Chapter 29 In Brief

Restoration priorities and benefits within landscapes and catchments and across the Amazon basin in the Amazon

Rio Parima na Terra Indígena Yanomami (Foto: Bruno Kelly/Amazônia Real)

THE AMAZON WE WANT
Science Panel for the Amazon

Restoration priorities and benefits within landscapes and catchments and across the Amazon basin

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Key Messages & Recommendations

1) Identifying priority locations for restoration across the Amazon basin depends on targets (e.g., increasing carbon stocks or conserving threatened species). These priority regions must be identified through participatory approaches involving local peoples and governments, supported by up-to-date scientific evidence.
2) Restoration strategies will be more effective if they consider complementary conservation measures, such as the protection of remaining primary forests (see Chapter 27).
3) For long-term success, restoration policies and programs must generate socioeconomic benefits for local populations (e.g., food security, employment, and income opportunities) and raise awareness of the benefits that forests and other natural systems provide.
4) Implementing restoration at the landscape- and catchment-scale must consider a broad range of restoration options, from encouraging the natural regeneration of secondary forests to restoring economic activities in degraded lands. This will help ensure restoration delivers the greatest benefits to the broadest range of stakeholders.
5) Restoring ecosystems in the context of climate change requires rebuilding more resilient ecosystems for the future, for example selecting tree species that are more adapted to drier climates or helping maintain the natural flow regimes in aquatic systems.

Abstract Restoration can be applied in many different Amazonian contexts, but will be most effective at leveraging environmental and social benefits when it is prioritized across the Amazon basin or within landscapes and catchments. Here we outline the considerations that are most relevant for planning and scaling restoration across the Amazon.

Prioritizing restoration actions across the Amazon basin When restoration has been identified as an important action to achieve a particular target, the first tier of prioritization involves identifying which areas to restore. Across ecosystems, systematic conservation planning aims to support decision-making regarding the allocation of resources[1].

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These approaches have been widely used to help identify priority areas for conservation or restoration across the world[e.g.2], and within catchments[e.g.3,4]. However, despite a growing number of global- and ecosystem-level prioritization exercises[2,5], very few formal analyses exist prioritizing restoration across the Amazon basin[6] or identifying optimal scenarios to realize multiple aims. Here we outline some of the key ecological and societal benefits that could be attained from a large-scale, basin-wide restoration program.

Conservation of the Amazon's threatened species and unique ecosystems Restoration can play a key role in supporting the conservation of the most threatened forest-dependent species, whose habitats have been reduced by deforestation and degradation. Restoration could play a key role in supporting the conservation of some of these species, including the Critically Endangered Belém Curassow (*Crax [fasciolata] pinima*[7]), Black-winged Trumpeter (*Psophia obscura)*, and the Kaapori capuchin (*Cebus kaapori*). Large-scale restoration across deforested regions could also benefit widely-distributed species that are of conservation concern. These include large and charismatic animals such as the Near Threatened Harpy Eagle (*Harpia harpyja)* and Jaguar (*Panthera onca*), and the Vulnerable White-lipped Peccary (*Tayassu pecari*[8,9]).

Improved functional connectivity of river systems A basin-wide approach to restoration can support the integrity and spatial connectivity of river systems[10,11]. Longitudinal and lateral connectivity are central organizing features of energy flows, food web structures, and nutrient dynamics in running water systems. As such, restoring aquatic ecosystems to more natural states involves supporting vital multi-dimensional linkages found throughout river basins, as well as sustaining the organisms embedded in these systems. Such restoration needs to focus on the full hydrological network, from headwaters to main channels, helping minimize disruption to flows of sediments, nutrients, and organisms[12,13].

Global climate benefits Natural forest regrowth can play a significant role in climate change mitigation[14,15,16]. For example, tropical Latin America's 2.4 Mha of secondary forests could accumulate total aboveground carbon stock of 8.48 petagrams of carbon (Pg C) in 40 years[14]. This is equivalent to all the carbon emissions from fossil fuel use and industrial processes for all of Latin America and the Caribbean from 1993 to 2014[14].

Biome-wide climatic benefits. Terrestrial restoration will help the Amazon maintain its hydrological integrity, with evapotranspiration from restored forests contributing to the east-west transfer of moisture. This could also support aquatic ecosystems, ensuring river discharge levels are maintained across the basin, and even nutrient transfer to floodplains. Increased humidity would also help prevent forest fires, which are one of the main determinants of large-scale forest dieback[17].

Socioeconomic benefits of restoration Restoration of forests and sustainable economic activities are a high priority for some of the most deforested regions of the Amazon, as these older deforestation frontiers include many municipalities with low scores on the Human Development Index (HDI)[18]. The transformation of unproductive lands into productive and sustainable agriculture or agroforestry systems could yield many direct economic and social benefits. The indirect effects of restoration, including local and regional climate regulation, could also be important for local economies. For example, maintaining or even reducing the length of the dry season could support double cropping systems that are vulnerable to climate change[e.g.19]. Other important benefits include goods produced on restored areas, improved health from better air and water quality, lower temperatures, reduced exposure to natural disasters, and increased access to natural systems.

Landscape and catchment approaches to restoration and conservation Once a region has been identified as a priority for restoration, landscape and catchment approaches can help ensure that restoration actions are effective and deliver the greatest benefits to the broadest range of stakeholders. Landscape approaches are often termed "integrated landscape approaches", reflecting the need to reconcile multiple and conflicting land-use claims and help establish multi-functional landscapes[20]. The term encompasses a wide-range of approaches[21], including integrated watershed management[e.g.22] and forest landscape restoration (FLR)[23]. FLR is promoted by many leading environmental NGOs and the Food and Agriculture Organization of the United Nations (FAO) as the Forest and Landscape Restoration Mechanism. FLR enables decision makers to consider all components of a landscape, from agriculture to restoration and forestry, and support long-term sustainability decisions through economic zoning[24]. It also calls for consideration of all ecosystems within a region, supporting restoration beyond *terra firme* forests, including savannas and flooded forests[25–27]. Here, we identify some of the key benefits of planning restoration within landscapes and catchments.

Integrating aquatic and terrestrial systems Terrestrial and aquatic systems are inextricably linked, and considering them together can provide large benefits for both[28]. In addition to water quality, land use can modify the magnitude and variability in river flows. Restoring aquatic systems often requires terrestrial interventions; for example, enhancing water quality, quantity, and ecological condition involves a suite of management practices[29], with a payment for ecosystem services scheme in the Bolivian Andes encouraging forest protection and livestock exclusion from headwater streams[30].

Improving connectivity for biodiversity Tropical species are inherently more sensitive to fragmentation than temperate species[31]. For example, Amazonian taxa, including many understory birds, have limited capacity to fly more than a few tens of meters[32] and are reluctant to cross even small roads[33], making them highly susceptible to human activities that fragment habitat into discrete patches[34]. Freshwater species are also susceptible to changes in connectivity[35], and the Amazon's migratory catfish have the widest-ranging metapopulations of all the world's freshwater fish[36]. Given this sensitivity, restoration will be most effective if deployed in a way that increases habitat *and* maintains or enhances connectivity, ensuring migration can take place and gene flow is permitted between populations. A mix of different restoration strategies can be used to improve connectivity between higher quality habitats. However, these will also require complementary conservation measures that protect remaining populations and habitats for threatened species.

Local climate benefits Restoration in deforested regions could provide important benefits for local climates[37]. For example, studies across the world show that increases in forest cover can help diminish urban heat island effects[38], and reduce the occurrence of excessive stream temperatures[39].

Reducing the risk of socio-environmental disasters By influencing temperature and humidity, landscape-level restoration could help reduce the risk of forest fires. Restoration could also be used to 'buffer' primary forest edges; these green firebreaks would help protect edges from hot microclimates, suppress grasses that help spread fires, and isolate forests from ignition sources. However, research is needed to evaluate the effectiveness of green firebreaks in the Amazon, including understanding the ideal widths and which restoration measures (tree planting or enrichment) are required to maximize their effectiveness and co-benefits (e.g., economic returns). Catchment-scale restoration can also help mitigate the risk of flooding, which is exacerbated by deforestation[40]. Models suggest that sub-catchment restoration of riparian forests is likely to be one of the most effective mechanisms to reduce flooding, with restoration across 10-15% of the catchment reducing the peak magnitude of flooding by 6% after 25 years[41].

Meeting multiple aims and optimizing benefits The landscape or catchment scale is often considered the most appropriate to consider different land use and ecosystem functions and trade-offs, and achieve multiple benefits[21]. Such approaches help prioritize restoration across the world[2], and could allow restoration actions to achieve a broader range of benefits whilst minimizing losses[42]. For example, within the Amazon, optimization has shown the complementarity between biodiversity and carbon storage targets, highlighting that large gains can be made for biodiversity conservation with only minor reductions in carbon storage[43]. With so many potential co-benefits of restoration, these must be considered as part of an integrated landscape and catchment planning processes[44]. For example, peri-urban restoration aimed at providing climatic benefits for cities could also provide important socioeconomic benefits if the forests provide fruits and other products for local consumption.

Encouraging a broader forest transition Restoration can also be viewed temporally, through the concept of forest transition[45], which refers to changes in forest cover (either shrinkage or expansion) over a given area (landscape, region, nation) and time period. Restoration could play an important role in forest transition planning if it is partly oriented towards timber production, which would relieve pressure on primary forests, the main provider of timber in the region. During the last 50 years, primary forests have been selectively logged and 108 Mha of forest (20% of the total forest area) are exploited for timber production[46]. The rising interest in tropical forest restoration is a unique opportunity to promote timber production on deforested lands, either through planting economically interesting timber species or enriching and managing secondary forests growing on abandoned agricultural lands for timber production[47].

Ensuring broader societal benefits from restoration Restoration exists within a social context, and therefore produces environmental conditions that must not only be ecologically sound but also economically feasible and socially acceptable. For example, nearly 300 million people in the tropics live on lands suitable for forest restoration, and about a billion people live within 8 km of such lands[48]. Many of these people live in poverty. Given the implicit challenges of restoring complex systems, landscape and catchment restoration has considerable potential to include local populations and improve local livelihoods over the long term[44,49–51]. Even when the primary aim of restoration is environmental, it must be guided by cultural expectations and values which influence both the goals and the eventual success[52]. Engaging a diverse range of stakeholders from the public, private, and civil society sectors, and building and sustaining coalitions supporting restoration is imperative. When done in this way, restoration can increase well-being through the sale of forest products, increased food supplies, improved water security, and the promotion of the diverse cultural values people place on landscapes[53–56]. Landscape restoration may also positively affect tenure and land rights for many Indigenous peoples, local communities, and landowners. It may also increase incomes, employment opportunities, and community resilience[57,58].

The climate resilience of restoration options Restoring ecosystems in the context of climate change requires understanding when it is best to rebuild past ecosystems, and when it is better to attempt to build resilient ecosystems for the future[59]. Determining where historical baseline targets are viable and where alternative targets must be considered is site-dependent and associated with projected changes[60]. We consider these issues in terrestrial and aquatic systems.

Climate resilience of terrestrial restoration The Amazon's primary forests are affected by climate change and climatic extremes, resulting in increased mortality of individual trees[61,62], and changes in species composition[63] (see also Chapter 23). The influence of climate change may be even more important for secondary forests[64]. There are three key reasons for concern. The first is spatial; secondary forests are predominantly found in drier parts of the Amazon, with greater seasonal variability[65] and where changes in dry season length are most pronounced[e.g.66]. The second is physiological; secondary forests are dominated by fast-growing trees with low wood densities[67] or thin leaves that are especially vulnerable to drought[61,62,68]. Third, secondary forests have higher understory temperatures and lower humidity levels[69], making them more vulnerable to extreme microclimatic conditions and fires[70].

This heightened sensitivity to climate change could be offset if existing gradients in dry season intensity and rainfall drive adaptations to greater drought or heat sensitivity. Primary forests are responding to climate change through changes in species composition[63], and the fast turnover of secondary forests and the high dispersal capacity of pioneer species may facilitate even faster changes in secondary forests, allowing drought-resilient secondary forests to emerge in the future[e.g. 71]. However, it also seems likely that there are natural physiological barriers that could limit forest cover[72], and more research is needed to understand these thresholds in secondary forests. Where forests are unable to change naturally, or where a faster rate of change is desired, enrichment planting could promote species better adapted to heat stress or longer dry seasons, but such interventions have yet to be tested and might be challenging to apply at scale.

Climate resilience of aquatic restoration The hydrological effects of climate change are likely to have a more substantial impact on the Amazon than other regions of South America[73]. Changes in water balance associated with climate change and deforestation will likely affect floodplain and river ecosystems in many ways (see also Chapter 23). In rivers, precipitation and discharge regimes regulate sediment transport and aquatic nutrient dynamics[74,75], and flood extent governs the input and processing of vast quantities of organic matter produced in terrestrial and seasonally-flooded ecosystems[76,77]. In the biological realm, altered seasonality in flood regimes could affect plankton community interactions, with potentially cascading food web effects[78]. Thus, in addition to understanding site-level conditions prior to disturbance, effective restoration of Amazonian aquatic ecosystems should pay attention to the catchment-scale hydrological, biological, and chemical alterations that are likely to occur from climate change.

Achieving meaningful restoration at scale Here we examine the policy levers and incentives that can support the large-scale restoration that is required to mitigate climate change, avoid dangerous tipping points, reduce pressure on primary forests, support local livelihoods, and develop a thriving and flourishing Amazonian bioeconomy.

Enforcement Many have experimented with technological and organizational solutions to restore environmentally-sensitive and sustainable economic production[e.g.79]. Yet, they will not be taken to scale as long as the negative externalities of exploiting the forest's natural capital go unaccounted for. For example, the low market prices of illegal timber undermine the value of legal timber[80], making it much more challenging for companies that follow legal and certification scheme practices to fund the monitoring and enforcement required to ensure post-harvest forest integrity across expansive and remote concessions (see Chapters 14, 19 and 29). Countering this requires changes in policy and governance (laws, taxes, subsidies) to make illegal logging economically unattractive. Green financial institutions are key partners to invest in land and landscape restoration, which requires efficient tools to monitor and verify environmental performance at plot, farm, and landscape levels. Monitoring and enforcement is also key to avoiding perverse effects of economic restoration, where technologies and policies promoting greater agricultural or silvicultural productivity paradoxically lead to increased deforestation[81], or where large-scale ecological restoration causes "leakage" of environmental harm [e.g.82].

Incentive-based measures Restoration can be incentivized by carbon and/or biodiversity offsetting, payments for ecosystem services (PES), and/or certification schemes. Yet, PES often fail in gaining scale[83], and such market-based interventions can generate conflict and weaken social ties[84]. Interestingly, less obvious policies may have important indirect effects on restoration dynamics, such as the Brazilian School Meal Program that has been fundamental in encouraging the consolidation of agroforestry systems and agrobiodiversity in some areas of the eastern Amazon[85].

Community-led restoration Some site-level restoration actions can be implemented by liaising with a relatively small set of stakeholders, such as property owners or reserve managers. Yet, to achieve sustainable transformations across landscapes and catchments, it is vital that restoration measures are viewed favorably by the people who live in or benefit from the region's economic activities. For example, implementing integrated farming systems on unproductive farmland requires the participation of all relevant stakeholders, both in the design and implementation phase. This ensures that research and extension programs meet the socioeconomic needs and cultural values of intended beneficiaries[86]. Unsurprisingly, some of the most successful examples of active restoration involve strong community buy-in and leadership. The *Rede Sementes do Xingu* and several community-led fisheries restoration and management programs provide positive examples of community engagement and leadership. The success of restoration initiatives in involving local people depends on effective and long-term support for capacity building and technical assistance, and ongoing and wide-ranging social collaboration and participation (see Chapter 29).

Policies Restoration can be supported at the national level through official commitments and legislation. For example, the Brazilian Native Vegetation Protection Law (NVPL, or forest code) sets forest-area limits for legal reserves, and requires vegetation to be preserved along watercourses and on other ecologically-sensitive settings such as steep slopes[87] The NVPL allows landholders to compensate for past forest clearance by buying or renting forests elsewhere; given issues around permanence, this has provided a mechanism to support the restoration of illegal farmland on national parks[88]. National legislation varies greatly across Amazonian countries. Developing a set of approaches that cut across Amazonian countries could be encouraged by linking national policies to the many international declarations and incentives that promote restoration, including the New York and Amsterdam declarations, the Bonn Challenge and Initiative 20x20, Sustainable Development Goal 15 Life on Land, the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change, zero deforestation commitments, and the fight against imported deforestation.

Conclusions To maximize its ecological and societal impact, restoration needs to be implemented in ways that consider its benefits across scales, including at the level of the biome, within landscapes and catchments, and across different groups of local actors and stakeholders. Applying the most appropriate restoration approaches to the right places will require novel prioritization exercises that consider multiple benefits and include the societal feasibility, ecological need, and the risks posed by climate change.

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