SCIENCE PANEL FOR THE AMAZON

POLICY BRIEF

THE AMAZON WE WANT
Science Panel for the Amazon

STRATEGIES FOR IMPLEMENTING AND SCALING UP FOREST RESTORATION IN THE AMAZON

Catarina Jakovac, Nathália Nascimento*, Silvia C. Gallegos, Danielle Celentano, Daniel Mascia Vieira, Carolina Cristina Fernandes, Silvio Brienza Junior, André Pellicciotti*

**co-leading authors*

KEY MESSAGES

(i) Parts of the Amazon region are approaching a critical tipping point. This transition towards lower biomass, local species extinction, and impoverished forests poses serious local, regional and global risks, underscoring the urgent need to halt deforestation, degradation and promote restoration. While signatory countries of international agreements have pledged to achieve zero deforestation and restore 30% of degraded ecosystems by 2030, progress in the Amazon has been limited and immediate action is needed.

(ii) Multiple restoration strategies are needed to achieve large-scale implementation across the Amazon. Strategies can be broadly classified as those that aim for full ecosystem recovery, such as natural forest regeneration and seed and seedling planting, or those that aim for partial ecosystem recovery with the production of goods, such as biodiverse agroforestry systems and biodiverse productive plantations. Each strategy provides distinct social and ecological benefits and requires unique enabling conditions (**Figure 1**). Aligning strategies with specific goals, socio-ecological opportunities and constraints, and cultural values will increase opportunities for effective long-term and large-scale restoration.

(iii) Ecological restoration, when combined with forest conservation, provides an opportunity to foster socio-bioeconomic development. Economic and social benefits include income generated from the production of seeds and seedlings, the implementation of restoration projects, the cultivation of forest-based crops, and the sustainable harvest of non-timber and timber products. These efforts support social inclusion, especially of youth and women, and capacity building.

(iv) Knowledge integration and the protagonism of Indigenous Peoples and local communities are key for restoration to be ecologically effective and socially just, improving Amazonian peoples' lives and rescuing and protecting their cultural values and beliefs.

RECOMMENDATIONS

(i) Create national roadmaps for forest restoration that align with international commitments and integrate national and local governance efforts. This strategy is crucial for fostering cross-sector collaboration, achieving long-term restoration goals, and advancing the socio-bioeconomic development of the Amazonian region.

(ii) Include conservation of primary and secondary forests and protection against deforestation and degradation, in restoration public policies and public and private restoration programs.

(iii) Recognize and promote natural forest regeneration as a restoration strategy in locations that have suffered low historical degradation. This is key for achieving large-scale restoration at low costs and with high ecological benefits.

(iv) Develop a restoration supply chain for the production of native seeds and seedlings, mainly through subsides, regulations and investment in infrastructure and logistics. This is urgently required to guarantee the quantities and diversity of species needed for the effective implementation of active restoration.

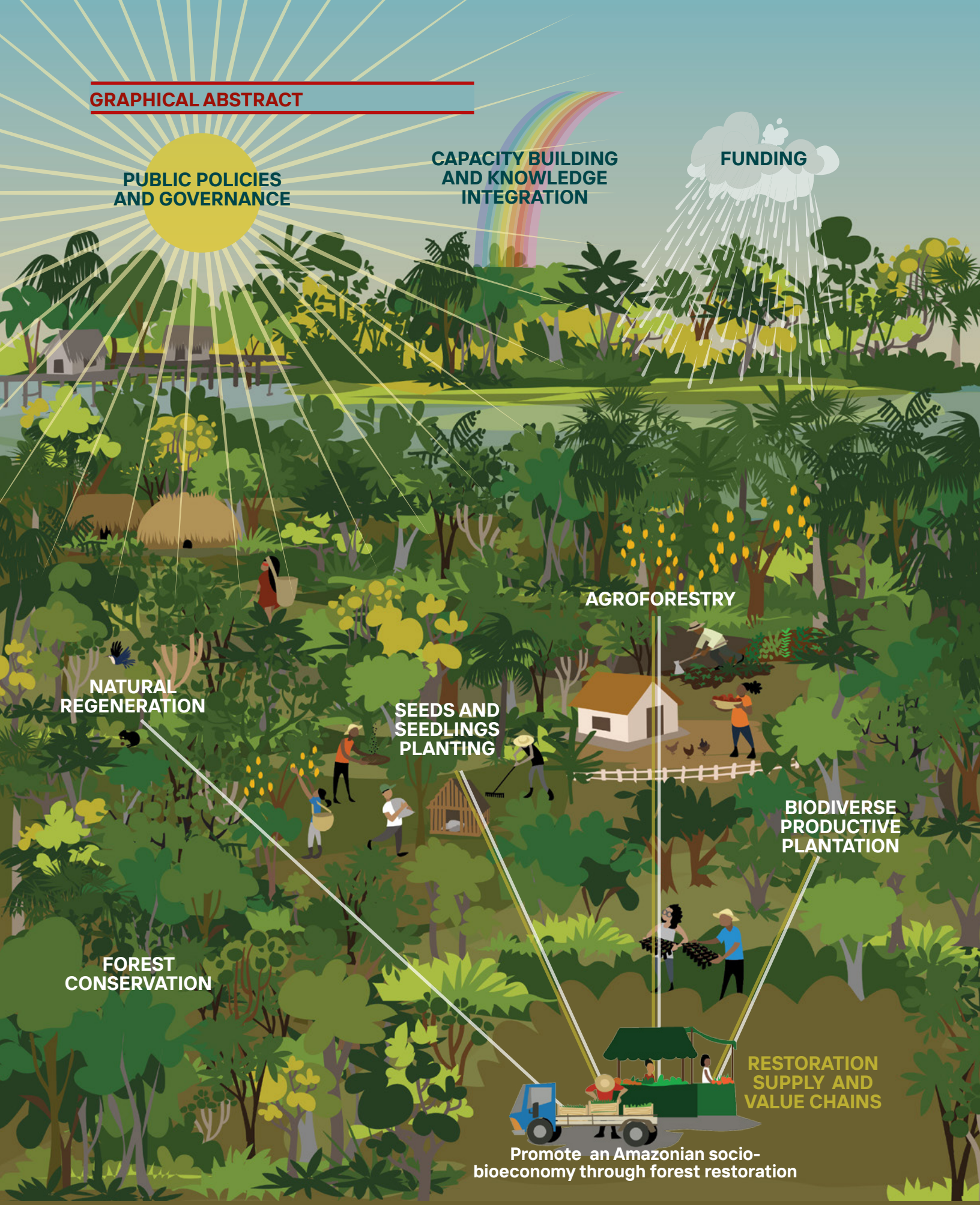
(v) Strengthen Amazonian socio-bioeconomies of standing forests and flowing rivers to promote productive restoration. This requires redirecting financial flows from activities that drive deforestation to those that promote restoration, implementing tax exemptions, and investing in infrastructure to guarantee the quality and flow of supplies and forest products.

(vi) Promote capacity building and the integration of scientific and Indigenous and local knowledge. This is crucial for designing effective restoration programs, engaging communities, and guaranteeing long-term ecologically and socially sound restoration efforts that align with local cultural values.

(vii) Secure financing mechanisms that consider the specific needs of different stages of the restoration process, which include planning, engaging stakeholders, implementation, maintenance, monitoring, adaptive management, and long-term protection against degradation. Additionally, payment for ecosystem services and subside or credit lines for productive forest restoration must be regulated and promoted.

(viii) In summary, seven priority actions are required to upscale restoration in the Amazon: (1) conserve and protect primary forests; (2) promote natural forest regeneration and conserve secondary forests; (3) develop a restoration supply chain; (4) strengthen Amazonian socio-bioeconomies; (5) promote awareness, capacity building, and knowledge integration; (6) strengthen public policies and governance; and (7) secure funding for effective restoration.

GRAPHICAL ABSTRACT



1. THE NEED FOR ECOLOGICAL RESTORATION IN THE AMAZON

The Amazon region is facing a critical transition to a state of permanent degradation with local and global consequence[1]. Immediate action is therefore required to stop deforestation, forest degradation, and fires, while promoting ecological restoration[2]. By signing the Paris Agreement and the Kunming-Montreal Global Biodiversity Framework, most Amazonian countries have pledged to achieve zero deforestation and restore 30% of degraded ecosystems by 2030. However, with just six years until the deadline, overall progress has been minimal. The record-breaking fires and droughts of 2023-2024[3] continue to demonstrate the increasing urgency to conserve and restore the biome with immediate action and stronger governance.

According to the UN Decade on Ecosystem Restoration, "ecosystem restoration means assisting the recovery of ecosystems that have been degraded or destroyed, along with the conservation of ecosystems that are still intact." This includes a range of practices, such as impact reduction, remediation, rehabilitation and ecological restoration[4]. This brief focuses on ecological restoration strategies that seek to fully or partially recover ecosystem structure, composition, and functions[5].

The goal of full ecosystem recovery requires restoring all key ecosystem attributes to closely resemble a primary or high-integrity reference system[5,6]. However, partial ecosystem recovery is usually the goal when restoration also aims to produce goods, such as through biodiverse agroforestry, biodiverse productive tree plantations, or the recovery of cultural values (biocultural restoration). Ecological restoration does not include monocultural forest plantations (e.g., eucalyptus, oil palm) because they offer low conservation value and limited capacity to restore ecosystem processes, and have commonly been drivers of deforestation in the tropics[7].

Ecological restoration is essential to stop and reverse biodiversity loss and maintain ecosystem services, such as climate regulation, soil and water conservation, and the provision of forest-based products. Large-scale restoration also boosts resilience to climate change and enhances human well-being by improving environmental conditions and creating economic opportunities. Forest conservation, protection and restoration reduce the costs and risks of agricultural production in deforested and degraded landscapes, like the Arcs of deforestation (**Figure 2**). Reducing deforestation in the Southern Brazilian Amazon, for example, could save up to 1 billion USD in agricultural losses annually by improving hydrological regulation[8].

This policy brief builds on previous recommendations of the Science Panel for the Amazon[2] to offer guidance for achieving large-scale ecological restoration in the Amazon. It suggests strategies based on state-of-the-art restoration science and practices to effectively implement forest restoration across the region's diverse socio-ecological realities. While the focus of this brief is on non-flooded forest ecosystems, the most extensive in the biome (**Figure 2**), other important freshwater ecosystems like wetland forest and tropical savanna systems urgently require other dedicated studies.

2. RESTORATION STRATEGIES FOR THE AMAZON´S SOCIO-ECOLOGICAL DIVERSITY

The diversity of ecological and socio-economic conditions in the Amazon requires multiple restoration strategies tailored to local contexts. Ecological settings in the region range from resilient landscapes with a predominance of old-growth forests to old agricultural frontiers dominated by extensive croplands and pastures (**Figure 2**). Socio-economic contexts include a variety of private, communal, and public lands, each with distinct socio-economic and legal constraints and opportunities[9] (**Figure 2**). The presence of diverse groups, such as Indigenous Peoples, Afro-descendent communities, riverine communities, and migrants adds to the range of cultural values and goals.

This brief focuses on four restoration strategies and provides an overview of where in the Amazon each method could fit best, emphasizing their distinct socio-economic and ecological benefits and requirements (**Figure 1**). However, to guarantee long-term restoration success and permanence, final decisions on restoration strategies must be made together with local stakeholders and align with their needs and goals.

Natural forest regeneration (passive restoration) refers to the spontaneous or assisted regeneration of forests in deforested and degraded areas, resulting in secondary forests[10]. Natural forest regeneration thrives only in less degraded landscapes with high forest cover[11], a low to mid-intensity land-use history with few

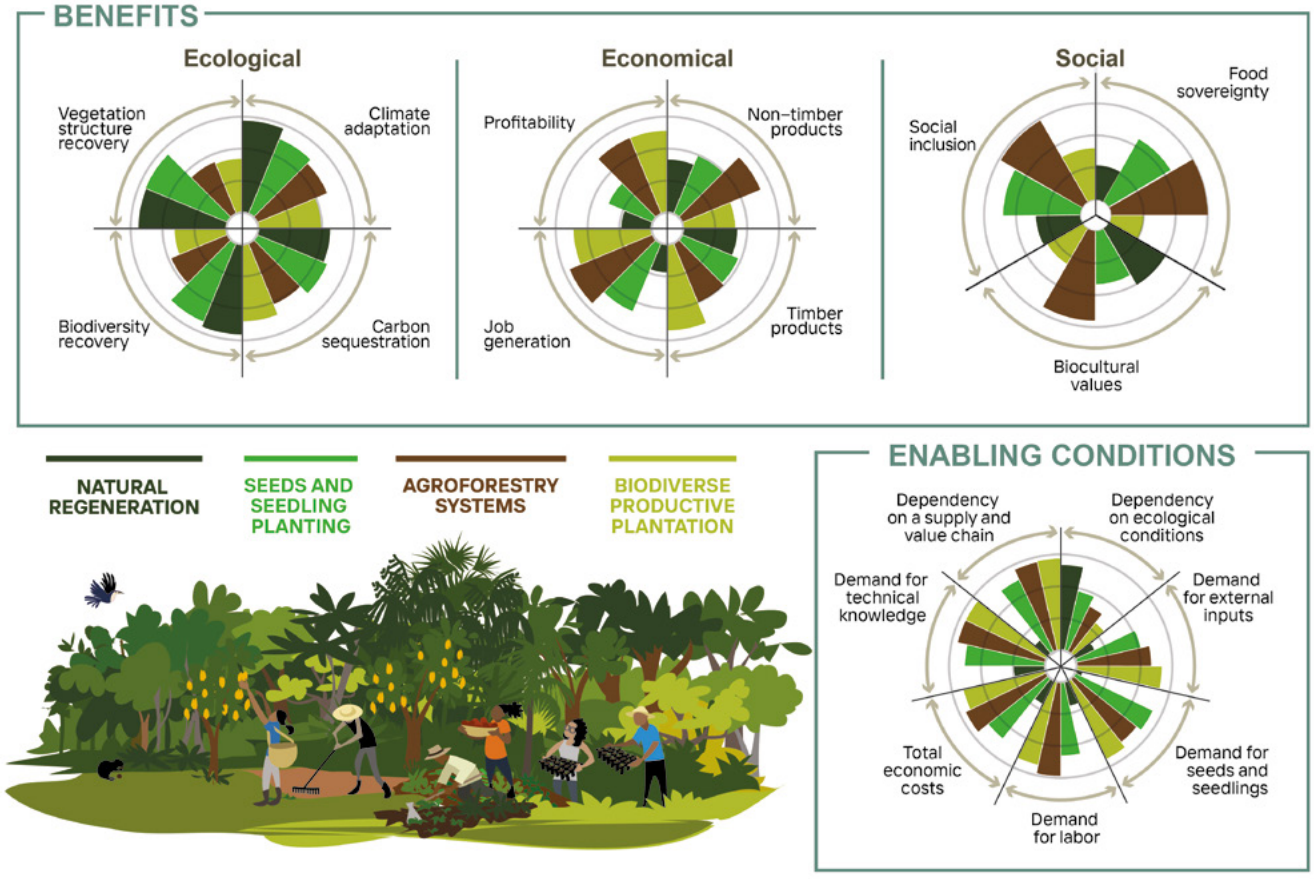


Figure 1: **Socio-Ecological Benefits and Enabling Conditions of Four Main Ecological Restoration Strategies.** Based on expert opinion, we attributed values from 0 to 3 (none, low, intermediate, and high) for each axis in the radar plots. In the upper graphs, the axes of the radar plots represent potential of ecological, social and economic benefits of each of the four restoration strategies: natural forest regeneration, seeds and seedling plantings, biodiverse agroforestry systems and biodiverse productive plantations. In the lower graph, the axes represent the socio-ecological conditions required for each of the four restoration strategies to thrive.

fire events, short duration of continuous land use, and no mechanized agriculture[12,13] (**Figure 1**). It is the cheapest restoration method, costing 300-650 USD ha^{-1} for protecting against disturbances, such as fires and cattle[14–16]. Management practices to assist regeneration can be applied to amplify the benefits of natural forest regeneration and improve forest recovery, although increasing its costs[17]. Under ecological conditions of low degradation, natural forest regeneration can recover high biodiversity levels and ecosystem processes at low economic costs (**Figure 1**), fostering resilient forest communities.

The use of seed and seedling plantings aiming for full ecosystem recovery (active restoration) refers to the planting of a diversity of native tree species to kick start forest recovery. Seed addition and seedling planting can be five to ten times more expensive than natural forest regeneration, costing 1,400-4,000 USD ha^{-1} and 3,000-7,000 USD ha^{-1}, respectively[14–16,18] (**Figure 1**). Most costs are related to soil preparation and amendments; supplies, such as seeds, seedlings, and fertilizers; and labor for planting and maintenance during the first 30 months after implementation[18]. However, restoration plantings provide direct and indirect social benefits, including the creation of income opportunities[19] within a restoration supply chain (**Figure 1**; Section 3.3). Active restoration also has the potential to deliver high ecological benefits, depending on the level of local and landscape degradation and planted species composition (**Figure 1**). It is needed for full ecosystem recovery in areas with low potential for natural forest regeneration and is well-suited for contexts characterized by low economic constraints and high accessibility to supplies, such as those found in the Arcs of deforestation (**Figure 2**).

Biodiverse agroforestry systems are sustainable farming practices that combine high diversity of native trees, shrubs, and herbs with crops[20]. They can deliver an array of food and forest products, contributing to diversifying income sources and enhancing food sovereignty, while partially recovering biodiversity and ecosystem processes (**Figure 1**). However, they are labor-demanding due to intensive and continuous management requirements, with costs varying from 1,500 to 4,700 USD ha^{-1}, depending on the availability of family labor or hired personnel[15,16]. This practice is common among smallholder farmers in the Amazon[21], as it enhances food sovereignty and aligns with Indigenous and local knowledge and cultures, serving as a suitable option especially for family farming within and outside protected areas (**Figure 2**).

Biodiverse productive plantations consist of consortia of multiple native species used for the selective harvesting of timber and non-timber forest products without clearcutting, also known as mixed plantations[22] and in Brazil as "*silvicultura de espécies nativas*"[23]. They demand good-quality seedlings and the application of silvicultural practices, being expensive to implement and maintain, with costs ranging from 3,700 to 4,600 USD ha^{-1} [15,16] (**Figure 1**). By optimizing productivity and biodiversity, ecosystem recovery in biodiverse productive plantations is lower than in other restoration strategies (**Figure 1**). It requires significant economic investment and access to technical knowledge, supplies, and labor. It is suitable for contexts with access to specific funding and markets of forest products, and where income generation is imperative. Biodiverse productive plantations are appealing economic alternatives to traditional commodities for private owners in the Arcs of deforestation and degradation (**Figure 2**).

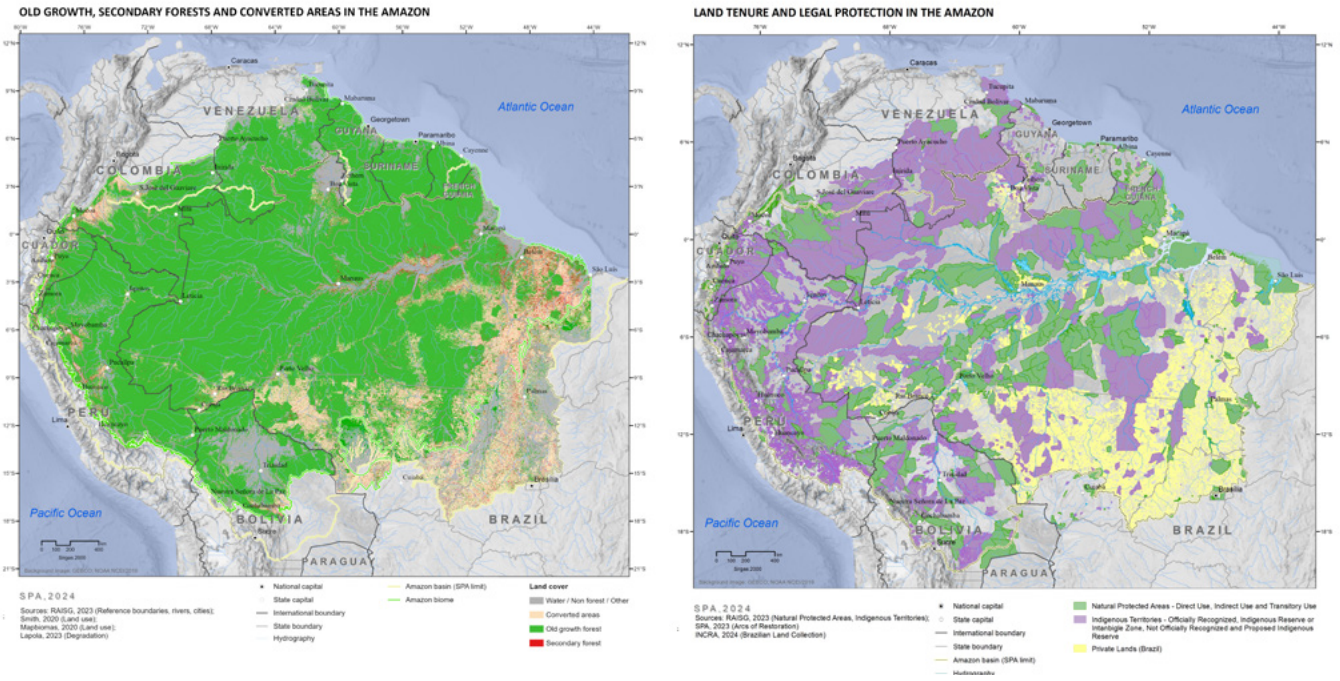


Figure 2: **Standing Forests, Deforested Areas, and Social Contexts Related to Land Tenure and Legal Protection.** To the left, a land cover map showing forest cover (demonstrating old-growth, degraded, and secondary forests) and deforested areas (including productive and unproductive lands). To the right, a map showing the location of protected areas, Indigenous territories and private lands (this last, only available for Brazil). Together, the maps show the predominance of private properties in the Arcs of deforestation, where forest restoration and protection are most urgently needed. Within these landscapes, opportunities are greater for seed and seedling plantings and productive forest restoration because of the low forest cover and the long-term land use, which restrict natural forest regeneration capacity. Indigenous Territories and protected areas may provide opportunities for natural forest regeneration, biodiverse agroforestry systems, and sourcing seeds for the restoration supply chain.

3. PRIORITY ACTIONS FOR UPSCALING FOREST RESTORATION

Upscaling forest restoration in the Amazon through the implementation of multiple restoration strategies that respect socio-ecological contexts requires seven priority actions to be executed in tandem: (1) conserve and protect primary forests; (2) promote natural forest regeneration and conserve secondary forests; (3) develop a restoration supply chain; (4) strengthen Amazonian socio-bioeconomies (5) promote awareness, capacity building and knowledge integration; (6) strengthen public policies and governance; and (7) secure funding for effective restoration.

3.1 Conserve and Protect Primary Forests

Primary forests (also known as “old-growth forests”) are forests that have not been clear-felled in modern history, but might have been subject to human interventions and management[24,25]. Primary forests must be conserved because they are irreplaceable in their biodiversity conservation value[26] and the provision of ecosystem services[27] and timber and non-timber forest products (NTFP)[22]. They are much easier, faster, and economically cheaper to conserve than to restore. Furthermore, standing forests regulate the climate[28], helping to avoid critical ecosystem transitions[1], and provide the seeds and animals necessary for full ecosystem recovery in restoration initiatives[11].

Deforestation and forest degradation undermine restoration efforts by transforming the local climate to hotter and drier conditions, causing local extinctions of plant and animal species and reducing seed availability and dispersal to restoration areas. Biomass and carbon recovery are reduced by 38% in landscapes with less than 40% forest cover compared to those with higher forest cover[11]. Higher amounts of forest cover in the landscape promote faster recovery and higher biodiversity levels in regenerating forests, fostering restoration success[29,30]. Forest conservation, therefore, must be included as a primary goal in private and public restoration programs and financing schemes. Standing degraded forests must also be protected from further degradation and restored[2].

Forests must especially be protected where deforestation pressure is the highest, such as in undesignated lands and in private properties in the Arcs of deforestation (**Figure 2**), where conventional, unsustainable economic models continue to expand through the forest (e.g., agribusiness in Bolivia and Brazil, coca plantations in Bolivia and Colombia, and oil palm plantations in Colombia, Brazil, and Ecuador)[2]. Restoration and conservation actions should not compete for attention and resources, but instead be allies in avoiding an Amazon tipping point by transforming the borders of the region into "Arcs of Restoration"[2].

3.2 Promote Natural Forest Regeneration and Conserve Secondary Forests

Natural forest regeneration can serve as a cost-effective strategy to upscale restoration if ecological conditions are adequate and there is willingness to protect the resulting secondary forests in the long-term[31]. The willingness to allow natural forest regeneration increases where there is minimal competition for productive land uses and there is a long-term commitment to protect the area from degradation (e.g., fire, cattle). In such contexts, natural forest regeneration is more efficient than any other restoration strategy (**Figure 1**).

Across the Amazon biome, forests are naturally regenerating in approximately 19 million hectares (estimates from 2020 by Smith et al. 2023[32]; **Figure 2**). From this total, about 7 million ha experience the fallow period of shifting cultivation systems that support local food production[33]. The remaining approximately 12 million ha compose ephemeral secondary forests that are recleared within less than 10 years[33]. These secondary forests help connect old-growth forest fragments by protecting them from degradation[32]. The long-term conservation of secondary forests, therefore, could serve as a major contribution to large-scale ecological restoration.

Encouraging people to allow natural forest regeneration and to conserve secondary forests in the long term involves recognizing these practices as a viable restoration strategy in the policy, finance, and implementation arenas (as the Brazilian Forest Code does), and regulating their use and management[34]. The potential to provide provisioning and regulating services increases with the age of secondary forests[35,36]. The combination of sustainable forest management with payments for ecosystem services, such as carbon and biodiversity credits, can further encourage landowners to conserve these areas, rather than clearing them for low-income, degrading uses.

Natural forest regeneration can be promoted in recently illegally deforested (public and private) lands because they still have high resilience; in protected territories, such as Indigenous territories and conservation units, where forest cover is high; and in legally protected areas within public and private lands, where there is low competition with other land use systems[2,37] (**Figure 2**).

3.3 Develop a Restoration Supply Chain

A robust restoration supply chain is crucial for guaranteeing the amount and diversity of seeds and seedlings needed for active and productive forest restoration (**Figure 1**). A restoration supply chain is characterized by three main links: (i) seed collection and processing, (ii) seedling production and commercialization, and (iii) restoration services and monitoring.

Upscaling restoration requires amplifying seed and seedling production. Currently, the Amazon region has limited groups of seed collectors[i] and seedlings nurseries. Restoring 1.25 million km² (125 million hectares) would require more than double the capacity of existing nurseries in the Brazilian Amazon[38]. Expanding production involves facilitating social engagement, promoting capacity building, reducing costs through tax exemptions for native seed commercialization[39], and investing in infrastructure and logistics. Additionally, government regulation of native seed production is essential to ensure seed provenance, identity, phenotypic diversity, and safe sanitary conditions[39]. These regulations must be balanced as excessive restrictions can hinder the development and viability of the activity.

A restoration supply chain will generate income opportunities and multiple social co-benefits. Expanding nurseries for native plant species could yield 34-146 million USD as income for seed collectors[40]. Social co-benefits include empowering Indigenous Peoples and local communities, building local agency capacity, and fostering social innovation and resilience[41]. Involving Indigenous Peoples and local communities in a restoration supply chain will promote social inclusion, diversify incomes, and support the preservation of Indigenous and local knowledge and cultural values.

Every location in the Amazon can be part of the restoration supply chain (**Figure 2**). Seed collection, particularly for endemic and endangered species, can be an opportunity in protected areas and Indigenous territories. Pioneer species, crucial for tree plantings, can be sourced from secondary forests close to restoration sites. Prioritizing the supply of seeds and seedling nurseries is crucial in the Arcs of Restoration, where natural forest regeneration might be low and plantings are needed. Additionally, creating platforms to connect producers and consumers within the restoration supply chain will enhance its effectiveness.

3.4 Strengthen Amazonian Socio-Bioeconomies of Standing Forests and Flowing Rivers

Adding economic value to restoration will help motivate landowners to exchange traditional commodities for native forests and productive restoration systems (**Figure 1**). Diversifying income sources through restoration will help build Amazonian socio-bioeconomies[42] and reduce reliance on subsidized monoculture crops and low-productivity pastures. It will also

i https://www.sementesflorestais.org/mapa-das-sementes.html

promote goods that require less mechanized cultivation, suited to family farming, Indigenous peoples, and local communities.

Public policies and incentives for building Amazonian socio-bioeconomies are, therefore, essential to increase the viability of productive forest restoration (**Figure 1**). Investing in structuring a supply chain will reduce restoration costs, creating specific credit loans and insurance schemes for biodiverse agroforestry and biodiverse productive plantations will reduce risks and increase adoption, and investments in logistics will enable the flow forest-based crops and fruits, timber, and non-timber forest products from restoration areas to agroindustries and consumers.

Payment for ecosystem services through carbon and biodiversity credits can complement income streams and help cover restoration costs. To ensure socially just and ecologically meaningful productive restoration efforts, these markets must be regulated. It is important to note that focusing solely on carbon sequestration may lead to low-diversity seedling plantings, while high-integrity biodiversity credits may encourage high-diversity forest restoration.

For effective implementation, forest restoration and socio-bioeconomies must be integrated into cross-cutting national, subnational, and local government agendas. For example, the Plan for the restoration of native vegetation in the State of Acre[43] in Brazil is promoting them through three strategies: (1) creating clear legal norms and handbooks for farmers and government agencies under the scope of the Federal Forest Code, (2) leveraging public and private investments to support payment for ecosystem services and market access for socio-biodiversity products, and (3) encouraging restoration in adjacent properties to maximize economies of scale and foster local cooperation especially for smallholder farmers.

Productive forest restoration should focus on areas where local people can benefit most, including private, communal, and Indigenous territories. Agroforestry systems may appeal to family farmers and Indigenous communities with knowledge of these practices, while biodiverse productive plantations could incentivize restoration in medium- and large-scale properties in the Arcs of Restoration, especially where the potential for natural forest regeneration is low (**Figure 2**).

3.5 Promote Awareness, Capacity Building, and Knowledge Integration

To maximize the impact and success of restoration practices, it is crucial to promote capacity building and the integration of scientific, Indigenous and local knowledge. Those involved in restoration efforts and in forest and rural extension programs — such as practitioners, technicians, researchers, consultants, government agents, and decision-makers — must be well-versed in available restoration methods, natural regeneration potential, and monitoring approaches.

The knowledge of the plant and animal biodiversity of Amazonian ecosystems is vital for promoting diverse restoration, ensuring proper monitoring, and preventing biodiversity loss[44]. Training programs should be provided for practitioners to support the choice of the restoration method and to define and disseminate best practices for seed collection and seedling production in order to increase

restoration effectiveness and minimize undesired impacts on forests[45]. Field guides for plant identification [46,47] and best-practices manuals should be disseminated to restoration practitioners, consultants, and technical staff of government agencies.

Integrating the knowledge of Indigenous Peoples and local communities with scientific knowledge is crucial for co-designing restoration strategies that are resilient to changing environmental conditions and suitable for various socio-ecological contexts[48]. Engaging local actors in the entire restoration process and empowering local peoples[49] will create conditions for the long-term persistence of restored forests. Such integration will also contribute to strengthening and restoring cultural practices and values through biocultural restoration.

3.6 Strengthen Public Policies and Governance

To promote large-scale forest restoration in the Amazon, countries must prioritize the implementation of international agreements, cooperate and share knowledge and technology, strengthen national and subnational restoration governance, and engage multiple sectors in the restoration process.

At the international level, cooperation among Amazonian countries can enhance national policy development and secure financial resources. Countries must work towards the goals of the Leticia Pact and the Belém Declaration, focusing on tools for monitoring deforestation, protecting standing forests, and implementing restoration initiatives. Strengthening cross-country platforms, such as the Amazon Regional Observatory (ARO) under the Amazon Cooperation Treaty Organization (ACTO), is essential, and should be supplemented by the establishment of a forest restoration observatory. This initiative could benefit from collaboration with regional coalitions, like the Alliances for Restoration in Brazil and Colombia, which are uniting various stakeholders from different sectors to empower the restoration community.

At the national level, countries must prioritize public policies for conservation, restoration. and the sustainable use of lands and forests[50]. Urgently redirecting policies and funding away from deforestation-driving activities to those supporting restoration––such as protecting and conserving primary and secondary forests (Sections 3.1 and 3.2), activating a restoration supply chain (Section 3.3), and creating robust socio-bioeconomies (Section 3.4) –– will lower costs and create economic opportunities for local communities, further motivating restoration on the ground. Tax incentives and regulations can encourage restoration on private lands, particularly in agricultural frontiers. Regulating payment for ecosystem services can help ensure socially just and ecologically meaningful restoration efforts. Addressing land tenure issues can reduce investment risks in restoration and facilitate private sector funding.

At the subnational scale, identifying priority areas for restoration and the implementation of specific restoration strategies will help channel resources, increase sustainable infrastructure investments, and prioritize public policies where they are most needed. This should be accomplished with the inclusion of local governments and stakeholders and the consideration of various opportunities, constraints, and interests across the region.

Monitoring programs must be a priority in order to support law enforcement, the tracking of international target achievements, and adaptive management and governance efforts. Such programs must include remote sensing monitoring tools, databases for registering and tracking restoration initiatives, and platforms for defining indicators and reference values for measuring the success (and failure) of restoration.

By promoting public policies, decentralized governance, and community engagement, governments can create the conditions for scalable, resilient forest restoration across the Amazon. National and subnational restoration agendas, aligned with international commitments, would help ensure that all sectors work together towards long-term restoration goals in ways that integrate conservation, economic development, and social justice for Amazonian communities.

3.7 Secure Funding for Effective Forest Restoration

Forest restoration can be expensive depending on the chosen strategy and level of degradation. Major expenses include land opportunity costs, protection measures, supplies, and labor. Restoration costs can be reduced through the conservation of standing forests (because they boost biodiversity recovery and do not need to be restored), the identification of priority areas for restoration[51], the promotion of natural forest regeneration where possible, the implementation of tax exemptions along a restoration supply chain, and the decentralization of infrastructure.

The private sector, non-governmental organizations, and governments must invest in the six priority actions described above, which are essential to enable restoration across the Amazon. Investments in infrastructure, capacity building, and logistics are crucial to allow for the implementation of the different restoration strategies where they are best suited. Platforms that connect financiers to areas available for restoration will help accelerate and upscale restoration.

Government programs can significantly boost restoration efforts. The Brazilian Development Bank (BNDES), for instance, is investing 36 billion USD to restore 24 million hectares and remove 1.65 billion tons of CO_2 by 2050 through its “Arc of Restoration” program. Regulated programs of payment for ecosystem services that include water, biodiversity, and biocultural benefits could be strengthened to help motivate landowners to restore and protect forests[52]. New initiatives, like private concessions for restoring public lands[53], and support for family farming, can enhance these efforts, provided they prioritize equity and biodiversity recovery.

Financing mechanisms for restoration should account for the specific needs and distinct phases of the restoration process, rather than focusing solely on the implementation stage. Essential steps include planning, stakeholder engagement, implementation, maintenance, monitoring, adaptive management, and safeguarding against degradation factors, such as cattle, fire, and illegal activities. Flexibility in resource allocation and timelines is crucial, as these may vary with regional conditions and the selected restoration strategies. Additionally, it is critical to establish mechanisms that ensure long-term protection, allowing for recovery processes that may span several decades.

GLOSSARY

Amazonian socio-bioeconomies are economies based on the sustainable use of healthy standing forests and flowing rivers. They involve activities that preserve cultural diversity and multifunctional landscapes, while enhancing the economic and social value of the region's biodiversity and agrobiodiversity [42].

Productive forest restoration aims to restore ecosystem functions and generate economic benefits. It includes strategies based on native species that create and maintain a forest structure over time and also provide forest crops and products, including Agroforestry and Biodiverse productive plantations [23].

Biocultural restoration aims to restore biophysical and sociocultural values based on the co-design of restoration strategies that address local needs and recover interdependent social–ecological systems [54,55].

Primary forests are those that originated through primary succession, that is, they have never been clear-felled in modern history[56]. Primary forests may have been managed by Indigenous Peoples and local communities[57].

Secondary forests are those that originated through secondary succession, that is, regenerated spontaneously in areas that were previously deforested by clearcutting[12]. Secondary forests might be at initial, intermediate, or advanced successional stages. Stands at advanced successional stages are often also called "old-growth forests" or "mature forests."

Old-growth forests is a term used to describe stands that are similar to primary forests in their composition, diversity, function, and structure, but whose origin from primary or secondary succession is unknown[58].

Degraded forests are primary or old-growth forests that suffered or are suffering occasional or chronic deleterious changes in forest conditions, such as ecosystem functions, properties, services, and species composition. Degradation can be caused by logging, edge effects, extreme droughts, fire, and other drivers[56].

4. ACKNOWLEDGEMENTS

The authors extend their gratitude to everyone who contributed to this policy brief. Special thanks go to the SPA Science Steering Committee members, including Jos Barlow, Marielos Peña-Claros, and Carlos Nobre, for their expert insights. The authors also appreciate the valuable peer reviews provided by Daniel Larrea-Alcazar, Paola Johanna Isaacs Cubides, Camila Loureiro Dias, Plinio Sist, and Corine Vriesendorp. The authors also wish to thank the contributors to the Public Consultation, including Géraldine Derroire, Karen Holl, Jürgen Kesselmeier, Sofia Corradi Oliveira, Aurelio Padovezi, Lourens Poorter, Camilo Torres Sanchez, Marcus Vinícius C. Schmidt, Carlos Sornoza, Trevor Walter, Jorge Watanabe. For their contributions to our effort to capture various measures of benefits and the conditions required for different restoration methods, we are thankful to Pedro Brancalion, Géraldine Derroire, Marcelo Lucian Ferronato, Roosevelt García-Villacorta, Aurélio Padovezi, Charles Clement, Karen Holl, John Parrota, and Lourens Poorter. We also thank Charlotte Smith for kindly sharing the secondary forest land cover maps. We are also grateful to the SPA Technical-Scientific Secretariat, particularly Julia Arieira (for general support coordination), Julie Topf (for copy-editing), and Diego O. Brandão (for the Portuguese translation) and Federico Viscarra (for the Spanish translation).

REFERENCES

1. Flores, B. M. *et al.* Critical transitions in the Amazon forest system. *Nature 2024 626:7999* 626, 555–564 (2024).

2. Barlow, J. *et al. Policy Brief: Transforming the Amazon through 'Arcs of Restoration'*. (2022) doi:10.55161/KJCS2175.

3. Costa, F. R. C. *et al. Policy Brief: Droughts in the Amazon*. (2024) doi:10.55161/LVYB6857.

4. Nelson, C. R. *et al. Standards of Practice to Guide Ecosystem Restoration - A Contribution to the United Nations Decade on Ecosystem Restoration 2021-2030. Rome, FAO, Washington, DC, SER & Gland, Switzerland, IUCN CEM*. (FAO; SER; IUCN;, Rome, Washignton, Switzerland, 2024). doi:10.4060/CC9106EN.

5. Gann, G. D. *et al.* International principles and standards for the practice of ecological restoration. Second edition. *Restor Ecol* 27, S1–S46 (2019).

6. Rosenfield, M. F. *et al.* Ecological integrity of tropical secondary forests: concepts and indicators. *Biological Reviews* 98, 662–676 (2023).

7. Almeida-Maués, P. C. R., Bueno, A. S., Palmeirim, A. F., Peres, C. A. & Mendes-Oliveira, A. C. Assessing assemblage-wide mammal responses to different types of habitat modification in Amazonian forests. *Sci Rep* 12, (2022).

8. Leite-Filho, A. T., Soares-Filho, B. S., Davis, J. L., Abrahão, G. M. & Börner, J. Deforestation reduces rainfall and agricultural revenues in the Brazilian Amazon. *Nature Communications 2021 12:1* 12, 1–7 (2021).

9. Nascimento, N. & Brancalion, P. H. S. Bioeconomia e restauração florestal na Amazônia. in *Bioeconomia para quem? Bases para um desenvolvimento sustentável na Amazônia* (eds. Marcovitch, J. & Val, A.) (Universidade de São Paulo. Escola de Comunicações e Artes, 2024). doi:10.11606/9786589321453.

10. Pickett, S. T. A., Collins, S. L. & Armesto, J. J. Models, mechanisms and pathways of succession. *The Botanical Review* 53, 335–371 (1987).

11. Bello, C. *et al.* Frugivores enhance potential carbon recovery in fragmented landscapes. *Nat Clim Chang* 14, 636–643 (2024).

12. Jakovac, C. C. *et al.* The role of land-use history in driving successional pathways and its implications for the restoration of tropical forests. *Biological Reviews* 96, 1114–1134 (2021).

13. Heinrich, V. H. A. *et al.* Large carbon sink potential of secondary forests in the Brazilian Amazon to mitigate climate change. *Nature Communications 2021 12:1* 12, 1–11 (2021).

14. Brancalion, P. H. S. *et al.* What makes ecosystem restoration expensive? A systematic cost assessment of projects in Brazil. *Biol Conserv* 240, 108274 (2019).

15. SEMAS-PA. *Plano Estadual de Recuperação Da Vegetação Nativa Do Estado Do Pará PRVN-PA*. (2023).

16. Sousa, G. F. *et al. Guia Synergia de Restauração Florestal Na Amazônia: Soluções Baseadas Nas Pessoas*. (Centro de Estudos Synergia, SãoPaulo, 2024).

17. Alves, A. A. *et al. Identificação Das Oportunidades e o Potencial Do Impacto Da Bioeconomia Para a Descarbonização Do Brasil* . (2022).

18. Brancalion, P. H. S. *et al.* Global restoration opportunities in tropical rainforest landscapes. *Sci Adv* 5, eaav3223 (2019).

19. Brancalion, P. H. S. *et al.* Ecosystem restoration job creation potential in Brazil. *People and Nature* 4, 1426–1434 (2022).

20. Smith, N. J. H., Falesi, I. C., Alvim, P. D. T. & Serrão, E. A. S. Agroforestry trajectories among smallholders in the Brazilian Amazon: Innovation and resiliency in pioneer and older settled areas. *Ecological Economics* 18, 15–27 (1996).

21. Alliance for Restoration in the Amazon. *Forest Landscape Restoration in the Amazon – Overview and Paths to Follow*. (2020).

22. Sist, P. *et al. Forest Management for Timber Production and Forest Landscape Restoration in the Amazon: The Way towards Sustainability*. (2023) doi:10.55161/WXNQ3205.

23. Brienza Júnior, S., Yared, J. A. G. & Martorano, L. G. Silvicultura de espécies nativas para restauração socioprodutiva na Amazônia. *Revista Opiniões* 68–69 (2023).

24. CBD. First draft of the Post-2020 global biodiversity framework. *https://www.cbd.int/doc/c/abb5/591f/2e46096d3f0330b08ce87a45/wg2020-03-03-en.pdf* (2021).

25. Lapola, D. M. *et al.* The drivers and impacts of Amazon forest degradation. *Science (1979)* 379, (2023).

26. Barlow, J. *et al.* Quantifying the biodiversity value of

tropical primary, secondary, and plantation forests. *Proc Natl Acad Sci U S A* 104, 18555–18560 (2007).

27. Gibson, L. *et al.* Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature* 478, 378–381 (2011).

28. Beveridge, C. F. *et al.* The Andes-Amazon-Atlantic pathway: A foundational hydroclimate system for social-ecological system sustainability. *Proc Natl Acad Sci U S A* 121, (2024).

29. Rozendaal, D. M. A. *et al.* Biodiversity recovery of Neotropical secondary forests. *Sci Adv* 5, (2019).

30. Arroyo-Rodríguez, V. *et al.* Landscape-scale forest cover drives the predictability of forest regeneration across the Neotropics. *Proceedings of the Royal Society B: Biological Sciences* 290, (2023).

31. Williams, B. A. *et al.* Global potential for natural regeneration in deforested tropical regions. *Nature 2024* 1–7 (2024) doi:10.1038/s41586-024-08106-4.

32. Smith, C. C. *et al.* Amazonian secondary forests are greatly reducing fragmentation and edge exposure in old-growth forests. *Environmental Research Letters* 18, 124016 (2023).

33. Nunes, Samia, Oliveira, L., Siqueira, J. O., Morton, D. C. & Souza, C. M. Unmasking secondary vegetation dynamics in the Brazilian Amazon. *Environmental Research Letters* 15, 034057 (2020).

34. Vieira, I. C. G. *et al.* Governance and policy constraints of natural forest regeneration in the Brazilian Amazon. *Restor Ecol* (2024) doi:10.1111/REC.14272.

35. Naime, J., Mora, F., Sánchez-Martínez, M., Arreola, F. & Balvanera, P. Economic valuation of ecosystem services from secondary tropical forests: trade-offs and implications for policy making. *For Ecol Manage* 473, 118294 (2020).

36. Poorter, L. *et al.* Multidimensional tropical forest recovery. *Science (1979)* 374, 1370–1376 (2021).

37. Barlow, J. *et al.* Chapter 28: Restoration options for the Amazon. in *Amazon Assessment Report 2021* (UN Sustainable Development Solutions Network (SDSN), 2021). doi:10.55161/OSPD2912.

38. Nunes, S. *et al.* Challenges and opportunities for large-scale reforestation in the Eastern Amazon using native species. *For Ecol Manage* 466, 118120 (2020).

39. Redário e Comitê Técnico de Sementes Florestais. *Desafios e Oportunidades Para o Desenvolvimento Da Cadeia Produtiva de Sementes Nativas Para a Restauração de Ecossistemas No Brasil.* (Redário e Comitê Técnico de Sementes Florestais).

40. Urzedo, D. I., Neilson, J., Fisher, R. & Junqueira, R. G. P. A global production network for ecosystem services: The emergent governance of landscape restoration in the Brazilian Amazon. *Global Environmental Change* 61, 102059 (2020).

41. Padovezi, A. *et al.* Native seed collector networks in Brazil: Sowing social innovations for transformative change. *People and Nature* 6, 1905–1921 (2024).

42. Garrett, R. *et al. Supporting Sociobioeconomies of Healthy Standing Forests and Flowing Rivers in the Amazon.* (2023).

43. Agência de Notícias do Acre. Acre inicia elaboração do Plano Estadual de Recuperação da Vegetação Nativa, o Peveg. *Acre inicia elaboração do Plano Estadual de Recuperação da Vegetação Nativa, o Peveg* (2024).

44. Holl, K. D., Luong, J. C. & Brancalion, P. H. S. Overcoming biotic homogenization in ecological restoration. *Trends Ecol Evol* 37, 777–788 (2022).

45. Urzedo, D. I. de, Piña-Rodrigues, F. C. M., Feltran-Barbieri, R., Junqueira, R. G. P. & Fisher, R. Seed Networks for Upscaling Forest Landscape Restoration: Is It Possible to Expand Native Plant Sources in Brazil? *Forests 2020, Vol. 11, Page 259* 11, 259 (2020).

46. Ribeiro, J. E. L. S. *et al.* Flora da Reserva Ducke - guia de identificação das plantas vasculares de uma floresta de terra-firme na Amazônia Central. (1999).

47. Ferraz, I. D. K. *et al.* Guia de Propágulos e Plântulas da Amazônia (ISBN 85-903572-4-4). (2004).

48. Eloy, L. *et al.* Manejo do fogo por povos indígenas e comunidades tradicionais no Brasil. *Biodiversidade Brasileira* 9, 55–55 (2019).

49. Schwartzman, S. & Zimmerman, B. Conservation Alliances with Indigenous Peoples of the AmazonAlianzas de Conservación con Indígenas del Amazonas. *Conservation Biology* 19, 721–727 (2005).

50. Fernandes, C. C., Marcovitch, J. & Pinto, K. E. F. How Governance Can Contribute to Amazon Biome Conservation? *Environmental Management and Sustainable Development* 13, 128–151 (2024).

51. Strassburg, B. B. N. *et al.* Global priority areas for ecosystem restoration. *Nature* 586, 724–729 (2020).

52. Antonelli, A., Rueda, X., Calcagno, R. & Nantongo Kalunda, P. How biodiversity credits could help to conserve and restore nature. *Nature 2024 634:8036* 634, 1045–1049 (2024).

53. Lupion, B. Pela 1a vez, Brasil vai conceder floresta para restauração. *Natureza e meio ambiente Brasil* (2024).

54. Gavin, M. C. *et al.* Defining biocultural approaches to conservation. *Trends Ecol Evol* 30, 140–145 (2015).

55. Pereira, C. A., Tabarelli, M., Barros, M. F. & Vieira, I. C. G. Restoring fire-degraded social forests via biocultural approaches: a key strategy to safeguard the Amazon legacy. *Restor Ecol* 31, (2023).

56. Lapola, D. M. *et al.* The drivers and impacts of Amazon forest degradation. *Science (1979)* 379, (2023).

57. Levis, C. *et al.* Persistent effects of pre-Columbian plant domestication on Amazonian forest composition. *Science (1979)* 355, 925–931 (2017).

SUGGESTED CITATION

Jakovac C.C., Nascimento, N., Gallegos, S.C., Celentano, D., Vieira D.L.M., Fernandes, C.C., Brienza Junior, S., & Pellicciotti, A.S. (2024). Strategies for implementing and scaling up forest restoration in the Amazon, Policy Brief. Science Panel for the Amazon, United Nations Sustainable Development Solutions Network, New York, USA. Available from https://www.theamazonwewant.org/spa-reports/.

DOI: 10.55161/DONQ6751

AUTHOR AFFILIATIONS

Catarina C. Jakovac - (UFSC) Centro de Ciências Agrárias, Universidade Federal de Santa Catarina, Rodovia Admar Gonzaga, 1346, Itacorubi, Florianópolis, SC - CEP 88034-000.

Nathália Nascimento - (ESALQ-USP) Escola Superior de Agricultura Luiz de Queiroz da Universidade de São Paulo. Av. Pádua Dias, 11 - Agronomia, Piracicaba - SP, 13418-900

Silvia C. Gallegos - (Martin Luther University Halle-Wittenberg, Germany & Herbario Nacional de Bolivia - Universidad Mayor de San Andrés, Bolivia). Institute of Biology/Geobotany and Botanical Garden, Martin Luther University Halle-Wittenberg, Grosse Steinstr. 79/80, Halle 06108, Germany. Herbario Nacional de Bolivia, Instituto de Ecología, Carrera de Biología, Universidad Mayor de San Andrés, Campus Universitario Cota-Cota, calle 27, La Paz, Bolivia

Danielle Celentano (Instituto Socioambiental & Aliança pela restauração na Amazônia). Instituto Socioambiental, Praça Dom José Gaspar, 134, 12 andar - CEP 01047-912, São Paulo/ SP - Brasil

Daniel Luis Mascia Vieira (Embrapa Recursos Genéticos e Biotecnologia). Embrapa Recursos Genéticos e Biotecnologia, Parque Estação Biológica, PqEB, Av. W5 Norte (final) Caixa Postal 02372 – Brasília, DF – CEP, 70770-917

Carolina Cristina Fernandes - (USP) Laboratório de Física Aplicada, Instituto de Física - Universidade de São Paulo. Rua do Matão 1371 - CEP 05508-090, Cidade Universitária, São Paulo - Brasil

Silvio Brienza Junior (Embrapa Florestas). Embrapa Florestas, Estrada da Ribeira, Km 111 - Parque Monte Castelo, Colombo - PR, CEP 83411-000, Brasil

André Schatz Pellicciotti (SEMA - Acre). Secretaria de Estado do Meio Ambiente do Acre - SEMA, Rua Benjamin Constant, nº 856 - Centro. Rio Branco – Acre CEP 69900-062