem carbon stocks exacerbate biodiversity loss, undermining the contribution of forests to both climate mitigation and adaptation.

Primary forests support the synergistic provision of many ecosystem services. These include the biodiversity values that – in addition to supporting carbon retention and climate mitigation – also support forest-proximate communities' opportunities for adaptation. Other ecosystem services supported by primary forests include: microclimate regulation; increased groundwater recharge; improved quality of air and water; sources of genetic material; the provision of non-wood products, including food, livelihoods and medicinal products; habitat maintenance for biodiversity; pollination services; soil quality, erosion control and sediment retention services; flood mitigation; biological control; and aesthetic, recreational, educational, and spiritual services (Dooley *et al*., 2022a; IPCC, 2022b). A major barrier is the lack of recognition of many of these ecosystem services and of standardized methods for their monitoring and valuation in relation to different forest management regimes (Meyfroidt *et al*., 2022).

To address the often overlooked importance of primary forests to adaptation, a recent FAO report delved into the concept of forest-based adaptation and outlined policy domains that could enhance the role of forests and trees in providing adaptation and resilience benefits (Libert-Amico *et al*., 2022). Forest-based adaptation encompasses a suite of climate actions that leverage forests and trees to bolster resilience and adaptation to climate change. This involves practices like sustainable forest management, conservation, restoration, and afforestation, as well as the integration of trees on farms and in cities. This approach bridges the gap between current adaptation efforts and the necessary measures to reduce climate-related risks and impacts. Moreover, it is considered accessible and feasible, aligns with most of the SDGs and synergizes effectively with mitigation strategies (IPCC 2022b). A set of ten principles for employing forests and trees to facilitate transformative adaptation were developed in collaboration with leading experts from organizations like the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) along with other partners (Djoudi *et al.*, 2022) and illustrated by 10 case studies in FAO's report on forest-based adaptation. These principles are presented in Figure 3.

Figure 3. Principles for forest-based adaptation. Adapted from Djoudi *et al.* 2022 and Libert-Amico *et al.* 2022.



Communities first

Society's responses to climate change and adaptation constraints are determined at the local scale across landscapes in which ecosystem processes unfold and stakeholders' interests and objectives interact and compete

Empowerment, capacities and assets

Recognize roles of different stakeholders and include the voices of most vulnerable and marginalized in forest and tree management. Enable empowering structures, institutions and collective decision-making mechanisms on adaptation.

Diversity is key to adaptation

Harness the role of social-ecological diversity in forest and tree systems for nature-based and transformative adaptation

Scenarios and monitoring

Envision future scenarios and adaptation pathways to assess climate-related risks for people, forests and trees, and use them in decision making.

Proactive transformations

Enhance the role of forests and trees to facilitate multiple transformations: the transformation into desired states of ecological systems, of food systems, and of human-nature relationships.

Policy integration

Intersectoral and multilevel approaches can link forest and tree management to other policies that address climate risks (e.g. climate policies, watershed management, carbon projects).

Rights and distributive justice

Promote equitable access to the ecosystem services generated by forests and trees. Protect the rights of Indigenous Peoples, women, youth and others who face structural inequities and barriers to adaptation.

Co-production

Co-produce knowledge of multiple forest and tree systems with diverse stakeholders and knowledge systems, with a special attention to power relations.

Trade-offs and synergies

Understand and manage trade-offs between different ecosystem services and their users. Build on the capacities of forests, trees and people to enhance adaptation and mitigation synergies.

Adaptive management and learning

Promote adaptive learning and enable stakeholders to build open, flexible management processes which allow them to harness the benefits of forests and trees to manage uncertainties and adapt to change.

Several vital lessons emerge from a deeper understanding of forest-based adaptation. Firstly, forest-based adaptation is not only a matter of policy but also a question of governance that necessitates the engagement of all stakeholders through both top-down and bottom-up approaches. Secondly, it is important to address the social determinants of vulnerability, including issues of equity and justice. Additionally, recognizing the interplay between ecological and social diversity offers avenues for transformation, as the well-being of both people and ecosystems are intricately linked. Fourthly, there is a need to anticipate changes due to climate impacts and to grapple with uncertainties and trade-offs within socioecological systems. Lastly, forest-based adaptation calls for a fundamental transformation of relationships across sectors and systems (Libert-Amico *et al.*, 2022).

The contributions of forests and trees towards transformational adaptation hold immense potential and are gradually gaining traction. It is imperative to further integrate forests and trees into national climate policies and planning. The active involvement of local communities in adaptation decision-making is crucial. These measures should be part of a comprehensive strategy to enhance resilience in the face of mounting risks and uncertainties. Climate policy and governance frameworks must recognise the critical adaptation services that derive from forests and trees, as well as supporting the adaptation of forests to warming climates through biodiversity protection and enhancement which supports ecosystem integrity and increased forest resilience (Libert-Amico *et al*., 2022).

EMERGING FINANCE AND POLICY OPPORTUNITIES FOR PROTECTING PRIMARY FORESTS

Adequate and sufficient financing for primary forests remains a significant challenge. Redirecting financial flows that drive deforestation towards sustainable practices is a critical step towards their protection. Financial institutions play a pivotal role in this process. For instance, more than thirty leading financial institutions, collectively managing over US$ 8.7 trillion in assets, have committed to tackle deforestation. These institutions, including Rabobank, Deutsche Bank, ABN Amro, Standard Chartered and BNP Paribas, are leading the way with commodity-specific deforestation policies across all high forest-risk commodities (Climate Champions, 2021). By recognizing and mitigating the risks associated with investments in sectors that contribute to deforestation, financial institutions can redirect funds towards more sustainable practices. This shift in financial flows can serve as an alternative finance source for the protection of forests, focusing less on carbon and more on a broader set of benefits. In fact, innovative applications of financial products at national and regional levels have been observed in support of biodiversity conservation (Cui *et al*., 2022).

Financial institutions are also increasingly adept at appraising, disclosing, and reducing biodiversity-related risks within their lending and investment portfolios. Their strategic funding choices and international cooperation can significantly sway biodiversity outcomes. By integrating environmental concerns into financial decisions, these institutions can influence corporate behaviour, propelling the adoption of sustainable practices that prioritize forest preservation and address deforestation within supply chains. National Biodiversity Finance Plans and other regional instruments could also be pivotal in amplifying conservation efforts, guiding financial flows toward biodiversity-friendly initiatives. Furthermore, the International Finance Corporation provides a structured approach for investors and financiers to identify eligible use of proceeds that constitute biodiversity finance (International Finance Corporation, 2022). In doing so, it is possible to ensure the sustained viability of the Earth's most critical ecosystems, while also promoting a more sustainable and resilient global economy. The commitment of these financial institutions not only contributes to environment protection but also signifies a shift towards a more sustainable financial sector.

Given the fundamental role that Indigenous Peoples play in protecting the ecosystems around the world, concern about the need for environmental and biodiversity protection from corporate investors should also translate into respect for Indigenous Peoples' rights as a core component of sustainable finance (Birss & Sirén Gualinga, 2023). Large-scale public funding is also needed to channel funds most effectively and directly, such as the Indigenous Peoples and Local Communities Forest Tenure Pledge for US$ 1.7 billion over five years that was launched at the UN Climate Change Conference (COP26) in Glasgow, along with the Global Forest Finance Pledge and the Congo Basin Pledge. Initiatives to channel public funding to compensate Indigenous Peoples for the ecosystem services they provide must play an increasing role in forest conservation finance. Funding to strengthen their collective territorial rights, facilitate community forest management and strengthen territorial governance would generate significant climate, biodiversity and livelihood benefits (Sze *et al*., 2022)

In this context, the current voluntary carbon market (VCM) finance presents challenges, especially for countries with large areas of primary forests, which are largely excluded from the market due to concerns over environmental integrity (i.e. that carbon credits represent verifiable emission reductions). Forest carbon credits present a dichotomy: they preserve non-climate benefits but can potentially undermine the climate benefits of forest carbon by allowing fossil carbon in the atmosphere (Seymour *et al*., 2022). Additionality is a key criterion for environmental integrity, and much of the recent critique of the VCM has centred on non-additional crediting, such as over-estimation of baselines and absence of deforestation threats (Haya *et al*., 2023). This has led to a decline in VCM transactions, partly due to concerns about reputational risk from corporate buyers wary of greenwashing accusations (Seymour *et al*., 2022). Additionality tests, which are largely based on historical average baselines of deforestation rates, would exclude credits from high forest jurisdictions. Permanence of forest carbon sinks in comparison to fossil sources and risk of reversal is also a concern given increasing threats of wildfires and other major disturbances. One proposed solution to address some of these environmental integrity risks is jurisdictional-scale crediting, which involves crediting forest-based emissions and reductions over large areas, such as entire countries or large states and provinces (Seymour *et al*., 2022). However, this approach is still being explored and developed, and prices for carbon remain too low to cover all the associated costs, being more a complement rather than the main driver of change in many cases. To move beyond these fundamental challenges, it's important to consider non-carbon crediting financial and policy mechanisms that more directly incentivise the non-carbon mitigation and important adaptation benefits of forests. Many countries are supportive of moving beyond carbon markets to finance forest and biodiversity conservation.

Several alternative finance sources for the protection of primary forests based on non-carbon benefits are gaining traction. These include:

- Emerging finance and policy opportunities for protecting primary forests are gaining momentum, particularly in the Asia-Pacific region, where innovative strategies are being deployed to support Integrated Landscape Management. Private sector engagement through **producer-public-private partnerships** presents a promising avenue, especially involving businesses in the agricultural, forestry, and extractive sectors. By actively participating in conservation efforts within buffer zones and larger landscapes, the private sector can promote sustainable practices while leveraging their technical expertise and innovative capabilities. This synergy not only mitigates adverse impacts on forests but also advances strategic conservation initiatives.
- The concept of **bundling and stacking of multiple ecosystem services** is a powerful alternative financing mechanism for the protection of primary and intact forest landscapes with numerous examples to build upon. The Green Climate Fund (GCF) is now reflecting this approach, going beyond the limitations of traditional carbon-centric models. This method, which involves bundling various ecosystem services, aims to optimize financial flows that mirror the multifaceted roles forests play. These roles range from carbon sequestration to biodiversity enhancement, water regulation, and cultural heritage preservation. Importantly, the GCF's 2022 guides on Ecosystem and Ecosystem Services (GCF, 2022a) and Forests and Land Use (GCF, 2022b) promote financial instruments that align with the inherent value of ecosystems, thereby strengthening efforts to maintain forest integrity and quality. This progressive financing strategy fosters a more sophisticated understanding of forest ecosystems, recognizing their extensive non-carbon benefits. In doing so, it aligns with the vision of directing financial incentives that reflect the comprehensive ecological value of these habitats. The initiative not only strengthens conservation efforts and climate resilience but also establishes a solid incentive structure for

communities and stakeholders on the front lines of forest management. By capitalizing on such a thorough valuation and investment in ecosystem services, the GCF aims to reinforce sustainable development paradigms and climate adaptation measures.

- **Domestic finance sources** can serve as an alternative finance source for the protection of primary and intact forests based on non-carbon benefits. These sources, which include public and private sector investments, can be directed towards sustainable agricultural practices that not only ensure food security but also contribute to forest conservation. By integrating conservation goals into agricultural financing, farmers can be incentivized to adopt practices that reduce deforestation and forest degradation. Furthermore, financial instruments such as green bonds and impact investments can mobilize domestic capital for conservation initiatives. These alternative finance mechanisms, when coupled with strong governance structures and policy frameworks, can play a pivotal role in preserving intact forests while supporting sustainable agricultural development. Green bonds and green banking can channel investments toward environmentally-friendly activities and discourage deforestation by incentivizing sustainable financing and penalizing unsustainable practices (Hermawan & Khoirunisa, 2023). Ecological fiscal transfers are another important instrument (Busch *et al*., 2021).
- **Payments for ecosystem services** can provide incentives for forest conservation and sustainable land use practices through beneficiaries of ecosystem services making a direct or indirect payment to a provider of those services. By monetizing the carbon and non-carbon benefits of forests, such as biodiversity conservation and watershed protection, mitigation contributions they can serve as an alternative finance source for the protection of primary forests based on non-carbon benefits. At the UN Climate Change Conference (COP28) in Dubai, Brazil announced the Tropical Forests Forever Facility, which aims to mobilize US$ 250 Billion to create a global payment mechanism that rewards landholders for forest area (ha) protected or restored – particularly incentivizing forest conservation with a substantial deduction in payment for any ha deforested[5].
- An **Ecosystem Services Tax** can be a viable alternative finance source for the protection of primary forests based on non-carbon benefits. This tax, levied on activities that degrade ecosystem services, generates revenue that can be reinvested in forest conservation. By taxing the negative externalities produced by certain economic activities, we can create a financial disincentive for behaviours that lead to forest degradation. The revenue generated from this tax can be used to fund initiatives that protect and restore forests, promote sustainable land use practices, and support communities that rely on these ecosystems for their livelihoods. This approach aligns economic incentives with conservation goals, promoting the preservation of forests for their myriad non-carbon benefits, such as biodiversity, water filtration, and soil erosion control and stability of hydrological cycles.
- **Debt justice** can be a powerful alternative finance source for the protection of biodiversity, including primary forests based on non-carbon benefits (Dempsey *et al*., 2021). Debt justice involves the restructuring or forgiveness of debt under the condition that debtor nations invest in sustainable practices, including forest conservation. This approach, often referred to as **debt-for-nature swaps**, allows indebted countries to relieve some of their financial burdens while simultaneously investing in the protection of their natural resources. The funds freed up through this process can be directed towards the preservation of primary and intact forests, recognizing their non-carbon benefits such as biodiversity, watershed protection, and the provision of livelihoods for local communities. This not only promotes environmental sustainability

5 https://news.mongabay.com/2024/03/how-to-reward-tropical-forest-conservation-interview-with-tasso-azevedo/

but also contributes to economic stability and social equity.

- **Trade mechanisms**, such as the EU Due Diligence Regulation and the Green Trade Facilitation Programme (TFP), are also being explored, although their effectiveness can vary greatly depending on the specific context and conditions. It's important to note that the dynamic nature of environmental finance and policy necessitates ongoing evaluation and adaptation to ensure that strategies remain relevant and effective.
- Exploration of emerging finance and policy opportunities for protecting intact forests highlights the critical nature of collaboration between international bodies and the **implementation of integrated programmes**. An example of such collaborative efforts is evident within the Indo-Malaya region, where initiatives from the Global Environment Facility (GEF), the International Union for Conservation of Nature (IUCN), and FAO unite to protect and sustainably manage primary forests. This joint initiative is not only a response to the immediate threats these forests face but also a proactive step towards sustainable management. Box 1 provides an overview of the Indo-Malaya Critical Forest Biome Integrated Programme (CFB IP) and its strategic approach to conservation in the region.

Notwithstanding the appeal surrounding "innovative" financing instruments, financing for what often amounts to sustainable rural development still faces some of the more conventional challenges, particularly given that grants alone are unlikely to be sufficient to finance long term conservation. Loans, guarantees and risk capital from both public and private sources will likely be needed. However, barriers remain, such as limited portfolios of financeable projects ready at the local level, along with undeveloped local financial markets and financial experience in forested areas, leading to higher cost and risk of operation (GCF, 2022a). There are limited options for communities or individuals to offer collaterals for loans, especially if tenure is not secure. Another major barrier is limited options to leverage upfront financing on the basis of potential future return from climate finance (e.g. results-based finance) (GCF, 2022a). Rural communities, local government and even countries often have limited capacity to absorb such upfront costs. Incentivising ongoing forest protection will require sufficient total economic return at a local level, which in turn will require effectively *blending* a number of economic flows, all of which of this must happen at a sufficiently low transaction cost to be feasible.

Box 1.

Indo-Malaya Critical Forest Biome Integrated Programme (IM CFB IP)

To conserve the primary forests of the Indo-Malayan biome, the Global Environment Facility (GEF) has initiated the Indo-Malaya Critical Forest Biome Integrated Programme (IM CFB IP), co-led by IUCN and FAO. This programme is vital due to the unique biodiversity, significant carbon storage, and essential ecosystem services these forests offer, influencing climate stability, and providing indispensable services to over 50 million people, many of whom belong to indigenous and local communities. However, these irreplaceable forests face severe threats, with more than 17 million ha having been lost in the past two decades primarily due to agricultural expansion, mining, infrastructure development, and illegal and unsustainable logging. The programme is currently under final stages of formulation and expected to enter operationalization by early 2025. For the current GEF8 cycle, three countries submitted proposals to engage: Lao PDR, Papua New Guinea, and Thailand, targeting key critical landscapes for conservation efforts.

The programme will improve management of primary forests by reinforcing effective and inclusive conservation and sustainable use inside and outside protected areas, including Other Effective Area-Based Conservation Measures, which are critical for connecting and buffering production landscapes. With the majority of remaining primary forests in the Indo-Malaya biome located outside protected areas, actions there are of particular importance. To achieve these objectives, it also encourages the development of integrated land-use plans and stronger governance, alongside law enforcement to combat illegal activities.

With an emphasis on a programmatic approach, the IM CFB IP aims to establish a clear vision for primary forest conservation in the region and to mobilize additional finance from private and philanthropic sectors to augment the impact of GEF funding.

Additionally, the program plans to launch a regional platform for knowledge sharing and learning involving annual conferences to promote South-South learning and capacity building. The regional coordination project will support all child projects to ensure they are coherent, well-coordinated, and adaptively managed, aligning with relevant external platforms and initiatives.

The IP is more than a conservation initiative; it embodies a comprehensive strategy committed to securing the long-term sustainability of the Indo-Malaya forests. This program significantly contributes to Target 3 of the Kunming-Montreal Global Biodiversity Framework, as well as others, in preserving biodiversity, addressing climate change, and promoting the well-being of human populations.

Source: FAO & IUCN, 2023.

CONCLUSIONS

This technical brief has outlined the critical significance of primary forests for climate mitigation and adaptation, and biodiversity conservation. Not all forests are equal: the benefits they provide vary according to their ecosystem condition. Primary forests with high ecological integrity are: more resilient in the face of climate change and other external stressors; more effective at providing essential ecosystem services such as water filtration and hydrological regulation; provide greater support for local communities' opportunities for adaptation. The rights of forest communities must be recognised, particularly the specific bundle of rights of Indigenous Peoples, and the role they play as stewards of forest and ecosystem integrity must be supported and included in financial investment decisions. Primary forests often fall outside of carbon-centric accounting and financing schemes, and so it is imperative that a broader range of innovative financing sources is leveraged, including direct public funds, redirection of harmful investments and subsidies, and private investment. The unique characteristics of forests with high ecological integrity can be built on to leverage finance. In particular, the key importance of the ecosystem services provided by forests in support of sustainable agrifood systems can help rationalize and structure incentives and investment. In practice, the effective conservation of primary forests will require integrated approaches at the landscape level that can help manage trade-offs and boost synergies in food production, climate action and biodiversity conservation.

REFERENCES

Artaxo, P., Hansson, H. C., Machado, L. A. T. & Rizzo, L. V. 2022. Tropical forests are crucial in regulating the climate on Earth. *PLOS Climate*, 1(8): e0000054. https://doi.org/10.1371/journal.pclm.0000054

Barber, C. V., Peterson, R., Young, V., Mackey, B. & Kormos, C. 2020. *The nexus report: nature based solutions to the biodiversity and climate crisis*. Hamburg, Germany, F20 Foundations, Campaign for Nature and SEE Foundation. https://foundations-20.org/wp-content/uploads/2022/07/The-Nexus-Report.pdf

Birss, M. & Sirén Gualinga, E. 2022. Without indigenous rights, sustainable finance isn't sustainable: the financial risks of the lack of corporate indigenous rights due diligence. *SSRN Preprint*. http://dx.doi.org/10.2139/ssrn.4265006

Blackman, A. & Veit, P. 2018. Titled Amazon Indigenous communities cut forest carbon emissions. *Ecological Economics*, 153: 56–67. https://doi.org/10.1016/j.ecolecon.2018.06.016

Bulusu, M., Ellsäßer, F., Stiegler, C., Ahongshangbam, J., Marques, I., Hendrayanto, H., Röll, A. & Hölscher, D. 2023. UAV-based thermography reveals spatial and temporal variability of evapotranspiration from a tropical rainforest. *Frontiers in Forests and Global Change*, 6: 1232410. https://doi.org/10.3389/ffgc.2023.1232410

Busch, J., Ring, I., Akullo, M., Amarjargal, O., Borie, M., Cassola, R. S., Cruz-Trinidad, A. *et al*. 2021. A global review of ecological fiscal transfers. *Nature Sustainability*, 4(9): 756–765. https://doi.org/10.1038/s41893-021-00728-0

CBD (Convention on Biological Diversity). 2010. *Forest Biodiversity Definitions*. Montreal, Canada, Convention on Biological Diversity. https://www.cbd.int/forest/definitions.shtml

Cook-Patton, S. C., Drever, C. R., Griscom, B. W., Hamrick, K., Hardman, H., Kroeger, T., Pacheco, P. *et al*. 2021. Protect, manage and then restore lands for climate mitigation. *Nature Climate Change*, 11(12): 1027–1034. https://doi.org/10.1038/s41558-021-01198-0

Dempsey, J., Irvine-Broque, A., Bigger, P., Christiansen, J., Muchhala, B., Nelson, S., Rojas-Marchini, F., Shapiro-Garza, E., Schuldt, A. & DiSilvestro, A. 2021. Biodiversity targets will not be met without debt and tax justice. *Nature Ecology & Evolution*, 6(3): 237–239. https://doi.org/10.1038/s41559-021-01619-5

Ding, H., Veit, P. G., Blackman, A., Gray, E., Reytar, K., Alatamirano, J. C. & Hodgdon, B. 2016. *Climate benefits, tenure costs: the economic case for securing indigenous land rights in the Amazon*. Washington D.C., World Resources Institute. https://www.wri.org/research/climate-benefits-tenure-costs

Djoudi, H., Dooley, K., Duchelle, A., Libert-Amico, A., Locatelli, B., Balinga, M.B., Brockhaus, M. *et al*. 2022. Leveraging the power of forests and trees for adaptation. *SSRN Preprint*. https://doi.org/10.2139/ssrn.4268299

Dooley, K., Keith, H., Larson, A., Catacora-Vargas, G., Carton, W., Christiansen, K. L., Eno-

kenwa Baa, O. *et al*. 2022a. *The Land Gap Report*. Melbourne, Australia, Melbourne Climate Futures. https://landgap.org/

Dooley, K., Zebedee, N. & Malte, M. 2022b. Carbon removals from nature restoration are no substitute for steep emission reductions. *One Earth*, 14. https://doi.org/10.1016/j.oneear.2022.06.002

Fa, J. E., Watson, J. E., Leiper, I., Potapov, P., Evans, T. D., Burgess, N. D., Molnár, Z. *et al*. 2020. Importance of Indigenous Peoples' lands for the conservation of Intact Forest Landscapes. *Frontiers in Ecology and the Environment*, 18(3): 135–140. https://doi.org/10.1002/fee.2148

FAO. 2020a. *Global Forest Resources Assessment 2020*. Rome, FAO. https://doi.org/10.4060/ca9825en

FAO. 2020b. *The State of the World's Forests 2020*. Rome, FAO and UNEP. https://doi.org/10.4060/ca8642en

FAO. 2023. Terms and definitions - FRA 2025. Forest Resources Assessment (FRA) Working Paper 194. Rome, FAO. https://www.fao.org/3/cc4691en/cc4691en.pdf

FAO & IUCN. 2023. *GEF-8 Indo-Malaya Critical Forest Biome Integrated Program*. Rome, FAO.

Forzieri, G., Dakos, V., McDowell, N. G., Ramdane, A., & Cescatti, A. 2022. Emerging signals of declining forest resilience under climate change. *Nature*, 608(7923): 534–539. https://doi.org/10.1038/s41586-022-04959-9

Garnett, S. T., Burgess, N. D., Fa, J. E., Fernández-Llamazares, Á., Molnár, Z., Robinson, C. J., Watson, J. E. M. *et al*. 2018. A spatial overview of the global importance of Indigenous lands for conservation. *Nature Sustainability*, 1(7): 369–374. https://doi.org/10.1038/s41893-018-0100-6

GCF. 2022a. *Ecosystems and ecosystem services sectoral guide* (Sectoral Guide Consultation Version 1). Incheon, Republic of Korea, Green Climate Fund. https://www.greenclimate.fund/document/sectoral-guide-ecosystems-and-ecosystem-services

GCF. 2022b. *Forests and land use sectoral guide* (Sectoral Guide Consultation Version 1). Incheon, Republic of Korea, Green Climate Fund. https://www.greenclimate.fund/document/sectoral-guide-forests-and-land-use

Ge, J., Huang, X., Zan, B., Qiu, B., Cao, Y. & Guo, W. 2023. Local surface cooling from afforestation amplified by lower aerosol pollution. *Nature Geoscience*, 16(9): 781–788. https://doi.org/10.1038/s41561-023-01251-x

Hasler, N., Williams, C., Denney, V. C., Ellis, P.W., Shrestha, S., Terasaki Hart, D.E., Wolff, N. *et al*. 2024. Accounting for albedo to identify climate positive tree cover restoration. Nature Communications, 15: 2275. https://doi.org/10.1038/s41467-024-46577-1

Haya, B. K., Alford-Jones, K., Anderegg, W. R. L., Beymer-Farris, B., Blanchard, L., Bomfim, B., Chin, D. *et al*. 2023. *Quality Assessment of REDD+ Carbon Credit Projects*. Berkeley, USA, Berkeley Carbon Trading Project. https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/berkeley-carbontrading-project/REDD+

Hermawan, S. & Khoirunisa, Z. A. 2023. The emergence of green banking: A sustainable financing strategy for protecting against deforestation in ASEAN. *The Journal of Environment & Development*, 10704965231211591. https://doi.org/10.1177/10704965231211591

INTACT. 2020. *Forest Carbon Factsheet*. International Action for Primary Forests. https://primaryforest.org/wp-content/uploads/2015/12/ForestCarbonFactsheet_26112015.pdf

IPCC. 2022a. Summary for Policymakers. In *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK, Cambridge University Press.

IPCC. 2022b. Summary for Policymakers. In *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK, Cambridge University Press.

Keith, H., Vardon, M., Obst, C., Young, V., Houghton, R. A. & Mackey, B. 2021. Evaluating nature-based solutions for climate mitigation and conservation requires comprehensive carbon accounting. *Science of The Total Environment*, 769: 144341. https://doi.org/10.1016/j.scitotenv.2020.144341

Kormos, C. 2018. Primary Forest: definition, status and future prospects for global conservation. In *Reference Module in Earth Systems and Environmental Sciences*. Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.09711-6

Lawrence, D., Coe, M., Walker, W., Verchot, L. & Vandecar, K. 2022. The Unseen Effects of Deforestation: Biophysical Effects on Climate. *Frontiers in Forests and Global Change*, 5: 756115. https://doi.org/10.3389/ffgc.2022.756115

Li, Y., Li, Z.-L., Wu, H., Zhou, C., Liu, X., Leng, P., Yang, P. *et al*. 2023. Biophysical impacts of earth greening can substantially mitigate regional land surface temperature warming. *Nature Communications*, 14(1): 121. https://doi.org/10.1038/s41467-023-35799-4

Libert-Amico, A., Duchelle, A., Cobb, A., Peccoud, V. & Djoudi, H. 2022. *Forest-based adaptation: Transformational adaptation through forests and trees*. Rome, FAO. https://doi.org/10.4060/cc2886en

Mackey, B. 2020. Understanding the importance of primary tropical forest protection as a mitigation strategy, Mitigation and Adaptation Strategies for Global Change, 25: 763–787. https://doi.org/10.1007/s11027-019-09891-4

Mather, A. S. 1992. The Forest Transition. *Area*, 24(4): 367–379. https://www.jstor.org/stable/20003181

Meyfroidt, P., de Bremond, A., Ryan, C. M., Archer, E., Aspinall, R., Chhabra, A., Camara, G. *et al*. 2022. Ten facts about land systems for sustainability. *Proceedings of the National Academy of Sciences*, 119(7): e2109217118. https://doi.org/10.1073/pnas.2109217118

Mildrexler, D. J., Berner, L. T., Law, B. E., Birdsey, R. A. & Moomaw, W. R. 2023. Protect large trees for climate mitigation, biodiversity, and forest resilience. *Conservation Science and Practice*, 5(7): e12944. https://doi.org/10.1111/csp2.12944

Ricketts, T.H., Soares-Filho, B., da Fonseca, G.A.B., Nepstad, D., Pfaff, A., Petsonk, A., Ander-

son, A. *et al*. 2010. Indigenous Lands, Protected Areas, and Slowing Climate Change. *PLOS Biology* 8(3): e1000331. https://doi.org/10.1371/journal.pbio.1000331

Rights and Resources Initiative. 2015. *Who Owns the World's Land? A global baseline of formally recognized indigenous and community land rights*. Washington D.C., Rights and Resources Initiative. http://rightsandresources.org/wp-content/uploads/GlobalBaseline_complete_web.pdf

Rights and Resources Initiative. 2018. *A Global Baseline of Carbon Storage in Collective Lands: Indigenous and local community contributions to climate action*. Washington D.C. Rights and Resources Initiative. https://rightsandresources.org/wp-content/uploads/2018/09/A-Global-Baseline_RRI_Sept-2018.pdf

Rights and Resources Initiative. 2020. *Rights-based conservation: The path to preserving Earth's biological and cultural diversity?* Washington D.C. Rights and Resources Initiative. https://doi.org/10.53892/ZIKJ2998

Rogers, B. M., Mackey, B., Shestakova, T. A., Keith, H., Young, V., Kormos, C. F., DellaSala, D. A. *et al*. 2022. Using ecosystem integrity to maximize climate mitigation and minimize risk in international forest policy. *Frontiers in Forests and Global Change*, 5: 929281. https://doi.org/10.3389/ffgc.2022.929281

Seidl, R., Honkaniemi, J., Aakala, T., Aleinikov, A., Angelstam, P., Bouchard, M., Boulanger, Y. *et al*. 2020. Globally consistent climate sensitivity of natural disturbances across boreal and temperate forest ecosystems. *Ecography*, 43(7): 967–978. https://doi.org/10.1111/ecog.04995

Seymour, F., Wolosin, M. & Gray, E. 2022. *Not Just Carbon: Capturing All the Benefits of Forests for Stabilizing the Climate from Local to Global Scales*. Washington D.C. World Resources Institute. https://doi.org/10.46830/wrirpt.19.00004

Smith, C., Baker, J. C. A. & Spracklen, D. V. 2023. Tropical deforestation causes large reductions in observed precipitation. *Nature*, 615(7951): 270–275. https://doi.org/10.1038/s41586-022-05690-1

Su, Y., Zhang, C., Ciais, P., Zeng, Z., Cescatti, A., Shang, J., Chen, J. M. *et al*. 2023. Asymmetric influence of forest cover gain and loss on land surface temperature. *Nature Climate Change*, 13(8): 823–831. https://doi.org/10.1038/s41558-023-01757-7

Sze, J. S., Childs, D. Z., Carrasco, L. R. & Edwards, D. P. 2022. Indigenous lands in protected areas have high forest integrity across the tropics. *Current Biology*, 32(22): 4949-4956.e3. https://doi.org/10.1016/j.cub.2022.09.040

Tauli-Corpuz, V., Alcorn, J. & Molnar, A. 2018. *Cornered by Protected Areas*. Washington D.C. Rights and Resources Initiative. https://www.corneredbypas.com/

Townsend, J., Moola, F. & Craig, M.-K. 2020. Indigenous Peoples are critical to the success of nature-based solutions to climate change. *FACETS*, 5(1): 551–556. https://doi.org/10.1139/facets-2019-0058

Verbiest, W. W. M., Smith, G. R., Mirzagholi, L., Lauber, T., Zohner, C. M., Maynard, D. S., Schemm, S. & Crowther, T. W. 2024. Enhanced local cooling effects of forests across the globe [Preprint]. https://doi.org/10.1101/2023.10.17.562656

Wang, G., Mang, S. L., Riehl, B., Huang, J., Wang, G., Xu, L., Huang, K. & Innes, J. 2019. Climate change impacts and forest adaptation in the Asia–Pacific region: From regional experts' perspectives. *Journal of Forestry Research*, 30(1): 277–293. https://doi.org/10.1007/s11676-018-0827-y

Watson, Evans, T., Venter, O., Williams, B., Tulloch, A., Stewart, C., Thompson, I. *et al*. 2018. The exceptional value of intact forest ecosystems. *Nature Ecology & Evolution*, 2(4): 599–610. https://doi.org/10.1038/s41559-018-0490-x

Wolosin, M. & Harris, N. 2018. *Tropical forests and climate change: the latest science*. Washington, D.C., World Resources Institute. https://www.wri.org/research/ending-tropical-deforestation-tropical-forests-and-climate-change-latest-science

Zeng, Z., Wang, D., Yang, L., Wu, J., Ziegler, A. D., Liu, M., Ciais, P. *et al*. 2021. Deforestation-induced warming over tropical mountain regions regulated by elevation. *Nature Geoscience*, 14(1): 23–29. https://doi.org/10.1038/s41561-020-00666-0

For more information, please contact:

Forestry Division – Natural Resources and Sustainable Production
FO-Publications@fao.org
www.fao.org/forestry/en

Food and Agriculture Organization of the United Nations
Rome, Italy

CD1733EN/1/07.24