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COP30 Presidency Roadmap to Halting and Reversing Deforestation and Forest Degradation by 2030

Abstract: Incorporating a broad range of contributions from Parties, indigenous peoples, local communities, academia, actors in the Action Agenda and other stakeholders, the *Roadmap for Halting and Reversing Deforestation and Forest Degradation by 2030* is a proposal by the COP 30 Presidency aimed at implementing paragraphs 33 and 34 of the first Global Stocktake of the Paris Agreement. It is an action-oriented document that offers guidance for the achievement of these goals; identifies existing means of implementation and solutions being accelerated in the Action Agenda; and highlights obstacles and gaps to be addressed. It also showcases policies and measures that have been successfully implemented in real situations and can be replicated in other contexts.

Executive Summary

A concise, political overview linking GST paragraphs 33 and 34 to concrete national action, international cooperation, and measurable results toward 2030.

Despite recent political commitments, the world remains far from a trajectory compatible with ending forest loss and degradation by 2030, while public and private incentives still favor conversion and the erosion of forest functional quality over conservation. Forests should be viewed not only as carbon stocks but as critical systems whose integrity stabilizes rainfall, temperature, water flows, food production, and provides energy security. This makes their protection central to climate resilience and economic stability (Lawrence et al., 2022). The Roadmap should therefore focus on a few high-impact actions: stopping conversion, preventing and reducing forest degradation, especially fire-driven degradation, securing land rights and direct finance for Indigenous Peoples and local communities, aligning trade and financial systems with forest goals, and strengthening coordination across institutions and international frameworks and conventions.

Part I – Why Halting and Reversing Deforestation and Forest Degradation Is Central to the Paris Agreement

1. **Paris Agreement, UNFCCC and other International Commitments**

GST1 § 33-34; PA Article 5; REDD+; COP Presidency's role in enabling implementation; Pact for the Future (UNGA 2024); CBD Kunming-Montreal; UNCCD LDN; UNFF; FAO Roadmap; Inter-American Human Rights Court Advisory Opinion 32/25.

The implementation challenge under the Paris Agreement is not the absence of mandates, but fragmentation across existing mandates and workstreams. Forests and ecosystems are addressed through disconnected tracks under the UNFCCC and beyond it, including mitigation, adaptation, agriculture, finance, NDC guidance, Article 6, and just transition, without a clear mechanism to align them toward halting and reversing deforestation and forest degradation. To overcome this fragmentation, the Roadmap should define a structured implementation architecture that connects existing mandates through a common coordination platform. This could be operationalized through a Joint Work Programme across the UNFCCC and the other Rio Conventions, with a clear mandate to align policies, finance, and reporting systems related to forests. At the national level, this would require the integration of forest-related objectives across NDCs, NAPs, and biodiversity strategies, supported by interoperable science-based monitoring systems and coordinated financial mechanisms. A central limitation in current climate governance is the incomplete accounting of forest degradation and fire-related emissions. The roadmap can address gaps to strengthen MRV systems, accounting for fire-induced degradation, while building on the Integrated Fire Management and Wildfire Resilience Call to Action endorsed at the Leaders' summit prior to COP30.

2. **Environmental and Scientific Aspects**

Climate stability; biodiversity conservation; ecosystem integrity; water cycle.

Forests are indispensable to climate regulation, biodiversity persistence, ecosystem integrity, and hydrological stability. Where deforestation, drought, degradation, and fire interact, they can create reinforcing feedback that weakens resilience and increases the risk of large-scale ecological tipping (Brando et al 2019). The scientific case extends beyond carbon: forests shape local and regional climate by moderating heat extremes, recycling moisture, and supporting rainfall generation across large areas (Larence et al 2022). Degradation caused by recurrent fire remains insufficiently reflected in climate governance, even though unmanaged burning can continue emissions, reduce biodiversity, and erode ecosystem functions, even where outright deforestation slows. At the same time, restoration plays a critical role in reversing these trends by recovering ecosystem services and enhancing carbon uptake, mainly when aligned with landscape-scale priority areas. The next step is to translate science into governance and implementation requirements, scaling up existing initiatives (described in the Illustrative cases sections).

To reflect the full climate and ecosystem role of forests, the Roadmap should require that forest-related policies, monitoring systems, and finance mechanisms go beyond carbon accounting to explicitly incorporate non-carbon functions, including rainfall regulation, temperature moderation, and hydrological stability. This includes strengthening MRV systems to capture forest degradation, particularly fire-driven degradation, and integrating these dimensions into national inventories, climate reporting, and results-based finance, while also tracking restoration outcomes and ecosystem recovery. In parallel, countries should adopt Integrated Fire Management approaches that combine coordinated governance and international cooperation, with prevention, early-warning, response, and community-based stewardship, ensuring that fire is addressed as a systemic driver of degradation rather than a residual risk, and that restoration investments are safeguarded against increasing fire risk.

3. **Socioeconomic Aspects**

Sustainable development; indigenous peoples; local communities; livelihoods; food security; poverty eradication; equity.

Allowing forest loss and degradation to continue creates avoidable systemic risk, because current economic and financial systems still fail to price the full value

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of standing forests. Standing forests support productive systems by stabilizing rainfall, reducing thermal stress, sustaining soil moisture, and helping maintain water and energy security, including for hydropower-dependent regions. When these forest functions are ignored, the result is higher exposure to crop losses, increased energy demand, public-health burdens, and weaker long-term resilience for economies and livelihoods. To correct this systemic mispricing, the Roadmap should promote the integration of forest-related risks and dependencies into financial, fiscal, and planning systems. This includes requiring companies, financial institutions, and insurers to assess and disclose their exposure to deforestation and degradation risks;aligning public investment decisions, subsidies, and development strategies with forest protection and restoration goals ; and aligning development planning with the role of forests in sustaining water, energy, and agricultural systems. In addition, IPLCs must be recognized as central actors in the implementation, with secure land tenure rights, direct access to finance and participation in the decision-making process. In parallel, strengthening data and monitoring systems to capture the economic value of forest ecosystem functions will be essential to support better decision-making and more efficient allocation of capital.

Part II – What Countries Can and Should Do

4. Deforestation: Drivers and Solutions

• Diagnosis, barriers, and data;

The diagnosis of deforestation differs systematically across the world's major forest regions because the dominant forms of forest loss, the permanence of land conversion, and the data challenges involved in detecting them vary by biome. At the broadest level, the literature shows that deforestation is still concentrated disproportionally in the tropics, where permanent conversion to agriculture remains the dominant mechanism of forest loss, whereas in temperate and boreal regions the analytical challenge more often lies in distinguishing permanent conversion from timber harvest, fire, shifting disturbance regimes, and transitions involving sparse or fragmented forest cover (Pendrill et al., 2022; Feure et al., 2025; Neumann et al., 2025). This means that a diagnosis cannot rely on a single global narrative or a single forest dataset, but must differentiate among humid tropical, seasonal tropical, subtropical, temperate and boreal systems.

Diagnosis and Barriers: In *tropical rainforests and subtropical humid forests*, the diagnosis is one of high and often spatially concentrated deforestation pressure associated with frontier expansion, commodity production, and permanent land-use change. These forests account for a disproportionate share of global forest-loss impacts because they combine high carbon density, strong hydrological functions, and extensive exposure to agricultural expansion (Cusack et al., 2016; Pendrill et al., 2022). The dominant direct drivers are commercial agriculture and livestock, frequently coupled with road building, logging, mining, and tenure-related processes that make forest conversion profitable and enforceable on the ground (Pendrill et al., 2022; Feurer et al., 2025). In these humid systems, the key data challenge is not only to detect canopy loss, but to distinguish permanent deforestation from degradation, temporary canopy removal, or plantation turnover. Peer-reviewed work has shown that this requires combining annual forest-loss products with datasets that differentiate natural forests from plantations and other tree-covered land uses, since tree-cover maps alone can

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misclassify forest conversion and thereby distort both policy targeting and compliance assessments (Neumann et al., 2025). For these regions, the most relevant data architecture therefore combines spatially explicit forest-loss detection, commodity-attribution layers, carbon-stock estimates, and land-tenure or infrastructure information to identify where permanent conversion is taking place and which supply chains are involved (De Sy et al., 2019; Neumann et al., 2025).

For *tropical moist deciduous forests, tropical dry forests, and subtropical dry forests* the diagnosis is more strongly shaped by seasonality, lower canopy closure, recurrent fire, and mixed land-use mosaics. In these systems, deforestation often coexists with degradation, woodland thinning, and repeated disturbance, which makes the boundary between forest loss and chronic structural decline harder to define than in dense humid forests. The literature indicates that these forests are often exposed to a combination of smallholder agriculture, grazing expansion, fuelwood extraction, charcoal production, and increasingly commercial agricultural encroachment, with pressures intensified by drought and fire interactions (Allen et al., 2017; David et al., 2022; Feurer et al., 2025). Recent work on tropical and subtropical dry woodlands further shows that loss is concentrated disproportionately in areas already exposed to agricultural conversion and other human pressures, underscoring that dry forests are neither marginal nor low-priority in the deforestation agenda (Keenan et al., 2023). In these regions, data limitations are particularly severe because dry and seasonal forests are harder to monitor with conventional optical remote sensing: canopy phenology, lower biomass, deciduousness, and mixed woodland structures increase classification error and can cause underestimation of both forest extent and forest loss (David et al., 2022). For that reason, the peer-reviewed literature recommends combining optical and radar remote sensing, seasonally appropriate baselines, and locally calibrated forest definitions to distinguish true deforestation from temporary canopy fluctuation or long-term degradation processes (David et al., 2022). In practical terms, diagnosis in these regions depends on integrating land-cover change, fire occurrence, dry-season vegetation dynamics, and land-use context, rather than relying on generic humid-forest detection methods.

In *temperate oceanic forests and temperate continental forests*, the diagnosis of deforestation is different from the others. These regions are not generally the global center of ongoing frontier deforestation, but they still experience important forms of permanent forest loss, fragmentation, and biome contraction associated with agriculture, urbanization, infrastructure, and long-term land-use change. In temperate rainforests specifically, recent peer-reviewed analysis has shown that land use and climate change have already caused major biome reduction and fragmentation, demonstrating that deforestation in these systems should not be treated as a historical problem alone (Silver et al., 2024). In broader temperate settings, the direct drivers of permanent forest loss are often more diffuse than in tropical commodity frontiers and may include agricultural expansion, peri-urban development, transport infrastructure, and conversion associated with long-settled landscapes. The data problem in temperate systems is therefore not only one of detection, but one of attribution: analysts must separate deforestation as permanent conversion from routine timber harvest cycles, secondary regrowth, and other management-related canopy changes. This is precisely why biome-aware monitoring systems and natural-forest baselines are necessary; without them, harvested plantations or rotation forestry can be confused with deforestation of natural forests, producing misleading estimates of loss and misdirected regulatory responses (Neumann et al., 2025). For temperate oceanic and continental forests, the most useful data streams therefore include

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forest-type maps, land-use conversion records, fragmentation metrics, and high-resolution time series capable of distinguishing conversion from harvest and recovery.

The diagnosis for *boreal coniferous forests and boreal tundra woodland* must also be treated separately from both tropical and temperate regions because these systems combine very large forest extents with lower population density, strong climate sensitivity, and extensive disturbance regimes. In core boreal forests, permanent deforestation is often less spatially dominant than in tropical frontiers, but it still occurs through agricultural expansion at the southern fringe, logging-associated land-use change, energy and mineral development, roads, and settlement expansion in previously remote areas (Girardin et al., 2024). In boreal tundra woodland and other ecotonal systems, the diagnosis is even more complicated because forest cover is naturally sparse, patchy, and transitional, making it difficult to distinguish deforestation from climate-driven shifts in vegetation structure, fire effects, or wetland dynamics. Peer-reviewed work on the prairie–forest ecotone highlights the importance of wildfire, human land use, oil and gas activity, and agricultural development as interacting pressures in these northern transition zones (Girardin et al., 2024). Here again, the main data issue is attribution. Standard forest-loss products are often insufficient on their own because sparse canopies, fire-prone mosaics, and low-density woodland structure can lead to ambiguous signals. The literature therefore supports the use of biome-specific monitoring frameworks that combine natural-forest baselines, disturbance histories, and land-use information to identify when canopy loss corresponds to true deforestation rather than to recurring fire, temporary disturbance, or non-forest vegetation dynamics (Neumann et al., 2025; Girardin et al., 2024).

Data (besides the list below, *see above limitations and applications of data for each type of forest*)

1. Forest loss and direct land-use drivers

Global, spatially explicit information on forest loss, its timing, and proximate drivers. The annual tree-cover loss and remaining forest extent by the Global Forest Watch (Hansen et al. 30 m, 2001–today) is a good source of information. Also, global maps of drivers of forest/tree-cover loss (e.g., WRI–Google DeepMind driver-of-loss dataset; AI-based attribution of loss to commodities, shifting cultivation, fire, forestry, etc. could also be combined. There is also crowdsourced driver attribution data such as the “Drivers of Tropical Forest Loss” Geo-Wiki campaign. This source was built based on point samples where experts labelled the driver of loss between 2008–2019. When it comes to modelled data, recent global modelled attribution of commodity-driven deforestation we have the DeDuCE model and associated input layers that link each loss pixel to specific commodities or land uses 2001–2022. There is also aggregated statistics on agricultural share of deforestation from FAO, Our World in Data, Global Forest Review indicators linking deforestation to agriculture and specific commodities. One example of usage of all this data could be the overlaying of the Global Forest Watch annual loss with commodity-attribution layers, that will allow to quantify the share and geography of cattle, soy, oil palm, cocoa, rubber, wood fibre, etc. in forest conversion by year and jurisdiction.

2. Commodity production, trade and supply chain

To connect land-use change to supply chains and consumer markets, it is necessary to use 1) spatial production maps for key commodities usually linked to deforestation (cattle/pasture, soybean, oil palm, cocoa, coffee, rubber, wood fiber, pulp and paper, and bioenergy crops); 2) subnational indicators of “deforestation linked to agriculture” by commodity administrative unit (like the Global Forest

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Review commodity indicator); 3) trade and supply-chain linkage datasets that connect producing municipalities/regions to exporters, traders, and importing countries (like Trase datasets for soy, beef, palm oil, and cocoa); 4) firm-level and shipment-level customs/trade data (where accessible) that can be joined to spatial production and deforestation layers to trace forest-risk exposure along supply chains; 5) global trade statistics for agricultural commodities, from sources like FAO and COMTRADE, that provide volumes, values, and trade flows. The combination of these data can help to identify which downstream markets and companies are exposed to deforestation risk.

3. Demand-side regulation and deforestation-free policies

To study uneven regulation, arbitrage and 2030-relevant policy trajectories, it is necessary to use all the possible legal and policy datasets on deforestation-free product regulations (EUDR, UK due diligence laws, and others emerging measures), including product scope, due-diligence requirements, and enforcement timelines. The EU Deforestation Observatory and similar initiatives provide harmonized forest cover and risk indicators tailored to regulatory implementation. Some countries also have country-level data on adoption and stringency of import regulations or voluntary standards linked to specific markets (certificates and/or zero-deforestation commitments).

Regulations such as the EUDR should incorporate incentive-based mechanisms alongside compliance requirements, particularly for exporting countries with limited financial and technical capacity, as is the case for many developing economies. Without such support, there is a risk that deforestation-free regulations become exclusionary rather than transformative. In practice, smallholder and family farmers in several least-developed exporting countries often require targeted technical assistance, capacity building, and access to finance to meet traceability and due diligence requirements associated with deforestation- and conversion-free (DCF) markets. Integrating these supportive measures can enhance both the effectiveness and equity of demand-side regulation.

4. Tenure, governance, illegality, and environmental crime

Addressing insecure tenure, illegality and environmental crime, it is necessary to compile spatial tenure and land-rights datasets for indigenous territories, community lands, land reform settlements, and private titles. But since some IPLC still do not have their territory recognized, indicators of tenure security and recognition on actual occupation is also necessary. Still, there is a risk of land rights not being respected, so governance and corruption indices at national or, where available, subnational scale could be used to proxy systemic enabling conditions for illegality. For those countries where illegal deforestation occur, geo-referenced records of illegal deforestation, fines, prosecutions, and seizures related to forest crimes and illegal commodity production.

5. Conservation finance, economic incentives and macro drivers

In order to model how macroeconomic shocks, price cycles, or subsidy reforms shift incentives for conversion versus conservation, we can overlap a) public and private conservation finance flows by country/region, including climate finance, REDD+ results-based payments, biodiversity funds, and domestic conservation budgets; b) agricultural subsidies, tax incentives and credit flows that favour expansion of forest-risk commodities (e.g., credit lines for cattle, soy or palm oil) versus support for conservation or sustainable production; c) macroeconomic indicators, such as GDP growth, exchange rates, commodity prices, terms of trade, and debt levels, which influence pressures for export-oriented expansion and land conversion; and d) valuation studies or datasets on

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ecosystem services and natural capital that estimate the long-term economic value of standing forests relative to converted land uses (like the analyses made by the InVest algorithm).

6. Forest condition baselines and legal thresholds

Supply-chain policies often hinge on distinguishing natural forests from plantations and non-forest land.The datasets described below are critical for operationalizing "deforestation- and conversion-free" trade rules and for aligning supply-chain metrics with national legality frameworks: a) High-resolution baselines of natural forests vs. other tree cover (e.g., Natural Forests of the World 2020 AI-based map distinguishing natural forest from other tree cover) and b) National and international forest definitions, land-cover maps, and legal land-use zoning layers (e.g., permanent protection, legal reserves, production forests) that determine whether conversion is legal or illegal.

• Policy, legal, institutional, and financial instruments for implementation;

Legal recognition of territorial rights, combined with georeferenced registries, direct access to finance, and stronger local governance, is among the most effective ways to lower deforestation and create conditions for long-term stewardship. For legal recognition of territorial rights, Brazil's indigenous territory homologation is one of the clearest examples: formal recognition of collective land rights was associated with substantially lower deforestation inside those territories, and the effect was strongest where property rights were fully secured. The same literature argues that rights only work when paired with enforcement and institutional support, not just legal recognition on paper (Baragwanath & Bayi, 2020). About georeferenced registries, governments should align land-use, agricultural, energy, and infrastructure policy through legally binding planning frameworks, zoning rules, and budget screening mechanisms that identify and reduce deforestation risk in public expenditure. Georeferenced land registries are concrete instruments. In Brazil and Colombia, digital registration and georeferencing have been used to map and formalize land claims, although the process can also expose conflicts if not paired with safeguards for customary landholders. This is a strong example of how cadastral systems can support forest governance when they are linked to territorial rights, monitoring, and enforcement (GRAIN, 2020). For local governance, a well-known example is Brazil's Amazon PPCDAm strategy, which combined command-and-control enforcement, protected areas, satellite monitoring, and land-use planning to reduce Amazon deforestation for several years. This is useful evidence that legal and institutional coordination across sectors matters, because the policy worked as a package rather than as a single measure (Boucher et al 2014). Another relevant case is zoning and territorial planning under REDD+ and forest governance programs, where governments use land-use rules, protected-area expansion, and spatial planning to align agriculture and conservation objectives. Planning frameworks can reduce deforestation risk when they are binding and tied to state implementation capacity.

Countries can also reduce pressure on forests by cutting food loss and waste and by shifting procurement, fiscal incentives, and dietary policies away from high-deforestation production models. Deforestation risk should be embedded in financial regulation and economic decision-making through subsidy reform, disclosure requirements for firms and financiers, and screening of public and private investments. Trade measures should combine deforestation-free requirements, interoperable traceability, commodity risk classification, and targeted support for local and family-based producers so that compliance does not

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become exclusionary.

• Processes for tracking progress, reporting outcomes, and iterative improvement;

Effective tracking of deforestation requires monitoring systems that move beyond generalized global indicators and instead integrate biome-specific detection, attribution, and validation approaches, reflecting the distinct dynamics of humid, seasonal, temperate, and boreal forest systems. The literature consistently shows that relying on a single metric, such as tree-cover loss, can lead to systematic misclassification of deforestation, particularly where temporary canopy disturbance, plantation rotation, or natural variability are prevalent (Neumann et al., 2025). As a result, robust monitoring frameworks must combine high-resolution remote sensing, land-use attribution, and forest-type classification to distinguish permanent conversion from degradation, harvesting, or natural disturbance processes. Effective tracking and reporting depend on linking biophysical monitoring to accountability mechanisms and governance processes. This includes aligning national monitoring systems with international reporting frameworks, ensuring transparency in data access, and enabling independent verification. By integrating spatial data on forest loss with information on drivers, tenure, and economic activity, monitoring systems can support more precise attribution of responsibility and more effective targeting of interventions. Such integrated approaches are essential to ensure that progress toward halting deforestation is both measurable and actionable across the diverse conditions represented by the nine forest regions.

• Illustrative cases and replicable solutions.

Monitoring systems should evolve from simple detection tools into integrated decision-support systems that combine satellite data, land registries, supply-chain information, and climate-risk analysis to guide enforcement and investment. Territorial or jurisdictional approaches can reduce leakage and transaction costs by shifting from actor-by-actor compliance to area-wide governance and accountability.

Brazil's PPCDAm (Action Plan for the Prevention and Control of Deforestation in the Legal Amazon) remains a leading example of large-scale deforestation reduction through combined use of real-time monitoring, credit restrictions, law enforcement, protected areas, Indigenous territories, and supply-chain pressure in beef and soy. Existing traceability initiatives in soy and cattle show that deforestation-free implementation is more feasible when market incentives, territorial governance, and transparent data systems are aligned. The replicable component of this case lies not in any single instrument, but in the integration of monitoring, enforcement, financial incentives, and territorial governance, which can be adapted to other frontier regions (Nepstad et al., 2014; Assunção et al., 2015).

Another well-documented example is the **Soy Moratorium in the Brazilian Amazon**, a supply-chain intervention in which major traders agreed not to purchase soy produced on recently deforested land. Using spatially explicit data, studies have shown that this agreement significantly reduced the expansion of soy into newly deforested areas without reducing overall production, illustrating that private-sector commitments, when combined with monitoring and transparency, can decouple commodity production from deforestation (Gibbs et al., 2015). This model is replicable in other commodity sectors, particularly where supply chains are concentrated and traceability systems can be implemented.

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In tropical forest regions more broadly, **jurisdictional approaches to REDD+ (Reducing Emissions from Deforestation and Forest Degradation)** have been identified as scalable solutions for aligning local, national, and international incentives. Evidence from early jurisdictional REDD+ programs shows that moving from project-level interventions to landscape or jurisdictional scales can reduce leakage, improve monitoring consistency, and enable performance-based payments tied to verified outcomes (Stickler et al., 2018). The replicable insight is that effectiveness increases when interventions are embedded within territorial governance systems rather than isolated projects, particularly when linked to national policies and international finance.

In dry and seasonal forest systems, **community-based forest management** has emerged as a replicable model for reducing degradation and deforestation pressures. A global meta-analysis shows that forests under community management often experience lower deforestation rates and better conservation outcomes compared to state-managed or open-access areas, particularly when communities have secure tenure and institutional support (Blackman et al., 2017). This evidence supports the conclusion that strengthening local governance and land rights is a necessary condition for sustainable forest outcomes, especially in regions where livelihoods are directly dependent on forest resources.

In temperate and boreal systems, **reduced-impact logging (RIL)** provides a well-documented example of a replicable solution to minimize forest degradation while maintaining production. Studies show that RIL practices can significantly reduce carbon emissions and structural damage compared to conventional logging, while maintaining long-term timber yields (Putz et al., 2012). This approach is particularly relevant where forest use is expected to continue, demonstrating that production and conservation objectives can be partially reconciled through improved management practices.

Across multiple regions, integrated monitoring systems combining satellite data with policy enforcement have proven to be a foundational, replicable solution. High-resolution remote sensing platforms, when linked to enforcement actions and policy instruments, enable near-real-time detection of forest loss and increase the effectiveness of governance interventions (Hansen et al., 2013; Assunção et al., 2015). The key lesson is that monitoring alone is insufficient; its effectiveness depends on institutional capacity to act on the information generated.

5. **Forest Degradation: Drivers and Solutions**

• Diagnosis, barriers and data;

Forest degradation remains systematically underrepresented in global climate and forest governance frameworks, despite evidence that it can account for a substantial share of emissions, biodiversity loss, and functional decline, often preceding or occurring independently of deforestation (Hosonuma et al 2012; Pearson et al 2017). Unlike deforestation, which is tipically characterized by complete canopy removal and land-use conversion, degradation involves partial loss of biomass, structure and ecosystem function, frequently through repeated or interacting disturbances such as fire, selective logging, drought and fragmentation (Putz & Redford, 2010; Matricardi et al., 2020).

Diagnosis: In *humid tropical and subtropical forests*, degradation is often driven by selective logging, edge effects, and recurrent fire, which interact to reduce biomass, increase vulnerability to drought, and create feedbacks that can

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eventually lead to forest collapse (Silvério et al., 2019; Brando et al., 2020). In these systems, degradation can affect larger areas than deforestation itself and may remain undetected in conventional monitoring systems because canopy cover is only partially reduced.

In *tropical dry and seasonal forests*, degradation is more strongly associated with chronic disturbance regimes, including repeated burning, fuelwood extraction, and grazing, which progressively reduce vegetation structure and resilience without necessarily triggering full canopy loss (Allen et al., 2017). These systems often exist in long-term degraded states, making it difficult to define clear baselines or thresholds between intact and degraded conditions.

In *temperate forests*, degradation is increasingly linked to management intensity and climate-driven disturbances, including pest outbreaks, storms, and drought, which alter species composition, reduce structural diversity, and weaken ecosystem resilience (Seidl et al., 2017). In these regions, degradation often manifests as a gradual loss of ecosystem complexity rather than abrupt change.

In *boreal forests and tundra woodland systems*, degradation is strongly influenced by climate-amplified disturbance regimes, particularly wildfire and insect outbreaks, which are increasing in frequency and intensity under warming conditions (Gauthier et al., 2015; Walker et al., 2019). These disturbances can lead to long-term changes in forest structure, carbon balance, and even biome transitions, especially in ecotonal areas.

Barriers: A central barrier across all forest regions is the conceptual and operational ambiguity of degradation, which lacks a universally agreed definition and is therefore inconsistently integrated into policy, monitoring, and finance mechanisms (Putz & Redford, 2010; Pearson et al., 2017). This ambiguity leads to systematic underestimation of degraded areas and weak alignment between scientific understanding and governance frameworks. A second barrier is the limited economic and policy recognition of degradation impacts. Because degraded forests often retain some canopy cover, they are frequently classified as “forest” in national inventories, masking declines in carbon stocks, biodiversity, and ecosystem services. As a result, financial and policy instruments tend to prioritize deforestation avoidance while neglecting degradation, even though degradation can significantly reduce ecosystem function and future recovery potential (Matricardi et al., 2020). A third barrier is the mismatch between drivers and governance structures. Degradation is often driven by diffuse and cumulative processes, such as small-scale logging, fire use, or fuelwood extraction, that fall outside conventional enforcement systems designed to address large-scale deforestation. This makes regulation more complex and requires approaches that integrate local practices, community governance, and cross-sector coordination (Hosonuma et al., 2012). Finally, climate change acts as a cross-cutting barrier, amplifying existing drivers and pushing forest systems beyond historical variability. Increasing drought, heat, and disturbance regimes reduce forest resilience and complicate both management and restoration efforts, particularly in tropical and boreal regions (Seidl et al., 2017; Brando et al., 2020).

Data: The literature consistently identifies data limitations as a major constraint for addressing forest degradation. Conventional remote sensing approaches, which are effective at detecting complete canopy loss, are less capable of capturing subtle structural changes, biomass reduction, and repeated disturbance events (De Sy et al., 2012; Matricardi et al., 2020). In *humid tropical forests*, degradation caused by selective logging and understory fires often occurs beneath the canopy and may not be detected by coarse-resolution satellite data, requiring higher-resolution imagery, LiDAR, or radar-based approaches to quantify

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biomass loss and structural damage (Asner et al., 2005; Matricardi et al., 2020). In *dry and seasonal forests*, monitoring is complicated by phenological variability and low canopy density, which can obscure degradation signals and increase classification uncertainty. Detecting degradation in these systems requires time-series approaches and integration with fire datasets to distinguish between seasonal dynamics and long-term decline (Allen et al., 2017). In *temperate and boreal forests*, distinguishing degradation from natural disturbance is a key challenge. Wildfire, storms, and pest outbreaks can cause large-scale biomass loss, but their classification as degradation or natural variability depends on context, baseline conditions, and recovery trajectories (Gauthier et al., 2015; Seidl et al., 2017). Across all regions, the literature emphasizes the need to integrate multiple data sources, including remote sensing, field inventories, and ecological models, to capture degradation processes more accurately and consistently (De Sy et al., 2012; Pearson et al., 2017).

• Policy, legal, institutional, and financial instruments for implementation;

Countries should replace suppression-only responses with Integrated Fire Management that links prevention, preparedness, early warning, response, recovery, and social governance of fire-prone landscapes. Fire governance should operate across sectors and borders, since agricultural practices, forestry, infrastructure, and climate conditions jointly shape burning patterns and impacts. Fire prevention and resilience improve when Indigenous and community fire practices are recognized, financed, and integrated through equitable partnerships rather than top-down incorporation. Climate and forest finance should explicitly cover degradation, prevention, and post-fire recovery instead of focusing almost exclusively on avoided deforestation.

• Processes for tracking progress, reporting outcomes, and iterative improvement;

Tracking forest degradation requires a shift from binary forest/non-forest monitoring towards continuous metrics of forest condition, including biomass, structure, and ecosystem function.The literature supports the use of multi-dimensional indicators, such as aboveground carbon stocks, canopy structure, disturbance frequency, and recovery rates, to capture the dynamics of degradation and regeneration over time (Pearson et al., 2017; Matricardi et al., 2020). In humid tropical regions, progress tracking should integrate data on selective logging, fire occurrence, and edge effects, linking these disturbances to changes in carbon stocks and forest resilience. This requires combining satellite-based detection with field-based calibration and models of biomass loss and recovery (Asner et al., 2005). In dry and seasonal systems, monitoring must explicitly incorporate fire regimes and grazing pressure, using time-series analysis to identify trends in degradation and recovery rather than relying on static classifications (Allen et al., 2017). In temperate and boreal regions, tracking systems should focus on disturbance regimes and recovery trajectories, distinguishing between natural variability and long-term degradation. This includes integrating climate data, disturbance records, and forest inventories to assess resilience and adaptive capacity (Seidl et al., 2017). Iterative improvement requires regular recalibration of monitoring systems, incorporation of new technologies (e.g., LiDAR, radar), and continuous refinement of degradation definitions and thresholds. The literature emphasizes that monitoring systems must be embedded in adaptive governance frameworks, where data informs policy adjustments, management interventions, and financial mechanisms in real time (De Sy et al., 2012; Pearson et al., 2017).

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Important to highlight that effective reporting depends on aligning degradation metrics with national inventories and international frameworks, ensuring that degradation is fully accounted for in climate reporting and finance mechanisms. Without this integration, degradation will remain systematically underestimated, limiting the effectiveness of efforts to halt forest loss and restore ecosystem integrity.

• Illustrative cases and replicable solutions.
Please refer to illustrative cases at the Deforestation section, as they overlap.

6. Forest Restoration, Reforestation and Afforestation

• Diagnosis, barriers and data;

Diagnosis: Restoration is most effective when implemented through clearly defined ecological models that match biophysical conditions, land-use history, and socioeconomic context. Three broad restoration pathways are consistently defined in the scientific literature: natural regeneration (most cost-effective when conditions allow), assisted natural regeneration, and active restoration through planting or direct seeding. Natural regeneration has shown recovery trajectories capable of restoring aboveground biomass and biodiversity at substantial rates within two decades (Poorter et al., 2016; Crouzeilles et al., 2017). Assisted natural regeneration, which includes protection from potential drivers of degradation, such as fire and grazing, uses enrichment planting and soil management. Those activities accelerate the process of regeneration in moderately degraded systems (Chazdon & Guariguata, 2016). In contrast, active restoration, through seedling planting or high-diversity direct seeding systems such as “muvuca” is required in highly degraded landscapes where seed sources and ecological memory have been lost (Rodrigues et al., 2011; Brancalion et al., 2019).

Empirical evidence from large-scale tropical restoration initiatives demonstrates that cost and timeline vary significantly across these approaches. Natural regeneration can cost as little as USD 50–500 per hectare, while assisted natural regeneration typically ranges from USD 500–1,500 per hectare, and active restoration through planting can exceed USD 2,000–5,000 per hectare depending on species diversity, labor, and logistics (Brancalion et al., 2019; Strassburg et al., 2020). Recovery timelines also differ: early structural recovery (e.g., canopy closure, carbon accumulation) can occur within 5–15 years, whereas full recovery of biodiversity and ecosystem function may require several decades (Poorter et al., 2016; Lennox et al., 2018).

Large-scale case studies illustrate the importance of combining ecological models with governance and supply-chain innovations. In the Xingu Basin (Brazil), restoration efforts integrating local seed networks and direct seeding techniques have restored thousands of hectares while generating income for local communities, demonstrating the feasibility of scaling restoration through decentralized seed supply systems (Urzedo et al., 2020). Similarly, restoration outcomes improve significantly when embedded within broader landscape governance frameworks that include secure land tenure, enforcement of forest protection, and alignment with agricultural systems, reinforcing the principle that restoration cannot succeed in isolation from the drivers of degradation (Chazdon et al., 2017).

These differences highlight that restoration planning must be spatially explicit, prioritizing areas where natural regeneration is feasible to maximize cost-

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effectiveness and scale. Restoration is necessary but should not be treated as a substitute for protecting the forests that still remain, since over-emphasizing restoration can obscure the much larger climate and ecosystem value of avoiding new loss.

Barriers: Large-scale restoration faces structural barriers since efforts remain small-scale, fragmented, and project-based, limiting economies of scale and landscape connectivity. Other barriers include, unclear distinctions between restoration and commercial plantations, limited data on ecosystem integrity and recovery trajectories, and the lack of spatially explicit prioritization that accounts for ecological functions, climate resilience and social dimensions. Ongoing deforestation, degradation and fire continue to undermine restoration outcomes, highlighting that restoration cannot succeed without addressing drivers. There are also operational gaps including insufficient seed and seedling supply chains, limited technical assistance, lack of locally adapted models and a weak science-to-implementation interface. Some of these barriers are applied to reforestation and afforestation. In both cases, there is a strong bias toward fast-growing exotic monocultures.

Data: There are several major global databases and platforms for forest restoration, reforestation, and afforestation, and they differ a lot in purpose: some track projects, some track pledges, and some track tree-cover change from satellites.

Project and restoration registries

- Restoration Database from the Society for Ecological Restoration/Restoration Resource Center is a searchable global database of restoration projects, filterable by country, region, biome, ecosystem, and cause of degradation (https://ser-rrc.org/restoration-database/)
- Restor is a global hub for nature restoration and conservation that lets users showcase and monitor projects and connect with the community; it had registered about 70,000 restoration sites by 2020 (https://pmc.ncbi.nlm.nih.gov/articles/PMC10191160/)
- Global Restoration Network Database is a directory of restoration-related databases and tools, including Global Forest Watch (https://www.lets-plant.org/databases)

Global commitments and pledges

- The Bonn Challenge is the best-known global restoration pledge framework, and its Barometer tracks progress on pledged restoration commitments (https://www.bonnchallenge.org/progress).
- The Global Restoration Commitments Database 2024 compiles restoration pledges worldwide and aligns them with the Bonn Challenge, Rio Conventions, and SDGs (https://grih.info/wp-content/uploads/2024/11/Global-restoration-database-2.0-Final-19_11_2024.pdf).

Geospatial and monitoring data

- Global Forest Watch provides open forest-monitoring data, including near-real-time change information and multiple datasets for land use and forest change; its open data portal offers broad downloadable layers (https://www.globalforestwatch.org/).
- The Targets Tracker in the Global Forest Review uses satellite-based geospatial data to estimate progress toward restoring 350 million hectares of lost and degraded forests by 2030 (https://gfr.wri.org/forest-targets-tracker).
- The Atlas of Forest and Landscape Restoration Opportunities maps

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potential restoration opportunities globally, based on biophysical and population data (http://atlas.smartforests.net/en/logbooks/forest-restoration-platforms/).

Afforestation and reforestation datasets

- A new global reforestation dataset compiled from more than 50 sources contains 1.29 million planting sites from 45,628 projects across 33 years, with satellite imagery and secondary data added for validation and context (https://www.nature.com/articles/s41597-025-05930-9).
- FAO's Forest and Landscape Restoration data-and-tools hub aggregates planning, monitoring, carbon, and project resources for FLR work (https://www.fao.org/in-action/forest-landscape-restoration-asia/knowledge-hub/data-and-tools/en).
- FAO's se.plan is a restoration planning tool that combines ecological data with benefits, costs, and risks to identify priority locations (https://www.fao.org/forest-monitoring/resources/videos/videos/se.plan---a-forest-restoration-suitability-decision-support-tool/en).

• Policy, legal, institutional, and financial instruments for implementation;

Regulatory frameworks should clearly separate ecological restoration from commercial plantations and should evaluate restoration by integrity, permanence, and biodiversity benefits rather than by area alone. These frameworks must prioritize native vegetation recovery and be embedded within integrated land-use planning aligned with NDCs, and NAPs. Financial instruments should direct resources toward high-integrity restoration, including results-based finance and blended finance mechanisms. Policies must also explicitly link restoration to the reduction of degradation drivers, particularly unmanaged fire, ensuring long-term ecosystem resilience rather than short-term gains.

• Processes for tracking progress, reporting outcomes, and iterative improvement;

Monitoring, Reporting and Verification (MRV) systems must move beyond area-based metrics to include ecological integrity, carbon uptake, biodiversity recovery, and the restoration of ecosystem services such as water regulation and climate stability. National monitoring systems should advance reporting in areas undergoing restoration, following a transparent, interoperable, and comparable reporting framework that enables alignment across countries and financial mechanisms. To ensure effectiveness and integrity, MRV systems must evolve beyond area-based metrics to include indicators of ecological integrity, carbon accumulation, biodiversity recovery, and ecosystem service provision. Recent advances in remote sensing combined with field data allow tracking of forest structure, biomass recovery, and degradation dynamics, enabling more robust evaluation of restoration outcomes over time (Bastin et al., 2019; Hansen et al., 2013). Integrating these metrics into national reporting systems and finance mechanisms is essential to align restoration investments with long-term climate and biodiversity goals.

• Illustrative cases and replicable solutions.

Evidence shows that restoration is most effective when embedded within broader governance frameworks that include secure land tenure, strong enforcement, and alignment with sustainable production systems. Illustrative cases include the Xingu Basin headwaters in Brazil, where diverse stakeholders

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were engaged in the restoration supply chain, and new social technology (e.g. Muvuca) was applied. Scaling these approaches requires coordinated policy support, long-term financing, and integration into climate and development strategies.

7. Sustainable Forest Management, Bioeconomy, Agroforestry

• Diagnosis, barriers and data;

The diagnosis, drivers, and barriers associated with sustainable forest management are not uniform across the world's forested regions, because forest structure, disturbance regimes, land-use pressures, and institutional settings vary substantially among humid, seasonal, temperate, and boreal systems.

Diagnosis: In *tropical rainforests and subtropical humid forests*, the central diagnosis is that these are highly productive, high-biomass, and high-biodiversity systems that deliver critical climate, hydrological, and ecological functions, but are also exposed to some of the strongest incentives for conversion to agriculture, pasture, timber extraction, and infrastructure development (Pendrill et al., 2022). A related but distinct pattern characterizes *tropical moist deciduous forests, tropical dry forests, and subtropical dry forests.* These forests are generally more seasonal, more water-limited, and often more intensively used by local populations for fuelwood, grazing, shifting cultivation, and smallholder production. Their diagnosis is therefore one of chronic human pressure combined with higher ecological sensitivity to drought and fire. In these dry and seasonal systems, degradation is frequently driven not only by land conversion itself, but also by recurrent burning, overgrazing, extraction of wood for energy, and cultivation practices that reduce regeneration capacity (Dimson 2020). In *temperate oceanic forests and temperate continental forests*, the diagnosis is different. These forests are generally embedded in stronger regulatory systems, with longer histories of formal forest management, extensive timber industries, and broader use of certification and monitoring tools. Their main challenge is not usually rapid frontier conversion on the scale observed in tropical regions, but rather the tension between wood production, biodiversity conservation, and resilience under accelerating climate change (Kuuluvainen et al., 2021, Mina et al., 2022). Finally, *boreal coniferous forests and boreal tundra woodland* are defined by vast landscapes, major carbon stocks, slow recovery rates, and rapidly intensifying climate pressures. The diagnosis in these northern systems is that sustainable forest management is being challenged by the interaction between industrial extraction and climate change at a pace that may exceed the adaptive capacity of current management regimes (Ameray et al., 2023).

Barriers: In *tropical rainforests and subtropical humid forests* the principal barriers to implementing sustainable forest management are less ecological than political and economic: weak governance, insecure tenure, fragmented land-use planning, and the persistent undervaluation of standing forests relative to alternative land uses. Even where reduced-impact logging and certified management systems exist, their adoption remains constrained by high transaction costs, limited finance, and policy environments that continue to reward conversion more strongly than long-term forest stewardship. These dynamics are particularly well documented for tropical forest frontiers and commodity-linked deforestation, where agricultural expansion and tenure insecurity reinforce one another (Sasaki et al., 2016). In *tropical moist deciduous forests, tropical dry*

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forests, and subtropical dry forests, the barriers to sustainable forest management are simultaneously ecological and institutional. On the ecological side, slower regeneration, lower biomass accumulation, and greater climatic variability reduce resilience and increase the risks associated with management failure. On the institutional side, these forests have often received less policy attention, less technical investment, and fewer adapted management models than wetter tropical forests. The literature shows that fire and grazing are recurrent causes of degradation in tropical dry forests, while restoration and management frequently require context-specific interventions such as control of repeated burning, support for natural regeneration, and stronger community-based governance. For that reason, sustainable forest management in these regions cannot simply replicate humid-forest models, but must be explicitly adapted to water limitation, fire dynamics, and the high dependence of rural livelihoods on forest resources (Hartung et al., 2021; Heeraja et al., 2021). In *temperate oceanic forests and temperate continental forests* the barriers to sustainable forest management are increasingly linked to legacy effects of past silviculture, policy misalignment between production and ecological resilience, and the difficulty of adapting management regimes fast enough to changing disturbance patterns. The recent literature shows that higher management intensity can reduce biodiversity and alter ecosystem-service trade-offs, while more disturbance-aware and closer-to-natural approaches are increasingly seen as necessary to maintain resilience. In practice, this means that sustainable forest management in temperate oceanic and continental forests depends not only on maintaining wood supply, but also on redesigning management systems to cope with multi-stressor environments and to restore structural and compositional diversity (Guignaberg et al., 2024; Asbek et al., 2021; Cope et al., 2018). For *boreal coniferous forests and boreal tundra woodland* the principal drivers include industrial logging, mining and energy development, and, above all, increasing fire, drought, insect outbreaks, and other climate-related disturbances. In boreal tundra woodland, these pressures are compounded by biome shifts associated with warming, including treeline advance and altered permafrost dynamics, which make historical baselines less reliable for future planning. The barriers are therefore both ecological and institutional: regeneration is slow, disturbances are becoming more frequent and severe, monitoring and enforcement are more difficult in remote areas, and conventional silvicultural approaches are often poorly suited to rapidly changing disturbance regimes. Peer-reviewed literature increasingly emphasizes that climate-induced risks in boreal forests are multiplying and that sustainable forest management in these systems must move beyond stable-yield assumptions toward adaptive strategies explicitly designed for uncertainty, disturbance, and long ecological timeframes (Venäläinen et al., 2020).

• Policy, legal, institutional, and financial instruments for implementation;

Governments should simplify administrative procedures, strengthen extension services and certification, and use procurement and finance to support community-based and local forest-compatible production systems. Enforcement systems should be reinforced through real-time monitoring, traceability requirements, and integration with satellite-based systems to detect illegal logging and associated degradation. Financial mechanisms should incentivize certified timber production and value-added processing, including preferential credit lines, public procurement policies, and market access for sustainably sourced timber. Policies must also explicitly integrate fire prevention and control into timber

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management systems to avoid post-logging degradation. Policy frameworks should align forest, agricultural, climate, and development agendas, ensuring that sustainable forest management, agroforestry, and bioeconomy strategies are embedded within national development planning. Public policies should redirect subsidies and fiscal incentives away from activities that drive deforestation and toward forest-positive economies.

• Processes for tracking progress, reporting outcomes, and iterative improvement;

Monitoring systems must integrate timber extraction into national MRV frameworks, capturing not only deforestation but also degradation caused by logging. This includes spatially explicit tracking of harvest areas, compliance with management plans, carbon impacts, and post-harvest recovery. Traceability systems linking forest origin to final markets should be mandatory to ensure legality and transparency. Indicators should also include biodiversity impacts, forest structure, and resilience to disturbances such as fire and drought. Continuous improvement requires linking monitoring data to enforcement, certification systems, and adaptive management to ensure that timber production remains within sustainable ecological thresholds.

• Illustrative cases and replicable solutions.

Experiences from the Amazon and other tropical regions show that well-managed forest concessions and community forest management systems can reduce deforestation and degradation while generating income. Reduced-impact logging (RIL) practices have demonstrated significant reductions in carbon emissions and forest damage compared to conventional logging. Certification schemes (e.g., FSC) and jurisdictional approaches that integrate timber legality, traceability, and deforestation-free commitments offer scalable pathways. Successful models combine secure tenure, strong governance, access to markets, and technical assistance, demonstrating that sustainable timber production can be a core pillar of a forest-positive bioeconomy when aligned with broader land-use planning and enforcement systems.

8. Forest Conservation

• Diagnosis, barriers and data;

Diagnosis: The diagnosis of forest conservation varies across forest biomes because ecological functions, pressures, and governance contexts differ substantially among humid, seasonal, temperate, and boreal systems.

In *tropical rainforests and subtropical humid forests*, conservation is critical due to their disproportionately high carbon density, biodiversity, and role in regional and global climate regulation. However, these systems remain under intense pressure from commodity-driven deforestation and infrastructure expansion, making conservation a frontline strategy to prevent irreversible ecological change (Pendrill et al., 2022; Cusack et al., 2016). Evidence shows that conservation effectiveness in these regions is strongly associated with governance and tenure regimes; for example, Indigenous Territories and Protected Areas in the Brazilian Amazon have experienced significantly lower forest loss compared to surrounding areas, despite covering a large share of remaining forest (Qin et al., 2023).

In *tropical moist deciduous forests, tropical dry forests, and subtropical dry forests*, the conservation challenge is shaped by long-standing human use, lower biomass, and greater exposure to fire and climatic variability. These systems are

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often characterized by mosaics of forest, agriculture, and grazing land, where conservation must coexist with livelihoods. Degradation and gradual loss of ecological integrity, rather than abrupt deforestation, are often the dominant processes, complicating conservation diagnosis and requiring approaches that maintain ecosystem function over time (Allen et al., 2017).

In *temperate oceanic and temperate continental forests*, conservation is less about halting large-scale frontier deforestation and more about maintaining forest integrity in landscapes already heavily influenced by human management. These forests are increasingly affected by fragmentation, land-use change, and climate-driven disturbances, including pests, droughts, and storms, which alter ecosystem structure and function even where forest cover remains (Seidl et al., 2017; Silver et al., 2024).

In *boreal coniferous forests and boreal tundra woodland*, conservation is challenged by the interaction between industrial resource extraction and rapid climate change. These systems store vast carbon stocks and regulate global climate processes, but are experiencing increasing wildfire, pest outbreaks, and biome shifts, particularly in ecotonal areas where forest boundaries are changing (Gauthier et al., 2015; Walker et al., 2019). Across all regions, the literature emphasizes that conservation must be understood not only as preventing forest loss, but as maintaining ecological integrity, resilience, and long-term ecosystem functioning.

Barriers: Across forest regions, a primary barrier to conservation is the misalignment of economic incentives, whereby land conversion and resource extraction remain more profitable and better supported than conservation (Börner et al., 2020). This barrier is particularly acute in tropical humid forests, where global commodity markets drive large-scale deforestation, and in boreal systems, where extractive industries such as logging, mining, and energy development exert strong pressure. A second major barrier is weak or insecure land tenure, which undermines conservation outcomes by reducing incentives for long-term stewardship. Evidence shows that secure tenure, particularly for Indigenous Peoples and local communities, is associated with lower deforestation rates and more durable conservation outcomes (Blackman et al., 2017; Qin et al., 2023). This barrier is especially relevant in tropical and subtropical regions, where tenure conflicts and unclear land rights are widespread. A third barrier is the limited integration of local communities into conservation governance. Conservation strategies that exclude or marginalize local actors often fail to achieve long-term success, particularly in dry and seasonal forests, where livelihoods are closely tied to forest use. Peer-reviewed evidence indicates that community-managed forests can perform as well as or better than strictly protected areas in reducing deforestation, particularly when supported by appropriate institutions (Porter-Bolland et al., 2012). Finally, monitoring and measurement limitations constrain conservation effectiveness across all regions. Existing systems often focus on forest cover rather than forest condition, biodiversity, or social outcomes, leading to incomplete assessments of conservation success (Börner et al., 2020).

Data: The same data described in the restoration and conservation sections are useful here. But it is important to consider that effective forest conservation requires integrated data systems that combine biophysical, socio-economic, and governance information. In *tropical humid regions*, spatially explicit datasets linking forest loss to commodity supply chains, carbon stocks, and land tenure are critical for identifying drivers and targeting interventions (Pendrill et al., 2022; De Sy et al., 2019). In *dry and seasonal forests*, monitoring must account for phenological variability and fire regimes, requiring time-series analysis and

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integration of fire datasets to distinguish long-term change from seasonal dynamics (Allen et al., 2017). In *temperate forests*, distinguishing permanent land-use change from timber harvest cycles requires combining forest-cover data with land-use records and forest-type classifications (Neumann et al., 2025). In *boreal systems*, monitoring must integrate disturbance data, including wildfire and pest outbreaks, with climate variables to distinguish anthropogenic change from natural variability (Gauthier et al., 2015). Across all regions, the literature emphasizes the importance of counterfactual-based evaluation methods, which compare conservation areas to similar non-protected areas to assess effectiveness rather than assuming observed forest persistence is attributable to conservation (Börner et al., 2020).

• Policy, legal, institutional, and financial instruments for implementation;

Secure tenure, FPIC, direct finance, and community-led governance should be treated as core conservation tools rather than secondary safeguards, especially where Indigenous Peoples and local communities already protect large shares of intact forests. Conservation finance should combine domestic tools such as PES (Payments for Ecosystem Services) with international mechanisms such as JREDD+, TFFF, concessional finance, and blended finance within a coherent architecture that preserves integrity and supports equitable benefit-sharing. The peer-reviewed literature consistently supports a portfolio approach to forest conservation. In *tropical humid forests*, the combination of Protected Areas, Indigenous Territories, law enforcement, and supply-chain interventions has proven effective in reducing deforestation (Nepstad et al., 2014; Gibbs et al., 2015). Indigenous and community tenure recognition is particularly important, as these governance systems have been shown to deliver strong conservation outcomes when rights are secure (Blackman et al., 2017; Qin et al., 2023). In *dry and seasonal forests*, conservation instruments must be adapted to local livelihoods, integrating community-based management, fire management, and support for sustainable land-use practices. In *temperate and boreal systems*, regulatory frameworks, certification schemes, and sustainable forest management standards play a larger role, reflecting stronger institutional capacity and established forest industries (Seidl et al., 2017). Financial instruments such as PES can support conservation across regions, but their effectiveness depends on design, targeting, and integration with governance systems (Calvet-Mir et al., 2015). The literature emphasizes that financial incentives must complement, rather than replace, regulatory and institutional measures, and should be structured to ensure additionality and equity (Börner et al., 2020).

• Processes for tracking progress, reporting outcomes, and iterative improvement;

Tracking conservation progress requires moving beyond area-based metrics toward impact-based indicators, including avoided deforestation, forest condition, and ecosystem integrity. In tropical forests, this involves linking forest-loss data to drivers such as commodity expansion and infrastructure (Pendrill et al., 2022). In dry and seasonal forests, monitoring must incorporate fire regimes and degradation dynamics (Allen et al., 2017). In temperate and boreal regions, tracking systems should distinguish between natural disturbance and

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anthropogenic change, integrating climate and disturbance data to assess long-term trends (Seidl et al., 2017; Gauthier et al., 2015). Across all regions, iterative improvement depends on adaptive monitoring systems that incorporate new data, refine methodologies, and inform policy adjustments over time. The literature highlights the importance of counterfactual evaluation, transparency, and independent verification to ensure that reported outcomes reflect real conservation impacts (Börner et al., 2020).

• Illustrative cases and replicable solutions.

Many cases from different regions indicate that effective conservation strategies share common features: they integrate governance, monitoring, and incentives; operate at appropriate spatial scales; and align economic and institutional systems with long-term forest protection goals. Comparative evidence from Brazil and other countries shows that protected areas and Indigenous or community territories are among the most effective land-based tools for reducing conversion under pressure. In the Brazilian Amazon, the combination of protected areas, Indigenous territories, and enforcement policies significantly reduced deforestation during the 2000s, demonstrating the effectiveness of integrated governance approaches (Nepstad et al., 2014; Qin et al., 2023). The Soy Moratorium further showed that supply-chain interventions can decouple agricultural expansion from deforestation when supported by monitoring and enforcement (Gibbs et al., 2015). Across tropical regions, community forest management has been shown to reduce deforestation rates and improve conservation outcomes, particularly where tenure is secure and institutions are strong (Porter-Bolland et al., 2012). In temperate and boreal forests, sustainable management and certification systems demonstrate that production and conservation can be partially reconciled when governance frameworks are robust (Seidl et al., 2017).

Part III – Fostering International Cooperation and Addressing Regulatory Bottlenecks

9. **Technical Cooperation, Capacity Building, Institutional Strengthening**

o Capacity building to address technical gaps, promote international standards' alignment, improve forest monitoring, data systems and measurement methodologies

International cooperation on forests is formally anchored in the United Nations Framework Convention on Climate Change, particularly through the REDD+ framework, which explicitly links implementation to the provision of technical, technological, and capacity-building support for developing countries (UNFCCC, 2010; UNFCCC, 2013a). These decisions call for national coordination entities, strengthening of institutional arrangements, and support for national forest monitoring systems and MRV (measurement, reporting, and verification). Peer-reviewed literature shows that capacity-building is a determinant of effectiveness, especially in tropical forest countries where institutional capacity shapes outcomes

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in monitoring, enforcement, and land governance (Stickler et al., 2018; Börner et al., 2020). In practice, effective cooperation requires long-term investments in MRV systems, land tenure administration, enforcement agencies, and inter-ministerial coordination mechanisms, rather than short-term project cycles. This need is particularly acute in tropical humid and seasonal forest regions, where governance fragmentation and tenure insecurity remain key structural drivers of forest loss (Pendrill et al., 2022). UNFCCC decisions explicitly recognize that capacity-building and institutional readiness are prerequisites for accessing results-based finance, reinforcing their central role in implementation (UNFCCC, 2013a).

o Model Forest Act Initiative (MOFAI)

In t*ropical rainforests and subtropical humid forests*, a MOFAI-type framework would likely be most effective where the main problem is not the absence of forest value, but the absence of coherent, enforceable land-use rules across forests, agriculture, infrastructure, and tenure systems. The literature suggests that conservation outcomes improve when legal protection is paired with effective governance, and when Indigenous and locally managed areas are recognized rather than treated as peripheral to conservation policy. That points to MOFAI being potentially most useful here as a tool to harmonize forest definitions, tenure recognition, deforestation controls, and cross-sector permitting rules in frontier regions facing commodity pressure (Zhang et al., 2023, Rakotonarivo et al., 2023). In *tropical moist deciduous forests, tropical dry forests, and subtropical dry forests*, the strongest added value of a MOFAI-type framework would likely be different. In these regions, the scientific challenge is often not only conversion, but chronic disturbance: repeated fire, fuelwood extraction, grazing, and dry-season pressures. The literature on tropical dry forests shows that fire responses are highly context dependent and strongly shaped by rainfall and recurrence, which means rigid "one-rule-fits-all" forest law is unlikely to work well. In these regions, MOFAI would likely be most effective if it enables place-based legal tools: community fire governance, differentiated zoning, seasonal-use rules, and legal space for locally adapted management instead of blanket prohibition (Hartung et al., 2021). In temperate oceanic and temperate continental forests, MOFAI would probably be most useful not as a basic anti-deforestation law, but as a way to modernize older forest statutes so they better incorporate biodiversity, climate adaptation, and multi-use landscape planning. The literature in these regions points less to frontier clearing and more to challenges of governance design: how to balance timber production, biodiversity conservation, protected-area effectiveness, and climate adaptation under rising disturbance risk. That suggests a MOFAI-type framework would be most effective if it updates legal standards for adaptive management, forest condition, and landscape connectivity rather than focusing narrowly on gross forest loss (Mabon et al., 2025; Zhang et al., 2023). In boreal coniferous forests and boreal tundra woodland, the science suggests MOFAI would be most effective where it embeds disturbance-aware and Indigenous-inclusive governance. The boreal literature emphasizes that extraction pressures such as mining can have large cumulative effects, while climate-driven wildfire and other disturbances are increasing. At the same time, reviews of boreal fire governance show that excluding Indigenous knowledge and cultural burning from governance systems has weakened resilience. In these regions, a MOFAI-type framework would likely be strongest if it clarifies cumulative-impact review, strengthens Indigenous co-governance, and legally recognizes that fire and disturbance are part of boreal ecology rather than treating all fire only as failure or

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illegality (Wells et al., 2020).

10. **Finance, Markets, Partnerships**

The UNFCCC framework recognizes that forest finance must be mobilized from a diversity of sources, including public, private, bilateral, and multilateral channels (UNFCCC, 2013a). This aligns with the literature showing that no single instrument can address deforestation and degradation at scale, and that blended approaches combining regulation, incentives, and markets are required (Börner et al., 2020). Empirical evidence demonstrates that partnerships between governments, private sector actors, and civil society are essential to align supply chains and financial flows with forest conservation goals. For example, commodity supply-chain initiatives such as the Soy Moratorium in Brazil illustrate how coordinated action across actors can reduce deforestation while maintaining production (Gibbs et al., 2015). Multi-actor partnerships, including jurisdictional initiatives and landscape-scale programs, are therefore central to international cooperation, particularly in tropical frontier regions where deforestation is driven by global demand.

o REDD+, TFFF and results-based finance

JREDD+ and TFFF are among the most promising near-term pathways for mobilizing forest finance at scale, but both depend on stronger demand signals, public support, and institutional capacity that builds on existing monitoring and safeguards systems. Redirecting mainstream finance will also require deforestation risk to be incorporated into financial supervision, central-bank analysis, development finance, and corporate disclosure frameworks. Sustainable land-use taxonomies can help guide investment by distinguishing deforestation-free, degradation-free, and restoration-aligned activities and linking them to green bonds, concessional loans, and investment portfolios.

o Multilateral and bilateral concessional finance

UNFCCC decisions identify multilateral climate funds, particularly the Green Climate Fund, as central channels for supporting forest-related mitigation and adaptation (UNFCCC, 2013a). These institutions provide concessional finance, including grants, concessional loans, and guarantees, which are critical for building enabling conditions and reducing investment risk. The literature highlights that concessional finance plays a key role in de-risking investments and enabling access to larger capital flows, particularly in early stages of forest programs (Buchner et al., 2019). Bilateral finance also remains important, especially for jurisdictional REDD+ programs and national strategies. However, both policy and literature emphasize that a major bottleneck is the fragmentation and insufficient scale of concessional finance, which limits its ability to catalyze systemic transformation.

o Alignment with development finance and private capital

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A central structural issue is the misalignment between conservation goals and broader financial systems. Deforestation persists because agricultural expansion and extractive sectors are embedded in global financial flows, while conservation remains comparatively underfunded (Pendrill et al., 2022). Aligning forest conservation with development finance requires integrating forest objectives into: 1) national development planning, 2) agricultural and infrastructure investment pipelines, and 3) financial risk frameworks. Peer-reviewed research emphasizes the importance of blended finance mechanisms, which combine concessional and private capital to overcome investment barriers and scale forest-positive activities (Börner et al., 2020). This alignment is particularly critical in tropical regions, where development finance institutions and private investors shape land-use trajectories.

o Carbon Markets

Carbon markets represent an important mechanism for mobilizing finance for forest conservation, particularly through REDD+ and jurisdictional approaches. Under the UNFCCC, results-based payments are linked to verified emission reductions and can interact with voluntary or compliance markets. The literature highlights that the effectiveness of carbon markets depends on environmental integrity, including robust MRV systems, safeguards, and the avoidance of leakage and non-additionality (Schneider et al., 2019). Jurisdictional approaches are increasingly favored because they address these risks more effectively than project-based systems. Carbon markets are therefore best understood as one component of a broader financial architecture, rather than a standalone solution

o Development of international value chains for sustainable forest products

The development of international value chains for sustainable forest products is essential to create positive economic incentives for conservation. These include timber from sustainably managed forests, agroforestry systems, and non-timber forest products. Peer-reviewed studies show that agroforestry and diversified production systems can enhance biodiversity, carbon storage, and resilience while maintaining economic viability (Tscharntke et al., 2011). However, scaling these systems requires certification, traceability, infrastructure, and market access. This dimension is particularly relevant in tropical and dry forest regions, where conservation must be compatible with livelihoods.

o Action Agenda

Peer-reviewed literature highlights that non-state actor engagement is essential to closing the implementation gap, particularly because a significant share of deforestation is driven by private-sector supply chains and investment decisions (Gibbs et al., 2015; Pendrill et al., 2022). Voluntary commitments, when combined with transparency and monitoring systems, can reduce deforestation pressures, as demonstrated by supply-chain interventions such as the Soy Moratorium (Gibbs et al., 2015). However, the literature also emphasizes that voluntary initiatives alone are insufficient and must be embedded within broader governance frameworks to avoid leakage and ensure accountability (Börner et al., 2020).

Within this context, the Action Agenda contributes to forest conservation through several key functions. First, it facilitates coalition-building across sectors and geographies, enabling alignment between producers, buyers, financiers, and

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governments. Second, it supports standard-setting and norm diffusion, including the development of deforestation-free commitments, disclosure frameworks, and sustainability standards. Third, it mobilizes finance and investment commitments, particularly from private actors, to complement public and concessional finance mechanisms.

The Action Agenda also plays a role in advancing jurisdictional and landscape-scale approaches, which are increasingly recognized as necessary to align supply-chain commitments with territorial governance systems. By encouraging companies and financial institutions to engage at jurisdictional scales, the Action Agenda helps reduce fragmentation and improve the effectiveness of interventions (Stickler et al., 2018).

However, both policy analyses and peer-reviewed literature identify important limitations. A central challenge is the lack of enforceability and heterogeneity in commitment quality, which can lead to uneven implementation and limited impact (Börner et al., 2020). In addition, there is a risk of misalignment between voluntary initiatives and national policies, particularly in countries with weak governance or conflicting economic incentives.

To address these limitations, the literature suggests that the Action Agenda should be more tightly integrated with UNFCCC mechanisms and national policies. This includes:

- Linking corporate commitments to national REDD+ strategies and MRV systems;
- Aligning financial-sector pledges with results-based finance frameworks and jurisdictional programs;
- Enhancing transparency through standardized reporting and independent verification;
- Ensuring that initiatives incorporate equity, including the rights of Indigenous Peoples and local communities, which are critical for long-term effectiveness (Börner et al., 2020; Pendrill et al., 2022).

In this sense, the Action Agenda should not be viewed as a substitute for formal climate governance, but as a complementary implementation platform that can accelerate action, mobilize resources, and test innovative approaches. Its effectiveness ultimately depends on its ability to bridge voluntary action with regulatory frameworks, financial systems, and territorial governance, ensuring that commitments translate into measurable and durable forest outcomes.

11. **International Regulatory and Institutional Adjustments and Improvements**

o Reforming multilateral regulations to make trade sustainable

International regulatory reform should reduce leakage by harmonizing trade rules and import requirements around deforestation- and conversion-free standards while remaining compatible with just-transition strategies in producer countries.

o Repression of environmental and related crimes at the transnational and national levels

Repressing forest crime will require stronger cross-border cooperation, interoperable traceability, anti-money-laundering tools, asset recovery, and better coordination among environmental, judicial, and financial authorities.

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o Access and benefit-sharing

International reforms should also tackle subsidy structures, debt pressures, and sectoral planning failures that continue to incentivize land conversion and undercut forest protection. A formal mechanism for joint work across the Rio Conventions could help align national plans, finance, and approaches to rights and stewardship, reducing fragmentation across climate, biodiversity, and land agendas. The deforestation roadmap should also be coordinated with the roadmap on transition away from fossil fuels so that climate mitigation does not create new forest pressures, including through poorly governed biomass expansion.

Conclusions and Recommendations

The proposed Roadmap for Halting and Reversing Deforestation and Forest Degradation by 2030 provides a scientifically grounded and policy framework to move beyond commitments toward implementation. The central challenge is not a lack of knowledge, mandates, or instruments, but the persistent fragmentation across governance systems, financial architectures, and sectoral policies. Addressing this fragmentation is therefore the primary condition for success. A core conclusion emerging from the document is that forests must be treated as integrated biophysical systems rather than as isolated carbon stocks. Their role in regulating rainfall, temperature, hydrological cycles, and ecosystem stability directly underpins agricultural productivity, energy security, and economic resilience. Failing to incorporate these non-carbon functions into governance, finance, and monitoring systems results in systematic underinvestment in forest protection and restoration and ultimately increases systemic risk across economies.

The evidence compiled throughout the document reinforces that halting deforestation alone is insufficient. Forest degradation, particularly driven by fire, selective logging, and chronic disturbance, represents a major, under-accounted source of emissions and ecological decline. Without explicitly integrating degradation into MRV systems, finance mechanisms, and policy frameworks, efforts to achieve the 2030 targets will remain incomplete and potentially misleading in their reported progress. Another key conclusion is that economic and financial systems remain structurally misaligned with forest conservation. Current incentives continue to favor short-term land conversion over long-term ecosystem value, largely because the full economic contribution of standing forests, especially their regulatory functions, is not priced into markets, fiscal systems, or investment decisions. Correcting this misalignment requires embedding forest-related risks and dependencies into financial disclosures, public investment planning, and private capital allocation.

The document also demonstrates that effective solutions already exist and are replicable across regions when implemented as integrated packages rather than isolated interventions. Successful cases, from Brazil's PPCDAm to jurisdictional REDD+ and supply-chain agreements such as the Soy Moratorium, show that combining monitoring, enforcement, financial incentives, and territorial governance can significantly reduce deforestation while maintaining production. The key lesson is that scalability depends on coordination across institutions, sectors, and spatial scales. At the same time, the synthesis highlights that there is no single global pathway. Forest dynamics, drivers, and governance challenges vary significantly across tropical, temperate, and boreal systems. This implies that implementation must be biome-specific, supported by differentiated data systems, policy instruments, and governance approaches that reflect local ecological and socioeconomic conditions. From an implementation perspective, the document underscores that strengthening institutional capacity, land tenure security, and governance systems, particularly for Indigenous Peoples and local communities, is not ancillary but central. Evidence consistently shows that where rights are secure and governance is inclusive, forest outcomes are more durable and effective. In terms of restoration, a critical consideration is that it should not be framed as a substitute for conservation. While restoration is essential for recovering ecosystem services and carbon stocks, its costs, timelines, and uncertainties make it inherently less efficient than avoiding forest loss in the first place. Prioritization must therefore be spatially explicit and strategically aligned with ecological and socioeconomic objectives. Finally, the Roadmap implicitly calls for a shift in how progress is measured. Area-based metrics alone are insufficient. Monitoring systems must evolve to capture forest condition, ecosystem integrity, and functional outcomes, linking biophysical data with governance, economic, and social indicators. This shift is essential to ensure that reported progress reflects real improvements in ecosystem resilience and climate outcomes.

Achieving the 2030 objective will depend on transitioning from fragmented, sectoral approaches to an integrated implementation architecture that aligns science, policy, finance, and governance. This requires not only scaling existing solutions but also reconfiguring the underlying systems that currently incentivize forest loss. Without such systemic alignment, the gap between commitments and outcomes is likely to persist.

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