The Amazon Assessment Report 2025

CONNECTIVITY OF THE AMAZON FOR A LIVING PLANET

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

Science Panel for the Amazon
THE AMAZON WE WANT

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About the Science Panel for the Amazon

The Science Panel for the Amazon is an unprecedented initiative convened under the auspices of the United Nations Sustainable Development Solutions Network (SDSN). The SPA aims to synthesize and communicate scientific knowledge about the Amazon, interwoven with Indigenous and Local Knowledge, to accelerate solutions for sustainable and equitable development. It is composed of over 300 preeminent scientists and researchers from the eight Amazonian countries, French Guiana, and global partners. These experts come together to debate, analyze, and assemble the accumulated knowledge of the scientific community, Indigenous Peoples, and other stakeholders that live and work in the Amazon, with the aim of providing recommendations, opportunities and policy relevant options for its conservation and sustainable development.

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Foreword

Jeffrey D. Sachs

With profound gratitude and admiration, I congratulate the **Science Panel for the Amazon (SPA)** on the release of the *Amazon Assessment Report 2025 - Connectivity of the Amazon for a Living Planet*. The SPA has, in a few short years, become an indispensable institution for the Amazon and the world. Convened under the auspices of the UN Sustainable Development Solutions Network (SDSN), the Panel brings together hundreds of world-leading scientists, practitioners, and knowledge-holders from the Amazon countries and global partners who generously contribute their time and expertise. The SPA embodies a gold standard of collaborative science in service of humanity: cutting-edge, rigorous, independent, and deeply rooted in the perspectives of the peoples and ecosystems it studies.

Since its establishment in 2019, the SPA has achieved extraordinary results. The inaugural *Amazon Assessment Report* (2021) was the first-ever comprehensive science-based assessment of the entire Amazon Basin, integrating contributions from more than 200 scientists and experts. That report established the foundation for evidence-based policymaking in the region and globally, highlighting the Amazon's unique value and the profound risks of inaction. It underscored the Amazon's unparalleled role in sustaining biodiversity, regulating the regional and global climate system, and supporting the lives and cultures of millions of people. The 2021 report also introduced the vital concept of the Living Amazon Vision as a guiding framework for conserving the ecological and socio-cultural connectivity of the Amazon and its peoples. This vision emphasizes that the Amazon is not only a mosaic of forests and rivers, but also of cultures, knowledge systems, and spiritual traditions intricately linked to nature.

Building on that foundation, the Science Panel for the Amazon focused attention on issuing policy briefs on urgent threats to Indigenous rights, governance, and sustainable development, while also identifying innovative pathways for socio-bioeconomic transitions and nature-based solutions. These successive assessments have significantly influenced national debates, regional initiatives, and global processes—from the Glasgow (COP26) to the

Baku (COP29) climate summits to the landmark **Belém Declaration of 2023**, signed by Amazonian heads of state, which explicitly recognized the importance of science-driven cooperation across the Amazon Basin.

The **Amazon Assessment Report** 2025 is released at a moment of intensifying global concern, and just in advance of COP30 in Belém, Brazil. The report deepens the great SPA contribution. It is at once a sober warning and an enormously constructive roadmap. The Report lays bare the **fragility of the Amazon ecosystem** and the urgent risks of ecological tipping points, while also **presenting practical, evidence-based strategies for reversing** the ongoing degradation and thereby building resilient, inclusive futures.

The Fragility of the Amazon

The *Amazon Assessment Report 2025* reminds us that the Amazon is a living system of planetary significance. Spanning 7.8 million square kilometers across eight countries and an overseas territory of France, it is home to 47 million people—including more than 2.2 million Indigenous Peoples representing over 400 ethnic groups—and to an extraordinary share of the world's biodiversity: nearly 13% of known species, 50,000 plant species, 3,000 freshwater fish species, and hundreds of mammals, reptiles, and amphibians. As the Report reminds us, the Amazon forests store carbon equivalent to 15–20 years of global CO_2 emissions, and its "aerial rivers"—atmospheric streams of water vapor—generate rainfall critical for agriculture, energy, and livelihoods across much of South America.

Yet this connectivity, which sustains both ecological balance and human wellbeing, is being disrupted at an alarming pace. The Report identifies **four urgent threats**:

1. **Rapid environmental degradation and fragmentation.** Nearly 300 million hectares of the Amazon Region are already fragmented, undermining biodiversity, ecosystem services, and human security.

2. **Expansion of illicit and extractive economies.** Illegal mining, illegal logging, and land-grabbing are spreading rapidly, fragmenting forests, fueling violence, and distorting local economies.

3. **Conflict and weak governance in border regions.** Tri-border areas have become hotspots of lawlessness, violence, and ecological destruction.

4. **Tipping points and irreversible collapse.** Synergistic effects of land-use change and climate stress may be pushing the Amazon toward a threshold beyond which it could shift to a degraded savanna-like ecosystem, losing its capacity to regulate climate, store carbon, and sustain biodiversity.

The conclusions are stark: without rapid action, the Amazon risks cascading system failure, with consequences for planetary climate stability, global health, and the security of millions of people.

Toward Solutions

What makes the SPA so valuable is not only its scientific rigor in diagnosing the problems, but its constructive, problem-solving approach. The *Amazon Assessment Report 2025* sets forth a series of transformational opportunities, grounded in evidence and aligned with the needs and hopes of the Amazonian peoples. These recommendations form an actionable agenda across five interrelated domains:

1. **Conservation through connectivity.** The Report calls for halting deforestation, degradation and wildfires by 2030, restoring at least 50 million hectares of degraded land, and expanding ecological corridors linking Indigenous Territories and Protected Areas.

2. **Strengthening the rights and resources of Indigenous Peoples and Local Communities.** The Report emphasizes that Indigenous Peoples and Local Communities are the indispensable custodians of the Amazon, managing nearly half the biome, and storing more than half its carbon. Yet more than 100 million hectares of Indigenous land remain without secure legal recognition. The SPA recommends titling at least 50 million hectares by 2030, ensuring direct access to finance, and guaranteeing that at least 20% of climate-related funds disbursed in the Amazon reach the Indigenous Peoples and Local Communities.

3. **Catalyzing socio-bioeconomic transitions.** To shift away from extractive models, the Report proposes reorienting at least 20% of rural credit and public investments toward sustainable socio-bioeconomic activities by 2035.

4. **Regional collaboration beyond borders.** The Report highlights the need for new transboundary governance agreements, the operationalization of a Pan-Amazon Observatory, and stronger regional enforcement against illicit economies. Shared resources—rivers, forests, and knowledge—must be managed collectively, transcending national borders.

5. **Scaling finance for conservation and restoration.** The Report outlines the design of a **basin-wide restoration finance architecture**, aligned with the Tropical Forests Forever Facility, to blend public and private finance, mobilize multi-billion-dollar flows, and guarantee direct access for Indigenous and community-led initiatives. It emphasizes reallocation of credit and subsidies away from deforestation drivers and toward forest-positive economies.

These recommendations highlight SPA's unique strength in integrating diverse knowledge systems—scientific, Indigenous, and local—into a coherent and pragmatic vision. This integration provides not just a map of what must be done, but a compass for how to get there.

The Road to Belém

The timing of this report could not be more critical. In just weeks, the world will gather in Belém, Brazil, for COP30—which I consider to be the "Rainforest Climate Summit." This COP will be the first time the UN climate conference is held in the heart of the Amazon, and the stakes could not be higher. The SPA's *Amazon Assessment Report 2025* offers the scientific foundation and policy roadmap that COP30 needs. It translates scientific and Indigenous knowledge into a strategy for action—one that will inspire not only Amazonian nations but also help to protect the forests, the rivers and their communities throughout the world.

All kudos to another outstanding contribution of the Science Panel of the Amazon.

Acknowledgments

The *Amazon Assessment Report 2025: Connectivity of the Amazon for a Living Planet* is the outcome of a collaborative and interactive process through which we co-created its content. The process has been both inspiring and enriching. We have learned from one another, listened to diverse voices, and drawn on different knowledge systems to deepen our understanding of the connectivity of the Amazon. Along the way, we identified initiatives, projects, and collaborations that contribute to building a more sustainable future for the Amazon Basin.

We extend our sincere appreciation to all those who shared their time, expertise, and perspectives in the preparation of this report. We are certainly indebted to the 146 experts who dedicated their time and expertise as Lead Authors, Contributing Authors, and Authors of the Calls to Action. It has been a privilege to work and collaborate with you all. Your collective efforts and commitment have been essential in shaping this assessment and advancing our shared knowledge of the Amazon's role at local, regional and global scales. Thank you.

We are very thankful to the SPA Strategic Committee, the Science Steering Committee, and the Advisory Group for their invaluable strategic guidance throughout this process. Our sincere appreciation also goes to the members of the Technical Scientific Secretariat, whose dedication was essential to the completion of this report.

We are grateful to the peer reviewers for their constructive feedback, which helped improve the report, and to the many stakeholders who enriched it through their input during the public consultation, and other channels such as interviews and focal groups.

The SPA gratefully acknowledges the generous support of the Gordon and Betty Moore Foundation, the Charles Stewart Mott Foundation, and the World Bank (WB), with financial support from the Global Environment Facility (GEF).

The situation is urgent and action is needed now. We recognize that finding effective solutions is not easy, yet we hope that the examples and insights presented in this report will inspire you—and many others—to contribute to building a more sustainable and equitable future for the Amazon and for the planet.

In gratitude,

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EXECUTIVE SUMMARY

1. Introduction

The Amazon is far more than the world's largest tropical forest—it is a living mosaic of interconnected terrestrial and aquatic ecosystems home to over 47 million people. Diverse histories, governance systems, and development pressures shape its rural and urban landscapes. The Amazon contributes to local, regional, and global well-being through ecological, hydroclimatic, spiritual, and sociocultural processes, connecting people and nature across vast scales. Therefore, conserving the Amazon requires maintaining these connectivities—across different ecosystems, peoples, and governance systems—to safeguard biodiversity; strengthen resilience to land-use and climate changes; and foster inclusive, equitable, and sustainable development. This is a matter of global importance for several reasons: the Amazon plays a vital role in climate change mitigation by storing carbon equivalent to 15–20 years of global CO_2 emissions; it accounts for approximately 20-25% of all available fresh water; it influences global rainfall and weather patterns; it harbors high levels of biodiversity; and millions of people in the region and beyond depend on it for their daily lives (Box 1). Conservation and restoration efforts are critical to avoid crossing "tipping points"—thresholds past which the degradation of Amazonian ecosystems will become widespread and potentially irreversible, with consequent losses of carbon storage, water cycling, and biodiversity.

Box 1:Facts About the Connectivity of the Amazon

- The Amazon Basin spans approximately 7.8 million km^2. It is home to around 13% of known species globally, with close to 50,000 plant species—including over 16,000 tree species and 390 billion individual trees—at least 3,000 freshwater fish species, 1,300 bird species, 425 mammals, 371 reptiles, and 427 amphibians. *Ecological connectivity refers to the movement and interaction of those species, and to ecological processes acting within and across ecosystems*[1,2,3,4] (Chapters 1, 4).

- Amazonian populations are highly diverse, encompassing 2.2 million Indigenous people of more than 400 ethnic groups (with and without recognized collective titles), Afrodescendant Peoples[5] (such as *quilombolas*, and Maroons), traditional and riverine Local Communities (rubber tappers[6,7] and Brazil nut and babassu nut collectors, among others[8,9]), family farmers, urban dwellers, and multi-sited households that integrate rural and urban economic strategies[10,11]. *Sociocultural connectivity refers to the interactions between these individuals, groups, and social networks through shared values, beliefs, and cultural practices*[12,13,14]. More than 8,113 Indigenous Territories and Protected Areas[15] across the Amazon are vital corridors for cultural continuity and knowledge exchange, safeguarding linguistic diversity, traditional resource management, and sustainable land-use systems (Chapters 1, 4, 5, 6).

- *The term ecological and sociocultural connectivity recognizes that ecosystems, institutions, and cultural values are interconnected*. Approximately 1.93 million km^2 of the Amazon are currently no longer ecologically connected (Chapter 4), but restoring this connectivity is crucial to support biodiversity (at genetic, species, and ecosystem levels) and to ensure the continued provision of ecosystem services that support local and national economies and socio-bioeconomies. In Brazil alone, ecosystem services provided by Amazonian forests are worth over USD 317 billion annually[16].

- Amazonian forests play a crucial role in affecting rainfall patterns on regional and global scales through "aerial rivers," which are large amounts of evapotranspired water vapor carried by low-level winds. The occurrence of these aerial rivers strongly depends on healthy and connected forests, and they make precipitation—

and therefore life—elsewhere possible. Aerial rivers enable *regional and global connectivity* as they carry water from the Atlantic Ocean across the Amazon Basin to the Andes, ultimately supplying the Pantanal wetlands, the Cerrado, and the La Plata and Orinoco River Basins with precipitation. Aerial rivers contribute approximately one-third of the rain that falls *within the Amazon Basin and up to 50% of the rain that falls in other regions*, supporting crucial economic activities such as *rainfed agriculture*[17] (Chapter 1).

- Rivers that connect the Andes, the Amazon, and the Atlantic Ocean are conduits for sediment, nutrients, and species migration, and these systems support *livelihoods, economic activities, cultural exchanges, and ecosystem functioning* on local to global scales. The Amazon River accounts for approximately 17%–20% of the world's river discharge to the oceans (Chapter 1). Fish is the most consumed animal-sourced food in the Amazon Basin, and fisheries support the livelihoods of millions of people (Calls to Action 20, 25). The Amazon rivers are also strategic axes for sustainable infrastructure, providing low-impact river transport, connectivity among remote regions, and responsible access to natural resources. Their conservation and balanced use promote sustainable value chains, reduce logistical costs, and strengthen the region's economic resilience to climate change.

- For many Indigenous Peoples, Afrodescendant Peoples, and Local Communities, *connectivity is a vital principle and a way of life* reflected in reciprocal human–nature relationships and people's spirituality. A people's *territory* represents a concrete expression of connectivity: it is where diverse worldviews are manifested; where knowledge associated with local resources is applied in management practices; where collective rights are exercised; and where relationships among human, non-human, and spiritual beings nurture the foundations of interconnected life systems.

- Integrating a One-Health approach, which links human and environmental health holistically, with Amazonian concepts such as "Living Well" (*Buen Vivir*) reinforces *the understanding that human and environmental well-being are interdependent and must be sustained together for a thriving planet* (Chapters 3, 5).

The 2025 Amazon Assessment Report of the Science Panel for the Amazon, entitled "Connectivity of the Amazon for a Living Planet", brings sciences together that support **ecological and sociocultural connectivity as the key strategy to conserve Amazonian ecosystems, advance sustainable development, and contribute to human and environmental well-being**. Ecological and sociocultural connectivity is defined as the interconnectedness among ecological and social systems, and it describes the flow and movement of resources, information, and people within and across geopolitical borders (Box 1). This report focuses on connectivity because it is key in so many ways—considering how a reduction in one component (such as forest cover) will influence another (such as rainfall patterns) and how those changes will cascade to affect local and national economies (for example, less rainfall will lead to a decrease in agricultural production) and human well-being. In addition, increasing and maintaining the ecological and sociocultural connectivity of the Amazon is crucial for climate mitigation and adaptation strategies and for sustaining fundamental ecological processes that stabilize the Earth's climate system. Therefore, it is essential to recognize that the Amazon provides ecosystem services at global, regional, and local levels, and that its conservation is of global importance.

In this report, we focus on eight dimensions of connectivity, devoting a chapter to each: regional to global connectivity (Chapter 1), disruptions to connectivity (Chapter 2), connectivity for health (Chapter 3), transboundary collaboration (Chapter 4), the connectivity of Amazonian peoples (Chapter 5), connectivity in production landscapes (Chapter 6), connectivity for socio-bioeconomies (Chapter 7), and knowledge connectivity (Chapter 8). Each chapter is followed by associated Calls to Action—short documents focusing on specific problems that need to be solved and on examples of solutions currently being implemented in the Amazon by diverse actors.

Here, in the Executive Summary, we highlight the key findings of the 2025 Amazon Assessment Report, organized into three sections. The first section identifies key underlying drivers (current economic models, illicit activities, ineffective governance, and global climate change) that are negatively affecting the Amazon's connectivity. The second section highlights the risks these drivers present to ecological and social systems in the Amazon. Finally, in the last section, we provide five overarching recommendations that highlight pathways forward for conserving the Amazon, avoiding tipping points, and contributing to sustaining a living planet while strengthening the Amazonian peoples' well-being, knowledge, and rights.

2. Key Underlying Drivers of Deforestation, Ecosystem Degradation, and Landscape Fragmentation

Deforestation and ecosystem degradation threaten the ecological and sociocultural connectivity of the Amazon and result from key drivers that need to be addressed for effective conservation and restoration. Four key underlying drivers are (1) current economic models that are based on the unsustainable extraction of natural resources, (2) illicit economies, (3) ineffective and fragmented governance, and (4) global climate change.

2.1. Unsustainable Extractive Economic Models Cause Deforestation, Ecosystem Degradation, and Pollution

The Amazon has been increasingly deforested, degraded, and fragmented in the last few decades[19]. Most of the deforestation and degradation is related to large-scale commercial agriculture, cattle ranching, illegal logging, mining, and oil exploration, with large-scale infrastructure corridors (roads, hydroelectric dams, and ports) being the underlying structural drivers leading to land-use reconfiguration. Many national economies rely heavily on extracting natural resources through fiscal incentives that favor extractive industries over sustainable alternatives. The unsustainable use of the Amazon's resources by public and private companies and industries has, in many instances, contributed to human rights violations; displacement of Indigenous Peoples (IPs); displacement of Afrodescendant Peoples and Local Communities (two separate categories who we hereafter refer to together as Local Communities (LCs) in this document); irreversible land degradation; and breaching of international conservation commitments (Chapters 1, 2, 3, 4).

2.2. Illicit Economies Cause Fragmentation and Instability

Illegal economies are among the most destabilizing forces in the region, negatively impacting ecosystems and people. A wide range of activities—including land grabbing, drug trafficking, illegal logging, wildlife trafficking, and mining of gold and rare earth minerals—are occurring throughout the Amazon region and spreading fast. These activities no longer occur simply as isolated efforts but rather reflect well-organized criminal networks operating across country borders. The increasing scale of these activities is speeding up forest fragmentation and degradation and undermining the Amazon's role in regulating climate and supporting biodiversity. These interconnected illegal economies form a systemic network that links criminal organizations, political and economic elites, and segments of public institutions, creating a self-reinforcing cycle of corruption, environmental degradation, and violence. These networks also cause socioeconomic instability and expose Indigenous Peoples and Local Communities to violence, exploitative labor practices, and displacement, while also eroding their right to self-determination (Chapters 2, 5).

2.3. Ineffective and Fragmented Governance Undermines Conservation Efforts

The Amazon spans eight countries and one overseas territory of France (French Guiana). Therefore, transboundary governance is critical to manage natural resources sustainably, plan for climate change adaptation and mitigation, and combat illegal activities. Currently, fragmented governance and poor infrastructure planning have facilitated the expansion of large-scale dams that fragment rivers and disrupt their connectivity. Governments have also been ineffective at stopping illegal economies and in providing sustainable alternative incomes in the Amazon. Rural poverty and limited livelihood options force people to resort to illegal activities (such as gold mining and coca cultivation). Additionally, the role of Indigenous Peoples' and Local Communities' governance processes and contributions in the conservation of the Amazon remains under-recognized. Transboundary regions, such as the Brazil–Peru–Colombia tri-border area, act as hubs for illegal economies; as a result, these border regions are especially impacted by human rights violations, deforestation, ecosystem degradation, habitat fragmentation, and pollution from extractive industries (Chapters 1, 2, 3, 4, 5).

2.4. Global Climate Change Affects Amazonian Ecosystems and Livelihoods Through Floods, Droughts, and Heat Waves

The effects of climate change are evident in the Amazon Basin through increased temperatures, a greater frequency and intensity of floods and droughts, and substantial changes in precipitation patterns. These changes affect river levels and the connectivity of aquatic and terrestrial ecosystems, with large negative implications for local communities and their livelihoods, because communities rely on rivers for both transportation and fisheries to support their well-being. Climatic changes are also reducing carbon uptake (through increased tree mortality), impacting biodiversity, compromising the provision of ecosystem services (such as pollination and seed dispersal), and increasing the likelihood of the Amazon reaching a tipping point (Introduction).

3. What Is at Risk?

The four drivers that fuel deforestation, environmental degradation, and fragmentation (discussed in the previous section) jeopardize the conservation of the Amazon. We highlight six urgent risks that must be tackled to prevent irreversible damage to the Amazon's ecological and sociocultural connectivity.

3.1. Declining Connectivity Disrupts People's Livelihoods and Security

Ecological and sociocultural connectivity in the Amazon is declining fast. Approximately 100 million hectares (18%) of the Amazon have been deforested, while another 193 million hectares (38%) are considered fragmented in the Pan-Amazonian region (Chapter 4 and Call to Action 1). The decline in connectivity has tremendously negative impacts on economic stability, biocultural and biological diversity, climate regulation and resilience, hydrological cycles, and human and environmental health. Connectivity loss also directly affects the livelihoods of millions of people and their water, food, and energy security, increasing disease transmission at the regional and continental scale (Chapters 1, 2, 3, 4, 5).

3.2. Illicit Economies Threaten Ecosystems, People, and Sustainable Development

The rapid expansion of illicit economies and organized crime fragments forests, displaces communities, increases violence, distorts local economies, and impacts human health. Gold mining, for instance, has led to the loss of thousands of hectares of forest in deforestation hotspots in the Madre de Dios region in Peru, the Yanomami Indigenous Territory in Brazil, and southern Venezuela. It has also led to mercury pollution in rivers, contaminating fish and other animals with methylmercury. Because many Amazonians rely heavily on fish in their diet, high levels of mercury (sometimes more than 30 times the recommended amount) have caused irreversible and severe health damage to numerous local Amazonian populations. Beyond environmental degradation, illicit economies fuel a humanitarian crisis marked by violence, displacement, and gender-based exploitation, eroding social cohesion and governance across Amazonian territories (Chapters 1, 2, 3, 4, 5).

3.3. Expansion of Monocultures Threatens Socio-Bioeconomies

Multifunctional production systems include diverse agricultural strategies that serve human needs and ecosystem functions and naturally support landscape connectivity. Indigenous Peoples and Local Communities have historically practiced such production systems but are now threatened by the expansion of monocultures and industrial commodities. This expansion puts at risk the connectivity of healthy standing forests and flowing rivers, the ecosystem services they provide, and the local knowledge and cultural practices associated with traditional food systems. At the same time, socio-bioeconomies link territories and local livelihoods with urban centers and regional and global markets. The sustainable harvesting, processing, and selling of Amazonian products (such as açaí, Brazil nuts, cocoa, and fish) rely on Indigenous and Local Knowledge systems, and these activities ensure well-being and a sense of participation in an integrated living system. In contrast, monocultures undermine the rights, knowledge, and livelihoods of Indigenous Peoples and Local

Communities in the Amazon. The limited financial, institutional, and political support given to socio-bioeconomies is insufficient to outcompete industrial agriculture, mining, illegal logging, and cattle ranching (Chapters 5, 6 and 7).

3.4. Environmental Degradation Imperils Human Health

Ongoing environmental degradation in the Amazon puts human health at risk on local, regional, and global scales. Healthy Amazonian ecosystems are deeply connected to human health because, beyond providing locally based and healthy nutrition, they reduce the transmission risk of zoonotic and vector-borne diseases and the risk of new epidemics and pandemics. The greater the environmental degradation and the pollution of air and water, the greater the likelihood of new diseases—including infectious diseases, water-related diseases, and respiratory and cardiopulmonary diseases. For example, the extreme droughts in the Amazon in 2024 fueled large wildfires, and their smoke traveled across the South American continent to densely populated urban areas, increasing the risk of respiratory and cardiovascular diseases (Chapter 3).

3.5. Sustainable Innovations Are Hampered by the Exclusion of Indigenous and Local Sciences and Their Disconnection from Western Academic Sciences

The Amazon encompasses multiple interconnected knowledge systems that can accelerate sustainable development through the co-production of innovative solutions. The knowledge systems of Indigenous Peoples and Local Communities provide the foundation for socio-bioeconomies that sustain livelihoods and protect biological, cultural, and social connectivity. Combining Indigenous and Local Sciences (ILS) and Western Academic Sciences (WAS) can provide solutions to support connectivity in production landscapes, but both kinds of sciences in the Amazon are underfunded, underrepresented, and poorly integrated across the Amazon. Only 4.4% of publications about the Amazon in 2019 had authors from more than one Amazonian country, highlighting the limited regional scientific integration. The lack of collaborative research agendas that include diverse knowledge systems limits the progress of Amazonian sciences and their capacity to co-produce knowledge, foster innovation, and shape conservation and sustainability policies at local, regional, and global levels (Chapters 4, 5, 6, 7, 8).

3.6. Synergistic Effects of Climate and Land-Use Change May Push Areas of the Amazon Toward a Tipping Point

The synergistic effects of land-use and land-cover changes, global climate change, and climate extremes are pushing the Amazon's most vulnerable areas toward tipping points—points at which the system loses its resilience (that is, its capacity to recover from perturbations). Losing the Amazon and its ecosystem services would have significant cascading regional and global effects. In such a scenario, reduced rainfall would threaten the continental security of food (through crop failures), water, and energy. Drier conditions would increase wildfire risks, causing air pollution (from the smoke) and respiratory health problems. Increased disease outbreaks would also risk new epidemics and pandemics. The carbon emissions released from forest fires and forest loss would contribute substantial amounts of greenhouse gases that accelerate global warming. Models suggest the risk of surpassing this point of no return increases if global warming rises above 2°C and deforestation exceeds 20% of the total area of the Amazon Basin (Chapters 1, 3, 4, 5).

4. Recommendations

Here, we provide five high-level recommendations based on this report's eight chapters and 31 Calls to Action—each with an overarching strategy and steps to navigate the way forward.

4.1. Conserve and Restore the Ecological and Sociocultural Connectivity of the Amazon

Prioritizing ecological and sociocultural connectivity is a key strategy for conserving the Amazon. Connectivity addresses the interactions among terrestrial and aquatic ecosystems, peoples, and governance systems, as well as the coordination between different social networks and the diversity of knowledge systems and practices that shape the Amazon. Connectivity is crucial for climate change mitigation and adaptation, sustainable development, and the livelihoods of millions of people in the Amazon and beyond. It is also intrinsic to the One Health approach, which integrates territory, spirituality, and ecological and human health and requires collaboration across political entities, organizations of all kinds, and government agencies. As stated in the Belém Declaration of the Amazon Cooperation Treaty Organization (ACTO), conserving the Amazon requires a regional approach that considers the cross-border and cumulative effects of local impacts on terrestrial and aquatic ecosystems as well as the illicit activities that are undermining Amazonian connectivity. Replacing illicit economies with socio-bioeconomies can regenerate degraded territories and provide sustainable livelihoods (Calls to Action 3, 6, 13, 17, 30; Chapters 1, 2, 3, 4, 5, 7, 8).

Overarching Strategy:

Halt deforestation, wildfires, and environmental degradation by 2030 through regional cooperation, enforcement of relevant laws, and implementation of conservation and restoration programs.

Steps to Halt Deforestation

- Strengthen **regional cooperation** through ACTO, and adopt a **basin-wide governance framework** that treats water as a common good and fosters joint strategies for transboundary enforcement and monitoring across the Amazon region.
- **Plan infrastructure and extractive projects on a regional, basin-wide scale** without disrupting connectivity by using ACTO's Integrated Information System (Calls to Action 13, 14). Integrate safeguards and risk management mechanisms to prevent negative impacts, eliminating or reconfiguring plans that undermine sociocultural and ecological connectivity, while promoting actions that enhance resilience and generate equitable benefits for communities and ecosystems.
- **Adopt a One Health framework** that recognizes the importance of biodiversity conservation for human health (Chapter 3) by integrating the health sector into national strategies for biodiversity conservation, climate change adaptation, infrastructure, tourism, and land-use planning. The One Health framework should embrace various knowledge systems, including Indigenous and Local Sciences and Western Academic Sciences (Call to Action 9).

Steps to Promote Restoration and Conservation

- Finance and implement the **conservation and restoration of transboundary ecological corridors that connect Protected Areas and Indigenous Territories**, prioritizing at least 50 million hectares of strategically important degraded lands to recover biodiversity, carbon, and water regulation as an ecosystem service—and maintain these restored corridors (Calls to Action 1, 2, 3, 9, 15).
- **Conserve and restore aquatic–terrestrial connectivity** (e.g., rivers, lakes, floodplain systems, and riparian buffers) to safeguard fish migration, seed dispersal, and river transportation through community-led watershed projects and monitoring activities (Calls to Action 3, 13, 14, 18).
- **Build long-term capacity and support community-led monitoring** of Indigenous Territories and Protected Areas through openly available data, appropriate infrastructure (e.g., monitoring, reporting, and verification processes), GPS, drones, and satellite data. Include clear metrics, adaptive funding windows, and mechanisms for rapid policy uptake (Calls to Action 18, 29).

4.2. Support Indigenous Peoples and Local Communities in Safeguarding the Ecological and Sociocultural Connectivity of the Amazon and Mitigating Climate Change

Indigenous Territories and Protected Areas comprise almost 50% of the basin, store nearly 60% of its total carbon, and have less deforestation and loss of ecological connectivity than other areas in the Amazon (such as unallocated public lands and unprotected areas)[18]. However, the rights of Indigenous Peoples and Local Communities are being violated and their livelihoods and territories threatened by conventional forms of infrastructure, agriculture for commodities, extractive activities, and illegal economies. Land insecurity, limited participation in decision-making processes, and restricted access to finance undermine the essential role of these peoples and communities as custodians of the forest and threaten their livelihoods. Recognizing the role of Indigenous Peoples and Local Communities in the conservation of the Amazon will ensure that biodiversity conservation targets are met and simultaneously contribute to territorial rights, climate resilience, and the maintenance of sociocultural connectivity (Chapters 4, 5).

Overarching Strategy:

By 2030, secure the full legal recognition and titling of at least 50 million hectares of unrecognized Indigenous and Local Communities Territories and ensure direct access to climate and biodiversity finance mechanisms for Indigenous Peoples and Local Communities—and immediately protect environmental and human right defenders (Chapters 4, 5).

Steps Toward Legal Recognition and Titling

- **Recognize Indigenous Peoples' (IPs') and Local Communities' (LCs') systems** of governance, management, and knowledge within normative and institutional frameworks. Establish permanent, intercultural coordination mechanisms between IPs, LCs, and subnational and national governments for integrated watershed and biome governance. These mechanisms should operate at multiple scales (local, basin-wide, and transboundary) and support joint decision-making. Their purpose is to align land-use planning, climate adaptation, and water resource management under shared ecological and cultural principles, ensuring that the Amazon is governed as a living system that sustains both biodiversity and collective rights (Calls to Actions 16, 18, 19, 21, 31).
- **Implement full legal recognition and titling of IPs' and LCs' Territories**, with awareness of the large diversity of territorialities across the Amazon (e.g., ancestral lands, collective reserves). Ensure and respect free, prior, and informed consent for any activities within these areas (Chapter 5 and Calls to Action 2, 5).
- **Expand and Connect Indigenous Territories and Protected Areas**. To support expansion and management decisions, use tools such as participatory mapping, and interweave Indigenous and Local Sciences (ILS) and Western Academic Sciences (WAS) (Calls to Action 16, 19, 29).

Steps Toward Direct Funding

- **Allocate direct funding mechanisms for Indigenous and Local Community organizations** to strengthen their territories' governance and sustainable management, including through the development of management plans, community-monitoring systems, and surveillance (Calls to Action 4, 6, 13, 16, 18, 19, 20, 21).
- **Establish transparent financing channels** that enable IPs and LCs to receive at least 20% of climate-related funds disbursed in the Amazon (Call to Action 4).

Steps Toward Protection of Environmental Defenders

- **All Amazonian countries should ratify the Escazú Agreement**, a regional agreement on access to information, public participation, and justice in environmental matters in Latin America and the Caribbean; this agreement contains a regional action plan on human rights defenders. Also, operationalize ACTO's module on socio-environmental defenders with civil society participation (Call to Action 8).

4.3. Promote Conditions That Support Socio-Bioeconomies

Ecological and sociocultural connectivity in the Amazon increases through the actions of small-scale production systems and socio-bioeconomies. Such systems are also more resilient to climate and socioeconomic shocks than large-scale monocultures because they maintain complex, ecologically connected landscapes and support local economies by producing and selling a diversity of Amazonian products. The conditions for promoting socio-bioeconomies, however, are lacking. For example, over 75% of rural credit in the Legal Amazon of Brazil is directed toward cattle ranching and soy monocultures, while less than 3% supports socio-bioeconomic systems that integrate production with conservation. Public policies (such as targeted subsidies), rural credit, infrastructure development, regulatory frameworks, and market diversification should support the transition from monocultural and degraded landscapes toward socio-bioeconomies. Scaling up socio-bioeconomic initiatives is crucial for competing effectively with extractive and illicit economies (Chapters 5, 6, 7).

Overarching Strategy:

By 2035, reallocate at least 20% of rural credit and public investments in the Amazon toward socio-bioeconomic activities.

Steps for Scaling Up Socio-bioeconomies

- **Reform credit and subsidy flow to support and increase socio-bioeconomic activities** to overcome key challenges and mitigate risks without crossing essential ecological thresholds. Redirect rural finance so <20% supports cattle/soy expansion and ≥40% is reallocated to forest-positive economies (agroforestry, non-timber forest products, restoration enterprises, sustainable fisheries), in line with the need to halt key deforestation drivers while scaling alternatives responsibly (Calls to Action 4, 27).

- **Expand socio-bioeconomic initiatives through decentralized production and collaboration** as a cost-sharing means (Calls to Action 23, 27). Link both urban and rural dwellers to reach broader segments of Amazonian populations and other markets. Diversifying and broadening access to local foods and other products expands labor allocation opportunities; improves incomes; helps reduce food imports; and makes healthy, affordable food available to urban dwellers (Calls to Action 20, 21, 22, 24, 26).

Steps to Promote Knowledge and Innovation

- **Establish a network of regional innovation hubs** designed and funded to accelerate applied science and biodiversity-compatible scaling of solutions (Call to Action 28).
- **Strengthen Amazonian universities and research centers to foster collaboration,** accelerating research in key areas of sustainability, and integrate knowledge networks into national and regional socio-bioeconomy strategies. Each Amazonian country (as well as French Guiana) should secure long-term national funding lines for Amazon-focused science with binding allocation targets. Research funding instruments should explicitly include Indigenous and Local Sciences (ILS) and traditional knowledge systems (Calls to Action 16, 30).
- **Support the knowledge systems of Indigenous Peoples and Local Communities**, which are a key part of sustainable development and socio-bioeconomy strategies. This entails financially supporting intercultural education, territorial schools, and community research centers that document, transmit, and innovate Indigenous and Local Knowledge (Calls to Action 16, 18, 19, 29, 30, 31).
- **Develop intercultural knowledge centers or community logistics centers** to connect local communities with the national research institutions (e.g., INPA [Brazil], IIAP [Peru], INABIO [Ecuador], SINCHI [Colombia]) of Amazonian countries. Invest in local technological infrastructure and human capacity to ensure digital sovereignty and regionally driven innovation (Call to Action 21).
- **Acknowledge the central role of women and youth as key guardians of biodiversity** by linking them to value chains that maintain healthy forests and flowing rivers. Women play crucial roles in traditional farming systems in the Amazon, holding valuable knowledge that should be transmitted to the next generation (see Call to Action 20 for an example on collaborative management of pirarucu and Calls to Action 19, 22).

4.4. Foster Cross-Border Collaboration to Manage Shared Resources and Stop Illegal Economies

Transboundary conservation is crucial for managing shared resources and addressing threats that transcend political borders, including deforestation, environmental degradation, wildfires, habitat fragmentation, pollution, and illicit networks. Regional and international collaboration among different sectors is necessary to promote sustainable economic activities that conserve ecosystems and offer alternative livelihoods to local communities. Also, public health programs and violence prevention against environmental defenders require regional strategies (Calls to Action 6, 8, 9, 10, 11). Illegal economies can further be dismantled through the implementation of regional frameworks such as the Leticia Pact and the Belém Declaration, through law enforcement, and through global partnerships that ensure clean, legal supply chains and support socio-bioeconomies (Chapters 1, 2, 3, 4, 5, 6, 7, 8).

Overarching Strategy:

Establish transboundary governance agreements aimed at dismantling illicit networks, managing shared resources and exchanging knowledge and experiences that increase sociocultural cohesion.

Steps to Promote Knowledge Exchange

- Establish and fund cross-regional research programs across the Amazon that co-design and operationalize partnerships between academic institutions, technology centers, and Indigenous and Local Knowledge holders to promote effective conservation in transboundary regions. These programs should adopt open-science agreements that guarantee interoperable, accessible data, while protecting sensitive Indigenous and Local Knowledge and local data sovereignty (Calls to Action 13, 29).

Steps to Promote Transboundary Governance

- **Align global frameworks** (e.g., the UNFCCC Paris Agreement, Kunming-Montreal Global Biodiversity Framework) **with regional and national strategies** across all of the Amazon.
- **Establish a basin-wide environmental and health monitoring system** through ACTO's unified regional data platform to coordinate real-time data sharing on deforestation, climate, fires, air quality, water flows, disease surveillance, and illicit activities throughout all Amazonian countries and French Guiana (Calls to Action 3, 12, 13, 18). Such monitoring will support cross-border law enforcement, the surveillance of diseases and epidemics (Calls to Action 7, 8, 10, 11, 12), and the effective management of shared resources (Call to Action 18).
- **Strengthen cross-border enforcement** to dismantle illegal activities through interoperable data across banks and customs agencies, and implement robust traceability systems for key commodities such as timber, cattle, and soybean (such as Trase and Simex) (Calls to Action 5, 6, 7, 13). Coordinated enforcement strategies should integrate federal, local, and Indigenous-led monitoring; strengthen anti-corruption measures; and promote transparency within agencies to dismantle cross-border criminal networks while protecting communities and ecosystems (Chapter 2).

4.5. Create Large-Scale Financial Mechanisms to Support Conservation and Restoration of Forests and Rivers and Enhance Connectivity

Financing climate measures is essential to achieving the recommendations mentioned above and ultimately conserving the connectivity of the Amazon in the long term. Although climate-dedicated finance has grown, current flows remain insufficient relative to the scale of adaptation and mitigation challenges. There is an urgent need to scale up climate finance, given the crucial role of the Amazon in mitigating global climate change, and to maintain the ecological and sociocultural connectivity that supports the provision of a multitude of ecosystem services. The financial mechanisms should also address the needs and rights of local populations. In particular, it is crucial to ensure direct funding access for Indigenous Peoples and Local Communities to prioritize ecological and sociocultural connectivity and community-centered restoration across all of the Amazon (Calls to Action 4, 15).

Overarching Strategies:

(1) Provide financial compensation to countries and communities for conserving healthy standing forests.

(2) Finance the restoration of regional ecological corridors connecting Protected Areas and Indigenous Territories, prioritizing at least 50 million hectares of strategically important degraded lands as scientific evidence suggests.

(3) Fund and develop community-centered restoration programs that prioritize Indigenous Peoples' and Local Communities' leadership, ensuring the majority of restoration funds flow directly to community-led initiatives (Chapter 5).

(4) Align global trade and finance with Amazon conservation through due diligence, traceability, and anti-money laundering measures to close the pathways that sustain environmental crime (Chapter 2).

Steps Toward Ensuring Adequate Financial Means

- **Advance the development and financing of the Tropical Forests Forever Facility** (TFFF), whose goal is to halt deforestation. The TFFF could channel long-term, performance-based finance from public and private investors at large scale for tropical forest protection (Call to Action 4).
- **Prioritize the allocation of climate finance** toward sustainable agriculture, forestry, and other land uses **to unlock their untapped mitigation and adaptation potential and deliver multiple co-benefits** for climate, biodiversity, and Amazonian populations.
- **Establish a basin-wide restoration fund** combining climate finance, debt-for-nature swaps, and innovative financial instruments and mechanisms to support coordinated conservation and restoration across all of the Amazon (Call to Action 15).
- **Mobilize capital for forest conservation and restoration by bringing diverse financial instruments under one regulated market**—for example, reducing emissions from deforestation and degradation plus additional forest conservation actions (REDD+); payments for ecosystem services (PES); carbon credits; and international debt capital markets (e.g., sovereign climate bonds and green, social, sustainability, and sustainability-linked bonds [GSSS]).
- Promote forest conservation as a viable, profitable climate solution. **Integrate the forest sector into carbon offset markets** through simple, credible, and adaptive methodologies and tools (such as Brazil's Emissions Trading System) to attract private investment.

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INTRODUCTION

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Abstract

The Amazon is under threat from deforestation, environmental degradation, and climate change, with changes happening at unprecedented rates. The conservation of the Amazon requires an integrated, transdisciplinary approach that considers the region's deep interconnections—across geological systems, climate systems, ecosystems, peoples, and governance systems—to shape an effective, inclusive path forward through sustainable development. This assessment report aims to provide science-based, actionable solutions that can conserve and restore healthy Amazonian environments, societies, and economies. We focus on maintaining and restoring the region's **ecological and sociocultural connectivity**, which is defined as the interconnectedness within and between ecological and social systems and depends on the flow and movement of species, resources, information, and people. Eight dimensions of ecological and sociocultural connectivity are highlighted, along with some of the current solutions and innovative interventions being created, developed, and implemented by diverse actors across various spatial and temporal scales. We hope to inspire our readers to look for long-term solutions that are scalable, fair, just, and appropriate for our vision of a living Amazon.

1. The Amazon Is Under Threat

The Amazon is exposed to many different pressures, with changes happening at unprecedented rates[a]. Deforestation (driven mainly by cattle ranching and intensive agriculture) and environmental degradation (from gold mining, oil extraction, dams, hunting, illegal logging, fires, and extreme droughts) destroy and fragment ecosystems, reduce biodiversity, harm ecosystem functioning, and reduce the provision of ecosystem services[2-5]. Deforestation and environmental degradation also threaten Indigenous Peoples (IPs), as well as Afrodescendant Peoples and Local Communities (two separate categories who we hereafter refer to together as Local Communities (LCs) in this document); these threats compromise their livelihoods, food sovereignty, biocultural diversity, lifeways, and knowledge systems[6-8].

Climate change due to global warming further disrupts Amazonian ecosystems and inhabitants[9-11]. For example, the 2023 and 2024 droughts had large consequences for the livelihoods of cities, towns, and villages along Amazonian rivers, reducing access to drinking water, transport, and food for several months. Because the Amazon region recycles moisture and produces "aerial rivers" that support rainfall across South America (see Chapter 1), these droughts also had large consequences for people living farther away from Amazonian rivers, in the Andes. In Bogotá, water to its eight million inhabitants was rationed for 12 months; and in Quito, access to electricity was drastically diminished due to the low water levels of hydroelectric dams.

Synergistic interactions between climate change, land-use change, and biodiversity loss are undermining both the region's ability to adapt to and mitigate climate change and the well-being and rights of Indigenous Peoples and Local Communities—and of the South American population in general[12-16]. These threats cannot be resolved in isolation but must be tackled through integrated, systemic solutions that consider the complex relationships between ecosystems, hydroclimate, biogeochemical processes, and social systems[17].

2. Facing the Future Requires an Integrated Approach Throughout the Amazon Region

The Amazon Basin[a] is inhabited by more than 47 million people of diverse identities, including Indigenous Peoples (with and without recognized collective titles; 2.2 million individuals in total), Afrodescendant Peoples[17] (including *quilombolas* and Maroons), Local Communities (traditional and riverine communities including rubber tappers[18,19] and Brazil nut and babassu nut collectors)[20,21], family farmers, urban dwellers, and multi-sited households that integrate rural and urban economic strategies[22,23,24]. In Brazil alone, over one million "forest citizens" inhabit territories that cover 31% of the Legal Amazon[25], and all depend directly or indirectly on Amazonian ecosystem services[16]. But the importance of the Amazon extends far beyond its borders: its ecological integrity is tightly linked to global climate stability, biodiversity preservation, and the well-being of people worldwide. Conservation of the Amazon—which has been shaped by processes acting over millions of years—is of local, regional, and global relevance. This underscores the need for an integrated approach to the conservation of the Amazon that considers the broader context of global connectivity and shared responsibility[26].

The Belém Declaration, signed at the Amazon Summit in August 2023 in Belém, Brazil, outlines a collective, region-wide vision for all of the Amazon, because sustainable development in the Amazon must be achieved through shared responsibility, cooperation, and integrated governance. All eight Amazonian countries and members of the Amazon Cooperation Treaty Organization (ACTO) signed the Belém Declaration, paving the way toward regional alignment and international engagement. The Leticia Pact, signed in 2019 by seven Amazonian countries, also called for regional cooperation to conserve ecosystems by promoting connectivity. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Nexus report further highlights the interconnectedness of the crises of biodiversity, climate and land-use changes, health risks, and food and water security[27] and also the need for holistic solutions. Historically, these issues have been tackled in isolation, which risks creating ineffective solutions and unwanted consequences. For example, efforts to increase carbon sequestration, such as tree planting, have led to monoculture forests that

a - Albert, J. et al. The multiple viewpoints for the Amazon: geographic limits and meanings. In Amazon Assessment Report (United Nations Sustainable Development Solutions Network, New York, 2021). https://eng-ar21.sp-amazon.org/220717_The%20Multiple%20Viewpoints%20for%20the%20Amazon%20(English) harm biodiversity goals and reduce the provision of other ecosystem services important for local communities[28].

3. Conserving the Amazon Depends on Ecological and Sociocultural Connectivity

The conservation of the Amazon requires an integrated, inter- and transdisciplinary approach that considers **connectivity**—ecological[29,30], hydrological[31-34], sociocultural[35,36], political, and economic—across various spatial and temporal scales. Connectivity is the dynamic and multidimensional interdependence between ecological systems, cultural practices, knowledge systems, and governance structures that sustain life, well-being, and resilience across the Amazon. Various disciplines have their own definitions of connectivity, several of which are discussed in the following paragraphs.

Ecological connectivity refers to the movement and interaction of species, energy, water, and ecological processes within and across ecosystems[29,30]. It encompasses various spatial scales through moisture flows (including aerial rivers), habitat corridors, landscape connectivity, aquatic–terrestrial links, regional migration, and global cycles.

Sociocultural connectivity refers to the interactions between individuals, groups, or social networks (e.g., communities, urban populations, institutions, governments, academia) through shared values, beliefs, and cultural practices[35,37,39]. In the Amazon, Indigenous Territories and Protected Areas are vital corridors for cultural and knowledge exchange and for safeguarding linguistic diversity and traditional land-use practices[36-38,39]. **Spiritual** dimensions of connectivity are evident in the holistic worldviews of Indigenous Peoples and Local Communities in the Amazon, which are based on a cosmopolitical network of interactions between humans and non-humans[37].

Sociocultural connections can be negative too, such as the interactions between organized crime and illegal activities (e.g., land grabbing, illegal land markets, gold mining, logging, wildlife trafficking, drug trafficking) or the effects of current economic models (based on neoliberalism, capitalism, and market-driven growth) on land-use change. These kinds of connections have led to many disruptions in the Amazon and are linked to cultural values that promote forest loss and exacerbate global climate change[40,41].

Political connectivity encompasses how political decisions, policies, and power dynamics flow between local, national, and international entities and how these relationships shape governance, policymaking, and the distribution of resources and power. Recognizing the role of power relations is key to understanding how these systems function, as power dynamics shape resource management and influence the distribution of benefits and burdens. Addressing these power structures ensures a more equitable and sustainable approach to managing both human and ecological systems, promoting resilience and long-term well-being for all.

This report unifies these different definitions and focuses on **ecological and sociocultural connectivity**, which is defined as the interconnectedness within and between ecological and social systems and depends on the flow and movement of resources, information, and people (**Figure 0.1**). Safeguarding ecological and sociocultural connectivity is a strategy to protect the integrity of the Amazon, which supports the well-being of the human and other-than-human world through reciprocal relationships, resulting in ecosystem services and spiritual health. Only by acknowledging and preserving the deep interconnections—across ecosystems, peoples, and governance systems—can we shape an effective, inclusive path forward for its conservation and sustainable development[38]. Such a path is needed to achieve effective, long-term conservation outcomes in the Amazon region.

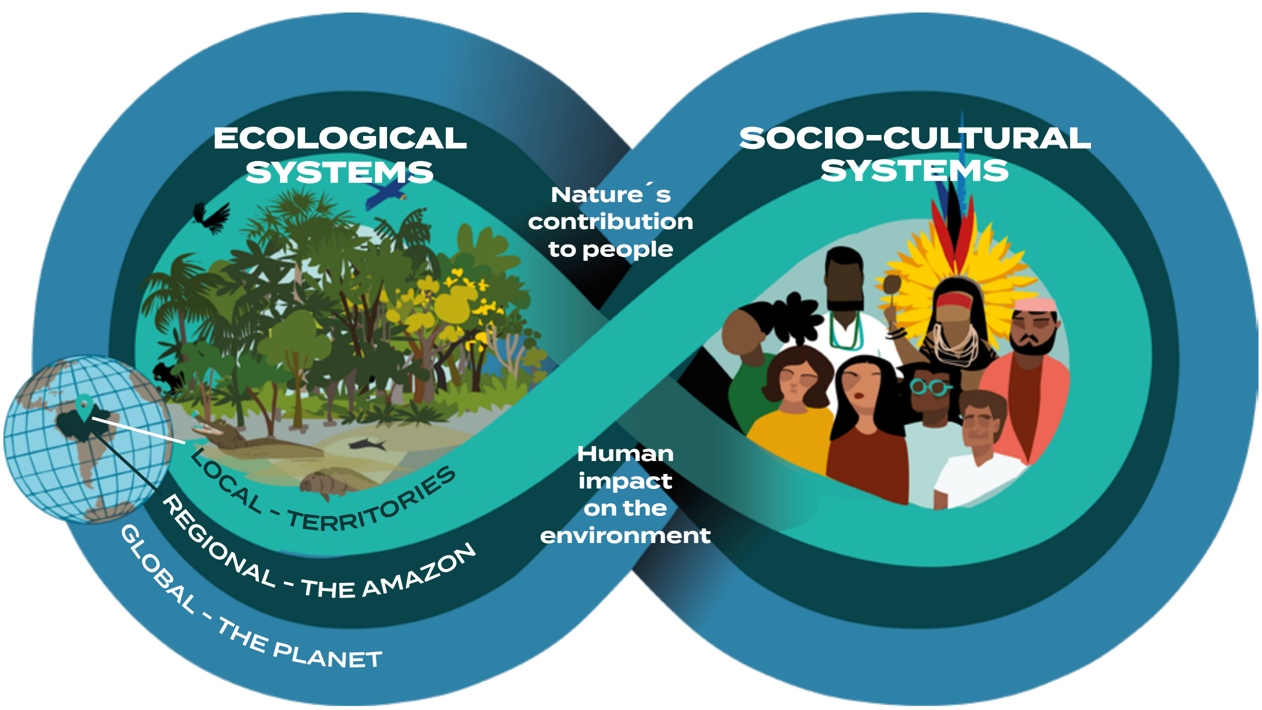

Figure 0.1. A conceptual overview of ecological and sociocultural connectivity, showing the interconnectedness between ecological and sociocultural systems, which depends on the flow and movement of resources, information, and people, and encompasses local to global scales.

An example of ecological and sociocultural connectivity in the Amazon comes from its importance in the global water cycle[33-36$42-45]. The rainfall of large regions across South America—including the Orinoco and Magdalena River Basins, the Pantanal wetlands, the Cerrado region, and the La Plata River Basin—depends on the functioning of the Amazon hydrological cycle. The Amazon forest contributes to “aerial rivers,” a term which describes the flow of large volumes of water vapor through the atmosphere, distributed by air currents (wind) throughout South America. The moisture from the Atlantic Ocean is “recycled” five to eight times by the Amazon’s forests through evapotranspiration, until it is blocked by the Andes, where moisture travels southwards, thus maintaining and recharging rainfall downwind[46]. This moisture recycling contributes 20%–50% of the rain that falls in the region and regulates continental and global weather through sea surface temperatures, rain, and clouds[47]. These aerial rivers also allow other biomes and economic activities to thrive[45-47], supporting local, regional, and global livelihoods. The aerial rivers are also crucial for the provision of clean water to large regions in the Andes and southeastern South America, constituting an immense economic contribution that has not yet been quantified. By providing rainfall, aerial rivers also regulate the flows of Andean and Amazonian rivers that transport people, economic products, sediments, and nutrients[48].

Deforestation, fires, landscape fragmentation, and climate change may be leading certain areas of the Amazon toward a tipping point[48-51]—a point at which the system loses its resilience (i.e., its capacity to recover from perturbations). For instance, although most wildfires in the Amazon result from human ignition, stronger dry seasons may increase the impact of natural fires and intensify the severity of human-ignited fires. This would lead to higher tree mortality and to a change in forest structure toward lower-stature forest and more susceptibility to future fires[48,50]. This reinforcing feedback would decrease the resilience of the Amazon forest, decreasing the capacity of the system to provide ecosystem services such as climate regulation and carbon storage[48,49].

The social and economic consequences of such a transition would be dire for

South America, because rainfall will be less predictable, threatening the supply of water for the continent and harming crop and forest yields, impacting food, water, and energy security. The risk of wildfires will increase, causing respiratory health problems due to fine particulate matter and releasing large amounts of CO_2 into the atmosphere that will accelerate global warming, lead to a huge loss of biodiversity, and threaten local livelihoods. Thus, these consequences affect ecological, climatic, cultural, political, and health dimensions and play out over various spatial and temporal scales.

4. About This Report

This assessment report aims to provide science-based, actionable solutions to conserve and restore healthy Amazonian environments, societies, and economies. In doing so, the report focuses on ecological and sociocultural connectivity, as its maintenance and restoration will guarantee the functioning of this interconnected ecosystem.

While ecological and sociocultural connectivity has many dimensions, this report focuses on eight aspects of such connections across various spatial and temporal scales (**Figure 0.2**). The eight dimensions were chosen carefully following expert consultation—including consultation with Indigenous Peoples and Local Communities—workshops, and strategic planning sessions and meetings, to add as many voices and actors as possible. The report, therefore, was developed in an integrative, transdisciplinary, and inclusive manner.

Each of the selected dimensions of ecological and sociocultural connectivity is developed in an individual chapter (**Figure 0.2**). The chapters also contain several Call to Action documents that provide examples of solutions that are being discussed or have been implemented in the Amazon to address the most urgent and/ or critical issues for maintaining or restoring the ecological and sociocultural connectivity of the Amazon at different spatial and temporal scales. In the paragraphs that follow, we provide short descriptions of each chapter.

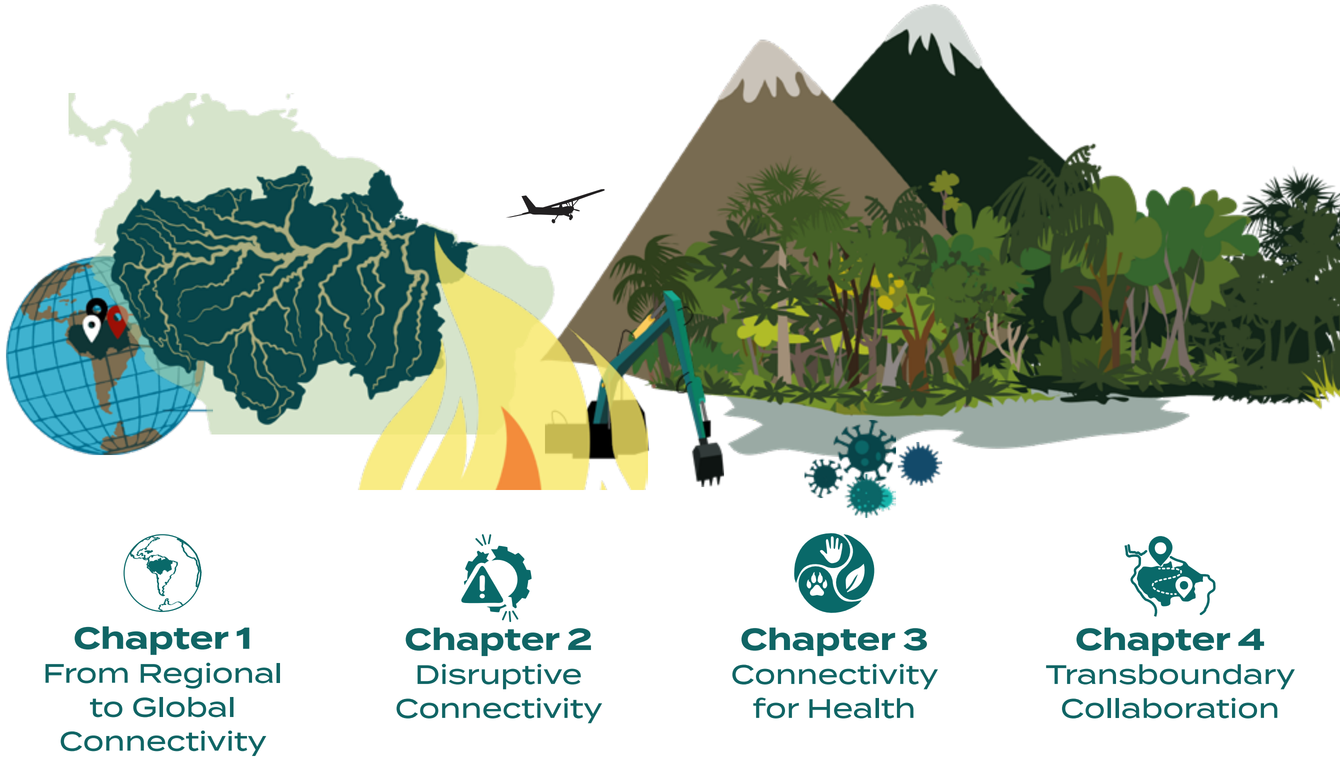

Figure 0.2. Overview of the structure of the 2025 Assessment Report on ecological and sociocultural connectivity in the Amazon.

Chapter 1 demonstrates **the importance of ecological and hydrological connectivity** for biodiversity, the stability of regional and global hydrology and climate, and the well-being of humanity through ecosystem services and cultural and spiritual connections. Ecological connectivity is fundamental for conserving today's biodiversity, which has come into being as a result of processes that have shaped it through time; millions of years of climatic changes and geological processes (such as plate tectonics, the Andean uplift, and the closing of the Isthmus of Panama) have driven speciation and formed the Amazonian ecosystems as we know them today[52,53].

Ecological and sociocultural connectivity is threatened by deforestation and illegal activities. **Chapter 2** highlights the convergence of **illegal economies** in the Amazon and the increasing role that organized crime has in environmental degradation. Illegal activities expose nearby communities to violence, lawlessness, health risks, social instability, and cultural loss[54]. These activities are exacerbated by major market distortions in the Amazon, including undesignated lands, land tenure insecurity, inadequate land taxation, and weak law enforcement[55].

Chapter 5
Connectivities of Amazonian Peoples

Chapter 6
Connectivity in Production Landscapes

Chapter 7
Connectivity for Socio-bioeconomies

Chapter 8
Knowledge Connectivity

Ecological connectivity is also intertwined with people's movements and **global health**[56,57]. **Chapter 3** explores how land-use change, forest fires, and increasing human–wildlife interactions increase the risk of vector-borne and zoonotic disease outbreaks, pathogen spillovers, new epidemics, and even pandemics. Deforestation reduces the available habitat for wild species, resulting in simplified ecological communities and increased populations of certain hosts and vectors of pathogens. Disrupting ecosystem connectivity, combined with climate change, can result in modified pathogen transmission dynamics, more frequent outbreaks, and the expansion of disease endemic zones, posing serious public health challenges. In contrast, healthy, connected ecosystems prevent such risks for diseases. Climate change also brings record-breaking heat waves that lead to a large number of deaths.

The Amazon is shared among eight countries and one overseas territory (of France), making **transboundary conservation** necessary. This aspect of connectivity is highlighted in **Chapter 4**, which calls for a regional approach to managing shared resources and addressing threats and challenges such as deforestation, environmental degradation, wildfires, habitat fragmentation, ecosystem contamination and pollution, and overexploitation[58]. The chapter also proposes transboundary monitoring systems to track illegal activities, preventing spillover effects between countries[31], and to track climate change, to provide early warnings and the means to mitigate climate disasters.

In particular, strong transboundary governance and legal protection are required in Indigenous and Local Territories. **Chapter 5** explores the **interconnectedness of Indigenous Peoples and Local Communities with Amazonian ecosystems, territories, and their inhabitants**. Connectivity is a way of life inherited through orally transmitted codes, encompassing community, territory, ancestors, and the spiritual relationship of reciprocity with nature[37]. Indigenous Peoples and Local Communities safeguard ecological and sociocultural connectivity and play a strategic role in the conservation of biodiversity and the implementation of sustainable practices, despite the structural challenges that threaten their livelihoods, territories, languages, and traditional practices[6-8]. Solutions to these threats include strengthening Indigenous Peoples' and Local Communities' economies; defending collective rights; recognizing women as guardians of socio-biodiversity; enacting autonomous monitoring of territories; and fostering intercultural, intergenerational, and spiritual connectivity[59].

These strategies point to a need for development of new economic and political paradigms, rooted in community practices, to guarantee the continuity of life in and beyond the Amazon. To maintain ecological and sociocultural connectivity, **production systems** should be incorporated into multifunctional landscapes that are predominantly forested, as highlighted in **Chapter 6**. Examples of such production systems include agroforestry systems, silvopastoral systems, community forest management, sustainable fisheries, non-timber forest product value chains, and traditional polycultures[38]. These systems not only generate income and improve community livelihoods through sustainable ventures but also promote biodiversity, support food and water security, and contribute to resilience to climate change.

Socio-bioeconomies, described in **Chapter 7**, are based on the natural resources of healthy standing forests and flowing rivers and on the cultural and historical connections of Indigenous Peoples and Local Communities with their territories. These reciprocal relationships shape their livelihoods and support knowledge systems rooted in coexistence with nature. Such economies, which are from and for the Amazon, go beyond a market approach, which focuses on profit and accumulation, and prioritize well-being for the human and more-than-human worlds[38,60].

Science and technology play a key role in accelerating sustainable development in the Amazon. **Chapter 8** underscores the importance of interweaving Western Academic Sciences with Indigenous and Local Sciences and Knowledge systems to align scientific advancements with regional realities and create more inclusive and effective conservation strategies[36,61-63]. Novel technologies like remote sensing, environmental DNA, and artificial intelligence also have the potential to support traditional conservation methods[63,64] if such tools are used ethically and provide collective benefits and equitable access.

5. Closing Remarks

We know that the connected Amazon system—and as a consequence our own future—is under threat. Given that the functioning of the Amazon depends on the maintenance and restoration of its ecological and sociocultural connectivity, this assessment report focuses on eight dimensions of connectivity and highlights some of the interventions being created, developed, and implemented by a multitude of diverse actors at different spatial and temporal scales. By providing concrete examples of these potential solutions in our Calls to Action, we hope to inspire our readers to look for and engage in long-term approaches that are scalable, fair, just, and appropriate for our vision of a living Amazon[41].

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CHAPTER 1

Amazon Connections from Regional to Global

Impacts and Vulnerabilities

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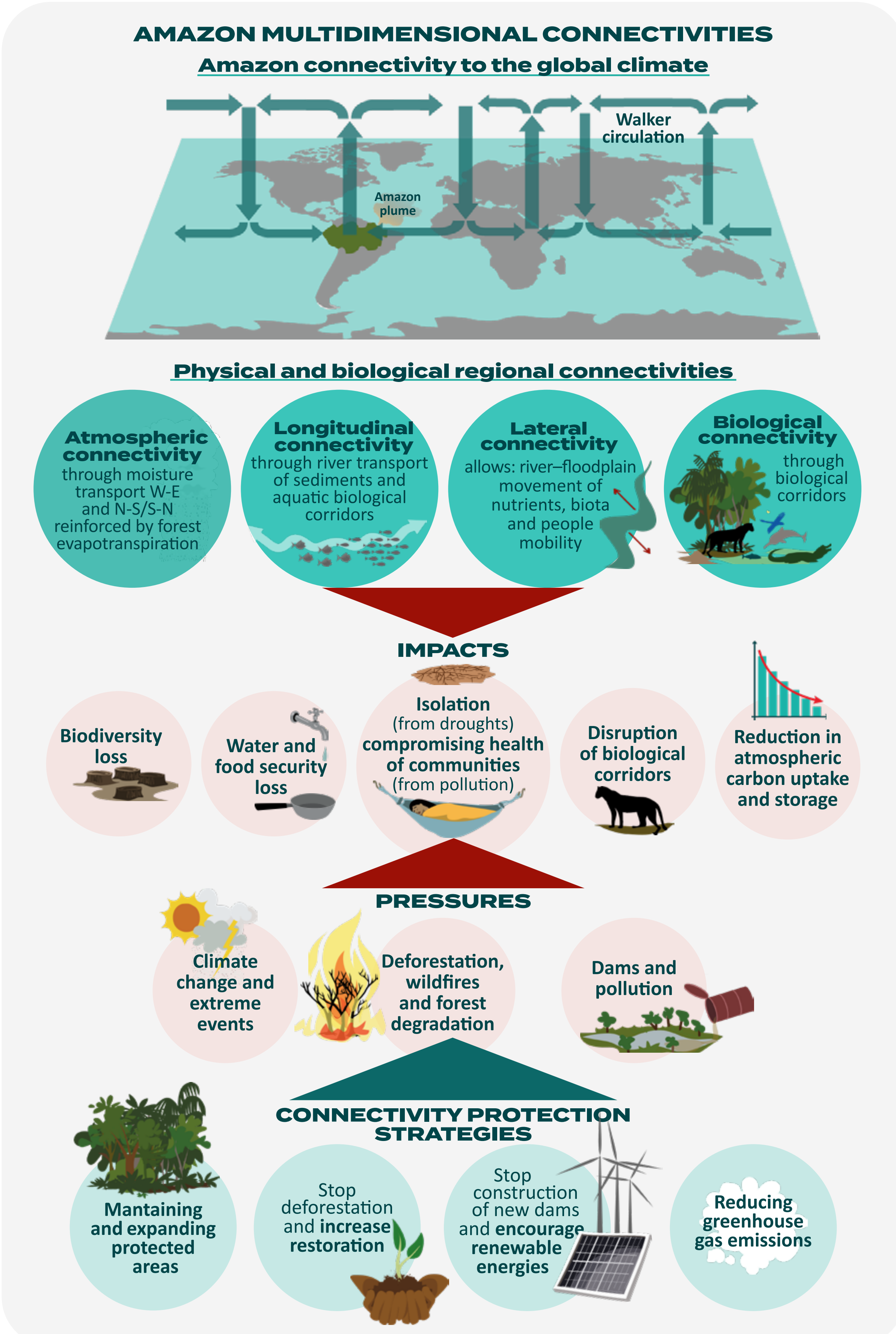
Abstract

The Amazon is a complex system of vibrant and interconnected ecosystems and human cultures, housing the largest species diversity on Earth. The many connections across the Amazon, linking the biosphere and atmosphere, the hydrology and biodiversity, are fundamental for global biodiversity, the stability of the global climate, and this, the well-being of humanity. The Amazon forest recycles between 30–50 per cent of its rainfall and exports moisture that shapes precipitation patterns across South America via "aerial rivers". The increases in deforestation, extreme wildfires, and the frequency of compound drought-heat events raise concerns around the possibility that large portions of the Amazon forest will experience significant degradation. These changes exacerbate the climate crisis at local, regional, and global scales that in turn compromise Amazonian connectivity and increase worldwide human vulnerability. The Amazon's climate both influences and is influenced by large-scale atmospheric phenomena that link weather and climate across vast distances, known as teleconnections. The Amazon forest sustains other biomes and economic activities for regions such as the Pantanal wetlands, the La Plata River Basin, and the Orinoco River Basin (N-S and S-N connectivity). The Andean-Amazon hydroclimatic system (E-W and W-E connectivity) conforms to a two-way interacting system, whereby the Amazon exports water vapor to the Andes through aerial rivers, and the Andes export river flows, sediments, and nutrients to the low-lying Amazon. Decreased river connectivity during extreme droughts isolates local communities and compromises their food and water security; below average floods can also impair floodplain-dependent activities, such as fishing. Without actions that prevent further degradation, Amazon forests are approaching critical environmental thresholds that threaten its ecological functions, biodiversity, and cultural connections.

Keywords
Amazon forest, biodiversity, drought, floods, aerial rivers, teleconnections, physical and biological connectivity, resilience, climate change



Graphical Abstract. Critical global and regional connectivities of the Amazon include the atmosphere, hydrology, carbon cycle, land, biodiversity, societies, and their interactions. To mitigate pressure and impacts, it is essential to safeguard various forms of connectivity and recognize that actions in one region can affect functions in another.

1. Introduction

The Amazon is a fundamental part of the Earth's cycles. This vibrant system of interconnected ecosystems and human cultures links the biosphere and atmosphere in connections essential to the balance of energy, water, and carbon and to the life of humanity on Planet Earth. The Amazon forest contributes around 30 to 50 per cent of the rain that falls in the region through the process of evapotranspiration[1]. The Amazon River accounts for approximately 17–20 per cent of the world's river discharge to the oceans[2]. This region contains more than 10 per cent of Earth's terrestrial biodiversity and stores an amount of carbon equivalent to 15–20 years of global CO_2 emissions (150–200 Gt C)[3,4]. The Amazon is home to more than 47 million people, including 2.2 million Indigenous Peoples of more than 400 ethnicities, as well as Afrodescendent and Local traditional Communities (hereafter IPs & LCs)[5]. This beautifully interconnected system, the life it supports, and the functions it plays are under threat from climate change, forest loss and degradation (e.g., from illegal timber extraction, fire, hunting), illegal land-grabbing and illegal mining (see Chapter 2). The disruption of these connectivities will cause irreversible harm to the global climate, biodiversity, and human well-being[6].

With the recent increase in deforestation, wildfires, droughts, heatwaves, and regional warming, concerns are growing about the potential collapse of the Amazon forest ecosystem. The Amazon River has experienced four "once-in-a-century" droughts in 2005, 2010, 2015–2016, and 2023–2024, and two "once-in-a-century" floods in 2012 and 2021, each progressively more severe than the previous one[7,8]. In turn, the damage to the Amazon forest further exacerbates the climate crisis at local, regional, and global scales, as well as at various levels, such as atmospheric, climatic, hydrological, and ecosystems[1,2].

The Amazon is one of the most diverse regions on Earth. This enormous biodiversity is unique in having an exceptionally high level of regional and local endemism, meaning that many species—particularly among plants, birds, amphibians, and insects—are found nowhere else. There are between 6,000 and 16,000 tree species across the Amazon, most of them are still unknown. Amazonian biodiversity is heterogeneously distributed across the region, with many species found only in restricted areas or in specific environments[9,10]. Hence, the loss of connectivity between rivers, forests, and savannas can lead to local extinctions or compromise genetic flow and ecosystem resilience[11]. The continuity of forest cover across vast areas enables the movement of terrestrial fauna, including large mammals, birds, and seed-dispersing species. This movement is essential for maintaining forest regeneration and ecological balance. Free-flowing rivers are critical for the seasonal movement and genetic connectivity of biota restricted to floodplain and riverine habitats[12]. The ecological connectivity of the Amazon—linking forests, rivers, and wetlands across a mosaic of ecosystems—supports critical ecological processes and functions such as evapotranspiration and photosynthesis. The series of continental-scale corridors are essential to preserve the vast biodiversity of South America under climatic and anthropogenic pressures. Increasing connectivity and preserving these corridors is crucial for climate adaptation strategies[13] and for maintaining fundamental ecological processes that enable forests to pump water from vegetation into the atmosphere through evapotranspiration. In this chapter, we synthesize the current understanding of the significance and threats to the physical, biological, and human connections, ranging from regional to global scales, providing a baseline for action to conserve the Amazon. Connectivity among the various terrestrial, seasonally flooded, and aquatic ecosystems is critical to the Amazon's ecological integrity.

Box 1.1. Degrees of connectivity.

The N-S, S-N, E-W, and W-E connectivity patterns refer to the characteristics that enable natural systems—such as hydroclimates, ecosystems, and biomes—to facilitate the movement of water, minerals, and organisms (including genes, spores, seeds) from one location to another. This connectivity is essential for maintaining biodiversity, supporting ecological functions, and ensuring the stability of carbon and hydrological cycles, as well as societal benefit on both regional and global scales[14].

2. Connectivity between the Amazon and Regional Climate System

The Amazon Basin receives most of its moisture from evaporation over the Atlantic Ocean (**Figure 1.1**), transported by aerial rivers—low-level winds that carry large amounts of water vapor (E-W connectivity). The forest actively contributes to these aerial rivers through evapotranspiration along preferential pathways[2,15]. The Amazon forest thus allows other biomes and economic activities to thrive in regions that would otherwise be more arid, such as the tropical Andes, Pantanal wetlands, Cerrado biome, La Plata River Basin[16], Orinoco River Basin (N-S and S-N connectivity)[17,18] and other regions, such as the northeast region of Brazil which is connected to the Amazon's hydroclimatic system, even though this region is less connected to the Amazon aerial rivers. Aerial rivers rely on release of organic gases from forests that form particles and help regulate rainfall and cloud formation. Andean-Amazon connectivity (E-W and W-E connectivity), facilitated by continental and aerial rivers, supports many natural and human systems in the Amazon. Andean-origin rivers contribute to the annual flow of the main Amazon River, exporting nearly all the sediments, as well as massive amounts of organic matter and nutrients to the lowlands[19,20]. Several of the large cities, both within and outside the region, rely on the Amazon's moisture supply for rainfall (and thus water), highlighting an essential aspect of connectivity[5,21].

As an active component of the global climate system, the Amazon both influences and is influenced by changes occurring even at large distances[6]. The Amazon's water and energy balance plays a key role in modulating broader atmospheric circulation, particularly the Hadley and Walker circulations[2]. Data from the last seven decades demonstrate that the connectivity between Amazon and the global climate system has changed[22]. For instance, the Amazon is gaining longer-range connectivity, with the ability to spread a perturbation faster and further, including a higher frequency of extreme hydroclimatic events such as droughts, floods, and heatwaves. The forest is gaining long-range connections associated with several highly dynamic components of the climate system, including the western Atlantic region, which is critical for the future stability of the Atlantic Meridional Overturning Circulation (AMOC)[23]. There is increased connectivity between the Amazon climate patterns and the South Asian monsoon region, as well as the climatically critical eastern and central Pacific regions[22]. The Tropical Atlantic Ocean exerts the most decisive influence on hydroclimate in the Amazon, contributing high amounts of oceanic moisture[15]. Furthermore, El Niño (La Niña) in the Tropical Pacific Ocean is frequently related to extreme warm (cool) and dry (wet) events. The increased temperature has a more substantial effect (increased water vapor in the atmosphere) than the loss of rainfall. Inter-annual variability of the climate system that can induce dry or wet conditions in the region[7,8,24].

The Amazon plays a crucial role in influencing rainfall patterns. Through a transpiration process, trees release water vapor into the atmosphere, facilitated by the uptake of carbon and the opening of stomata, which contributes to cloud formation and precipitation. This process is vital for maintaining the region's hydrological cycle. Furthermore, water vapor emitted by trees contributes to the formation of clouds, which ultimately lead to rainfall. Evapotranspiration from forests thus helps regulate local climate conditions, including temperature and humidity, which in turn influence rainfall patterns. However, water vapor in the atmosphere is insufficient to cause precipitation – cloud formation and precipitation also require aerosols – small particles around which water can condense and that can coalesce to form droplets. Here, forests also play an active role. Trees are sources of volatile organic compounds (VOCs), such as isoprene and monoterpenes, as well as sesquiterpenes. These compounds undergo chemical reactions in the atmosphere to produce aerosols (Cloud Condensation Nuclei - CCN), which combined with high humidity are essential for cloud formation and precipitation. Deforestation and forest degradation can disrupt these processes, potentially altering rainfall patterns and impacting the entire ecosystem. This is particularly important during the dry season when the risk of wildfire is high. For example, smoke from biomass burning consists of a large concentration of aerosol particles that overwhelms natural forest particle sources, altering cloud microphysics and reducing precipitation[25].

Biodiversity in the Amazon is intricately linked to and dependent on the region's climate patterns. Seasonal variations in rainfall and temperature determine river discharge and seasonal flooding of vast floodplains and govern critical biological events such as flowering, fruiting, and reproductive cycles across numerous species[26,27]. The predictable annual cycle of seasonal flooding has been disrupted by damming the rivers and by altered climatic conditions. These changes can lead to asynchronous processes among species, such as fruits being ripe and falling in dry floodplains, inaccessible for aquatic organisms and may compromise ecosystem stability and resilience[28,29]. They also influence the timing and amount of VOCs emitted from ecosystems, with potential consequences for cloud formation and precipitation.

Changes in climatic patterns have also been suggested to affect species composition biomass and the capacity of forests to absorb carbon, even in undisturbed forests[30–32]. These subtle decadal changes can only be detected through long-term monitoring[33], such as that led by local research institutions and hydrological-meteorological services[34,35] or through partnerships with local traditional populations[36,37].

3. Aerial Rivers: Connectivity from Tropical Atlantic-Amazon-Orinoco-La Plata Basin

As trade winds from the tropical Atlantic by the westward flow, they pick up moisture through the Amazon forest evapotranspiration[1]. As shown in Figure 1.1, the air masses are displaced to the central and southern parts of the Amazon. When these moisture-laden winds (aerial rivers) encounter the Andes Mountains, they are forced to rise, resulting in heavy rainfall in the region[38,39].

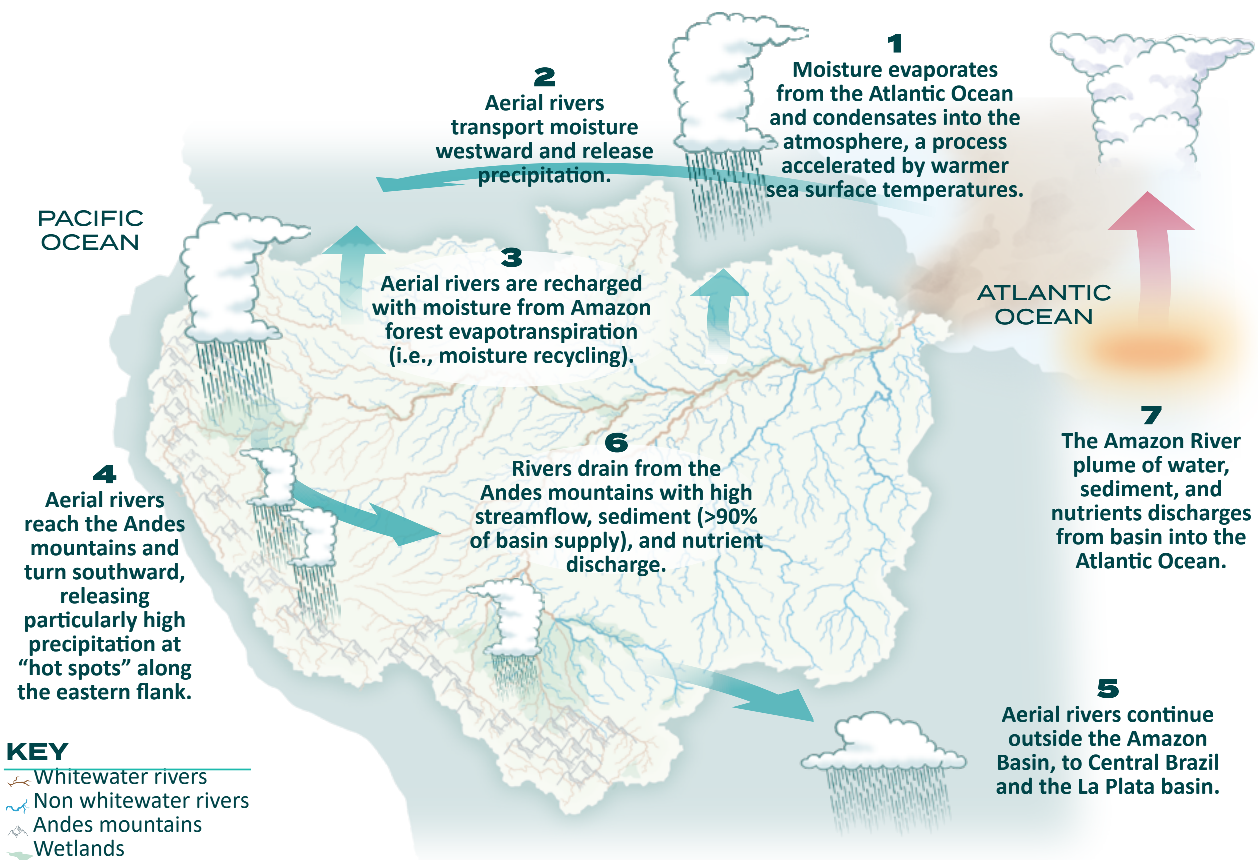


Figure 1.1. Key processes along the Atlantic-Andean-Amazon (AAA) hydroclimate pathway reflect how the regional water cycle is linked through continental hydrology, moving water vapor by the trade winds from the tropical Atlantic to the Amazon and the Andes (E-W connectivity) and then parallel to the Andes to southern Amazon and the La Plata Basin (N-S connectivity), through regional-scale atmospheric circulation by the aerial rivers east of the Andes. These processes along the AAA pathway underpin social-ecological systems within and beyond the boundaries of the Amazon Basin Source: Beveridge et al. 2024[2].

Depending on the season, the aerial rivers connect the moisture-laden trade winds from the equatorial Atlantic and the Amazon Basin with southeastern South America[40]. The humidity carried by these aerial rivers is responsible for much of the rain that falls in the agribusiness region in west-central Brazil, southeast and south of Brazil, and the La Plata Basin (including Bolivia, Paraguay, Uruguay, south of Brazil, and north of Argentina). The total amount of water released into the atmosphere by the forest is around 20 billion tons daily[40], equivalent to the 17 billion tons of water discharged daily by the Amazon River to the ocean. To the north, the aerial rivers transport moisture that induces rainfall in the Orinoco River basin[18].

Aerial rivers are dependent upon the Amazon forest evapotranspiration, but deforestation, wildfires, and tree mortality weaken the Amazon's capability to recycle atmospheric moisture. Tree die-off -driven by drought, wildfire, and warming- decreases evapotranspiration and disrupts water vapor movement toward the Andes and La Plata Basin[41]. Tree mortality has increased in the Amazon, peaking during years of climate extremes, resulting in a reduction in the forest's carbon sink capacity[30,42]. The disrupted hydrological connectivity between regions leads to altered rainfall patterns in South America while simultaneously undermining ecological processes tied to forest function and biodiversity. The loss of canopy cover alters microclimates, soil moisture retention, and the phenological cues of many species, creating a feedback loop that leads to further degradation. Several ecosystems and biotas have been shown to recover very slowly, become less resilient to subsequent wildfire events, or not recover after decades following wildfire[43,44]. Severe reduction in fossil fuel emission, strategic ecological restoration, combined with forest regeneration, can help re-establish climate–biodiversity feedback, supporting both hydrological stability and the recovery of species and ecosystems[45,46].

4. From Aquatic to Terrestrial Connections: W-E Connectivity from the Andes to the Atlantic

The health of the myriads of hydrological networks, forests, and other ecosystems is a key element for the integrity of ecological connectivity between the Andes and the lowland Amazon. Hydrological connectivity can be understood in its different dimensions: longitudinal (upstream-downstream connections along a river network), lateral (river-floodplain interactions), and vertical (surface-subsurface or surface-lower atmosphere connections) directions, all with varied temporal components[47]. These interactions complete the shaping of the complex Atlantic-Andes-Amazon hydroclimatic system[2]. In return, the Atlantic Ocean receives the massive outflow of the Amazon River, which discharges approximately 6,600 km³ of fresh water per year—approximately 20 per cent of the global fresh water discharge that reaches the oceans. The Amazon also contributes 40 per cent of all riverine sediment entering the Atlantic, playing a crucial role in maintaining the ocean's nutrient balance, promoting marine biodiversity, and sequestering carbon dioxide[48]. Much of the Amazon River's streamflow originates in the western Amazon Basin, where rainfall is most abundant[38]. This region also has the highest run-off per unit area[2] and produces 90 per cent of the total sediment in the basin[20]. Increased Amazon River discharge to the Atlantic Ocean in recent years, associated with the intensification of extreme hydrological events, has been hypothesized to affect the Amazon River plume salinity and lead to feedback processes that further alter the basin's rainfall[49].

Many of the Amazon Basin's extensive river systems serve as conduits for sediment and nutrient transport, connecting floodplain biodiversity and facilitating the migration of aquatic species. These systems have also allowed cultural exchange, development, and maintenance of the livelihoods of millions of riverine people for millennia. The hydrological regimes of the Amazon rivers offer opportunities for agricultural small-scale activities near the floodplains, which have good potential for agriculture but are frequently impacted by sudden floods (locally called 'Repiquetes') related to high rainfall amounts in the Andes-Amazon transition zone[50,51]. If this is agriculture such as soy crops and pastures, or livestock, they lead to deforestation of the riverside vegetation.

Many of the Amazon's most important fish species rely on the productivity of Andean tributaries and main-stem floodplains, which receive sediment-rich waters from the Andes and support annual fish migrations, both along drainage networks and between rivers and floodplains. These processes distribute Andean-dependent energy and nutrient resources to adjacent, lower-productivity aquatic systems[52]. River-floodplain migration is a fundamental adaptation for multiple species, including arapaima also known as pirarucu (Arapaima gigas), the largest-scaled freshwater fish on Earth and the basis of one of the leading community-based productive chains in the Amazon[53,54] (See Call to Action 20, Chapter 6).

More connected lakes in river-floodplain systems sustain greater arapaima populations[55], and the annual flood pulse is a fundamental driver of Amazon aquatic ecosystem functioning[56], including reproductive cycles. Alterations in the river flood pulse, and thus the natural river-floodplain connectivity, can directly harm ecological adaptations and the people who depend on the ecosystem services they provide. There has been a 26 per cent increase in the maximum inundation extent along the Amazon River floodplains in the central Amazon, leading to longer flood durations and enhanced river-floodplain connectivity[57]. Damming of major Amazonian tributaries has disrupted natural flooding cycles, sometimes suppressing or reducing flood duration, which is detrimental to fish reproduction and ecosystem functioning and affects local communities' livelihoods. Damming lowland rivers contributed to CO_2 and CH_4 emissions, depending on factors like the amount of flooded organic matter, water temperature, and the age of the dam, making reservoirs significant but complex components of the global carbon cycle, if forests are flooded[58–60].

Natural longitudinal connections between the Andes and Amazon are crucial for allowing regional migration and species diversification[61]. The disruption, fragmentation, or complete loss of this vital Andes-Amazon connection may lead to the loss of stability in many species' populations and the degradation of ecological functions. Dam expansion across the basin has directly threatened longitudinal connectivity and the maintenance of free-flowing rivers, as well as the ecosystem services dependent on them[62]. The operation of dams affects downstream hydrology[63,64] and can also affect river-floodplain connectivity and flood duration over floodplain forests, as shown for the Uatumã River with the large Balbina dam[65].

The Amazon's blue-green longitudinal connectivity is vital for supporting species that need both terrestrial and aquatic environments. The lowland tapir (Tapirus terrestris), for example, a large, wide-ranging herbivore, relies on riparian forests, floodplains, and savanna–forest mosaics for foraging, mineral access, and movement. Tapirs use riparian corridors and seasonally flooded forests for mobility, feeding, and thermoregulation, particularly during dry periods. Similarly, vertebrate frugivores, including primates and birds, alternate the use of resources from both uplands and floodplains along the annual cycle[66,67]. Migratory species are a critical component of Amazonian fisheries[68], with at least 223 fish species known to perform fresh water migration in the Amazon. They account for the main fish species captured and sold at commercial fish markets in much of the lowland Amazon. Such examples provide evidence that many Amazonian species exhibit complex patterns of habitat use, and that disruptions in riverine connectivity that impede migratory species' ability to complete their life cycle have potential impacts on the livelihoods and economy in the Amazon.

Longitudinal and lateral connectivity along riverine pathways are critical to the persistence and life histories of migratory fish species, as is temporal connectivity. Temporal changes in river flow cue many fish species' migrations; this temporal predictability could be considered another dimension of riverine connectivity to which migratory fishes are attuned. The Amazon's hydrological connectivity also supports the life cycles of long-range migratory aquatic mammals, such as river dolphins. Inia geoffrensis and Sotalia fluviatilis rely on the longitudinal and lateral connectivity of river systems to complete essential behaviors, including feeding, reproduction, and migration. Male and female river dolphins exhibit different migration patterns; males travel long distances through rivers, while females stay within restricted areas to care for their young offspring. These movements are closely tied to the seasonal flood pulse, which governs prey availability and habitat accessibility across the basin and is dependent on free-flowing and connected rivers. Migratory fish species, by connecting distant habitats, help facilitate the transfer of nutrients and energy across the Amazon[69].

The western Amazon has higher species richness and endemism than the more eastern or downstream subbasins[70]. This reverse gradient is unlike many large river basins, where fish species richness usually increases in a downstream direction. It also underscores the importance of longitudinal connectivity. Some Amazonian terrestrial groups have their distributions delimited by large rivers[10,71], meaning that Amazonian rivers serve as corridors for aquatic and floodplain biota but may act as substantial barriers to the connectivity of some terrestrial taxa. For these terrestrial species, bounded by current river channels and floodplain belts, connectivity along the interfluves is essential, allowing them to maintain sufficient habitat and some capacity for adaptation in the event of habitat loss or climatic extremes. Terrestrial connectivity along altitudinal gradients in the base of the Andes or the Guianan tepuis is also essential for maintaining a species' ability to perform seasonal movements and adapt to changing climates.

Deforestation is concentrated in certain Amazonian interfluvial areas. The net loss of forest within some interfluves, such as the areas between the Xingu and Tapajós, Tapajós, and Tocantins, and the eastern Tocantins River in the southeastern Amazon, for example, may impair ecological processes. For instance, in the Paquiçamba Indigenous Territory, one of the last remaining undisturbed upland forests of the lower Tapajós-Xingu interfluve, the Brazil nut (Bertholletia excelsa) trees stopped producing fruits in the previous 10 years after the widespread deforestation around the Indigenous Territory triggered by the TransAmazon highway and the construction of the Belo Monte dam[72]. So, even when preserving the forest, the ecological patterns that depend on ecosystemic processes, such as pollination, seem to be affected by the delimitation of the Indigenous Territory.

5. Threats to the Amazon and Promoting Resilience

Due to warming trends, the increase of compound dry and warm events, deforestation, and degradation, there is now evidence of a large-scale loss in the Amazon forest's capability to recover from stress and disturbance since the early 2000s, with faster resilience being lost faster in drier regions and less remote areas with increased human land-use[73]. Thus, in the driest and most deforested regions of the Amazon, the warming trend is intensified (**Figure 1.2**). In addition, the dry season over southern Amazon is already 4-5 weeks lengthier over 40-45 years[74]. There is a risk that the large area (38 per cent) of the already degraded Amazon forest, due to extreme drought, wildfire, logging, and edge effects, will remain degraded due to feedback from climate, biotic, and abiotic factors and processes, such as wildfire[75,76]. In the central Amazon's Negro River Basin, repeatedly burned lowland forests are shifting into white-sand savannas, a change unlikely to reverse, with long-term consequences for animal communities[77]. Other areas of floodplain forests, repeatedly disturbed by wildfires, have also been reported to be highly vulnerable to collapse and shift into a fire-prone state if these regions become drier, as predicted[43,78].

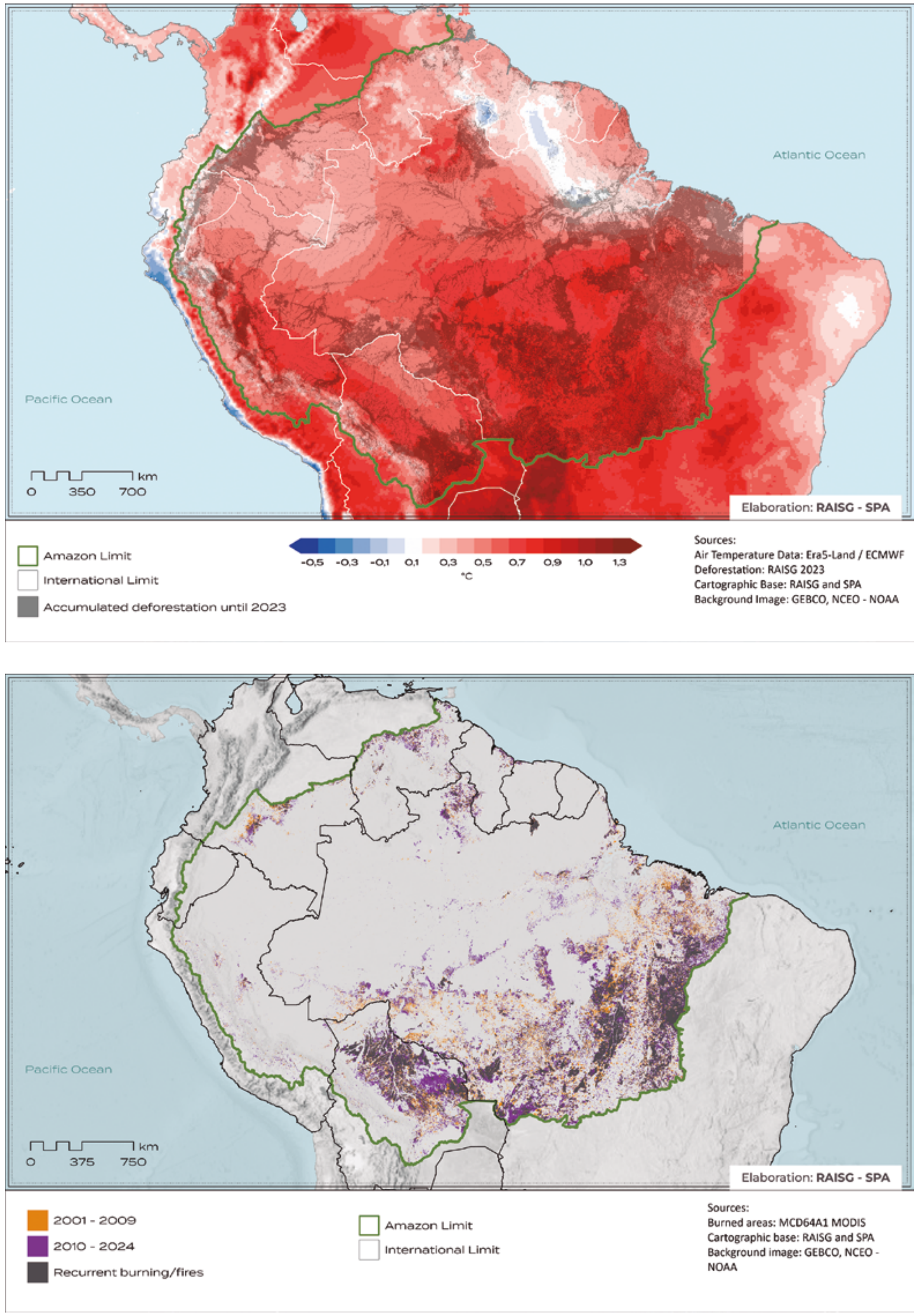


Figure 1.2. Climate, land use and wildfires across the Amazon. a) Warming of surface air temperature in tropical South America (colors) is represented as the difference in average annual temperature between the periods 1998–2024 and 1981–1997 using ERA5-Land available from European Center for Medium-Range Weather Forecasts. Deforested areas in 2023, relative to the original native forest in 2000, are shown as black dots. The dark green line represents the limit of the Amazon region as defined by the Science Panel for the Amazon (See Chapter Introduction). b) Burned area during the periods 2001-2009 and 2010-2024 and overlapping area in both periods using satellite data from MODIS burned area product.

Model experiments on Amazon deforestation indicate rainfall reduction in the Amazon and an increase in temperature during both the wet and dry seasons. Reduced regional precipitation might result in substantial economic losses in agriculture, with crop yields declining by 0.5 per cent for each percentage point reduction in rainfall[79]. This can increase the risks associated with wildfire frequency[80], reduction in carbon sequestration[81] by natural vegetation, and compromise livestock and even human health[82].

A suppression or reduction in the aerial rivers' coverage and moisture transport could affect the climate in regions such as the tropical Andes, including glaciers and paramos[83], the Pantanal, Cerrado, and the Amazon, and have consequences at the river's exit region and in the atmospheric and surface water balance over the Parana-Plata River Basin[84]. Extreme droughts have become increasingly frequent in the Amazon[24,85] as land-use change and human-induced climate change progress[46,86], affecting tree mortality and wildfire incidence[80,87], and carbon emissions[5,88]. While the high biodiversity of the Amazon may allow ecological communities to adapt, as observed within tree communities[32], species are likely to be lost in this process. Record-breaking droughts, as seen in 2023 and 2024, pose additional threats to hydrological connectivity[8,24]. Decreased longitudinal and lateral connectivity during these droughts isolates communities and increases their food and water insecurity because rivers are too low to support the transportation of food, people, and medicines; floods of 81 per cent or below average can impair floodplain-dependent activities, such as fishing[89].

The most extreme heatwaves in the Amazon co-occurred with extreme drying signals[90–92], compromising biodiversity, ecosystem connectivity, and functioning in the Amazon. Such events have been observed to reduce forest leaf area and forest evapotranspiration, potentially leading to the onset of a significant change that compromises the future of these systems[93]. Drought-heatwave episodes are often associated with high fire activity[91], but also vice versa, increased drought sensitivity in forests degraded by fire[94]. For instance, the catastrophic fires in the Amazon, Cerrado and Pantanal wetlands during the droughts in 2015, 2020, and 2023-2024 made these ecosystems more water-limited and likely more fire-sensitive under the predicted more intense and longer dry seasons[94]. The increased frequency of compound drought-heatwave events also increases the risk of Amazonian forests approaching critical thermal thresholds beyond which the photosynthetic machinery of these trees begins to fail, leading to irreversible damage.

There is a risk to ecological connectivity when compound events of drought and heat favor wildfires. In 2023, the Amazon experienced the death of almost 300 river dolphins (Inia geoffrensis, Boto cor-de-rosa) due to extreme temperatures in lakes and streams[24]. This mortality event is likely to be only one of many others across the Amazon. Drought-heat compound events and their consequences are among the most critical natural threats to the Amazonian population. Land-use cover change and global climate change can be concurrent or opposing processes regarding irreversible transitions that culminate in severe degradation of vegetation and its services. These are referred to as tipping points. A tipping point involves the strong feedbacks between vegetation change and climate that reinforce each other, causing rapid degradation of forests and regional climate. One tipping could be the collapse of the Amazon tropical forest. The risk of surpassing this point of no return increases if global warming rises above 2°C and deforestation exceeds 20 per cent of the total area of the basin[95]. Both deforestation and forest degradation can accelerate the reaching of that tipping point, which could translate into extended droughts, wildfires and forest collapse[46,75].

Box 1.2. Fire and connectivity in the Amazon: from Indigenous stewardship to global change tipping points.

Nearly 400 Indigenous groups across the Amazon[96] have used fire as an ecological and cultural connector for millennia. Their practices enrich soils, maintain mosaics, promote biodiversity, reduce emissions, and mitigate health risks[97–99]. Despite centuries of colonization, Indigenous fire management continues to sustain biodiversity, carbon storage, and soil fertility[97–102].

Today, climate change, deforestation, and fragmentation are reshaping the conditions under which these practices evolved[80,81,103,104]. Extreme wildfires disrupt Amazonian connectivity, amplifying climate change through emissions and hydrological changes that dry forests, open canopy cover, and fragment ecological corridors and cultural fire networks[76,105]. This reinforcing feedback pushes the system toward potential tipping points where vast areas may irreversibly shift to degraded, fire-prone states[14,106].

Restoring fire as a connector—rather than a destructive force—while respecting diverse cultural and political contexts is critical for safeguarding the Amazon and its role in global climate regulation.

6. Protecting Amazonian's Connectivities

The protection of Amazon Indigenous Territories and protected areas is fundamental to maintain Amazonian connectivity. For example, in Brazil, the Amazon Indigenous Territories influence the rainfall that supplies water to 80 per cent of the agricultural area in the Central-West region of Brazil[107]. Up to 30% of the average rainfall that falls on the country's agricultural lands is directly related to the efficient recycling of water in the Amazonian Indigenous territories and the generation of water vapor transported by the aerial rivers to the southern Amazon[107]. Given that agriculture and livestock farming are among the activities that consume the most water in Brazil, the rainfall coming from the forest and its Indigenous Territories and protected areas transported by the aerial rivers contributes directly to irrigate the lands dedicated to agribusiness and to guarantee national food security.

Although Indigenous Territories protect a large portion of the Amazon[108], these territories are continuously threatened by illegal invasions and even attempts to change legal frameworks that protect them. Indigenous Territories are also threatened by impacts in surrounding areas or changes in climatic patterns. Some Indigenous communities have developed monitoring programs to quantify impacts related to river damming and/or climate change, in some cases establishing partnerships with non-Indigenous researchers[36,58]. The collaboration between Indigenous and non-Indigenous scientists has the potential to value local knowledge, provide protagonism for local people in decision-making, and improve western scientific understanding of the impacted ecological processes (see Chapter 8). However, Indigenous knowledge has historically been used by academic researchers without proper recognition, and Indigenous researchers often end up without academic titles or authorship in published studies. Building collaborative research agendas that incorporate, recognize and reward local researchers and local institutions is fundamental for improving Amazonian science and making it more effective in protecting the biome.

7. Conclusions

The Amazon forest plays a crucial role in the global climate system by influencing energy, water, and carbon balances, while also sustaining a rich array of ecosystems and human cultures. It is a significant source of atmospheric water vapor, which drives rainfall and impacts economies and livelihoods both within and beyond the region. Additionally, the forest supports a diverse array of species, thereby ensuring genetic diversity and ecosystem resilience. This area functions as an essential continental-scale ecological corridor, facilitating the migration and preservation of South America's vast biodiversity amid climatic and human pressures. The Amazon is home to millions of people and hundreds of cultures. Indigenous Peoples and Local Communities have played a crucial role in maintaining this ecosystem and its vital connections.

This interconnectedness is vital for ecological processes, biodiversity, and the stability of regional carbon and hydrological cycles. Unfortunately, the Amazon faces increasing threats from deforestation, forest fragmentation, fires, droughts, and heatwaves, raising concerns about its potential collapse, which could worsen the climate crisis. These threats undermine connectivity, negatively affecting water security, livelihoods, and biodiversity. The loss of resilience in the Amazon, particularly in degraded areas, highlights the urgent need for conservation and sustainable management to preserve its crucial role in supporting our planet. Indigenous Peoples and Local Communities play a significant role in safeguarding a large portion of Amazonian territory; maintaining their cultural resilience and permanence is crucial for Amazonian conservation.

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CALL TO ACTION 1

Halt Amazon Deforestation and Degradation

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The Overview

The Amazon is a complex and interdependent mosaic of ecosystems that supports billions of lives. Deforestation has caused the loss of around 18% of the Amazon region, and 38% of the remaining forest is degraded, disrupting ecological and socio-cultural connectivity, accelerating carbon emissions, exacerbating water and food insecurity, causing economic instability, and weakening climate resilience[1]. The system may be approaching a tipping point, with models indicating that ecosystem transitions could affect as much as 47% of forest area by 2050[2].

The Facts

- Between 1985 and 2023, 12.4% of Amazon forest area was lost due to anthropogenic activities such as large-scale commercial agriculture, cattle ranching, logging, mining, and infrastructure expansion.

- The Amazon Basin's ecosystem connectivity is rapidly declining due to deforestation, mining, dams, fires, and oil and gas exploitation (**Figure C1.1.1**), with nearly 25% of lowland forest, river, and wetland area already affected[3].

- Potential vegetation modeling suggests a critical threshold of cumulative deforestation, ranging from 20% to 50%, beyond which forest mortality accelerates[2].

- Of the Amazon's remaining forest area, 38% has been degraded due to logging, fire, drought, and fragmentation, which has increased in recent decades, with fragments becoming smaller and more dispersed[1,4]. Some of these degradation drivers interact; for example, logged-over forests have higher risk of forest fires[5].

- Carbon emissions from degradation (0.05–0.2 GtC y^{-1}) are as high as those from deforestation[1], and yet degradation is not properly accounted for in national carbon budgets.

- Indigenous Territories (ITs) and Protected Areas (PAs) cover 54% of the Amazon Basin and have higher connectivity, making them essential for ecological processes. ITs (28.5% of the region) experience 85%–92% less forest loss than adjacent areas, while deforestation in PAs is 38%–90% lower than in non-protected areas[2,3,6]. Unlike deforestation, forest degradation—beginning with logging—affects many ITs in Brazil.

- Indigenous Peoples (IPs) and Local Communities (LCs) defend their territories against deforestation and promote forest restoration through agroforestry systems[7-9] , but loss of Indigenous and Local Knowledge, threats to territorial rights, and lack of financial and technical support undermine their capacity to manage and protect these areas[10] .

Global/Regional and Synergistic Connections

- Ecosystem connectivity in the Amazon is critical for sustaining biodiversity, species movements, and ecological functions, but multiple anthropogenic pressures are rapidly disrupting it[3].
- Deforested and degraded forests release CO_2, impacting global emissions; disrupt regional rainfall patterns; and intensify extreme droughts, accelerating further forest degradation across the Amazon[2].
- Deforestation and degradation threaten global carbon markets, as undetected emissions from degraded forests undermine carbon credit integrity[11].
- Deforestation and degradation increase species extinction risks and disrupt ecological interactions, reducing ecosystem services and endangering agriculture, fisheries, and local economies[1].
- Weak governance in degraded areas fuels land speculation, illegal logging, conflicts over land rights, and increased fires, droughts, and air pollution that disproportionately harm IPs and LCs[1].
- Global to local geopolitical changes affect deforestation and degradation rates mostly in non-designated Brazilian lands, which are neither included in Conservation Units nor protected by IPs or LCs[12,13].

The Solutions Space

Major Recent Governmental Efforts

- **Brazil's Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm)** played a significant role in reducing deforestation by 83% between 2004 and 2012, and it was relaunched in 2023 with four major foci: (i) promoting sustainable production activities; (ii) environmental monitoring and control; (iii) land and territorial planning; and (iv) normative and economic instruments. Key measures included keeping a municipal blocklist and conducting satellite surveillance (the Real-Time System for Detection of Deforestation—DETER). Deforestation reductions were also strongly influenced by macroeconomic shifts that reduced profitability of export-driven commodities like soy and beef[13].

- **ITs and PAs are avoiding deforestation and maintaining connectivity[3,7]. The Brazilian map of conservation priorities** estimates that 80% of the Brazilian Amazon should be permanently protected within ITs and PAs at a cost of USD 1.0–1.6 billion for establishment and USD 1.7–2.8 billion a year for maintenance and management[3,14].

Collaborative Efforts

- **IPs and LCs monitor impacts within their territories more efficiently** than expensive official monitoring strategies that are often implemented by the companies that exploit natural resources[15,16]. These local monitoring initiatives are supported by civil society, collaborative research projects, and recently also by the Brazilian Ministry of Science, Technology and Innovation and the Global Environment Fund as a strategy to integrate Indigenous and Local Knowledge into conservation practice.

Selected Key Tools

- **Brazil's Rural Environmental Registry (CAR)** provides georeferenced mapping of forested and agricultural areas, ensuring more effective tracking of exported commodities. Real-time satellite tracking—through the Legal Amazon Deforestation Satellite Monitoring Project (PRODES) and DETER—provides early-warning systems. CAR, PRODES, and DETER could be expanded and harmonized for all Amazonian countries. Open access to integrated deforestation and degradation data platforms—including AMA de RAISG (a platform of the Amazon Network of Georeferenced Socio-Environmental Information) and MapBiomas—improves transparency and accountability.

Positive Efforts for Scaling

- **Strengthening commodity traceability and certification programs** is crucial to ensure sustainable supply chains. However, existing initiatives—such as the Meat Terms of Adjustment of Conduct (Meat TAC), Green Seal, Brazil's Soy Moratorium, and the Roundtable on Responsible Soy—often overlook "indirect" deforestation[17]. Effective certification must recognize and address indirect impacts. Aligning such initiatives across multiple countries would prevent deforestation-linked products from shifting to less-regulated areas.

Best Practices

- **Valuing IPs' and LCs' traditional culture and knowledge and providing the means for their quality of life (for "living well"—bem viver, buen vivir) protects the Amazon** region by creating conditions for people to remain in their territories. Initiatives that value Indigenous and Local Knowledge in Indigenous schools, research centers led by Indigenous researchers, multicultural collaborative research projects, and formal recognition of Indigenous and Local Knowledge are essential for leading a transformation in Amazonian research, governance, and conservation.

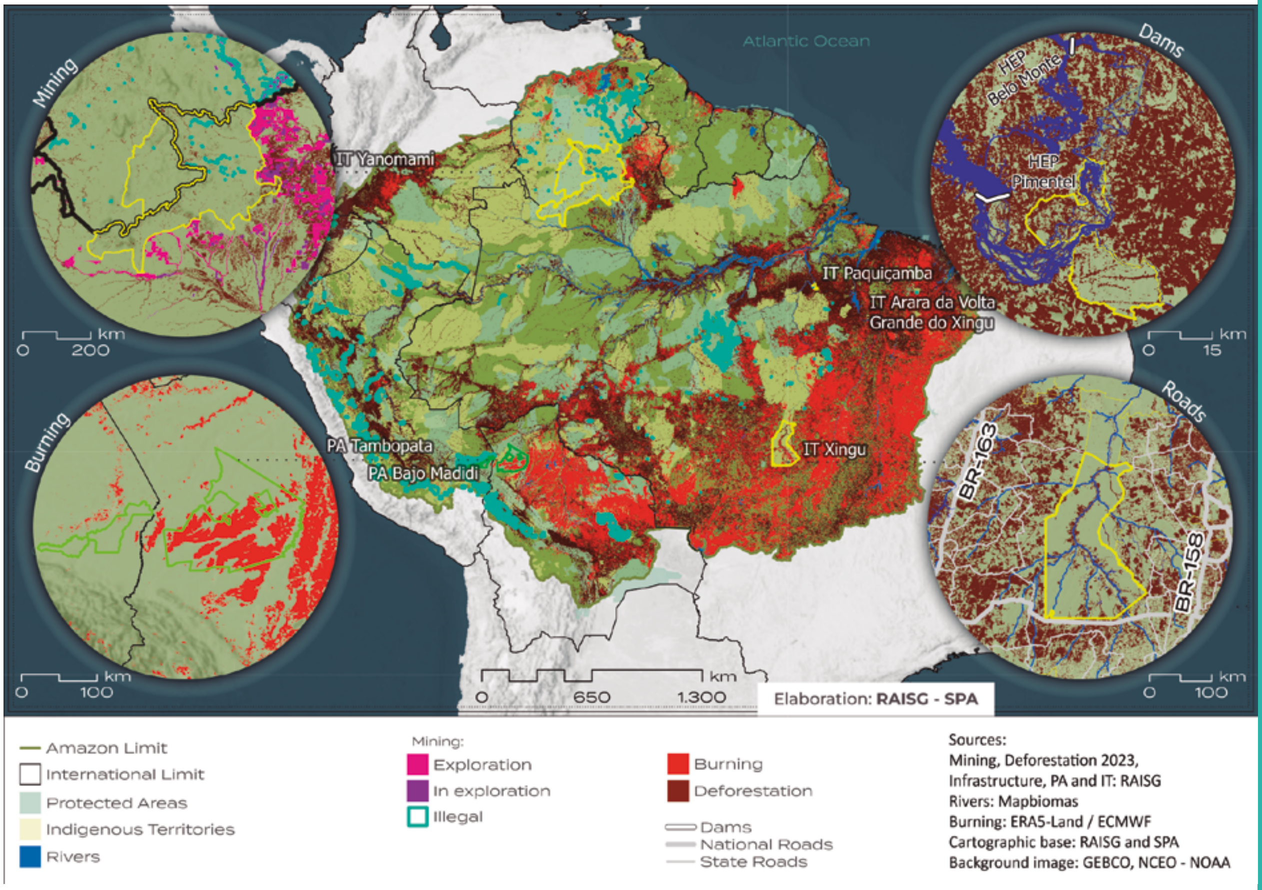

Figure C1.1.1. Deforestation and forest degradation, including wildfires, are closely linked to illicit activities in the Amazon and are also driven by road and dam expansion. While Protected Areas and Indigenous Territories help mitigate these impacts, forests continue to face increasing pressures.

Recommendations

- **Establish an upper limit for cumulative deforestation at 10%** of the original forest biome cover, which requires an end to large-scale deforestation and the restoration of at least 5% of the biome[2].

- **Protect, expand, and legalize ITs and PAs,** while prioritizing undesignated public lands, ensuring adequate funding for their establishment and management, and ensuring livelihood opportunities for these populations to remain in their territories[3].

- **Support and enhance public and independent databases** that integrate deforestation, degradation, land use, and biodiversity data for better transparency and decision-making.

- **Strengthen, respect, recognize, and expand IP- and LC-led monitoring initiatives** across the Amazon, ensuring these communities play a key role in governance and get the credit for doing so.

- **Develop integrated governmental transboundary programs** to prevent deforestation and forest degradation — with specific measures targeting illegal activities — and a basin-wide ecosystem monitoring system, using satellite data, artificial intelligence (AI) analytics, biodiversity data, and community-based observations.

- **Integrate forest degradation into carbon accounting systems,** ensuring its inclusion in nationally determined contributions (NDCs) to the Paris Agreement targets under the United Nations Framework Convention on Climate Change (UNFCCC) and reforming REDD+ (referring to reducing emissions from deforestation and forest degradation in developing countries, plus other forest-related activities) and national greenhouse gas inventories to account for degradation-related emissions and prevent hidden carbon losses[11].

- **Ensure deforestation- and degradation-free global supply chains** by enforcing corporate accountability, requiring carbon market transparency, and aligning commodity trade policies with international deforestation regulations (e.g., the EU Regulation on Deforestation-free Products).

- **Expand financial incentives for conservation,** including biodiversity credits, REDD+ funding expansion, and debt-for-nature swaps[11]. At the same time, end subsidies for economic activities with high environmental costs (e.g., pasture and soy).

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Reduce and prevent extreme wildfires

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Photo credit: Ruth Salazar Gascón.

The Overview

Extreme wildfires in the Amazon forest, intensified by climate change and extreme weather events (droughts and heatwaves), are driven by deforestation, agriculture, mining, and forest degradation from logging and edge effects, threatening biodiversity and local communities while emitting smoke and greenhouse gases (GHGs)[1,2]. Once rare in humid forests, extreme wildfires now risk pushing ecosystems toward irreversible tipping points, disrupting natural cycles, public health, the livelihoods of IPs and LCs, and exacerbating climate change[5,6]. The loss of lands of Indigenous Peoples and Local Communities (IPs and LCs) and erosion of their patch-based traditional fire practices—which historically helped control fire spread and maintain landscape connectivity—also contribute to the climate crisis[3,4]. Current Amazon zero-fire policies centered on suppression are often ineffective, costly, and dismissive of IPs' and LCs' fire practices.

The Facts

- Extreme wildfires in the Amazon historically occur in the "arc of deforestation" driven by land-use change[1].

- From 2001–2024, ~370 million hectares burned (Figure 1.2.1); From 2001 to 2019, wildfires affected only ~11% of the Amazon's ITs and PAs. In contrast, ~75% of burned areas were outside[7].

- IPs' and LCs' fire use is controlled, seasonal, and patchy, and the fires are of limited size in contrast to the destructive and extensive agro-industrial fires[5,8].

- Climate change delays the start of the wet season and boosts fire events. The number of extreme fire weather days has tripled since 1971, and may double the area burned by 2050[9].

- The smoke from fires alters cloud formation, intensifying drought[10,11].

- Fire-related smoke is responsible for ~16,800 Deaths each year^{-1} [12].

- IPs' and LCs' lands act as carbon sinks with much lower CO_2 emissions (0.60 tonnes CO_2e $ha^{-1}.yr^{-1}$) than outside lands (3.2 tonnes CO_2e $ha^{-1}.yr^{-1}$), but face growing threats and exclusion from policies[13,14].

- Logging, legal or not, increases the likelihood and intensity of forest fires[15].

- The continued expansion of ranches and settlements, both large and small, provides new ignition sources for forest fires, which usually spread from intentional burning in newly cleared areas or from cattle pastures being burned to control invading woody vegetation [16].

Global/Regional and Synergistic Connections

- Global commodity demands (such as beef and soy) drive deforestation and the use of fires for pasture and land clearing[17].
- Wildfires hinder 56–82% of the Amazon forest regrowth after complete deforestation, disrupting local, regional, and global carbon and moisture cycles[18].
- Amazon carbon emissions more than doubled—from 0.9 to 1.9 Gt CO_2 yr^{-1} between 2010–2020—driven by rising deforestation and fires, undermining progress toward the Paris Agreement goals[19].
- Black carbon emitted by Amazonian biomass burning is transported to the Andes, where it contributes to glacier melting, harming regional health and water security[20,21].
- Controlling the larger wildfire risks stemming from non-traditional actors, such as cattle ranchers and loggers, requires policy changes and strong government command-and-control[22].

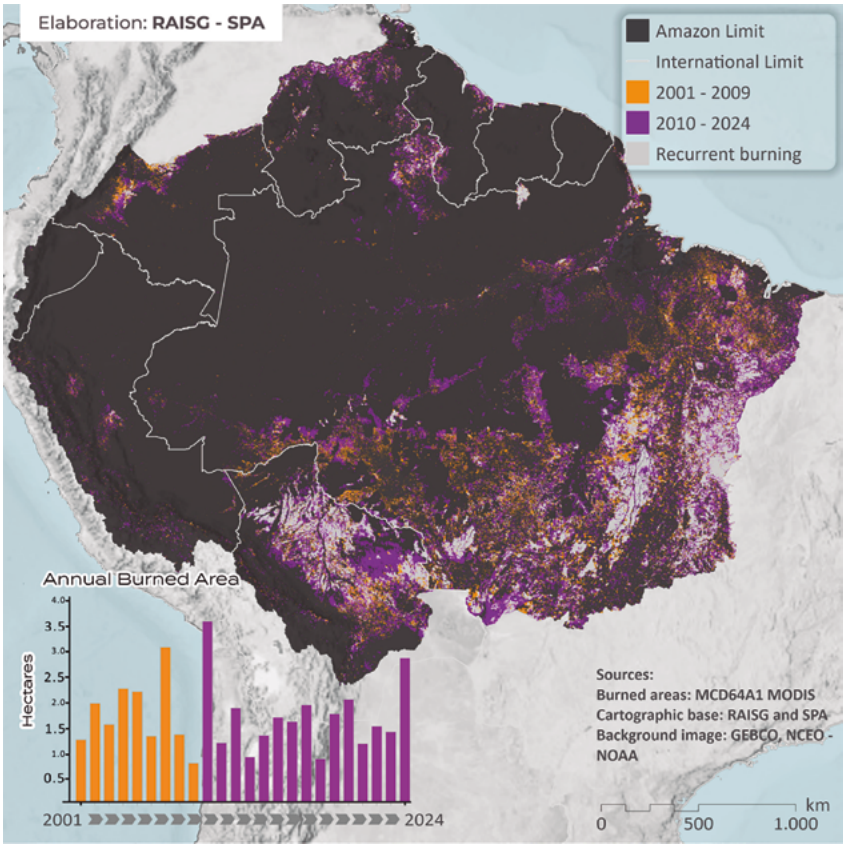

Figure 1.2.1. Burned area recurrence from 2001 to 2024 from the MCD64 A1 product.

The Solutions Space

Collaborative Efforts

- In recent years, **FAO and UNEP launched the Global Fire Management Hub** to strengthen countries' capacity for integrated fire management and reduce wildfire impacts on people, landscapes, and climate. Its first Plenary (FAO, June 2025) gathered global experts to connect capacities, build partnerships, and shape joint strategies for coordinated international action.

- **The Memorandum of Understanding for Integrated Fire Management** was approved by the member countries of the Amazon Cooperation Treaty Organization (ACTO) in 2021, establishing the Amazon Network for Integrated Fire Management (RAMIF) to coordinate regional fire policies and promote sustainable fire management that respects the Amazon's ecological and cultural significance, particularly for IPs and LCs.

Major Recent Governmental Efforts

- **The Integrated Fire Management (IFM) Law was** enacted by Brazil in 2024, establishing a national policy to prevent and combat fires by integrating technical, scientific, and traditional knowledge, and prohibiting the use of fire for deforestation. The law recognizes the ecological and cultural role of fire for IPs and LCs, and aims to reduce large wildfires and GHG emissions and support climate goals under the Paris Agreement.

Positive Efforts for Scaling

- In Brazil, **the Federal Brigade Program, implemented by FUNAI and IBAMA** through its Specialised Centre Prefogo, follows the Integrated Fire Management approach, empowering Indigenous brigades and applying prescribed burns guided by ancestral knowledge. This integration has strengthened cooperation between communities and environmental agencies, thereby enhancing the protection of traditional territories and supporting efforts to conserve biodiversity and mitigate climate change[23].

- **In Venezuela's Canaima National Park, Pemón communities and scientists co-developed a fire management model** based on patch mosaic burning[24], which reduces wildfire risk and preserves biodiversity; this approach inspired Venezuela's 2021 national IFM platform and has been shared through Parupa Fire Intercultural Network with IPs and LCs in the north Brazil and Guyana as a scalable climate-resilient solution rooted in traditional knowledge[6].

Best practices

- **Recognizing IPs' and LCs' land rights** has proven effective in reducing extreme wildfires and preserving biodiversity, as shown in Bolivia, Brazil, and Colombia, where land titling has significantly lowered carbon emissions. We note that titling for non-traditional occupants has the opposite effect[25].

- **Through participatory fire and land management**, FAN Bolivia partners with Indigenous communities, combining traditional knowledge and modern tools—from satellite imagery to local early warning systems—to monitor fire risks, plan integrated actions, and build resilience through training, collaboration, and informed decision-making.

- **Traditional knowledge about the use of fire is being integrated through initiatives such as PAAMARI**. PAAMARI, which means "fire" in the Indigenous Asháninka language, is an Integrated Fire Management (IFM) strategy led by the Central Asháninka del Río Ene (CARE). This initiative combines traditional knowledge and modern science to reduce the risk of wildfires while respecting cultural fire practices. Since its launch, the number of wildfires has dropped from 25 in 2023 to 9 in 2024, with none reported so far in 2025 — a true model of community-based climate action.

Figure C1.2.2. (a) Wildfires in a recently deforested area in Gleba Abelhas, an unprotected federal forest in Canutama, Amazonas state, August 2023. Photo credit: Marizilda Cruppe / Greenpeace (b) Controlled Indigenous fire used by the Pemón Peoples as part of their swidden cultivation practice preserves forest edges and contrasts with uncontrolled wildfires often used for deforestation or land clearing.

Figure C1.2.3. The 1st National Meeting of Pemón Elders in Kama Meru, Venezuela, gathered leaders from nine Indigenous groups to defend Mother Earth and share traditional fire knowledge, including community leaders and elders from Canaima National Park, Venezuela. Discussions focused on climate change, Indigenous rights, cultural identity loss, and creating an elders' council for community-led solutions. Photos: Bilbao and Gutiérrez, 2025.

Recommendations

Immediate Priorities (Urgent: within 2–3 years)

These are foundational actions necessary to shift current fire management paradigms and build momentum for long-term change:

- **Recognize the impacts of climate and land-use changes** in developing resilient and sustainable fire management strategies.
- **Develop integrated and collaborative strategies** that promote intercultural and intersectoral fire management rather than fire suppression and fire-risk adaptation strategies.

- **Facilitate inclusive dialogue among IPs and LCs**, communities, researchers, and policymakers to interweave scientific and traditional knowledge and promote interdisciplinary research to inform improved fire governance.

Medium-Term Priorities (Achievable in 5–10 years)

These depend on the groundwork laid by the immediate priorities and require deeper structural and institutional changes:

- **Accelerate global climate action**, prioritizing emissions reduction and climate mitigation strategies as central pillars of wildfire prevention.

- **Establish and strengthen forums** that foster collaborative learning and revitalize IPs' and LCs' fire knowledge.

- **Promote community-based research led by IPs and LCs** in ecosystems where traditional fire practices are under-documented.

- **Facilitate collaborative planning** among IPs and LCs representatives, as well as other relevant actors, to define concrete steps for respectful and impactful research, and the interweaving of their respective traditional practices.

- **Invest in a long-term fire and climate monitoring system** to assess how human, climate, and landscape factors influence fire ignition and spread in order to guide prevention, preparedness, and response efforts.

- Extreme wildfires do not happen by chance — they are the outcome of long-term pressures and human choices. Moving beyond control measures means **tackling their root causes** through shared knowledge, dialogue, and designing and implementing inclusive policies that strengthen resilience and support sustainable fire and land management. We call for collective action to make this shift a reality.

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Improve the Connectivity of Amazonian Waters

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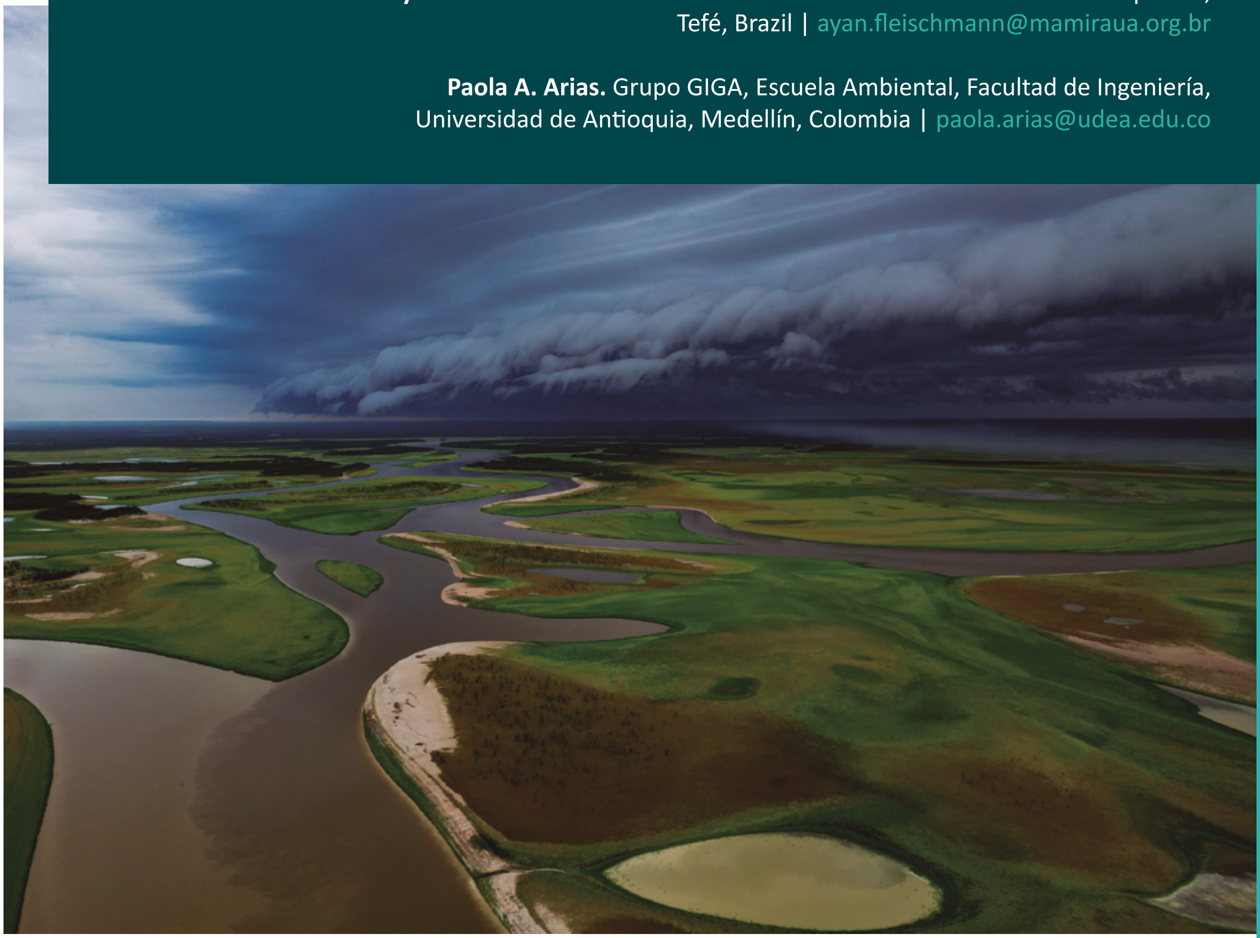

Photo credit: André Zumak.

The Overview

The Amazon's hydrological cycle is an interconnected and complex system encompassing the largest river system on Earth and multiple social and ecological interactions. River surface waters connect along drainage networks and between rivers and adjacent floodplains. The land is connected to far-distant regions through atmospheric processes (so-called "aerial rivers"). Yet these different ecological and socio-cultural dimensions of connectivity have been threatened by various pressures, from dams that disrupt drainage networks to climate changes that isolate areas such as riverine communities. Because of these factors, we urgently need to conserve free-flowing rivers and restore interrupted rivers to re-establish connectivity along Amazon watercourses.

The Facts

- The Amazon Basin contributes to regional precipitation: from 16% to 70% for the La Plata River Basin, 50% for the tropical Andes, and 6% for the Magdalena and Orinoco River Basins[1–3].

- Maximum annual inundation extent has increased by 26% along the Amazon's mainstream floodplains since 1980 due to increased maximum water levels, and this has translated into increased river–floodplain connectivity[4].

- Fragmentation of the Amazon River network has risen by ~40% in the past decade with dam expansion, which has disrupted downstream river–floodplain connectivity and flood-pulse dynamics, as observed in the Uatumã River below the Balbina Dam[5].

- 12% of the floodplain forest is estimated to have died and 29% may be undergoing mortality since the large Balbina Dam disrupted downstream Uatumã River–floodplain connectivity[6] .

- During the high-water season, 89% of non-Indigenous localities in the Brazilian Amazon are within 5 km of the nearest major water body, and many of these communities become isolated during extreme droughts[7].

- The surface waters of several central Amazon lakes decreased by up to 80% during the 2023–2024 droughts, largely disconnecting rivers and adjacent aquatic systems[8].

Global/Regional and Synergistic Connections

- The Atlantic–Andes–Amazon pathway connects regional components of the hydrological cycle and the river system with the dynamics of the Atlantic Ocean, scaling the regional and global hydroclimate to the Amazon's socio-ecological systems[9].

- Deforestation reduces atmospheric moisture transport from the Amazon to other regions; for instance, it reduces transport to the Magdalena and Orinoco Basins by about 53%–79% and to the northern La Plata Basin by about 22%[10,11].

- Most Indigenous Peoples and Local Communities in the Amazon live near water bodies such as rivers and lakes, and thus socio-ecological systems (e.g., fisheries and palm swamps) are directly dependent on a healthy and predictable river–floodplain pulse.

- Spanning eight countries and an overseas territory of France, the Amazon River Basin requires transboundary management of its water resources, but this is currently hampered by the size of the territories, lack of resources, and relatively poor gauging of hydrological systems.

- Amazon wetlands are among the main natural sources of methane globally, and changes in floodplain inundation dynamics will likely affect the fluxes of this important greenhouse gas[12,13].

The Solutions Space

Selected Key Tools

- Most studies focus on the governance of water in lakes, rivers, and aquifers (blue water), neglecting water in soil that is available for plant uptake and transpiration (green water) and atmospheric water. **Atmospheric moisture recycling and transport can be partly integrated into existing governance approaches**, depending on the types of moisture exchange, and some proposed frameworks are available[14].

Collaborative Efforts

- **Community engagement for the management of natural resources** has improved the quality of life of riverine people and the conservation of river–floodplain systems; a fisheries example is the management of arapaima, which is today one the main economic chains in the Central Amazon[15,16].

- **Codevelopment of adaptation strategies with Local Communities and valuing of Indigenous and Local Knowledge** have been promoted in multiple initiatives, such as in the context of the Amazon Waters Alliance (formed from a merger of the Amazon Waters Initiative and the Citizen Science Network for the Amazon), and such efforts are required to strengthen local to regional capabilities to deal with ongoing environmental challenges[17].

Major Recent Governmental Efforts

- **The Amazon Network of Water Authorities (ANWA)** was created in 2023 by the Member States of the Amazon Cooperation Treaty Organization (ACTO), and it is seeking a common agenda of transboundary water resources management among all Amazonian countries—for instance, developing a joint protocol to monitor water quality across the basin.

Figure C1.3.1. Floodplain riverine community in the Mamirauá Reserve, Central Amazon, during high- and low-water periods. Photo credit: Miguel Monteiro.

Recommendations

- **Expand monitoring of hydrological cycle components across the basin,** develop local training, and strengthen cooperation and protocols for data collection and management among Amazonian countries by promoting open and participatory science perspectives and ethical data governance with the FAIR (findability, accessibility, interoperability, and reusability) and CARE (collective benefit, authority to control, responsibility, and ethics) principles.

- **Include Indigenous Peoples and Local Communities in discussions of transboundary water resources management** from the Andes to Central Amazon; promote transdisciplinary scientific approaches; and strengthen community-based approaches to managing natural resources and improving habitat quality in Andean and river–floodplain environments.

- **Establish a policy of free-flowing rivers across the basin,** with no building of new large dams (>10 megawatts), in order to maintain river-network and river–floodplain connectivity.

- **For dams already in operation, improve current approaches to transferring biota and nutrients downstream** in order to partially recover the prior longitudinal connectivity.

- **Promote policies of zero deforestation and zero forest degradation** to ensure adequate atmospheric moisture transport from the Amazon to the nearby regions.

- **Explicitly integrate blue, green, and atmospheric water into global efforts to promote and finance conservation of tropical forests.**

Key Recent Literature

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CALL TO ACTION 4

Scale Up Systems and Frameworks for Climate Finance in the Amazon

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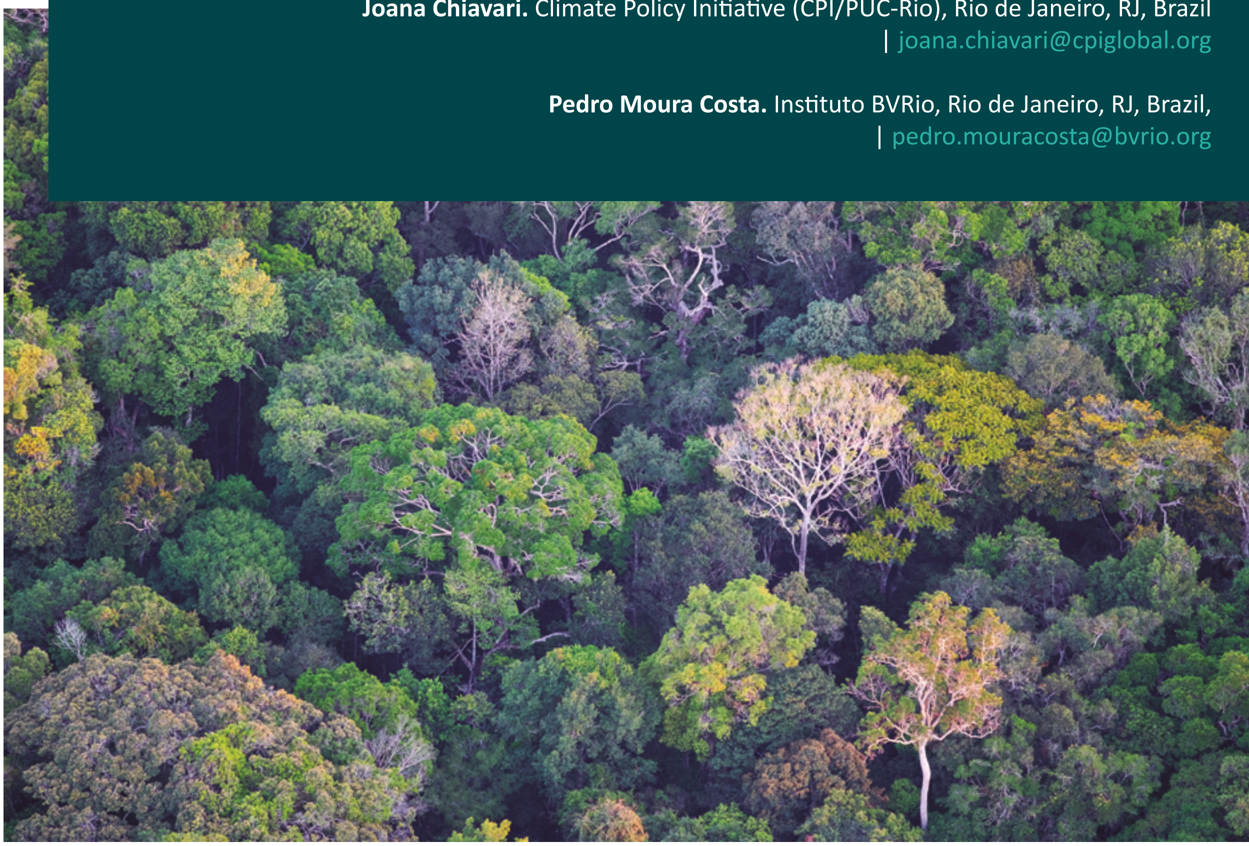

Photo credit: Paulo Brando.

The Overview

Climate finance is essential to harnessing the Amazon's many environmental services to benefit climate and communities, offering a means to combat deforestation, scale restoration, and promote conservation through models such as the socio-bioeconomy. Private, public, and multilateral actors mobilize capital through grants, credit, equity, blended finance, payments for ecosystem services (PES), results-based mechanisms, debt restructuring, carbon credits, and risk-sharing instruments. Although climate-dedicated finance has grown, current flows remain insufficient relative to the scale of adaptation and mitigation challenges[1]. There is an urgent need to scale up climate finance to unlock the full potential of the Amazon in advancing the global climate agenda to match the region's ecological importance and socio-economic complexity—while at the same time, financial mechanisms should address the needs and rights of local populations.

The Facts

- Scaling up is critical, because most existing climate finance initiatives remain too small for the Amazon's scale and climate urgency.

- Flows to agriculture, forestry, and other land use (AFOLU) hold great untapped emissions reduction opportunities. Globally, mitigation flows should increase 65-fold, from USD 18 billion to USD 1,170 billion annually through 2030, to realize this emissions reduction potential[1].

- Voluntary carbon credits are conceptually hindered by the need to address concerns over additionality and governance and have not been a reliable funding source for the agenda, with a small (and falling) value of voluntary carbon markets and only ~USD 500 million mobilized in 2024[2].

- Brazil's updated Nationally Determined Contribution (NDC) to the Paris Agreement targets under the United Nations Framework Convention on Climate Change (UNFCCC) emphasizes the role of forests[3].

- Climate finance for Brazil's native forests, however, represents a minimum amount of overall climate finance flows to and within the country and is largely provided by international, followed by domestic, public actors[4].

Global/Regional and Synergistic Connections

- International negotiations on carbon markets are progressing toward a regulated carbon market. This offers a promising pathway to finance tropical forests at scale.

- Global markets for green, social, sustainability, and sustainability-linked (GSSS) bonds reached USD 6.9 trillion by the end of 2024[5], illustrating the potential of this type of capital for climate mitigation and adaptation for the Amazon region.

Figure 4.1. Photo credit: Paulo Brando.

The Solutions Space

Selected Key Tools

- **Various financial instruments can mobilize capital for forest activities.** Debt finance mechanisms, such as GSSS bonds, stand out as promising instruments to mobilize finance at large scale without resulting in land grabbing and activity displacement.

- Examples that need to be significantly scaled up to make the necessary impact include **corporate-led blended finance mechanisms like the Responsible Commodities Facility** and mechanisms established by multilateral organizations, like the World Bank Amazon Reforestation-Linked Outcome Bond.

- **Carbon credits, generated by projects or jurisdictions, that avoid emissions or sequester carbon, could play a crucial role.** Studies indicate that linking carbon finance directly to net CO_2 forest removals could transform the Amazon region and make restoration a more profitable land use than low-productivity cattle ranching[6].

- **PES schemes offer landowners financial incentives to conserve forests, delivering carbon, biodiversity, and water benefits**. When backed by strong monitoring and enforcement, they have proven effective in reducing deforestation, making them a valuable policy tool for forest conservation — such as the Floresta+ Amazônia Program in Brazil.

Major Recent Governmental Efforts

- In 2023, emerging markets reached a record USD 209 billion in GSSS bonds issuance[7]. The issuance of corporate and sovereign (i.e., government) bonds specifically for forest finance remains limited, but there has been progress, such as Brazil's issuance of USD 4 billion in sovereign sustainable bonds financing environmental and social investments, including forest conservation and restoration[8]. Another example includes Uruguay's sustainability-linked bond to finance forest protection.

- **Debt-for-nature swaps**—an instrument that transforms sovereign debt into investments in forests through agreements between debtor and creditor countries—**gained traction through the US Tropical Forest and Coral Reef Conservation Act (TFCCA)**. This initiative invested in tropical forest ecosystems, with agreements signed between the US and Peru. In 2024, Ecuador carried out the world's first debt-for-nature swap focused on Amazonian terrestrial and freshwater conservation—contrasting with earlier marine-focused deals—refinancing USD 1.5 billion in debt and channeling hundreds of millions into forest and river protection.

- Another example is the Fondo de Acción Social from Colombia, focused on sustainability and children.

- **Brazil is advancing its domestic emissions trading system (ETS), which allows the land-use sector to generate and sell offsets**. Its ability to attract funding for the sector, however, is contingent on the adoption of streamlined, dynamic offset methodologies, such as those used for UNFCCC forest reference emission level (FREL) reports or the Tropical Forest Forever Facility (TFFF) approaches.

Positive Efforts for Scaling

- **Existing forest finance mechanisms**, such as jurisdictional REDD+ (which refers to reducing emissions from deforestation and forest degradation in developing countries plus other forest-related activities), **need to be scaled up** to match the Amazon's size and climate urgency (see, for instance, the Iwokrama project in Guyana). At the same time, new mechanisms like the TFFF present strong opportunities for replication and broader impact, particularly for protecting standing forests.

- **Strengthening and expanding the use of debt finance instruments**, such as GSSS bonds, could unlock significant finance to drive large-scale forest conservation and restoration. Scalable and reliable capital mobilization is necessary.

- **The TFFF**—a novel, endowment-style funding mechanism focused on halting deforestation—**is currently negotiating with international investors to raise USD 125 billion for tropical forest protection worldwide**. As of June 2025, expressions of interest have been received from the UK, France, Germany, Norway, Singapore, United Arab Emirates, and China, highlighting growing commitment to forest conservation finance.

- These efforts can be complemented by improving governance and transparency frameworks to scale up regulated carbon markets to occupy specific niches.

Recommendations

- **Prioritize the allocation of climate finance toward AFOLU sectors** to unlock their untapped mitigation and adaptation potential and deliver multiple co-benefits for climate, biodiversity, and the Amazonian population.

- **Further explore the role of international debt capital markets** (sovereign climate bonds and GSSS bonds) to attract capital at the landscape level for forest conservation and restoration in the Amazon.

- **Scale up financial instruments** such as jurisdictional REDD+, PES, and carbon credits under a regulated market to mobilize more capital for forest conservation and restoration.

- **Advance the development and financing of the TFFF**, which aims to provide long-term, performance-based funding from public and private sources, focused on halting deforestation and valuing forests intrinsically.

- **Support domestic market-based tools** such as Brazil's ETS with simplified, dynamic methodologies to integrate forest sector offsets and attract private investment.

- **Foster collaboration among multiple interested parties at local, national, and regional levels** to strengthen legal protections, ensuring forest conservation and halting deforestation through improved monitoring, enforcement, and sustainable land-use practices.

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CHAPTER 2

The Disruptive Connectivity of Illegal Economies:

Multidimensional Threats to Human and Ecological Systems in the Amazon

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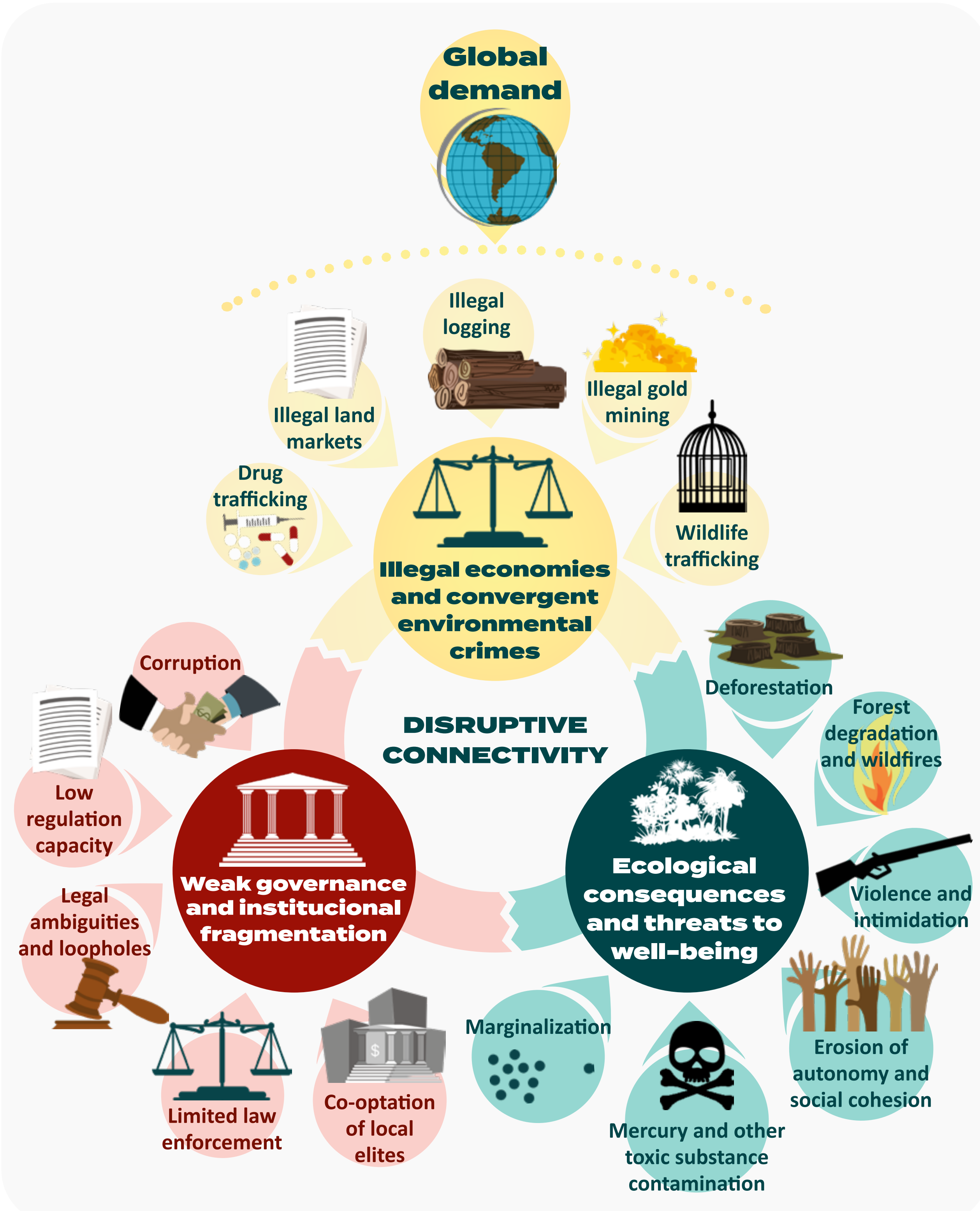
Abstract

Illegal economies in the Amazon Basin—including land grabbing, illicit deforestation, illegal gold mining and logging, drug trafficking, and wildlife trafficking —pose an escalating threat to the region's ecological integrity, human well-being, and formal economic systems. They are not isolated crimes; they form an interconnected system that fragments forests, displaces Indigenous and Afrodescendant Peoples and Local Communities (hereafter IPs & LCs), and undermines the Amazon's role in regulating climate and supporting biodiversity. Driven by global demand, weak governance, and entrenched corruption, illicit networks reconfigure land use, concentrate power in criminal hands, and sever critical connections between ecosystems and cultures. At the same time, interest groups within state institutions and local governance structures influence legislation, capture regulation, and legalize irregular and illegal practices, further deepening environmental degradation. The convergence of these illegal economies has negative environmental impacts that jeopardize the food security of millions, undermining agricultural systems and depleting wild food sources. Indigenous Peoples and Local Communities—key stewards of Amazonian connectivity—face aggressions, gender-based violence, displacement, and the erosion of territorial and cultural autonomy. Public health is also threatened by mercury contamination, pollution from drug production, wildfire smoke, and the spread of vector-borne diseases in degraded landscapes. The economic consequences are both complex and far-reaching. Illicit activities erode public revenues through tax evasion and the circumvention of financial systems, while also imposing significant economic, social, and environmental costs. This vicious cycle undermines long-term development, weakens institutions, and intensifies pressures on already vulnerable ecosystems and communities. This chapter argues that illegal economies must

be understood as systemic drivers of fragmentation and instability. Addressing them requires coordinated, cross-border strategies that integrate socio-ecological connectivity into governance, protect Indigenous Peoples and Local Communities’ autonomy, and ensure their safety. Regional cooperation is essential to confront transnational environmental crimes, while regenerative and inclusive high-integrity socio-bioeconomy initiatives can offer sustainable alternatives. Stronger state capacity, transparency, and local partnerships are critical, and global trade must align with Amazon protection through traceability, due diligence, and closing environmental money laundering loopholes.

Keywords

Illegal economies, organized crime, violence, environmental impacts, fragmented connectivity



Graphical Abstract. Interconnections between global demand, illegal economies, weak governance, and ecological consequences. It highlights how these dynamics reinforce each other through disruptive connectivity, undermining environmental integrity and human well-being.

1. Introduction

The Amazon Basin is increasingly threatened by disruptions to its connectivity through the complex interplay of legal, informal, illegal, and criminal activities (Table 2.1). These domains are deeply interwoven, often blurring the lines between what is legal and what is not. For instance, commodities such as gold—although legally traded—are frequently extracted from protected areas and through illicit means, causing environmental degradation and circumventing regulatory oversight. Similarly, land acquired through force or intimidation is often formalized via legal loopholes or corrupt practices. Public and private actors operating under a façade of legality have targeted community leaders and local populations to seize resources and undermine territorial governance. The result is a paradox in which legal frameworks—designed to protect ecosystems and communities—are exploited to legitimize actions that degrade the environment and erode governance. Weak institutional capacity, corruption, and gaps in legal structures perpetuate this cycle, with harmful consequences for both ecosystems and the people who depend on them.

Table 2.1. Definition of different types of activities affecting the environment in the Amazon.

LEGAL	INFORMAL	ILLEGAL	CRIMINAL
State-authorized and regulated. Examples: legal agriculture and licensed mining.	Not officially regulated, but they aren't always illegal. They often stem from gaps in legal access or the inability to meet regulatory requirements.	Explicitly prohibited by law and carried out without necessary permits.	Organized, illegal activities carried out for profit, often involving violence or coercion.
e.g., legal timber concessions granted to private companies or communities, complying with quotas, species restrictions, and documentation requirements.	e.g., timber harvesting in private lands without full compliance with all administrative requirements or incomplete paperwork, which falls into regulatory gaps but is not necessarily fully illegal.	e.g., harvesting timber from Indigenous Territories or protected areas without authorization.	e.g., large-scale illegal logging networks operating with forged documents and laundering timber through illicit supply chains, often linked to organized crime.

Illegal economies in the Amazon Basin—ranging from land grabbing and illicit deforestation to illegal gold mining, drug trafficking, and unlawful wildlife and timber extraction—are not isolated criminal acts. They form a cohesive, expanding network that fragments the region's ecological, social, and territorial connections[1]. These illegal networks exploit the region's structural weaknesses, adapting quickly and operating across borders with significant knowledge of local territories. In contrast, public institutions remain fragmented, struggling to address these challenges effectively[2]. This hidden system of control reshapes land use, shifts power dynamics, and disrupts the environment and local communities.

This convergence of illegal activities operates through complex feedback loops. Profits from drug trafficking fuel activities like illegal gold mining while drug money is laundered through both gold and illegally deforested lands. Other common practices of money laundering include integrating illegally extracted natural resources from the Amazon into formal markets and global supply chains with weak oversight, using document forgery, fraud, and corruption[3]. Criminal organizations strengthen their control via violence and corruption, which in turn undermines or co-opts state institutions. Meanwhile, Indigenous and Local Communities territories face increasing encroachment[4].

The ecological consequences are severe: illegal mining, land grabbing, and illegal logging degrade vast forested landscapes, disrupting biogeochemical cycles and undermining the Amazon's role as a global climate regulator. These activities often pave the way for the expansion of agribusiness monocultures, which further accelerate forest loss and habitat fragmentation. As forest fragments become more isolated, species mobility declines, ecosystem functions deteriorate, and climate resilience diminishes[5]. Social connectivity is also fractured: communities are displaced, armed groups recruit young people, and intergenerational knowledge systems weaken.

Illegal economies are deeply rooted in the region's political economy, manifesting not only in active participation but also in passive coexistence and economic dependence. They distort land markets, fuel unregulated revenues, and become embedded in local life. Addressing this system requires understanding it as a cross-border network of actors, activities, and impacts. Breaking the cycle demands systemic solutions that tackle root causes, strengthen governance, and restore ecological and sociocultural connectivity.

Now is the time to rethink transnational cooperation—shifting from enforcement alone to strategies that integrate economic, social, environmental, and political realities of Amazonian territories and communities, recognizing the influence of power relations and vested interests.

2. Territorial Appropriation and Criminal Land Economies: How Illicit Networks Reshape Forest Frontiers in the Amazon

In the Amazon, legal and illegal land grabbing are closely intertwined: unregulated land markets, unlawful deforestation, and the conversion of forests into agricultural and cattle ranching areas—often enabled by human-made forest fires—operate in tandem, blurring boundaries between legality and illegality. These dynamics are driven by speculative interests that exploit weak governance and land policies, limited enforcement, deeply entrenched corruption, and legal loopholes to seize public lands and territories traditionally occupied by Indigenous Peoples[6].

In several regions of the Amazon Basin, land grabbing has become a primary mechanism for the privatization and conversion of public forests (see Call to Action 5), a process increasingly driven by the expansion of agriculture (such as soy cultivation and cattle ranching) and the rising global demand for both legal and illegal commodities.[7] Typically, this involves illegally clearing and burning forest lands, followed by using fraudulent documents and corrupt practices to formalize land claims[8]. Fires are frequently used as a low-cost method to clear forests for pasture or agriculture, particularly in newly occupied territories. Legal or not, these fires drive biodiversity loss, increase carbon emissions, and are often used to claim ownership of disputed lands, while the resulting air pollution severely affects human health—reducing life expectancy by two to four years in parts of the southwestern Amazon.[9] In Bolivia alone, more than 1,5 million hectares burned in 2024, surpassing all previous records.[10]

Once regularized, these lands are incorporated into formal land markets and converted into pasture or cropland, generating speculative profits while reinforcing cycles of illegality. The dismantling or weakening of environmental policies—together with expectations of land regularization, amnesty, or legalization—has further incentivized these practices in several Amazonian countries. In Brazil, in 2019, 30% of the deforestation occurred in the so-called Undesignated Public Forests (UPF), which are public forest lands not allocated by the federal or state governments to a specific tenure status[11]. The proportion of illegal deforestation on public lands increased from 43–44% between 2015 and 2018 to 49–52% between 2019 and 2021, reflecting the intensification of land grabbing and illegal clearing[12].

Land grabbing operates within a broader framework of organized crime. Networks of actors engage in illegal activities often linked to violence, coercion, and the forced displacement of Indigenous Peoples and Local Communities. Evidence from Brazil shows widespread dispossession typically follows when land grabbing becomes a primary source of capital accumulation and political power[13]. In these settings, efforts by state officials, community leaders, and environmental defenders to oppose such practices are often met with threats, intimidation, and, in some cases, violence. In Colombia, the withdrawal of the Revolutionary Armed Forces of Colombia (Fuerzas Armadas Revolucionarias de Colombia – FARC, by its Spanish acronym) following the 2016 Peace Agreement altered territorial control in vast areas of the Amazon. This created opportunities for cattle ranchers, loggers, and land investors to expand their activities, accelerating deforestation. Much of this forest loss occurs in fragmented and isolated patches, disrupting ecological connectivity between the Andes and Amazon regions and reducing the movement capacity of species[14].

Illegal land appropriation and deforestation also function as mechanisms for laundering proceeds from other criminal activities. Land cleared of forests becomes a valuable asset for illicit financial flows. Criminal networks involved in drug trafficking (see Call to Action 6) and illegal mining (see Call to Action 7) frequently invest in land and cattle to legitimize their profits[15]. Practices such as “cattle laundering,” in which livestock raised on illegally deforested land are introduced into legal supply chains, obscure production origins[16]. In 2010, about 75% of deforested areas in Brazil’s UPFs were turned into pastures—a land use that continued even a decade later[17]. Between 2018 and 2021, more than 90,000 cattle raised on illegally occupied lands entered Brazil’s formal meat industry[18].

Irregular land markets and the expansion of agriculture and cattle ranching through land grabbing contribute significantly to deforestation, ecosystem degradation, and social injustice in the Amazon. These processes reinforce land concentration, marginalize traditional populations, and hinder inclusive, sustainable land governance efforts.

3. The Convergence of Illicit Economies: Disruptive Connectivity, Territorial Embeddedness, and Environmental Degradation in the Amazon Basin

The convergence of illegal economies in the Amazon Basin constitutes a systemic and growing threat to the region's ecological integrity and social stability. These illegal economies are not isolated phenomena but interconnected elements of a highly adaptive criminal network that exploits Amazon's vast and remote territories, and takes advantage of weak institutional presence, and porous borders to expand and entrench its operation.

At the core of these dynamics are networks that may include criminal organizations, segments of political and economic elites, private actors, and public officials, whose actions or inaction sustain parallel illicit economies. Their presence and influence vary across the Amazon Basin. In parts of Colombia, Venezuela, and, more recently, Ecuador, criminal actors exert significant territorial control and at times establish parallel forms of governance. In other areas, such as regions of Brazil, Peru, and Bolivia, their involvement in environmental crimes tends to be more localized, though emerging evidence points to expanding influence in several border and remote territories.

Gold mining—and the widespread use of mercury—have become one of the most environmentally destructive among these illegal activities. Sustained by high international gold prices (Figure 2.1), over 4,000 illegal mining sites have spread across the region, including within Indigenous Territories and Protected Areas, according to data published recently by the Amazon Regional Observatory (ORA) of the Permanent Secretariat of the Amazon Cooperation Treaty Organization (OTCA, by its acronym in Spanish)[19]. The mining process involves extensive forest clearing for camps, open-pit operations, and river dredging, fragmenting once-continuous landscapes and disrupting ecological corridors essential for wildlife movement and ecosystem functions[20].

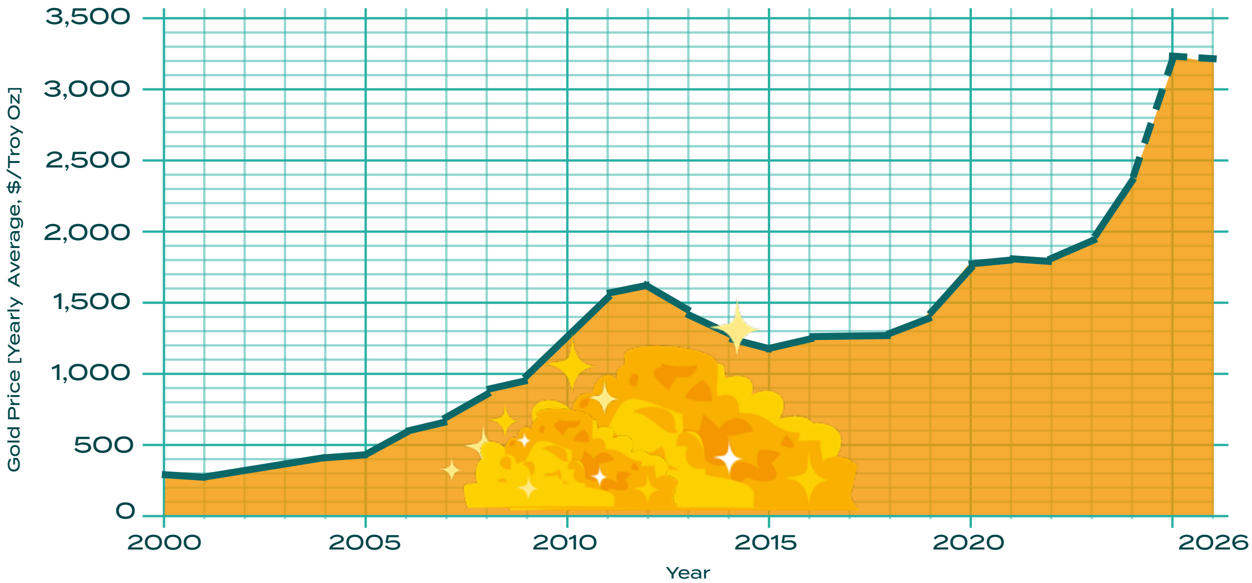


Figure 2.1. Evolution of gold price in the world market. *Source: World Bank.*

Illegal mining across the Amazon is embedded in a system where criminal organizations, legal businesses, and corrupt state actors converge. Armed groups are key drivers in some parts of the Amazon—controlling territories through extortion, corruption, and human rights abuses—but they operate within a broader web of actors. Venezuela offers a clear example: as of September 2024, more than 67,000 hectares have been deforested in the Amazonas and Bolívar states[21] due to mining tied to networks that bring together the National Liberation Army (Ejército de Liberación Nacional, ELN), FARC dissidents, and other criminal groups, often in collusion with civilian and military authorities. Although the Arco Minero policy is officially focused on the Bolívar state, illegal mining has spread into the Amazonas and Delta Amacuro states, operating without environmental oversight or respect for the rights of local communities.

Coca cultivation in the Amazon has expanded in recent years (Figure 2.2), alongside shifting criminal dynamics. New alliances among Colombian dissidents, Brazilian gangs, and Peruvian smugglers have turned areas like the Putumayo tri-border into key trafficking hubs. In the Colombian Amazon, coca crops expanded from 34,486 hectares in 2019 to 64,562 hectares in 2023—an 87% increase, according to the United Nations Office on Drugs and Crime[22]. While no entirely new coca hotspots have emerged, existing Amazon regions have grown substantially, blurring the lines between old and new cultivation areas. In Peru, coca cultivation in the Amazon Basin areas increased by 72% from 53,5050 to 92,134 hectares during the same period, based on National Commission for Development and Life without Drugs (DEVIDA) figures[23], while in Bolivia it rose by 21%, from 25,500 to 31,000 hectares. Similar trends may emerge in Venezuela and Ecuador, although official data are lacking. While coca cultivation is not currently considered a primary driver of deforestation at the regional scale, local studies indicate that its direct and indirect impacts on forest loss can be significant in specific areas[24].

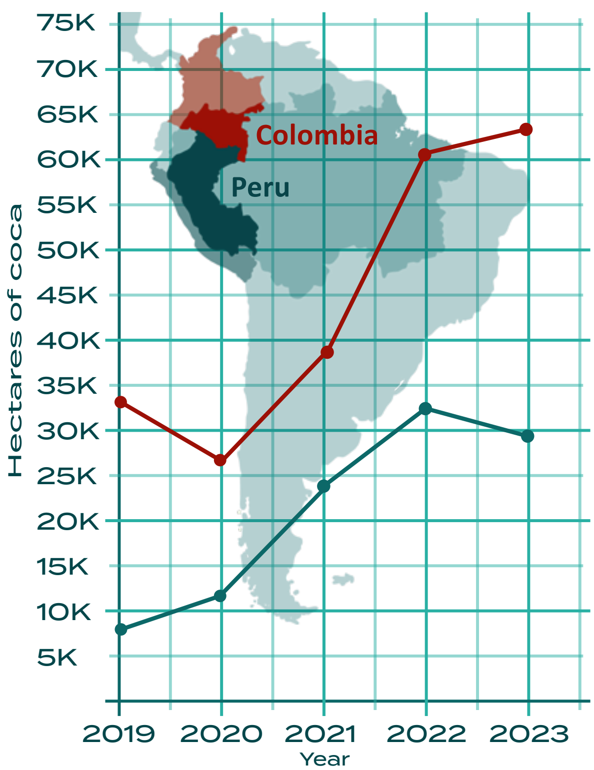


Figure 2.2. Hectares of coca crops in the Amazon of Colombia and Peru. *Colombian data includes the Amazonian departments: Amazonas, Caquetá, Guainia, Meta, Putumayo, Vaupés, and Vichada. Peruvian data includes the Amazonian departments: Amazonas, Loreto, Madre de Dios, San Martín and Ucayali. Source: UNODC (2024)[22] and DEVIDA (2024)[23]*

Drug trafficking, meanwhile, has transformed large parts of the Amazon into strategic corridors for the global cocaine trade. Approximately 40% of the world's cocaine passes through the region, transported via remote rivers, clandestine airstrips, and informal road networks, fueling violence across the Amazon (see Call to Action 8) [25]. Beyond the drug trade itself, trafficking serves as an enabler of other illegal economies. Criminal groups often reinvest drug profits into illicit mining[26], using gold both as a revenue source and as a vehicle for money laundering. This convergence strengthens the integration of illegal markets and embeds them more deeply into local economies and social systems[27].

Wildlife trafficking and illegal logging intensify the convergence of illicit economies by sharing routes and infrastructure with other illegal trades. Millions of animals are poached annually to meet international demand, using smuggling methods that rely on fraud and corruption[28]. A significant positive correlation was found between the most profitable species and those becoming increasingly rare[29]. Although experts highlight the growing role of organized crime, the accurate scale of wildlife trafficking in the Amazon remains challenging to determine.

Illegal logging continues to be a significant driver of forest degradation. Despite existing regulatory frameworks, a large proportion of Amazonian timber is extracted and traded illegally[30]. In the tri-border region of Peru, Colombia, and Brazil, this activity is supported by well-organized criminal networks that use fraudulent permits, bribery, and shell companies to integrate illegally harvested timber into formal markets. Much of this timber originates from protected areas and Indigenous Territories, contributing to forest loss and undermining local governance[31].

The convergence of illicit economies rooted in Amazonian territories and resources has fostered a parallel system of governance in some areas that erodes ecological integrity and weakens local institutions. These interlinked activities—enabled by shared infrastructure and networks—intensify deforestation, pollution, and violence.

4. Human Impacts of Illicit Economies: Violence, Dispossession, and the Erosion of Social and Cultural Resilience in the Amazon

The expansion of illegal economies across the Amazon has generated a complex humanitarian crisis that disproportionately impacts Indigenous People, Local Communities, and environmental defenders. This crisis is marked by increasing violence, public health threats, the erosion of territorial autonomy, and gender-based exploitation[32]—forces that collectively weaken the social fabric and undermine sustainable livelihoods.

Throughout the region, Indigenous leaders, land defenders, and park rangers have been targeted and killed for denouncing illegal activities or resisting territorial encroachments. The Amazon has become one of the world's most dangerous regions for environmental and human rights defenders. Between 2012 and 2023, at least 2,106 land and environmental defenders were murdered globally. Colombia, Brazil, and Peru alone accounted for 43% of these deaths[33]. In Colombia, Global Witness reports that the convergence of drug trafficking, coca cultivation, and armed conflict frequently traps environmental defenders and their communities in violent confrontations. In Venezuela, between 2016 and 2023, at least 28 Indigenous People were killed or disappeared in the context of mining-related conflicts[34].

Homicide rates in the Amazon consistently exceed national averages, with violence concentrated not only in rural areas but increasingly in urban centers[35]. In 2024, Manaus was the fourth most violent city in Brazil[36], while Leticia in Colombia recorded a homicide rate of 38.2 per 100,000 inhabitants in 2024—among the highest for cities of its size[37]. In the Brazilian Amazon, the homicide rate reached 32.3 per 100,000 in 2023, compared to 21.2 per 100,000 at the national level. This surge in violence correlates with road expansion, agricultural frontiers, and illegal extractive activities, which facilitate territorial disputes and strengthen the presence of organized crime[38]. It is important to note that Amazonian women are also the target of a growing wave of violence, further highlighting the region's deepening insecurity[39].

In several parts of the region, armed groups have supplanted formal governance, enforcing rules, administering punishment, and exploiting resources with impunity. Communities are displaced from ancestral lands or coerced into compliance with illicit operations under threat of violence[40]. These dynamics are especially evident in some regions of Colombia, Peru, and Venezuela, where organized groups linked to mining or drug trafficking exert territorial control and restrict civil rights.

Beyond physical harm, the incursion of illegal economies undermines Indigenous governance and cultural resilience. Traditional authorities are often displaced, co-opted, or silenced, while young community members are recruited by armed groups or drawn into illicit labor due to economic necessity[41]. As forests are cleared and rivers are polluted, hunting, fishing, and the cultivation of traditional foods decline, forcing communities to rely on activities that threaten their survival[42]. The erosion of local institutions and cultural practices fractures intergenerational ties and weakens collective identity. Women and girls face acute risks under these conditions, including heightened exposure to sexual violence[43], being forced into sex work, and the loss of protective community networks[44]. Gender-based violence becomes both a tool of domination and a consequence of social collapse.

The public health consequences are equally alarming. Artisanal and small-scale gold mining releases mercury into waterways and the atmosphere, contaminating food chains and water sources[45]. A 2021-2022 study by the National Coordinator for the Defense of Indigenous, Indigenous Origin, Peasant Territories and Protected Areas (CONTIOCAP, by its initials in Spanish) and the Documentation and the Information Center Bolivia (CEDIB, by its initials in Spanish) found high mercury contamination in Indigenous communities along the Beni, Madre de Dios, and Mamoré rivers. 865 hair samples in 26 communities showed all examined individuals had mercury levels above the World Health Organization safety limit, with an average of 10-20 ppm, 20 times higher than permitted limits[46]. Among the Yanomami in Brazil, all individuals tested in several communities showed mercury contamination, with neurological and developmental damage cases[47]. Mining also introduces other toxic substances, such as cyanide and hydrocarbons, while chemicals used in coca cultivation and cocaine processing degrade soils and pollute aquatic systems[48]. Deforestation and ecosystem disruption contribute to the resurgence of diseases such as malaria, compounding the region's health burdens[49].

These impacts are reflected not only in mortality and disease rates but in the erosion of autonomy, dignity, and cultural continuity among Amazonian peoples. The social costs of illegal economies mirror and intensify environmental degradation, underscoring the deep interdependence between ecological integrity and human well-being in the Amazon.

5. Illicit Economies and Economic Disruption: Undermining Fiscal Capacity, Sustainability, and Local Livelihoods in the Amazon

Illicit economies in the Amazon Basin generate substantial revenues that bypass formal economic systems, undermining state authority and compromising sustainable development. Environmental crimes—specifically illegal mining, logging, wildlife trafficking, and drug production—are estimated to generate billions of dollars in illicit income annually[50].

Illegal gold mining, mainly small-scale alluvial gold mining operations, is rising across the region[51] (Figure 2.3). In Brazil, small-scale legal or illegal gold mining operations have expanded far beyond the extent of industrial mining operations. Between 1985 and 2022, the area occupied by industrial mining increased fivefold, from 360 km² to 1,800 km². During the same period, small-scale gold mining areas expanded by nearly 1,200%, from 218 km² to 2,627 km². By 2022, small-scale operations covered a larger area than industrial mining, with over 91% of this activity concentrated in the Amazon region. Critically, at least

77% of small-scale mining sites active in 2022 exhibited clear signs of illegality[52]. Between 2019 and 2020, gold miners extracted approximately 49 tons of gold, equivalent to 28% of Brazil's total production[53]. Using the average annual gold prices for those years, the value of this volume of gold ranges between $2.2 billion and $2.8 billion USD. However, much of this gold was exported or sold with minimal taxation or royalty payments, resulting in substantial public revenue losses and undermining government fiscal capacity.

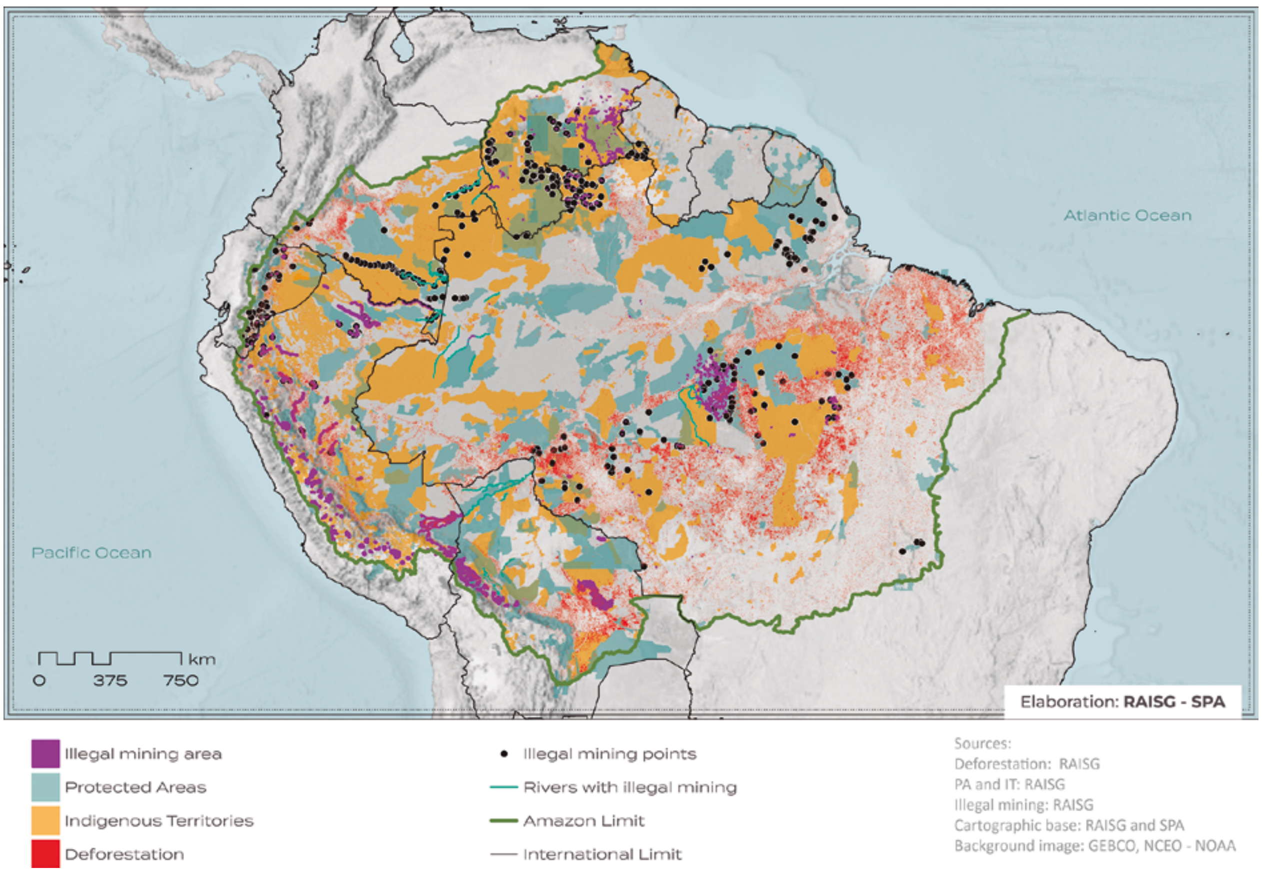


Figure 2.3. Illegal mining in the Amazon*, showing both areas and rivers being affected. Protected Areas and Indigenous Territories are also affected by illegal mining.*

In Colombia, gold mining in the Amazon remains comparatively small in scale; however, illegal mining constitutes over 80% of all mining activities at the national level[54]. Between 2010 and 2018, the Colombian state is estimated to have lost approximately $5.6 billion due to financial crimes associated with illegal mining, including tax evasion and money laundering[55]. In Peru, gold mining in the Amazon comprises a significant portion of the national extractive industry. While precise estimates are challenging due to the clandestine nature of the activity, recent studies indicate that more than 40% of Peru's total gold production originates from illegal mining operations[56]. Bolivia has consistently exported more gold than its reported production from registered (mostly cooperative) miners, indicating under-reporting and significant cross-border smuggling—particularly from Peru. In Suriname and Guyana, much of the gold extraction occurs through organized criminal groups and informal and illegal operations. Both countries struggle to control the illegal gold mining, which has expanded rapidly and caused deforestation and mercury contamination[57].

Tax losses to Amazonian countries occur through multiple channels, including unpaid extraction royalties (e.g., for gold and timber), corporate tax evasion by front companies, and the broader economic drag caused by a large informal sector. The primary beneficiaries of these evasions are business owners and exporters who facilitate and profit from illicit trade. In contrast, the miners responsible for extracting the gold receive minimal economic benefits, often working under precarious conditions[58].

Artisanal and small-scale gold mining in the Amazon has been economically evaluated by the Conservation Strategy Fund, revealing significant social and environmental costs. These costs, encompassing deforestation, soil degradation, and mercury contamination, are estimated to range from $187,200 to $389,200 per kilogram of gold extracted, substantially exceeding the metal's market value[59]. This disparity indicates that the private profits derived from such mining activities are considerably lower than the associated socioeconomic costs, leading to a net reduction in societal well-being.

Deforestation jeopardizes the immense value of the Amazon forest, which is estimated, in Brazil alone, to provide ecosystem services worth over $317 billion annually. According to the World Bank, this valuation—derived from integrated biophysical and economic methods—quantifies and monetizes key ecosystem services such as carbon storage, water regulation, and biodiversity[60]. The estimated annual value of these services is up to seven times higher than the combined profits from activities like large-scale agriculture, logging, and mining that typically drive deforestation.

The expansion of illicit markets in the Amazon distorts local economies, drives inflation, and deepens social inequalities[61]. In areas with limited livelihood options, income from illegal activities—such as unregulated mining and coca cultivation—often becomes a primary means of survival. Illegal mining is closely linked to exploitative labor practices. Its rapid growth has intensified the use of forced labor and precarious working conditions across the region, often in circumstances analogous to slavery[62]. In addition, the influx of illicit capital reshapes local economies. While it can provide short-term income and employment for some populations, it also raises the cost of living. It undermines traditional livelihoods and community-based activities, such as ecotourism or sustainable harvesting. In the border regions of Colombia, surveys reveal that for many families, coca cultivation is among the few available economic opportunities despite its links to violence and insecurity[63].

Over time, the persistence of these illicit economies contributes to the normalization of illegality within social and economic systems, undermining governance and complicating efforts to implement sustainable and legal alternatives. The economic consequences of these illicit economies are not limited to immediate financial losses but include the high costs of restoring degraded ecosystems and rehabilitating affected communities. According to some estimates, it will cost $0.7-1.2 billion per year until 2030 to implement the Brazilian restoration plan, depending on the area that recovers through natural regeneration[64].

6.Conclusions

The expansion of illegal economies in the Amazon is accelerating the fragmentation of ecological and social systems. Far from being isolated criminal activities, they have evolved into an ecosystem of resource extraction and territorial control that transcends national borders and environmental boundaries, linking criminal organizations with legal businesses and corrupt state actors. Their convergence—enabled by impunity, corruption, and high demand for illicit commodities—creates a feedback loop that entrenches illegality and dismantles resilience.

The consequences extend far beyond environmental degradation. As forest corridors are broken and water systems polluted, the Amazon's ecological connectivity weakens, diminishing its capacity to support biodiversity and regulate the global climate. Simultaneously, human connectivity—defined by cultural continuity, community autonomy, and Indigenous territorial integrity—is eroded through violence, forced displacement, and social fragmentation.

This systemic crisis cannot be resolved through isolated interventions. A coordinated regional response is needed—one that recognizes the interdependence between human well-being and ecological stability. Strengthening land tenure, restoring degraded ecosystems, protecting defenders, and promoting legal economic alternatives must form part of a broader strategy to dismantle the illicit networks undermining Amazonian connectivity. Only by addressing these dynamics systemically can we secure a sustainable future for the forest and its peoples.

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Dismantling the Illegal Land Market

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Photo credit: Institute for Conservation and Sustainable Development of the Amazon (IDESAM).

The Overview

Illegal land markets in Amazonian countries are a substantial driver of territorial fragmentation, with far-reaching impacts that extend beyond forest loss. This fragmentation destabilizes ecological systems and severely weakens institutional, legal, and socio-political structures, facilitating persistent governance fragmentation, legal ambiguities, and power vacuums. Illegal land appropriation thrives in these environments, where regulatory disconnects across municipal, state, and national levels undermine cohesive territorial governance. Addressing this structural fragmentation requires an integrated, systemic approach targeting root causes rather than isolated enforcement actions.

The Facts

- Agricultural expansion drives illegal land markets and has caused 54.2 million ha of deforestation in the Amazon from 2001 to 2022, primarily due to cattle ranching and cash crops often linked to land speculation[1].

- Loopholes and ambiguous land laws in Brazil and Colombia allow powerful actors to appropriate and legitimize private ownership of public lands through regulatory grey areas[2-4].

- Corruption and systemic fraud enable illegal land markets, eroding institutional integrity and allowing criminal networks to dispossess Indigenous Peoples and Local Communities[2,4-6].

- Illegal land markets are closely tied to organized crime, involving illegal deforestation (66%), logging (32%), environmental damage (19%), and mining (7%)[7,8].

- These markets thrive in frontier areas with weaker governance, disconnected enforcement strategies, and insecure tenure **(Figure C2.5.1)**. For example, Brazilian Amazon's undesignated public forests have concentrated 32% of 2020 deforestation[9-11].

Global/Regional and Synergistic Connections

- Illegal land markets are deeply linked with illegal logging, mining, and drug trafficking, forming cross-border networks that facilitate money laundering, violence, and conflicts across Amazon countries.

- Commodities like beef and soy produced on illegally acquired land enter international markets, connecting Amazon deforestation to global demand and trade.

- Weak governance and uneven enforcement encourage land grabbing and agricultural expansion to cross borders, spreading environmental degradation into less regulated areas.

- These illegalities deepen corruption and inequality, undermine governance, eroding regional cooperation and threatening Indigenous and Local Communities' rights.
- Illegal land markets exacerbate landscape fragmentation, undermining connectivity, biocultural diversity, and socio-ecological resilience.

Figure C2.5.1. Landholding in a public land area in the Amazonas state, Brazil. Photo credit: Carolle Alarcon Eichmann (2018).

The Solutions Space

Collaborative efforts

- **Multi-stakeholder collaboration is critical to overcoming fragmentation and combating illegal land markets in the Amazon.** Private-sector initiatives like Brazil's Amazon Soy Moratorium[12] and cattle agreements[13] (and recently launched Beef on Track), supported by NGOs, Indigenous Organizations, and government agencies, use supply chain traceability to exclude products sourced from illegally appropriated lands, leading to significant reductions in deforestation and inspiring similar programs in Peru and Colombia.

- **Indigenous-led land titling** with civil society support has also proven effective in Colombia, where almost 20 million hectares of land are being legally formalized as Indigenous local governments, creating an effective long-term deforestation barrier.

- In Peru, examples of formal titling of Achuar and Secoya territories have strengthened local governance and reduced illegal logging and mining.

- **IPs and LCs play a central role in territorial monitoring** through participatory mapping and near real-time systems like the Monitoring of the Andean Amazon Project (MAAP), which enables rapid responses to illegal activities.

- **Regionally, frameworks such as the Leticia Pact and Belém Declaration promote cross-border cooperation to combat illegal mining, logging, and drug trafficking.** Initiatives like Origens Brasil unite companies, NGOs, and Indigenous peoples Peoples to foster ethical trade and transparent supply chains that protect forests and livelihoods.

Selected key tools

- **Traceability platforms such as TRASE and SIMEX** enhance transparency across timber, soy, and cattle supply chains by integrating satellite imagery, official registries, and trade data to expand monitoring and accountability beyond Brazil to the broader Amazon Basin.

Major Recent Governmental Efforts

- **Governments across the Amazon are advancing integrated policies and operations to curb illegal land markets.** Brazil's Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm, its abbreviation in Portuguese) combines protected area expansion, land tenure regularization, and coordinated law enforcement[14].

- **Federal Police operations now target organized crime networks** linked to land grabbing and illegal logging[7], bolstered by the new Center for International Police Cooperation in Manaus, which facilitates regional collaboration.

- In Colombia, **specialized police units have dismantled land grabbing networks**, seizing timber and dismantling illicit infrastructure tied to environmental crime.

- **A landmark example of international cooperation, Operation Green Shield (2025)**, mobilized 1,500 officers from Brazil, Colombia, Ecuador, Peru, and the UAE to combat illegal mining, logging, and trafficking using real-time data sharing via ArcGIS.

Positive efforts for scaling

- **Brazil's Rural Environmental Registry (CAR, its acronym in Portuguese)** is central to regulating land use but suffers from verification bottlenecks. Strengthening CAR through transparency, coordination, and community oversight is critical.

- Media exposure of illegal land brokers on digital platforms has also improved accountability, offering a scalable path for regional land governance.

Recommendations

- **Strengthen & Coordinate Enforcement:** Establish specialized task forces to dismantle land-grabbing networks, enforce sanctions for illegal deforestation, and enhance cross-agency and cross-border cooperation against illegal mining, logging, and trafficking.

- **Close Legal Loopholes and Secure Public Lands:** Prohibit legal regularization of illegally deforested areas, freeze the sale of undesignated public forests, and accelerate their demarcation for conservation, as Indigenous territories or Integral or Sustainable use forests.

- **Improve Land Registries and Transparency:** Integrate and modernize land registration systems to detect overlapping claims, prevent fraud, and trigger automatic inspection. Ensure open data and public access to strengthen accountability.

- **Secure Indigenous and Local Community Rights:** Advance land titling and protection for Indigenous and Local territories supported by community-led monitoring and aligned with regional land use planning for balanced territorial governance.

- **Mobilize private sector accountability:** Mandate traceability for timber, cattle, and agricultural supply chains, enforcing deforestation-free procurement and independent verification of origin.

- **Protect Environmental Defenders and Combat Corruption:** Implement the Escazú Agreement and shield land governance institutions from political interference and corruption.

Key Recent Literature

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Address the Socio-Environmental Harms of Illicit Drug Activities

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Photo credit: Juan C. Garzón Vergara.

The Overview

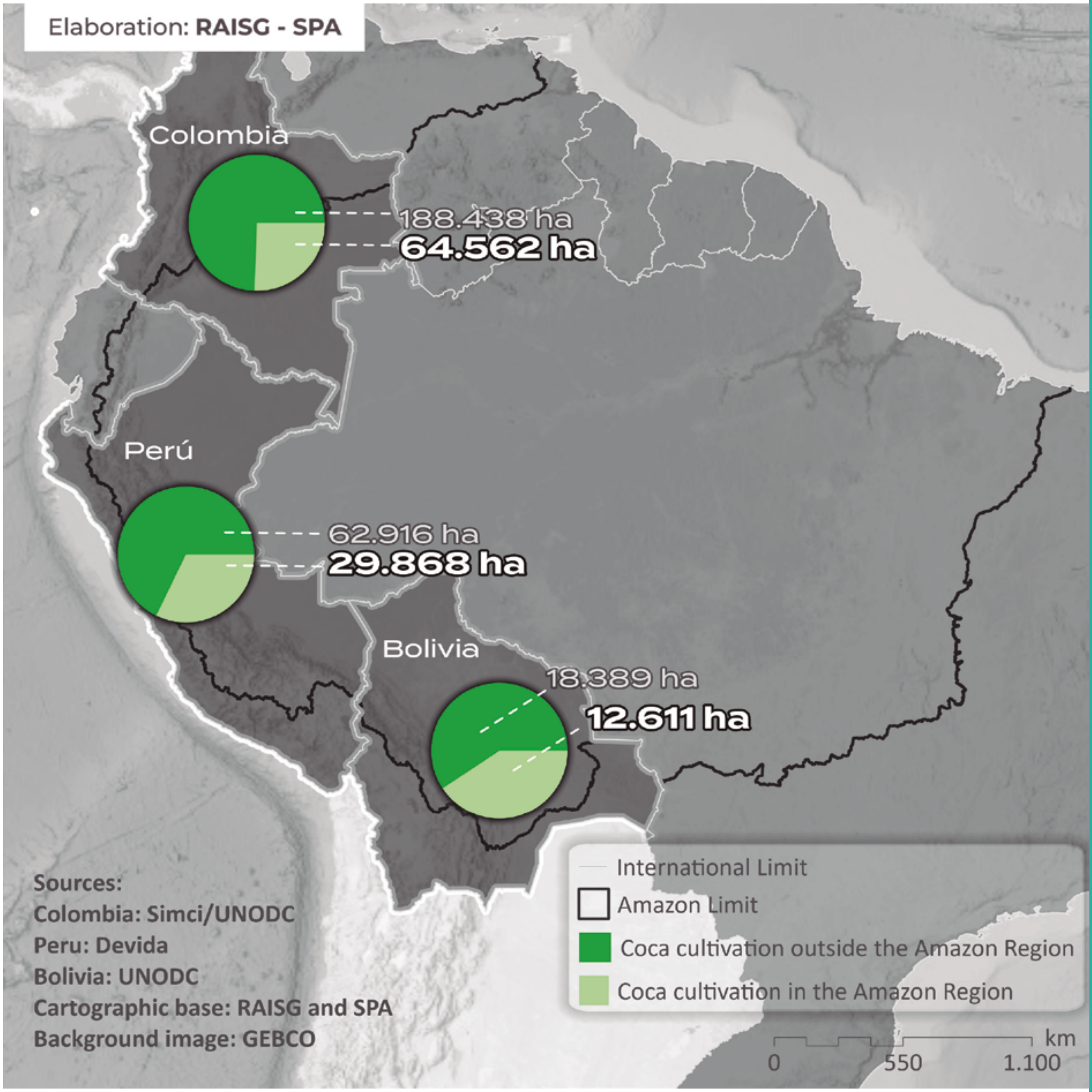
Across key territories of the Amazon, illicit drug production and trafficking fuel environmental degradation and territorial conflict. These harms are driven by an expanding global illicit drug market and reinforced by illicit financial flows and overlapping legal and illegal economies, deepening ecological and social pressures. Environmental crime policy responses often replicate punitive drug control approaches, focusing on symptoms over root causes and hindering integrated, preventive, and rights-based strategies. Yet current responses continue to overlook these dynamics. This Call to Action urges a rethinking of drug policy through an environmental lens—enhancing enforcement to protect ecosystems and communities, disrupting illicit finance, integrating environmental safeguards, advancing sustainable transitions, and upholding the rights and roles of Indigenous Peoples and Local Communities.

CALL TO ACTION 6

The Facts

- Colombia, Peru, and Bolivia account for the majority of global coca cultivation **(Map C2.6.1; Figure C2.6.1)**[1] (~376,000 hectares).
- In the Peruvian and Colombian Amazon, direct deforestation from coca is under 8%, but surrounding areas experience up to 40% deforestation[2,3].
- Over 1,300 clandestine airstrips tied to drug and gold trafficking have been identified in Peru, Brazil, and Venezuela, affecting Indigenous Territories and Protected Areas[4].
- In Colombia, 57% of coca-growing households live in monetary poverty[5].
- In Peru, coca cultivation in Indigenous territories rose 120% between 2019 and 2022, reaching >18,000 hectares[6].

Figure C2.6.1. Coca cultivation in the Valle de los Ríos Apurímac, Ene y Mantaro (VRAEM), Peruvian Amazon. Photo credit: Douwe den Held.



Map C2.6.1. Coca cultivation areas in Bolivia, Colombia, and Peru, 2021. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Global/Regional and Synergistic Connections

- The sustained expansion of the global illicit drug market, within the framework of the international drug control regime, continues to drive environmental degradation and social harm in drug production **(Figure C2.6.2)** and trafficking zones across the Amazon[1,7,8].

- Drug trafficking intersects with illegal mining, logging, and wildlife trade, compounding environmental degradation and weakening ecological resilience[8].

- Illicit revenues are integrated into legal economies—particularly through agriculture, land speculation, and cattle ranching—undermining land governance and long-term sustainability[9].

Figure C2.6.2. A counternarcotics operation conducted by the Colombian Police in a forested area with coca cultivation in the Amazon. Photo credit: Juan C. Garzón Vergara.

The Solutions Space

Major Recent Governmental Efforts

- **In Colombia,** **the 2023–2033 National Drug Policy** **includes, for the first time, a chapter addressing the environmental impacts of the illicit drug economy**. The government also announced a national program for ecological and productive transformation at the Sixteenth Meeting of the Conference of the Parties (COP16) to the Convention on Biological Diversity in Cali, which seeks to link livelihood transition with forest conservation, though implementation remains pending.

- **In Brazil, the National Secretariat for Drug Policies and Asset Management (SENAD) promotes sustainable alternatives in drug transit areas** and co-leads, with the Ministry of Indigenous Peoples (MPI), a national strategy to address socio-environmental harms of drug trafficking in Indigenous Territories.

- In Peru, the National Commission for Development and Life without Drugs (DEVIDA) has promoted **sustainable agriculture and forest-compatible livelihoods** in Amazonian Indigenous areas.

- **At the United Nations level, two resolutions** adopted by the sixty-eighth session of the Commission on Narcotic Drugs **mark progress in recognizing the environmental dimension of drug policy**. One calls for integrating environmental considerations into drug control strategies, along with improved data and coordination. The other seeks to strengthen alternative development measures to address environmental and socio-economic challenges across the illicit supply chain.

Selected Key Tools and Collaborative Efforts

- **Illicit Crop and Deforestation Monitoring:** Colombia's Integrated Illicit Crops Monitoring System (SIMCI) and Peru's national monitoring systems provide critical information on illicit crop expansion through satellite imagery. Regional platforms such as the Monitoring

CALL TO ACTION 6

of the Andean Amazon Project (MAAP) and the Amazon Network of Georeferenced Socio-Environmental Information (RAISG) offer geospatial analysis on deforestation linked to coca cultivation, trafficking routes, and clandestine infrastructure.

- **Early Warning System (Peru):** Since 2023, a pilot project in Flor de Ucayali—supported by the COPOLAD Cooperation Program between Latin America, the Caribbean and the European Union on drug policy; DEVIDA; and the Ministry of Justice—has helped detect environmental crimes and human rights violations linked to drug trafficking.

- **The Center for Drug Studies and Community Social Development (CDESC, Brazil):** CDESC documents the impacts of illicit economies on ecosystems and communities, supporting territorial risk assessments and informing public policy.

- **United Nations Office on Drugs and Crime (UNODC) Practical Guide (2023):** This guide offers concise recommendations to integrate environmental criteria into alternative development, supporting more sustainable and resilient interventions in drug-affected areas.

Positive Efforts for Scaling

- **Territorial Pacts for Forest Protection (Colombia):** In Caquetá, local authorities are working with local farmers and Indigenous communities to reduce deforestation and transition away from coca cultivation.

- **Community Forest Monitoring Groups (Peru):** Indigenous federations have created monitoring brigades that use Indigenous Knowledge, satellite alerts, and mobile tools to detect environmental crimes.

- **Inclusive bioeconomies as an alternative to illicit economies:** Small-scale projects have supported non-timber forest products (e.g., açaí) and agroforestry in the Colombian Amazon and sustainable fishing in Brazil, paired with conservation incentives and governance measures[10].

Recommendations

- **Strengthen environmental enforcement to protect ecosystems and communities.** Deploy multidisciplinary units to support governance in the field by investigating environmental crimes linked to drug economies—such as deforestation, illegal mining, and land grabbing. Prioritize coordination to prevent socio-environmental harm and safeguard the rights, wellbeing, and security of local populations.

- **Disrupt illicit financial flows from drug trafficking that drive environmental harm.** Use financial investigation tools to trace drug revenues laundered through legal sectors—particularly cattle, gold, timber, and land. Strengthen coordination between financial intelligence units and environmental authorities, enforce due diligence in high-risk supply chains, and promote transparency in land and asset ownership.

- **Integrate environmental dimensions into drug policy reform.** Mandate strategic environmental assessments (SEA) for drug control strategies to identify unintended socio-environmental harms. Integrate sustainability and rights safeguards into drug policies, and explore regulatory alternatives that ease ecological pressure and strengthen local resilience.

- **Support sustainable transitions in drug-affected territories.** Scale up investment in socio-bioeconomy initiatives tailored to local conditions. Promote non-timber forest products; payments for ecosystem services (PES); and access to land rights, finance, and technical assistance.

- **Protect and strengthen the rights and roles of Indigenous Peoples and Local Communities.** Adopt differentiated, context-specific policies that safeguard the lives, territories, knowledge, and culture of Indigenous Peoples and Local Communities.

Key Recent Literature

- United Nations Office on Drugs and Crime (UNODC). *The drugs-crime nexus in the Amazon Basin*. Research Brief – World Drug Report 2023. (UNODC, 2023).
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Disrupt Illegal Gold Mining

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Photo credit: Amazonia Real / Marizilda Cruppe

The Overview

Across all of the Amazon – including eight countries and an overseas territory of France, illegal artisanal and small-scale gold mining (ASGM) is accelerating deforestation, disrupting hydrological systems, and mobilizing toxic mercury—while financing criminal networks that erode state authority, often in Indigenous territories. These measurable, cross-border impacts now outpace conventional monitoring and enforcement, undermining climate and biodiversity goals, public health, and governance across the Basin.

This Call to Action is intended to provide a concise overview of the scale, drivers, and impacts of illicit gold extraction across the Amazon. It highlights key facts and trends, presents illustrative tools and approaches, and points to opportunities for coordinated action to dismantle illegal supply chains, reduce deforestation and biodiversity loss, curb mercury pollution, and strengthen the rights, health, and territorial security of Indigenous communities.

The Facts

- By 2024, ASGM has caused the loss of more than 2 million hectares of Amazonian forest (**Figure C2.7.1**), spreading across all of the Amazon, with approximately 36% occurring within Protected Areas and Indigenous Territories (**Map C2.7.1**).

- ASGM in the Amazon Basin produces an estimated 200–300 metric tons of gold annually, and 50%–80 % (over 150 tons) is illicitly mined — fueling deforestation, biodiversity and carbon loss, habitat fragmentation, mercury pollution, and large-scale river degradation and sedimentation[1,2].

- Record-high gold prices are intensifying ASGM expansion — pushing mining into new frontiers and amplifying cascading impacts from deforestation to mercury emissions and river sedimentation[3].

- ASGM emits an estimated 160–200 metric tons of mercury annually, though actual totals are likely higher due to underreporting and illegal trade. Globally, ASGM releases exceed 2,000 tons of mercury per year.

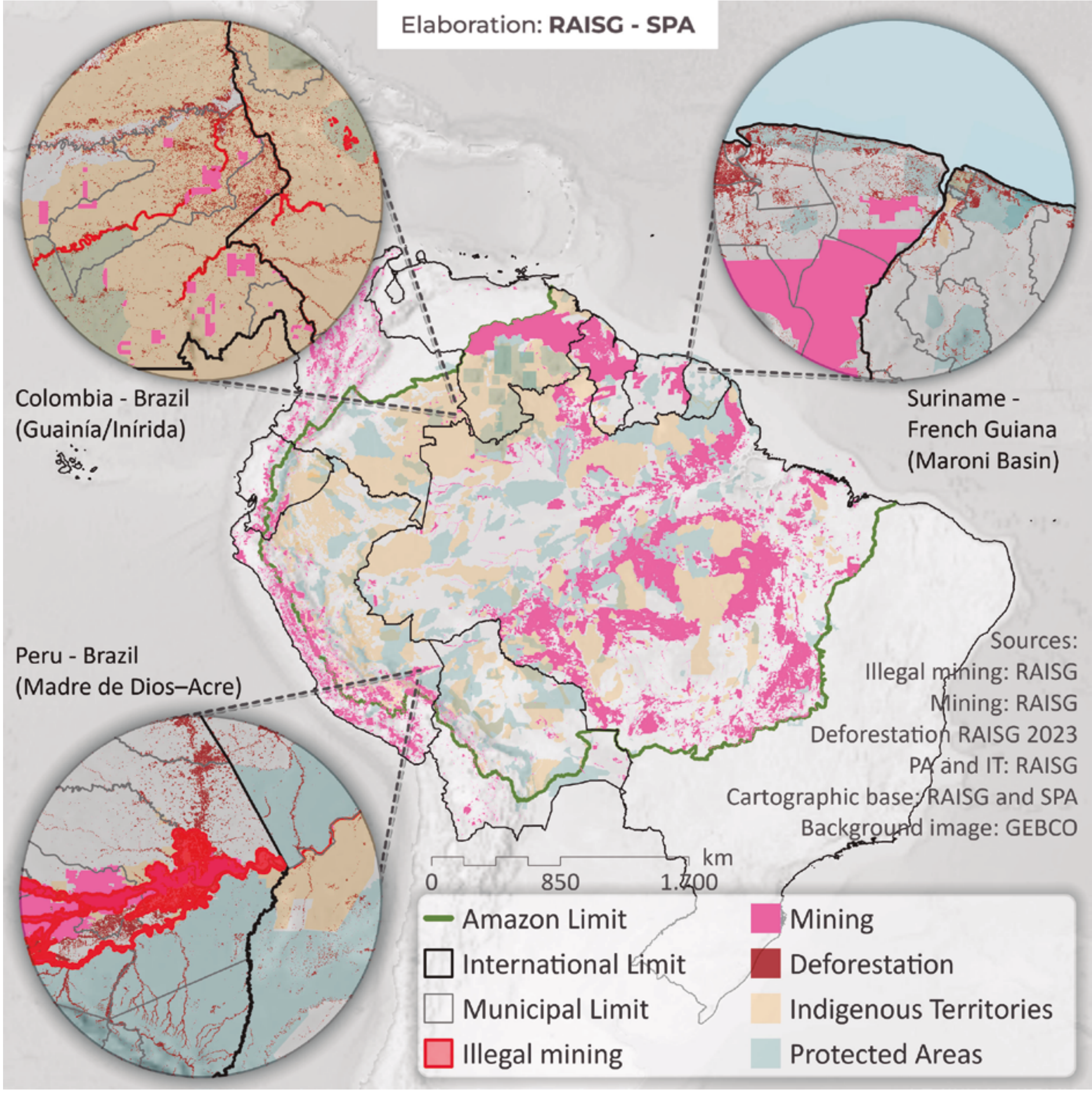
- Mercury exposure in Indigenous and riparian communities near ASGM sites often exceeds the World Health Organization's safety thresholds by more than 20-fold, posing severe, multigenerational health risks (**Figure C2.7.2**).

Global/Regional and Synergistic Connections

- **Mining-driven deforestation releases carbon stores**, weakening Amazon climate stability and jeopardizing national mitigation commitments. Forest loss accelerates mercury cycling, contaminating rivers, fish, and downstream food webs across the Basin.

- **Mining in Indigenous and riparian lands** drives displacement, violence, cultural disruption, and long-term toxic exposure risks. **Illicit gold infiltrates global market**, bypasses regulatory controls, and undermines the credibility of supply chains, certifications, and consumer assurances.

- **Illegal mining activities** overlap other environmental and organized crime activities, including wildlife trafficking, illegal logging, and narcotics and human trafficking routes—**creating transnational networks of corruption and instability**.



Map C2.7.1. Distribution of illegal gold mining (ASGM) across the Amazon forest, showing major hotspots in border regions between Peru–Brazil, Colombia–Brazil, and Suriname–French Guiana. The map highlights deforestation and overlaps with Indigenous Territories and Protected Areas.

Figure C2.7.1. Widespread degradation from gold mining in La Pampa region of Madre de Dios, Peru—one of the Amazon's most intensely mined zones. Forest loss, mercury, and sediment disruption threaten biodiversity, climate, and Indigenous territories. Photo credit: CINCIA.

Figure C2.7.2. Hair sample analysis for mercury biomonitoring in an Amazonian community provides critical data on human exposure linked to gold mining and informs public health interventions. Photo credit: Jason Houston / CINCIA.

The Solutions Space

Major Recent Governmental Actions

- **Integrated crackdowns with territorial coordination:** In Brazil's Yanomami region and Peru's La Pampa mining region, joint military-police operations have curbed mining activity in the short term, underscoring the need for sustained presence, legal follow-through, and ecological restoration to prevent displacement and rebound.

- **Connectivity-enabled enforcement:** Brazil's Federal Prosecutor's Office partnered with Starlink to curb satellite internet use in mining zones, requiring user IDs, enabling geolocation, and cutting service to terminals linked to illegal operations. The approach has already disrupted logistics, with replication efforts underway.

- **Cross-border coordination mechanisms:** Brazil, Colombia, and Peru conduct joint river patrols and data exchanges with support from Amazon Cooperation Treaty Organization (ACTO) and regional platforms, improving early warning and enforcement reach.

Collaborative Efforts

- **Shared enforcement intelligence:** In Peru, the Observatory of Illegal Mining and Related Activities in Key Biodiversity Areas (OMI) and, in Colombia, the Amazon Regional Alliance for the Reduction of the Impacts of Gold Mining (ARAIMO) provide alerts to government agencies and use geospatial and civil society data to guide response against illegal mining.

- **Community-driven monitoring systems:** Indigenous and Local Communities use GPS tools, sampling kits, and drones to collect environmental data. In Brazil, Munduruku communities in Pará and partners in Roraima work with nongovernmental organizations and prosecutors to document incursions and defend their land.

Positive Efforts for Scaling

- **Forensic traceability at scale:** The *Ouro Alvo* program, led by Brazil's Federal Police, uses artificial intelligence (AI) and geochemical fingerprinting to trace gold supply chains and identify laundering networks[4].

- **Science-to-policy mercury monitoring:** Brazil's Fundação Oswaldo Cruz (Fiocruz), Peru's Centro de Innovacion Cientifica Amazonica (CINCIA), and the National Natural Parks of Colombia (PNN) generated mercury baselines fish and human populations in watersheds impacted by mining. These findings have shaped national policy and offered scalable monitoring models.

- **Restoration methods with institutional uptake:** CINCIA's trials of 70+ native tree species have been used to develop reforestation protocols for ASGM-degraded lands and have catalyzed additional restoration initiatives by the Peruvian National System of Natural Protected Areas (SERNANP).

- **Aquatic sensing and biodiversity forensics:** In Peru, French Guiana, and Suriname, eDNA (i.e., environmental DNA), aquatic drones, and networked sensors assess mercury, sediment, and biodiversity loss in mining ponds.

Selected Key Tools

- **Mining-specific satellite alert systems:** Platforms like Monitoring of the Andes Amazon Programa (MAAP), which delivers rapid alerts on illegal mining; Radar Mining Monitoring (RAMI), which detects alluvial sites with radar and optical data; and Amazon Mining Watch, which tracks ASGM disturbances; and the Amazon Network of Georeferenced Socio-Environmental Information (RAISG), which maps incursions across Indigenous Territories and Protected Areas.

- **Geochemical and isotopic tracing:** The Brazilian Federal Police's *Ouro Alvo* program uses isotope analysis and trace-element fingerprinting to link seized gold to its source and trace mercury pathways.

- **Financial intelligence tools:** Brazil's Federal Police, the United Nations Office on Drugs and Crime (UNODC), and INTERPOL track illicit gold and mercury flows using goAML, the FIU.net system, and Palantir Gotham, while the Financial Accountability and Corporate Transparency (FACT) Coalition leverages trade-tracking tools like Panjiva to expose laundering networks.

- **Regulatory tools for enforcement and compensation:** Conservation Strategy Fund's Mining Impact Calculator measures environmental and economic impacts to inform penalties and restitution, while Worldwide Fund for Nature Brazil's (WWF-Brazil's) Gold Transparency Portal enhances supply-chain transparency to deter illegal mining, tax evasion, and gold laundering.

Recommendations

- **Build regional innovation hubs and policy-integration platforms** to scale science-based solutions that disrupt illegal gold mining systems, accelerate knowledge transfer, and operationalize an Innovation Hub initiative as proposed by the Science Panel for the Amazon[5].

- Build an **Amazon-wide network of analytical laboratories** to support basin-scale mercury monitoring, and integrate their data into national health, environmental, and enforcement policies aligned with Minamata Convention on Mercury targets.

- **Scale science-based restoration** programs to reclaim gold-mined landscapes; recover ecosystem functions; and align with national climate, biodiversity, and socio-bioeconomy strategies.

- **Deploy science-based gold forensic tracing and illicit finance tools** to uncover criminal gold and mercury flows, dismantle laundering networks, and strengthen cross-border enforcement across Amazonian supply chains.

- **Fund and equip Indigenous Peoples' and Local Communities' monitoring and early-warning networks** that combine Indigenous and Local Knowledge with digital tools to detect incursions, defend territory, and inform enforcement and governance decisions.

- **Build and deploy environmental intelligence systems** that fuse multimodal inputs—archival data, satellite imagery, acoustic and biophysical sensors, and text—processed through AI to transform raw signals into actionable intelligence on mining and enable rapid, real-time responses.

Key Recent Literature

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Safeguard Amazonian Defenders and Their Role in Preserving the Socio-Ecological Connectivity of the Amazon

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Photo credit: Bruno Kelly / Amazonia Real

The Overview

Across the Amazon, socio-environmental defenders are on the front lines protecting their territories and communities. Confronting illegal logging, mining, land grabbing, and drug trafficking, as well as policies that enable dispossession, they face escalating violence, criminalization, and aggressors acting with impunity. In 2022, one in five killings of environmental defenders occurred in the Amazon, making it a high-risk region for those defending nature. These crimes follow systematic, organized patterns that weaken communities, threaten Indigenous people survival, and facilitate resource exploitation. The commitments made in the Belém Declaration of the Amazon Cooperation Treaty Organization (ACTO) and the standards set by the Escazú Agreement (i.e., the Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean) must be fully implemented to guarantee defenders' rights. Protecting defenders is not only a duty but a prerequisite for preserving the Amazon's socio-ecological connectivity.

The Facts

- Global Witness documented 196 killings of land and environmental defenders in 2023, of which 85% occurred in Latin America, 55.10% of them in the Amazonian countries of Colombia (79), Peru (4), and Brazil (25)[1].

- Between 2014 and 2022, at least 296 land and environmental defenders were killed in the Amazon—39 in the last year alone, including 11 Indigenous people[2]. In 2022, the region accounted for over one-fifth of the 177 defender killings worldwide.

- In the Colombian Amazon, 44 attacks were recorded in 2023—including killings, threats, forced displacement, disappearances, arbitrary detentions, information theft, kidnappings, criminalization, torture, and sexual violence[3].

- In 2023, the Brazilian Amazon recorded 8,603 intentional violent deaths (32.2 per 100,000 inhabitants). This is 41.5% higher than Brazil's national average[4] (Figure C.2.8.1).

- At least 29 environmentalists and Indigenous leaders were killed between 2010 and 2023 for defending the Peruvian Amazon from extractive activities by illegal invaders[5]. Most cases are linked to gold mining, illegal logging, coca cultivation, land trafficking, and protest-related violence.

- Between 2017 and 2024, civil society and Indigenous Peoples' organizations in Bolivia documented 250 attacks against environmental and land defenders. In the Bolivian Amazon, incidents have targeted park rangers from Protected Areas, Indigenous leaders, environmental organizations, and both Indigenous and rural women[6].

- Indigenous Peoples are only 5% of the global population but account for 40% of environmental defenders killed[7].

- Amazon countries that have ratified the Escazú Agreement: Bolivia (2021), Ecuador (2020), Guyana (2022), Colombia (2024). Signed but not ratified: Brazil, Peru. Not signed: Suriname, Venezuela.

Figure C2.8.1. Indigenous leaders from the Serras region, in Tabatinga community, present evidence of violence affecting their communities. Photo: Yolanda Mêne / Amazônia Real.

Global/Regional and Synergistic Connections

- Rising global demand for commodities such as strategic minerals, soy, livestock, and oil is intensifying pressure on tropical forests and attracting transnational organized crime[8]. These dynamics pose severe threats to ecosystems and their defenders. Mining is the leading driver of killings of environmental defenders in Latin America, linked to half of all cases, while agribusiness is the primary cause in Asia, accounting for 85% of such deaths.

- Organized, armed groups linked to regional and transnational criminal networks operate across the Amazon Basin, many involved in violence against environmental and human rights defenders[9].

The Solutions Space

Collaborative Efforts

- **Conversaciones de la Amazonía** is a regional gathering where, at its fourth meeting, Indigenous Peoples and Local Communities shared strategies for monitoring and defending territory and life—both human and non-human.

- **Red de Redes Amazónicas** is a coalition of 12 regional civil society networks advancing coordinated Pan-Amazonian advocacy. Its priorities include enforcing Escazú standards on biodiversity and climate and promoting civil society engagement in monitoring violations against socio-environmental defenders.

Major Recent Governmental Efforts

- **Amazon Regional Observatory:** The Belém Declaration commits ACTO member states to protecting socio-environmental defenders through the creation of a Regional Observatory, established as a binding mechanism under Resolution 6. The observatory is tasked with monitoring risks, facilitating information exchange, and enhancing coordination among governments. It will also identify tools, funding opportunities, and good practices to strengthen defender protection.

Best Practices

- **Indigenous Guard Exchanges and Agreements:** In Ecuador and Colombia, Indigenous regional organizations and guard units engage in joint commitments and regional exchanges to strengthen territorial defense, coordinate surveillance strategies, and develop shared protection protocols for communities and their leaders.

- **Action Plan on Human Rights Defenders in Environmental Matters:** At the third meeting of the Conference of the Parties to the Escazú Agreement, State Parties adopted a regional Action Plan focused on four pillars: knowledge generation, public recognition, national capacity building, and periodic monitoring and evaluation. An ad hoc regional working group for Latin America and the Caribbean will oversee its implementation through 2030.

Recommendations

- **Amazonian countries that have not yet ratified the Escazú Agreement should do so** without delay, ensure its integration into national legal frameworks, and actively participate in the implementation of the Regional Action Plan on Human Rights Defenders in Environmental Matters through the adoption of concrete institutional and legislative protection measures.

- A**mazonian states must fully operationalize ACTO's Resolution 6**, which establishes a dedicated module on socio-environmental defenders within the Amazon Regional Observatory, ensuring the effective participation of local organizations and independent networks in its design and operation.

- Amazonian states are required to **formally recognize and strengthen autonomous territorial monitoring** and surveillance practices as key strategies for self-protection by Indigenous Peoples and Local Communities, ensuring their integration into public policy and territorial governance frameworks.

- Minimum **cross-border governance capacities must be developed** through the harmonization of regulatory and institutional frameworks, enabling Amazonian states to coordinate responses to shared challenges such as organized crime.

Key Recent Literature

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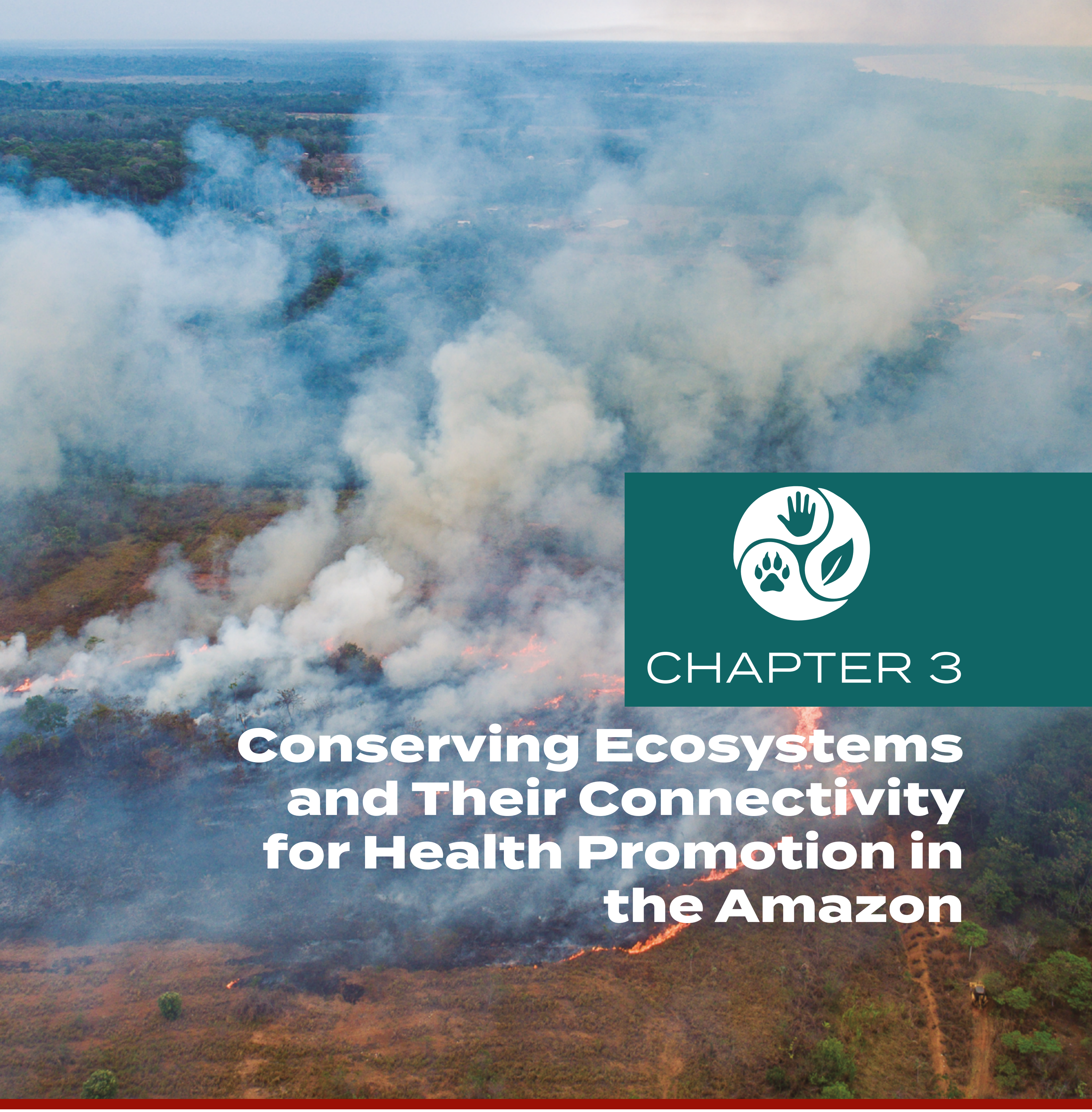

CHAPTER 3

Conserving Ecosystems and Their Connectivity for Health Promotion in the Amazon

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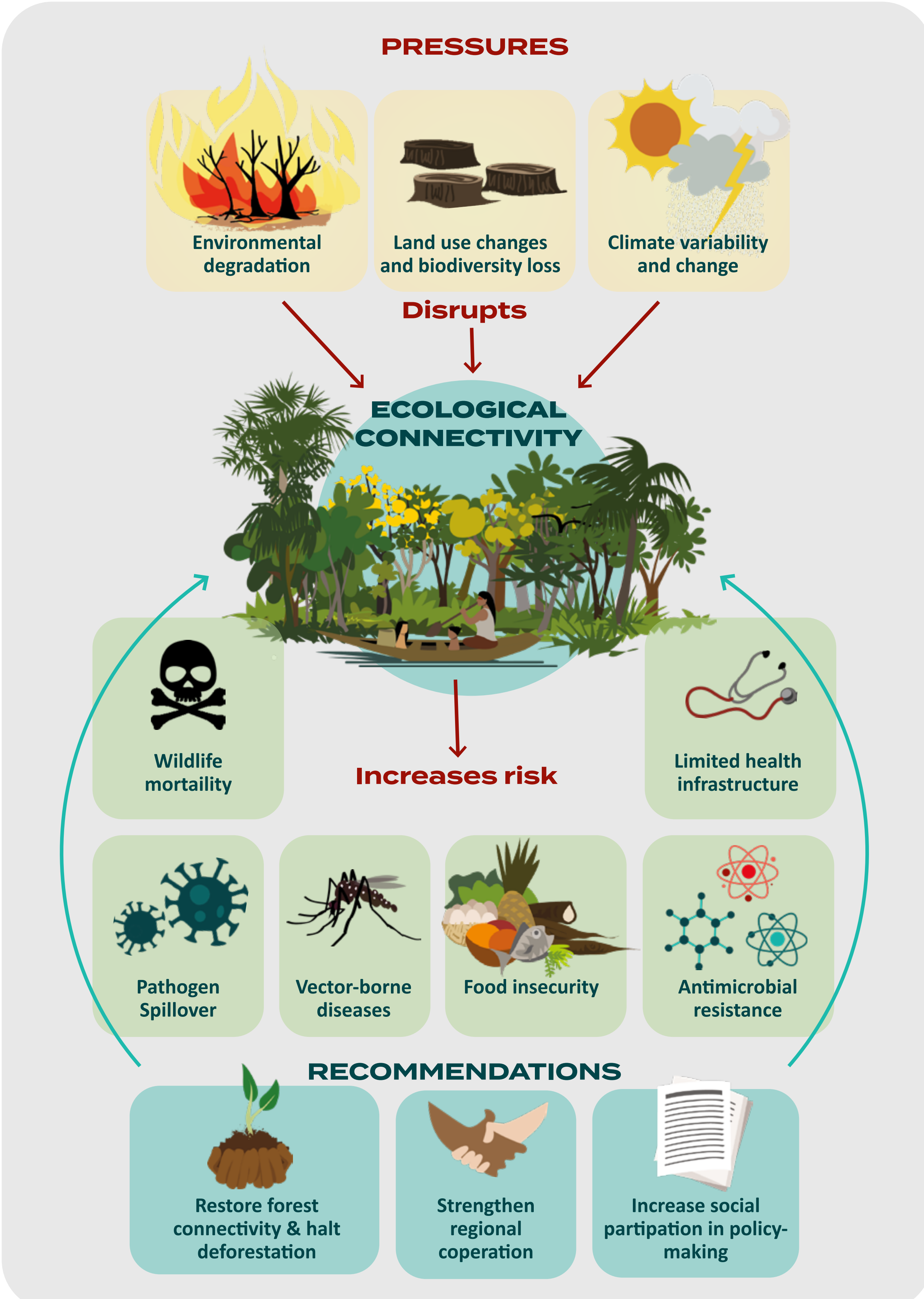
Abstract

The Amazon has been experiencing a convergence of ecological, climatic, and sociopolitical pressures that threaten ecosystem integrity, provision of ecosystem services, and human health. This chapter highlights how deforestation, forest fragmentation, wildfires, habitat loss, ecosystem degradation, and climate change are accelerating the risks of emerging infectious diseases, especially vector-borne and zoonotic threats, heat-related illness, air pollution from fires, nutritional insecurity, and overall mortality impacts. It also examines how structural weaknesses in public health systems (underfunding, geographic inaccessibility, and cultural exclusion) exacerbate vulnerabilities across the Amazon's diverse populations, especially Indigenous and Afrodescendant Peoples and Local Communities (hereafter IPs & LCs). The COVID-19 pandemic, recent arboviral outbreaks, and persistent health inequities underscore the urgent need for integrated, equitable responses.

Taking a One Health perspective, the chapter proposes a comprehensive approach that positions ecosystem conservation as a public health intervention. Key recommendations include halting deforestation, forest fires, and degradation, embedding health indicators into land-use and climate planning, and establishing regional One Health platforms. The chapter also emphasizes the need to strengthen primary health care, promote intercultural models that respect IPs & LCs knowledge, and enhance community surveillance and regional cooperation. By linking environmental governance with health equity, the Amazon can become a model for planetary health resilience. Achieving this vision requires decisive political leadership, sustained public investment, and a shift toward a socio-bioeconomy rooted in forest stewardship, social justice, and scientific collaboration.

Keywords

One Health, infectious diseases, spillover, deforestation, climate change



Graphical Abstract. Ecological connectivity is disrupted by different pressures, *increasing the threats of diseases emerging from this disruption. The One Health framework is needed to tackle these issues.*

1. Introduction

The Amazon provides essential ecosystem services: it regulates climate and the hydrologic cycle, purifies water sources, hosts monumental biodiversity, and supplies edible and medicinal plants, as well as cultural services that support identity, spiritual well-being, and mental health, particularly for Indigenous Peoples and Local Communities (see Chapter 1 and 5). However, the biome is under intense anthropogenic pressure from sources such as deforestation, mining, livestock farming, fires, degradation, pollution, and climate change [1.] These pressures are bringing ecosystems closer to multiple interconnected tipping points—states where environmental conditions cross specific thresholds with irreversible consequences—including the forest–savanna transition (estimated at 20%–25% deforestation and 2°C global warming), hydrological cycle disruption, and biodiversity collapse, with irreversible consequences for human and nonhuman health. Cultural and ecological protections against disease emergence are eroding, with health impacts becoming increasingly common consequences of disrupting ecological connectivity in the Amazon[2.]

Forest integrity is a natural barrier against zoonotic and vector-borne diseases (VBDs)[1,2]. Within the forest, diverse viruses, bacteria, and other pathogens can affect humans and wildlife. Habitat loss and fragmentation reshape the ecological niches of vectors, hosts, and pathogens, leading to shifts in species composition, changes in host and vector behavior, and modified geographic distributions[3]. Land-use change, fires, droughts, landslides, heat waves, the accelerating globalization of markets and trade, and urban expansion are changing disease transmission dynamics, causing more frequent outbreaks[4-6]. A vast pool of undescribed zoonotic viruses combined with growing habitat disturbance increases the risk of pathogens crossing species barriers, potentially leading to spillover events or even pandemics (**Figure 3.1**)[7-9]. A regional, integrated approach emphasizing the One Health framework is vital, as the well-being of Amazonian communities is crucial for the region's conservation[10-13.]

The One Health approach recognizes that human, animal, and environmental health are interconnected and that effective solutions must address these three dimensions simultaneously. Some practical examples of strategies include monitoring the health of both humans and animals; treating wildlife mortality as early warnings (sentinels) of infectious diseases; reducing deforestation to lower the spillover risk; and combining environmental, animal, and human health in joint surveillance systems. One Health has already shaped policies for malaria elimination, rabies control, food safety, and antimicrobial resistance management[14,15]. Rather than viewing health impacts as consequences of environmental change, this chapter positions One Health as the central organizing framework for analyzing and responding to the interconnected crises of ecosystem degradation, climate change, and health system limitations in the Amazon.

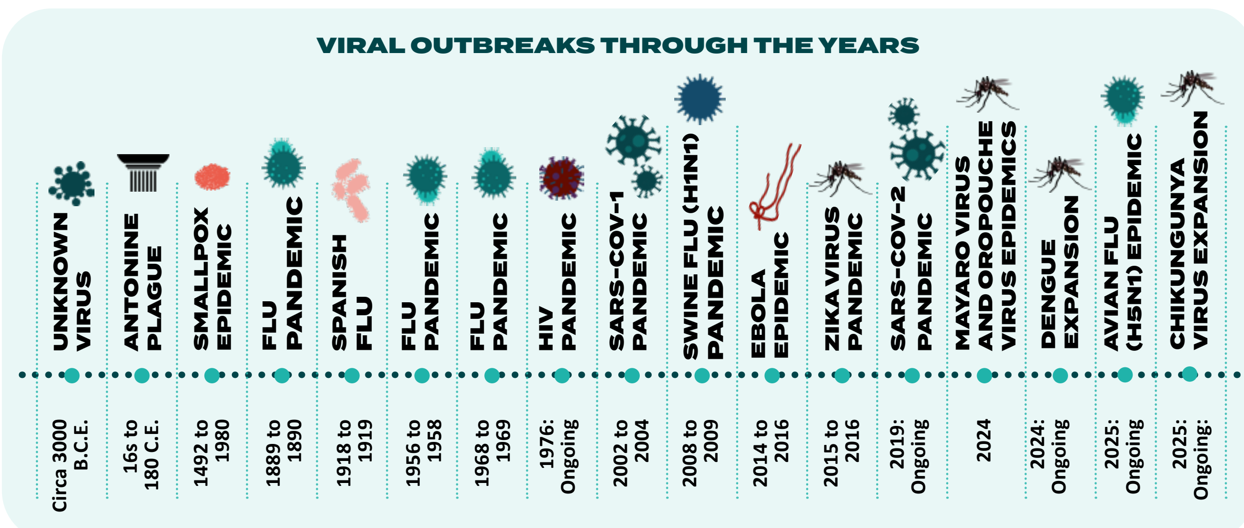


Figure 3.1: Timeline of history's most notable viral pandemics and epidemics. Most major pandemics have been attributed to mutated influenza viruses (H1N1, H2N2, H3N2) that were thought to have originated in animal reservoirs and which subsequently spread to humans. The 2003 SARS-CoV-1 pandemic is regarded as the first pandemic of the twenty-first century and, similar to SARS-CoV-2, likely emerged from bats. Two recent epidemics have originated in the Amazon: Mayaro fever and Oropouche fever. Note 1: Although the agent responsible for the outbreak 5,000 years ago is not known, due to the rapid mortality and transmission rate, scientists hypothesize that the disease was likely caused by the measles virus. Note 2: Based on descriptions by Greek physician Galen, the Antonine Plague may be attributed to smallpox. Source: Adapted from Marie and Gordon (2023)[16].

2. Human–Wildlife Interactions and Spillover Risk and Other Health Problems Related to Environmental Degradation

Deforestation reduces the available habitat for wild species, resulting in simplified ecological communities and increased populations of certain hosts and vectors of pathogens[17,18]. Fragmented habitats intensify edge effects, conditions that can increase the abundance of vectors, enhance the contact between humans and wildlife, and facilitate pathogen sharing[19,20]. The historical occupation of the Amazon has been closely tied to vector-borne diseases such as dengue, Chagas disease, cutaneous leishmaniasis, malaria, and yellow fever. The recent increase in deforestation related to development projects has exacerbated VBDs associated with biodiversity loss and caused shifts in land use and cultural practices (see Call to Action 10)[20].

Road construction brings habitat loss and fragmentation, biodiversity loss, sociocultural degradation, increases in informal and precarious activities, and exposure to pathogens and vectors[21]. Human mobility facilitates disease spread by bringing people closer to source areas of infected vectors or transporting infected vectors and hosts, including viremic humans, to distant regions[18]. For example, the opening of the BR-319 highway in the Brazilian Amazon has caused a 400% increase in malaria cases, and the paving of the Peruvian section of the Interoceanic Highway caused at least an additional 9,826 dengue cases in 202222,23. Roads are also associated with increased atmospheric pollution and exposure to smoke from fires[22,24].

Mining in the Amazon is responsible for severe health impacts that disproportionately affect IPs & LCs, best understood through a One Health lens linking human, animal, and environmental health. Gold mining contaminates rivers with mercury, harming aquatic ecosystems and fish populations, while exposing human communities that rely on fish to elevated mercury levels, leading to cognitive impairment in children such as among the Matsigenka people in Peru[25]. Illegal mining has likely sustained malaria transmission in Guyana, Brazil, Colombia, and Venezuela, as deforestation, stagnant water pits, and increased human mobility create mosquito breeding sites and promote human-vector contact. Its recent expansion has caused a humanitarian crisis among the Yanomami people and other communities in the

Brazilian Amazon, marked by rising malnutrition, malaria, violence, and the precariousness of health services[26]. Many of these activities are often connected to transnational criminal networks, compounding risks to IPs & LCs (see Chapter 2).

The wildlife and bushmeat trade increase zoonotic risks through direct human–animal contact[27]. For example, antibodies against the hepatitis B virus were detected for the first time in free-ranging Amazonian wildlife in the Yagua Indigenous community on the border between Brazil and Peru[28]. In recent years, the local and global demand for animal-source foods have grown, and travel and trade have become increasingly globalized. About 40,000 primates and four million birds are traded annually worldwide, bringing wild animals closer to humans, providing interfaces for pathogen spillover, and allowing the introduction of vectors during transport[29,30]. Hunters face risks when entering wild habitats, while capturing animals, and during slaughter, which allows contact with animal blood (see Call to Action 11).

Food insecurity is directly linked to environmental degradation, which disrupts human–wildlife interactions, worsens vulnerabilities and creates new nutritional challenges, particularly for IPs & LCs that depend on natural resources. Ecosystem degradation reduces the availability of traditional foods such as fish and bushmeat, forcing greater reliance on less nutritious options. These changes compromise community health and resilience, while increasing susceptibility to diseases, including arboviruses[4,6]. Anemia remains a serious public health issue in the Amazon, caused by (but not limited to) infections and exposure to metals and other chemicals. The shift away from traditional diets to rising consumption of ultra-processed foods (UPFs) was accompanied by a sharp increase in anemia (from 6% to 23%) and obesity (from 0% to 30%) in Awajún women in Peru[31,32,33]. Implementing policies that limit the consumption of UPFs and encourage diets based on local, seasonal, and organic foods is crucial for improving health and sustainability[27]. Policies such as Brazil's National School Feeding Program are vital tools for ensuring adequate childhood nutrition, with lasting positive impacts[7,34]. The connection between human–wildlife interactions and nutritional outcomes reflects the broader impacts of ecosystem degradation on community health and resilience.

3. Climate Change and Disease Emergence Pathways

Together with deforestation, climate variability and change increase the risk of VBDs, reflecting complex relationships between environmental factors and regional disease prevalence[9,12]. Changes in climate and weather are driven primarily by the current global climate crisis, exacerbated by regional deforestation and land-use changes that alter local and regional climate systems.

Prolonged warm spells and dry conditions elevate dengue transmission risk, especially in highly urbanized areas[35,36]. All Latin American countries saw an increase in the estimated basic reproduction number (R0) for dengue transmission by Aedes aegypti between 1951–1960 and 2013–2022, with an average increase of 54%[37]. Some of the largest increases occurred in Amazonian countries, including Bolivia (145%), Peru (95%), Brazil (94.5%), Colombia (65.8%), and Ecuador (59.5%). Favorable climatic conditions, combined with increasing urbanization and connectivity through roads and air travel, have contributed to recent outbreaks of the Oropouche virus (OROV) and Mayaro virus (MAYV)38. OROV was endemic to the Amazon but has recently expanded beyond, with Espírito Santo state (southeast Brazil) reporting the highest number of confirmed cases (see Call to Action 10).

Increased climate variability from the El Niño–Southern Oscillation (ENSO) has contributed to increased incidence of dengue, malaria, leptospirosis, and ten other infectious diseases in Ecuador39. Cutaneous leishmaniasis and the seasonality of its vectors are also notably associated with ENSO cycles[4,40,41]. Malaria clusters are positively associated with rainfall, with overlapping seasonal peaks, while higher temperatures, particularly around 24°C–26°C are linked to increased incidence in a parabolic relationship[42,43]. Conversely, improved water infrastructure, like aqueduct coverage, negatively affected malaria cases after 2015[44]. The effects of temperature, terrestrial water content, and precipitation on various malaria vector species highlight the ongoing vulnerability of Indigenous and rural populations in the Amazon[44].

Climate change directly affects pathogen activity, altering their virulence and resistance, distribution, as well as indirectly influencing host–pathogen epidemiology. It can intensify the spread of antimicrobial resistance (AMR), the natural or acquired ability of microorganisms to resist the effects of antimicrobial treatments, by increasing the abundance and diversity of resistance genes in aquatic microbial communities[45]. There are positive synergies between strategies for addressing climate change and those for managing AMR. Many climate-sensitive infectious diseases are also susceptible to AMR, such as malaria and infections caused by fungi, helminths, and vibrios[46].

Heat waves exacerbate cardiovascular, respiratory, renal, and metabolic diseases. Exposure to extreme heat is linked to a range of health problems, from mild symptoms like headaches to severe outcomes, including heatstroke and death. From 2013 to 2022, infants in Latin America were exposed to 2.2 million more person-days of heat waves per year compared to the 1986–2005 baseline. Older adults (65+) experienced an additional 13.3 million person-days of heat waves annually. This means infants faced 248% more heat-wave days, and older adults 271% more heat-wave days, compared to the 1986–2005 baseline. The largest increases in heat exposure for infants were observed in Guatemala, Ecuador, and Venezuela. For older adults, the largest increases occurred in Ecuador, Colombia, and Guatemala[37]. In Brazil, the risk of heat stress exposure was highest in the northern region and among the most socially vulnerable populations[47]. The 2023–2024 record-breaking drought, heat waves, and thermal aquatic stress in the Amazon were associated with massive death rates of fishes and dolphins[48.]

Droughts compromise water supply, fuel malnutrition, increase water and food insecurity, and represent a significant threat to the most vulnerable populations, such as IPs & LCs7. Droughts increase fire activity, leading to more hospitalizations, particularly among older adults and children[51]. Forest fires, mostly human induced, drive biodiversity loss and release fine particulate matter (PM2.5 and PM10) that affects lungs, eyes, and throat, thus increasing respiratory and cardiovascular diseases[49,50]. Fires also promote the migration of rodents and other animal hosts, favoring the transmission of zoonoses and VBDs[51]. Floods destroy crops, homes, and infrastructure; increase exposure to pollutants; and trigger outbreaks of leptospirosis, acute diarrhea, and other waterborne diseases[52].

These extreme climatic events impact human health by causing heat-related illness, physical injuries, mental health disorders, and excess overall mortality[53]. The combination of these direct and chronic impacts creates unsustainable pressure on health care systems, leading to a significant increase in demand for emergency services and hospitalizations[54]. This overload is compounded by supply chain interruptions and infrastructure damage, which hinder access to essential medications and treatments[55]. The result is a spiral of vulnerability that can lead to the operational collapse of the system, with billions in financial costs and a disproportionate burden on the most vulnerable populations[56]. Consequently, the increasing intensification and frequency of these events, which are driven by climate change, demand integrated and robust strategies for public health mitigation and adaptation[57].

4. Connecting Communities to Health Care and Implementing the One Health Framework in the Amazon

Health systems in the Latin American region are highly fragmented and segmented, leading to significant challenges in providing quality care and ensuring equity[7]. Amazonian countries have deficient health systems compared to more-developed countries, an exception being Brazil's Unified Health System (SUS)[58]. Evaluating health status within the Amazon is challenging due to scarce and fragmented cross-country data, differing and unshared diagnostic methods, weak information management systems, poorly equipped or nonexistent surveillance laboratories, limited diagnostic capacity in resource-limited areas, and incomplete surveillance programs. Health promotion faces, additionally, several structural issues, such as inadequate basic sanitation, mobility challenges, intermittent electricity supply, and insufficient water quality for IPs & LCs. The sparseness of populations, challenging transportation routes, high transportation costs, and shortages of health care professionals restrict health care access and reduce the effectiveness of surveillance and disease diagnosis.

The COVID-19 pandemic has revealed that public health infrastructure is woefully inadequate throughout the Amazon[59]. While countries like French Guiana and Suriname managed early control through strict lockdowns, Brazil's continued air travel and political polarization worsened the already precarious public health infrastructure and contributed to severe outbreaks, culminating in the interruption of oxygen supply to hospitals in Manaus and particularly affecting vulnerable communities[60]. The crisis has highlighted the critical need for continued investment in global health security preparedness and surveillance[63,64]. Because humans, animals, and pathogens can now travel globally in less than a day, often faster than disease incubation periods, surveillance has identified the Amazon as a hotspot for coronaviruses and other pathogens, with largely unknown zoonotic spillover risks (see Call to Action 11)[64].

Intercultural health remains a key challenge in the Amazon. For example, IPs in Brazil face higher infant mortality rates, lower life expectancies, childhood undernutrition and anemia, a high burden of infectious and parasitic diseases, and intense exposure to pollutants such as mercury, agrochemicals, and particulate matter from wildfires. Forced acculturation, land displacement, and violence contribute to poor mental health, substance abuse, and high suicide rates among Indigenous youth63. Different IPs & LCs have distinct conceptual frameworks for understanding health, illness, and healing (see Chapter 5) that must be respected and integrated into public health strategies. For example, recent work in French Guiana has highlighted the importance of recognizing "health communities" that acknowledge the distinct perceptions of diseases, risks, and healing practices among different Indigenous and Maroon communities. These differential approaches to how people conceptualize health require adaptive public health strategies that respect cultural diversity while maintaining scientific rigor.

The recent Conference of the Parties to the UN Convention on Biological Diversity (CBD) has established a series of One Health metrics and recommendations, recognizing the interconnection between the health of ecosystems, humans, and nonhumans. National Adaptation Plans (NAPs) for climate change and National Biodiversity Strategies and Action Plans (NBSAPs) are central tools to guiding countries in assessing and responding to climate and biodiversity vulnerabilities, and should include One Health indicators. These plans have been promoted by, respectively, the UN Framework Convention on Climate Change (UNFCCC) and the CBD. In Latin American NAPs, health topics are integrated mainly into the agriculture, food security, and water sectors, but they are rarely addressed in areas like biodiversity, infrastructure, and tourism50. This indicates limited adoption of the One Health framework. While many NAPs describe climate change impacts on health, few provide details on how adaptation measures will be implemented, financed, or monitored. In Amazonian countries, health sector priorities focus on infectious diseases (Brazil, Colombia, Suriname, and French Guiana), infrastructure (Colombia and Peru), and disaster risk management (Peru, Brazil, and Colombia), while issues like malnutrition, cardiorespiratory diseases, injuries, toxicity, and mental health receive more limited attention[48].

Enhancing global health security while adopting the One Health framework in the Amazon requires stronger regional cooperation and cross-border infectious disease surveillance. Amazonian governments must prioritize health and ensure funding aligns with the urgency of the region's health challenges.
A shift from segmented insurance models to universal, rights-based systems is urgently needed[10]. Public investment in health must be increased and sustained, restructuring health systems around primary health care, promoting multisectoral action and the participation of IPs & LCs. The concepts and aspirations of health systems must be reviewed and redefined by engaging citizens in dialogues that will help build a shared vision and assess the changes needed to overcome the historical and structural deficiencies exposed and worsened by the COVID-19 pandemic. It is also necessary to strengthen coordination between existing networks to ensure continuity and quality of care. Animal disease notification systems should be connected to public health surveillance, as wildlife mortality can be treated as early warnings of zoonotic spillovers and human epidemics. It is imperative to increase public health investment to at least 6% of the gross domestic product, to allocate 30% of this investment to primary health care, and to reduce out-of-pocket spending[10]. In a highly interconnected region characterized by significant biodiversity, prevalent poverty, fragile health systems, potential emerging pathogens, and increasing human mobility, the establishment of an interdisciplinary and cross-country regional surveillance program focused on human, nonhuman, and environmental health is imperative[10].

5. Conclusions

Environmental, climatic, political, and sociocultural drivers intersect in the Amazon, shaping ecological connectivity and directly influencing health outcomes for human and nonhuman populations (Figure 3.2). Evidence presented in this chapter demonstrates how deforestation, forest fragmentation, fires, and climate extremes converge with weak health systems to exacerbate disease risks, nutritional insecurity, and inequities. Loss of forest integrity accelerates spillover potential, alters vector dynamics, and undermines food and water security, while road building, extractive activities, and illegal economies amplify pollution, human mobility, violence, and social exclusion. At the same time, the intensification of droughts, floods, and heat waves disrupts agricultural and hydrological cycles, magnifies vector-borne and zoonotic threats, and pushes the biome closer to ecological collapse. Protecting and restoring ecosystems is therefore not only a conservation strategy but a critical public health intervention, yielding co-benefits for biodiversity, carbon storage, water security, air quality, disease prevention, and health promotion.

Strengthening equitable and intercultural primary health care, especially for IPs & LCs, can bridge surveillance gaps, respect diverse knowledge systems, and empower communities to co-manage health and environment. NAPs and NBSAPs must embed health indicators, secure financing for surveillance, and expand integrated approaches across sectors following the One Health framework. Regional cooperation, underpinned by international health regulations, offers opportunities for cross-border surveillance, shared public health surveillance laboratories, and coordinated responses to health threats. Realizing this vision requires decisive leadership, transparent governance, sustained public investment, and a shift toward a socio-bioeconomy that prioritizes nature stewardship, social justice, and scientific collaboration. As the Amazon nears ecological and societal tipping points, it is urgent to safeguard the health of humans, animals, and the environment.

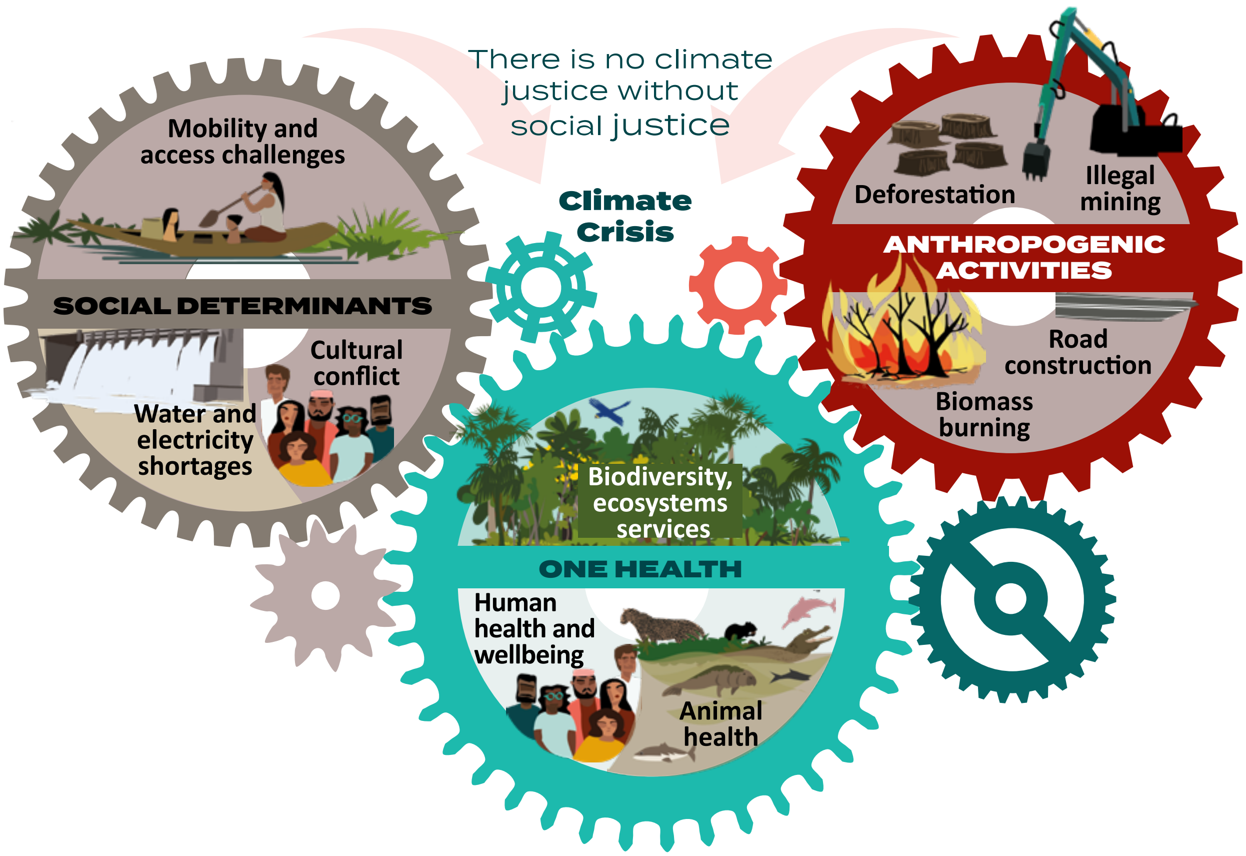


Figure 3.2. Anthropogenic activities and social inequalities interact with the global climate crisis to shape ecological connectivity in the Amazon and determine the health of humans, nonhumans, and the environment. Land-use change and climate extremes combined with limited health infrastructure increase disease risk in the region. Protecting the forest, promoting regional cooperation, and strengthening intercultural health care under a One Health framework are essential to keeping this intricate system working and ensuring resilience, equity, and sustainability for generations to come. Source: Adapted from Dorigatti et al. (2025)[68].

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Support Human Health Through Conservation, Management, and Surveillance of Forest Landscapes

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The Overview

Deforestation and fires in the Amazon continue to endanger countless species and jeopardize vital ecosystem services, including those essential to human health. Forest fires, for example, produce a toxic haze that can lead to respiratory and cardiovascular diseases and infections in humans; mining can increase mercury concentration in watersheds, with toxic effects on skin and the cardiovascular, pulmonary, urinary, and gastrointestinal systems[1,2]. When it impairs forest integrity, land-use change ends up favoring species that can adapt to anthropic habitats and can also act as disease hosts and vectors[3]. As a consequence, the abundance of those species rises, increasing zoonotic and vector-borne disease transmission risks. In addition, the creation of forest edges due to forest fragmentation also increases the likelihood of contacts between people and animals at the interface, further boosting the risk of zoonotic disease transmission. Therefore, the conservation and restoration of forests is key in preventing diseases and safeguarding human health.

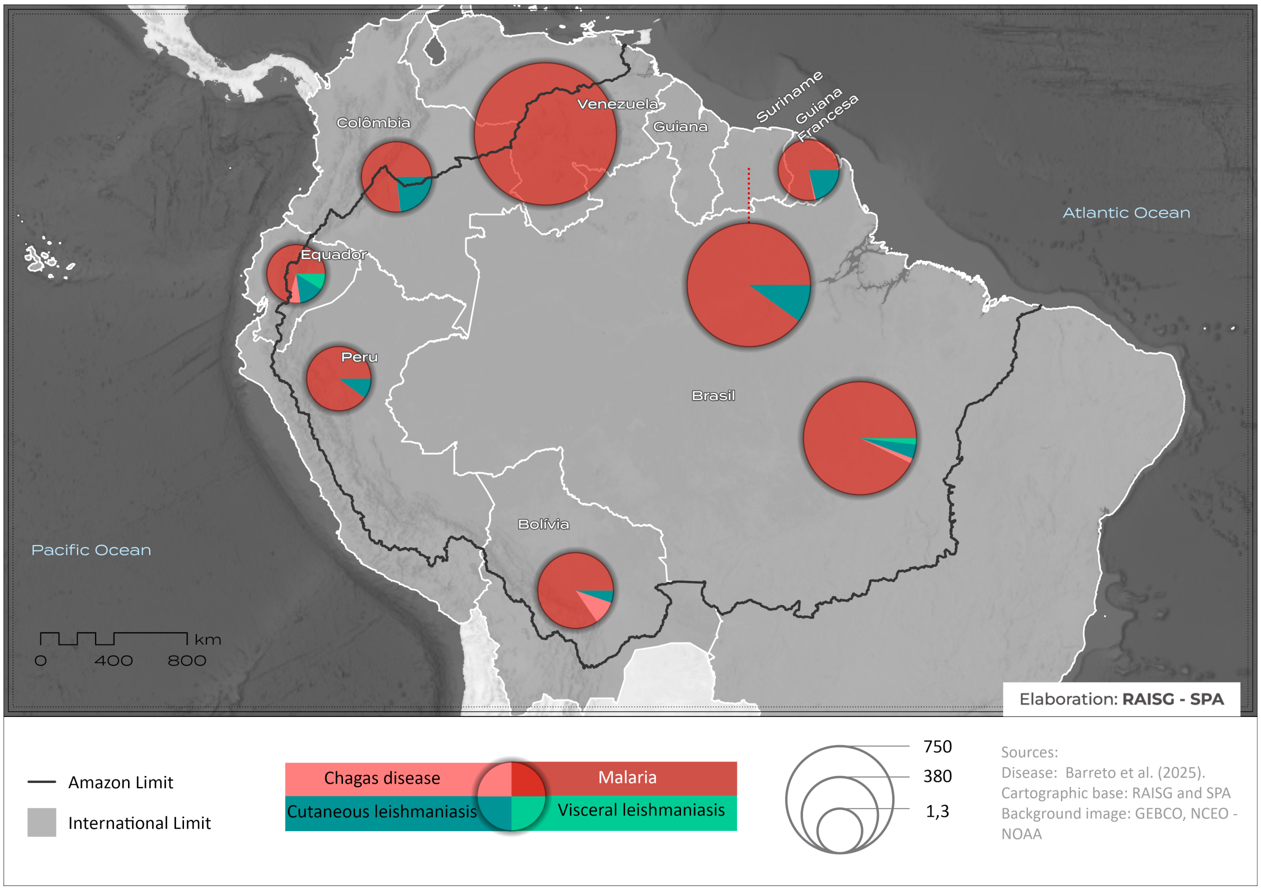

Figure C3.9.1. Total average incidence for the Amazon biome between 2001 and 2019 for Chagas disease, cutaneous leishmaniasis, visceral leishmaniasis, and malaria[1]. Incidence is given in number of cases per 100,000 people. CO=Colombia, EC=Ecuador, etc.

The Facts

- Between 1985 and 2023, 88 million ha of Amazon forest were lost. Legal and illegal mining expanded by 1,063%, agriculture by 598%, and cattle ranching by 298%[4].
- Between 2001 and 2019, the interface of forest with transformed landscapes increased by 230%, and 923,784 km² of the Amazon biome burned[5].
- Between 2001 and 2019, 28,429,422 cases of fire-related zoonotic and vector-borne diseases were reported in the Amazon region (**Figure C3.9.1**)[5].
- Every 1 km² of the Amazon deforested generates 27 new malaria cases in humans[6].
- Every hectare of the Amazon burned generates a cost of USD 2 million in health costs alone and can lead to 18,240 new disease cases[1].
- Economic losses from disability-adjusted life years from mercury contamination due to artisanal small-scale gold mining in the Amazon (**Figure C3.9.2**) range from USD 100,000 to 400,000 per kilogram of gold extracted[7].

Global/Regional and Synergistic Connections

- Global markets of beef and soybean drive most Amazon deforestation[8].
- 20% of the malaria risk due to Amazon deforestation is explained by the international trade in goods[6].
- The toxic haze produced by forest fires can harm the health of populations far from the fire source, having a transboundary negative effect[1].
- Transnational gold trade networks, which combine legal and illegal actors, have particularly destructive impacts on human communities, especially Indigenous Peoples and Local Communities. For example, in the Caura River Basin, in Venezuela, 92% of Indigenous women had elevated mercury levels in their bodies.

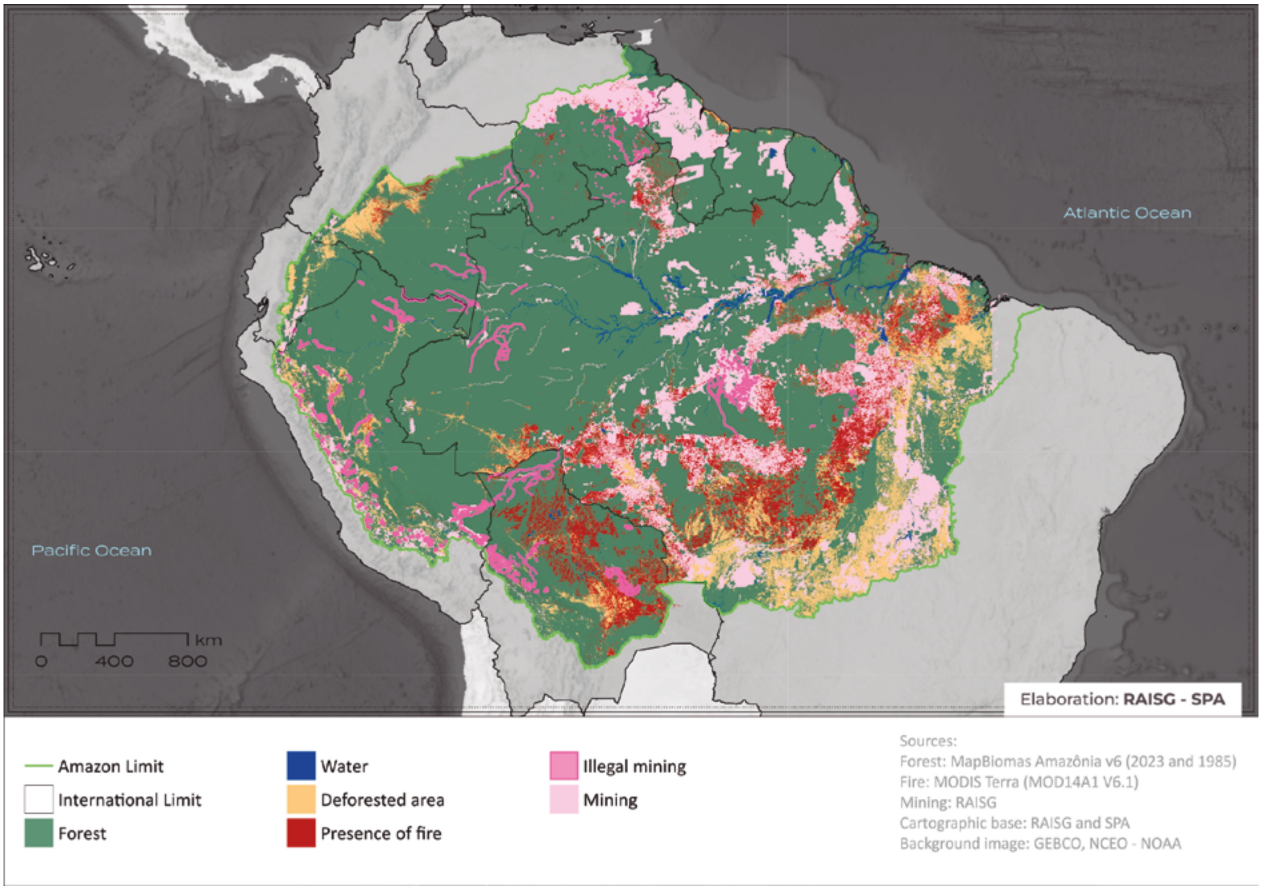

Figure C3.9.2. **Spatial extent of threats to Amazonian ecosystems:** forest loss, fires, and mining.

The Solutions Space

Selected Key Tools

- **The Information System on Wildlife Health (SISS-Geo) by Fundação Oswaldo Cruz (Fiocruz)** is a free online tool for monitoring the health of wild animals in natural, rural, and urban environments. This citizen-science tool increases collaboration in the investigation of infectious agents and supports public health agencies.

Collaborative Efforts

- **The One Health International Network (OHLAIC)** fosters collaboration among experts from over 20 Latin American nations regarding environmental, animal, and human health.

Major Recent Governmental Efforts

- **Countries in the Amazon region are reviewing National Biodiversity Strategies and Action Plans (NBSAPs) and National Adaptation Plans (NAPs)**—tools developed under global environmental frameworks—to incorporate health outcomes, creating synergistic benefits for both environmental conservation and public health, and recognizing the interconnectedness of biodiversity, ecosystems, and human health.

- **The National Plan for Malaria Elimination in Brazil** aims to reduce malaria cases below 68,000 by 2025 and to eliminate malaria in Brazil by 2035. This plan works through the Brazilian Unified Health System and supports decentralized diagnosis and treatment, enhanced surveillance systems, and multisectoral collaboration.

Positive Efforts for Scaling

- **The Malaria Potential Assessment** (Ordinance No. 01/2014 Ministério da Saúde [MS]/ Secretaria de Vigilância em Saúde [SVS], 2014), which under Brazilian legislation is requested during environmental licensing processes in malaria-endemic regions, is a good example of One Health legislation that integrates public health into environmental decisions. The findings of this assessment serve as the basis for the Malaria Control Action Plan (PACM), which in turn is necessary for issuing the project's Health Condition Certificate (ATCS), required in the environmental impact assessment.

- **In French Guiana, the Health and Environment Regional Action Plan 2024–2028 (PRSE)** identified, among 24 other actions, the study, control, and mitigation of leptospirosis as a key health priority.

- **In the state of São Paulo, Brazil, a joint Resolution** from the Secretariat for the Environment, Infrastructure and Logistics (SEMIL) and the former São Paulo State Superintendency for Endemic Disease Control (SUCEN) from the State Health Secretariat (SES) **made conducting an epidemiological assessment of Brazilian spotted fever vulnerability in endemic areas mandatory** during the licensing process for real estate and housing developments. This is a good example of collaborative work between the environmental and health sectors to prevent increased risk of this disease.

- **The Atlantic Forest Restoration Pact (PACTO) in Brazil**, a national movement created in 2009, coordinates and integrates public and private actors with the goal of restoring 15 million hectares in the Brazilian Atlantic Forest by 2050. This would have co-benefits for human health: for example, restoring 6 million ha could reduce the abundance of rodents that transmit hantavirus by benefiting more than 2.8 million people. Restoration efforts in the Amazon could have similar effects.

- **Toolkits for self-diagnosis and self-medicating for malaria** have been developed, helping to reduce malaria incidence in remote regions of the Amazon.

Recommendations

- **Recognize** forest management, conservation, and restoration as components of **preventive health** care to mobilize the health sector to actively support conservation efforts.

- **Increase collaboration among sectors** and disciplines and break down the silos among different policies and countries to better prepare for and minimize zoonotic spillover risks.

- **Integrate public health indicators into countries' NBSAPs**, and use the Kunming-Montreal Global Biodiversity Framework (GBF) indicators to measure the impacts of conservation efforts on public health.

- **Harness legal mechanisms to halt both legal and illegal deforestation:** this is key to avoiding human-wildlife interactions and reducing spillover risks. Employ demand-side initiatives such as product labeling and certification and green procurement standards to address trade-related global environmental issues2.

- **Enforce the control and mitigation of more cryptic (although devastating) illegal and informal activities**—especially mining—to (i) prevent zoonotic spillover and (ii) reduce cumulative effects of mercury poisoning (e.g., neurocognitive and neuromotor impairments and increased cardiovascular and metabolic risk) that add to the population's vulnerability.

- Forest restoration, the creation of protected areas and the recognition of Indigenous Territories **can be seen as ecological countermeasures to reduce spillover risks** and protect human health. Landscape management plans integrating public health outcomes can also be important in the creation of healthy landscapes, especially to avoid negative effects of restoration on disease risk.

Key Recent Literature

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Mobilize Public Health Systems to Address the Growing Threats of Tropical Diseases

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The biting midge Culicoides paraensis is considered the primary vector of the Oropouche virus in Brazil. Until 2023, this virus was endemic to the Amazon region, with only sporadic cases reported. However, starting in 2024, there was a significant spread of cases across the country, including urban areas where the virus had never been previously recorded. Source: Royalty-free image obtained from Freepik.

The Overview

Central and South America are recognized as hot spots for emerging and re-emerging vector-borne and zoonotic diseases. The region has seen frequent outbreaks of infectious diseases, some of which—like Zika and chikungunya—have escalated into major public health concerns. More recently, the Oropouche and Mayaro viruses have drawn increasing attention. These pathogens can evolve, gain resistance, and spark new outbreaks. Climate change and extreme weather further exacerbate risks by disrupting ecosystems and altering vector dynamics. Additionally, deforestation increases the likelihood of spillover events and enables viruses to invade rural and urban areas, by destroying the natural environments of both vectors and reservoirs. Effective control of arboviral diseases relies on coordination, data integration, strong health systems, and rapid action in high-risk environments.

The Facts

- Over the past century, around 200 different viral species have been identified in mammals (including humans) and mosquitoes in the Brazilian Amazon.
- Since the beginning of 2024, approximately 26,000 cases of Oropouche virus have been reported across 12 countries in the Americas, with Brazil, Cuba, Panama, and Peru accounting for the majority.
- In 2025, the Amazon region reported a sharp increase in Mayaro fever cases, particularly in the state of Acre, Brazil, where the number of cases rose by 175% compared to the same period in 2024.

Global/Regional and Synergistic Connections

- Global connectivity through air travel underscores the significant potential for pathogen translocation.
- Regarding Oropouche fever, travel-related imported cases were reported in many countries, such as the USA, Canada, and Europe. In 2024, the virus was detected in urban and rural areas where no transmission had previously been reported.

The Solutions Space

Selected Key Tools

- **Program for Monitoring Emerging Diseases (ProMED):** Established in 1994, the ProMED initiative plays a key role in the early detection of health threats. It is an internet-based platform that relies on expert review and draws from both formal and informal sources to monitor emerging infectious diseases. ProMED is designed to supplement, rather than replace, existing disease surveillance systems.

- **The Project Wolbachia-Singapore**, led by the National Environment Agency (NEA), is a national initiative aimed at reducing dengue transmission by controlling populations of *Aedes aegypti*, the primary mosquito vector. The program involves the large-scale release of male mosquitoes infected with the naturally occurring bacterium *Wolbachia*, which prevents their offspring from developing when they mate with wild females, thus reducing mosquito populations over time. This innovative, environmentally friendly approach has demonstrated significant reductions in dengue incidence in treated areas and serves as a model for sustainable vector control strategies that could be adapted in other countries facing similar arboviral challenges.

Collaborative Efforts

- **The World Health Organization's Global Arbovirus Initiative** (launched in 2022) aims to strengthen global preparedness and response to arboviral diseases such as dengue, Zika, chikungunya, and yellow fever. The program focuses on enhancing surveillance systems, vector monitoring, diagnostic and vaccine development, and international cooperation to reduce the public health and socioeconomic impact of these emerging diseases. By promoting coordinated actions and data sharing among countries, the initiative seeks to build a more resilient and integrated global response framework for arbovirus prevention and control.

- Efforts to halt deforestation are key to reducing the risk of zoonotic diseases. For example, the **Amazon Region Protected Areas Program (ARPA)** led by the Brazilian government in partnership with international donors and nongovernmental organizations, supports the creation, expansion, and long-term management of Protected Areas in the Brazilian Amazon. Covering over 60 million hectares, the program helps safeguard biodiversity, support traditional communities, and reduce deforestation through sustainable development and conservation efforts.

Major Recent Governmental Efforts

- In December 2023, Brazil's Ministry of Health established a **National Arbovirus Room** to track a potential rise in cases. That same month, a fund of USD 50 million was allocated to support states and municipalities in implementing contingency measures for disease surveillance and prevention, with a strong focus on combating arboviruses.

- **The development of interactive panels** and dashboards focused on the epidemiological surveillance of major circulating arboviruses in Brazil enhances real-time understanding of disease spread. It also promotes data transparency on cases and deaths, which is essential for decision-makers and public officials.

Positive Efforts for Scaling

- An **Integrated Surveillance with Technology (VITEC) system** was developed in Foz do Iguaçu, Brazil. Designed for public health use, it integrates entomological and epidemiological data into a single platform to support the management of vector-borne diseases and zoonoses. The tool helps guide prevention and control efforts based on transmission risk scenarios.

Recommendations

- **Engage in joint decision-making** across all levels of management, which is essential to address the growing challenge of arboviral diseases and to strengthen Brazil's Unified Health System (SUS).

- **Integrate real-time data** and scientific knowledge to enhance hazard surveillance and the prevention of arboviral diseases.

- **Conduct risk assessments** for national and cross-border hazards.

- **Strengthen the primary care network** and laboratories to ensure rapid and accessible testing for arboviruses in local health centers.

- **Monitor and respond to environmental changes**, establishing protocols for rapid action in recently deforested or degraded areas, where there is a greater risk of spillover.

Figure C3.10.1. **Deforestation is a major driver of viral spread and epidemic emergence.** As humans encroach on wild habitats, they become more exposed to zoonotic risks and may serve as accidental hosts in arbovirus cycles. Photo credit: Marizilda Cruppe / Amazonia Real

Key Recent Literature

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Avoid a Pandemic from the Amazon

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Photo credit: Raphael Alves / Amazonia Real

The Overview

About 75% of emerging infectious diseases (EIDs)—new infectious diseases or those that are increasing in incidence—are caused by pathogens that "spill over" from animals into people (zoonotic pathogens)1. EID events have risen since the 1940s and are projected to increase several-fold in the coming decades[2,3]. Environmental degradation is a major driver of EIDs[2]. Key pathways for spillover include deforestation, wildlife hunting and trade, and intensive livestock farming near natural areas[4,5,6]. Preventing pandemics requires tackling these risks, especially in the Amazon's deforestation frontiers.

The Facts

- Many viruses identified in wild mammals of the Amazon Basin show pandemic potential, and its forests are thought to harbor the largest number of undiscovered viruses worldwide[7,8].

- Viral spillover risk increases when deforestation exceeds 25%, a threshold surpassed in most of the Amazon's Arc of Deforestation[9,10].

- The Brazilian Amazon, for example, has nearly four cattle per person, and livestock often serve as intermediary hosts for EIDs[11,12].

- Wildlife meat consumption in central Amazon cities is comparable to timber in monetary value, being driven more by culture than nutritional need[13,14].

- The Amazon's wildlife trade is intense, driving a multimillion-dollar (USD) global industry[15].

- Investing in pandemic prevention costs less than one-twentieth of yearly losses from EIDs[4].

Global/Regional and Synergistic Connections

- An EID originating from the Amazon could spread globally because of increased human mobility, as seen with the Oropouche virus[7,16]. Cities like Belém and Manaus have direct flights to Portugal, the United States, Panama, Colombia, and Venezuela[17].

- International demand, particularly from China and Europe, contributes to deforestation in the Amazon, which is a key pathway for zoonotic spillover. In 2024, exports made up 32% of Brazil's meat, 64% of soy, and 31.7% of timber production, contributing 19.7% of the country's gross domestic product (GDP)[18,19,20].

- Wildlife trade in the Amazon is driven by international demand from the pet and fashion industries and online markets in the United States, Europe, and Asia, fueling the capture and export of thousands of live birds, mammals, and their parts a year[21,22,23].

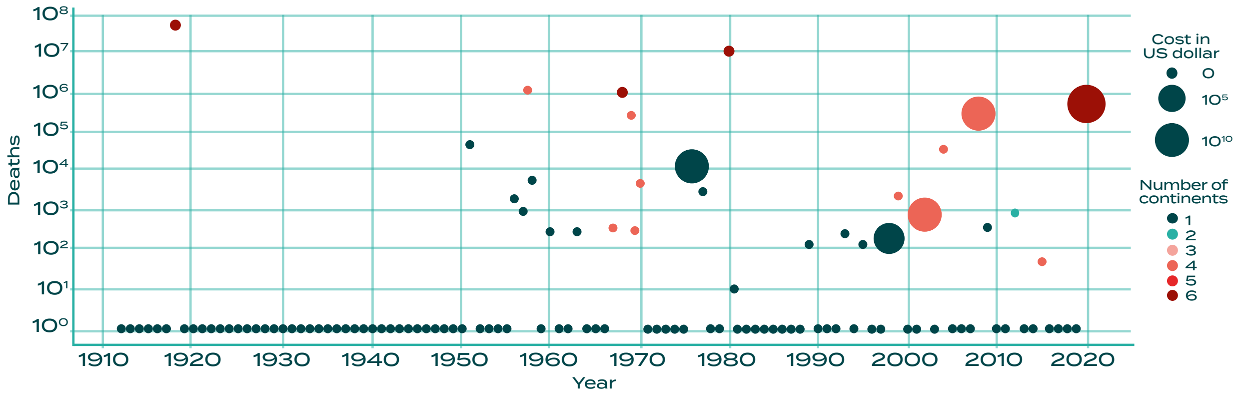

Figure C3.11.1. Human deaths per year from novel zoonotic viral outbreaks since 1912. The size of the symbol shows economic costs for just the five cases for which estimates were available. Note that the number of outbreaks has increased dramatically over time. Source: Adapted from Bernstein et al., 2022. We acknowledge Dr. Aaron Bernstein from the Boston Children's Hospital and the Center for Climate, Health, and the Global Environment for granting permission to use the figure [4].

Figure C3.11.2. Seizure of illegally hunted wild meat in 2015 in Manacapuru, Amazonas state, Brazil. Contact with wildlife fluids is a major source of viral spillover. Agents were likely untrained, handling the meat without personal protective equipment. Photo credit: BPMA/AM, ((o))Eco.

The Solutions Space

Selected Key Tools

- **Deforestation Detection System.** DETER is a deforestation alert system for the Brazilian Amazon based on satellite imagery and has been in operation since 2004. It supports enforcement by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), enabling a quick response and preventing deforestation from spreading. Other Amazonian countries have similar systems for detecting land use change, such as Geobosques in Peru, the Sistema de Monitoreo de Bosques y Carbono (SMByC) in Colombia, and the Sistema de Información y Monitoreo de Bosques (SIMB) in Bolivia.

- **MapBiomas Amazonia.** A collaborative initiative in operation since 2017 to generate annual land-cover and land-use maps. The project supports research, policy, and civil society initiatives with reliable data on land-use dynamics across all Amazonian countries.

- **Wildlife Trafficking Observatory.** Interactive dashboard with data on wildlife seizures in Brazil, compiled from news reports and digital media covering efforts to combat wildlife trafficking and illegal fishing.

- **Amazônia in Loco.** Digital platform with interactive maps and visualizations of over 80 socioeconomic and environmental indicators from 25 public databases to support decision-making and promote responsible, sustainable investments across the 772 municipalities of the Brazilian Amazon.

Collaborative Efforts

- **Community-designed solutions** to deforestation, implemented with support from the non-profit Health in Harmony, deliver essential medical services (e.g., vaccinations) to rainforest communities while protecting millions of hectares of forest in the Brazilian Amazon.

Major Recent Governmental Efforts

- Brazil's **Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm)**, launched in 2004, has reduced deforestation by 70% while the GDP of Amazon states grew by 140% from 2004 to 2012[24]. Its effectiveness, however, relies on strong federal political will, as reflected in the varying outcomes since 2012.

- Brazil is developing its **Action Plan for the Prevention and Combat of Wildlife Crimes** (PACIfauna), aimed at tackling environmental offenses.

- Brazil is also leading international efforts to include a new protocol under the United Nations Convention **Against Transnational Organized Crime** (UNTOC) to help close major gaps in international legislation related to deforestation, hunting, and the trafficking of wild species.

Positive Efforts for Scaling

- The **Fiocruz Genomic Network** is a Brazilian initiative for the surveillance of viruses. To enhance its role in spillover prevention, it should prioritize surveillance of viruses in wildlife with pandemic potential already recorded in the Amazon.

Recommendations

- **Strengthen, expand, and adapt PPCDAm** to the different regional realities to ensure effective monitoring and control of deforestation across Amazonian countries.

- **Develop national strategies on wildlife crimes** to strengthen wildlife crime legislation, hire agents, create national databases, and raise awareness of the dangers of eating wild meat and keeping wild pets.

- **Keep domestic animals away** from the forest edge, and bolster veterinary capacity to help farmers keep their livestock healthy.

- **Establish multisectoral surveillance** to detect pathogen threats in people, domestic animals, wildlife, and the broader environment.

- **Invest in the health and economic security of communities** living in and near the Amazon.

- **Develop an Amazon-wide database** of genomics and serology for viruses circulating in mammals and birds.

Key Recent Literature

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Strengthen Wildlife Health Surveillance Systems for Early Warnings and Disease Prevention

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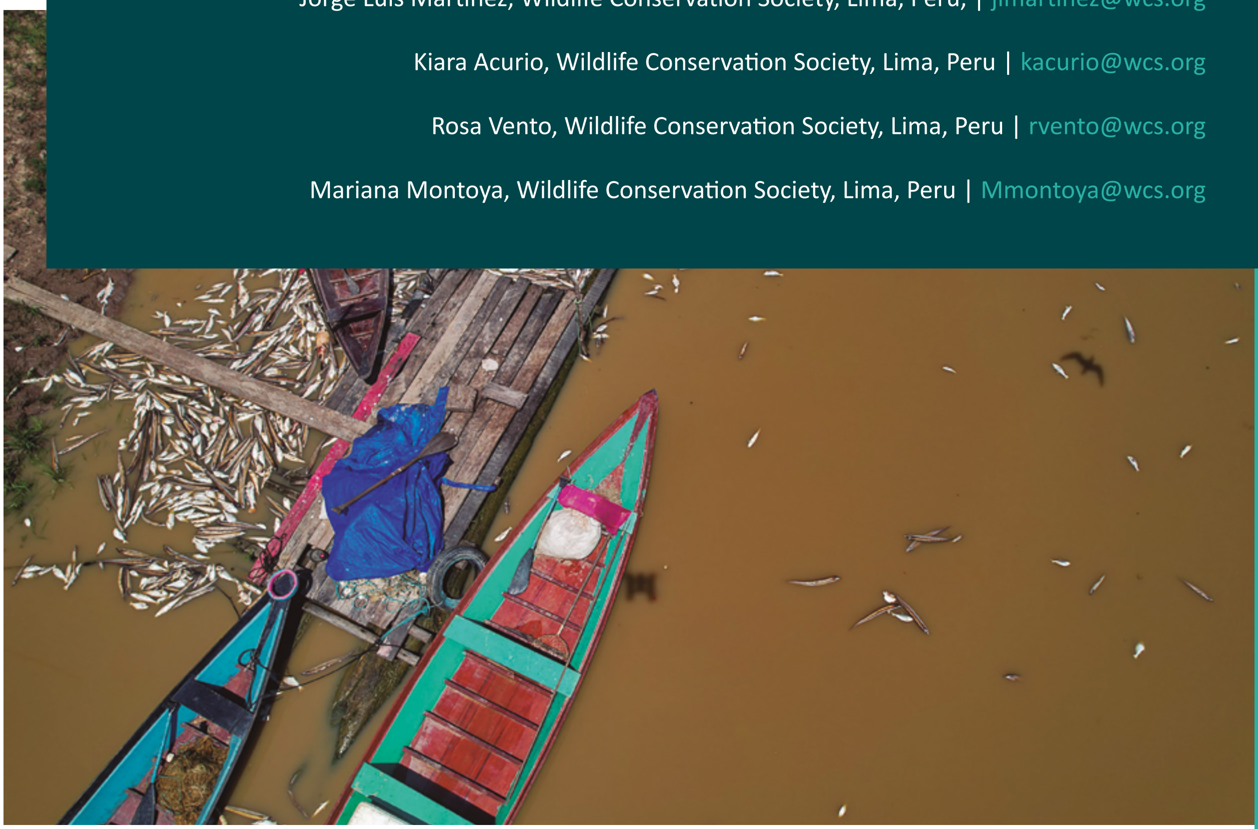

Photo credit: Alberto César Araújo / Amazonia Real

The Overview

Land-use change, inadequate infrastructure, wildlife traffic, and climate change degrade ecosystems in the Amazon and promote contact between people and wildlife, fostering disease outbreaks and exposure to pollutants that affect public health, food security, biodiversity, and the economy. Wildlife health surveillance provides early warning of diseases to enable prevention, and protection of human and animal health, but its implementation remains limited due to lack of information, collaboration, and resources[1].

The Facts

- The PREDICT project (2009–2014) - funded by the Emerging Pandemic Threats program of the United States Agency for International Development (USAID) - identified 815 new viruses in wildlife in high-risk areas (Gilardi and Mazet, 2018). An estimated 1.7 million unknown viruses exist, half of which may pose a risk to humans[2].

- In Brazil (2017–2018), 732 confirmed cases of yellow fever were recorded in non-human primates, allowing for geographic monitoring of the disease and the implementation of control and prevention measures in humans[3].

- In the Peruvian Amazon, wild birds have shown evidence of high exposure to mercury, highlighting the toxic impact of illegal mining on ecosystems[4].

Global/Regional and Synergistic Connections

- Between 1940 and 2004, 34% of emerging zoonotic diseases were related to land-use change and bushmeat consumption[5].

- The outbreak of new wildlife-related diseases, such as COVID-19, can have global, regional, and local impacts.

- High and intact biological diversity contributes to reducing disease transmission; for example, hantavirus infection prevalence in host species increases in ecosystems with lower diversity[6].

- Global climate change favors the redistribution of vectors, alters animal physiology, and increases susceptibility to disease. These phenomena are exacerbated in fragmented and polluted ecosystems.

Figure C3.12.1. Bat sampling. Wildlife health surveillance can help us understand the dangers and risks associated with wildlife such as bats. Photo credit: Andre Baertschi © WCS.

Figure C3.12.2. Baby woolly monkey (Lagothrix sp.)—a victim of illegal wildlife trafficking. Illegal trafficking increases interactions between humans and animals, promoting the outbreak and cross-species spread of diseases. Photo credit: Musuk Nolte © WCS.

The Solutions Space

Collaborative Efforts

- **The quadripartite One Health partnership (FAO, UNEP, WHO, WOAH)** advances multisectoral collaboration and capacity building to address health risks at the human–animal–environment interface, with actions relevant to wildlife health surveillance.

- **The World Health Organization (WHO) Wildlife Health Framework** supports risk management, early warning, and surveillance of wildlife diseases as part of One Health approaches (WHO, 2022).

- **The Pan American Health Organization (PAHO) One Health policy** promotes regional cooperation and technical support to countries for improving disease surveillance.

Major Recent Government Efforts

- In Peru, in 2022, during an outbreak of highly pathogenic avian influenza, a **temporary multisectoral working group on avian influenza** was created, enabling the integration of the health, agriculture, production, and environmental sectors for multisectoral surveillance and response to the outbreak.

- In Peru, in 2023, **a national prioritization of zoonotic diseases** was carried out with the participation of all sectors and civil society, to develop multisectoral surveillance of rabies, avian influenza, echinococcosis, yellow fever, and leptospirosis.

- Since 2014, Brazil has been working to strengthen zoonotic disease surveillance through **Fiocruz's Institutional Platform for Biodiversity and Wildlife Health**, a strategy that combines science, technology, and civil society participation to support the National Health Surveillance System (SNVS) and biodiversity conservation.

Positive Efforts for Scaling

- Since 2022, Peru's National Service of State-Protected Natural Areas (SERNANP) has incorporated into its surveillance system **procedures to record unusual wildlife mortality and disease events** for early warning and coordination with the human and animal health sectors.

- Through **the initiative WildHealthNet**, the Wildlife Conservation Society promotes the implementation of national wildlife health surveillance systems through training, technology, and inter-institutional collaboration and coordination.

Recommendations

- **Promote and consolidate multisectoral cooperation opportunitie**s at different levels of government to coordinate disease prevention and response actions, integrating wildlife health surveillance into existing systems.
- **Incorporate wildlife health surveillance as a key component of wildlife management.**
- **Generate basic information on health events in wildlife** based on case reports in the Amazon by creating participatory health surveillance networks and establishing formal reporting chains between interested local parties and health authorities.
- **Promote research on risk analyses** that support identification of preventive measures and informed decision-making.
- **Collaborate with academic institutions to develop validated tests** to identify pathogens and contaminants from animal samples. **Promote the development of diagnostic capacity** in local and regional scientific institutions.
- **Invest in training programs** for local actors based on their roles and functions, from event collection and reporting to data analysis for interested local parties (e.g., park rangers, communities, health care workers).
- **Share information** with neighboring countries and international bodies to improve understanding of epidemiological dynamics and develop appropriate responses.

Key Recent Literature

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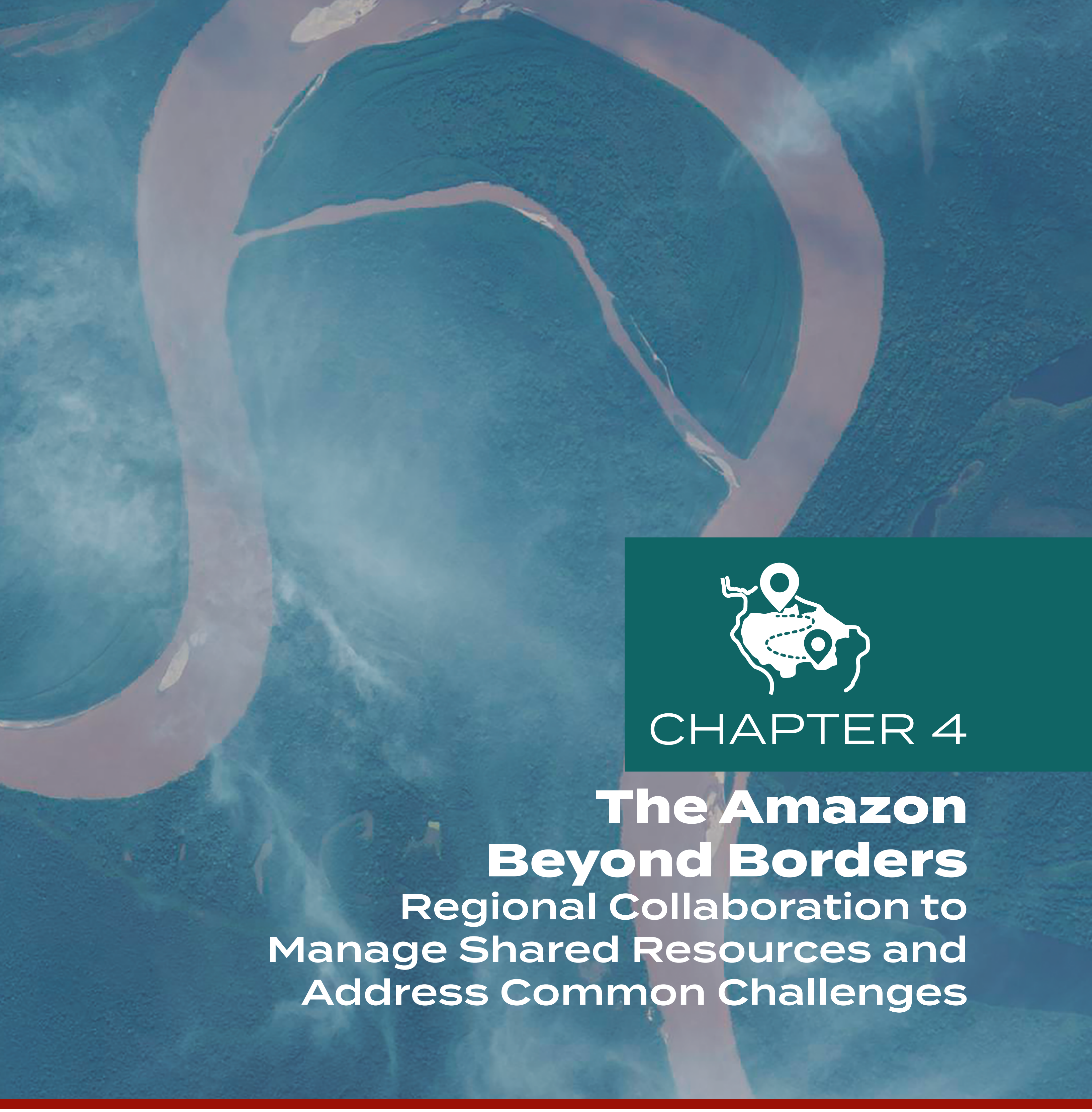

CHAPTER 4

The Amazon Beyond Borders

Regional Collaboration to Manage Shared Resources and Address Common Challenges

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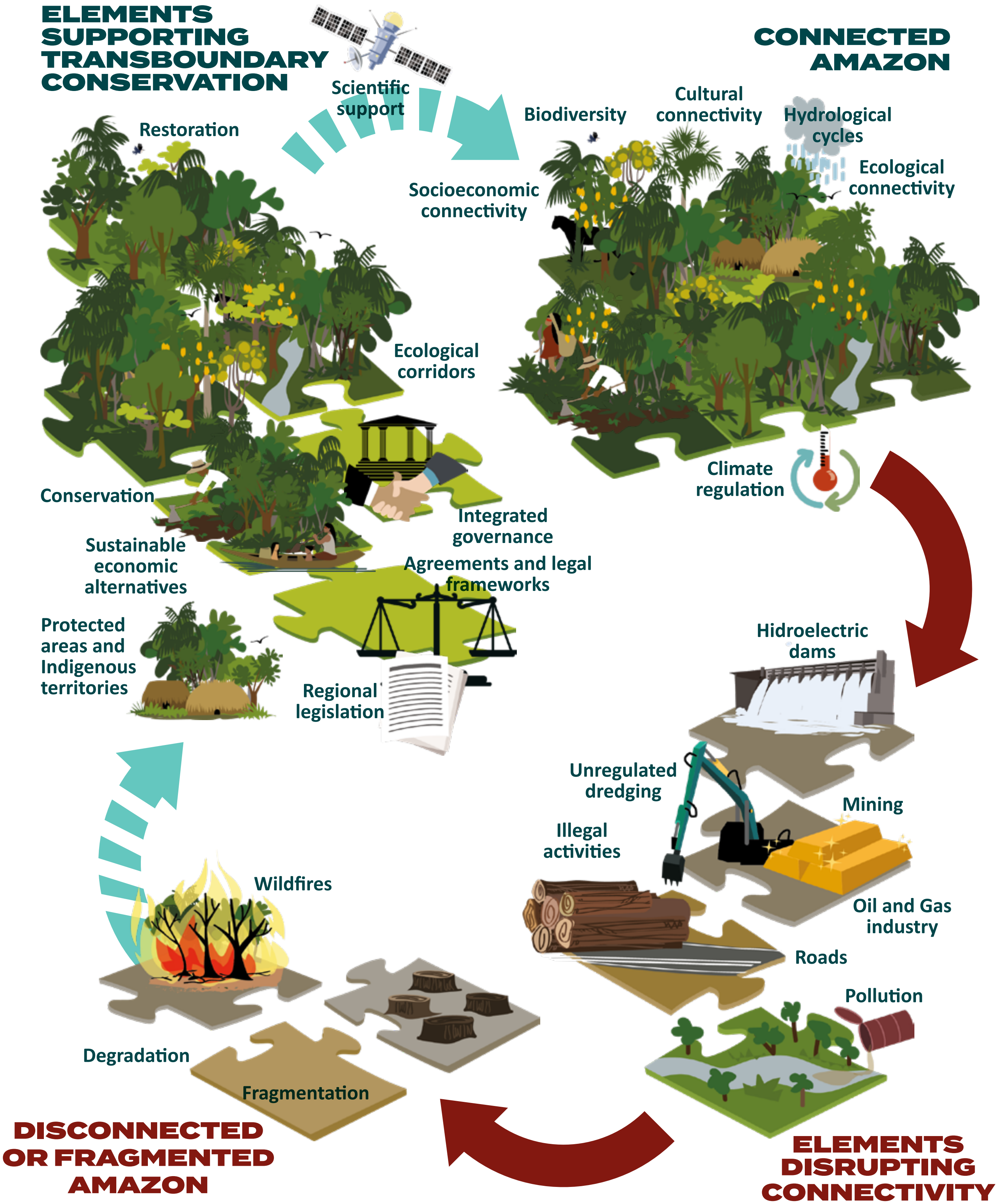
Abstract

The Amazon Basin spans eight countries and one overseas territory, encompassing over 100 subnational political units, each with unique historical trajectories, cultural heritage, and ecological characteristics. This chapter examines the ecological, hydrological, and socio-cultural dimensions of connectivity, providing a framework for evaluating the environmental health and resilience of the region and its inhabitants, while evidencing key measures for improvement. Conservation approaches that recognize all three dimensions are essential. For example, Protected Areas (PAs) remain a key conservation approach, yet their effectiveness depends on integration with surrounding landscapes. Here, we focus on transboundary conservation, which requires cooperation across national and international boundaries, including the sharing of information, communication, consultation, coordinated action, and joint decision implementation. Transboundary governance is essential for managing shared resources such as water bodies and protected area corridors in this complex context of competing goals and multi-scale interactions. Despite complex challenges, transboundary conservation offers a path to address unsustainable practices, strengthen ecological resilience, and support vulnerable communities. Its success, however, depends on inclusive approaches that consider Indigenous and local monitoring, as well as equitable data sharing. However, governance capacity in the Amazon region, as well as efforts towards concerted territorial planning and coordinated data systems, remain insufficient. As stated in the Belém Declaration, transboundary governance in the Amazon must consider both Indigenous and Afrodescendant Peoples and Local Communities (hereafter IPs & LCs) and institutional environmental governance. Transboundary conservation presents numerous opportunities for cross-border governance and regional cooperation, empowering IPs & LCs, improving socioenvironmental conditions, and promoting science-based conservation and monitoring. Transboundary conservation is more necessary than ever, requiring joint governance grounded in respect for national sovereignty and guided by an integrated vision that connects PAs, Indigenous Territories, and productive landscapes, ensuring the functional continuity of this vital ecosystem for the planet.

Keywords:

Drivers of change, transboundary conservation, environmental connectivity, regional governance, monitoring.



Graphical Abstract. Transformations of the ecological, hydrological and sociocultural connectivity of the Amazon with the elements that disrupt, maintain or restore the various dimensions of connectivity. (1) A connected, healthy landscape that supports nature and people; (2) Weakening of connectivity by a diversity of drivers; (3) A degraded landscape emerges, marked by fires and deforestation; (4) Transboundary conservation and restoration help reestablishing connectivity, though full reconnection remains incomplete.

1. Introduction

Due to climate change, deforestation, land degradation, wildfires, and water stress, some parts of the Amazon Basin are approaching a tipping point that threatens the maintenance of large-scale forest ecosystems and undermines the well-being, livelihoods, and knowledge systems of Amazonians, including Indigenous Peoples (IPs) and Local Communities (LCs)[1,2]. IPs & LCs have already raised concerns, reporting declining fisheries and altered rainfall cycles as early warning signals of accelerating environmental change.

Scaling up practical, concerted actions to protect and restore terrestrial and freshwater ecosystems is crucial to addressing the rising and interwoven threats to ecosystems and people. The 2021 Amazon Assessment Report[3] highlights the Amazon Basin's crucial role in the global and regional climate regulation, carbon cycle, regional water security (see Chapter 1), biodiversity, and socio-cultural diversity. It emphasizes the urgent need for transboundary conservation to maintain ecological and biocultural connectivity across borders, especially as deforestation surpasses 18% of the Amazon region[3], degradation reaches 38%[4], and given the strong interdependence between Amazonian ecosystems and the regional climate system. The need for solutions considering the Amazon's complex and irreplaceable biocultural diversity and its connectivity for ecosystem resilience is urgent.

According to the International Union for Conservation of Nature[5], transboundary conservation is defined as 'a process of cooperation to achieve conservation goals across one or more international boundaries. It proposes three types of international cooperation for Protected Areas (PAs) across borders: Transboundary Protected Areas - clearly defined geographical spaces; Transboundary Conservation Landscape and/or Seascape - an ecologically connected area that includes both protected areas and multiple resource use (e.g., integrated management of watersheds shared by multiple countries in the Amazon); and Transboundary Migration Conservation Areas - wildlife habitats that span two or more countries and are necessary to sustaining migratory species' populations. All transboundary conservation requires cooperation across international boundaries, involving various forms of collaboration, including the sharing of information, communication, consultation, coordinated action, and joint decision implementation.

The Global Biodiversity Framework (GBF) under the Convention on Biological Diversity proposes a target to conserve

30% of the planet's land area by prioritizing biodiversity-rich areas by 2030[6]. The GBF explicitly recognizes and promotes the conservation of Indigenous and traditional territories as a vital component of its goals, supporting their land and resource rights, as well as conservation strategies that ensure their full and effective participation in decision-making processes. In 2021, the Coordinator of Indigenous Organizations of the Amazon Basin (COICA) and its national associated organizations in the Amazon countries, in collaboration with a coalition of organizations, launched the initiative "Amazonia for Life: Protect 80% by 2025"[7], a motion approved by the 2021 International Union for Conservation of Nature (IUCN) World Conservation Congress. In 2025, IUCN approved Motion 068 for urgent action to protect and restore the Amazon by 2030.

Implementing this resolution from a transboundary conservation perspective, particularly in the Amazon region, implies reducing physical (e.g., infrastructure, deforestation, and fragmentation) and non-physical (e.g., contrasting conservation policies and socio-political pressures) barriers, as well as managing climate change adaptation. The effectiveness of the global network of PAs is increasingly threatened by climate-related potential transboundary range shifts. Globally, under a 2°C warming scenario, 24% of protected lands would face climate change impacts[8], meaning that in the current climate conditions, nearly one-quarter of these areas are expected to change in the near future. Given these pressing present and future challenges, fast and robust coordinated initiatives are needed to ensure ecological and social connectivity.

In this chapter, we discuss the importance of transboundary conservation and governance in the Amazon, advocating for a regional approach to manage shared resources, addressing opportunities and threats that transcend political borders, such as deforestation, degradation, wildfires, terrestrial and aquatic fragmentation, pollution, illegal activities, overexploitation, territorial conflicts, rural violence, and climate change.

2. Ecological, Hydrological, and Socio-Cultural Connectivity of the Amazon

Amazon's connectivity can be assessed through multiple interdependent dimensions. This chapter will focus on the ecological, hydrological, and socio-cultural dimensions. Together, they provide a holistic framework to evaluate the environmental health and resilience of the region and its inhabitants, while identifying areas most vulnerable to environmental and anthropogenic disturbances. Despite ongoing conservation efforts, the Amazon continues to suffer increasing fragmentation and degradation of its terrestrial and aquatic ecosystems - much of which is driven by illegal activities (see Chapter 2) - due to deforestation, human-caused fires, expansion of agro-industrial frontiers, mining, infrastructure development, and poorly coordinated policy decisions across countries[1,9–10], which further disrupt transboundary connectivity.

These pressures not only alter land cover, as widely monitored by satellite imagery, but also lead to deeper, less visible disruptions: the erosion of ecological connectivity[11,12]. The ill use of natural resources across national borders has direct impacts on downstream aquatic systems, disrupts species flows, affects ecosystem services, and endangers the integrity of IPs & LCs' territories[1]. This progressive disconnection compromises Amazon's resilience and capacity to adapt to global environmental changes[1].

2.1. Ecological Connectivity

Ecological connectivity refers to the extent to which lands capes enable the movement and interaction of species, energy, water, and ecological processes across ecosystems[13,14]. In recent decades, the Amazon region has undergone a rapid decline in ecological connectivity. Between 1985 and 2023, the area classified as ecologically disconnected more than doubled[15]. Currently, approximately 193 million ha, equivalent to about 23% of the Amazon region, are considered ecologically disconnected, with an additional 13% exhibiting severely reduced connectivity (Figure 4.1A and B). This is due to the fact that for every hectare of forest lost, another 0.4 ha becomes isolated, and 0.8 ha undergoes functional degradation[15]. This diminishes the movement of species, gene flow, seed dispersal, and other critical processes that enable ecosystems to adapt to climate change and continue delivering ecosystem services[1].

Protected Areas (PAs) cover 25.5% of the Amazon Basin and Indigenous Territories (ITs) cover approximately 28.5%, with 82% officially recognized, 11% lacking legal protection, and 7% classified as Indigenous lands (proposed or existing) or intangible zones[16]. Protected Areas remain key conservation tools, yet their effectiveness depends on their integration with surrounding landscapes, including ITs, collective lands, and undesignated public forests that function as de facto corridors - pathways that allows wildlife to move between fragmented habitats, but which is not formally designated corridor. Undesignated lands are highly vulnerable to deforestation and forest degradation[17], and the network of PAs could be expanded by legally designating public lands as PAs or sustainable use conservation areas. Conservation strategies limited to isolated "islands" of protection are insufficient[18,19] to adequately safeguard key ecological processes, such as those previously described.

For example, parks such as Tinigua and La Macarena in Colombia serve as critical connectors between the Andean and Amazon biomes. However, escalating deforestation and illegal activities are rapidly fragmenting this corridor (Figure 4.2A). Similarly, in Maranhão (eastern Amazon, Brazil), ITs represent some of the last functioning ecological corridors, but are increasingly encircled by agricultural lands, grasslands, and urban expansion (Figure 4.2B). With the diminishing availability of resources for their traditional livelihoods and the lack of sustainable income-generating alternatives that can sustain forests standing, some IPs & LCs may be drawn into illegal economies, deepening environmental and social vulnerabilities[11,20–22] (see Chapter 2).

2.2. Hydrological Connectivity

The Amazon Basin is the world's largest river basin and contains the planet's most extensive network of free-flowing rivers, with over 1,000 tributaries that sustain biodiversity and underpin countless communities' livelihoods and cultural identity[23]. However, the cumulative impacts of existing and proposed dams, dredging projects, and channel modifications increasingly threaten the integrity of this system (Figure 4.1C), especially when decisions are taken unilaterally at the national scale, indicating that collective actions among countries and states are needed[24,25]. An analysis of 340,000 km of critical rivers—classified as freshwater connectivity corridors—identified that in 2019, 16 of 26 rivers over 1,000 km remained free-flowing[10]. If all proposed dams are constructed, only nine would retain this status.

Hydrological connectivity from the Andean headwaters to the Atlantic facilitates both ecological processes and the dispersal of pollutants. Industrial pollutants, especially mercury from illegal gold mining (see Chapter 2), are transported across the Basin, degrading water quality and altering aquatic ecosystems[21,22]. Over the last two decades, international gold demand has driven widespread soil degradation and the formation of wasted landscapes—infertile deserts of sand and gravel—eliminating topsoil rich in microbial biodiversity[26]. The interconnected nature of the Amazon's hydrology calls for integrated, multi-scale governance frameworks to manage shared aquatic resources across national borders.

2.3. Socio-Cultural Connectivity

Beyond ecological networks, socio-cultural connectivity is essential to conserving the Amazon's socio-environmental fabric. ITs and PAs are vital corridors for cultural continuity, knowledge exchange, and traditional resource management[27]. These territories safeguard linguistic diversity, traditional practices, and sustainable land-use systems that have co-evolved with the forest for generations[28].

Over 50% of the Amazon Basin is protected by ITs and PAs, which play a vital role in conserving biodiversity through culturally embedded stewardship[16] (Figure 4.1D). These communities' relationships with the territory are not only a matter of heritage but also form the basis for ecosystem resilience[12,29] (see Chapter 5). Disruptions to these networks, including land grabbing, forced displacement, and deforestation, undermine the transmission of knowledge systems critical to biodiversity management, climate adaptation, and sustainable resource use[29].

The erosion of cultural connectivity has far-reaching implications. Reduced access to sacred sites, medicinal and edible plants, or traditional fishing and hunting grounds impacts both physical and cultural well-being[29]. For instance, weakening traditional governance systems reduces community resilience in the face of external pressures[30]. Such losses must be urgently addressed through inclusive policies, legal recognition of Indigenous land rights, and support for self-determined governance systems (see Chapter 5).

Integrated conservation approaches that recognize both ecological and socio-cultural dimensions of connectivity are essential[31]. Strengthening IPs & LCs participation in policy and land planning, restoration efforts, and monitoring systems will ensure that conservation strategies are not only effective but also equitable[32]. Legal protection, inclusive governance, and the valorization of Indigenous and Local Knowledge (ILK) are indispensable for Amazon's long-term resilience.

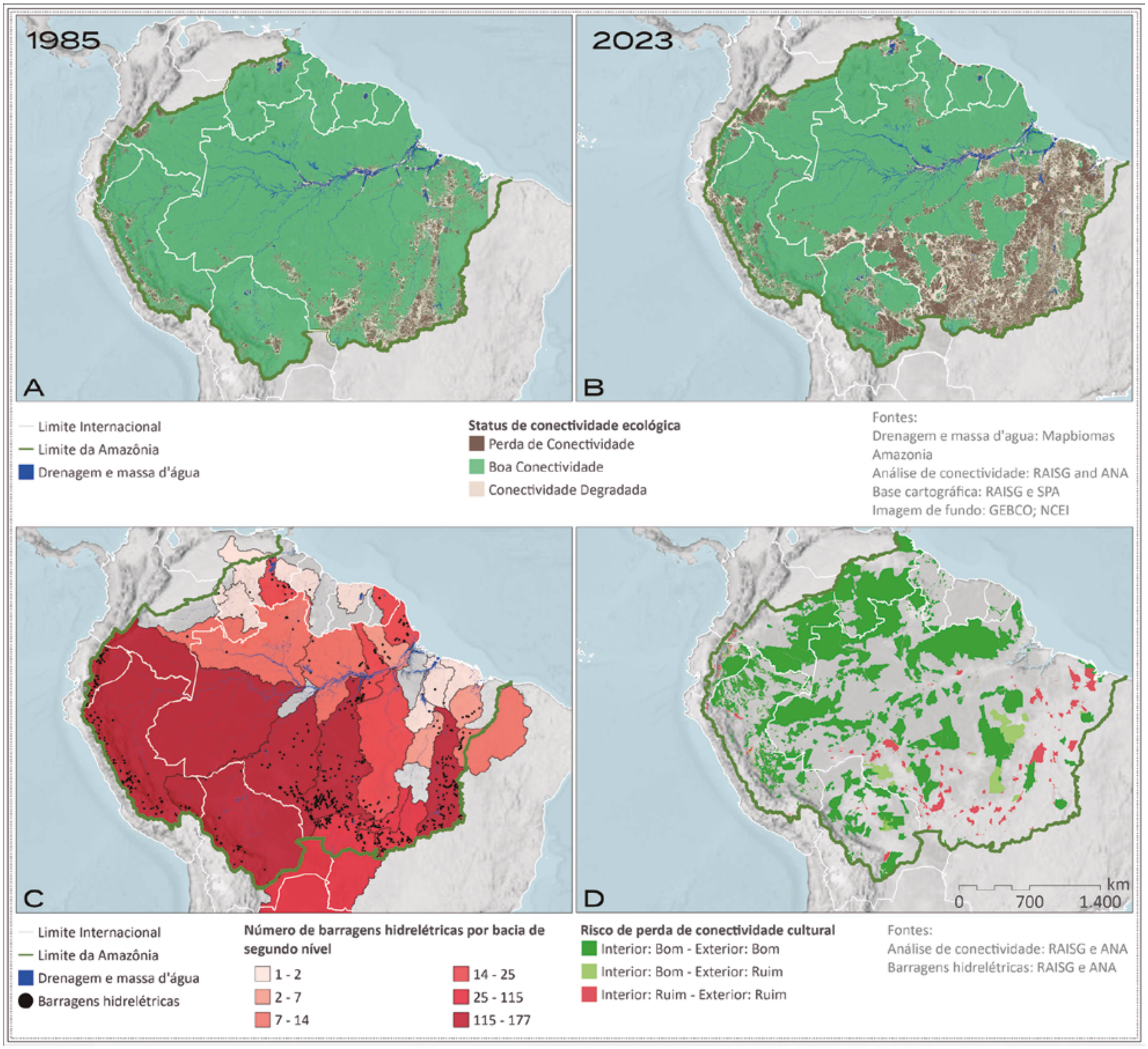


Figure 4.1. Changes in ecological connectivity of the Pan-Amazon from (A) 1985 and (B) 2023 based on the level of forest fragmentation due to deforestation in 1985 and 2023 respectively[15]; (C) Pressures on hydrological connectivity represented by the number of river dams small, medium and large per basin level 2[33]; and (D) risks to socio-cultural connectivity based on the distribution of ITs and PAs with proportion of fragmented forest inside[22]. Here, the landscape ecology concept of connectivity was translated into streamflow metrics. Degraded connectivity refers to the process by which previously continuous habitats become fragmented and more isolated, corresponding to conditions where flows are still possible but concentrated in narrow bottlenecks or in areas affected by edges. In contrast, lost connectivity reflects areas where landscape resistance is so high that it completely impedes flow, creating effective barriers between fragments.

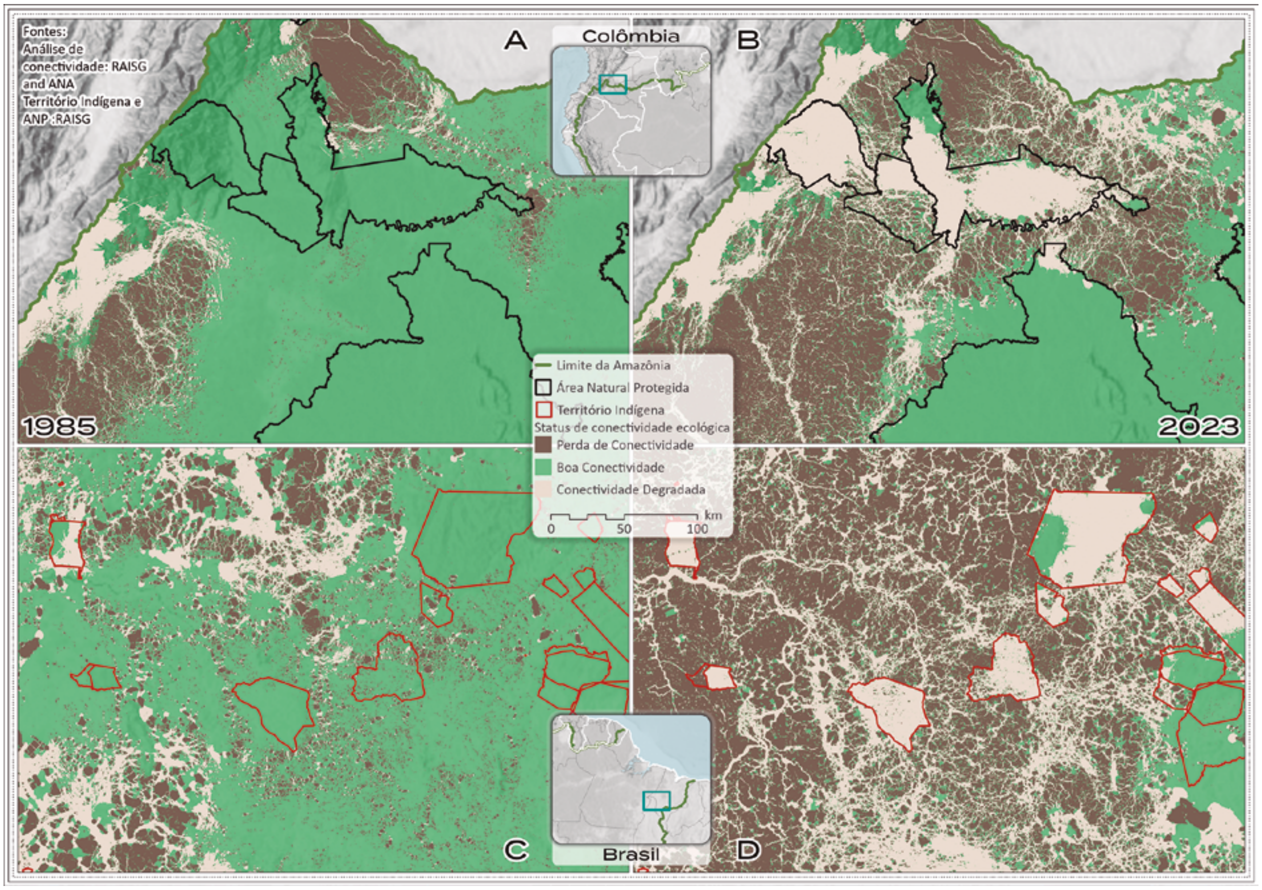


Figure 4.2. Ecological connectivity in Protected Areas[15] in the northern Amazon (Colombia) in 1985 (A) and 2023 (B); and ecological connectivity in Indigenous Territories (Maranhão Case, Brazil) in 1985 (C) and 2023 (D).

3. Governance

The Amazon is connected by a complex hydrological system of rivers, wetlands, and aquifers. Transboundary water resources shared by two or more countries present particularly complex challenges due to overlapping jurisdictions and diverse environmental pressures. The growing need for transboundary conservation areas contrasts sharply with the ongoing expansion of commodity-driven industries and national energy-mining agendas, which often override conservation commitments. Since the early 2000s, the program Initiative for South American Regional Integration of the South American Council of Infrastructure and Planning (IIRSA/COSIPLAN) has intensified infrastructure development to support industries—including cattle ranching, selective logging, mining, and monocrop farming—by expanding access of private actors to energy, logistics, and land in different parts of the Amazon[34]. Many infrastructure projects have been associated with significant environmental and social impacts, including deforestation, lack of public participation, human rights violations, and breaches of international conservation agreements[35]. In addition, recent political shifts toward more conservative governments in several Amazonian countries have further weakened environmental, territorial, and social policies. This led to the weakening of governance capacity and an increase in illicit activity, insecurity, and violence[35].

Transboundary governance is essential for managing shared resources across rivers and PAs and ITs corridors, in this complex context of competing goals and multi-scale interactions across borders. A strengthened transboundary governance of conservation corridors is needed to help counter unsustainable practices, increase ecological resilience, and empower vulnerable communities[32]. Governance capacity in the region, however, remains low, and collaborative efforts toward concerted territorial planning and coordinated information systems are scarce.

The growing number of people living near borders adds to the complexity of transboundary governance, which requires institutional coordination across multiple jurisdictions. This includes traditional populations, migrant farmers, and growing urban populations near the border, as well as Indigenous transboundary groups living under multiple national legal frameworks, including Indigenous Peoples in Isolation and Initial Contact (PIACI) whose territorial mobility and decision to remain uncontacted require special mechanisms of protection and interstate coordination that respect the principle of non-intervention. For example, the MAP region—comprising Madre de Dios (Peru), Acre (Brazil), and Pando (Bolivia)—shares common land-use histories and socio-environmental challenges, offering a strong foundation for collaborative governance[31]. Similarly, the Leticia–Tabatinga area, located at the intersection of Colombia, Brazil, and Peru, houses knowledge centers and holds potential for regional cooperation. In this context, both IPs & LCs governance systems and intergovernmental arrangements in place can play key roles in strengthening transboundary governance in the Amazon.

3.1. Indigenous Peoples' and Local Communities' Governance

Transboundary governance led by IPs & LCs involves long-standing struggles to incorporate their cosmovision into nature conservation policies. These communities play a vital role in protecting, stewarding, and defending their territories and ecosystems (Box 4.1).

Box 4.1. Indigenous Governance (by Fany Kuiru - General Coordinator - COICA).

My grandfather used to say: "The government is to serve, and authority is to defend the territory and the community." He was the chief, government, and authority of the Jitomagaro clan of the Uitoto people.

The Indigenous government is recognizing the millennia-long existence of care and defense of territory in the Amazon. Indigenous government is in the territory; the territory is the foundation of the government. Hence, it is important to strengthen Indigenous Peoples' own environmental governance systems in coordination with state governments and other sectors.

Over time, these territorial and community governments have evolved in response to the need for dialogue with the State. National and international Indigenous organizations are structures created to defend the rights of Indigenous Peoples, exercise advocacy, and, in some cases, represent them in international fora. They serve as the intercultural bridge of communication between the State, international agencies, and Indigenous territorial governments.

According to COICA in the Amazon Basin, 511 Indigenous Peoples have their own systems of government at the community level, and they are at the frontline of caring for, defending, and conserving territories and ecosystems. We have examples of new Indigenous government models, such as in Colombia, where Indigenous authorities are now recognized as the Governing Council of the Indigenous Territorial Entities (ETIs—Decree 632 of 2018), with the same powers as a government within the country's political-administrative system (governors and mayors). Furthermore, the Colombian State recognizes Indigenous authorities as environmental authorities (Decree 1275 of 2024).

To conserve the Amazon, it is urgent that the other States sharing this region take the Colombian case as a reference and join efforts to prevent the Amazon from reaching its tipping point.

While national and international Indigenous organizations and leaders have emerged to defend Indigenous rights, engage in advocacy, and represent their communities in global fora, it is critical to strengthen governance systems developed by IPs & LCs through recognition and coordination with local and state governments and other sectors. This is particularly relevant for the PIACI, who also require non-contact protection measures that guarantee the inviolability of their territories, prevent interventions, and recognize their right to self-determination. This includes enforcing existing regulatory instruments in the countries of the Amazon Basin and the United Nations Office of the

United Nations High Commissioner for Human Rights' International Guidelines, which establish differentiated protection obligations for peoples in isolation, relevant to regional and interstate environmental governance.

Amazonian Indigenous Peoples are organized through COICA to address transboundary governance issues. COICA serves as a key platform for ensuring the participation of Indigenous Peoples and incorporating decolonial perspectives into Amazonian governance. It promotes governance principles such as Rights of Nature, Buen Vivir (Living Well), care ethics, and body-territory concepts, alongside Indigenous and Local Knowledge. The Amazon Mechanism for Indigenous Participation (MAPI) was ratified by consensus at the Fifth Summit of the Amazon Cooperation Treaty Organization (ACTO) in Bogotá, and aims to guarantee Indigenous Peoples equal voice and vote, with equal representation alongside governments, in decisions affecting the Amazon. The MAPI is a binding tool to guarantee rights, strengthen Indigenous governance, and advance the protection of the Amazon.

Similarly, local communities have recently developed innovative practices and governance arrangements that hold major potential to connect across borders. Non-timber forest products' extractivists, afrodescendants, and *ribeirinhos* communities are some of these local groups who have been engaged in translocal arrangements for sustainable production, such as collectives (e.g., *Coletivo do Pirarucu*) and networks (e.g., *Rede de Sementes do Xingu*).

3.2. Intergovernmental Governance

Transboundary governance through institutional environmental governance in the Amazon relies on regional and transnational legal frameworks that provide the foundation for environmental protection and recognition of IPs & LCs rights[30]. These agreements and conventions establish not only rights but also responsibilities, emphasizing the importance of community participation in environmental governance (Box 4.2). At the national government level, ACTO holds the institutional architecture upon which transboundary initiatives can be co-designed and implemented for knowledge building and sharing, institutional innovations, transboundary regulations, and territorial planning for inclusive sustainable development.

Box 4.2. Key International Agreements Related to Environmental Governance in the Amazon.

1978 – Amazon Cooperation Treaty: Fosters cooperation among Amazonian countries for sustainable resource management.

1992 – Convention on Biological Diversity: Supports biodiversity conservation and equitable benefit-sharing.

1995 - The eight Amazonian countries decided to create ACTO to strengthen and implement the objectives of ACT.

2015 – 2030 Agenda for Sustainable Development: Outlines 17 Sustainable Development Goals aimed at eradicating poverty, protecting the planet, and promoting prosperity.

2018 - Escazú Agreement: Guarantees access to environmental information, public participation, and justice in environmental matters in Latin America and the Caribbean.

2023 – Belém Declaration: A collective agreement among Amazonian countries to address deforestation, forest degradation and wildfires, and climate change, with a focus on local participation and strengthening the Amazon Cooperation Treaty Organization.

2025 - Bogotá Declaration: Document reaffirming Amazon countries' commitment to continue multilateral cooperation aimed at addressing the Amazon's climate, social, environmental, and economic challenges.

While these frameworks recognize the central role of IPs & LCs, there is a need to strengthen governance capacity. Without robust, inclusive governance, achieving sustainable development and ecological balance will remain elusive. State and interstate arrangements (i.e., subnational jurisdictions) play a strategic role in overcoming fragmented institutional capacities and promoting intergovernmental and North-South cooperation. The Interstate Consortium for Sustainable Development of the Legal Amazon Region, created in 1991 by the Amazonian states in Brazil, or the Governors' Climate and Forests Task Force are models that can be out-scaled to include more Amazonian jurisdictions. Considering the regional diversity of the Amazon, such a governance arrangement can ensure accountability for contextual factors at the subnational level.

4. Solutions and Opportunities related to Transboundary Conservation

The ecological, hydrological and socio-cultural dimensions of connectivity must be mainstreamed into territorial planning, PAs management, and IPs & LCs governance frameworks to mitigate threats to conservation. Restoration and remediation of critical areas, barrier mitigation, and continuous monitoring should become core strategies to ensure Amazonian resilience[36]. Innovative indices such as the Catchment Area-based Fragmentation Index (CAFI) and the Rainfall-adjusted CARFI provide valuable tools to assess river fragmentation and inform decision-makers[37].

The Tarapoto Lake system also demonstrates how transboundary and Indigenous governance of shared water resources can help safeguard hydrological connectivity, protect fisheries, and conserve freshwater species such as the pink river dolphin. The transboundary management of Amazonian rivers, supported by hybrid governance models and legal innovations such as the recognition of river rights in Colombia, Ecuador, and Peru, underscores the need for cooperative strategies to safeguard connectivity, fisheries, wetlands, and freshwater biodiversity across borders[26].

Another example is the Convention for Migratory Species of Wild Animals, which in 2024 included two migratory Amazonian catfish species to Appendix II, highlighting the need for international cooperation to ensure their conservation across their natural range. A further illustration of an effective conservation strategy is the safeguarding of jaguar populations—a keystone species across the Neotropics—by strengthening PAs and ITs, along with establishing connectivity corridors, particularly along the critical border regions of the Brazilian, Peruvian, Colombian, and Venezuelan Amazon[38].

In this section, we outline the key components that should be incorporated into the design of solutions for transboundary conservation.

4.1. Strengthening Cross-Border Governance and Regional Cooperation

Effective Amazon resource management demands a multi-stakeholder body to unite IPs, LCs, governments, and institutions. A proposed Amazon Conservation Council (CCA)—comprising IP, LC, governmental, and scientific representatives—could forge binding agreements on deforestation, pollution, funding, and sustainable development. The rule of law and democratic institutions are key to the enforcement of agreements.

The Belém Declaration outlines a multifaceted framework to enhance regional integration and address shared challenges in the region. Strengthening the ACTO by embedding Indigenous, Local, and scientific voices into its governance would enable it to lead the CCA, translating member consensus into actionable policies for regional authorities. The establishment of MAPI as a permanent body within the ACTO, as outlined in the Bogotá Declaration, is an important step in this direction.

4.2. Interweaving Indigenous and Local Knowledge for Enhancing Ecological and Socio-bioeconomic Connectivity

Collaboration among different knowledge systems (see Chapters 5 and 8) is essential for the effective management of existing PAs and ITs. Biocultural corridors linking ITs, PAs, and community reserves can enhance regional connectivity, addressing gaps in formal conservation approaches. Also, large-scale restoration in degraded Amazon areas must interweave Indigenous and Local ecological knowledge, prioritizing native species to prevent ecological disruption[39] (see Call to Action 15).

Governments should promote sustainable agroforestry models to provide economic alternatives to deforestation-driven illegal activities, thereby ensuring local livelihoods while protecting ecosystems. Supporting these initiatives is critical to curbing environmental degradation and meeting community needs (see Chapters 6 and 7).

4.3. Addressing Climate Change, Pollution, and Hydrological Connectivity

Transboundary Amazon conservation demands a Basin-wide monitoring system for water quality, ecological shifts, and river connectivity, supported by collaborative scientific and local partnerships (see Call to Action 13). Connecting ILK with satellite technology and mobile tools can enhance early warning systems for droughts, floods, and wildfires, empowering communities to mitigate disasters. Pollution from plastics, mining, and oil industries further underscores the need for transnational monitoring.

Plans to expand renewable energy, widely considered by policymakers as critical for achieving regional climate goals, often overlook the cross-border environmental and social impacts of associated infrastructure. The cumulative effects of hydroelectric power plant dams on sediment flow, biodiversity, fisheries and greenhouse gases require multi-criteria planning at the Basin level, not at the national scale (see Call to Action 14). Transitioning some large hydropower projects to small hydrokinetic turbines (e.g., Brazil's potential for 626 MW market capacity) offers sustainable alternatives, minimizing river disruption while powering isolated communities. Prioritizing such innovations in policy and investment is key to harmonizing energy security and conservation. Cooperation and engagement are possible while fully respecting each nation's sovereignty and jurisdiction. All agreements and implementation efforts should be preceded by appropriate approval processes in accordance with national laws and protocols.

4.4. Controlling Gold Mining and Soil Degradation

Mining activities have led to significant mercury contamination in Amazonian rivers, threatening both biodiversity and human health (see Chapter 3). The impact is particularly severe in areas affected by illegal mining, which lack proper protocols and monitoring (see Call to Action 7, Chapter 2). To address this, cross-border task forces equipped with real-time monitoring and effective enforcement mechanisms are needed (see Call to Action 14). Governments must prioritize sustainable alternatives, such as forest and freshwater systems' conservation and sustainable use (e.g., agroforestry and fisheries) through economic transition programs to shift miners toward legal livelihoods. Integrated policies are urgent to curb illicit activities such as illegal mining and coca cultivation (see Chapter 2).

Human-assisted, Artificial Intelligence-driven tools (e.g., satellites, drones) enhance the transboundary tracking of deforestation, selective logging, and mining, while native species-based soil remediation technologies are critical for rehabilitating degraded lands before restoration. Innovations in satellite-based forest monitoring are increasingly enabling near real-time detection of small-scale disturbances in tropical forests[40].

Restoring degraded ecosystems is urgent, especially in areas where gold mining, deforestation, and forest degradation have caused severe damage[41,42]. Restoration must be socially just and ecologically effective, prioritizing tenure security and IPs & LCs leadership. Restoration efforts should focus on soil regeneration, water quality monitoring and remediation, stopping industrial pollutants, and ecological restoration with native species to recover their ecological functionality. Sustainable economic alternatives are also key: socio-bioeconomy, agroforestry, value-adding to biodiversity products, and different forms of conservation payments should replace illegal economies, ensuring that forest conservation aligns with local livelihoods[18].

4.5. Empowering Indigenous Peoples and Local Communities

Empowering IPs & LCs requires legally reinforcing their land rights and resource governance, enabling sustainable economic activities that conserve forests and aquatic ecosystems (see Chapter 5). Backing Indigenous-led conservation through funding, capacity-building, and partnerships with non-governmental organizations (NGOs) is vital for fostering socio-bioeconomies (see Chapter 7)[43]. Integrating traditional ecological knowledge into cross-border policies enhances Amazonian biodiversity management.

Growing civil society pressure in Amazonian countries urges governments to safeguard PAs and ITs, human rights, and ecosystems' integrity. Environmental NGOs, academia, and global actors advocate stricter climate accountability, ensuring governments honor commitments despite political shifts. Notably, in the 2023 referendum of Ecuador, 59% supported halting oil extraction in Yasuní National Park's Ishpingo-Tambococha-Tiputini oil field, triggering phased withdrawal of operations. In Brazil, Indigenous advocacy spurred the 2023 creation of the Ministry of Indigenous Peoples, bolstering land protection as a climate strategy.

4.6. Science-Based Conservation and Monitoring

An open-access Amazon Environmental Data Platform is critical for timely conservation decisions and knowledge sharing, as scientific knowledge is often not broadly accessible to inform urgent policy actions (see Call to Action 13). Many Amazonian institutions currently provide research outputs on sustainability, but require consolidation into an accessible digital platform. Organizing applied environmental data by theme in a regional database can streamline impact assessments for projects, capturing lessons learned. Strengthening cross-border research networks and implementing multilingual tools (Spanish/Portuguese/English/French) will improve scientist-policymaker collaboration. Integrating machine learning and remote sensing enables real-time tracking of deforestation, land-use shifts, and hydrological changes.

5. Conclusions

Transboundary conservation in the Amazon is critical to conserving and restoring its ecological integrity, maintaining biodiversity, and securing the livelihoods of Indigenous Peoples (IPs) and Local Communities (LCs). Given the magnitude of current threats, coordinated transboundary action is needed to ensure the Amazon's long-term resilience. A regional approach to conservation must prioritize ecological, hydrological, and socio-cultural connectivity, which will require multinational conservation corridors, stronger enforcement against environmental crime, and interconnection with IPs & LCs land management practices.

Environmental governance plays a critical role through the engagement of multiple actors, intercultural dialogue and decision-making, and robust policy enforcement. Strengthening governance mechanisms at all levels is imperative for addressing environmental, social, and economic challenges. Amazon countries must commit to binding transboundary conservation agreements, implement cumulative impact assessments for large-scale infrastructure projects, and establish transboundary monitoring systems to track deforestation, forest degradation, overexploitation of natural resources, river pollution, and biodiversity loss in real-time. Strengthening IPs & LCs territorial rights and investing in science-based conservation strategies interwoven with Indigenous and Local Knowledge will strengthen protection efforts.

The future of Amazon connectivity and resilience depends on collective action at all levels: local, national, regional, and global. By adopting science-based policies, including Indigenous Peoples and Local Communities' leadership, and developing sustainable economic models for the region, we can safeguard this irreplaceable ecosystem on which our future depends.

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Monitor Collaboratively and Share Data Among Amazonian Countries

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Photo credit: Planet Labs.

The Overview

The Amazon Basin faces growing cross-border environmental threats, including deforestation, wildfires, habitat fragmentation, pollution, and climate change. Countries use distinct monitoring systems that vary in scope, methods, and definitions, making regional data hard to compare. Water, soil, and biodiversity monitoring remain limited. Though regional tools exist, they are underused by governments. This fragmentation weakens early warning systems and regional action. Currently, shared governance mechanisms that link national and local monitoring efforts under a common regional vision are lacking. A coordinated, transboundary monitoring approach is urgently needed to improve transparency, policy-making, and conservation efforts.

The Facts

- Cross-border surveillance is crucial to combat the expansion of illegal activities tied to transnational criminal networks (see Chapter 2).

- National environmental monitoring systems such as Brazil's Legal Amazon Deforestation Satellite Monitoring Project (PRODES), Peru's Geobosques, and Colombia's Forest and Carbon Monitoring System (SMByC) generate annual deforestation data across millions of hectares of Amazonian forest. However, differences in scale, methodology, and data transparency limit regional comparability and coordinated conservation strategies.

- The datasets of regional monitoring initiatives such as the Amazon Network of Georeferenced Socio-Environmental Information (RAISG) and MapBiomas Amazonia remain underused by governments in policy planning and enforcement at both national and regional levels (see Chapter 4).

- At the territorial level, community-based monitoring (see Call to Action 18, Chapter 5), has effectively deterred illegal activities, complemented official systems, and improved the early detection of environmental change. However, these efforts remain dispersed and under-supported, limiting their broader integration into national and regional frameworks.

Global/Regional and Synergistic Connections

- Due to the Amazon Basin's ecological connectivity (see Chapter 1), local deforestation and degradation have regional and global consequences. The degradation of the Amazon weakens the planet's capacity to regulate the climate, safeguard biodiversity, and sustain livelihoods. Land-use change is also displacing communities, eroding ecological resilience, and threatening irreplaceable ecosystems.

Figure C4.13.1. Satellite image showing forest, deforestation, agricultural area, and area affected by fires in the municipality of Paranatinga, in the state of Mato Grosso, Brazil. Photo credit: Planet Labs, image mosaic from October 2024, selection by Roberta Rocha (Amazon Environmental Research Institute, IPAM).

The Solutions Space

Selected Key Tools

- **Satellite-based environmental monitoring systems**, such as PRODES and the Real-Time Deforestation Detection System (DETER) in Brazil, SMByC in Colombia, and Geobosques in Peru, **generate annual deforestation data** across millions of hectares of Amazonian forest. However, differences in scale, methodology, and data transparency limit regional comparability and coordinated conservation strategies.

- RAISG and MapBiomas Amazonia produce annual, harmonized deforestation and land-use maps across all of the Amazon, showing how **open data, shared methodologies, and transparency can advance regional monitoring and accountability**.

Collaborative Efforts

- The Amazon Waters Alliance, coordinated by Wildlife Conservation Society (WCS) and regional partners, **fosters transboundary cooperation for freshwater ecosystem monitoring and sustainable management of fisheries**. Its open-data platform, Ictio.org, connects community members, fishers, and scientists across the basin to track migratory and food fish species that indicate ecosystem health.

- Community-led monitoring in Brazil's Xingu Indigenous Park uses drones, GPS mapping, and field patrols to detect and deter illegal activities and complement official systems. This example highlights the importance of **Indigenous Peoples' and Local Communities' participation in environmental monitoring** (see Call to Action 18, Chapter 5).

- **In the Ecuadorian Amazon, community-based oil monitoring initiatives have enhanced environmental accountability and data transparency through local participation**. Such efforts enable communities to independently collect and validate information on extractive impacts to complement official systems and inform decision-making[1].

- The "Amazon Network of Networks" (*Red de Redes Amazónicas*) connects existing regional networks and Indigenous, academic, and technical organizations, strengthening collaboration and data exchange across the basin. It aims to **integrate scientific, technical, and community-based knowledge for decision-making** at regional and transboundary scales, linking bottom-up initiatives with institutional mechanisms.

Governmental Efforts

- The Amazon Regional Observatory, established under the Amazon Cooperation Treaty Organization (ACTO), provides a **shared reference center for environmental information** by integrating national datasets and promoting data exchange among member states. Building on this institutional foundation, the Amazon Network of Water Authorities (RADA, the Spanish acronym) strengthens water governance and data interoperability, showing how coordinated regional mechanisms can address transboundary environmental challenges.

- The Amazon Fund, managed by the Brazilian National Development Bank (BNDES) and supported by Norway and Germany, illustrates how existing financial mechanisms can strengthen both national and regional monitoring systems. By funding initiatives on deforestation control, sustainable forest management, and collaborative programs with ACTO, it demonstrates the potential for **scaling equitable and coordinated financing across all Amazonian countries.**

Recommendations

- **Build an interoperable regional monitoring system** that connects existing national and independent platforms through common standards for data collection, validation, and sharing. Rather than a centralized structure, an interlinked system should promote data interoperability and transparency, supporting large-scale monitoring and ground truthing across the Amazon Basin.

- **Integrate independent and community-generated data** into official decision-making processes and transboundary planning to strengthen regional coordination and enhance environmental governance, land-use planning, and enforcement mechanisms.

- **Harmonize governance frameworks** to jointly monitor and mitigate shared challenges, supporting effective cooperation among Amazonian countries and institutions at multiple levels.

- **Establish targeted and accountable funding mechanisms** to support long-term sustainability and foster transparency in climate and conservation finance. This includes publishing progress reports to build trust and linking international funding to measurable transparency milestones.

- **Empower citizen science and participatory science to expand environmental data collection across the basin** through mobile and satellite technologies and standardized protocols, ensuring that community knowledge contributes meaningfully to scientific and policy processes.

- **Promote the use of monitoring data to inform nature-based and community-driven solutions**, particularly in areas affected by illegal mining and deforestation, ensuring that environmental information supports sustainable territorial planning and local livelihoods.

- **Leverage and strengthen existing frameworks**—such as ACTO, the Leticia Pact, and the Belém Declaration—to promote shared governance and data harmonization across the basin[2,3].

- **Ensure alignment with international principles of open and responsible science**, following the United Nations Educational, Scientific and Cultural Organization (UNESCO) Recommendation on Open Science, and adopting the FAIR (findable, accessible, interoperable, reusable) and CARE (collective benefit, authority to control, responsibility, ethics) principles for data governance.

Key Recent Literature

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See full list of references here

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Plan Infrastructure Development Through Integrated Regional Strategies

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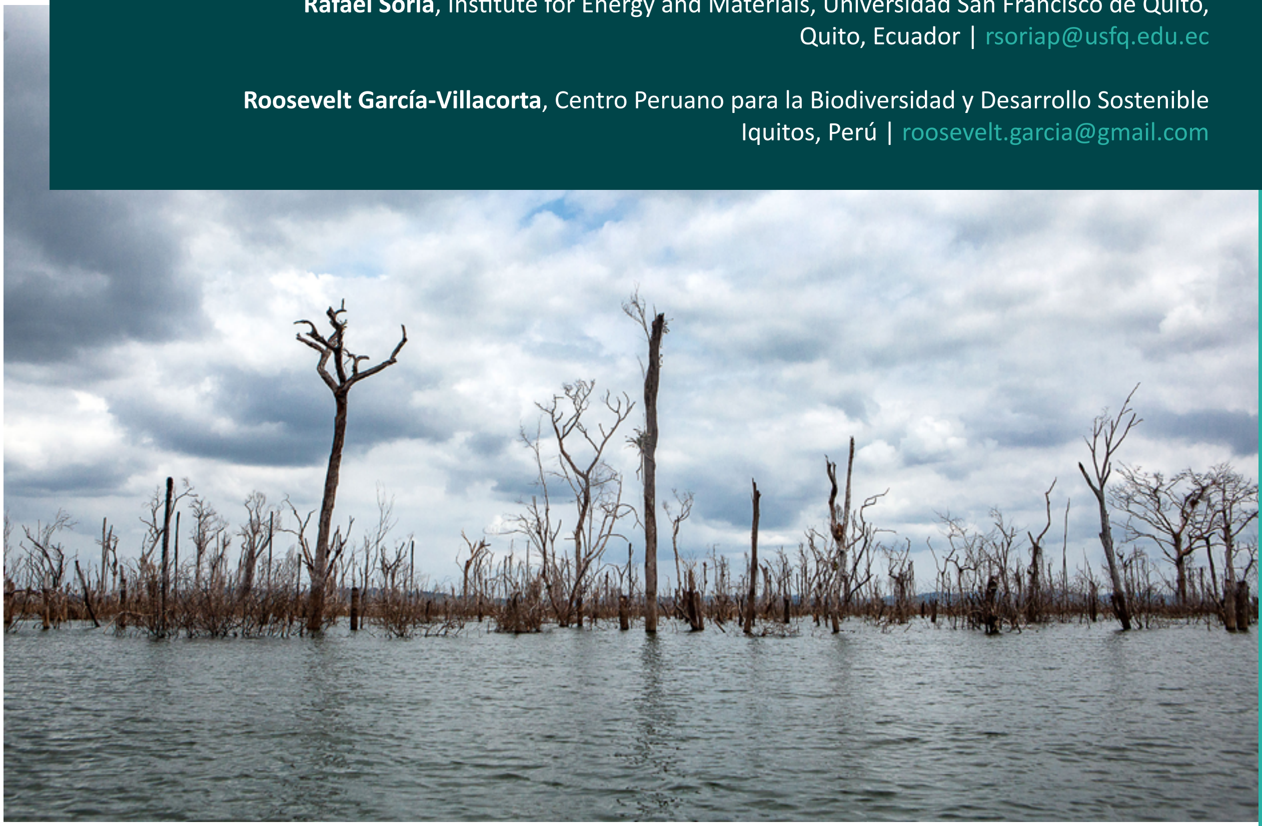

Photo credit: Lilo Clareto / Amazônia Real.

The Overview

Major infrastructure projects in the Amazon, such as hydroelectric dams and roads, have led to extensive deforestation, ecosystem degradation, the establishment of illegal economies, and the disruption of forest and river connectivity. Currently, most infrastructure projects are developed in isolation by individual countries, with little consideration for their socio-economic and environmental impacts on neighboring sub-basins or the Amazon as a whole. To address these impacts, Amazon Basin governments must engage in coordinated, cross-border dialogues and action focused on the sustainable planning and development of infrastructure, considering nature-based solutions, regional assessment of projects, advanced technology, and Indigenous and Local Knowledge (see Chapter 4). This is essential to account for cumulative and transboundary negative impacts, and ensure the long-term conservation of the Amazon. Key priorities include: (i) an integral evaluation of the potential sources of green energy projects (solar, wind, hydro, geothermal) with the least negative impact and the highest energy output; (ii) computationally-informed strategic hydropower planning for lower-impact, and smart location of small hydroelectric facilities - considering that the definition of “small” dams varies significantly across countries, though a capacity of up to 10 MW is increasingly recognized as the international standard[1]; (iii) the management of legal and responsible mining issues; (iv) the mitigation of environmental impacts of the hydrocarbon industry; and (v) alternatives to road expansion.

Figure C4.14.1. Unpaved stretch of BR 319, between Humaitá and Realidade, in southern Amazonas, Brazil. Photo credit: Alberto César Araújo/Amazônia Real.

The Facts

- Approximately half of South America's remaining hydropower potential is located in the Amazon[2]. As Amazonian countries seek to comply with their climate change mitigation commitments, known as nationally determined contributions (NDCs), the region is expected to see a significant expansion of medium- and large-scale hydropower over the next decade.

- Mineral exploitation, especially through illegal economies, is severely contaminating Amazonian rivers, deforesting pristine forests, and destroying the soil conditions that sustain biodiversity, affecting communities' health and altering the fluvial landscape.

- Latin America has total proven oil reserves of 305 billion barrels and additional oil resources of 851 billion barrels[3], and a significant fraction of this oil is found in the Amazon. For example, 100% of Ecuador's oil resources are in the Amazon.

- Road infrastructure is a primary driver of accelerated land-use change in the Amazon, as it facilitates colonization, illegal mining, illicit crops, and deforestation.

Global/Regional and Synergistic Connections

- Amazonian hydropower expansion critically connects global climate mitigation and biodiversity conservation. It is expected to occur as countries seek to achieve their NDCs, disrupting fish migration and sediment flow and affecting the livelihoods of downstream communities[4].

- Illegal extractive economies in the Amazon (see Chapter 2) exemplify the intersection between regional governance, global markets, and water security. River pollution from illegal mining degrades local and transboundary ecosystem services, and by entering the food chain it compromises public health. Addressing these challenges requires international cooperation on tracing minerals, stopping financing and mercury trafficking into the region.

- Amazonian road and oil infrastructure planning lies at the nexus of economic connectivity, social justice, and global climate stability. Transportation corridors and oil exploration in highly biodiverse areas represent decisions that directly link NDCs with global sustainable development objectives.

The Solutions Space

Selected Key Tools

- **Transboundary integrated planning tools**, such as the Integrated and Sustainable Management of Transboundary Water Resources developed by the Amazon Cooperation Treaty Organization (ACTO), enable the **modeling of cumulative impact scenarios** of hydroelectric projects in shared basins.

- **The MapBiomas platform provides detailed monitoring of land-use changes**[5].

- **Mineral-tracing systems**, such as the Alliance for Responsible Mining's Fairmined certification, **are effective in promoting responsible mining practices**. This approach should be complemented by legislating proactive restoration practices, such as saving and storing topsoil and refilling mining ponds, that help mitigate the enormous impact of mining in the Amazon Basin[6,7].

Collaborative Efforts

- Initiatives such as ACTO's Implementation of the **Strategic Action Program in the Amazon River Basin and the Amazon Network of Water Authorities (**RADA, the Spanish acronym) **promote transboundary water governance in the Amazon**. RADA's goals include establishing regional monitoring protocols, supporting water-source revitalization, and facilitating information exchange to harmonize standards among member countries. By involving operators, Indigenous Peoples and Local Communities, and research centers, these types of multinational consortia optimize the planning and operation of transboundary infrastructure, such as hydroelectric facilities, reducing environmental impacts while maximizing shared benefits[4,8].

- Initiatives such as the Golden Roots project implemented by the Alliance for Responsible Mining have **established standards for small-scale operations to meet strict environmental requirements**. In addition, the Amazon Basin Project (ACTO/Global Environment Facility/United Nations Environment Programme) is developing the Panorama on Mercury Contamination in the Amazon Region. By quantifying emission sources and identifying areas vulnerable to contamination, the assessment aims to support the Minamata Convention Assessments (MIAs).

- **Regional restoration efforts remain fragmented** (see Call to Action 15). Better coordination is needed to address both mercury pollution in rivers and soil degradation, which undermines restoration efforts. ACTO's RES/18 on the Amazonian Network of Forest Authorities (RAFO, the Spanish acronym) is a promising effort in this regard.

- **Cross-sectoral planning initiatives**, such as Green Bond Framework of the Development Bank of Latin America (CAF), provide tangible mechanisms for integrating coordination across energy, transport, and conservation sectors, enabling more cohesive planning among governments.

Best Practices

- **Successful experiences in Amazonian regional planning reveal promising practices that remain to be scaled up**. The "source-to-sea" approach adopted by ACTO's Strategic Action Program (SAP) represents an innovation in water governance, recognizing the continuity of hydrological flows and the need for basin-scale coordination.

- **Integrated environmental assessment models that consider the cumulative impacts of multiple projects**, implemented across the Amazon Basin and in some Brazilian sub-basins[9], offer scalable assessment frameworks. These models help assess trade-offs between energy output and environmental impacts, such as in locating dams. The models should also integrate other green energy technologies available in each country, such as wind and solar, into their analyses.

- **Technical dialogue platforms** facilitated by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) and the Latin American Energy Organization (OLADE) **advance energy integration by separating technical discussions from political**

negotiations. This approach first establishes consensus on objective environmental impact criteria before addressing economic aspects[10].

- Innovative mechanisms such as Ecological Fairmined, a certification offering a premium of 6 USD per gram for gold extracted without chemicals (higher than the 4 USD for standard Fairmined gold), are creating effective **economic incentives for more responsible practices**. However, it is important to recognize that mercury pollution is only one aspect of the broader socio-environmental impacts of mining in the Amazon. The resulting land and soil degradation can significantly limit the potential for other economic activities.

- **Indigenous Territories in the Amazon have lower deforestation than other areas**. However, legal and illegal mining occurs on over 20% of this area, significantly increasing deforestation where it happens. Despite limited legal protections, communities like Tres Islas in Peru have taken action, overturning 127 mining concessions. In Colombia, the Yaigojé Apaporis people stopped a mining concession by securing national park status for their land, highlighting the need for stronger Indigenous rights[11].

Recommendations

- **Hydropower expansion in the Amazon must be coordinated regionally**, prioritizing projects with the least socio-ecological impact to solve the needs of local populations and advance real electrical integration among countries[12]. Transboundary electricity integration can reduce ecosystem impacts and avoid cumulative effects while optimizing generation from different renewable energy sources at national level.

- **Avoid constructing new large and medium-scale hydroelectric dams in the Amazon**, to guarantee the conservation of free-flowing rivers and watershed corridors[2]. Taking advantage of the complementarity of solar, wind, and hydroelectric resources in each country[13] would reduce the pressure on Amazonian rivers.

- **Efforts to guarantee universal access to electricity must be intensified through options other than hydroelectric potential**, such as solar energy and biofuels. In isolated areas, microgrids powered by hydrokinetic turbines, solar photovoltaic energy, and/or engines fueled with advanced and local biofuels should be developed[14].

- **Governments should jointly plan the best options for new transportation infrastructure**, minimizing the environmental and social impacts of roads, rails, and waterways in the Amazon region. Low-carbon and multimodal transportation options should be deployed[14].

- **Implement nature-based infrastructure** such as green roads, fish passages in small hydropower systems, and engineered wetlands for sediment and pollution control.

- **The region's governments must collaborate to prevent the establishment and expansion of illegal economies** (see Chapter 2) by providing economic incentives based on responsible natural resource management and sound regulations. For example, regulations can be developed to prevent money laundering through mining, stop mercury trafficking, and stop the commercialization of illegal gold through legal loopholes in other countries.

- **Platforms** such as MapBiomas could be enriched to include an infrastructure layer in the map of the Amazon, which **can serve as a source for collaboration, discussion, and decision-making.**

Key Recent Literature

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Fund Basin-Wide Restoration

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Photo credit: Isabella Leite Lucas.

The Overview

The Amazon region is facing unprecedented threats from deforestation and degradation, bringing the biome closer to a system-level tipping point[1–4]. To avoid this, numerous small-scale restoration projects have been implemented. The map in this Call to Action shows the current state of Amazon conservation priorities and disturbance levels across the basin. However, the existing fragmented approaches to restoration cannot match the scale of the current threats to the biome's integrity, and the Amazon still urgently requires coordinated large-scale and multi-country restoration initiatives[5,6]. This Call to Action argues that, when it comes to restoration, a system-level approach to funding basin-wide restoration—coupled with deforestation control and greenhouse gas emissions reduction—is needed to prevent the Amazon from tipping into another vegetation state.

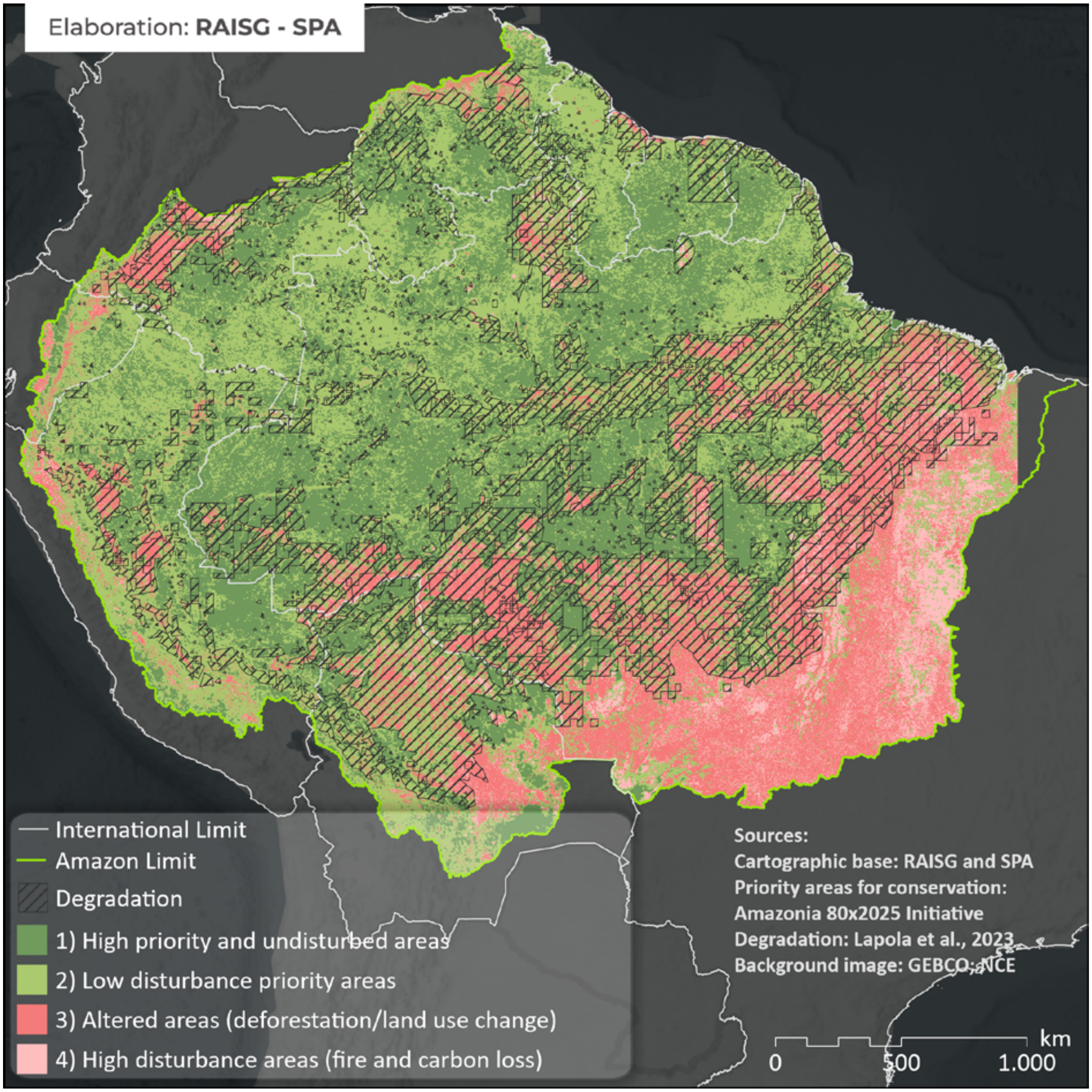

Figure C4.15.1. ***Amazon conservation priority areas and disturbance zones.*** The map illustrates the spatial distribution of conservation priorities and environmental disturbance across the Amazon Basin. The visualization categorizes areas into four key zones (see legend for more information). The predominance of green areas in the central and western Amazon contrasts with the extensive red zones along the eastern and southern borders, highlighting the "arc of deforestation," where anthropogenic pressure is most intense. This spatial pattern underscores the urgent need for the coordinated, basin-wide restoration approach advocated in this Call to Action.

The Facts

- Eighteen percent of Amazon region has been deforested[4], approaching the 20%–25% threshold that could push the region toward a tipping point[2,3]. At least 38% has been degraded[7].
- Human activities have ecologically disconnected 193 million hectare of forests (23% of the Amazon region), which could recover their carbon stocks, biodiversity, and ecosystem services if further degradation is avoided[1].
- Forest conservation provides USD 410 per hectare in ecosystem services annually[5].
- Current restoration efforts such as Brazil's Arc of Restoration initiative are extremely important[8]. Carbon sequestration potential through large-scale forest restoration and by avoided deforestation is 48 billion tons of CO_2[9].

Global/Regional and Synergistic Connections

- Mitigation initiatives in the Amazon could sequester 48 billion tons of CO_2 through forest restoration and avoided deforestation over 30 years, making it critical for achieving Paris Agreement targets under the United Nations Framework Convention on Climate Change (UNFCCC) and limiting global warming to 1.5°C[9].
- Large-scale restoration corridors would reconnect fragmented habitats for endemic species, thus supporting global biodiversity targets of the Kunming-Montreal Global Biodiversity Framework, especially as 10%–47% of the Amazon forest faces tipping point risks by 2050[2].
- Basin-wide restoration would stabilize hydrological cycles, benefiting over 40 million people across all of the Amazon. A 17% decrease in dry season rainfall has been observed[10] and could significantly impact key sectors such as agriculture, food and water security, and energy, with effects extending beyond the region.

- Restoration economies could generate sustainable income streams worth USD 410 per ha annually from ecosystem services while transitioning communities away from extractive industries toward sustainable livelihoods[5].

The Solutions Space

Selected Key Tools

- **The** Arc of Restoration Program **of the Brazilian National Development Bank (BNDES):** BNDES launched a USD 204 million program in 2023 to restore 60,000 km^2 of degraded Amazonian lands by 2030, aiming to capture 1.65 billion tons of carbon from the atmosphere[8]. This is a significant, large-scale financing mechanism that could be replicated across the basin.

- **The Amazon Fund:** As of October 2025, the revitalized fund has mobilized over USD 1.142 billion since its creation in 2008. It has supported 139 projects, with over USD 816 million in funding approved and USD 549 million disbursed. Recent additional donations since 2023 demonstrate strong international appetite for climate finance in support of large-scale conservation and restoration[11].

- **Brazil's Legal Framework:** Brazil reaffirmed in 2023 its national target to restore 12 million ha of native vegetation by 2030, a target originally established under the National Native Vegetation Recovery Plan (PLANAVEG) launched in 2017. The updated version, PLANAVEG 2025–2028, which launched in 2024, provides regulatory and strategic foundations for large-scale initiatives and carbon credit mechanisms. From an implementation perspective, the *Restoration Observatory* and the *Amazon Restoration Alliance* provide essential platforms for monitoring and coordinating restoration efforts across the Amazon.

- **Colombia's Payments for Ecosystem Services:** The program demonstrates how governments can incentivize restoration through direct payments to landowners and communities for forest recovery.

- **Initiative 20x20 (a regional public–private partnership):** A country-led alliance launched at the twentieth session of the Conference of the Parties to the UNFCCC (COP 20) in Lima in 2014 to protect and restore 50 million ha by 2030, bringing together governments, investors, and technical partners across Latin America and the Caribbean.

Positive Efforts for Scaling

- **Geovisor for the Arc of Deforestation in the Colombian Amazon** was implemented by the Colombian banking industry for the analysis and management of environmental and social risks by financial institutions. Such examples innovate the financial sector.

- Launched in 2019 by the Inter-American Development Bank (IDB) Lab, **the Natural Capital Lab** uses innovative financial mechanisms—such as green bonds and concessional finance—to support sustainable projects in the Amazon. The Lab secured USD 1 billion in Amazonia bonds to promote sustainable agriculture and forest conservation across Peru, Ecuador, and Bolivia.

- Organizations like the **Xingu Seed Network** provide community-based restoration models that combine Indigenous and Local Knowledge with Western scientific methods. So far, approximately 8,800 ha have been restored in the Xingu and Araguaia river basins.

- The **LEAF Coalition**, launched in 2021, is a global public–private initiative mobilizing at least USD 1 billion to support tropical forest conservation through results-based finance, involving multiple governments and major corporations.

Collaborative Efforts

- **The Amazon Sacred Headwaters Initiative (ASHI)** is a cross-border, Indigenous-led restoration coalition operating across territories in Peru and Ecuador, covering over 34.8 million haectares of forest. Since its launch in 2017, ASHI has secured tens of millions of dollars and brought together 30 Indigenous Peoples and over 60 partners, including nongovernmental organizations and local governments, to advance large-scale restoration (Personal communication, ASHI, 2024).

Recommendations

- **Establish a basin-wide restoration fund** combining climate finance, debt-for-nature swaps, and innovative financial instruments and mechanisms to support coordinated restoration across all Amazonian countries and French Guiana.

- **Create regional landscape restoration corridors** connecting Protected Areas and Indigenous Territories, prioritizing at least 50 million hectares of strategically important degraded lands based on the best available science.

- **Develop community-centered restoration programs that prioritize leadership by Indigenous Peoples and Local Communities**, ensuring the majority of restoration funds flow directly to community-led initiatives with secure land tenure and that local capacities to manage the extra funding from restoration projects are developed.

- **Strengthen international cooperation through the Amazon Cooperation Treaty Organization (ACTO)** to harmonize restoration policies, share best practices, and coordinate transboundary restoration efforts.

- **Create a basin-wide investment platform** replicating successful models through aligned project pipelines and blended finance. Amazonian governments should lead, with ACTO support, partnering with multilateral development banks, climate funds, and Indigenous and Local Community organizations to coordinate public–private capital flows toward Indigenous- and Local Community–led and national restoration priorities.

- **Establish common environmental and social standards for basin-wide restoration, covering biodiversity outcomes, transparency, Indigenous Peoples' and Local Communities' rights, and benefit sharing**. These standards should be co-developed by governments, Indigenous and Local Community groups, scientists, and regional institutions to ensure scale does not compromise equity or ecological quality, while building investor trust.

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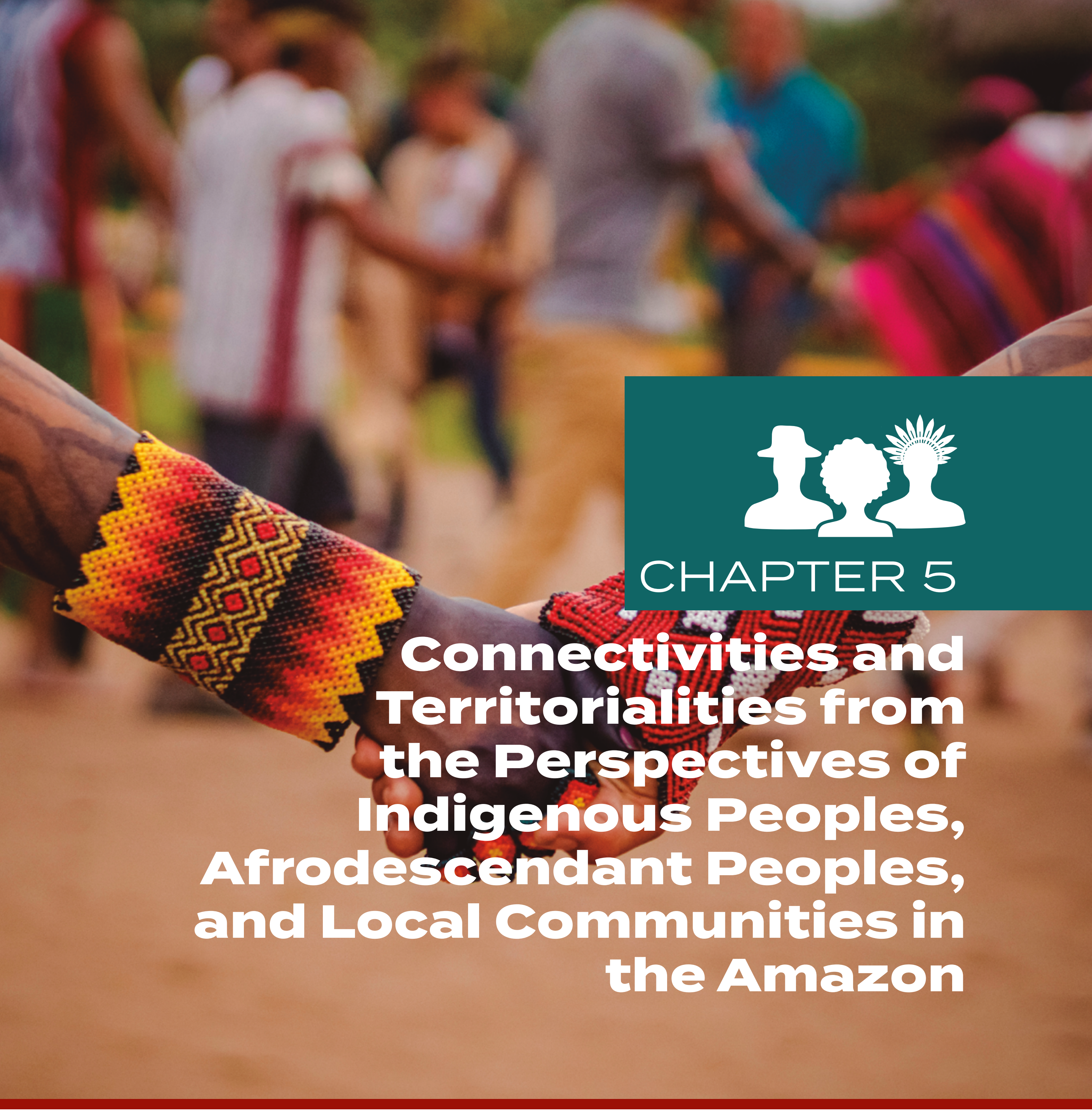

CHAPTER 5

Connectivities and Territorialities from the Perspectives of Indigenous Peoples, Afrodescendant Peoples, and Local Communities in the Amazon

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Chapter citation

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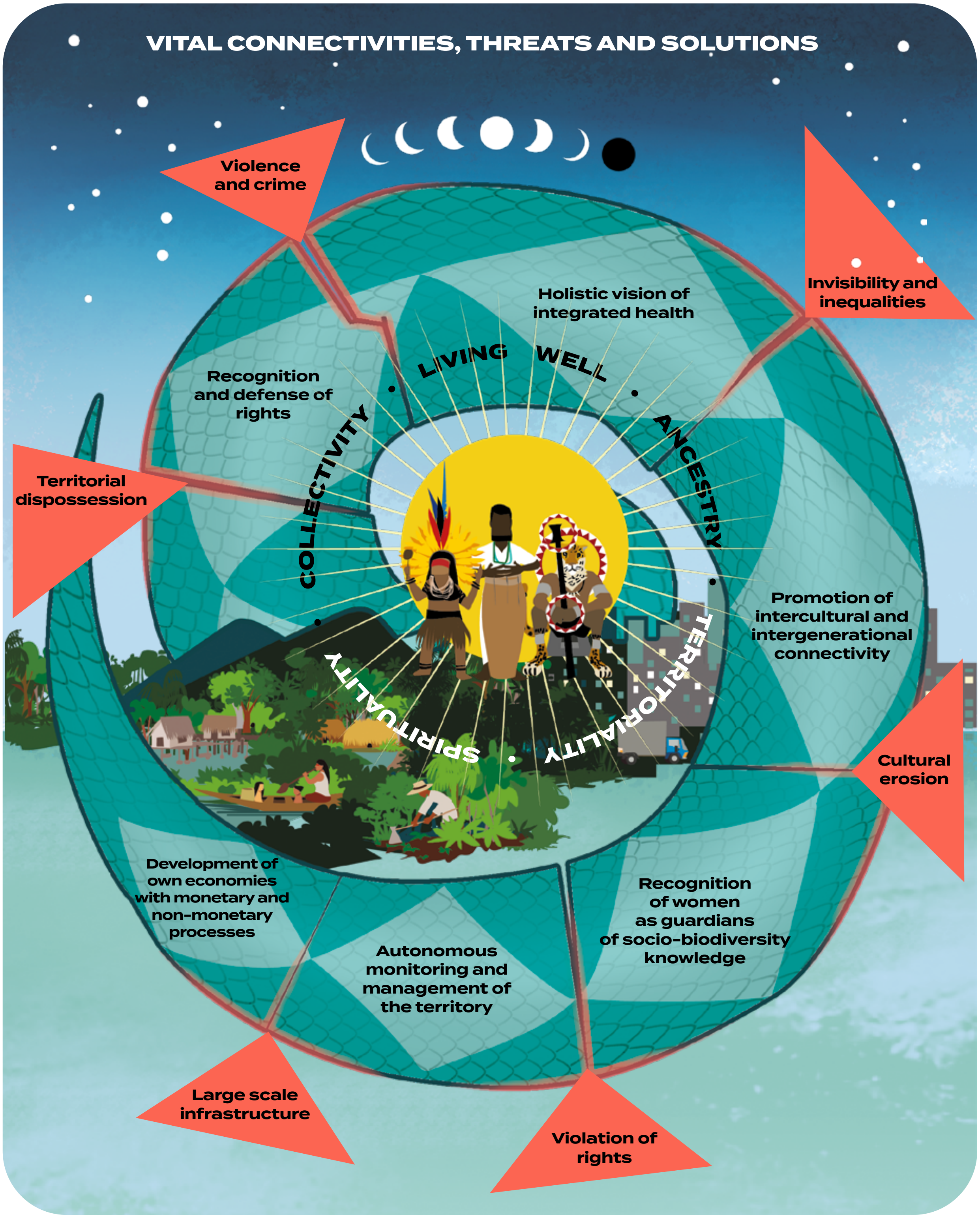
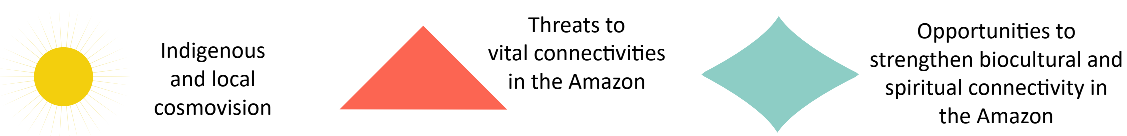
Abstract

This chapter approaches connectivity in the Amazon from the perspectives of Indigenous Peoples (IPs), Afrodescendant Peoples (APs), and Local Communities (LCs). It highlights the profound interconnection between their ways of life, their knowledge systems, and their ties to the territory. The adopted methodology is a reflective exercise that places the voices of various IPs, APs, and LCs at the center, in dialogue with scientific and academic knowledge. Territoriality is presented as a fundamental pillar that interconnects peoples and communities with their territories in physical, spiritual, sociocultural, symbolic, and political ways. The notion of connectivity is proposed, in an exploratory manner, as a vital principle and a comprehensive way of life, transmitted ancestrally through oral codes, collective memory, and interactions with the territories and biocultural diversity of the Amazon. In broader terms, the process of co-producing knowledge articulates three main axes for reflecting on connectivity: 1) diverse interpretations and approaches to the concept of connectivity; 2) identification of risks and threats that endanger these vital connections; 3) emphasis on solutions promoted by the peoples and communities themselves from their territories.

Keywords:

Territories, Spirituality, Indigenous Peoples, Afrodescendant Peoples, Local Communities





Graphical Abstract. The image shows connectivity in the Amazon (in blue), the threats that affect it (in red), and opportunities to strengthen reciprocity with Mother Earth (in green). The central spiral symbolizes movement, transformation, and ancestral memory, and its core represents the territories of Indigenous Peoples (IPs), Afrodescendant Peoples (APs), and Local Communities (LCs).

1. Introduction

This chapter investigates multiple forms of connectivity that link Indigenous Peoples (IPs), Afrodescendant Peoples (APs), and Local Communities (LCs) with ecosystems, territories, cities, and Amazonian sociobiodiversity, highlighting their reciprocal and integrated nature at different levels. The approach is based on the concept of territoriality as a dynamic, historical, and spiritual relationship with territories, based on unique ways of inhabiting, caring for, and defending living spaces[1].

The analysis is framed within a transdisciplinary approach that promotes equitable dialogue in the co-production of knowledge, articulating ancestral and academic knowledge based on unique experiences and links with Amazonian realities (Figure 5.1). These processes did not involve approaching Indigenous Peoples in Isolation and Initial Contact (PIACI), who must be protected in accordance with the principle of no contact and in respect for their right to self-determination (Box 5.1).

The dialogue involved overcoming epistemic, linguistic, and cultural barriers in the co-creation of knowledge, conditioned by the limitations of online work. The inclusion of oral and cultural expressions was encouraged through workshops, surveys, and virtual dialogues. These interactions showed the complexity of translating the ways of life that sustain connectivity for IPs, APs, and LCs within conventional scientific frameworks.

The selection of literature was conducted through consultation with key sources and based on the authors' experience, with particular emphasis on publications by Indigenous and Afrodescendant Peoples, and other historically invisibilized Amazonian groups[2,3]. To provide visibility and highlight these perspectives, this approach gathers textual quotations, expressions, and concepts from authors, peoples, and communities through workshops, surveys, or published sources. The method focuses on incorporating such voices into the discussion.

The information was validated in the corresponding territorial contexts, based on the authors' experiences in several Amazonian countries. This representation is illustrated in Figure 5.1, which delimits the Indigenous and Afrodescendant Territories in the Amazon, and where each author of the chapter lives or works.

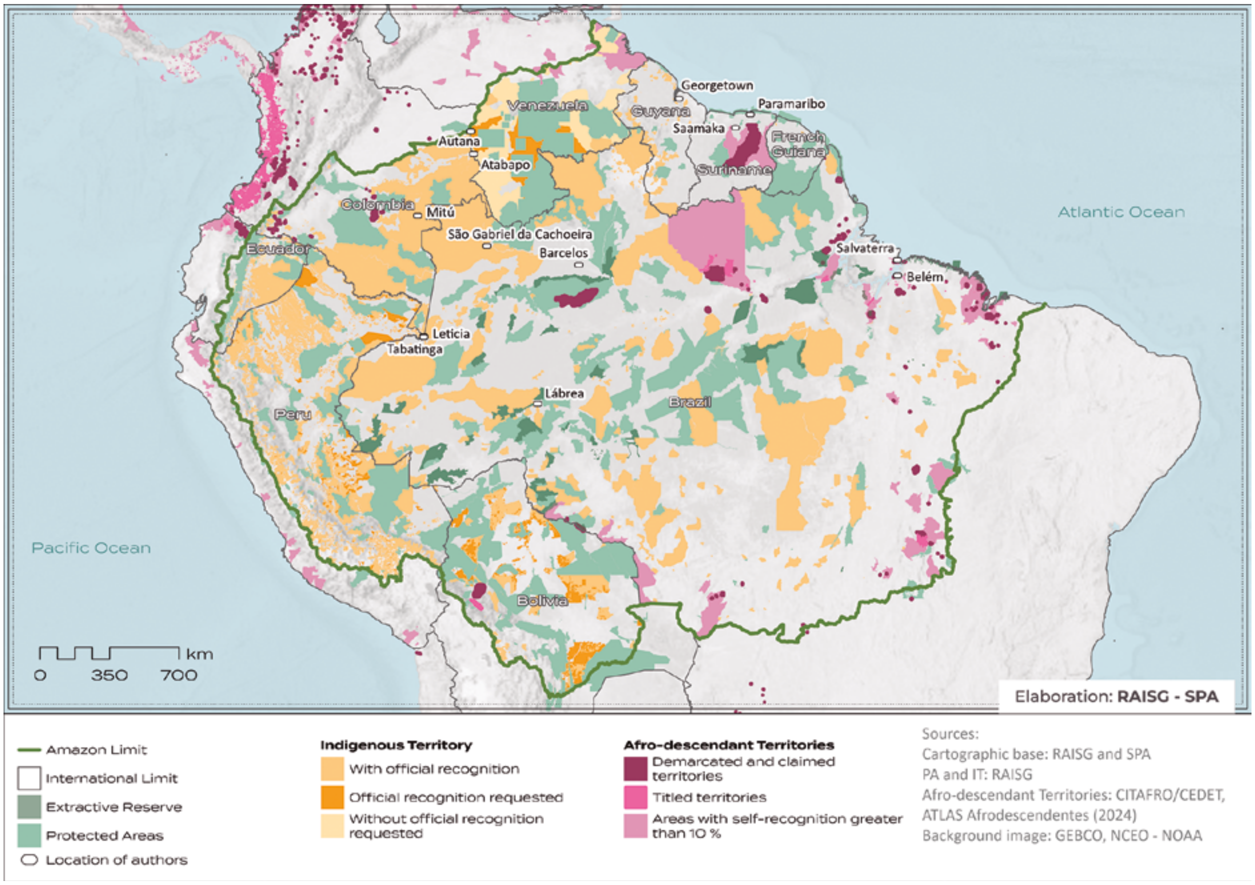


Figure 5.1. Representative map of Indigenous, Afrodescendant, and Local Community Territories in the Amazon. Approximately 410 Indigenous Peoples inhabit the Amazon region, including around 80 in voluntary isolation, speaking nearly 300 different languages4. The map also indicates the location and regional incidence of the chapter authors. It is important to note the existence of significant data gaps and the underrepresentation of territories traditionally occupied by Indigenous Peoples, Afrodescendants, and Local Communities.

The chapter is organized into three sections: (i) conceptualizations that highlight a relational vision of territory, in which ancestry, spirituality, and Living Well (*Buen Vivir*) sustain the continuity of peoples and their lifeways; (ii) analysis of threats affecting territories, livelihoods, and self-determination; and (iii) initiatives led from the territories to address pressures and strengthen ties. Based on these experiences, the following question is raised: how do IPs, APs, and LCs understand and experience connectivity, and how do their experiences, threats, and responses reveal situated forms of knowledge, resistance, and regeneration? The chapter concludes with recommendations based on proposals from Amazonian organizations and communities.

Box 5.1. Note on the Recognition and Designation of Indigenous Peoples (IPs), Afrodescendant Peoples (APs), and Local Communities (LCs) in the Amazon.

As a transdisciplinary group of authors, we affirm the right to self-determination and self-designation of sociocultural groups whose lives and spiritualities are deeply linked to the region's ecosystems. This includes IPs, APs, and LCs (the latter including riverine communities, extractivists, family farmers, fishers, among other groups).

The authors propose formally distinguishing Afrodescendant Peoples from the generic category of Local Communities[5], recognizing their ethnic identity, unique knowledge, and territorial ties. This proposal arises from the struggles and demands of APs for ethnic-racial justice and recognition, and was developed in a working document, drafted with the participation of invited authors of African descent who contributed their experiences, knowledge, and territorial perspectives[6]. This proposal is based on international advances such as the Second International Decade for People of African Descent (UN, 2025–2034) and Decision 16/6 of the Convention on Biological Diversity[7], which highlight the role of APs in biodiversity conservation and environmental and climate justice.

In this chapter, we use the spelling *Afrodescendant* as a single, unhyphenated word in English, aligning with the form commonly used in official documents across Latin America, in both Spanish and Portuguese, to ensure consistency. This choice emphasizes identity and cultural heritage, without implying dual nationality or binational origin. For more details on the spelling of IPs, APs, and LCs, see Athayde et al. (2025)[6].

We also recognize the specific rights of Indigenous Peoples in Isolation and Initial Contact (PIACI), who require differentiated protection based on the principle of no contact. Instruments such as Convention 169 of the International Labor Organization (ILO) and the United Nations (UN) Declaration on the Rights of Indigenous Peoples oblige States to guarantee intangible territories and avoid all forms of external interference[8,9].

2. Diverse Interpretations and Approaches to the Concept of Connectivity

2.1. Connectivity, Ancestry, and Spirituality

In this chapter, an exploratory approach is taken to the concept of connectivity as a vital principle and a holistic way of life, transmitted through oral codes, collective memory, and interactions with territories and biocultural diversity in the Amazon. This connectivity articulates territory, community, spirituality, history, languages, past and future generations, and reciprocal relationships with nature. It reflects the interdependence between ecosystems, cultures, and social dynamics, deeply linked to cultural, linguistic, and territorial rights, as well as the right to self-determination of peoples and communities.

Relationships with territories have generated practices and knowledge that conserve shared landscapes. As the Yanomami leader (shaman) Davi Kopenawa says: "The earth has life. If you destroy it, the spirits also die. And if they die, the sky will fall on us"[9]. For the Yanomami, *urihi* (land-forest) is a living entity composed of humans, non-humans, spirits, rivers, and mountains. Its destruction breaks vital networks: "The land-forest will only die if it is destroyed by white people (...) the *xapiripë* spirits will end up fleeing (...) and thus everyone will die"[10]. In this framework, spirituality is the core that sustains connectivity and ancestry. Aura Dalia Caicedo Valencia affirms that "Afrodescendant spirituality is a daily practice that manifests itself in rituals, songs, and community norms, serving as a source of resistance against colonization and territorial dispossession"[11].

In the Andes, Quincho Apumayta recalls that "the farm is not the property of the human community, but (...) of the *sallqa* (untamed wilderness), of the *wakas* (sacred entities, places, or guardian spirits)"[12]. This vision reaffirms the unity between land and spirituality. In the words of Humberto Cholango: "Nature is not a resource, it is our mother, our home, our life"[13]. This expression reflects the Kichwa worldview in which Pachamama, a Quechua word that literally means Mother Earth, is not a resource or property, but a living being that sustains, cares for, and balances life. Recognizing Earth as Mother implies a relationship of reciprocity.

Biocultural connectivity was recognized by the Inter-American Court of Human Rights in the case of *Sarayaku v. Ecuador* (2012), highlighting the spiritual, cultural, and physical connection to the land. This connection underpins the recognition of Nature as a subject of rights, with its own dignity, in accordance with Indigenous and Afrodescendant worldviews. Advisory Opinion OC-32/25 (2025) reinforces this interrelationship, recognizing the legal personality of Nature and its connection to human rights as a basis for addressing the climate crisis. Recognizing these epistemological differences is key to building bridges between knowledge systems[14,15] (Call to Action 16 and Call to Action 31, Chapter 8). Author Gloria Rivera[16] warns that the current socio-environmental crisis stems from the Western view that abruptly separates human beings from nature and multispecies relationships.

Thus, spirituality, ancestry, and connectivity converge as a single relational principle that gives meaning to life, guides governance, and resists the fragmentation imposed by colonial paradigms (see Call to Action 17).

2.2. Connectivities and Territorialities

Although the Amazon is often thought of as a remote and rural space, the region is also deeply urban. Numerous individuals from Indigenous, Afrodescendant, and Local Community backgrounds who reside in urban areas, maintain strong connections with their ancestral territories. The notion of territorial self-determination is key to overcoming these barriers. This connectivity transcends geography: it is expressed in memory, spirituality, cultural practices, Indigenous economies (see Chapter 7 and Call to Action 19), languages, and intergenerational relationships. Territoriality is not only a physical space; it is a symbolic dimension of belonging and continuity. As Abdias do Nascimento said, “The quilombo is a territory of freedom and memory, where life is reshaped in relation to the land and the ancestors”[17]. Among riverine communities, the river organizes economic, social, and cultural life: it is not only a resource, but also identity and subsistence[18].

Nêgo Bispo[19,20] suggests territoriality as counter-colonialism, where “land, memory, and community life are inseparable.” For André Baniwa[21], Indigenous governance supports the autonomous and sustainable management of the territory. Milton Santos[22] contributes the concept of “used territory,” defined as a living space produced by social relations. Krenak[23] expresses it this way: “The territories are our bodies and spirits. We are earth, water, sun, blood.” The concept of integral territory, developed by the IPs of the Peruvian Amazon, includes not only the productive use of space, but also the emotional, cognitive, spiritual, and political ties that sustain it, as well as the history and symbolic ecology that inhabit it[2].

The ancestral territories of Indigenous Peoples such as the Asháninka (Brazil, Peru) and the Yanomami (Brazil, Venezuela, Guyana), Tikuna (Brazil, Colombia, Peru) have been fragmented by political borders that, although imposed, have become dynamic and porous. These borders can hinder traditional cultural configurations, but they also offer opportunities for cross-border connectivity, such as in binational protected areas[24,25].

2.3. Living Well: Connectivity and Collective Well-being

The philosophies of Living Well express a relational ethic that links people, territories, nature, and spirituality[26]. These practices reflect a holistic view of human and non-human well-being, in which collective well-being is defined from broader collectives that include people, plants, animals, natural elements, and the spiritual world. This conception challenges the prevailing individualistic and anthropocentric approaches, proposing a life based on reciprocity, respect, and interdependence among all beings in the territory. In the Andes, the concepts of *Sumak Kawsay* and S*uma Qamaña* promote harmony with all living beings[27,28]. In Africa, *Ubuntu*, "I am because we are," and *Ukama* emphasize reciprocity and interdependence[29,30].

In the Amazon, Living Well is expressed as biocultural and spiritual connectivity, guiding the ways of life of IPs, APs, and LCs. In Tapajós, organizations such as the Tapajós-Arapiuns Indigenous Council integrate Living Well into their resistance to extractivism[31]. In the Tupé Sustainable Development Reserve (Brazil), the community of Livramento articulates environmental management and cultural preservation in local enterprises[32]. In the Ecuadorian Amazon, the Kichwa, Shuar, and Achuar peoples practice Living Well through agroforestry, community governance, and respect for natural cycles[33].

These visions support an expanded notion of health, close to the One Health approach, and promote intergenerational links and the regeneration of life[21,34,35] (see Chapter 3). Thus, Living Well and connectivity converge as ethical, political, and ecological foundations rooted in the territories, offering alternatives to the dominant development model.

3. Threats and Challenges to Vital Connectivities in the Amazon

Connectivity and territoriality are fundamental pillars of community Living Well in the Amazon. These dimensions sustain not only biodiversity, but also the spiritual, cultural, and political fabric of IPs, APs, and LCs. However, there is evidence of a process of systematic erosion caused by multiple converging forces: extractivism and illegal exploitation of resources, violence, discrimination, cultural loss, and legal frameworks that violate collective rights.

3.1. Territorial Dispossession and Ecological Degradation

The advance of harmful extractivism, such as illegal mining (see Call to Action 7, Chapter 2), oil extraction, agribusiness, and the imposition of infrastructure without prior consultation (hydroelectric dams, roads, power lines, among others), fragments ecosystems and erodes connectivity and territoriality (see Chapter 2). Illegal mining grew by 625% between 2011 and 2021, and more than 70% occurs in protected areas[36]. In the Legal Brazilian Amazon, *garimpo* (illegal gold mining) occupies almost 20,000 hectares[37]. According to the Atlas Amazonia Under Pressure 2020, elaborated by the Amazon Network of Georeferenced Socio-Environmental Information (RAISG), in 2020 there were 833 dams in the region, of which 177 are in operation or under construction and 184 are planned, along with 238 small hydroelectric plants in operation and 350 planned[38]. This expansion of dams fragments ecosystems, alters the natural flow of rivers, and directly affects the territories of peoples and communities, as well as protected areas.

These extractive processes not only erode territorial connectivity but also generate new forms of exclusion under the discourse of sustainability. An analysis by InfoAmazonia reveals that 61% of carbon credits traded in the Brazilian Amazon overlap with mining areas, equivalent to 40.1 million tons of potentially “contaminated” carbon[39]. This contradiction between green economy and extractivism deepens the violation of collective rights and reinforces the ecological and cultural exclusion of Amazonian peoples.

The tensions between extractivism and sustainability are also reflected in the cultural and economic practices of Amazonian peoples. Author Paulette Bynoe emphasizes that Indigenous practices are key to sustainable development policies. In Guyana, rock-carved petroglyphs convey messages of conservation for future generations. Subsistence activities such as agriculture, fishing, ecotourism, and forest product gathering, depend on ecosystems but face growing threats from illegal mining, logging, and infrastructure projects, especially where environmental legislation is not adequately enforced.

3.2. Violence, Criminalization, and Illegal Practices

Violence against land defenders, organized crime, illegal logging, and clandestine mining intensify conflicts and spread fear (see Calls to Action 7 and 8, Chapter 2). In the last 10 years, 1,733 environmental defenders have been killed in the Amazon[40]. Structural violence against Amazonian peoples intensifies in contexts of extractivism and militarization. In Brazil, the rate of violence against Indigenous people exceeds the national average by 26%, according to the "Atlas da Violência 2023"[41]. Impunity for environmental and social crimes, such as the murder of Asháninka leader Edwin Chota, exacerbates this situation[42]. These cases show how community resistance is paid for with lives, and how defending the territory remains a high-risk struggle.

Gender-based violence in the Amazon represents a critical dimension of this problem. It is understood as "any conduct that harms the integrity or physical health of a woman," including psychological, sexual, patrimonial, and symbolic violence, according to Brazil's Maria da Penha Law[43]. According to the Igarapé Institute[44], violence against women in the Amazon regions of Brazil, Colombia, and Peru is almost double that of other regions. In the Brazilian Amazon, the female homicide rate is 48% higher than in the rest of the country, and sexual violence is 30% higher. In 2023, during the Third March of Indigenous Women, the femicide of Maria Clara Batista, a young Karipuna woman murdered by a non-Indigenous man in Oiapoque, was denounced. The case sparked outrage and led the National Indigenous Peoples Foundation (Brazil) to commit to prevention policies[45]. Such cases reveal the structural violence experienced by Indigenous, Afrodescendant, and Local Community women, which often go unseen, and the urgent need to guarantee their safety both within and outside their territories.

3.3. Invisibility, Discrimination, and Structural Inequalities

One of the biggest problems affecting sociocultural connectivity and territoriality in the Amazon is the historical invisibility of the presence and contributions of IPs, APs, and LCs (see Call to Action 31, Chapter 8). As author Martha Rosero-Peña points out, in reference to the Afrodescendant Peoples of the Amazon, “despite their fundamental role in the sustainable management of resources and in the construction of knowledge about sustainability, their contributions have been routinely underestimated”[4]. This lack of recognition is reflected in their limited participation in decision-making spaces on environmental and climate governance, despite their key role in mitigation, adaptation, and solutions to climate change. Collectives from these peoples have asserted their rights to participate in national, Amazonian, and international debates, such as the Bogotá Declaration of the Amazon Cooperation Treaty Organization, the Afrodescendant Coalition for the 30th Conference of the Parties to the United Nations Framework Convention, and the Declaration of the National Council of Traditional Peoples and Communities of the Articulation of Indigenous Peoples of Brazil, fighting for ethnic-racial and climate justice[46-50].

Structural racism, understood as the set of norms, practices, and institutions that perpetuate racial inequalities in a systemic manner[51], manifests itself in the denial of territorial rights, exclusion from decision-making, and the devaluation of ancestral knowledge. Author Maria Páscoa Sarmento expresses it clearly: “Biointeraction in our Brazilian and Pan-Amazonian *quilombola* territories is under constant threat due to socio-environmental conflicts, made possible, among other things, by the denial of the right to recognition of our territories of belonging within the sphere of the national states.” In Brazil, although the 1988 Constitution guarantees the titling of more than 7,000 quilombola territories, only 494 are officially delimited[52], which has facilitated violence and rights violations, as documented by the National Coordination of Black Quilombola Rural Communities of Brazil and Terra de Direitos[53].

Author Miqueias de Souza, member of the Ituxi riverine Community in the Brazilian Amazon emphasizes the importance of gaining a deep understanding of the reality of local communities in order to support public policies that promote equal rights in the face of class patterns imposed by a consumerist, competitive, and class-based society. He also proposes compensatory and mitigating mechanisms for those who care for the forest, recognizing their role in sustainability.

3.4. Loss of Knowledge, Languages, and Intergenerational Links

Cultural erosion is advancing with displacement, migration, and irrelevant educational models. In the words of the Confederation of Indigenous Nationalities of the Ecuadorian Amazon, "the virtual platforms provided by the Ecuadorian State for education do not include the native languages of the Amazonian peoples, and the curriculum continues to be homogeneous. [...] Thus, the path of 'intercultural dialogue' that the State should promote in the field of education remains distant"[54]. These ruptures weaken the ancestral, spiritual, and community legacy (see Call to Action 17).

The increasing loss of Indigenous languages in the Amazon represents a profound rupture in socio and biocultural connectivities. Each language expresses a unique way of inhabiting and caring for the world. Its disappearance silences memories, knowledge, and intergenerational links[55]. As Isaías Sales Tukano[56] affirms: "Language is the spirit of the people. It is through language that we connect with our ancestors, with the beings of the forest, and with the territory. When we lose our language, we also lose part of our collective soul." This erosion, driven by policies of assimilation and displacement, compromises the continuity of systems of life. Revitalizing languages is urgent in order to protect collective memory and biocultural resilience.

3.5. Imposition of External Models and Violation of Collective Rights

Legislation and public policies that ignore biocultural diversity threaten territorial rights and ways of life. The Brazilian "death combo" (Bill 490, Bill 191, among others) accelerates the dispossession of IPs, APs, and LCs. In other countries, regulations such as the "Special Land Access Project" (Peru), the relaxation of environmental standards (Colombia, Ecuador), and centralized water control (Ecuador) reinforce this pattern[57,58]. Alicia Cawiya, a Huaorani leader, expresses this clearly in her speech to the Ecuadorian Parliament defending Yasuní: "Water is a treasure that is worth more than gold"[59].

In Brazil, the Temporal Framework is a legal thesis that limits the rights of IPs to the lands they occupied or disputed on October 5, 1988. This interpretation ignores historical displacements and restricts new demarcations. Although the Federal Supreme Court (STF) declared it unconstitutional, the National Congress approved Law No. 14.701/2023, which maintains the temporal framework. Currently, the law remains in force but faces constitutional challenges in the STF. In 2025, a conciliation commission attempted to revise the rule without reaching consensus, raising concerns about a setback in Indigenous territorial rights.

Author Nathalia Nascimento points out that, although Amazonian governments promote discourses on conservation and socio-bioeconomies, legal decisions contradict these narratives. The slow pace of land demarcation, the licensing of projects with high environmental impact, and the advance of agribusiness persist. In addition, basic rights such as health (the Yanomami case), education, and transportation are being violated. Most alarming, according to Nathalia, is the strategy of some local governments to divide traditional leadership and dismantle social movements, which reinforces the urgency of strengthening connectivity and alliances between peoples.

Figure 5.2. Examples of risks, impacts, and threats to vital connectivity from the perspectives of Indigenous Peoples, Afrodescendant Peoples, and Local Communities in the Amazon.

4. Opportunities and Solutions: Pathways to Territoriality and Connectivity

The opportunities and solutions linked to Amazonian territorial connectivity are both diverse and complex, reflecting the multiplicity of sociocultural and territorial contexts in which they develop. In this scenario, new initiatives are emerging that are increasingly promoted and led by the IPs, APs, and LCs themselves from their territories, who demand respect and freedom to fully exercise their collective rights. This section addresses the opportunities and solutions prioritized by the authors throughout the collective co-creation process of this chapter.

4.1. Recognition and Defense of Rights

A central solution is to guarantee territorial rights as a fundamental condition for the respect and valorization of IPs, APs, and LCs in the Amazon. It is urgent to advance in the demarcation of territories, self-governance, and ensure Free, Prior, and Informed Consent (FPIC) in all processes that affect their territories[8,60,61].

Autonomous consultation and prior consent protocols allow IPs, APs, and LCs to define their organization, representatives, and rules to be recognized in state or business processes[62-64]. The cases in Table 5.1 (Appendix) demonstrate their contribution to the strengthening of these peoples.

4.2. Holistic View of Health

For IPs, APs, and LCs, health is linked to territory, spirituality, and ecological balance (see Chapter 3). Its continuity requires spaces for intergenerational transmission and the articulation of intercultural health systems, which integrate ancestral methods of healing and medical care with Western medicine systems[65,66]. Recording their practices represents not only the protection of their knowledge, but also intergenerational perpetuity, as in the case of the Yanomami people (Brazil) with the Yanomami Traditional Medicine Manual, and the Matsés (Brazil, Peru) with the Encyclopedia of Matsés Traditional Medicine, transcribed in their original language. Table 5.2 (Appendix) presents examples of health practices and rituals of Amazonian peoples.

The Bahserikowi Indigenous Medicine Center, created in 2017 in Manaus (Brazil) by Tukano leaders, is a pioneering space for intercultural practice and dialogue in Indigenous medicine[67-69]. During the pandemic, *quilombolas* from Salvaterra (Pará, Brazil) promoted the COVID-19 Combat Group, bringing together local leaders and health agents for community self-management[70].

4.3. Promotion of Intercultural and Intergenerational Connectivity

Community education centers should promote collective learning in the territories, respecting their own methods that integrate generations in cultural, productive, and spiritual practices, strengthening cultural and ecological ties[71-73] (see Call to Action 16). The examples in Table 5.3 (Appendix) show that there is no single model but rather approaches adapted to the realities of each territory, such as the Baniwa Indigenous School, intercultural bilingual schools in Peru, Colombia, and Brazil, and alternating models in riverine communities. It is essential to value, protect, and revitalize Indigenous languages and local dialects, as they are carriers of memory and culture and maintain a deep connection with Amazonian territories[55].

It is crucial to decolonize urban education so that new generations recognize the values of ancestral peoples and combat structural racism[74]. Affirmative action policies, such as the implementation of quotas in public universities in Brazil, have expanded access to higher education for students from traditional peoples and promoted inter- and transdisciplinarity[75].

4.4. Recognition of Women as Guardians of Sociobiodiversity Knowledge

The role of women emerges as fundamental, as their voices and leadership embody unique forms of knowledge, management, and territorial care that have historically been made invisible[76]. Strengthening their network organization supports territorial coordination, the strengthening of their agendas, and the fight against violence and exclusion. As author Paulette Bynoe points out, "women are key agents in the process of adapting livelihoods, which is essential for sustainable human development"[77].

In Brazil, the *Associação das Mulheres Ribeirinhas* de Porto de Moz (Pará) demonstrated how women's organizations can influence forest management in the *Verde para Sempre Extractivist Reserve*, while the *Cooperativa de Mulheres Agroextrativistas do Acre* consolidated the inclusion of women farmers and rubber tappers in public procurement policies such as the National School Feeding Program (PNAE) and the Food Acquisition Program (PAA)[78]. The Women Guardians of Solano actively participate in the implementation of the Gender Action Plan (PAG), ensuring the equitable participation of women in the management of the region's natural resources[79].

4.5. Autonomous Monitoring and Management of the Territory

Strengthening Indigenous Peoples and their Autonomous Territorial Governments (GTA) is essential to ensuring self-determination and effective governance in the Amazon[80-82]. In Peru, the Autonomous Territorial Government of the Wampís Nation (GTANW), created in 2015 as the first Amazonian Indigenous government with its own structure, and the Autonomous Territorial Government of the Awajún Nation (GTANA), established in 2021, are noteworthy. In Colombia, efforts are underway to formalize Indigenous Territorial Entities (ETIs), strengthening control over their territories. The aim is to remedy the violation of the fundamental rights of the Yuruparí peoples, restore territorial integrity, and comply with the constitutional mandate to build a State with consolidated and functional ETIs (Ruling T-106 of 2025).

Since 2016, the sovereignty of community monitoring (see Call to Action 18) of data has been recognized as a right linked to territorial self-management, in line with the UN Declaration on the Rights of Indigenous Peoples[9]. The use of drones, satellites, and artificial intelligence has strengthened this process, reducing deforestation by up to 52% in the first year of a project with IPs in Peru[83].

Access to the internet and social media has become a strategic tool for raising the profile of territorial initiatives, such as the installation of internet by the Federation of Indigenous Organizations of the Rio Negro in communities along the Rio Negro and the coordination of more than 80 young people from 34 Indigenous Peoples in the Network of Communicators of the Coordination of Indigenous Organizations of the Brazilian Amazon[84-87].

4.6. Development of Own Economies with Monetary and Non-Monetary Processes

Indigenous, Afrodescendant, and Local Community economies integrate activities such as collective work, food security, comprehensive health, and festivities, which serve both economic functions, through collaborative monetary and non-monetary exchange systems, and sociocultural functions that strengthen community life (see Call to Action 19)[88,89]. The participation of IPs, APs, and LCs in socio-bioeconomies must ensure their leading role in innovation, the fair distribution of benefits, and the valorization of their knowledge[90-93] (see Chapter 7 and Call to Action 19). To this end, access to technical support, self-financing, and collective selling, as well as regional public procurement food security programs such as PNAE, and PAA, are essential, without compromising autonomy[94,95]. According to Raqueline Nery, executive secretary of the Médio Juruá Fund, the Médio Juruá Territory (Amazonas, Brazil) brings together 1,900 families in 58 communities that have managed to improve their quality of life through sustainable sociobioeconomy chains (pirarucu, oilseeds, handicrafts, and tourism). This has been possible thanks to the 5 million reais that the Fund invested in strengthening local capacities, conservation, and the financial autonomy of the communities.

5. Conclusions

The Amazon is a territory of multiple living connections, where connectivity manifests itself as a vital, ancestral, and holistic principle. For many Indigenous Peoples, Afrodescendant Peoples, and Local Communities (IPs, APs, and LCs), it represents systems of life deeply rooted in the territory, transmitted orally from generation to generation through collective memory and interaction with ecosystems. This connectivity intertwines spirituality, history, languages, knowledge, reciprocal relationships with nature, and care for future generations. This multidimensional connectivity forms the basis of a living fabric that promotes regional sustainability and ecological and sociocultural diversity. It is also an expression of ways of life that promote Living Well and harmony with Mother Earth.

However, forces such as invisibility, structural racism, gender inequality, the violation of territorial and cultural rights, violence, and the imposition of foreign economic and political models compromise the integrity of these links. The expansion of megaprojects and decontextualized bioeconomies accelerates the loss of territories, languages, traditional practices, and relationships with nature.

Faced with this scenario, we propose paths based on the valorization of diversity, self-determination, and the recognition of Indigenous and local knowledge systems. We highlight, in particular, the fundamental role of women in valuing socio-biodiversity, given their ancestral knowledge and practices of caring for and managing territories. Among the prioritized solutions, explored in depth in the Calls to Action, are the strengthening of Indigenous and local economies, autonomous monitoring, intercultural education, and spiritual connectivity as a pillar of conservation.

Rather than offering a closed definition, this proposal is an invitation to a “dialogue of knowledge systems” to imagine and build ways to strengthen the vital connections necessary for a Living Amazon. These opportunities and innovations emerge in the territories of Amazonian peoples and communities as sustainable paths, rooted in ancestral knowledge, community practices, and a deep respect for life in all its forms.

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Appendices

Table 5.1. Some examples of Community Protocols for Free, Prior, and Informed Consultation and potential impact on connectivity with their territories.

PEOPLE/ ORGANIZATION	COUNTRY	YEAR	SCOPE/MAIN OBJECTIVE	LEGAL STATUS / RECOGNITION	POTENTIAL CONTRIBUTION TO COMMUNITIES / CONNECTIVITY
Munduruku People	Brazil	2014	Protocol for consultation processes regarding hydroelectric and mining projects in the Tapajós basin.	Key reference in environmental litigation; recognized in national and international forums.	Strengthened the Munduruku's capacity to reject megaprojects and consolidate their territorial governance.
Xingu Indigenous Territory Association	Brazil	2017	Regional protocol for Xingu communities guides interaction with the state and companies.	Recognized by public bodies in administrative proceedings.	Promotes inter-community coordination in the Xingu Indigenous Territory, strengthening ties within the community and with the State.
Quilombola Community of Abacatal/Aurá (Pará)	Brazil	2017	Autonomous protocol for territorial defense against mining and urban expansion in Belém (PA).	Applied in local processes; cited in academic literature.	Raised awareness of urban *quilombola* communities and strengthened their defense against mining and urban expansion.
Juruna People (Yudjá, Xingu)	Brazil	2017	Defines representativeness and cultural conditions for consultation processes (Belo Monte case).	Recognized by decision by the TRF-1 (Federal Regional Court of the 1st Region).	Defined culturally appropriate representation mechanisms; used in defense against Belo Monte.
Waorani People (Pastaza, Ecuadorian Amazon)	Ecuador	2019	Protocols and standards for prior consultation in defense of their territory against oil tenders.	Recognized by court ruling (Pastaza Provincial Court, 2019).	Allowed the Waorani to stop oil tenders and strengthen territorial and cultural connectivity.
Wampís People	Peru	2022	Relationship protocol and FPIC establishing authorities, timelines, and cultural procedures.	Officially adopted by the Wampís Autonomous Territorial Government.	Consolidated the political autonomy of the Wampís Territorial Government and its binational coordination (Peru-Ecuador).
ORAU (Regional Organization of Ucayali's Interethnic Association for the Development of the Peruvian Rainforest - AIDESEP)	Peru	2024	Regional protocol for Amazonian peoples of Ucayali.	Political recognition within AIDESEP and coordination with the Peruvian government.	Strengthens AIDESEP Amazonian networks; promotes regional coordination in Ucayali.
Tacana II People (Madre de Dios River)	Bolivia	2024	Prior Consultation Protocol for Amazonian territories (infrastructure, hydrocarbons, mining).	Officially presented with support from Fundación Tierra and Anabolivia.	Increases the negotiating power of the Tacana II; protects cross-border socio-environmental connectivity.

Source: Prepared by the authors.

Table 5.2. Examples of Health Practices and Rituals of Amazonian Peoples and Communities.

PEOPLE/ COMMUNITY	COUNTRY/REGION	TRADITIONAL HEALTH PRACTICE	CULTURAL/SPIRITUAL BASIS
Achuar	Peru – Ecuador	Ritual diets and use of visionary plants	Balance between body, territory, and spirit; dreams as diagnosis and guidance
Asháninka	Peru – Brazil	Phytotherapy with master plants and traditional midwifery	Illness is associated with spiritual or social imbalance; women hold key knowledge
Munduruku	Brazil (Tapajós)	*Pajelança* ritual and use of Amazonian plants	Focused on community cohesion in the face of external threats (mining, hydroelectric dams)
Shipibo-Conibo	Peru (Ucayali)	Ritual use of ayahuasca	Spiritual diagnosis and healing through *icaros* (chants)
Wampís (GTANW)	Peru (Amazonas – Loreto)	Own system of territorial surveillance and traditional medicine	Combines healing plants with spiritual practices; coordination with the 'Life Plan'
Yanomami	Brazil – Venezuela	Shamanic shamanism with *yãkoana* (ritual powder)	Healing through dialogue with *xapiri* spirits; balance between body, forest, and community
Amazonian Quilombolas	Brazil (Amapá, Pará, Maranhão, Amazonas)	Use of medicinal plants, *benzedeiras*, and Afro-Indigenous syncretic practices	Cultural resistance to slavery; Afro-Catholic spirituality and Amazonian *orixás*
Riverside dwellers	Brazil (Amazonian floodplains)	Riverside phytotherapy, use of river knowledge and midwifery	Intrinsic relationship with flood and fishing cycles; spirituality linked to the river
Local mestizo communities	Peru, Colombia, Brazil (riverine and peri-urban areas)	Combination of traditional medicine, healing practices, and popular Catholic practices	Hybrid practices that integrate indigenous, African, and European heritage in rural and urban contexts

Source: prepared by the authors.

Table 5.3. Experiences of Intercultural Education in the Amazon Region: Indigenous Peoples, Afrodescendant Peoples (*Quilombolas*) and Local Communities (*Ribeirinhos*).

PEOPLE/NATION	COUNTRY / REGION	EXAMPLE OF INTERCULTURAL EDUCATION	IMPACT ON THE COMMUNITY
Asháninka	Peru and Brazil (border)	Bilingual education programs (Asháninka and Spanish); integration of midwifery, traditional medicine, and forest management into the local curriculum.	Strengthening of comprehensive health practices and sustainable land management.
Baniwa	Brazil (Upper Rio Negro, Amazonas)	Construction of the Baniwa Indigenous School (2000); Indigenous teacher training courses; more than 100 teachers trained; integration of crafts, agriculture, and food security into the curriculum.	Strengthening of youth leadership and intergenerational transmission of knowledge; access to postgraduate studies.
Shipibo-Conibo	Peru (Ucayali)	Intercultural bilingual schools with instruction in Shipibo and Spanish; use of traditional chants (*icaros*) and plant knowledge in community education.	Cultural enhancement and transmission of spiritual and medicinal knowledge.
Ticuna	Brazil, Colombia, Peru (Amazonian tri-border area)	Bilingual education programs in the Ticuna language; community schools in border areas; strengthening of cultural identity in urban and rural contexts.	Protection and revitalization of the Ticuna language; cross-border cultural cohesion.
Wampís	Peru (Loreto and Amazonas)	Wampís Autonomous Territorial Government with proposals for intercultural bilingual education; integration of the Wampís Statute and Life Plan into educational processes.	Consolidation of educational autonomy; coordination with territorial governance.
Afrodescendants of the Colombian Pacific and Amazon regions	Colombia (Chocó, Valle, southern Amazon)	Afro-Colombian ethno-education programs recognized by the Ministry of Education (Law 70/1993); inclusion of Afro knowledge in the curriculum in the Pacific and Amazon regions.	Strengthening of cultural citizenship; visibility of Afro contributions to national and regional history.
Afrodescendant communities of Chota (Ecuador)	Ecuador (province of Imbabura, Chota Valley)	Afrodescendant community schools that integrate music (*marimba, bomba*), history of the African diaspora, and cultural revitalization projects.	Reaffirmation of Afrodescendant identity; revitalization of cultural practices in educational contexts.
Communities in Extractivist Reserves (RESEX, Acre and Pará)	Brazil (RESEX Chico Mendes – Acre; RESEX Tapajós-Arapiuns – Pará)	Integration of the formal curriculum with practices of rubber, chestnut, and açaí extraction and community forest management.	Promotes community autonomy; strengthens the management of extractive territories.
Floodplain communities (Pará, Amazonas)	Brazil (Islands and riverbanks of the Amazon)	Contextualized education with agro-extractivism (açaí, cassava flour, fishing) and spirituality linked to the river.	Reinforces spirituality associated with the floodplain and family livelihoods; expands access to formal education.
Agricultural Family School of the Middle Juruá Territory (Amazonas)	Brazil (Middle Juruá, Amazonas)	Alternating pedagogical model (school time/community time), combining local knowledge, family farming, community management, and territorial management.	Trains young community leaders; connects education with sustainability and territorial governance in the Middle Juruá.

Sustainable Riverside Schools (Belém and Marajó, Pará)	Brazil (Islands of Belém and the Marajó Archipelago)	Community garden projects, solar energy, and teaching biodiversity applied to everyday riverine life.	Strengthens sustainable practices; improves food security and environmental awareness.
Quilombolas of Amapá and Maranhão	Brazil (North and Northeast regions)	Quilombola school education experiences with an emphasis on territoriality, ancestry, and dialogue with EIB; Ministry of Education framework (2012).	Official recognition of the specific nature of Quilombola education; strengthening of youth and community leadership.
Quilombolas of the Lower Trombetas (Oriximiná, Pará)	Brazil (Western Pará)	Community schools linked to territorial defense; intercultural training projects with universities (Federal University of Western Pará, Federal University of Pará).	Consolidation of Afro-Amazonian identity; transmission of knowledge related to mining, fishing, and forest management.
Quilombolas of Salvaterra (Marajó, Pará)	Brazil (State of Pará)	Community education processes linked to *Malungu*; integration of agriculture, medicinal knowledge, and territorial defense in formal and informal spaces.	Strengthening of *quilombola* identity; resistance to structural racism; protection of traditional knowledge.
Riverside communities of the Lower Amazon	Brazil (Western Pará)	School calendar adapted to the water cycle; teaching fishing, navigation, and subsistence practices.	Strengthens riverine identity; promotes the transmission of knowledge about fishing and river management.

Knowledge Dialogues to Strengthen Ancestral Knowledge and Interculturality in Education Systems

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Photo credit: Simone Athayde.

The Overview

Educational systems for Indigenous Peoples (IPs) in the Amazon tend to render cultures invisible, weaken biocultural and territorial ties, and exclude Indigenous knowledge, which accelerates migration and language loss. There is an urgent need to transform these systems with comprehensive and contextualized approaches that acknowledge ancestral knowledge, strengthen the territory, promote intercultural dialogue, and value education as a tool for a healthy environment and learning from difference. In this Call to Action, we focus on Indigenous Peoples and Indigenous intercultural education, without considering Afrodescendant Peoples (APs) or Local Communities (LCs), although they also face similar challenges related to colonization, discrimination, and exclusion.

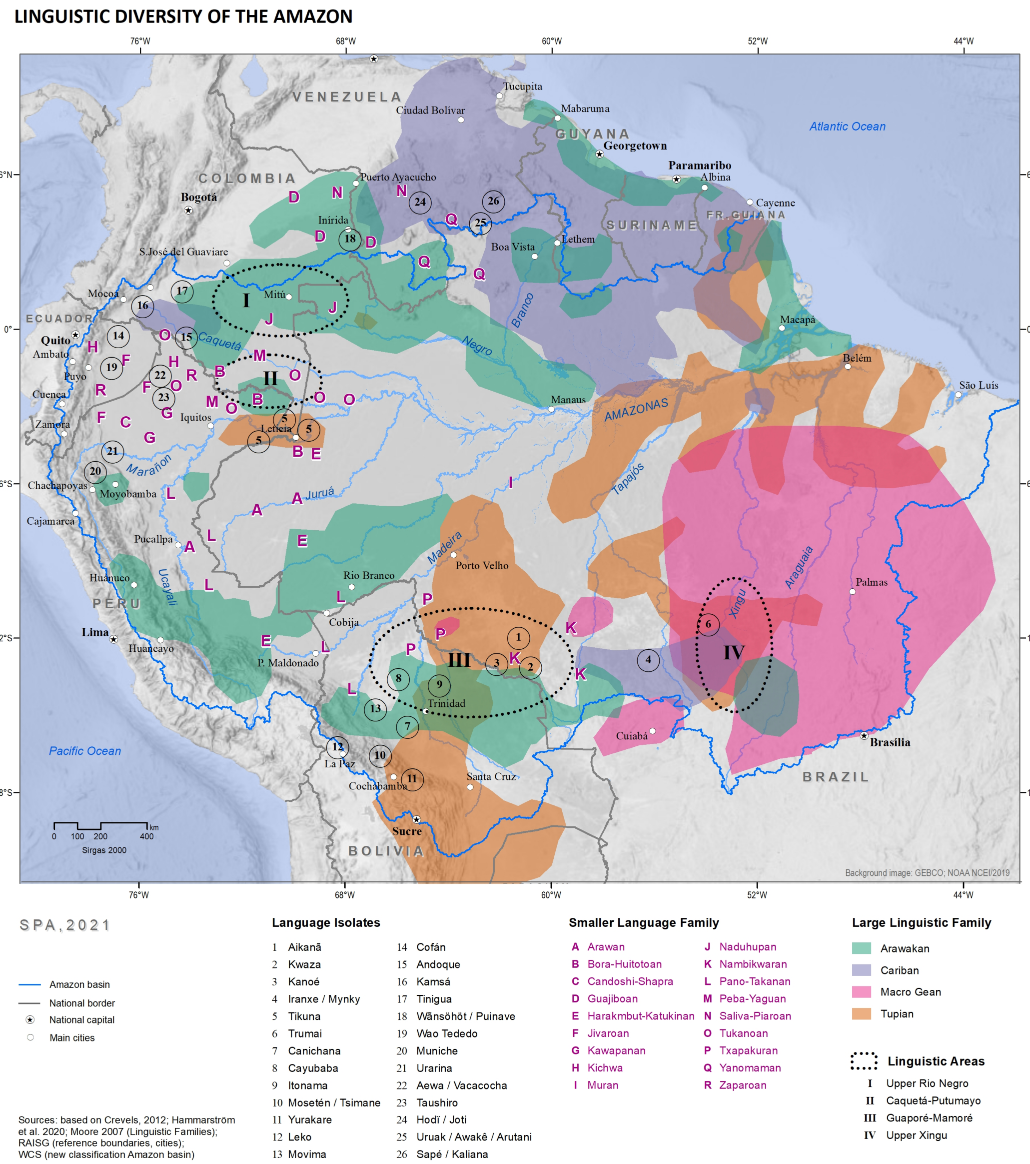

Figure C5.16.1. Linguistic diversity in the Amazon region. The map[5] shows the geographical distribution of Indigenous language families in the Amazon basin[1]. More than 300 Indigenous languages are spoken in the region, belonging to some 50 language families and numerous linguistic isolates. This situation reflects one of the highest concentrations of linguistic diversity on the planet. However, this wealth is marked by profound vulnerability, as many languages are spoken by small communities or by fewer than 1,000 speakers, and several are critically endangered[5]. Linguistic isolates, defined as languages with no known relationship to other languages, highlight the historical and cultural complexity of the Amazon, while territorial fragmentation and external pressures threaten the intergenerational transmission of this ancestral linguistic knowledge.

The Facts

- Approximately 2.2 million Indigenous people belonging to over 400 different groups and speaking over 300 different languages live in the Amazon region, including around 80 living in voluntary isolation1 (**Figure C5.16.1**). However, most national education systems in the region continue to prioritize dominant languages and Western curricula, marginalizing local knowledge[2].

- The lack of nearby educational centers in many Indigenous Territories (ITs) forces students to migrate, contributing to cultural disconnection and the erosion of ancestral knowledge[3].

- The limited availability of long-term funding for Indigenous education initiatives remains under-implemented due to bureaucratic delays and a lack of strong local governance[4].

- Although countries such as Brazil, Peru, Bolivia, and Colombia have intercultural education policies in line with the United Nations (UN) Declaration on the Rights of Indigenous Peoples, which favor the use of native languages and Indigenous knowledge, their implementation remains limited and disjointed. As a result, Indigenous and Local knowledge systems remain largely invisible in mainstream education, reducing the relevance and inclusiveness of learning for young people[4].

Global/Regional and Synergistic Connections

- International Indigenous Languages Decade (2022-2032, UN Educational, Scientific and Cultural Organization): Promotes the revitalization and promotion of languages that are fundamental to cultural identity, knowledge transmission, and bilingual education.

- UN Permanent Forum on Indigenous Issues highlights the role of languages in the transmission of knowledge, climate resilience, and sustainable development.

- Goal 4 of the Sustainable Development Goals promotes inclusive and equitable education that respects cultural diversity and ensures parity in educational access.

- Convention 169 of the International Labor Organization acknowledges the right of Indigenous Peoples to have their own institutions, languages, and educational systems.
- Amazon Cooperation Treaty Organization facilitates regional dialogue and the integration of Indigenous perspectives into public policy.

Figure C.5.16.1. Examples of formal bilingual and intercultural policies in Amazonian countries, including the overseas territory of French Guiana.

COUNTRY / OVERSEAS TERRITORY	POLICY	INCLUSIVE AND BILINGUAL EDUCATION PROGRAMS	LANGUAGES IN EDUCATION
Bolivia	Plurilingual Education	Community-based	36 languages
Brazil	EIB (Intercultural Bilingual Education)	3,359 schools, 1,120 in the State of Amazonas	Over 180 languages
Colombia	PEBI (Intercultural Bilingual Education Program)	Implemented by the Cauca Regional Indigenous Council at the national level for IPs	12 IPs with their respective native languages
Colombia	Ethnopedagogy (Decree 804)	Community-led	Over 65 languages
Colombia	Decree 0481 of 2025 SEIP (National Indigenous Education System)	Applicable to Indigenous reserves and territories throughout Colombia	Over 84 Indigenous languages from 115 peoples
Ecuador	EIB (DINEIB), Constitution of the Republic of Ecuador	More than 1,500 schools	14 languages
French Guiana	French curriculum, somewhat bilingual	Pilot programs	*Kali'na, Wayana*
Guyana	Draft Indigenous Policy (Amerindian Act)	Limited	Some programs
Peru	EIB (National Policy): Law on Intercultural Bilingual Education and Supreme Decree Nº 006-2016-MINEDU	Over 20,000 schools	48 languages
Suriname	No formal policy Check Rutu Foundation and Le Pichon and Kambel (2016)6.	Pilot projects include the *Kali'na, Lokono* and *Saamaka* languages	A policy is being developed to include the *Kali'na, Wayana, Arawak, Tiriyó, Saamaka*, and *Ndyuka* languages in education systems
Venezuela	Organic Law on Indigenous Peoples and Communities. Official Gazette Nº 38,344	Supported by the State	44 languages (limited)

The Solutions Space

Recent Major Government Efforts

- Countries such as Ecuador (through the National Directorate for Intercultural Bilingual Education, DINEIB) and Brazil (through Indigenous school councils) have **decentralized educational governance**, allowing IPs to manage schools and curricula.

- In Bolivia and Colombia, there are **national policies that establish bilingual education** from early childhood, resisting transitional models that progressively eliminate Indigenous languages. For more bilingual and intercultural policies in Amazonian countries, see **Table C.5.16.1**.

- In Colombia, the recent approval of a statewide public policy that establishes **the National Indigenous Education System (SEIP)** represents a significant step toward autonomy for IPs in terms of developing and managing their own education systems.

- In 2016, **the National Learning Service (SENA) created its Policy of Pluralistic and Differential Care**. As a result, there are models of ethnopedagogy that integrate the histories, sciences, and geographies of IPs and APs into training curricula.

Positive Efforts for Scaling

- **Local Research Route:** Developed by SENA in the Vaupés region of Colombia, this initiative promotes research skills among Indigenous youth from 27 groups. By integrating technical and ancestral knowledge based on sustainable practices that respect life and the natural environment, this initiative contributes to strengthening their cultural identity (C5.16.2).

- The ***Escola Viva Indígena Baniwa e Koripako Pamáali*** (EIBK-Pamáali), Brazil: The EIBK-Pamáali, founded in 2000 by the Baniwa and Koripako peoples in the Upper Rio Negro (Brazil), is a model of intercultural and plurilingual Indigenous education. Managed by local leaders, it integrates traditional knowledge and national standards, promoting community learning, sustainability, Indigenous rights, and the use of the Baniwa language (**Figure C5.16.2**).

- In Suriname, where Dutch is the main language of instruction, the pilot project "Maths, Naturally!" (2010–2014), led by the Rutu Foundation with support from UNICEF, strengthened the learning of Indigenous and Afro-descendant children through bilingual education in Kali'na, Lokono, and Saamaka. The initiative promoted intercultural pedagogies and community participation, driving recent policies that reintroduce multilingualism and incorporate local languages into the education system (**Figure C5.16.2**).

- The ***Aprendo en Casa*** ***and Canaima programs:*** In Peru and Venezuela, the Aprendo en Casa and Canaima Educativo programs used technology during the pandemic to promote inclusion and bilingual education. In Peru, content was adapted to Indigenous languages; in Venezuela, connectivity was expanded in remote areas. Both initiatives strengthened cultural identity and demonstrated that technology can reduce gaps, democratize learning, and value the knowledge and languages of historically excluded communities.

Figure C5.16.2. Relevant examples of knowledge dialogues and intercultural education initiatives in the Amazon. A) Local research seedbed in ethno-ornithology in Vaupés (Colombia), developed as part of the 'Local Research Route' program led by SENA. Photo credit: Gloria A. Rivera Velasco. B and C) Students from the EIBK-Pamáali Living School. Photo credit: Indigenous Organization of the Içana Basin (OIBI). D) Pilot project "Maths, Naturally!" led by the Rutu Foundation and supported by UNICEF in Suriname. Delivery of bilingual books to schoolteachers. Photo credit: Rutu Foundation.

Recommendations

- **Create the Amazonian Fund for Intercultural Education.** Promote the creation of this fund with the participation of the eight Amazonian countries, aimed at financing scholarships, educational projects, and research that will integrate ancestral knowledge, sustainability, and territory. This fund should also support research on the status and strengthening of Indigenous languages and cultural revitalization programs.

- **Strengthen intercultural teacher training.** Implement mandatory teacher training programs, with in-person and virtual sessions, co-teaching by local experts, ongoing mentoring, and certification in intercultural pedagogy, aimed at both Indigenous and non-Indigenous teachers. These actions improve teaching skills and expand instruction in native languages, as demonstrated by the experiences of Ticuna teacher training in Brazil.

- **Revitalize Indigenous languages and cultures in schools.** Create a regional language and cultural revitalization plan that supports autonomous Indigenous schools, integrates instruction in local languages into formal education systems, develops language assessments, and funds bilingual and culturally relevant educational materials.

- **Co-create curricula with local communities.** Establish working groups with IPs, APs, and LCs to design flexible curricula that reflect their worldviews, knowledge systems, biocultural practices, and technical knowledge, along with teaching materials adapted to the territory.

- **Establish educational pathways starting at the local level and extending to higher education.** Implement programs for access, transition, and continuity in education, from rural schools to technical and university education, with scholarships and retention models adapted to Amazonian contexts. These pathways should include specific offerings for adult students and relevant intercultural education, as demonstrated by the experience of Amawtay Wasi University in Ecuador.

- **Institutionalize community participation in educational policies.** Create permanent mechanisms for consultation, monitoring, and evaluation with local leaders, guaranteeing multi-year funding, direct participation in policy formulation, and territorial autonomy in educational planning and management. The creation of intercultural technical units within ministries and local governments is also recommended.

- **Establish a Pan-Amazonian Network for Intercultural Education.** Bring together Indigenous, Afro-descendant, and Local Community organizations, as well as governments and universities, to design common agendas, coordinate cross-border programs for the exchange of teachers and materials, and promote the appreciation of ancestral knowledge as intangible cultural heritage. Initiatives such as the Uka Network, led by Indigenous organizations in the Peruvian Amazon, illustrate the potential of these alliances to strengthen intercultural education in the region.

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Establish Spiritual Connectivity to Conserve the Amazon

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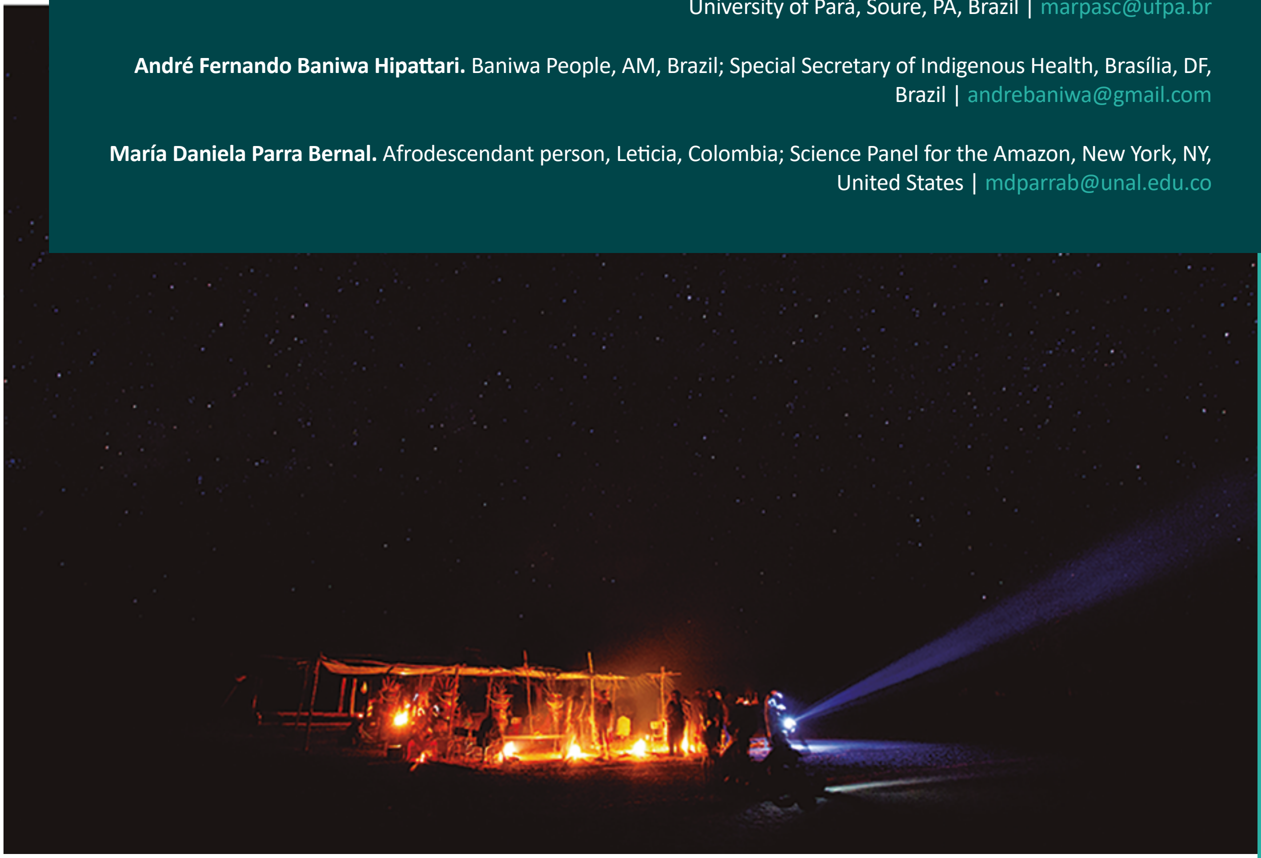

Photo credit: Paulo Santos / Amazonia Real

The Overview

There are diverse forms of spiritual connectivity among Indigenous Peoples (IPs), Afrodescendant Peoples (APs), and Local Communities (LCs), such as Living Well (Buen Vivir)[1] and *Ubuntu*, which share a common foundation in relational ontology: all beings, human and non-human, are part of the cycle of life. In this sense, spirituality has structured collective knowledge systems that sustain social cohesion, ecological resilience, and territories with lower rates of deforestation in the Amazon; it is not simply an ornament or an aspect of culture, but a vital principle for collective well-being. Nevertheless, these forms remain largely invisible and insufficiently interwoven into conservation policies, and they are not acknowledged as modes of environmental governance.

Figure C5.17.1. Nascimiento de Ka'mari. A symbolic representation of holistic interdependence for the care of life and the preservation of the vital principle of spiritual connectivity for territorial management. The work reflects part of the traditional spiritual connectivity of the Yuruparí People. Photo credit: Jeisson Castillo.

The Facts

- Over 385 IPs and APs in the Amazon integrate spiritual practices as the basis of their territorial governance and cultural identity[2,3] (see Figure C5.17.1 for a symbolic representation).
- In Indigenous Amazonian worldviews, and similarly among some Afrodescendant Communities, knowledge systems are sustained by relational interaction with non-human beings (e.g., plants, animals, rivers, mountains, constellations), all perceived as bearers of agency and knowledge.
- It is estimated that approximately half of the Amazon is legally protected, but between 2015 and 2020, 5% of deforestation occurred within Indigenous Territories (ITs)[4], implying the loss of "places of power" recognized by various ethnic groups as essential to their cosmologies.

Global/Regional and Synergistic Connections

- The United Nations (UN) Declaration on the Rights of Indigenous Peoples (2007) recognizes cultural and spiritual practices as fundamental to territorial sustainability, conservation, and well-being.
- International platforms such as the UN's Local Communities and Indigenous Peoples Platform and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services promote the interweaving of ancestral and scientific knowledge. This multi-knowledge governance approach, supported by research in political ecology, has been shown to enhance both the social legitimacy and the effectiveness of environmental policies.
- International commitments, such as Convention 169 of the International Labour Organization (ILO 169), recognize and protect the social, cultural, religious, and spiritual values and practices of Indigenous Peoples. However, the gap between rhetoric and actual implementation remains a critical obstacle to the realization of the rights and participation of IPs, APs, and LCs in decision-making processes.

The Solutions Space

Selected Key Tools

- **Indigenous well-being** indicators that combine spirituality and environmental metrics have been developed by the Sinchi Amazonian Scientific Research Institute through community consultations and applied in participatory land-use planning processes in Indigenous Communities in the Colombian Amazon to ensure effective and culturally legitimate monitoring.

- **The Amazon Conservation Team (Colombia) has promoted** participatory maps that identify spiritual sites important to Indigenous Communities for integration into national geographic information systems to monitor and protect Indigenous Territories and Protected Areas.

- **Community protocols**, such as those implemented by the National Coordination of Black Rural *Quilombola* Communities (CONAQ) in Brazil, combine their own social and cultural indicators with environmental metrics to monitor the ecological and spiritual health of territories. These tools ensure their visibility and effective inclusion in national conservation plans.

- **The** Life Plans of IPs function as normative and strategic frameworks that interweave their knowledge systems into a collective roadmap. These instruments position spirituality as a core element of territorial governance (see also Faith for the Earth Coalition[5]), acknowledging that rituals, ceremonies, and spiritual relationships serve as mechanisms of ecological regulation.

Collaborative Efforts

- **The** Gaia Amazonas Foundation (Colombia) has supported the IPs of the eastern Colombian Amazon to become territorial entities, using the guidelines of knowledge systems and ways of life of these peoples. This has resulted in the legal recognition of more than 25 million hectares of ITs, such as the creation of the Yaigojé-Apaporis Indigenous Reserve and the strengthening of traditional governance in other Indigenous territories of the Colombian Amazon.

- **The regional** Amazon Sacred Headwaters Alliance is led by Indigenous organizations such as the Coordinator of the Indigenous Organizations of the Amazon Basin (COICA), the Confederation of Indigenous Nationalities of the Ecuadorian Amazon, and the

Interethnic Association for the Development of the Peruvian Rainforest, in partnership with international scientific institutions. It has designed a collaborative territorial planning model that combines the worldviews of "Living Well" (*Buen Vivir*, or *Sumak Kawsay* in Quechua) with scientific methods, including ecological analysis and satellite monitoring.

- **Amazonian Indigenous Communities**, such as the Bará in Colombia with *dabucurí* and the Shipibo-Conibo in Peru with *íkaros*, **engage in intercultural rituals and ceremonies** to strengthen territorial and interethnic alliances. The Shipibo-Conibo *íkaros* was declared part of the National Cultural Heritage in 2016, legally reinforcing the cultural and environmental protection of Shipibo-Conibo territories.

Major Recent Governmental Efforts

- **The governments of Ecuador and Bolivia have constitutionally adopted the "Living Well" model** as the central axis of their environmental policies. This framework emphasizes that environmental conservation must be articulated with the maintenance of spiritual connectivity as an essential element of collective well-being, and it has influenced government programs that actively connect Indigenous knowledge systems and spirituality into territorial conservation projects.

- Some **Amazonian governments are advancing the formal inclusion of Indigenous governance systems** based on spirituality and ancestral knowledge in their national climate and biodiversity policies. For instance, in Colombia, this is reflected in the legal recognition of Indigenous Territorial Entities (ETIs) through Decree 1953 of 2014, which created a special administrative and fiscal regime, and more recently through Decree 488 of 2025, which established fiscal and operational rules for their functioning.

- In preparation for UNFCCC COP30, **Amazonian Indigenous leaders presented a position paper affirming the importance of Indigenous territories not only as physical spaces but also as sacred sites** where spirituality, nature, and community converge. The declaration demands the comprehensive protection and urgent legal demarcation of these territories, especially those occupied by peoples in voluntary isolation, arguing for their vital role in climate mitigation and the conservation of global biodiversity.

- **CONAQ has integrated ancestral spiritual practices (ubuntu) with concrete territorial protection strategies**, generating legal frameworks and public policies specific to *quilombola* and other Afrodescendant communities. These recent government efforts include territorial recognition and inclusion of these communities in national biodiversity, climate adaptation, and sustainable development plans.

Recommendations

- **Call on states to adopt, through binding law, Indigenous, Afrodescendant, and Local territorial planning** as an integral foundation for national conservation plans, with verifiable mechanisms differentiated according to the cultural and spiritual characteristics of each group.

- **Instruct multilateral agencies to recognize the ways of living of IPs, APs, and LCs as conservation technologies to guarantee the Living Well of humanity**. Practices such as low-impact agriculture, sustainable extractivism, and the medicinal use of plants are examples of knowledge critical for the conservation of forests and entire ecosystems. Funding should be channeled directly through Indigenous, Afrodescendant, and Local funds that implement their own life and territorial management plans.

- **Include spiritual, relational, and community indicators, which are part of the Living Well concept, into official environmental monitoring systems**.

- **Legally mandate free, prior, and informed consent (FPIC)** as an essential requirement for any intervention in Indigenous, Afrodescendant, and Local territories, ensuring that such processes explicitly respect their own ritual, cultural, and productive calendars.

- **Institutionalize the permanent and effective participation of IP, AP, and LC spiritual, cultural, and traditional representatives** in national and subnational councils for the environment, sustainable development, and territorial planning, with a decisive voice and vote.

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Acknowledge, Raise Awareness, and Strengthen Independent Community Monitoring

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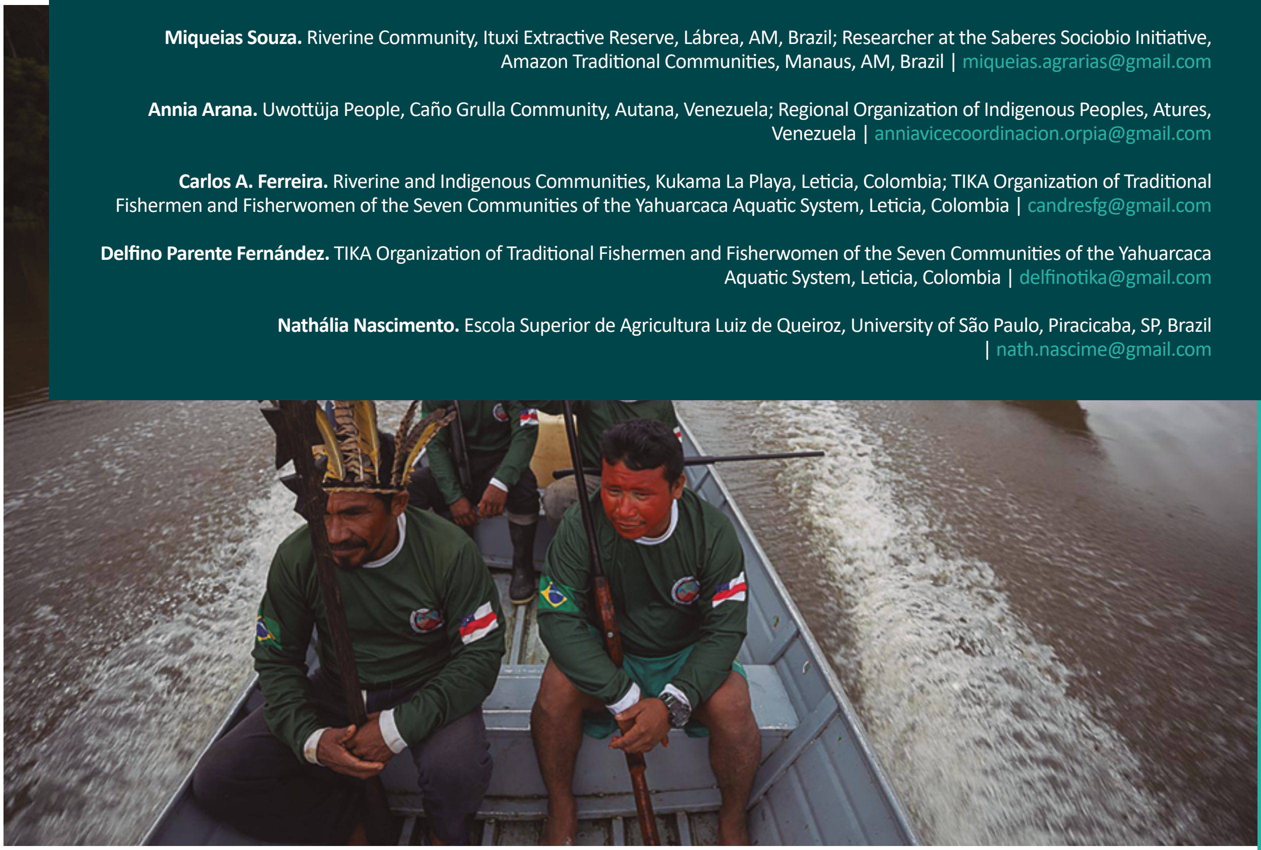

Photo credit: Bruno Kelly / Amazônia Real

The Overview

For generations, Indigenous Peoples (IPs), Afro-descendant Peoples (APs), and Local Communities (LCs) in the Amazon have developed practices, understandings, and methodologies for community monitoring systems that are integrated with their territories. These systems protect territories, generate knowledge, strengthen governance, support the defense of socio-environmental rights, and are recognized in various conventions and treaties. However, these monitoring practices and systems have not been implemented in official management systems. By consolidating social organization and connecting local struggles with global agendas, their territorialities offer inspiration to offset predatory development models.

The Facts

- IPs, APs, and LCs protect their territories from invasions and external pressures, and ensuring their rights is a vital strategy for preventing deforestation[1-3], protecting biodiversity[4,5], and mitigating climate change by avoiding a 2°C increase by 2030[6].

- More than 20% of Indigenous Territories (ITs) in the Amazon have mining overlaps[7].

- The science of IPs, APs, and LCs in their territories has systemic and relational foundations and can transform academic knowledge (see Chapters 5 and 8).

- Community monitoring strengthens territorial governance and socio-ecological systems by integrating not only environmental data, but also local histories and cosmologies (see Chapter 5).

- Monitoring supports political advocacy and the defense of socio-environmental rights, as well as reinforces legal complaints and actions, alliances, innovations, and negotiation processes with states and companies (see Call to Action 13, Chapter 4).

Global/Regional and Synergistic Connections

- International commitments on climate, deforestation reduction, and ecological restoration (e.g., the Paris Agreement, the Glasgow Climate Pact, and the United Nations (UN) Decade on Ecosystem Restoration) acknowledge the importance of traditional knowledge and community monitoring systems to official systems, reinforcing the role of "locally led adaptation" for mitigation. In terms of biodiversity, agreements such as the Convention on Biological Diversity, the Nagoya Protocol, and the Kunming-Montreal Global Biodiversity Framework recognize the rights and direct participation of IPs and LCs with regard to their territories and other species and their uses. The International Labour Organization's Convention 169, the UN Declaration on the Rights of Indigenous Peoples, the 2030 Agenda, and the Escazú Agreement lay the legal foundations for free, prior, and informed consultation and the protection of environmental advocates, providing support for territorial self-determination.

Figure C5.18.1. Map with examples of community monitoring initiatives mentioned in the Call to Action. It should be noted that this is not a complete list (see legend for the categories). The map features examples discussed in The Solutions Space section.

The Solutions Space

Collaborative Efforts

- **Social mobilization**, recognized within national frameworks, are organized into communities (e.g., associations, collectives, and local networks of IPs, APs, and LCs) that maintain monitoring systems, at times with support from partners. Participatory methodologies, community protocols, and feedback assemblies are key to their legitimacy. Their transnational circulation promotes interoperability and strengthens horizontal alliances (**Figure C.5.18.1**).

- **Cross-sectoral efforts and networks between communities, universities, and civil society organizations create territorial monitoring platforms**[8-9]. These initiatives include biodiversity monitoring at the local, state, and federal levels, such as the Participatory Monitoring of Biodiversity in Amazon Conservation Units Project of the Ecological Research Institute and the Biodiversity and Natural Resource Use Monitoring Program (Brazil). There are also experiences focused on community autonomy, the centeredness of narratives, and the use of data for public advocacy[10,11], such as fisheries governance in the continental Amazon[12,13] (e.g., Ictio). Community fishing agreements that restore populations and have generated fairer incomes (e.g., Tika organization in Colombia), participatory management of pirarucu, and co-management in Amazonian aquatic systems[10-14], bringing together organizations from Bolivia, Brazil, Colombia, Ecuador, the United States, France, and Peru through the Amazon Waters Alliance.

- **Collective governance includes community monitoring practices, such as self-demarcation[15] and territorial surveillance**. The importance of protecting Indigenous Peoples in isolation and initial contact (PIACI) stands out, especially in Brazil and Peru, where monitoring is led by Indigenous associations, with the support of civil society and international organizations. Such monitoring implements non-contact strategies and appropriate technologies to ensure effective protection[16-20]. Notable examples include Indigenous protocols for the protection of PIACI by the Regional Organization Aidesep Ucayali in Peru and the protection of the Pirititi by the Waimiri Atroari in Brazil[20].

- The Amazon Sacred Headwaters Initiative brings together more than 20 Indigenous nationalities in defense of their territories against oil expansion and other extractive industries. Their collective action protects the ecological and sociocultural connectivity of the region, helping to maintain biological corridors between watersheds, strengthening cross-border Indigenous governance, and preventing the emission of tons of CO_2.

Best Practices

- **When successfully implemented, integrated fire management combines advanced climate monitoring technologies with intercultural and territorial approaches**. For a shared and effective agenda, it is essential to start from a basis of respect for community knowledge, values, and practices. This agenda should include control, safety, training, technology transfer, and impact mitigation actions, also incorporating studies and new techniques adapted to the local context. Notable examples include A'uwẽ hunters who burn according to established cultural protocols, manage fire in a conservationist manner, and do not cause environmental degradation through burning[21].

- **Co-management and community hunting** in Ecuador[22], the Wapichan protocols and territorial plans in Guyana (e.g., Forest Peoples Programme and Kanashen Community Owned Conservation Area), Indigenous and Maroon rangers in Suriname[23,24], and independent reports against illegal mining in Venezuela demonstrate the diversity of local practices.

- **Monitoring led by women, which receives little media coverage, deserves special attention**. Some examples include the Munduruku women in the Tapajós basin, who are fighting for the security of their territory[25], the Yanomami and Indigenous and Afro-descendant associations monitoring COVID-19 and other health and sanitation issues[26-28] (e.g., Observatório da COVID-19 nos Quilombos), and the monitors of the Maró IT[29]. Women's movements such as the Yarang in Xingu, Kumirãyõma among the Yanomami, and the babassu coconut crushers strengthen ecological restoration and women's networks, expanding community and ecosystem resilience and integrating practices of environmental monitoring, communality, and spirituality.

- **Community monitoring is key in the face of large-scale state and corporate projects that curtail rights and cause damage**[30]. In the case of the Belo Monte hydroelectric dam (Brazil), the Juruna people and riverine communities documented the impact on flooding and fishing, producing their own data to counter official underestimations[31-33], as well as in the case of the Teles Pires River hydroelectric dams[34]. On the BR-174 highway, the Waimiri Atroari community and its supporters have been monitoring traffic and wildlife roadkill for over 20 years, as well as managing wildlife corridors[35-39]. Independent monitoring in the context of pesticides used by agribusiness in the Xingu Indigenous Park, illegal gold mining (see Chapter 2), mercury contamination in the Munduruku and Yanomami ITs[40,41], and the impacts on the quality of water and ecosystems in Cochabamba (Bolivia) also demonstrate the importance and strength of community monitoring in the face of the development model.

Recommendations

- **Institutional acknowledgement and autonomy:** Integrate community monitoring into protected area plans, water, climate, and land use policies. Formalization of co-governance agreements between communities, the public sector, universities, NGOs, and research institutions, guaranteeing data sovereignty and respect for epistemologies and temporalities, with adequate support.

- **Infrastructure and technical support:** Develop intercultural and logistical centers that connect communities, researchers, and technicians. Equip these centers with appropriate technologies and local tools, ensuring continuous and autonomous monitoring. Include mixed teams of young people, women, community members, and external professionals.

- **Training and intercultural exchanges:** Implement training processes that integrate technological management and epistemological reflection. Include territorial monitoring in educational programs starting in elementary school and encourage regional exchanges.

- **Community indicators and participation of women and young people:** Define local indicators that reflect cultural values, seasonal cycles, and worldviews. Recognize the role of women in oversight and knowledge production, documenting their contributions to science and conservation. Establish active listening methodologies to ensure participatory governance and data sovereignty.

- **Direct and sustainable financing:** Create international, national, and local financing mechanisms without intermediaries that ensure continuous and predictable resources. Include funds for technology, infrastructure, and training. Promote mechanisms that strengthen community financial autonomy in the management of monitoring systems.

Key Recent Literature

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See full list of references here

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Support and Promote the Economies of Indigenous Peoples, Afrodescendant Peoples and Local Communities

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Photo credits: Associação Quilombola de Agricultores e Produtores Rurais do Rio Capim (AQAPRIC) and Danilo Miranda.

The Overview

The economies of Indigenous Peoples (IPs), Afrodescendant Peoples (APs), and Local Communities (LCs) in the Amazon integrate ancestral knowledge, sustainable resource management, and community governance[1] (see Chapter 7). They are concrete expressions of cultural sovereignty, economic resilience, and environmental stewardship. In addition, they offer alternatives to dominant extractive models, strengthen identity, and promote dignified and resilient ways of life facing the threats of climate change, globalization, and historical exclusion. Anchored in community cooperation, these initiatives depend crucially on territorial recognition as a basis for confronting the threats of megaprojects, extractive policies, and bioeconomy projects that do not consider their own modes of production and exchange.

CALL TO ACTION 19

The Facts

- IPs, APs, and LCs' direct access to financing for their economies remains an exception. Between 2011 and 2020, less than 1% of the Official Development Assistance (ODA) allocated to climate action was directed toward guaranteeing the rights and territorial and environmental management of Indigenous Peoples. Only 17% of this percentage was invested directly in Indigenous organizations and networks or in projects that explicitly mention them[2].

- Territorial pressures affect production, logistics flows, and the food and economic security of local populations.

- In Brazil, around 67% of agricultural and extractive facilities located on Indigenous lands have as the main objective of meeting their own food needs through horticultural production[3].

- Bioeconomy strategies can put pressure on the territory if they are not created collectively, altering ways of life and jeopardizing food security, as well as physical and spiritual connectivity.

- World Bank assessments reveal significant physical and digital "connectivity gaps" in the Amazonian corridors of Brazil, Colombia, and Peru—bottlenecks that increase transportation costs and isolate community producers from markets[4].

Global/Regional and Synergistic Connections

- Support for the local economies of IPs, APs, and LCs contributes directly to the Sustainable Development Goals (SDGs), particularly those related to poverty eradication (SDG 1), decent work and economic growth (SDG 8), responsible consumption and production (SDG 12), climate action (SDG 13), and life on land (SDG 15).

- Instruments such as Convention 169 of the International Labour Organization and the United Nations Declaration on the Rights of Indigenous Peoples ensure free, prior, and informed consultation (FPIC) on projects that affect their territories, which is essential to strengthening these economies.

- The Convention on Biological Diversity, by recognizing rights to traditional knowledge, together with the Paris Agreement and the goals of restoration and climate justice, reinforce the importance of local economies of IPs, APs, and LCs as pillars for biodiversity conservation, climate action, and sustainable development based on territories[5].

The Solutions Space

Collaborative Efforts

- Multi-stakeholder networks between communities, Indigenous organizations, non-governmental organizations, universities, and governments, such as **Rede Xingú+, the Coletivo da Castanha, and Rede Origens Brasil, support technical, legal, and organizational training processes and provide logistical and commercial assistance.**

- **Digital platforms like Biomas a um Clique (Biomes in a Click)**, along with local and green markets, **are essential for fair trade** of products and services from Amazonian communities.

Major Recent Governmental Action

- Public procurement programs for food, handcrafts, and environmental services from traditional communities, such as the Food Procurement Program and the National School Feeding Program in Brazil, **promote solidarity-based economies and local economies.**

- **Inclusive national development plans** such as the Ministry of Integration and Regional Development's BioRegio Plan and the Ministry of the Environment and Climate Change's National Socio-Bioeconomy Plan in Brazil recognize local economies as drivers of the "economy for life" and regional convergence.

- Under the leadership of the Ecuadorian government—in line with the White Paper on Bioeconomy and in coordination with ministries, local governments, and international organizations—as well as with the active participation of leaders from the Kichwa, Shuar, and Waorani communities, **the production chain for morete (a local palm fruit) was developed**. This process seeks to export 10 tons of pulp by 2025, implementing an inclusive community-focused bioeconomy model[6].

Positive Scaling Initiatives

- Experiences of ecological community tourism, such as those developed in **the Parc Amazonien de Guyane**, where more than 90% of the local economy depends on ecotourism and cultural activities managed by IPs, APs, and LCs, demonstrate the potential for integrating environmental education, cultural identity, and sustainable income generation.

- **Ecuador's Socio Bosque Program** provides payments for environmental services, supporting 70 community bio-ventures nationwide and benefiting 46,000 people in the Ecuadorian Amazon.

- **Certifications and seals of origin**, such as those of Indigenous origin, family farming, and traditional peoples, contribute to strengthening fair trade and the solidarity economy. A notable example is Tikuna chocolates from Colombia.

- **The Pimenta Baniwa** brings together more than 70 local varieties of *Capsicum* peppers and symbolizes the agrobiodiversity of the Baniwa territory. The project holds a central place in the social and cultural life of local residents and strengthens the local economy through sustainable alternatives that reduce the pressure of illegal activities. The entire process, from cultivation to packaging, is led by Baniwa women, who receive a significant share of the final value of the product.

- *Quilombola* communities such as Novo Jauara, Berajuba, and **the Associação Quilombolas de Agricultores e Produtores Rurais do Rio Capim, in Pará, Brazil, develop their own models of economic organization** based on cooperation and the exchange of traditional knowledge, strengthening community economies that value their territories and ways of life.

- **Self-managed community funds**, such as the Fundo Médio Juruá, which supports more than 1,900 families in 58 communities and has channeled almost BRL5 million since 2017; the Fundo Podáali, led by Indigenous communities; and the Amazon Fund for Life, from the Coordinator of Indigenous Organizations of the Amazon Basin, with an initial allocation of USD10 million (2023/24) for Indigenous economy projects led by organizations from the eight countries, are key examples of financial mechanisms aimed at promoting sustainable economies and expanding communities' direct access to resources for their development.

Figure C5.19.1. Pimenta Baniwa. Photo credits: Organização Indígena da Bacia do *Içana* (OIBI).

Recommendations

- **Unblock the titling of Indigenous, Afrodescendant, and Local territories** through participatory mechanisms and the effective implementation of FPIC, guaranteeing legal security as a basis for their economies.

- **Create and provide sustainable resources to specific national and regional funds for the strengthening of community production chains**, with simplified access and cultural relevance.

- **Promote, finance, and protect collective brands and fair-trade certifications for Amazonian products**, reinforcing their cultural, ecological, and economic value in local and international markets.

- **Invest in intercultural technical, financial, and political training programs**, aimed especially at women and young people, to consolidate local management and leadership capacities.

- **Integrate local economies as strategic components of national development plans and climate agendas**, recognizing their contribution to the SDGs, climate justice, and biodiversity conservation.

- **Encourage multisectoral partnerships** involving communities, the responsible private sector, universities, and international cooperation for innovation in community-based products, services, and economic models.

- **Promote territorial management plans that encourage collaborative and collective decision-making**, impacting ways of life, sustainable development, the generation of goods and services, and relations with external markets.

- **Establish community territorial observatories to monitor, document, and defend territorial, environmental, and cultural rights** (see Call to Action 18). The recognition and effective protection of territories are essential for IPs, APs, and LCs to consolidate economic models based on autonomy, social justice, and environmental sustainability.

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CHAPTER 6

Fostering Connectivity in Production Landscapes:

Supporting Multifunctional Systems for Biodiversity and Well-Being

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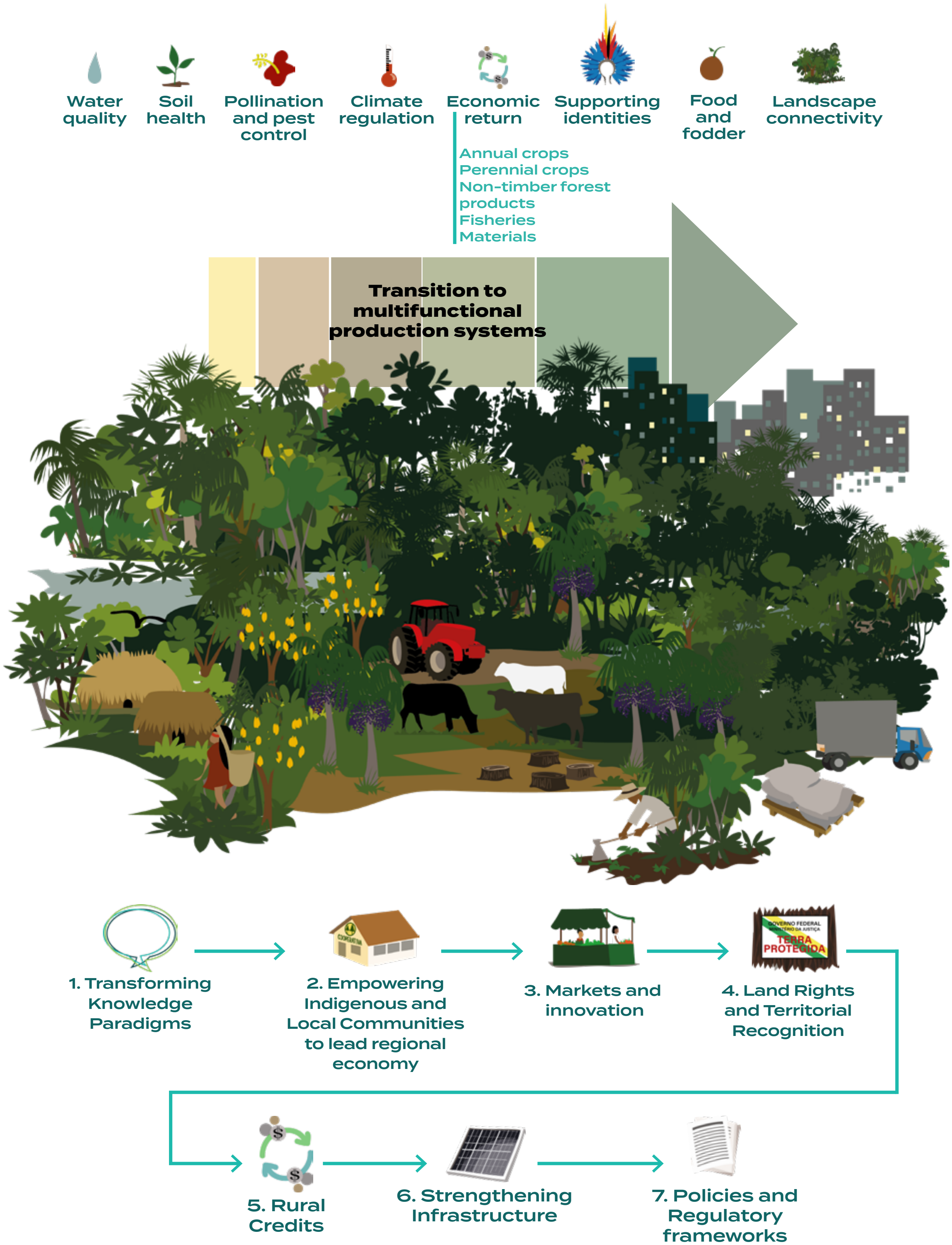
Abstract

Multifunctional production systems have long been managed by Indigenous and Afrodescendant Peoples and Local Communities (hereafter IPs & LCs) in the Amazon. These systems supply food along with other essentials for a good quality of life—such as medicines, artisanal and construction materials—while sustaining biodiversity, ecosystem functions, cultural heritage, and local economies. In contrast, dominant development models have promoted extensive monocultures and pastures, which now occupy the majority of deforested areas in the region. Despite these changes, multifunctional production systems persist over time, evolve, and form the backbone of Amazonian economies that are based on socio-biodiversity. Yet, they face converging threats: statistical invisibility, erosion of Indigenous and local knowledge, economic fragility, declining productivity, weak infrastructure, labor constraints, and escalating climate risks. This chapter addresses the current configuration of production systems in the Amazon and their major social, economic, and environmental implications, while considering their contributions to landscape connectivity. It shows how multifunctional production systems offer viable pathways for restoring degraded areas and adopting more ecologically resilient, climatically adaptive, economically viable, inclusive, and sustainable Amazonian land uses. This chapter also highlights the socioeconomic and environmental trade-offs inherent in different land-use configurations, showing that multifunctional systems can enhance ecological integrity while generating employment, supplying products, and supporting cultural heritage. We present pathways and mechanisms that can support complex multifunctional landscapes. These include transforming knowledge construction paradigms, financing systems, and land tenure and also repurposing existing credit mechanisms. Our approach also involves empowering communities to lead commercial ventures and to develop value-added supply chains, and reframing public policies and public opinion in support of multifunctional production systems. Continuing to recognize and strengthen multifunctional production systems developed by Indigenous and rural communities is vital for shaping a future Amazon that is socially just, socially and ecologically connected, adaptive, and economically viable.

Keywords

socio-bioeconomy, land-use transition, landscape connectivity, well-being, multifunctional landscapes



Water quality
Soil health
Pollination and pest control
Climate regulation
Economic return
Annual crops
Perennial crops
Non-timber forest products
Fisheries
Materials
Supporting identities
Food and fodder
Landscape connectivity
Transition to multifunctional production systems
TERRA PROTEGIDA
1. Transforming Knowledge Paradigms
2. Empowering Indigenous and Local Communities to lead regional economy
3. Markets and innovation
4. Land Rights and Territorial Recognition
5. Rural Credits
6. Strengthening Infrastructure
7. Policies and Regulatory frameworks

1. Introduction: History and Evolution of Production Systems in the Amazon

Prevailing development models have, in recent decades, prioritized the expansion of large-scale monocultures and pasturelands in the Amazon. By contrast, for centuries, Indigenous and Afrodescendant Peoples and Local Communities (hereafter IPs & LCs) (see Chapter 5) have developed a variety of integrated and multifunctional production systems, which today supply timber, fruits, oils, nuts, fish, and other non-timber forest products (NTFPs), and processed goods to local, regional, and global markets[1]. These have involved the domestication of globally important crops such as manioc, cacao, sweet potatoes, tobacco, coca, quinine, among others[2]. Rooted in evolving cultural knowledge and experience, these practices continue to adapt to new pressures, technologies, and markets, influencing land use and environmental management, with larger implications for the Amazon as a whole.

Multifunctional production systems are those that support both ecological integrity and productive land uses, rather than compromising one for the other. They maintain and enhance the ecological multifunctionality of the landscape[3]. Multifunctional landscapes are territorial mosaics that emerge from the spatial and temporal diversity of land-use systems while maintaining the ability of ecosystems within a landscape to uphold their functionality, for instance, to regulate water and nutrient cycles, erosion, temperature and to nurture diverse vegetation and aquatic systems[1]. These systems are nature- and knowledge-based, providing not only products for the market but also abundant and nutritious food, medicines, and other goods, while also delivering several other types of contributions essential for good quality of life, such as sustaining biodiversity (including agrobiodiversity), moderating microclimates, and maintaining cultural heritage and livelihoods.

In the Amazon, multifunctional production systems are management systems that include monocultural and polyvarietal agricultural systems, such as systems for manioc production, highly productive agroforestry, forest and savanna management, and aquatic resource management (see **Figure 6.1**). Amazonian multifunctional production systems have persisted, adapted, and evolved in response to regional changes for millennia, with their continuity documented over the last centuries. They are dynamic systems that respond to local needs, external pressures, and opportunities, in part by incorporating new technologies and adapting to environmental changes. They support local consumption as well as exports, generate employment across rural and urban areas, and deliver environmental benefits at local, national, and global levels[1]. In recent years, this array of features has been captured by the terms socio-biodiversity and socio-bioeconomy: socio-biodiversity encapsulates the wide range of benefits, products, and managed landscapes resulting from the knowledge systems and management practices of Amazonian IPs & LCs; and socio-bioeconomy refers to an economy built upon production systems that rely on socio-biodiversity. By foregrounding the contributions of local populations, these terms expand the concept of the bioeconomy, which remains important as an umbrella term but has been appropriated by a wide range of actors, from governments to biotechnology industries[4]. This rich array of production systems is facing significant challenges from deforestation, fires, logging, mining, climate extremes, and illegal economies—and also from lack of access to credit support, logistical infrastructure, and markets.

This chapter explores the implications of different production systems for landscape connectivity and multifunctionality in the Amazon basin. It briefly describes the current mosaic of Amazonian production systems, their socioeconomic and environmental contributions, and the implications of recent changes in these systems for the ecosystem goods and services they provide. It argues that multifunctional production systems can offer an adaptable framework for restoring landscapes and transitioning the region toward more climate resilient, biodiversity rich, and socially inclusive landscapes. The chapter also highlights the challenges multifunctional production systems face—as well as the potential that exists for consolidating and amplifying what multifunctional production systems and landscapes could contribute to the future of the Amazon.

Multifunctional production systems rely on natural and anthropogenic inputs, agrobiodiversity (i.e., the diversity of domesticated and semidomesticated species and varieties), and ecosystems supporting agriculture and fisheries production. For instance, human-dependent domesticates, such as manioc, are managed alongside semidomesticated species, such as palms and Brazil nut trees (*Bertholletia excelsa*). These systems are integrated into the spatial and temporal variability of resources and natural cycles (see Chapter 7), and they combine production systems designed for different purposes and goods. Beyond their economic value, they offer a range of material and nonmaterial benefits—from food and climate security to contributions to the well-being of both nearby and distant populations. Historically, multifunctional production systems have helped maintain landscape integrity and connectivity, which contributes to upholding ecological functionality and flows between ecosystems and counteracts the effects of ecosystem fragmentation[5]. Multifunctional production systems can help distribute labor demand across seasons while enhancing the resilience of producers and ecosystems to environmental and economic shocks[1]. These systems and their historical and cultural contexts help to continuously build connections between ecological systems and human communities themselves by nurturing economic, historical, and symbolic value and cultural meanings. In many ways, such systems have been key to maintaining and restoring landscape connectivity in the Amazon: by combining diverse land uses, they have allowed soils and forests to recover, restored degraded areas, and supported the conservation of forests and their ecosystem services, which are central to long-term productivity in the Amazon. Two concrete examples are the açaí palm (*Euterpe oleracea*) agroforestry economy managed by riverine producers along the Amazonian floodplains and the community-based management of fisheries (see Call to Action 20); these examples highlight the economic, social, and ecological importance of multifunctional production systems to promote socially inclusive and sustainable production at the regional scale.

By contrast, extensive pastures now occupy over 70.8% of the land deforested in the Amazon from 1985 to 2023, while sharing space with large-scale monocultures[6]. These are production systems that largely undermine the ecological functions of the landscapes that they replace. Since the 1970s, medium- and large-scale monocultures have displaced communities and promoted extensive deforestation, forest degradation, and forest fragmentation. Non-native species have also been introduced, such as oil palm, acacia trees, African grasses, eucalyptus (grown in plantations), and various fishes—and their ranges have expanded. Illegal mining is present in some areas, often triggering other speculative activities, such as land grabbing, that are increasingly intertwined with drug trafficking networks (see Chapter 2)[7,8]. In recent decades, such simplified monoculture systems have been encouraged and supported by government subsidies, substantive credit lines, infrastructure development, a large state-run research apparatus in the case of Brazil, and active land markets. In the context of this explosive expansion of Amazonian monocultures, multifunctional production systems have evolved new arrangements and segmented markets. Today, these systems coexist with extensive cattle ranching and monocultures. A regional overview of these contrasting Amazonian production systems through time and their impacts on ecosystem connectivity is presented in **Figure 6.1**.

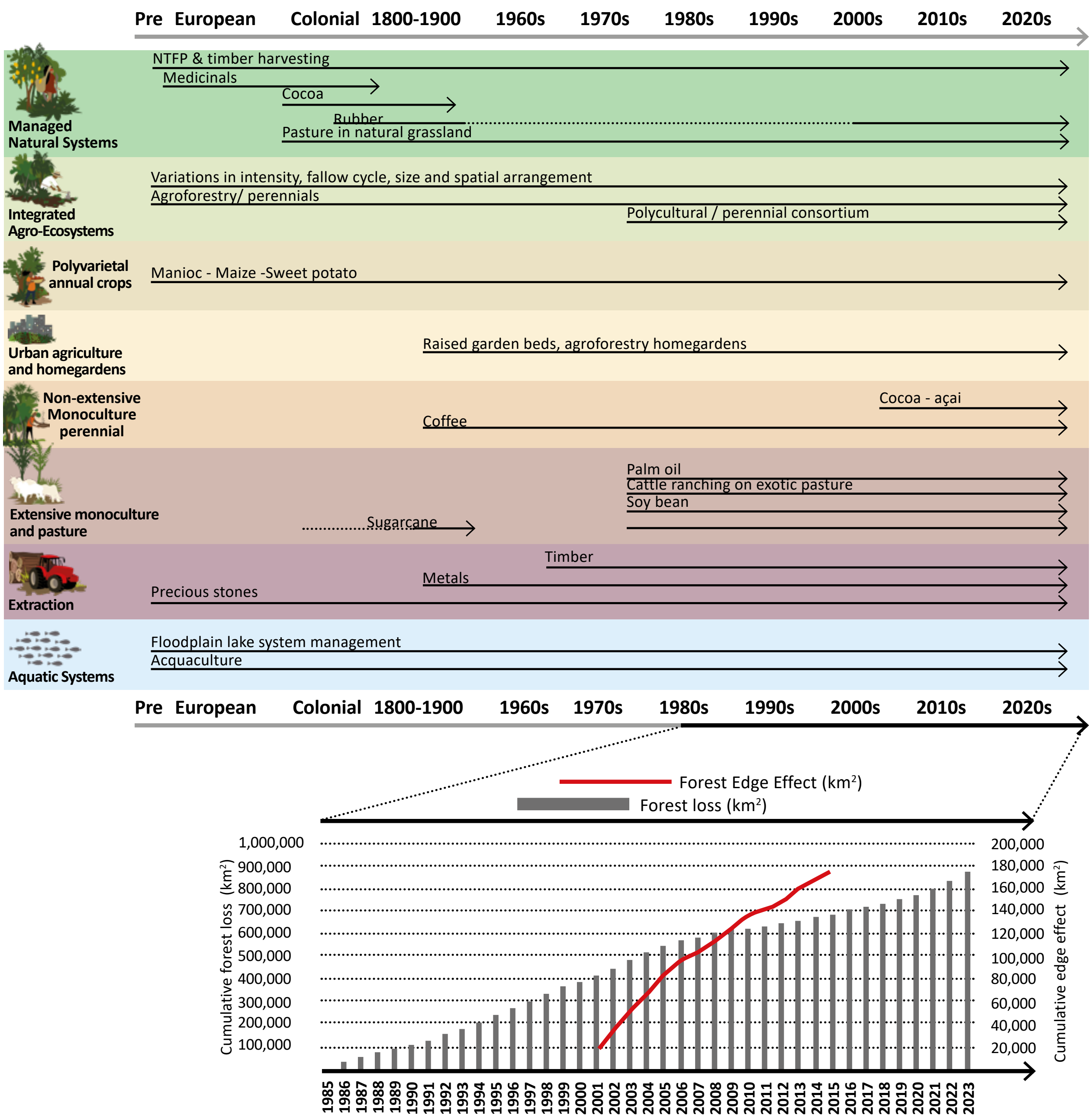


Figure 6.1. Amazonian production systems over time and recent effects on deforestation and fragmentation. The evolution of production systems from multifunctional to simplified forms has been accompanied by increased disruption of landscape connectivity, as evidenced by rising deforestation and intensified forest edge effects. (MNS: managed natural systems; IAE: integrated agroecosystems; PAC: polyvarietal annual crops; NMP: non-extensive monoculture, perennial; EMP: extensive monoculture and pasture; EXT: extraction; AS: aquatic systems; UAH: Urban agriculture and homegardens.) Source: Figure modified from literature[9,10].

Recently, policies supporting ecosystem restoration are emerging in Brazil, Colombia, Bolivia, and Peru, and these countries are seeing increasing adoption and intensification of agroforestry systems with cocoa, açaí, and non-natives like coffee[11,12]. Institutional structures in rural economies are undergoing extraordinary changes, influenced by patterns of land ownership, access rights, collective and communal uses, and migration, as well as financing stimulated by social movements, government policies, and regional and global economics. The increasing need for complex economic portfolio strategies involving both urban and rural income sources and the prevalence of circular migration between indigenous, rural, and urban areas often exacerbates problems of local governance[13].

The configuration of production systems in the Amazon has major social, economic, and environmental implications for the region and beyond. Land-use decisions shape local and regional climate responses; affect the ecological connectivity of natural systems; and have implications for employment, urbanization, migration, and human well-being. Multifunctional production systems and landscapes offer an adaptable framework for transitioning monofunctional systems and fragmented landscapes into a more resilient, inclusive, and sustainable Amazon in the face of climate change and social inequality. They have direct relevance to the region's complex economic, employment, and conservation dilemmas[14]. However, multifunctional systems lack support and face increasing threats from multiple angles, including (i) prices, costs, and markets; (ii) illegal economies and organized crime; (iii) territorial threats; (iv) spillover effects across landscapes (fire propagation, agrochemical pollution, emerging infectious diseases); and (v) climate extremes and other climate-related risks[15].

2. Characterization and Implications of Production Systems in the Amazon

2.1. Categorization of Production Systems

Production systems in the Amazon today reflect contrasting histories and knowledge systems, and divergent and conflicting worldviews. They represent distinct ways of relating to and valuing nature as part of food production, land and resource management, and ways of seeing and understanding the world (see categories of **Figure 6.1 and Table 6.1**). Here, we group these production systems into two categories that vary in land-use intensity, biodiversity, and socioeconomic characteristics: (i) multifunctional production systems developed by IPs and LCs and (ii) introduced and hybrid systems (**Table 6.1**). **Box 6.1** highlights examples of traditional multifunctional systems, showcasing their material and nonmaterial dimensions[16]. Further details related to each category are provided in the Annex .

Table 6.1. Overview of the main Amazonian production systems: Multifunctional systems of Indigenous Peoples and Local Communities vs. introduced and hybrid systems.

SYSTEM	DESCRIPTION
I. MULTIFUNCTIONAL PRODUCTION SYSTEMS DEVELOPED BY INDIGENOUS PEOPLES AND LOCAL COMMUNITIES	
i.1) Agriculture with polyvarieties and polycultures **[PAC]***	Diversified and multifunctional food production systems use semidomesticated and domesticated combinations of root and tuber cultivation (e.g., cassava, yams, sweet potatoes); trees and palms; and cereals (e.g., corn, rice), herbs, and legumes[17,18].
i.2) Multiple-use agroforestry and forest management **[IAE][MNS-F]***	Gardens, agroforestry systems , and surrounding areas of mature and regenerating forests are cultivated and managed using Indigenous and Local Knowledge (ILK) and practices to manage landscapes mosaics providing resources like annual crops, fruits, fibers, medicines, and wood while promoting social welfare[19–22]. These practices are implemented at different scales, from homegardens to intensive agroforestry systems occupying larger areas[19–23].
i.3) Fishing management **[AS]***	The management of coastal, floodplain, and lake systems involves sophisticated techniques integrating ILK, scientific understanding of fish population dynamics, community-based institutions, and biodiversity protection for long-term sustainability[24].
i.4) Pasture on native grassland **[MNS-P]***	Cattle ranching in these systems is based on extensive (low density of animals/hectare) management techniques, where animals graze on native pastures with minimal human intervention, based on traditional and introduced practices, usually following natural ecological cycles, such as flooding[25].

II) INTRODUCED AND HYBRID SYSTEMS (SYSTEMS THAT ARE EXPANDING IN THE REGION)	
ii.1) Monoculture **[EMP]***	Monocultures maximize production by focusing on a single crop, usually genetically modified and lacking polyvarieties, replacing on-site plant diversity and significant adjacent plant diversity via edge effects and fragmentation compared to polycultures.
ii.2) Polycultures / hybrid agroforestry **[IAE]***	Primarily practiced by smallholder and mid-scale producers (with, e.g., coffee, cocoa, açaí, black pepper), this approach incorporates diverse plant species and trees, enhancing agricultural diversification, income sources, and environmental recovery[26].
ii.3) Forest management for timber and non-timber forest products **[MNS]***	Forest management, the extraction of timber and non-timber forest products (NTFPs) at a larger scale, includes a variety of best management practices to support its sustainability. NTFP production is a long-standing tradition and has significant relevance for local markets, though it primarily relies on a few products that are commercialized regionally and globally, such as essential oils, nuts, and fruits. Programs and funding initiatives to promote timber products and NTFPs have been implemented over the past several decades, with renewed momentum in recent years driven by a new wave of interest in the bioeconomy. But currently timber is often extracted illegally from public and protected areas.
ii.4) Large-scale fishing and aquaculture **[AS]***	Industrial fishing has expanded through policy support and financial incentives, primarily targeting native species for local, regional, and international markets, but it is often unregulated, compromising sustainability and biodiversity.
ii.5) Extensive and intensive pastures **[EMP] [NMP]***	Pasture systems span all property sizes in the Amazon but are largely dominated by the conversion of vast forest areas into extensive cattle ranching with exotic and sometimes invasive species, primarily driven by large landowners and agribusiness corporations for meat and leather production[27]. Proposed innovations in pasture management include actions such as restoring degraded areas, implementing rotational grazing, and integrating trees and crops into silvopastoral systems to boost productivity while reducing deforestation and emissions. However, these practices remain largely localized.
ii.6) Urban agriculture and homegardens **[UAH]***	Following techniques common among IPs & LCs, urban horticulture, including the production of herbs and medicines, continues to increase in urban areas of all sizes. Homegardens mixing perennial fruits, horticulture, and domesticated animals are common in Amazonian cities[28,29].

* MNS: managed natural systems (Forests (F) or Pastures (P); IAE: integrated agroecosystems; PAC: polyvarietal annual crops; NMP: non-extensive monoculture, perennial; EMP: extensive monoculture and pasture; AS: aquatic systems; UAH: Urban agriculture and homegardens.

Box 6.1: Indigenous and traditional production systems: A holistic approach to reconciling.

The Deni people's relationship to pirarucu

A concrete example of Indigenous production systems is the management of pirarucu by Indigenous Peoples. For the Deni people in Brazil, for example, the pirarucu is an equal. These fish are first considered beings with whom humans relate, with their own agency, and they are cared for through figures such as mothers or guardians of the water world—before they are seen as "natural resources" or "objects of management[30]." Such conceptions of the living world break with the idea that natural resources are just commodities. This model goes beyond the simple relationship between humans and fish stocks and informs a perspective to fisheries management that aim for the well-being of both humans and other beings[4].

The Baniwa people's relationship to manioc swiddens (*roças*)

Another example of an Indigenous production system is the Indigenous swidden gardens of the Upper Rio Negro along the borders of Brazil, Colombia, and Venezuela. For the Baniwa people, manioc is the body of Kaali, who represents the figure of the guardian or owner of the swiddens and food. Manioc (*ikaaletti hidzaakowa*) means "for the heart to beat strong within the human body," which is why the Baniwa people care for and manage their swiddens and manioc plants, in order to never run out. Kaali is always there accompanying women's work[16]. "The *roça* (swidden) itself, is considered as an unknown world, a place the size of the world for how diverse it is. In addition to knowing the secrets of the *roça* and its mysteries, we also understand its language, because it communicates with us through signs."

Land use in the Amazon is increasingly dominated by introduced, extensive, homogeneous systems. These systems can include genetically modified organisms. Management of these systems often degrades soils, disrupts socio-environmental connectivity, and drives deforestation and forest degradation, thus contributing to regional and global climate instability[31]. These landscape modifications have led to forest fragmentation, which has significant negative effects, including disruption of ecological services such as water supply and regulation, biodiversity support, and carbon storage and sequestration[32]. These impacts extend well beyond the local, with the hydroclimatic effects of deforestation affecting the water and glacial dynamics in the Andes (see Chapter 1) as well as water availability for rainfed agriculture in the Cerrado and the Southern Cone region of South America, including major cities. The change from natural ecosystems or multifunctional production systems to extensive monocultures and pastures has undermined sustainability at the landscape and regional levels, for instance, by contributing to the disappearance of pollinators and pest predators, with impacts on crop yields and local extinctions of numerous plants and animals[33]. Finally, landscape modifications are also fragmenting the sociocultural identities of IPs & LCs, particularly riverine communities, through displacement and urbanization driven by large-scale production and the deforestation of places that hold significance in their cosmologies (see Call to Action 16, chapter 5).

2.2. Socio-Ecological Outcomes and Benefits of Different Production Systems

A synthetic comparative analysis of the socio-ecological and economic benefits provided by distinct Amazonian production systems is presented in **Figure 6.2**.

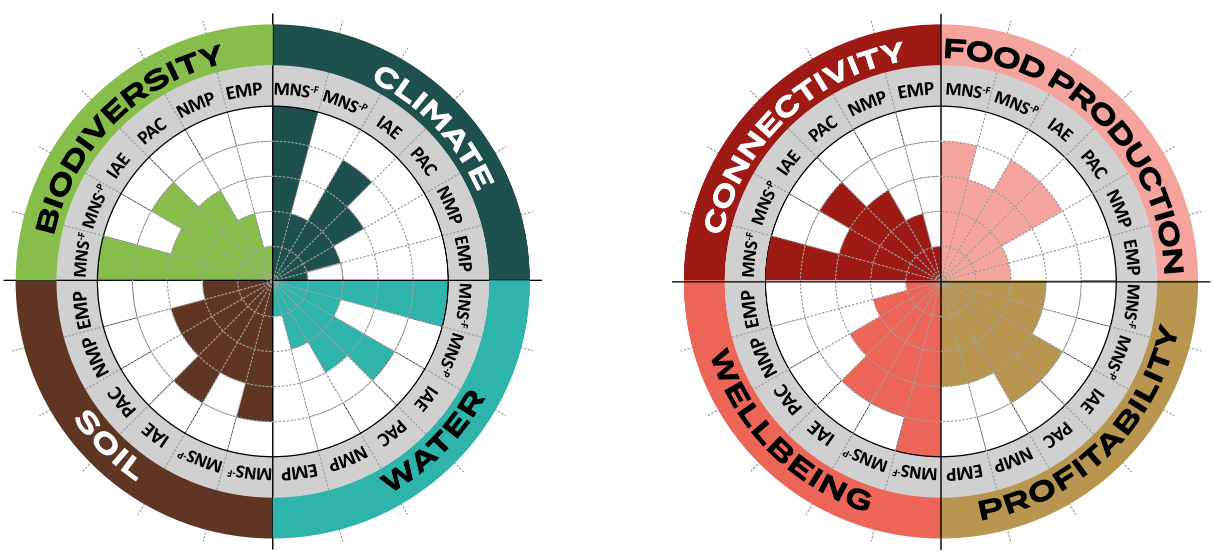


Figure 6.2. Socio-ecological benefits of six Amazonian production systems. Based on expert opinion (18 experts in total), we assigned comparative values from 1 (low) to 5 (high) for each axis in the radar plots. The axes of the radar plots represent the potential ecological, social, and economic benefits for each of the six production systems: managed natural systems—forests (MNS-F), managed natural systems—livestock in native pasture (MNS-P); integrated agroecosystems (IAE); polyvarietal annual crops (PAC); non-extensive monoculture, perennial (NMP); extensive monoculture and cattle on non-native pasture (EMP). For a description of these systems see Table 1.

In general, higher values were associated with production systems with greater structural and functional complexity, while extensive monocultures and cattle ranching with non-native pastures were associated with the lowest socio-ecological benefits. Managed forest systems (MNS-F in **Figure 6.2**) were associated with median to high benefit values for all categories. And notably, cattle ranching with native pastures (MNS-P) can have fewer negative impacts than monocultures and cattle ranching with introduced species (EMP), while also surpassing the value of non-extensive perennial monocultures (NMP) and providing greater value in the areas of habitat creation, seed dispersion, and pollination[34]. Regarding economic returns, polyvarietal annual crop systems (PAC) and integrated agroecosystems (IAE) show slightly higher performance compared to the other systems. As would be expected, for landscape connectivity, perennial monoculture activities (NMP) and cattle ranching with non-native species (EMP) contribute less than systems with greater structural complexity. However, it is important to recognize that the Amazon today is a mosaic being shaped by conflicting actors and perspectives on land use and resource management. Emerging socio-bioeconomy initiatives in the region are fostering collaboration among these contrasting actors; however, some of the outcomes so far have raised concerns[35]. The diverse social, economic, and environmental values associated with multifunctional production systems are not equally recognized by Amazonian's diverse groups of producers, as some prioritize immediate economic gains and large-scale production over multifunctional approaches.

2.3. Challenges and Opportunities for Multifunctional Production Systems

In the Amazon, examples of multifunctional systems include agroforestry, shifting cultivation, sustainable fishing practices, and the management and harvesting of NTFPs; these systems allow for natural regeneration and have inspired a variety of hybrid systems[36,37]. Some studies are revealing the profitability and co-benefits offered by multifunctional production systems (see Call to Action 21). In Colombia, an economic analysis of different production systems found that diverse systems recovered investments faster than simpler systems, with investments of monocultures not being recovered after six years[38]. (see Call to Action 21). And in Brazil, researchers have found that fruit and horticultural production generated an average income of approximately USD 3,300 per hectare—thirteen times higher than cattle ranching, which yielded only USD 250 per hectare (**Figure 6.3**)[39]. Other studies show that diverse systems, when adequately supported, tend to be more successful than monocultures[40].

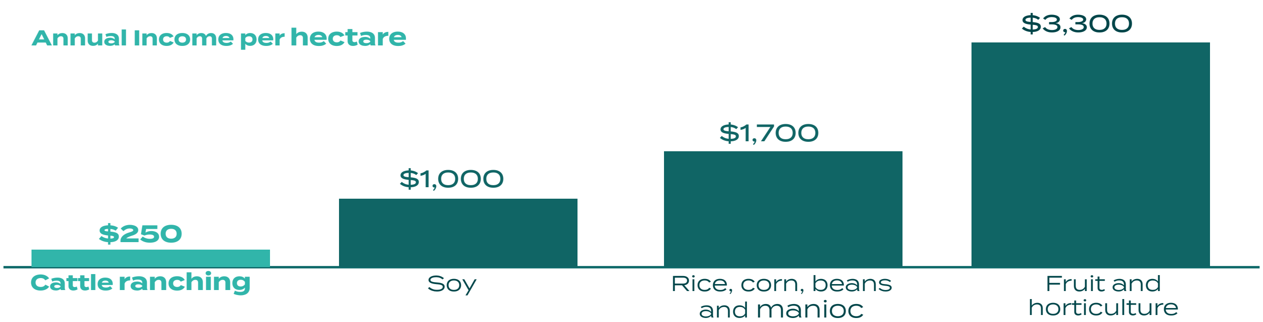


Figure 6.3. Annual income per hectare from different agricultural activities in the Brazilian Amazon. Figure based on reference [39]. The Conversation, CC-BY-ND. Source: Ecology and Society (2017)

Despite their significant socioeconomic and environmental value, multifunctional systems have been largely overlooked by government actors and, more broadly, by the agricultural sector resulting in their marginalization in terms of incentive policy in different spheres. They receive disproportionately low levels of credit, research funding, and technical assistance compared to large-scale simplified systems. For example, in the Brazilian Amazon, incomplete estimates of these systems estimate that they cover 8.4 million hectares and generate billions of Brazilian reais in value, yet these systems receive only a third of the development credit relative to their gross production value compared to introduced systems[41] (see **Box 6.2**).

Box 6.2. The invisibility of multifunctional production systems in Brazil.

Available statistics for multifunctional production systems indicate that the integrated agroecosystems managed by family-based productive structures constitute a large-scale economy with its own dynamics, revealing both the potential and limitations of these systems within the Amazon.
In Brazil, using categories from the 2017 agricultural census, family-based production comprised 186,300 farms and employed 404,000 workers, while its gross production value (GPV) grew at an annual rate of 4.2%, increasing from USD 400 million in 1995 to USD 1.1 billion in 2017 [41]. They contribute a negligible amount to the net total carbon emissions of the agricultural sector: zero between 1995 and 2006 and only 1% from then until 2017 [41]. Taking into account the industrial and service activities related to the supply chains of just thirteen of the main products from these systems, the sector reached a value of BRL 12 billion in 2020 [42]. Yet, these systems continue to receive relatively limited support in public policies. In 2017, development credit accounted for only 9% of their GPV, and no more than 8% of its establishment received technical assistance. In contrast, large-scale simplified production systems received credits equivalent to 29% of their GPV in the case of livestock and 28% in the case of grain production, with no less than 20% and 34% of farms, respectively, benefiting from technical assistance[41].

Multifunctional production systems face a convergence of challenges that threaten their sustainability. These include statistical invisibility, erosion of Indigenous and local knowledge, economic fragility, declining productivity, weak access to both extension services and logistical infrastructure, labor constraints, and escalating climate risks. Inadequate recognition and support hinder effective policies and investment. Innovations that once boosted productivity are now faltering under market pressures and environmental degradation. Infrastructure deficits and market asymmetries reduce profitability, while climate extremes disrupt ecological cycles, threatening livelihoods and food security. Preserving these systems requires reinforcing their cultural, economic, and ecological foundations while ensuring they remain resilient amid intensifying environmental and socioeconomic pressures. In **Table 6.2**, we highlight six dimensions related to their capacities, their limits, and the challenges they face.

Table 6.2. Challenges faced by multifunctional production systems that affect their capacities and socioeconomic and environmental contributions.

CHALLENGES	IMPLICATIONS OF THESE CHALLENGES
1. STATISTICAL INVISIBILITY	Official statistics and research on vital production activities are relatively limited and inaccurate, as statistical agencies fail to capture the diversity of multifunctional production systems[43]. Indigenous Peoples and Local Communities often operate through informal and fragmented value chains, which undermines the appropriate valuation of these systems and affects the formulation of appropriate public policies and investment strategies (e.g., political economies of regional development choices)[41].
2. KNOWLEDGE AND INTERGENERATIONAL PERPETUITY	The loss or erosion of collective action and Indigenous and Local Knowledge has been documented in the Amazon, reflecting a broader global trend and caused by several factors[44]: (1) youth migration to urban areas, with new migration dynamics being periodic and circular (e.g., youth migration during tourist season in Alter do Chão, Brazil); (2) environmental degradation (e.g., biocide overuse, water contamination, and fire outbreaks); (3) changing economic opportunities (consider that remittances, conditional cash transfers, retirement funds, and other forms of revenue have vastly changed the income portfolios of people previously dependent on management of complex systems); and (4) limited institutional support[44]. Also, formal education rarely includes Indigenous and Local Knowledge. However, there are promising examples, such as the Rural Family Houses (i.e., *Casas Familiares Rurais*), a model combining classroom learning with practical experience on family farms[44,45].
3. ECONOMIC PRECARITY	The evolution of the economic foundations of growth over the last three decades reveals the capabilities and weaknesses of multifunctional production economics as a basis for sustainable development. To reach sustainable development, it is necessary to correct social inequalities and allow the creation of capacities oriented toward sustainable forms of production and commercialization[46–49]. Yet, multifunctional production systems face high logistical costs (for transportation, storage, and marketing), which significantly reduce their economic returns. Economic returns depend directly on increases in physical productivity (i.e., the output produced per worker per year)[50,51]. If the physical productivity of a family-based economy is increasing and market conditions (e.g., the selling price of a product) remain stable, the result will be an increase in labor income. This was the case in the Brazilian Amazon between 1995 and 2006, when the expansion of multifunctional systems led to a rise in net labor income (6.9% per year)[41]. Then, between 2006 and 2017, despite labor productivity declining, net labor income only stagnated due to improvement in market conditions[52].

4. PRODUCTIVITY DECREASE	The growth in physical productivity that enabled the increase in household income in Brazil during the years 1995–2006 resulted from a series of innovations in forest management[53–55]. Notable examples include innovations that combined Indigenous, local and Western scientific knowledge, such as low-impact açaí management—developed by riverine farmers and built upon by agencies such as the Brazilian Agricultural Research Corporation (Embrapa)—and cocoa intensification along the Transamazon highway in Brazil. However, forest management innovations can result in unsustainable intensification of production systems, eventually causing declines in physical productivity. This has been observed in the case of intensified açaí palm management, which has led in some cases to depletion of diversity, which is further exacerbated by climate change[55].
5. MARKET AND INFRASTRUCTURE CONDITIONS	Structural challenges in logistics and infrastructure—such as deficiencies in information, communication, energy, storage, and transportation—significantly impact production and transaction costs[56]. Recent growth of demand for products (e.g., açaí and manioc flour) has allowed producers to capture returns from selling their products. Yet, it has also created pressure to increase supply, leading to the simplification of some multifunctional production systems[57]. The success of this trajectory raises strategic concerns about maintaining and strengthening multifunctional systems, unless productivity and local value retention of multiple elements in the system are strengthened[58,59].
6. CLIMATE RISKS AND CASCADING ECOLOGICAL EFFECTS	Many populations in the Amazon have very precarious livelihoods, made more so by threats of climate events. Climate change, combined with land-use change, is altering rainfall; increasing droughts, floods, and fires across the Amazon; and disrupting food systems and ecosystem resilience. IPs & LCs face challenges in managing agriculture, fishing, and forest harvesting as historic climate patterns shift. These changes reduce productivity (e.g., Brazil nuts, açaí, cocoa; see Chapter 7), impair river transport, and threaten biodiversity through habitat loss and biotic homogenization[60]. Ecological connectivity is critical to sustaining socio-biodiversity and multifunctional systems under climate change conditions[61,62].

Multifunctional production systems can offer an adaptable framework for restoring degraded areas into multifunctional landscapes. Potential benefits can include improving ecosystem connectivity in ecological and hydrological corridors (which may include incorporating forest fragments and remnants to increase habitat connectivity), decreasing systemic risks involving neighboring land-use systems (e.g., accidental fire risk), and improving economic efficiency by creating conditions for sharing and reducing costs of the logistical infrastructure that connects diverse producers to markets. A shared understanding of the importance of restoring multifunctional landscapes and protecting local to regional watersheds can increase the likelihood of collaboration among diverse actors and foster coordinated actions that enhance connectivity and minimize land-use conflicts.

3. Solutions: Transition Pathways to Resilience

The potential for a thriving new era that reconciles multifunctional production systems and resilient landscapes in the Amazon depends on a variety of structural and other factors coming together, as well as bottom-up initiatives connecting actors and the economic and environmental sectors. These efforts can foster innovation, build on existing elements, and promote transitions to sustainable land-use systems and integration of forest-crop-livestock systems[63]. A large-scale transition to regenerative agriculture, especially in livestock systems, would generate significant opportunities for forest restoration, vital to enhancing socioecological resilience and averting possible tipping points. These systems can be supported and maintained by intentional territorial planning aimed at restoring fragmented landscapes across the Amazon[63]. Along with supporting initiatives on the ground, it is important to increase regional capacity for applied research that supports small- and mid-scale multifunctional production systems with fit-to-purpose access to new technologies, value-aggregation opportunities, and access to new markets. Investments in these areas are also important for engaging and attracting younger generations to continue to manage and advance these systems, and to continue benefiting from multifunctional production systems. Here, we outline some key factors that can contribute toward fairer and more sustainable production systems and landscapes in the Amazon.

3.1. Transforming Paradigms of Knowledge Creation

One of the key challenges in promoting multifunctional production systems is that the scientific and technical expertise concentrated in universities and research institutes—where the vast majority of budgets and infrastructure are located—is largely geared toward highly specialized and simplified agronomic models focused on livestock and monocultures. In addition to the disproportionately low investment in complex agronomic systems in Amazonian research institutions, these models continue to prioritize monocrops, global commodity production, and large-scale output[64]. In contrast, production systems based on socio-biodiversity require knowledge rooted in a deep understanding of the sociocultural and biological foundations of the localities of production. Incorporating Indigenous and Local Knowledge systems is essential to inform, enhance, and guide academic research, as well as to foster the development and support of transformative knowledge grounded in local realities.

Strengthening local capacity is key to generating cutting-edge information on ecological aspects of Indigenous and local practices, protecting and co-designing innovative multifunctional systems, and creating opportunities for more creative and less strenuous manual labor. Implementing comprehensive curriculum reform across agricultural, forestry, and animal production education—grounded in socio-ecological and agroecological principles—would promote sustainable production systems, strengthen sociobioeconomies, advance forest restoration, and enhance landscape connectivity. Equally important is the creation of spaces for dialogue and co-production of knowledge and experimental practices between the academic community, IPs & LCs (especially in rural communities), and other land-use actors. Finally, rural education initiatives—such as the Rural Family Houses (*Casas Familiares Rurais,* in Brazil), where rural students alternate between school training and application of the practices in their own communities—can generate cascading benefits by promoting transformative education and empowering young people to flourish in innovative rural activities (see Call to Action 20).

3.2. Empowering Indigenous Peoples and Local Communities to Lead the Regional Economy

Empowering local communities to lead commercial ventures ensures they are not just labor in the regional economy but also key decision-makers. This fosters a sense of ownership and responsibility for sustainable practices, which are key to their long-term success[65]. Historically, Indigenous and Local Knowledge has often been appropriated or marginalized by modern societies, as seen in examples from the cocoa and rubber industries. A fundamental shift is needed—from neglect and appropriation to recognition, support, inclusion, and equitable benefit sharing—which can happen through training opportunities and inclusive educational policies. Limited access to markets and poor infrastructure and financial systems directly undermine the profitability and sustainability of local initiatives. Training in financial management, marketing, cooperative governance, accountability, institutional relations, and natural resource management can help transform this reality (see Call to Action 20). Such initiatives are feasible in remote areas only when supported by strong community social organization and institutional partnerships with governmental and non-governmental organizations. Integrating innovative technologies into local production systems—such as in processing, packaging, or marketing—can increase value-added activities, open access to new markets, and improve the competitiveness of locally produced goods and services. Empowerment also requires direct funding and formative programs involving a range of actors, from civil society organizations to public institutions. Grassroots organizations are particularly well positioned to bridge the gap between environmental stewardship and economic development, enabling culturally relevant, context-specific models of sustainable entrepreneurship, as highlighted in the Calls to Actions 20-22. The participation of IPs & LCs in spatial planning and policy development is fundamental to fostering their leadership.

3.3. A New Vision for Markets and Innovation

Enhancing multifunctional production systems requires recognizing and supporting multiple development pathways tailored to local Amazonian realities. The current land-use priorities are based on large-scale and high-input agro-industries led by major corporations or on illegal economic schemes and are focused on regional land transformations from complex to highly simplified agricultural systems and extraction of natural resources—timber and fish, for example—at the expense of local communities. However, this large-scale-driven model—involving some industries dependent on distant markets and requiring substantial biological and infrastructural resources—may not align with or may exclude many Amazonian contexts[66]. Systems aligned with this model tend to promote ecological uniformity and undermine the integrity of socio-ecological systems. Multifunctional production systems, however, are fundamentally rooted in supplying a wide variety of biodiversity-based products to local and regional markets, but they can also engage national and international markets—as in the case of açaí, most famously, but also Brazil nuts and aguaje (*Mauritia flexuosa*) in Peru[67,68]. These complex systems supply the bulk of produce to local urban markets, often through short supply chains, which offer the advantage of lower transportation and storage costs.

To strengthen this model, strategies should promote a distinctly "Amazonian industrialization"—with an approach that is flexible and adaptive to the diversity and capacity of various types of supply systems (see Call to Action 28, chapter 7). Market-oriented innovation should enhance the value of the diversity of Amazonian products and services (including tourism), their symbolic significance, and their uniqueness. Promising examples include certified area of origin labels for products like manioc flour and guarana (Paullinia cupana), but also cocoa, açaí, and Brazil nuts (see Call to Action 24, Chapter 7). Shifting consumer preferences—encouraged through campaigns promoting sustainable Amazonian products—can drive market demand for new industries. Policies such as Brazil's Food Acquisition Program (PAA), the National School Feeding Program (PNAE) (see Call to Action 22), the Minimum Price Guarantee Policy for Socio-biodiversity Products (PGPMBio), and others are essential to improving the income and livelihoods of IPs and LCs living in Indigenous areas as well as rural and urban areas in Amazonian countries[69].

3.4. Shifting Paradigms in Land Rights and Territorial Recognition

Multifunctional production systems are largely characterized by the use of common-pool resources (CPRs), such as fisheries, timber and non-timber forest products, water, and agricultural and semidomesticated species. The use of CPRs by one group of actors affects resources available to other groups of actors. Furthermore, multifunctional production systems usually involve resources transcending a combination of private, common, state, and open-access property regimes. Coordination and governance are key for the sustainable use of CPRs[70]. Identity and ethnic movements, small farmers associations, and the growing awareness of the environmental dimension of agrarian issues have contributed to the development of governance arrangements that recognize, protect, and formalize collective and/or coordinated management of CPRs in the Amazon[41,71,72]. Institutional innovations should aim to further secure land and resource access for rural smallholder producers—both long-established and more recent—as well as ensure the constitutional demarcation and protection of IPs' & LCs' Territories, which form the foundation of multifunctional production systems and landscapes. These innovations must establish new rules, institutions, and governance arrangements adapted to the diversity of land tenure categories that are sharing the landscape and affecting each other on it.

3.5. Aligning Rural Credit with Multifunctional Production Systems

Technical assistance and rural development credit policies are designed around technological development policies and are associated with high-input, mostly monocultural systems. Biodiverse systems receive minimal policy support[52,73]. In 2017, in the Brazilian Amazon, rural development credit and subsidies accounted for only 9% of the production value of multifunctional production systems, while simplified large-scale production received credit equivalent to 29% in the case of livestock and 28% in the case of grains[41]. Brazil's Agriculture and Livestock Plan (Safra Plan) 2025–2026 allocated 5.7 times more funding to large-scale agriculture (BRL 516 billion), which is dominated by monocultures, than to family farming (BRL 89 billion), which is typically more diversified[74]. In another example, a recent national analysis indicated that the disbursements of Brazilian "Low Carbon Agriculture" funds were around 500 times greater for conventional systems (e.g., direct planting or pasture recuperation) than organic production and agroforestry[75,76].

A shift is needed to reduce incentives to simplified systems and to adapt financing mechanisms to the realities of multifunctional production systems. These should be grounded in the characteristics of diversified, biodiversity-based systems—such as agroforestry and other integrated systems and their multiple benefits. Financing should also take into account diverse land tenure arrangements, including both private and communal property, as well as associative and cooperative structures.

3.6. Strengthening Infrastructure to Unlock the Potential of Amazonian Production Systems

Amazonian multifunctional production systems have long suffered from the historical neglect of public policies related to infrastructure development, including logistical infrastructure to access markets. One of the main challenges to the competitiveness of socio-biodiverse products is the high cost and inefficiency of existing logistical services and infrastructure. A clear example is the Brazil nut *Bertholletia excelsa* (traditionally called "Pará nut" in Brazil): in the Brazilian Amazon, the nut is exported with minimal processing due to difficulties in meeting international sanitary standards, among other barriers. In contrast, Bolivia and Peru have made significant progress in addressing these bottlenecks by adopting alternative processing techniques and storage facilities, in and outside the Amazon. In other areas, both local cooperatives and large industries have developed various product processing techniques such as those for açaí and for andiroba oil (*Carapa guianensis*). Thus, cooperation, exchange, and technology-sharing among Amazonian countries would be highly beneficial (see Chapter 7). Currently, inadequate support systems, regulatory norms, and taxation and fees place a heavy burden on local producers and cooperatives, limiting their ability to compete in national and international markets. To unlock the full potential of forest economies, it is essential to implement investment programs focused on improving sustainable infrastructure, storage, and services, including transportation and processing facilities. These improvements would reduce operational costs, enhance producers' market access, and support compliance with sanitary and quality standards. Through targeted subsidies and regional cooperation, governments and international partners can help lower barriers to entry and increase the competitiveness of Amazonian multifunctional and socio-biodiverse production systems. Urban areas, through their scale and diversity, can play a key role in bringing high-tech, specialized production to biodiversity-based production systems, fostering infrastructural and informational innovations that connect Indigenous and rural producers to urban consumers.

3.7. Strengthening Public Policies and Regulatory Frameworks

Strengthening institutional infrastructure and aligning regulatory frameworks with Amazonian sociocultural and environmental realities are essential for supporting multifunctional production systems. Current misalignments, such as difficulties in meeting sanitary and environmental standards, create barriers for local communities and Amazonian products. To overcome this, tailored mechanisms are needed to enable locally led commercial initiatives and ensure broader market access. Efforts should focus on streamlining bureaucratic processes and revising overly stringent sanitary regulations, which are vital for ensuring that Amazonian biodiversity-based products meet international quality and safety standards, while also recognizing local practices and Indigenous and Local Knowledge. At the same time, strengthening the capacity to regulate and monitor compliance is essential to incentivize good practices and ensure countries meet their socio-environmental commitments.

Rural local actors cannot bear the ongoing responsibility of conservation without external support[77]. Policies such as payments for environmental services (PES), co-designed with all the necessary safeguards, can provide essential incentives, compensating them for ecosystem stewardship as they maintain ecosystems that supply them with livelihoods (see Chapter 7). Several Amazonian countries—including Brazil, Bolivia, Peru, and Ecuador—have established national PES policies and programs[78]. These policies can be supported by intergovernmental funds, nongovernmental organizations, and international cooperation, reflecting the global value of these ecosystem services. However, the success of such policies ultimately hinges on whether investments effectively reach producers, local organizations, and communities who are directly responsible for and bear the costs for maintaining the integrity of Amazonian ecosystems[77].

4. Conclusions

Deeply rooted in Indigenous and Local Knowledge, multifunctional production systems have evolved over centuries through adaptive responses to economic, cultural, and environmental changes. They sustain agrobiodiversity and food production, create and support ecologically complex landscapes, provide employment, and are at the foundation of regional economies, while also maintaining critical ecosystem functions and landscape connectivity that support water regulation, pollination, biodiversity, and carbon capture and storage. More recently, policies and investment frameworks have spread that favor large-scale, input-intensive monocultures and extensive pastures, driving deforestation, social displacement, and ecological fragmentation. In this chapter, we discuss how multifunctional production systems offer an adaptable framework for transitioning the region toward more environmentally sustainable and socially inclusive landscapes of production and stewardship. Aligning public policies, rural credit, sustainable infrastructure development, market access, and regulatory frameworks is key to enhancing socio-ecological connectivity and the spatial and functional diversity of production systems. These measures can help guide the transition from monocultural and degraded landscapes into more complex, ecologically connected mosaics that are more resilient to climate and socioeconomic shocks. They also support sustainable economies without undermining the rights, knowledge, or livelihoods of Indigenous Peoples and diverse Local Communities in rural areas of the Amazon.

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Expand Fishing Co-Management to Transform Knowledge and Governance Frameworks in Amazonian Production Systems

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Photo credit: Instituto Juruá.

The Overview

Overexploitation in the Amazon threatens ecosystems, food security, and local livelihoods. The pirarucu (***A****rapaima gigas*), or arapaima, which is the largest scaled freshwater fish on Earth, has declined sharply due to overharvesting. In Amazonas state, Brazil, community-based co-management demonstrates how sustainable fisheries can integrate biodiversity conservation with human well-being[1,2,3]. Through fishing accords, Indigenous and riverine communities protect territories, restore fish stocks, and generate income[2]. This Call to Action conveys how the pirarucu management model strengthens local governance and partnerships, reduces inequalities, and advances conservation, although infrastructure, logistics, and market challenges remain[3].

The Facts

- Overfishing can compromise protein acquisition for millions of Amazonian families, because they rely on fisheries for food security[4].
- Co-management of culturally important species has been advocated as an effective tool to reconcile the goals of biodiversity conservation and human welfare[5].
- Arapaima co-management plans have proliferated throughout the Amazon over the last several years, currently involving >3,000 fishing households from >450 rural communities (IBAMA[1], pers. comm.).
- Other aquatic species—such as the high-value *tambaqui* fish (*Colossoma macropomum*), freshwater turtles (*Podocnemis* spp.), and caimans (*Melanosuchus niger*)—also benefit from the protection of *Arapaima*, which serves as an umbrella species for the conservation of water bodies[2].
- Although the pirarucu case stands out as one of the most promising examples of socio-bioeconomy—delivering clear governance, social, and ecological benefits—it also highlights a persistent dilemma in the Amazon: the market price still does not cover the production cost[6].

Global/Regional and Synergistic Connections

- Community-based management, such as in sustainable fisheries, plays a vital role in mitigating global climate change while aligning with international biodiversity commitments like the Kunming-Montreal Global Biodiversity Framework.
- A transboundary fishing policy across the Amazon is imperative to ensure coordinated and sustainable management of shared aquatic resources.

Figure C6.20.1. Sustainable harvesting of pirarucu before processing. Photo credit: Instituto Juruá.

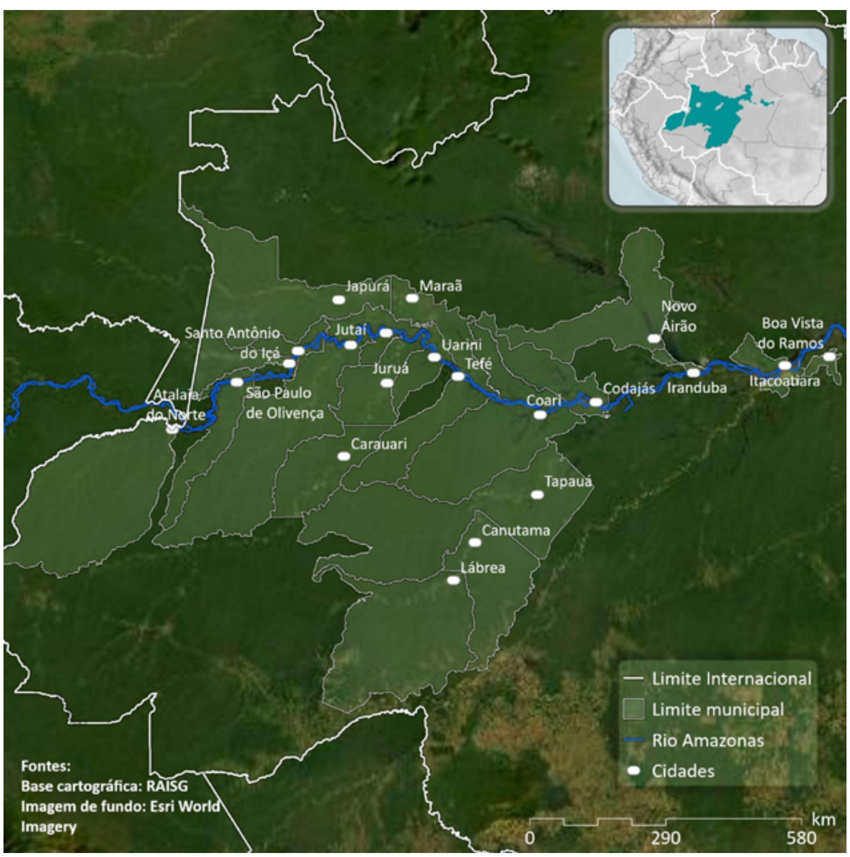

Figure C6.20.2. Areas where community-based management of pirarucu is implemented within Amazonas state, Brazil.

The Solutions Space

Collaborative Efforts

- **The collaborative management of pirarucu** combines Indigenous and Local Knowledge from fishers with scientific expertise from the Mamirauá Institute for Sustainable Development (IDSM). This approach has promoted unprecedented participation of women and youth in fisheries, advancing gender equity in traditionally male-dominated spaces.

- **The Coletivo do Pirarucu is a network of ~2,500 families** that has strengthened regional governance and advocacy in 28 territories and generated BRL 24 million for communities in 2021. This organizational dynamic offers an inspiring model for other biodiversity-based value chains in the Amazon.

Selected Key Tools

- The co-management of pirarucu relies on **community-based population monitoring** that uses direct visual counts by local fishers and nongovernmental organizations. Their monitoring enables accurate stock assessments and provides the basis for defining sustainable quotas. In the Juruá River, fishing agreements enabled a 425% population recovery in 11 years, with densities up to 50 times higher than in unprotected areas.

- Pirarucu co-management also relies on **community-based territorial protection of floodplain lakes** to reduce illegal fishing. Protected lakes host up to 50 times more pirarucu than unprotected lakes.

Major Governmental Efforts

- The Brazilian government, through ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade) and IBAMA, has provided **a legal framework for community fisheries management** that grants legal fishing rights and promotes the marketing of sustainably managed fish.

- The Amazonas State government, in Brazil, promoted **sustainable pirarucu in public food procurement** via institutional programs (e.g., school meals) that expanded market access.

Positive Efforts for Scaling

- **The value chain of pirarucu contributes to climate change mitigation** by protecting 15 million hecates of forest in the Brazilian Amazon, reducing greenhouse gas emissions. It connects fisheries with carbon conservation and sustainable economic development.

Recommendations

- **Secure long-term financial support** for community-based fisheries through public funding, environmental service payments, and impact investment.
- **Respect and strengthen legal, intellectual, and territorial rights of Indigenous Peoples and Local Communities** to ensure the physical protection, intellectual property rights, and autonomy of local fishers.
- **Expand the inclusion of sustainably managed pirarucu** in institutional food procurement programs such as school meals and hospitals.
- **Invest in cold chain logistics and local infrastructure** to reduce post-harvest losses, reduce logistic expenses, and increase market access for remote communities.
- **Train and empower grassroots organizations** to strengthen local stewardship and to take the lead in management and commercial arrangements, with an emphasis on gender equity and intergenerational leadership.
- **Support efforts to ensure fairer trade conditions** and equitable access to national and international markets for sustainably managed pirarucu.
- **Strengthen multi-actor governance platforms**, such as the Coletivo do Pirarucu, to coordinate actions, share knowledge, and influence public policy at broader scales.

Key Recent Literature

- Castello, L. et al. Lessons from integrating fishers of arapaima in small-scale fisheries management at the Mamirauá Reserve, Amazon. *Environ. Manage.* **43**, 197–209 (2009).
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Empower Local Communities through Multifunctional Systems to Address Territorial Conflicts and Landscape Fragmentation in Colombia

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Photo credit: Julian Gomez

The Overview

Deforestation and environmental degradation[1] on the territories of Indigenous Peoples and Local Communities (IPs & LCs) result in habitat loss and fragmentation, biodiversity loss, and pollution that threaten traditional lifestyles[2]. Although the drivers vary across the Amazon, deforestation is often linked to illegal activities, resulting in socio-territorial conflicts, insecure land tenure, and even forced displacement. The Colombian Amazon in particular has been impacted by forced displacement of IPs and LCs. This Call to Action explores how sustainable value chains rooted in multifunctional systems are supporting ecosystem conservation, territorial rights, the livelihoods of IPs and LCs, and the territorial empowerment of communities.

The Facts

- In the Colombian Amazon, armed conflict and illicit activities have caused widespread deforestation and forced displacement of IPs and LCs. From 2014 to 2022, the Llanos del Yarí Yaguara II Indigenous Reserve lost about 17,800 hectares of forest, equivalent to 5.6 million tons of carbon lost[3]. This reserve is the territory of the Pijao, Piratapuyo, and Tucano peoples in Meta, Guaviare, and Caquetá, and one of seven Indigenous reserves in Colombia where 60% of deforestation in Indigenous areas has occurred. In 2022, 218 of the 230 Amazonian reserves in Colombia lost more than 3,200 hectares of tree cover, totaling 19,181 hectares.

- Between 2016 and 2023, the Colombian Amazon lost 788,313 hectares of forest, equivalent to 60.5% of the national forest cover lost during this period. Peru lost 3 million hectares between 2001 and 2023, and Ecuador one million between 2001 and 2024.

- **Drivers of deforestation** include crops for illegal use, illegal mining, illegal logging, unplanned road infrastructure, land grabbing, extensive cattle ranching, and agricultural expansion[4]. The socioeconomic conditions in countries such as Colombia, Peru, and Ecuador pose challenges to providing alternative livelihoods and conserving forests.

- Alternative economic activities such as **multifunctional production systems** relying on traditional knowledge and based on Amazonian fruits, honey, seeds, and wood can support the territorial empowerment of communities, as well as crafts and ecotourism (**Figure C6.21.1**).

- **Agroforestry arrangements** that combine native species for differentiated markets favor (soil) restoration and reduce the need to add chemical compounds to increase productivity. Restoration combinations that include potential carbon credits, timber, non-timber native forest products such as oils (cacay), Amazonian fruit trees (copoazu, açaí, cacao), and short-cycle crops benefit the recovery of ecosystem services. Their profitability exceeds those of monoculture and dual-purpose livestock systems by two to three times[5] .

- The countries bordering the Amazonian Andes (Colombia, Peru, Ecuador) are fundamental in conserving the ecological connectivity of the basin, and the movement of species between Central and South America.

Figure C6.21.1. Agroforestry and multifunctional production systems can support conservation and the territorial empowerment of communities. Photo Credit: ADOBE STOCK / By: Leckerstudio.

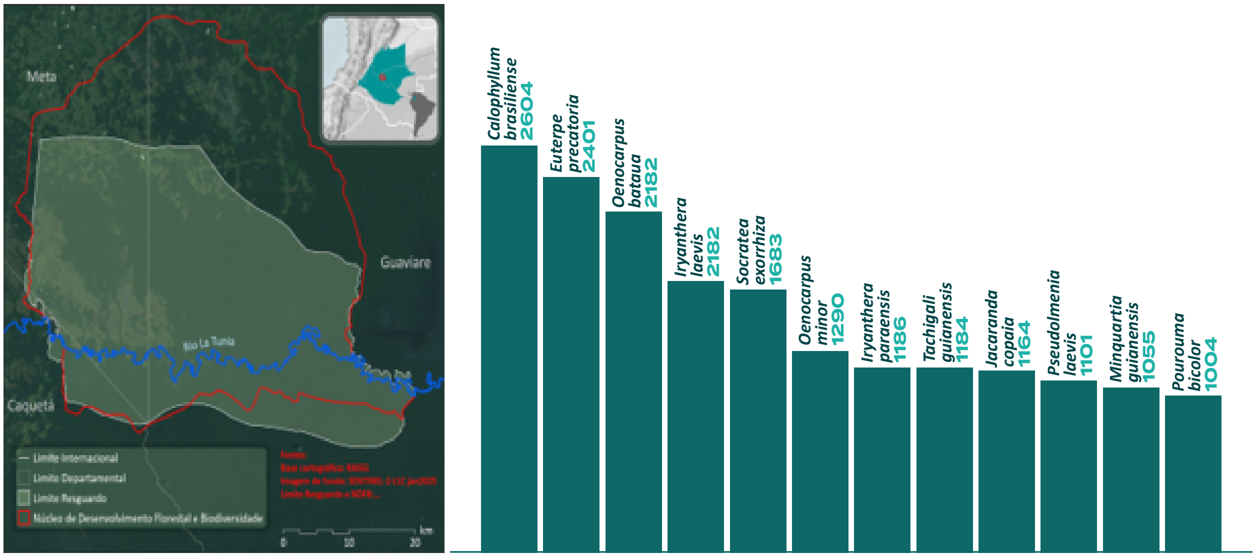

Figure C6.21.2. Number of individuals of the most abundant native species planted in the community-based project "Contribución a la gestión integral del bosque en el núcleo Yaguará II" (Contribution to the integrated management of the forest in the Yaguará II core) within the Llanos del Yarí Yaguará II Indigenous Reserve in La Macarena, a region formally designated as a Forest and Biodiversity Development Core to protect its biodiversity and livelihoods. The total number of species planted is 208.

The Solutions Space

Major recent government effort

- **The Colombian government has designated Amazonian regions as a "Forest and Biodiversity Development Core"** to strengthen Indigenous governance and capacities to use forest resources as a strategy to reduce deforestation and maintain conserved areas through an integrated program that benefits the involved Amazonian areas.

Collaborative efforts

- **In 2023, the community-based project "Contribución a la gestión integral del bosque en el núcleo Yaguara II"** (Contribution to the integrated management of the forest in the Yaguará II core), within the Llanos del Yarí Yaguara II Indigenous Reserve, funded by the National Environmental Fund (FONAM) and implemented by the Alexander von Humboldt Institute, opened opportunities for IPs to engage in Amazonian biodiversity-based agroforestry activities, promoting uses and livelihoods characteristic of the Amazon region. Those communities were displaced until 2023, and this strategy is part of the reallocation program. With this project, 420 hectares of forests were restored using 208 species (native and productive), with 27,000 individual productive plants and 59,000 trees and palms (**Figure C6.21.2**).

- **The Climate and Land Use Alliance** aims to conserve tropical forests in Colombia, Ecuador, and Peru by strengthening the territorial rights of IPs and LCs and supporting sustainable, traditional lifestyles.

Best Practices

- **The Amazon Indigenous REDD+ (Reducing Emissions from Deforestation and forest Degradation)** initiative promotes the inclusion of IPs and their forest management practices to support territorial rights and inclusive conservation.

- **The Amazon Scientific Research Institute (SINCHI)** has several research projects that link forest conservation to agroforestry practices in Amazonas, Caduetá, Putumayo and Guaviare (in Colombia).

Recommendations

- **Improve the infrastructure of biodiversity-based agroforestry products** by strengthening access to roads, public services, storage capacities, and sanitation, to ensure the economic viability of biodiversity-based agroforestry production (see Chapter 6).

- **Strengthen mechanisms that favor land-tenure security** to promote activities such as tourism and access to credits and other incentives.

- **Develop complementary productive activities**, such as forest management, the use of non-timber forest products, nurseries, and the acquisition of plants for land restoration, to finance other activities.

- **Dismantle barriers to market access and product commercialization** to make the area more visible in terms of commercial and economic opportunities, ultimately improving the quality of life for local communities. Improve the technological capacities of IPs and LCs, using software, computers, and apps to enable the commercialization of their products and enhance interaction with the wider world.

- **Governments, financial institutions, and the private sector should promote biodiversity-based markets** for IPs and LCs, ensuring their livelihoods, economic opportunities, and the conservation of their territories and biodiversity in the Colombian Amazon.

Key Recent Literature

- Hernández-Ospina, M.J.D. Gómez Gil & C. Gil. Paz ambiental en áreas en disputa. El Resguardo Yaguara ii: un territorio marginalizado y estratégico. *In Paz Ambiental: Ecos de La Naturaleza En La Transformación Social* (Instituto Colombo-Alemán para la Paz–CAPAZ e Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, 2025).

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Expand the Market Access of Family Farmers' Cooperatives in the Amazon

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Photo credit: Pexels.

The Overview

Amazonian family farming is rooted in multifunctional production systems and closely related to the livelihood of family farmers and local communities. It is essential for food security, cultural diversity, and territorial resistance in the context of increasing pressures at the socio-environmental frontier[1]. On their own, Amazonian family farmers face limited access to credit and rural extension services, as well as the risks of debt and policy vulnerability. Strengthening these families requires expanding their opportunities to access short food supply chains, linking their establishments and cooperatives to stable institutional markets, and empowering them in governance so that policy design reflects their needs and knowledge.

CALL TO ACTION 22

The Facts

- Family farming accounts for over 90% of all farms in the world, producing 80% of the world's food by value[2].
- In the Brazilian Amazon in 2017, family farms represented 81% of rural properties, and this sector employed 74% of all workers in rural properties[3].
- Family farming cooperatives in the Amazon can be almost statistically invisible in official open data sources. For example, in the northern regions of Brazil, only 3.2% of family farming units (EAP-AF) have producers associated with cooperatives.[2,4].
- Family farming in the Amazon faces commercialization barriers due to institutional and logistical challenges, such as encountering unsatisfactory sales prices when dealing with brokers or intermediaries—which, in the case of fishing, can reduce income by up to 27%—as well as seasonal uncertainty or transportation difficulties when selling products at local fairs[5,6].
- Family farmers in the Amazon face difficulties accessing new credit lines. For example, 25% of family farmers in Brazil are in debt, which restricts their access to new credit lines[7].
- Family farming in the region faces growing pressures from the recent push for urbanization n and also from the need to adapt to face competition with agribusiness and to prevent the disruptive threats of climate change[8].

Global/Regional and Synergistic Connections

- Government initiatives can help connect family farm products to local and regional markets. Market access can allow these farming families to sustain their livelihoods while also supporting nature conservation.
- Enabling diversified production systems to sell quality food directly supports marginalized populations and aligns with the United Nations Decade of Family Farming (2019–2028) and the Sustainable Development Goals (SDGs).

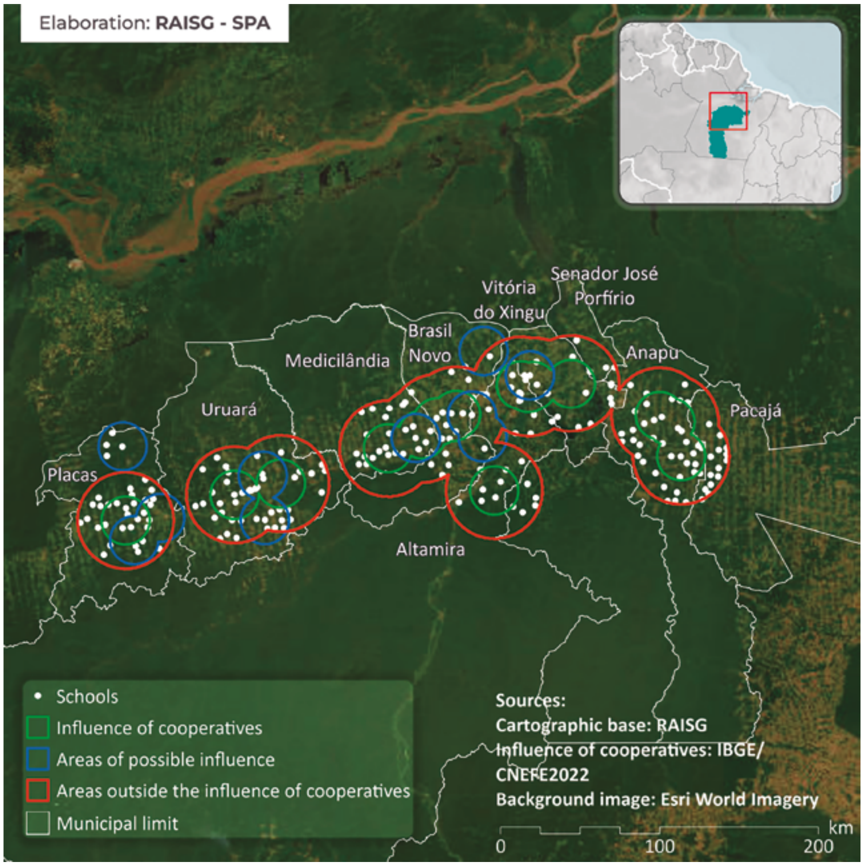

Figure C6.22.1. **Map showing schools** and the areas being covered by 16 cooperatives in seven municipalities in the midwest of Pará, Brazil, along the BR-230 Trans-Amazonian Highway. Schools within the area of influence of cooperatives have higher indicators of education performance (Table C6.22.1). Source: Data from authors, unpublished.

Table C6.22.1. Differences in average socioeconomic attributes between schools inside (inner) and outside (outer) the cooperatives' influence area (based on School Census and Socioeconomic Level Indicator [INSE]). Schools within the influence circle showed better student performance in math and language (Socioeconomic indicator), reduced gender gaps in attendance, and strengthened youth and adult education. Sources: INEP School Census, INEP INSE, unpublished data from authors.

	INNER		OUTER		BETTER PROSPECT
ATTRIBUTE	MEAN	STANDARD ERROR	MEAN	STANDARD ERROR	
Socioeconomic indicator of the basic education schools (INSE)	4.37	0.05	4.24	0.07	No difference
Number of female students	51.59	4.11	39.05	3.70	Inner
Number of male students	54.69	4.74	45.94	4.50	No difference
Number of enrollments in education for adults	5.06	1.06	0.67	0.33	Inner

The Solutions Space

Major Governmental Efforts

- In Brazil, recent public government planning efforts have strengthened the connection between family farming and traditional communities through the use of public purchasing programs. One example is the **National School Feeding Program (PNAE)**, which links family farming to education through purchases to provide school meals (see **Figure C6.22.1**). This has resulted in an increase in education performance in the region surrounding the municipality of Altamira (PA), along the Transamazon Highway (BR-230)[9,10], closing the gap with the rest of the state. Another example is the Food Acquisition Program (PAA), which purchases food with the aim of assisting lower-income individuals[11,12].

- The **School Meal Regionalization Program (PREME)** in Amazonas state, Brazil, supports local cooperatives, agro-industries, and rural producers by purchasing food for school meals, reaching 1,200 accredited producers in 2025.

- Another notable initiative was a program to **distribute regional school food in Indigenous schools** in Tefé, Amazonas state. This was supported by the Institute for Sustainable Development of Agriculture and Forestry Development of Amazonas State (IDAM), which facilitated the delivery of local products, strengthening local sales, adding cultural and nutritional value to meals, and paving the way for communities to benefit from PAA and PNAE.

Selected Key Tools

- Institutional food markets mediate access to the products of family farming, and by fostering the **Protected Geographical Indication (PGI)** category, they add value to products based on their origin certification[13,14].

Collaborative Efforts

- **The Catrapoa Initiative** (in Amazonas state, Brazil) was created to adapt school food to the cultures of Indigenous Peoples and Local Communities. It promotes the direct purchase of food from family farms near schools, and it benefited approximately 350 Indigenous producers and 20,000 students between 2019 and 2020.
- **The Alimenta Saber project** in Acre, Brazil, with financial support from the Amazon Fund (administered by the Brazilian National Development Bank, BNDES), supports sustainable food production by family farmers and their integration with PNAE.

- Another project with a third-sector organization taking on a facilitating role was a **project with the Sateré-Mawé People in Maués**, Amazonas (Brazil), funded by the United Nations Development Programme (UNDP) and partnered with Slow Food Brazil, which supported Indigenous producers in supplying local schools.
- In Ecuador, **Chakras Amazónicas** supports family farmers from the Kichwa community in selling products grown using Indigenous farming practices. This collaboration includes a nongovernmental organization (Trias), an Indigenous organization (Kallari), and other institutions (e.g., Ikiam University) and aims to sell products like cacao, vanilla, *guayusa*, and coffee.
- In Peru, **the community of San José de Parinari** harvests *aguaje* fruits (*Mauritia flexuosa*) in a legal, sustainable, and traceable manner in the Marañón River Basin in Loreto. Public and private actors are involved in this collaboration to support and improve local livelihoods.
- In Guyana, **a cassava processing facility** was established in 2024 to support sustainable, community-based farming. This project has created employment opportunities for youth, diversified agricultural products, and contributed to mangrove forest conservation through sustainable forest management, thereby promoting family farmers as forest caretakers and carbon stewards.

Recommendations

- **Support family farmers in establishing community cooperatives** to participate in public expenditure bidding processes, and offer training courses to enhance their chances of securing contracts.

- **Promote inclusive governance mechanisms** that allow cooperatives to influence decision-making in public programs and territorial planning.

- **Improve farmers' access to markets and income, and support further development of family farming agro-industry initiatives,** with the aim of further diversifying farmers' means of acquiring income, capital, relevance, and market reach.

- **Establish a publicly accessible database listing cooperatives engaged in school food supply chains,** including details on their products and the local governmental entities that purchase their services.

- **Strengthen technical assistance and training mechanisms** to adapt cooperatives to government initiatives' requirements**—and create more space for family farming in the public budget.**

- **Work with the nutritionists responsible for developing school feeding menus,** with the aim of promoting appreciation for and the inclusion of regional products.

Key Recent Literature

- Cavalcante, D.F.S. et al. Determinants for overcoming the partial commercialization of the production of family farmers. *J. Agric. Educ. Ext.* (2025). DOI: 10.1080/1389224X.2025.2477453.

- Costa, F.A. et al. Complex, diverse and changing agribusiness and livelihood systems in the Amazon. *Acta Amaz.* **54**, e54es22096 (2024).

- Machado, P.M.O. et al. Compra de alimentos da agricultura familiar pelo Programa Nacional de Alimentação Escolar (PNAE): estudo transversal com o universo de municípios brasileiros. *Ciênc. Saúde Coletiva* **23**, 4153–4164 (2018).

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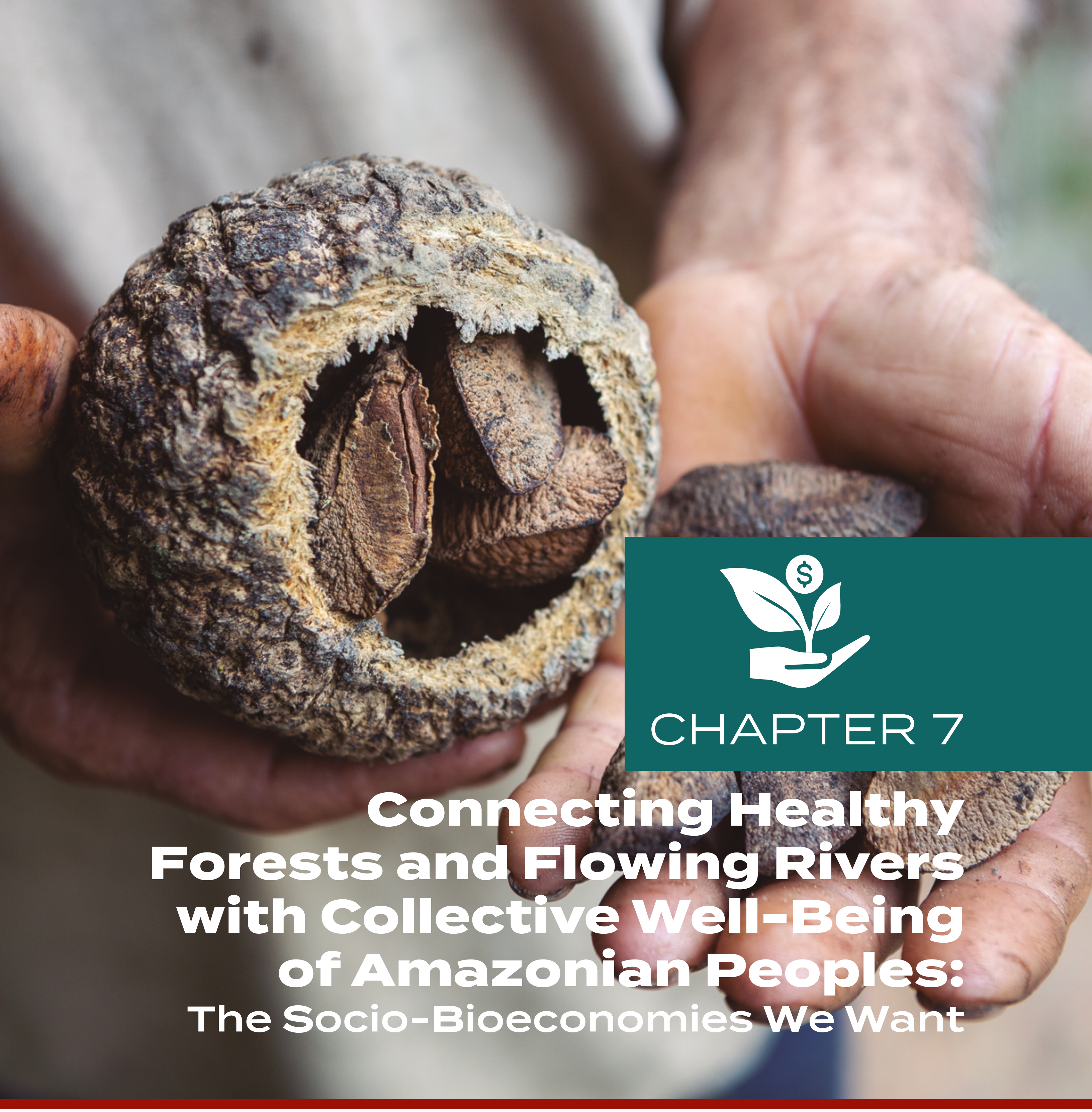

CHAPTER 7

Connecting Healthy Forests and Flowing Rivers with Collective Well-Being of Amazonian Peoples:

The Socio-Bioeconomies We Want

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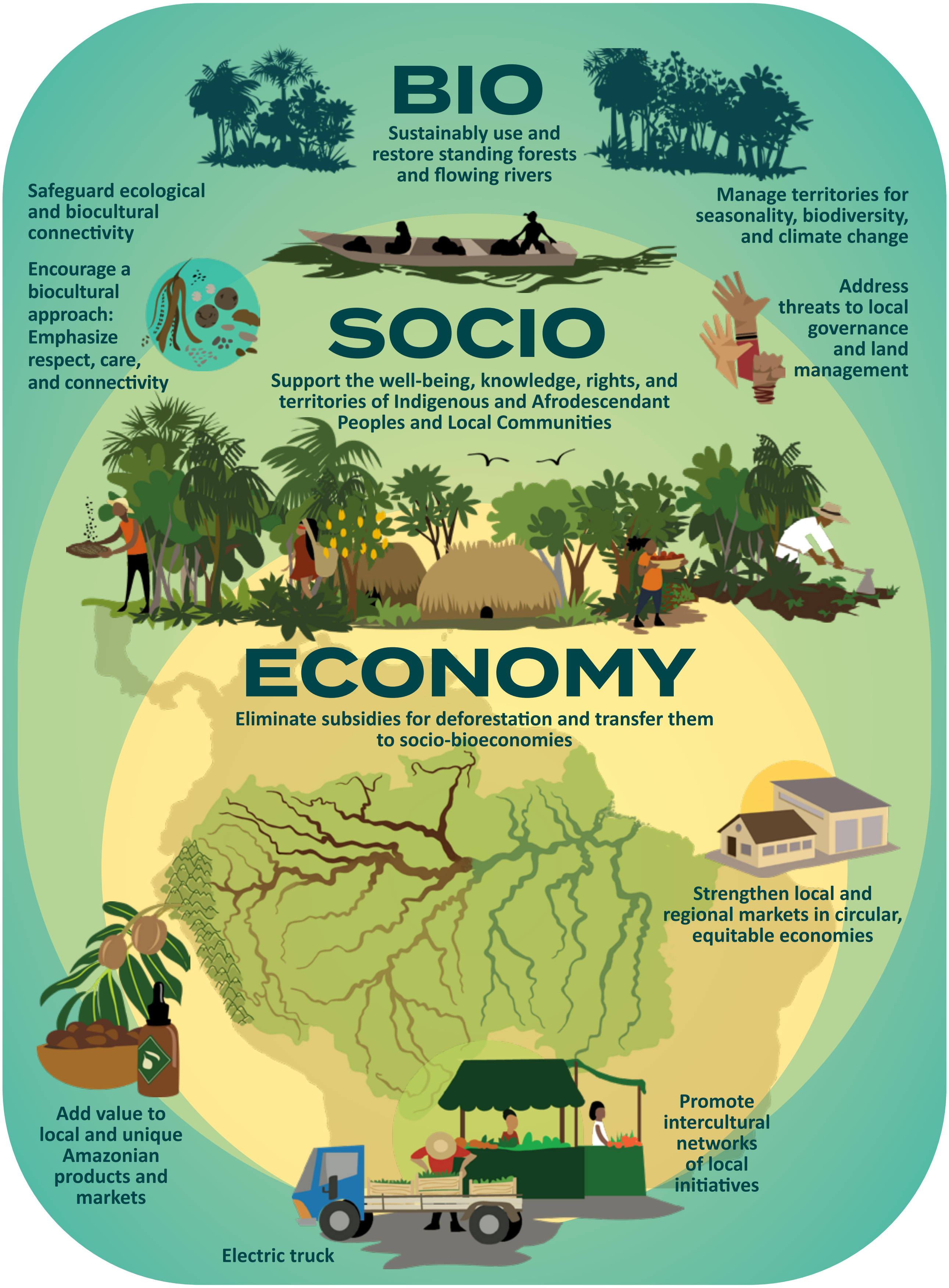
Abstract

This chapter focuses on the deep interdependence between Amazonian peoples and their environments. This interdependence forms the foundation of socio-bioeconomies—systems of production, exchange, and consumption that contribute to a well-connected Amazon through the sustainable use and restoration of thriving standing forests and flowing rivers, benefiting both local communities and the planet as a whole. Diverse Amazonian communities share an intricate, place-based connection to their territories and the natural resources that sustain their livelihoods and that hold the potential of yielding commercial products with added value. Valuing territorial-based knowledge systems supports the rights and territories of Indigenous and Afrodescendant Peoples and Local Communities (hereafter IPs & LCs) that are exercised through local governance and resource management systems. These elements help promote well-being and equitable benefit sharing, shifting away from profit maximization as the primary economic driver and toward sustaining ecosystem integrity and the intricate web of forest and riverine life. The chapter's first subtheme explores the principles of self-defined local economies, which are rooted in cultural and social knowledge systems that promote well-being and justice. Local socio-bioeconomies include diverse initiatives by Indigenous and Afrodescendant Peoples, smallholder local communities, and urban dwellers. The second subtheme focuses on well-being beyond the human realm, emphasizing the sustainable management of natural systems. It highlights ecological practices that sustain biodiversity and respect biological life cycles and seasonal rhythms. The third subtheme addresses how to overcome key challenges and mitigate risks without crossing essential ecological thresholds. It presents concrete strategies for advancing territory-based socio-bioeconomies that sustain and improve local livelihoods, encourage market creativity and diversification, and protect the integrity of forests and rivers under the stewardship of diverse local communities.

Keywords

Socio-bioeconomy, Indigenous and local knowledge, biocultural approach, territory, value chains



Graphical abstract: ***Subsidies supporting deforestation must be replaced by support for socio-bioeconomies*** *that are intrinsically connected to the biodiverse forests and rivers of the region, supporting local people's rights and managing territories and resources sustainably.*

1. Introduction

This chapter focuses on the inherent interrelationships between Amazonian people and their territories as the foundation for socio-bioeconomies: socio-ecological systems that support livelihoods and value chains and that safeguard biological, cultural, and social connectivity and diversity throughout the region while contributing to planetary resilience[1–6] (see also Chapters 5 and 6). These Amazonian socio-bioeconomies support the knowledge, self-determination, rights, and territories of Indigenous and Afrodescendant Peoples and Local Communities (hereafter IPs & LCs) and offer concrete strategies for advancing territory-based socio-bioeconomies that sustain and improve local livelihoods through diverse markets and protect the integrity of forests and rivers under the stewardship of diverse local communities[3,7]. Socio-bioeconomies have also been a means for people to defend their territorial rights and demand participation in decision-making in the face of profoundly antagonistic actors (see Chapter 2) and forces that currently dominate the region[8-9] (see Chapters 2, 3, 5, and 6). Socio-bioeconomies also are embedded in the broader Amazonian economy, with strong ties to Amazonian cities and to scientific and technical advancements that can support and enhance local livelihoods.

While conventional economics focuses on individual profit maximization, socio-bioeconomies value equitable governance, collective decision-making, and respect for unique ecological and cultural contexts[1,9]. Central to this approach is valuing Indigenous and local knowledge perceptions and practices, while remaining in dialogue with scientific insights and technologies for innovation (see Chapter 8). This chapter acknowledges the Amazon's large diversity of small-scale producers, whose work ranges from subsistence and low-impact activities to participation in complex, specialized value chains that connect local rural and urban populations to regional and global markets by adding social and economic value to the Amazon's socio-biodiversity. While the socio-bioeconomy framework originates from Indigenous knowledge systems and ecological dynamics, it also benefits urban inhabitants and smallholder farmers as it invites them to consider the collective consequences of their own practices and decisions.

Amazonian IPs & LCs are highly diverse (see Introduction and Chapter 5), but through their varied interactions with the biodiversity of their territories, they come to embody culture, history, memory, identity, economy, and social care, forging holistic and reciprocal relationships with the common goods that sustain their well-being. This is often expressed in the Indigenous concept of "living well" (*buen vivir*)—a plural and relational Indigenous philosophy centered on living in harmony with nature, community, and spirit. It emphasizes reciprocity, territorial autonomy, and collective well-being, rejecting extractivist and individualist models of development. Amazonian socio-bioeconomies are rooted in reciprocal connectivity among all beings, embodying a sense of participation in an integrated living system (a biocultural approach)[1].

To address the current economic pressures on Amazonian ecosystems and communities and the unrelenting focus on markets, growth, and Gross Domestic Product (GDP) requires innovative, diversified, multiscale, and complementary solutions. Disseminating socio-bioeconomic principles and practices to non-Indigenous rural and urban Amazonian populations amplifies these possibilities. Socio-bioeconomies may not replace the dominant capitalist systems, with which they are often interconnected, but with the appropriate incentives and subsidies to enhance equity, their growth and emergence can contribute to mitigating climate change and curbing food insecurity, and to promoting social-ecological resilience.

Diversifying and broadening access to local foods and other products expands labor allocation opportunities; improves incomes; helps reduce food imports; and makes healthy, affordable food available to urban dwellers[10]. Increasing access also helps promote awareness among local Amazonian urban populations of the uniqueness and sustainable foundations of local foods (see **Box 7.1**) and other high-value Amazonian goods, like cosmetics and medicines[11]. Scaling of initiatives through interconnected hubs, production sites, and networks could potentially reach broader segments of Amazonian populations and other markets by linking both urban and rural dwellers in decentralized production and collaboration as a means of cost-sharing rather than employing a vertical non-collaborative approach[12–15].

Box: 7.1 Food sovereignty and the Amazonian Culinary Research Institute

Nelson Méndez, Amazonian Chef

Nelson Méndez, Chef and Head of Amazonian Culinary Research Institute, Puerto Ayacucho, Venezuela[16].

As a resident of the Venezuelan Amazon and a member of the Baré Indigenous People, I have leveraged my culinary expertise as an Amazonian chef (Golden Fork Award winner as Venezuela's best chef) to support Indigenous Peoples. I created the Amazonian Culinary Research Institute ten years ago, empowering and training over 45 Indigenous chefs and cooks, and further benefiting school cafeterias and their staff in these communities. As a laboratory, we explore food preparations made from products bought daily directly from Amazonian Indigenous fishers and harvesters. This entails taking into account seasonality and production calendars that are shifting with climate change, with implications for the reproductive cycles and growth of fish and the availability of ripe fruits.

One of the most important aspects for the Indigenous Peoples living in our Amazon is our food security and sovereignty. This relates to both the tangible and intangible (spiritual) worlds, invoked by shamans who channel spiritual and natural energies to ensure and provide food and to seek permission for hunting and fishing. In the case of the Venezuelan Amazon, Indigenous groups embody unique roles, such as the Jivi, who are excellent fishermen; the Uwottüja, who are farmers (*conuqueros*), hunters, and gatherers; the Baré, who boast a rich culinary tradition; the Yanomami, known for their expertise in mushroom gathering; and the Sánema, who are honey collectors. These Indigenous Peoples have also developed food processing techniques that, had they been patented, could have generated significant economic benefits. For example, the domestication of bitter cassava produces *mañoco* flour and cassava bread, and subproducts like *catara* sauce that serve to preserve, flavor, and tenderize hunting and fishing proteins. Indigenous Peoples have also mastered food preparation techniques that have allowed for the conservation and storage of food. The art of smoking, drying, grinding, and salting fish represents a millennia-old culinary feat that ensures food security. Furthermore, their techniques for extracting and storing fruits from palm trees such as *seje* and *manaca* (açai) enable us to consume medicinal superfoods as part of our seasonal diet. Our ancestral habit—now seen as futuristic and innovative by the Western world—of consuming high-quality protein via insects is equally noteworthy.

These dietary habits and exchanges among our peoples could be promoted as part of "zero-kilometer," carbon-neutral, or "farm to table" movements in contexts where people have lost contact with the source of the food they eat. But these exchange systems have been taking place for millennia, creating perfect trade balances (e.g., a fisherman exchanges goods with a farmer) to guarantee food security.

Through projects and agreements with Indigenous communities and their traditional authorities, we intend to leverage and standardize products and recipes while obtaining quality-assured items with proper sanitary permits. By developing what Indigenous peoples have always understood as a medicinal and sensorially unique gastronomy with unparalleled flavors, we can create standardized, quality products that are labeled with designations of origin and sustainability seals. All of this serves as an alternative to extractive mining and overexploitation of native Amazonian food resources, which are currently affecting the Amazon.

2. Self-Defined Local Socio-Bioeconomies Based on Cultural and Social Knowledge Systems for Well-Being

The Amazon biome has been shaped for millennia by ecological and geological processes in interaction with human populations[17]. This interaction has been shaped by livelihood systems over generations, guided by local knowledge systems that share key principles: recognition of a cosmopolitical network of relationships between humans and non-human beings; the practice of ritual prescriptions and restrictions that maintain ecological balance through reciprocity; and an approach informed by annual cycles and careful observation of the surroundings (see Chapter 5 and this chapter)[2,18].

Amazonian IPs & LCs recognize multiple, coexisting economic rationalities, beyond efficiency or profitability, articulated with ancestral cosmovisions (i.e., cosmic worldviews) of life, production, and exchange that are grounded in reciprocity and respect for living territories[19]. They manage seasonally variable landscapes as systems based on horticulture, agriculture, agroforestry, fishing, hunting, and gathering of fruits, fibers, oils, and insects[11]overlooking the socioecological roles of urban populations. This oversight can hinder sustainability by neglecting rural–urban connections. We compared the prevalence and quantity of wild meat consumed, bartered, and traded commercially in rural, peri-urban, and urban areas of the Brazilian Amazon to inform policies aimed at including local people in conservation. We also examined social factors influencing wildlife access. These factors included household management (single vs. dual adult households. They rely on their historical knowledge, cultural identity, and tradition as a source of autonomy and sovereignty, which are central for exercising political and environmental governance[20–22]. All these low-scale, high-diversity economies share common principles that contribute to maintaining ecosystem connectivity and health, which underpin maintenance of water cycles and climate regulation. Amazonian cities and small urban centers rely on forest and river products and therefore often interact with these local production systems through public services and market exchanges.

The circularity of multifunctional production systems distinguishes them from monoculture commodity production systems that dominate the world economy; the latter type of systems have contributed to the planetary crisis by promoting pollution, biodiversity loss, and climate change (Chapter 6). Yet low-impact, culturally based production systems such as diverse fisheries (see Call to Action 23) and food plot systems are often invisible in official statistics and marginalized in relations with regional, national, and international economies and policies, despite their importance in producing food and sustaining food security and livelihoods[23] (see Chapter 6). Fish caught in local rivers and fruit collected from local trees are not registered through receipts or official documentation, yet research shows smallholder producers are responsible for a significant proportion of food production (e.g., 57.8% of some food products in the Brazilian Amazon state of Rondônia in 2017–2018), and wild/capture fisheries comprise over 90% of fish consumed in the Amazon[24–26].

Relatively few practical investments have focused on improving strategies for these diverse, multifunctional production systems compared to the massive investments made in specific market commodities[27]. As a consequence, some individuals in Indigenous and local communities have engaged in illegal practices of mining, logging, wildlife trade, and drug trafficking, putting at risk the traditional, sustainable interdependence between Amazonian peoples and their environment. The lack of effective support for IP & LC territorial rights and for socio-bioeconomies threatens people's ability to support their communities and enhance commercial exchange. Younger generations, especially, may see participation in destructive activities such as cattle ranching or illegal activities as a more attractive alternative for earning income. The presence of these actors also threatens the territories, governance systems, and physical security of IPs & LCs (see Chapters 4 and 5).

Territorial management by IPs, APs, and LCs depends on achieving land tenure rights, which are often inherently collective and based on community-based governance mechanisms such as Indigenous land councils, territorial assemblies, and traditional authorities[28]. Through their organizations and with the support of civil society groups, IPs & LCs have designed governance tools to use, protect, and develop their territories and waterways in a sustainable and self-determined manner, often in coordination with the broader state structure, and to exercise their sovereignty when dealing with third parties[25,29].

3. Territorial Management and Sustainable Use of Resources According to a Biocultural Approach

IPs & LCs have developed practices that enhance biocultural conditions specific to each aspect of a territory including the socio-ecological processes that support a territory's complexity. Comprehensive territorial management contributes to safeguarding ecological and sociocultural integrity by maintaining ecosystem connectivity. Land-use planning instruments receive different names across the Amazon: *Planes de Vida*, *Planes de Calidad de Vida*, *Planes del Buen Vivir*, *Planes de Gestión Territorial Comunitaria Para Vivir Bien*, *Planos de Desenvolvimento Etnoambientais*, and *Planos de Gestão Territorial e Ambiental de Terras Indígenas*[30–33]. Rooted in knowledge of the land, forests, rivers, and natural cycles and the people's cosmovision, these instruments involve a collective reflection on the past, present, and future as well as the community's cultural values, knowledge systems, and strategies for well-being[34–36]. They also strengthen leadership and capacities to dialogue and negotiate with external actors. For example, the Kawsak Sacha

– Living Jungle[37] proposal by the Kichwa people of Sarayaku in Ecuador has gained visibility at international climate meetings.

One of the defining features of local territorial planning is the integration of natural cycles—including seasonal changes, high water, low water, flowering, fruiting, harvests, animal migration and reproduction patterns, growth and regeneration cycles, and other biological and ecological rhythms of the territory. Interactions among biological, hydrological, and social events are often integrated into ecological and seasonal calendars and embodied in traditional land and resources uses and practices (see **Figure 7.1**)[34,38,39].

These land-use planning instruments show the many ways that IPs & LCs understand, value, inhabit, use, shape, and participate in their biodiverse territories and how they adapt to environmental and climatic changes. For example, hunting, fishing, and gathering restrictions are often related to specific natural cycles coordinated with sacred or historically meaningful site management practices; this is especially important when places of cultural significance coincide with places of high ecological value, like spawning areas and mineral-rich salt licks for large mammals and birds, among others[40]. Dissemination of these socio-bioeconomy principles and practices could potentially benefit broader segments of Amazonian populations. Developing sustainable livelihood systems for local populations is the first stage to permit further product diversification oriented to value chains and markets.

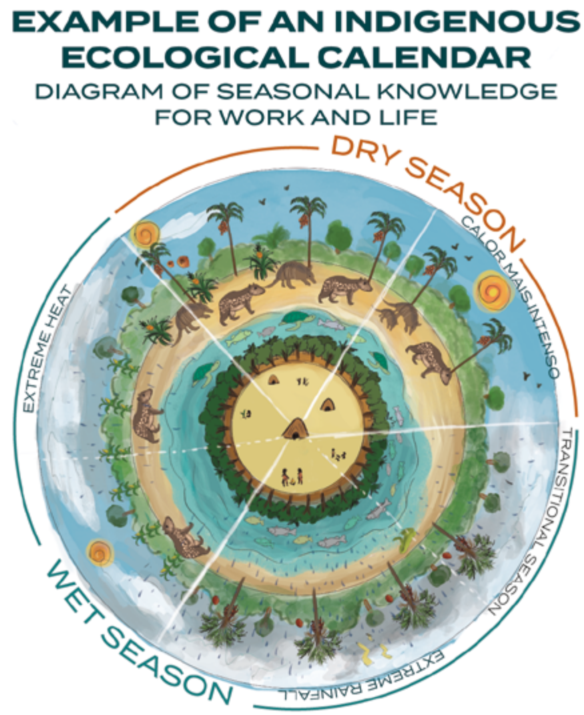


Figure 7.1: ***Indigenous ecological calendar*** *referencing seasons and rituals for territorial and resource management.*

Understanding natural cycles in time and space contributes to a sense of circularity of production and attention to the use of by-products. For example, the practices associated with planting and transformation of the staple crop cassava/manioc (*Manihot esculenta* Crantz.), often based on women's intergenerational knowledge, include techniques for soil management and cyclical forestry, with fluctuations in time and space to allow for forest transition following harvest cycles (see **Figure 7.2**). Many varieties of these plants, categorized into two main groups of bitter and sweet cassava (*Manihot palmata* and *M. aypi*, respectively), are managed by local Amazonians[41]. People make use of leaves, roots, and other plant parts, as well as by-products, for *tucupí*, *fariña* flour, and *casabe*, and they implement specific technologies to transform otherwise poisonous plants into edible, shelf-stable products for the market. The domestication of hundreds of products over thousands of years based on Indigenous plant science underlies the current potential for expanding socio-bioeconomies.

Figure 7.2: ***Spatial distribution and rotation of a diversified food plot, showing two points in the yearly cycle of a chagra agroforestry system*** *(three months and one year) of the Nonuya people (known as the People of the Center) of the Colombian Amazon as depicted by Abel Rodríguez, /Mogajé Guihu. Source: Abel Rodríguez (2013). "El ciclo anual de la chagra." Ink on paper Tinta sobre papel, 50 x 70 cm. Source: Courtesy of Cortesía de Tropenbos Colombia.*

Non-timber forest products (NTFPs) are important components of the past and current trajectory of socio-bioeconomies of the Amazon, transcending generations. The grandparents tapped rubber; the parents cracked Amazon nut shells; and new generations have climbed *açaí*, *aguaje*, or *majo* trees and today do so to supply markets with these globally cherished "superfoods." Historically, local relations with national and international conventional economies have been based on a few products such as timber, babassu oil, cacao, rubber, Amazon nuts, and açaí, which have become commodified and have acquired consolidated supply chains (see Call to Action 24).

These value chains have generally not fairly remunerated local communities. For example, less than 5% of the US$400 million trade in Amazon nuts stays in the hands of local collectors[42]. As demand increases, food and other products, such as rubber and cacao, are produced in monocultures or synthesized, reducing the competitiveness of local collection–based systems. The challenge for socio-bioeconomic initiatives lies in reducing unfair disparities between the value chain links by improving economic benefits for actors in the first link of each chain, thereby promoting a more equitable trade (see Call to Action 25)[38,43]. Another challenge is that the development and expansion of these NTFP market chains without ensuring a commitment to circular practices has generated significant waste and by-products, as seen in the açaí chain and others[44].

Amazon nuts (*Bertholletia excelsa* Bonpl.*)* are one of the best-established Amazonian products in the global market, providing income to large numbers of producers and representing about 70% of cash income for rural communities in Bolivia[45]livelihood needs and desires for better living conditions may continue to place these resources under considerable stress as income needs and opportunities intensify and diversify. We aim to identify the socioeconomic and biophysical factors determining the income from forests, husbandry, off-farm and two keystone forest products (i.e., Amazon nut and timber. However, climate variability has had major impacts: in 2017, the extreme heat and drought caused by the El Niño–La Niña transition drastically reduced natural fruit production and further declines were recorded in 2023–2025 [46–49]. Such events illustrate how climate change threats and price volatility can affect the incomes of families, concessions, or extractive reserves. The development of climate monitoring systems (focused on climate anomalies and their impact on fruit production) and early warning of declines in fruit production could help to address these risks[50].

Socio-bioeconomies can be strengthened by the introduction of new technologies and small-scale local processing plants to add value to existing and new products, increasing safety and efficiency through appropriate innovations and increasing urban employment opportunities. Only 200 processing plants currently exist across the Pan-Amazon region, adding value to pulp from native fruits, oil seeds, Amazon nuts, and other NTFPs[51] (see **Figure 7.3**). Without adequate, sustainable infrastructure, IPs, APs, and LCs are exposed to exploitative commercial exchange dynamics that have existed for centuries in the region. Improving marketable products for small producers with innovations from local knowledge, science, and technology should be part of a multifaceted approach to promote a diversity of local products, while carefully avoiding the risks and limits of socio-biodiversity principles that have been shown to exist in scaling markets for Amazonian products[52].

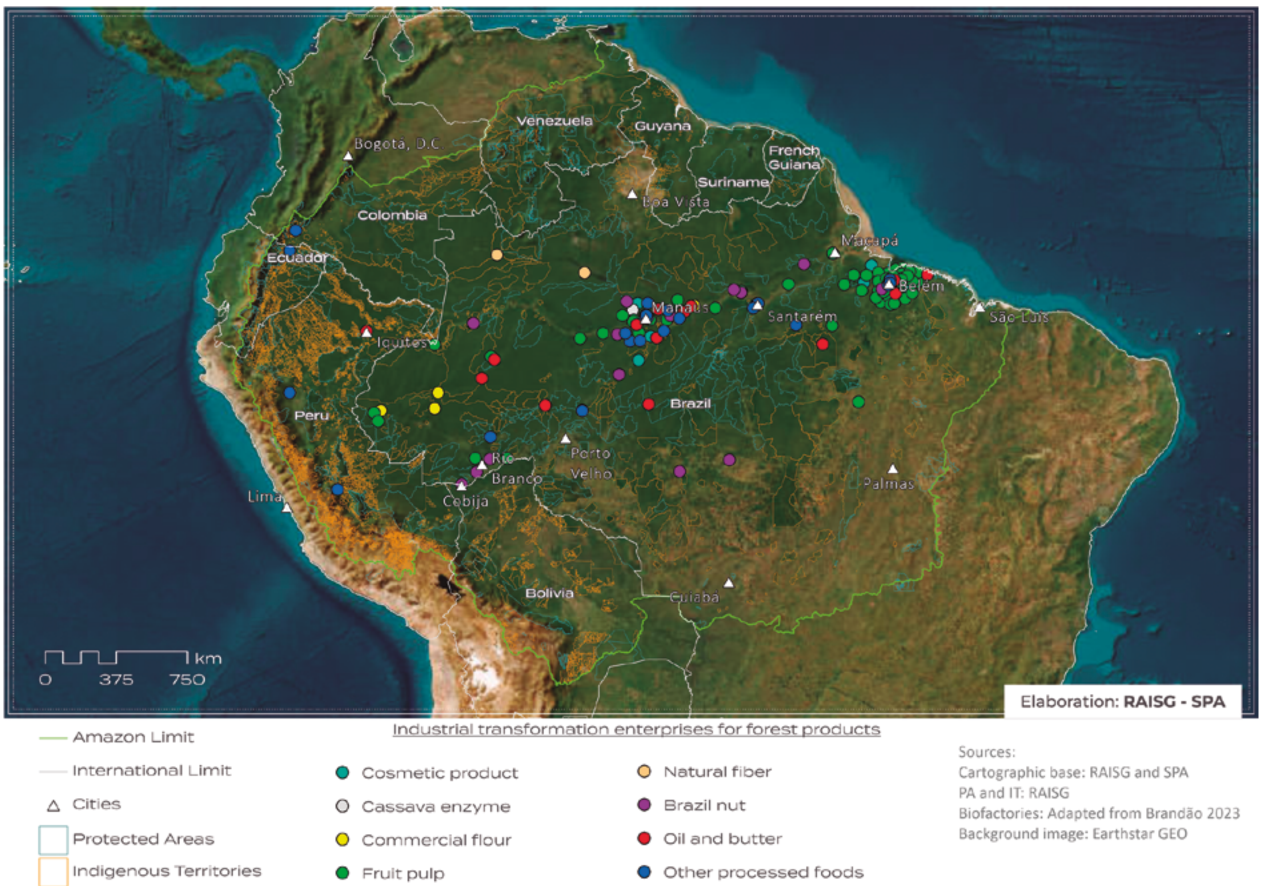


Figure 7.3: ***Existing processing enterprises for non-timber forest products across the Amazon.***

There is also a key need to create new value chains capable of handling not only specific NTFPs but multiple products at the same time to reduce incentives for monocultures. These value chains should embrace circularity innovations, such as utilizing waste streams—for example, using açaí residual biomass (core and fiber) to produce biopolymers with new material applications, such as bioplastics, or using fiber from Amazon nut husk waste to produce twine. Value chains also can incorporate circularity strategies through territorial restoration, agroforestry, and other approaches to secure resources for the future[44,53–55] .

The industrialization of biodiversity products can benefit communities if it aligns with the socio-bioeconomy principles[2] addressed throughout this chapter; this involves active participation by local producers using collective networks to ensure autonomy and sustainable growth. Differentiated markets, such as organic and fair trade, tend to pay better prices for high-quality products, also recognizing their origins and added value related to local knowledge systems and practices (see Call to Action 26). However, significant obstacles stand in the way of achieving improved product value, identity, handling, and hygiene, while also reaching increased demand and prices in regional and niche markets. These obstacles include limited information access, technical expert shortages, logistical remoteness, lack of effective marketing and production volumes, and bureaucratic complexity.

Perhaps the main contributions of these emerging chains are to support women's active participation in harvesting and selecting products, processing materials, and commercial sales; a key way this happens is through the creation of collective microenterprise initiatives that contribute to women's economic empowerment—and through the promotion of women's participation in such initiatives[56–59] (see Call to Action 27). Indigenous and local women in the Xingu Seed Network, for example, collect and sell native seeds for forest restoration, generating income and contributing to recovery of degraded areas[60]. Nonetheless, a recent study in seven regions of the Peruvian Amazon found that the lack of support networks and training in financial management and marketing made it difficult for women to enter more competitive markets, while many Indigenous women had limited market participation altogether[61].

4. Addressing Challenges and Maintaining Safeguards to Promote Socio-Bioeconomies of Standing Forests and Flowing Rivers

The Amazon's high ecosystem diversity provides opportunities but also contributes to a multiplicity of operational, logistical, and infrastructural challenges for socio-bioeconomies; these challenges compound the threats posed by stakeholders who are linked to destructive activities (see Chapters 3, 5, and 6). Addressing bottlenecks—including financing, transportation, energy access, water supply, and digital connectivity—is essential to advancing local Amazonian socio-bioeconomies. Realizing the full potential of socio-bioeconomies in the Amazon requires innovation and collective action so multiple parties share the high costs of capacity building, infrastructure for quality control, and marketing. This requires the interweaving of scientific knowledge with Indigenous and Local Knowledge systems, technology, innovation, and entrepreneurship to leverage opportunities at different scales. Strategies for achieving these goals should include a focus on engaging youth in innovation through the creation of meaningful pathways that work with traditional knowledge systems and practices to promote intergenerational knowledge transfer.

Moreover, interventions and scaling up must be guided by careful consideration of each specific biocultural context and local resource, ensuring that adjustments come progressively and are life-sustaining, instead of leading to socio-environmental degradation[62]. Circular economy principles should inform the early design of products and endeavors, with attention to their full life cycle and the use of by-products. Growth should not be defined by exponential increases in size, production capacity, or output, which risk breaching biophysical and sociocultural tipping points. Instead, development should protect and provide broader public support for a network of small-scale, intercultural, and decentralized hubs that support distributive, horizontal production networks (see **Figure 7.4** and Call to Action 28). The continuous and systematic monitoring and evaluation of socio-bioeconomies is important to understand and manage trade-offs and adapt these activities to support the main goals established by communities.

Figure 7.4: ***Schematic representation of socio-bioeconomy networks of communities connecting rural and urban areas****:* *Community-based resource harvesting and production sites are linked in diverse ways to local processing plants and markets.*

Key guidelines to support socio-bioeconomy principles include[2,63,64]

- securing IPs & LCs territorial rights and the right to free prior and informed consent;
- establishing joint agreements for collective care of territories through daily practices and uses of nature grounded in customary norms;
- involving local initiatives in broader networks for governance, self-determination, decision-making, and collective monitoring;
- promoting market product diversification, especially for food systems;
- supporting endogenous research on practices for seed and soil recovery and for community monitoring with a biocultural approach;
- interweaving ancestral, local, and scientific knowledge in developing solutions, technologies, products, and services; and
- implementing mechanisms for environmental services payments tied to local practices and knowledge.

The dominant economic and policy environment in the Amazon currently provides relatively little support for socio-bioeconomies compared to the massive incentives for large-scale commodity agriculture, mining, selective logging, and cattle ranching[65,66]. For example, energy investments often prioritize large-scale investments that serve extractive industries (like hydropower for mining in Belo Monte and the gold mine Belo Sun in Brazil) over decentralized microgrids that support energy security for off-grid communities. National policies must improve the incentives and conditions for practices compatible with healthy ecosystems, while simultaneously reducing incentives for the harmful land-use activities that threaten socio-bioeconomies.

4.1. Policies

At state, national, and Pan-Amazon cross-national levels, there must be a focus on developing specific indicators and mechanisms to stimulate demand and finance for socio-bioeconomy solutions. Developing the conditions and logistics to increase the sustainable supply of products to allow competitive rates of return on investments can increase recognition of the added value of sustainable socio-bioeconomy products and services. Furthering these goals requires cooperation among diverse parties, which would be aided by improved means of communication.

Information-sharing portals require users to have internet access and digital skills to develop culturally relevant content. Such platforms can help to directly link communities and cooperatives supporting socio-bioeconomic activities to development banks, philanthropists, and private investors with shared objectives and needs—and whose interests are aligned with the protection of the Amazon. Enhancing positive transboundary spillovers and reducing negative ones entails broader bilateral and international partnerships and cooperation to expand knowledge, innovation, and marketing opportunities for socio-bioeconomic networks, products, and processes (see Chapter 4), while prioritizing local economic and cultural development instead of focusing only on global demand for "market-ready" products and "superfoods."

To effectively support socio-bioeconomies, policies must go beyond a focus on product-based value chains and strengthen circular, multifunctional networks that integrate knowledge, environmental services, and community resilience[63]. Clear frameworks should be maintained to uphold rights, enhance food systems, and ensure monitoring and competitiveness. As shown by the North Amazon Alliance and the Terra do Meio Network, collective decision-making and territorial networks are key to mobilizing actors, guiding investment, and linking rural and urban economies[2]. Collective governance systems, associative schemes, decision-making, and monitoring are fundamental for investments, scaling, priority-setting, and influencing public and private economic sectors.

4.2. Finances

New sustainable funding lines from philanthropic sources, both public and private, must focus on socio-bioeconomy research, innovation, and development efforts to understand how business models can successfully overcome bottlenecks in value chains. Social technologies and micro-infrastructure tailored to specific contexts can add value and diversify products across communities, in compliance with the Nagoya Protocol and principles of the Convention on Biological Diversity and in alignment with recently adopted mechanisms for respecting rights and ensuring effective participation of IPs & LCs. Investments in socio-bioeconomies can help achieve goals associated with reducing greenhouse gas emissions and adapting to climate change. Investing in regenerative supply chains is key to phasing out fossil fuel dependency while enabling energy sovereignty and accelerating the shift to mechanical and renewable energy systems in a socio-bioeconomy. This includes infrastructure for product storage and transportation and redesigned supply chains to support low-carbon logistics and circular resource flows.

Financial mechanisms based on quantifying ecosystem services (provided by nature) such as carbon sequestration have been presented as options, but their implementation has introduced risks of commodification of nature by setting a market price on natural assets. In contrast, placing a price on human efforts—such as restoration and protection of an area's vegetation, water bodies, and biodiversity—compensates for an "environmental" service (provided by people managing natural systems) that delivers multiple ecosystem benefits (e.g., water, climate, and biodiversity). Digital genetic sequencing may help to provide opportunities to generate fair benefit sharing, since payments for genetic resources and environmental services are directly or indirectly tied to knowledge and management practices of IPs & LCs, yet the practicalities and asymmetries linked to this highly technical approach have yet to be addressed.

Financial mechanisms with flexible time frames should directly support the productive activities chosen by communities, prioritizing those that safeguard greater diversity of species, generate technological innovation and knowledge, and involve collective decision-making, while adding tangible capital to local business models[67]. There is a particular need to improve and adapt existing financing mechanisms to provide direct funding for small or community-based enterprises that may lack formal tenure arrangements to serve as collateral, and for philanthropic territorial institutional funds created and managed by local communities to protect their territories and to finance their own projects related to value chains in their territories[68,69]. As an example, in Peru five Shipibo communities in Ucayali and the Belgica native community in Madre de Dios have received Forest Stewardship Council certification to support their sustainable forest management programs.

4.3. Niche Markets

Western niche markets that recognize the uniqueness of Amazonian products are directly related to socio-bioeconomies, valuing elements beyond the commodity model. Each product represents an entire universe—integrating traditional knowledge, careful preparation, and the transformation of wild or domesticated plants, all rooted in the specific knowledge of each territory. Controlled origin designations for some Amazonian products safeguard traditional practices and enhance socio-biological diversity, promoting local products and cultural heritage while ensuring traceability and compliance with international standards[70–73]. The first geographic indication status granted to an Indigenous group in Brazil was in 2020 for the *waraná* of the Sateré-Mawé Indigenous People[74]. This status acknowledges the cultural legacy and superior qualities of wild guaraná. Similarly, the official designation of origin "Cacao Amazonas Peru" protects a native cacao lineage domesticated by Awajún and Wampis communities in Peru[75].

Accessing niche markets with price premiums through value-added products that retain income at local levels is an important strategy, but this should be carefully examined on a case-by-case basis. High humidity, remote locations, and the lack of specialized machinery can complicate on-site processing. In many cases the benefits of local processing might not outweigh the logistical and financial costs, and outsourcing processing could be more efficient. Traceability also faces significant challenges in remote Amazonian regions due to a lack of digital infrastructure, high costs, and insufficient financial returns. Innovations to develop traceability tools specific to the Amazon's unique context and using a shared-benefit model across communities without expecting immediate market return could create an inclusive system that prevails over time[76] the sustainable use of non-timber forest products (NTFPs. Niche markets offer more benefits when community representatives work together with actors throughout the value chain and are involved in decision-making, not just as recipients of price premiums[77].

In addition to placing Amazonian commodities and products in the global market, it is important to strengthen local and regional markets that are not solely focused on global market trends and chasing niche-market premiums. Daily life goods and perishable food products drive local and regional commercial dynamics. Producers for global markets may experience economic instability if prices drop suddenly, which can undermine food security in communities reliant on products like açaí for both income and food. Although Amazonian IPs & LCs live in the most biodiverse places on earth, their purchasing options could be compared to urban food deserts. Initiatives should avoid overreliance on single markets, thus reducing reliance on one sole product, niche, or region; incentivizing local trade; and ensuring agroforestry and regenerative agriculture practices that maintain the diversity of crops for sustenance.

Building local economies gives local communities the opportunity to develop businesses that meet their own community needs, provide diverse goods and services that keep revenue circulating locally, and create dynamic markets that can grow organically without heavy reliance on external expertise. Most of the developments of innovative Amazonian cuisine, medicine, cosmetics, and art have taken place in the absence of Western models of innovation and commercialization. These resources and products were built to fulfill specific needs—not those of a foreign market willing to pay a premium, but from local trade between communities to meet local needs for goods and services. For example, Amazonian honey from native bees has limited demand outside the Amazon because its medicinal properties are not widely recognized. Yet, even without high global market value, it contributes to health, sustains traditional practices, and supports the local economy. Local markets play an essential role in building local capacity and Indigenous empowerment by creating culturally relevant job opportunities for young community members and providing effective alternatives to extractive industries. School feeding programs and programs at other public institutions such as the military and hospitals have significant potential to acquire food from IPs & LCs, strengthening food production resilience and broader nutritional security, knowledge systems, and resilience.

4.4. Justice and Well-Being

Means must be provided for IPs & LCs to protect themselves from encroachment and violent threats (see Chapter 5) and to effectively participate in decision-making at all levels. This is important to allow them to exercise their rights and ensure that justice remains embedded in socio-bioeconomy developments, through design processes to gather input, understand values, and weigh trade-offs. Design and implementation processes must build on existing Indigenous, Afrodescendant, and local knowledge and initiatives and develop strong cross- and intra-scalar participatory designs and feedback opportunities in dialogue with technical and scientific expertise.

More broadly, the development of a socio-bioeconomy of healthy standing forests and flowing rivers thus requires pivoting away from conventional economic development policy thinking (e.g., focused on GDP) toward growth-agnostic metrics that better measure well-being, such as the Human Development Index and the Gross National Happiness Index. Socio-bioeconomies can cultivate a vision of societies grounded in cycles and processes that ensure the Amazon's continued performance in regulating life-sustaining planetary systems.

5. Conclusions

IPs & LCs have lived in the Amazon for thousands of years with a deep understanding of the interconnectedness between human and non-human well-being. Their ways of life emphasize interrelation, reciprocity, and shared responsibility. Their practices cultivate the ethics for securing ecological, social, and cultural connectivity and provide a concrete, long-term foundation for future socio-bioeconomies based on respect for healthy standing forests and flowing rivers. Yet IPs & LCs currently are threatened by illegal activities and violence and by a development approach driven by economic growth that has been favored by mainstream policies and programs (Chapters 2, 5, and 6).

Socio-bioeconomies generate the diverse food and other resources needed to support the nutrition, health, culture, education, and other needs of IPs & LCs, both rural and urban, while respecting their rights to their territories and self-determination. Their territorial strategies provide means not only for their livelihoods but also to maintain the capacity of the Amazon to regulate life-sustaining systems that are fundamental for human existence at a global level—by sustaining incredible biodiversity; storing carbon; and regulating temperature, water cycles, and rain patterns. Overcoming the threats and marginalization these historic Amazonian systems are facing requires combining and co-constructing diverse ways of knowing—traditional and scientific—while strengthening critical factors such as acquired rights, infrastructure, transport, financing, energy, and information. These efforts can help these systems thrive as a concrete response to the planetary crisis by safeguarding the integrity of the region.

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Support Biodiverse Fisheries That Underpin People's and Nature's Health

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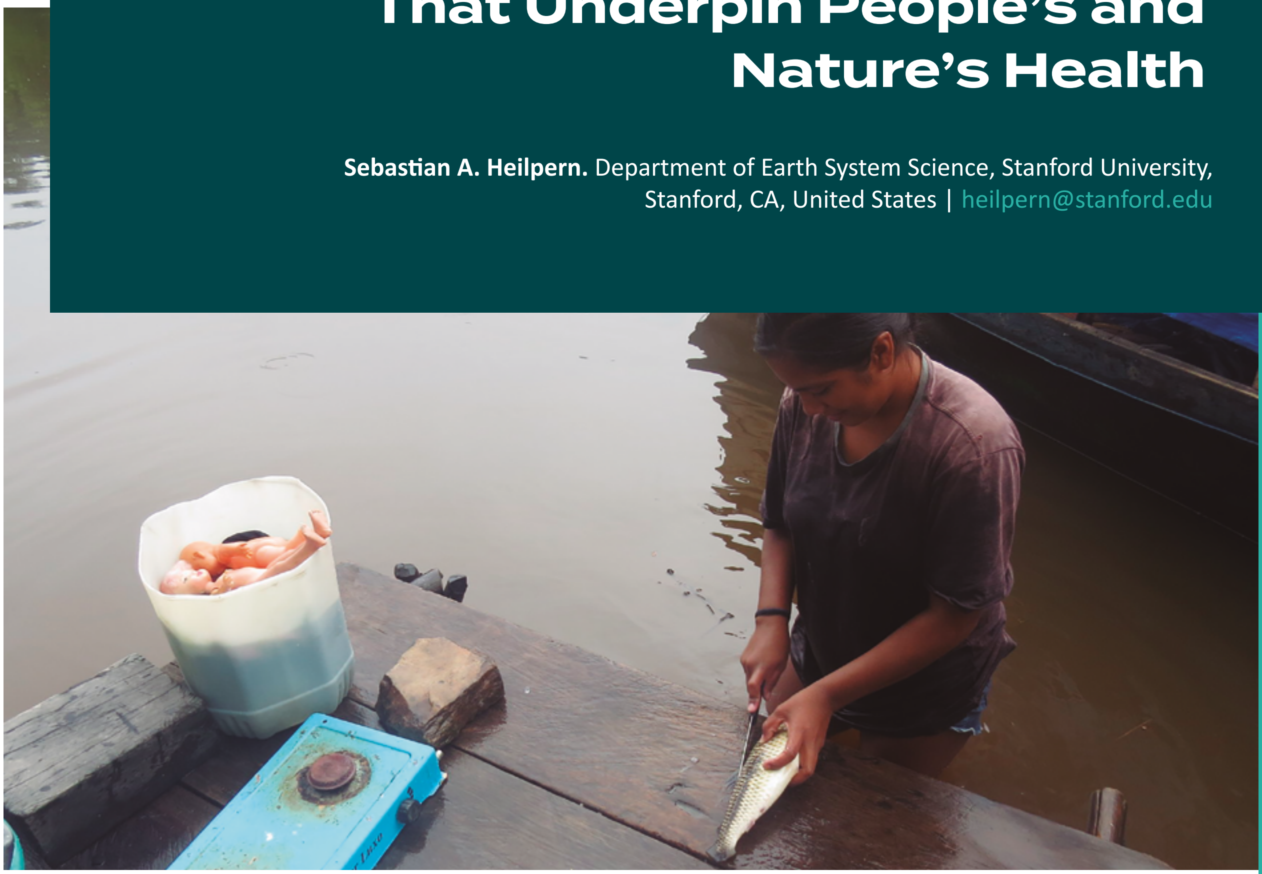

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The Overview

Fisheries underlie food security and livelihoods for millions of people throughout the Amazon Basin, yet they are changing due to factors including overexploitation, habitat degradation, and climate change. Additional extractive activities, such as artisanal gold mining, are polluting waters, elevating mercury levels in fish and undermining the ability of fisheries to sustain human nutrition. At the same time, together with the rapid pace of urbanization, Amazonian food systems are shifting, with aquaculture expanding rapidly alongside other farmed animal-sourced foods like beef and poultry. Sustaining access to biodiverse and productive fisheries is key for Amazonian food security and sovereignty, ecosystem integrity, and reducing the overall environmental footprint of food systems.

CALL TO ACTION 23

The Facts

- Fish are the most-consumed animal-sourced food in the Amazon, with per capita intake > 50 kg per year—and the Amazon's fish diversity is among the highest and most species-diverse in the world, with over 120 species featured in local diets **(Figure C7.23.1)**[1].

- Small-scale fishers, many living in riverine communities, supply the vast majority of the region's fish and are key for meeting growing urban demand for animal-sourced protein **(Map C7.23.1)**[2].

- Fish nourish people with protein, micronutrients, and omega-3 fatty acids. They are more nutritious and carry lower land-use and greenhouse gas footprints than other animal-sourced foods; small fish are especially accessible and nutritious, with low levels of contaminants (e.g., mercury)[3].

- Fish preparation and consumption methods reflect diverse cultural traditions shaped, in turn, by the diversity of fish species themselves **(Figure C7.23.2)**.

- Fisheries biodiversity is changing due to unsustainable harvests; habitat fragmentation from dams, roads, and other infrastructure; and hydrological changes due to climate change and deforestation[4].

- Aquaculture expansion presents both challenges and opportunities for sustainable food systems, offering lower greenhouse gas and land-use footprints than beef but being less nutritious and more capital intensive than wild fisheries[5].

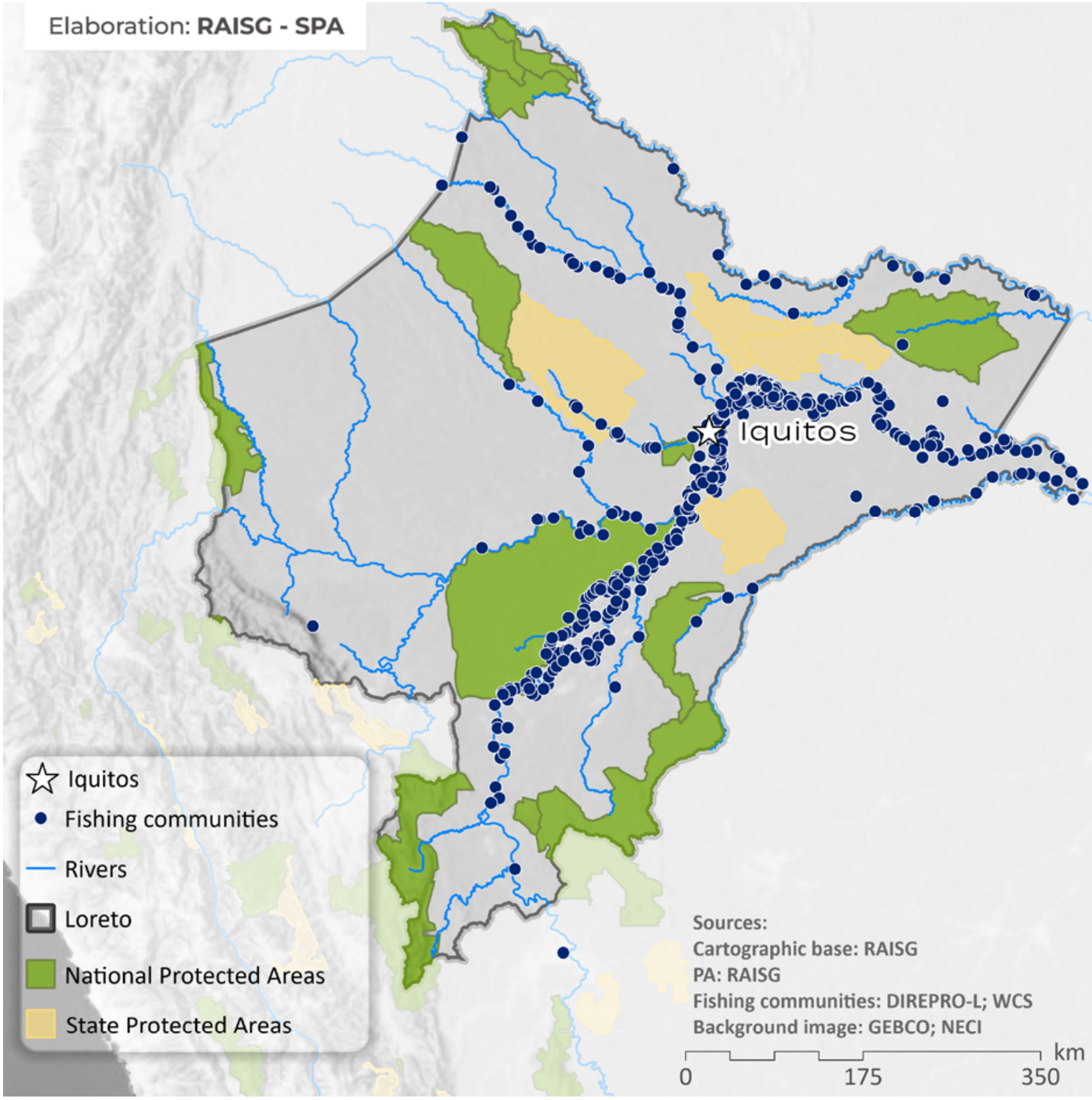
Global/Regional and Synergistic Connections

- Climate change is modifying hydrological cycles and increasing water temperatures, leading to mass fish die-offs, and reducing fisheries productivity. Droughts and extreme water levels can strongly affect hydrological connectivity, impeding navigation for people and reducing access to fishing grounds and movement between communities and cities.

- Global gold demand underlies the expansion of artisanal gold mining in the Amazon, which devastates ecosystems, pollutes waters, and increases the prevalence of mercury in the food chain, which is a powerful neurotoxin for both fish and people.

- Demand for fish continues to grow, and Amazon aquaculture production has the potential to contribute to global markets. But caution is warranted, especially due to the spread of non-native species (e.g., tilapia), poor farm management (and its associated greenhouse gas emissions and eutrophication risks), and the generally lower nutritional quality of farmed fish in comparison to wild fish. Additionally, although aquaculture is often promoted to reduce pressure on wild fisheries, evidence for such benefits remains limited

Figure C7.25.1. A remarkable diversity of fishes are consumed in the Amazon, with estimates exceeding 120 species in some locations. However, this diversity, which underlies food security, is poorly accounted for in food system information. Photo credit: Jaime Choclote / Wildlife Conservation Society



Map C7.25.1. Most fish supplied to the city of Iquitos, Peru, originate from productive habitats across the department of Loreto. Small-scale fishers from riverine communities (blue points) either transport and sell their catch directly in urban markets or participate in trade networks involving boat operators, intermediaries, and fishmongers, among others. Data from Dirección Regional de la Producción de Loreto, Perú, and the Wildlife Conservation Society.

Figure C7.25.2. **The many ways people prepare and consume fish**—reflected in diverse dishes, recipes, and preferences—highlight the interconnectedness between cultural and biological diversity. Photo credit: Sebastian Heilpern.

The Solutions Space

Selected Key Tools

- Ictio is an open database and platform for collecting fisheries information; facilitating participatory science; and promoting collaboration among fishers, researchers, and governments.
- Hydrological information is a data bottleneck, and even when available, data is inaccessible to the public. P**articipatory efforts such as WhatsApp group** Boletim das Águas do Médio Solimões, led by *Instituto Mamirauá*, share real-time hydrological information and connect people across the riverscape.

Collaborative Efforts

- **Amazon Waters Alliance**, comprising 30 organizations from across the basin, aims to connect initiatives and actors to generate knowledge, solutions, and actions supporting the conservation of the Amazon Basin's connectivity and integrity at scale.

- **The Colectivo Pirarucú** links consumers to sustainably managed arapaima fisheries through its brand *Gosto da Amazônia*, which promotes biodiversity conservation, fair and transparent trade, and sustainable local economic and societal development (see also Call to Action 20, Chapter 6)

Major Recent Governmental Efforts

- **The Dirección Regional de la Producción de Loreto**, in Peru, has deployed large-scale fish monitoring efforts in urban ports, standardizing data collection and making it accessible to the public[6].

- **Sustainable Development Reserves in the Brazilian Amazon, such as the Mamirauá and Amanã Reserves**, are public–private partnerships that aim to integrate biodiversity conservation and social rights of riverine communities by conducting research and informing policy[7].

- **Food security efforts like the Peruvian national program "A Comer Pescado"** are culturally sensitive interventions that aim to leverage fish and their high nutrient quality to improve nutritional outcomes.

Positive Efforts for Scaling

- **Fisheries co-management agreements**—where resource users, government environmental agencies, civil society organizations, and scientists participate in a polycentric governance arrangement to manage fishes—can lead to diverse benefits for people and nature. Examples include the Middle Juruá Initiative in Brazil, the organization Sapopema in the lower Brazilian Amazon, and *Instituto del Bien Común* in the Peruvian Amazon (see Call to Action 20, Chapter 6)[8].

Recommendations

- **Improve monitoring of fisheries in food systems**, using complementary approaches like participatory citizen science and government monitoring programs—and make the information accessible.

- **Harmonize and strengthen fisheries regulations across countries and jurisdictions** to enable effective co-management at multiple scales, ensuring coordinated governance that supports biodiversity, livelihoods, and positive social outcomes[8].

- **Ensure that practices, agreements, and priorities of Indigenous Peoples (IPs) and Local Communities (LCs) remain central in fisheries governance**, so that harmonized regulations build on—rather than override—Indigenous and Local Knowledge and negotiated agreements.

- **Enact regulations based on species traits, and improve fishing ban enforcement**; focus on regulations that respect species' ecological life histories, especially migration timing, and that acknowledge ecological and cultural calendars.

- **Encourage consumption of a variety of nutrient-rich and resilient species**, such as smaller fish, by promoting fairs and culinary innovation, upholding cultural traditions, and including fishes in dietary guidelines and school lunches.

- **Develop native-species-based aquaculture to promote forest restoration**, especially in areas degraded by cattle ranching and where wild fisheries cannot be supported; seek to meet demand for fish and value-added products from fish (e.g., fish oil, steaks, and flour). And critically, prioritize native species over non-natives such as tilapia, avoid investing in aquaculture over sustainable fisheries management, and promote small-scale farmers and equitable benefit sharing.

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Heilpern, S. A. (2025). Call to Action 23: Support Biodiverse Fisheries That Underpin People's and Nature's Health. In Amazon Assessment Report 2025 - Connectivity of the Amazon for a Living Planet. Science Panel for the Amazon. Sustainable Development Solutions Network, New York, US. Available at: www.sp-amazon.org/publications. DOI: 10.55161/SLIH7347

Build Equitable Global Supply Chains for Amazonian Biodiversity Products While Protecting Standing Forests and Flowing Rivers

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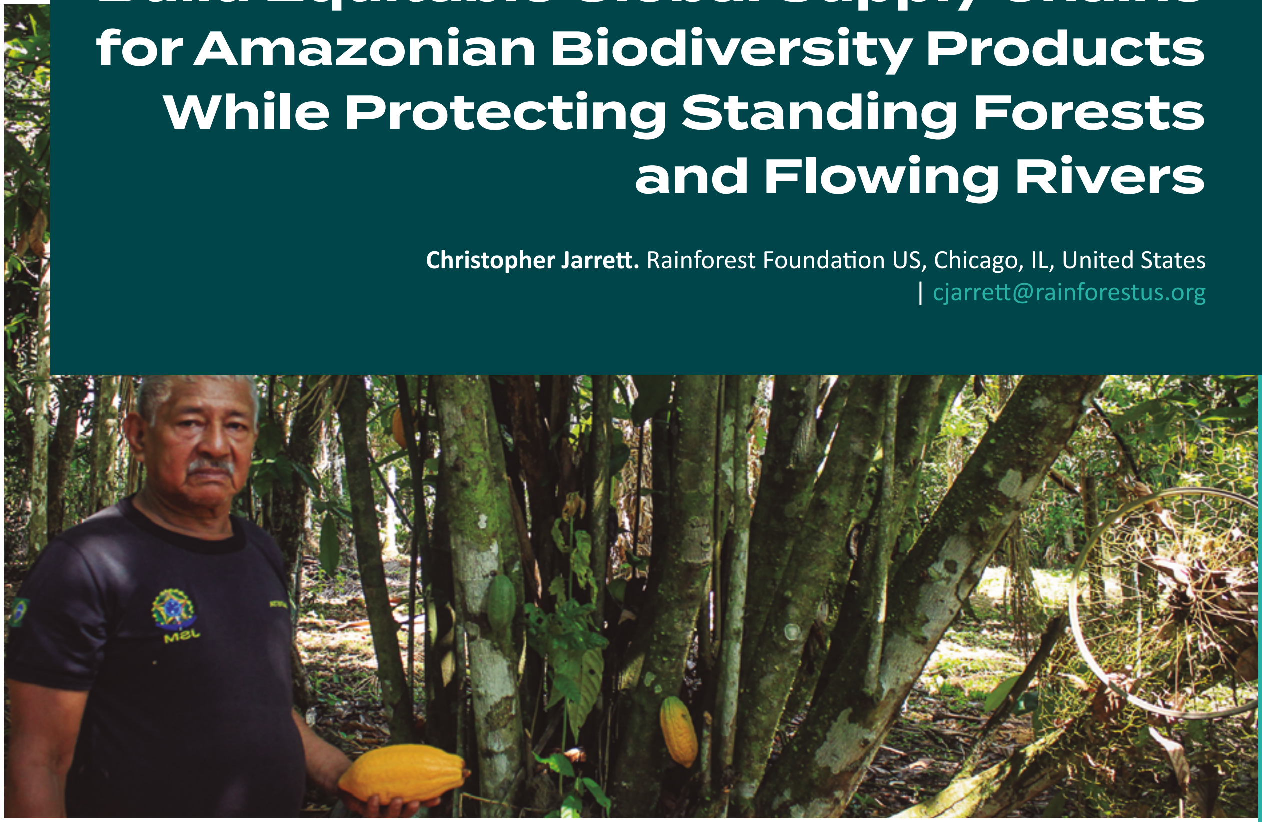

Photo credit: Wérica Lima / Amazonia Real

The Overview

Major industries have developed in recent decades around commodities from a wide range of species native to the Amazon. These commodities provide opportunities to promote regional enterprises and increase the scale of economic activity that depends on the Amazon's standing forests and flowing rivers. Although the commercialization of native Amazonian species can support forest and river protection in Indigenous Territories, Afrodescendant lands, and Protected Areas, it also presents major challenges: the boom-and-bust dynamics of global markets, the difficulties of equitably distributing risks and rewards, and a lack of formal recognition of Indigenous Peoples' (IPs') and Local Communities' (LCs') rights and intellectual property. Amazonian products have also mostly been exported as commodities, with few value-added processes occurring at the local level. Weak regulation and poor coordination with local authorities have further undermined sustainable, traditional practices and increased the risk of overharvesting.

The Facts

- Many Amazonian products are available on the global market, including fruits such as *Euterpe oleracea* (açaí, huasaí), *Myrciaria dubia* (camu camu), *Passiflora edulis* (maracujá, maracuyá, passion fruit), and *Theobroma grandiflorum* (cupuaçu, copoazú); **food and ornamental fishes** such as *Arapaima gigas* (pirarucu, paiche, arapaima) and *Osteoglossum bicirrhosum* (aruanã, arawana, arahuana); **stimulants** such as *Paullinia cupana* (guaraná), *Ilex guayusa* (guayusa), and *Theobroma cacao* (cacao); **nuts** such as *Bertholletia excelsa* (castanha-da-amazônia, nuez de castaña, Brazil nut); and **essential oils and other vegetable oils** such as *Copaifera officinalis* (copaiba), *Carapa guianensis* (andiroba), and *Attalea speciosa* (babaçu, babassu).

- The global Brazil nut market is increasing, with Bolivia becoming the world's largest producer and exporter (USD 175 million in 2024)[1]. This commodity supports the livelihoods of about 300,000 people in the Brazilian Amazon along with important Brazil nut initiatives in Peru and Bolivia[2,3,4]. IPs also increasingly sell directly to buyers[5].

- The global market for açaí berries[6] is expected to reach nearly USD 30 billion by 2034. Pará state accounts for 67% of Brazil's açaí output[7]. Prominent Indigenous açaí businesses have also recently taken hold in Amapá, Brazil, increasing the proportion of benefits from açaí supply chains that stay in the region[8]. At the same time, market pressures have led to negative socioenvironmental outcomes, such as biodiversity loss in managed açaí forests[9].

- The global guaraná market was over USD 7 billion in 2023 and is forecast to reach nearly USD 9 billion[10] by 2030. In 2020, Brazil's patent office granted the Sateré-Mawé the first Designation of Origin to an Indigenous People for waranà (native guaraná) from the Andirá-Marau Indigenous Territory[11].

Global/Regional and Synergistic Connections

- Maintaining high-quality products is a persistent challenge when developing longer supply chains based on Amazonian species, given limitations in processing and quality-control infrastructure; this dynamic is particularly acute when accessing international markets.

- International certification systems (organic, fair trade, Rainforest Alliance, etc.) can provide standards and guidelines for fair compensation and benefit sharing, sustainable land management, and other key dimensions of supply chains, while also helping to stimulate demand and added-value compensation—but they should supplement appropriate government regulation and should not replace direct trade relationships. Global certification standards should also be combined with attention to the unique needs and challenges of the specific political and sociocultural contexts in which enterprises operate. Efforts should also be made to ensure that local producers are not dependent on external certification for market access, as this can impose steep costs and favor larger enterprises.

- Close monitoring of the balance between supply and demand—and of trends in production systems related to agrobiodiversity or harvesting levels—is essential to ensure local smallholders continue to be the primary beneficiaries and that sustainable production dynamics are maintained over time when those smallholders participate in the global market.

Figure C7.24.1. ***Women from Ally Guayusa,*** an Indigenous-owned guayusa export association in Ecuador. Photo credit: James Roh.

Figure C7.24.2. ***Brazil nut*** harvesting and processing for national and international markets is an important livelihood option for many Indigenous and non-Indigenous people throughout the Amazon basin.
Photo Credit: Adobe Stock.

The Solutions Space

Key Tools and Resources

- **"The Best Practices Guide for Responsible Markets,"** developed by the *Instituto Conexões Sustentáveis* (Conexsus), provides useful guidelines for businesses, especially in the Brazilian context.

- **The *Sello Chakra Amazónica* certification** is an alternative process for assessing the alignment of supply chains with Indigenous production and knowledge systems and increasing the visibility of products grounded in the Amazonian socio-bioeconomy.

- **The Amazon Indigenous Rights and Resources (AIRR) project** (2019–2024) generated various tools and identified lessons learned for Indigenous enterprises across the region, it produced the guide "Investing in the Amazon Region: Breaking Down Barriers Between Impact Investors and Indigenous Enterprises"[12].

Collaborative Efforts

- **Canopy Bridge** connects Amazonian producers with potential buyers through research, alliances, and a directory of products.

- **The Aliados Foundation** has organized the **Center for Innovation and Investment for Bioeconomy and Regenerative Agriculture in the Amazon**, supporting a wide range of Indigenous led-enterprises.

- **The Amazon Investor Coalition** is a platform for collaboration on building sustainable enterprises across Amazonia.

- **The Amazon Business Alliance** is a coordination space for the development of businesses dependent on standing forests in the Peruvian Amazon.

- ***Despensa Amazónica*** ("Amazon Pantry") is an organization in Peru that supports Amazonian producers and promotes sustainable cuisine based on Amazonian products.

Recommendations

Entrepreneurs and Investors

- **Develop enterprises with ownership and governance structures that include producers, workers, and local communities on boards and other decision-making bodies.**

- **Source from and support production systems such as agroforestry and native forest collection that protect (agro)biodiversity.** Monitor and swiftly address shifts to monocultures or overharvesting due to exponentially increasing demand from the global market that may impact forest and river ecosystems.

- **Avoid overreliance on conventional certification processes for assessing supply chain sustainability and equity.** Where possible, adopt Indigenous-led certification processes that measure IPs' inclusion and leadership. Avoid the appropriation of Indigenous names, symbols, and other cultural representations for marketing purposes, and provide recognition and fair compensation when using IPs' knowledge or intellectual property.

Governments

- **Provide land tenure security for IPs and LCs** to ensure they control how their lands are managed, inhabited, and used for livelihood and commercial purposes.

- **Subsidize smallholders and cooperatives** to enable maximal benefits from new industries in the Amazon to flow to local communities. Invest in small businesses and transportation and processing infrastructure to enable local people to develop their own enterprises and to participate in adding value , rather than just raw material production.

Indigenous Peoples and Local Communities

- **Formally recognize territorial rights and self-governance instruments and structures—**and secure free, prior, and informed consent; these are essential preconditions for equitable development of commercial enterprises involving IPs and LCs and their territories (see Chapter 5).

- **Maintain diverse livelihood strategies to ensure resilience to market fluctuations and avoid overdependence on a single product.** Also maintain coherence with cultural and ecological calendars to align with life cycles and avoid overexploitation. Develop local processing plants and other enterprises, unions, and collective marketing, with an emphasis on moving up the value chain toward more value-added processes and shorter supply chains.

Key Recent Literature

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Share Benefits Equitably with Local Actors and Communities

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Photo credit: Diego Oliveira Brandão.

The Overview

The economy of the Amazon is dominated by agricultural commodities such as beef and soy, biodiversity-based products such as açaí and Brazil nut, and mineral products such as gold, all of which are produced and exported with little value added locally. These sectors often incorporate rural and urban local populations into global commodity chains, often in an inequitable way. The current economic land-use production model has produced the highest tropical deforestation and degradation rates in the world, with the Amazon region accounting for the majority of South America's population living in poverty. Indigenous peoples have domesticated hundreds of native species and discovered substances, aromas, and flavors that are essential to the food, cosmetics, and pharmaceutical industries but remain largely excluded from the fair distribution of benefits. Strengthening economic and social connections among local urban and rural stakeholders represents an opportunity (and challenge!) to reinforce local value chains and ensure fair and inclusive distribution of benefits.

The Facts

- In global value chains such as tourism, local populations receive only around 2% of the total expenditure of a tourist[1]. Fair benefit sharing is an important measure to address the high levels of inequality across the region[2].
- About 90% of Brazil's Amazonian municipalities lack the infrastructure and technologies to add value to biodiversity-based products. As a result, Indigenous Peoples, Afrodescendant Peoples, and Local Communities are often forced to sell raw products as low-value commodities outside of the benefit-sharing rules[3].

Global/Regional and Synergistic Connections

- Faced with the interconnected challenges of hunger, the climate crisis, deforestation and degradation of Amazonian biomes, and biodiversity loss, rethinking agrifood systems in the Amazon has become globally urgent. Models based solely on maximizing agricultural productivity and extractivist logic have failed to deliver inclusive prosperity and sustainability[3].
- In the Peruvian Amazon, most rural communities with favorable ecological and cultural conditions for ecotourism remain outside mainstream tourist routes. Among some of these, 85% of the population believes tourism can generate employment, and 90% expect it to bring economic benefits to the community[4].
- While riverine communities sell a kilogram of pirarucu (*Arapaima gigas*) fish for around $2, a luxury handbag made from pirarucu leather can sell for nearly $1,000 in U.S. stores. The profits from this added value rarely reach the people doing the fishing or their local organizations[5].

Figure C7.25.1. The regional meeting "Conversaciones de la Amazonía," organized by the North Amazon Alliance in 2023 around local Amazonian economies, provided concrete examples of initiatives across the Amazon in which benefits are equitably distributed. Photo credit: Felipe Rodríguez / Gaia Amazonas.

Figure C7.25.2. Natural and processed products from Amazonian biodiversity originating in Indigenous Peoples' and Local Communities' territories. Photo credit: Felipe Rodríguez / Gaia Amazonas.

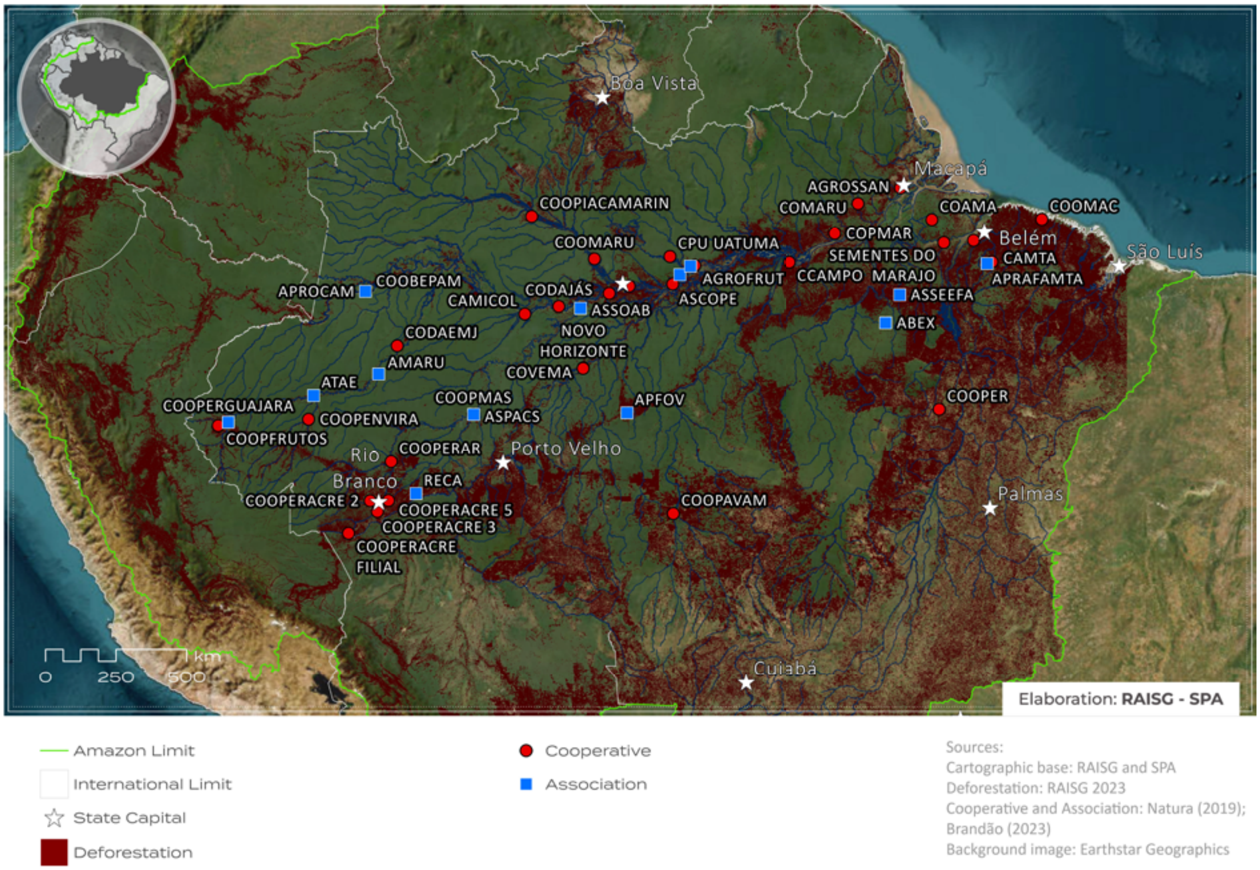

Figure C7.25.1. **Associations and cooperatives of smallholder farmers, Indigenous Peoples, and Local Communities** in the Brazilian Amazon that are either receiving benefit-sharing or have the potential to do so, as they supply natural and processed products derived from Amazonian biodiversity to national and global value chains. Source: Natura[6] (2019), Brandão[7] (2023).

The Solutions Space

Collaborative Efforts

- **"Conversaciones de la Amazonía"**, organized by the North Amazon Alliance in 2023, provided a platform for local communities to share initiatives and ensure fair benefit distribution (Figure C7.25.1). A compendium documented 17 cultural and economic value-added projects across five Amazonian countries (Figure C7.25.2), including lyophilized açaí, Brazil nuts, manioc products, handicrafts, spices, and fruit juices.

- **Gaia Amazonas** has bridged the gap between producers and external consumers, helping local producers overcome one of the main regional challenges—high transportation costs—thereby increasing their market access and income.

- **"La Tienda Solidaria" in Leticia, set up and run by Habitat Sur**, is a shop where diverse entrepreneurs are able to showcase and sell their locally produced and sustainable products in the center of the city, paying fair percentages for sales management and commercial services.

- In Bolivia, **the Tacana Indigenous Community of San Miguel launched an ecotourism enterprise** building on the success of a collective water project. Revenue from the lodge is intended to benefit the entire community, including support for the local school, while partnerships with external organizations help develop local skills, with several members becoming fluent in English to serve international visitors[6].

Major Recent Governmental Efforts

- In 2015, **Brazil created the National Fund for Benefit-Sharing** (FNRB, its abbreviation in Portuguese) to promote the sustainable use of genetic resources and associated traditional knowledge, increasing its capital from BRL 2.6 million in 2020 to BRL 11.2 million in 2025 through contracts with private companies.

- Brazilian national institutions such as the **Genetic Heritage Management Council** (CGen, its abbreviation in Portuguese) have been providing grants to support the emergence of biodiversity-related entrepreneurships.

- In 2025, **53 companies in Brazil that make use of biodiversity contributed to the FNRB**, providing benefits to some associations and cooperatives of the Indigenous Peoples and Local Communities (Map C7.25.1). Globally, the Convention on Biological Diversity offers implementing guidelines for countries to address the benefits from biodiversity uses under Article 8(j).

Positive Efforts to Scaling Benefit Sharing

- Scientists are creating the **Amazonia Institute of Technology (AmIT)**, with decentralized centers across the Amazon region. The initiative includes floating laboratories, research bases, and educational hubs that can be replicated in different territories.

Recommendations

- **Benefit distribution must reflect the specific social organizations** on a case-by-case basis, to make sure there is equitable benefit sharing.
- **Supporting and scaling up initiatives developed by family or interest groups within Indigenous settlements** — such as those in biocultural tourism, including bird observation and other activities — can promote a more balanced distribution of benefits.
- Local and regional government entities, together with local populations, should **develop local linkages among the producers**; for example, by public agencies purchasing local products[9].
- **We must bridge the gap between science/academia (universities and research centers) and Indigenous and local producers**. Scientists have identified investing in AmIT as the most promising way to scale solutions to Amazonian challenges.
- **Flexible and adequate standards are necessary when working with Amazonian local producers.**
- **Invest in small-scale, highly sustainable enterprises capable of processing biodiversity products into higher-value industrial goods**. Developing local processing capacity will be essential to increase economic opportunities, add value locally, and enable fair and equitable benefit sharing for Indigenous Peoples, Afrodescendant Peoples, and Local Communities.

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Develop Marketable New Amazonian Socio-Biodiversity Products

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Photo credit: Isabella Leite Lucas.

The Overview

Despite the Amazon's tremendous biodiversity, few of its species are managed and sold on the market. Marketable new Amazonian socio-biodiversity products are scarce due to a lack of (1) trust, (2) clear biocultural protocols, and (3) botanical inventories that can facilitate sharing and identifying Indigenous and Local Knowledge (ILK) about biodiversity in order to open new market opportunities and allocate labor. Traditional products from Indigenous Peoples (IPs) and Local Communities (LCs) are not embedded in the market because they require rigorous local research and national and regional legal frameworks that enable a direct but fair relationship between ILK (**Figure C7.26.1.**), and Western Academic Sciences and industrial development. This Call to Action explores opportunities to identify new Amazonian socio-biodiversity products and bring them to markets.

Figure C7.26.1. Ñamepaco women researchers using plant guides to identify which plants would better match with the body care uses already collectively selected after they collected and mapped these plants from their territory. Photo credit: Felipe Rodríguez / Gaia Amazonas.

The Facts

- The Amazon is home to 50,000 vascular plants, including at least 1,450 known medicinal and aromatic plants, and 84% of all known Amazonian arboreal plant species are useful to humans[1,2].
- Over 300 Indigenous languages are spoken today in the Amazon, but many are disappearing; knowledge of the hundreds of still-undescribed uses of plants, fungi, and insects is threatened by cultural erosion and biodiversity loss[3].
- The 2010 Nagoya Protocol to the Convention on Biological Diversity (CBD), signed by all Amazonian countries except Suriname, and the recent agreement signed at the sixteenth meeting of the Conference of the Parties (COP 16) to the CBD in Cali, Colombia, both call for fair and equitable sharing of benefits arising from the utilization of genetic resources and ILK[4].

Global/Regional and Synergistic Connections

- Global access and benefit-sharing (ABS) challenges: Fair international ABS implementation faces persistent transparency and governance challenges[5]. Many ABS agreements involve complex and costly procedures, requiring significant investments of time, money, and capacity in contexts with unclear legal and administrative frameworks, complicating assessments of their equity and effectiveness[6,7].

- A growing number of international and regional actors have expanding interests and engagement in socio-bioeconomy activities across the Amazon region. Global appreciation of the importance of ILK for conceptualizing socio-bioeconomy is also growing.

- Demand is growing for plant-based health care globally, with a particular interest in Amazonian plant species[8]. This demand, however, requires addressing possible invisible costs associated with overrunning production capacity and following sustainability practices and principles.

The Solutions Space

Selected Key Tools

- The Ñamepaco people published a methodology with the support of Gaia Amazonas to **identify species for the development of extracts** that could be commercialized or used for subsistence—this methodology is worth replicating in other parts of the basin. The Ñamepaco Indigenous People use and manage more than 200 healing plants for 90 different diseases, and in 2024, local Ñamepaco researchers identified 20 plants used for body care; traditional authorities prioritized two for commercialization.

- The Matsés, an Indigenous group in the Peruvian Amazon, have been working with the non-governmental organization Acaté since 2012 to **document their ethnomedicinal practices**, creating a 500-page traditional medicine encyclopedia in their language. Women healers play a central role in transmitting knowledge and making decisions about which plant medicines to document and explore, and they develop viable long-term projects to generate revenue for Matsés communities and provide alternatives to unsustainable and destructive activities.

Major Recent Governmental Efforts

- **Brazil has shown the strongest commitment across Latin American countries to integrate research and innovation into socio-bioeconomy**, with support from the Ministry of Science, Technology, and Innovation (MCTI). It will be important to evaluate the impact of these grants, including how these funds impact communities and their traditional knowledge systems[9].

- The National Institute for the Defense of Competition and the Protection of Intellectual Property (Indecopi) in Peru has a **National Registry of Collective Knowledge, a platform** that documents and protects the ancestral knowledge of Indigenous Peoples, granting certifications and establishing clear rules for access and benefit-sharing.

Positive Efforts for Scaling

- **The Amazon Food&Forest Bioeconomy Financing Initiative**, developed in 2024 by Impact Bank and The Nature Conservancy Brazil, provides financial support through a fintech platform. The initiative seeks to aggregate cross-sectoral projects and foster partnerships to help promote the development of socio-bioeconomy businesses.

- **In 2023, the Latin American Bioeconomy Network launched a set of guiding principles**, a key tool for policies and investments that promote sustainable development in the region, facilitating knowledge sharing among member countries, including key Amazonian nations such as Brazil, Colombia, and Ecuador.

- **The Indigenous Peoples and Local Communities Forest Tenure Pledge** at the 2021 United Nations Climate Change Conference (COP26) promised investments of USD 1.7 billion, the first time donors (governmental and philanthropist) called attention to the need to fund IPs and LCs directly.

Recommendations

- To **develop equitable new Amazonian biodiversity products**, center local actors and their knowledge, which is built from the territory and has the potential to scale to regional, national, and international markets.
- **Recognize territorial rights and self-governance**, and ensure free, prior, and informed consent as essential preconditions for equitable development of commercial enterprises involving Indigenous IPs and LCs (International Labor Organization (ILO) Conference 169 - Indigenous and Tribal Peoples Convention, 1989).
- **Financing initiatives should prioritize culture-based solutions** as a way to ensure knowledge persistence and sustainability of the Amazon region.
- Identify which local communities are developing marketable new products across the Amazon Basin, and **produce and share a shortlist of lessons learned**.
- **Improve endogenous research** and introduce innovative methodologies to identify proven ILK regarding the use and processing of plants.
- **Create territory-specific biocultural protocols** to define how ILK is structured and applied by local people, including their principles on how it can be used and for which purposes.
- **Conduct scientific or industrial research** to develop new products using Amazonian plants or molecules. These new products should have market potential and should be developed with the collaboration of IPs and LCs.
- **Integrate innovative finance mechanisms** and applied research into value chains, and involve market actors from the very beginning, with the consent of the involved IPs and LCs[10].

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Scale Socio-Bioeconomies Responsibly

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Photo credit: Mucho Colombia SAS

The Overview

The rapid expansion and extractive growth of both traditional industries and non-timber forest products (NTFPs) have intensified. The surging global demand for açaí, for example, has transformed biodiverse floodplains into monocultures, reducing species diversity and compromising vital forest functions. Responsibly scaling socio-bioeconomies that respect thresholds and principles related to sustainability requires alternative scaling methods such as more diverse plant polycultures that are compatible with biodiversity and/or accomplish large-scale restoration (**Figure C7.27.1** and **Map C7.27.1**). Furthermore, technologies and infrastructure are needed to support the biological and cultural initiatives that underpin the socio-bioeconomy, including translating Indigenous and Local Knowledge (**Figure C7.27.2**) and forest logics into practical economic and design principles, such as product and material circularity, to guide scale-ups. This Call to Action outlines these principles and provides recommendations to guide responsible scaling to support the Amazon Basin's long term conservation, including the wellbeing of its residents.

The Facts

- Almost 85% of açaí's weight is residual biomass, primarily discarded as waste[1]. This exemplifies the need to encourage circularity in NTFPs to safeguard forests and rivers while supporting local communities.

- Large-scale enterprises are promoting their own interpretations of circular bioeconomies. Rather than applying circularity principles from the outset to prevent harm, as seen in Indigenous practices, their focus is typically on repurposing waste and utilizing secondary biomass from existing linear value chains. These enterprises present a significant economic opportunity[2], estimated to reach USD 7.7 trillion by 2030. Their potential growth could hinder the scaling of the circular socio-bioeconomy addressed in this chapter by capturing financial resources and market attention.

- Socio-bioeconomic products face obstacles in meeting minimum health and safety standards required by key markets[3], underscoring the need for adequate technologies and infrastructure to support their scaling.

Global/Regional and Synergistic Connections

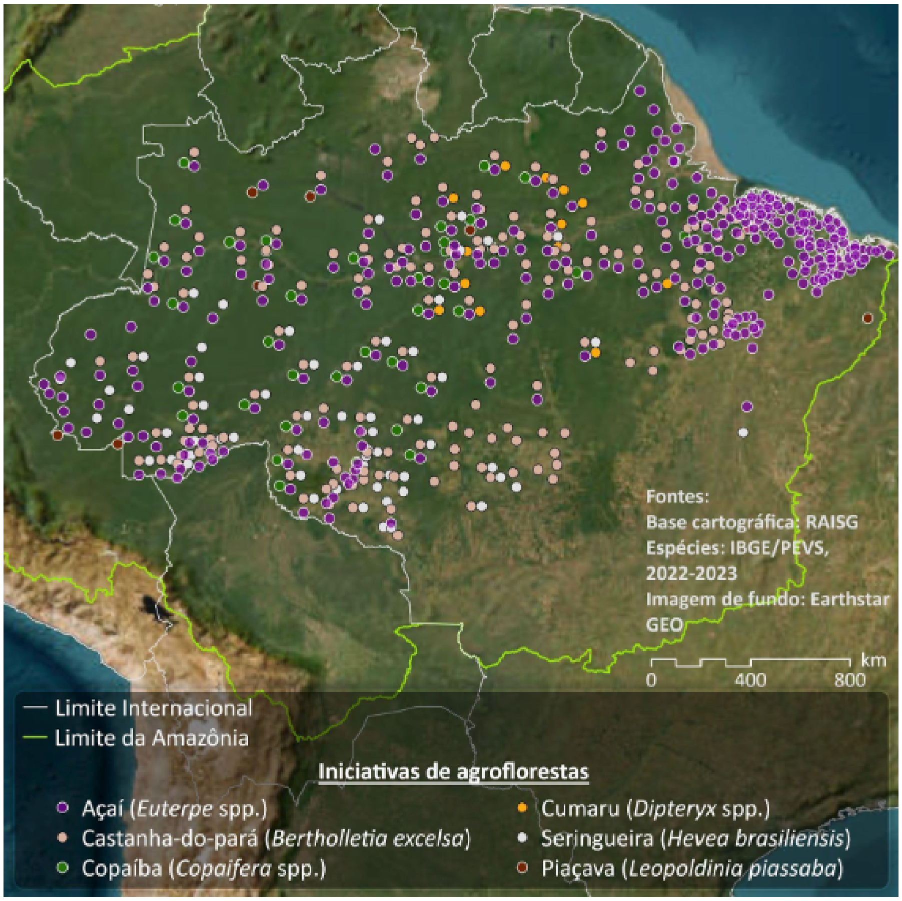
- Health-Driven Global Demand: Consumers increasingly seek products with natural health benefits in cosmetics, food, and pharmaceuticals, driving demand for socio-bioeconomy commodities and consumer goods. This results in accelerated pressure to scale up operations. While this opens market opportunities, it also risks prioritizing profit over core principles.

- Biomaterials and New-tech Drivers: The socio-bioeconomy drives high-value manufacturing, and is stimulating research in new technology fields such as synthetic biology and artificial intelligence (AI), which can promote biomimicry and other approaches beyond NFTP scaling. However, it is essential to avoid cultural appropriating culture and marginalizing local communities.

- Sustainable Development Goal 9: Socio-bioeconomies can contribute to building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation[4].

Figure C7.27.1. A diverse agroforestry system in the Amazon. Source: Mucho Colombia SAS.

Figure C7.27.2. Utensils and the process of tucupí, fariña, and cassava production by Cofán women in Putumayo region, Colombia. The ancestral principle of circular production is applied at the raw material level. Source: Mucho Colombia SAS.



Map C7.27.1. Municipalities in the Brazilian Amazon with agroforestry initiatives implemented using native species.

The Solutions Space

Best Practices

- **Mahta**, a Brazilian superfoods business, has embraced nutritional and ecological synergies by selling products with 12 Amazonian ingredients that grow together in agroforestry systems. Thus, rather than relying on a single product and overexploiting one single species, they created a recipe with increased nutritional value while using the diverse bounty of agroforestry systems.

- **Darvore**, a beauty company, has developed a *copaíba* balm and a moisturizer encapsulated in either *tucuma* or *copoaçu*, depending on the benefit and intended use. They account for life cycle and seasonality as key factors of product design.

- To prevent harm during scaling, it is important to **apply circularity from the outset**, at ideation and raw material levels. An example of circularity used at scale across the Amazon by the different Indigenous communities, is harvesting and transforming wild cassava (*Manihot* spp.) into *tucupí* sauce and casabe through ancestral chemistry without waste (see Chapter 7).

- **"Ask nature" is a repository of biomimetic innovations kept by the nonprofit Biomimicry Institute** to promote the practice of looking to nature for inspiration to solve pressing design problems, in this case, letting the vast biodiversity of the Amazon inspire innovations in materials, technology, and machinery that mimic natural solutions.

- **Cayro** is a Colombian cosmetics company that switched from cattle ranching to cacay nut (*Caryodendron orinocense*) cultivation. It has also created a fair pay network of small-scale collectors of the cacay nuts from natural forests.They also transfer 5% of their profits to a nonprofit organization dedicated to biodiversity conservation to include harm mitigation in their business model.

Positive efforts for Scaling

- In the Bolivian Brazil nut industry, local communities **share the cost of infrastructure** by collaborating.[5] Whether this strategy ca be successfully adapted (i.e for promoting cross-industry collaboration) and replicated remains unproven; however, it holds potential as a viable roadmap for other Amazonian industries at scale.

- **Sanctu**, a Brazilian-led initiative, has developed a **scalable**, **cross-issue business model** for **smallholder farmers** in the Amazon. Their approach includes farm design for **combined regenerative pasture, ecosystem restoration, and agroforestry**, along with low-cost financing and market access. The goal is to scale from 10 to 50,000 guardians, restoring and monitoring 5 million hectares to create the largest regenerative farm without holding any land.

- **"Got Milk?" and "Avocados from Mexico" are examples of collaborative, rather than single-brand, food industry marketing campaigns that promote a product to generate**

demand. This strategy, known as "co-opetition" marketing, enables cost-sharing to generate demand and could help address the high costs of awareness for IPs & LCs scale-ups.

- In 2016, the Asháninka People established an agreement with the fashion brand **Osklen**. This partnership ensured that royalties were paid for the use of their iconography in a collection, **creating a profit sharing model** and a more equitable scaling practice. While the broader implications of cultural commodification require further research, this initiative directly links the profit of a large-scale enterprise with the community's income, contrasting with historical business practices of unequal supplier relationships and appropriation.

Recommendations

- **Position a definition of socio-bioeconomy** from Indigenous People and Local Communities, forest and river logics, highlighting coexistence, reciprocity, circularity, and diversity among human and beings as a practical alternative to human-centered design.

- **Enforce land-use policies incorporating Indigenous and Local Knowledge and their territorial management plans** on specific ecosystems to provide a clear model for scaling.

- **Develop financial instruments that support socio-bioeconomic growth,** with tailored strategies for the following:
    - Transitions from monocultures to biodiverse agroforestry systems;
    - Circular collaboration across industries and formation of a network of small-scale, decentralized production hubs for aggregate production;
    - Local and non-local partnerships exploring (i) technologies and infrastructure solutions that withstand climate and geographical challenges and respect biocultural thresholds and forest connectivity, and (ii) biomimicry with equitable profit and knowledge sharing;

- Promoting the use of Indigenous technologies and practices in enterprises owned by Indigenous peoples;
- Knowledge-sharing with collective rights;
- Integration of circularity at initial stages of product development, especially for products at the edge of large-scale production (e.g., copoaçu, burití).

- **Maintain a database and mapping system for biodiversity-based compounds** and processes that include drawbacks and best practices. Further practical research is needed on how Indigenous and Local Knowledge can be integrated into innovations and practical frameworks for business[6], entrepreneurs and other conservation efforts to shift practices towards socio-bioeconomic principals.

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Establish a Network of Innovation Hubs to Catalyze Amazonian Regenerative Socio-bioeconomies

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Credit photo: Superintendência da Zona Franca de Manaus (Centro de Bionegócios da Amazônia, 2024).

The Overview

Emphasis on capitalist, extractive development approaches over regenerative, collaborative economies has resulted in unsustainable commodity extraction that degrades biodiversity and concentrates wealth, often out of the region. Socio-bioeconomies can help conserve the Amazon and support sustainable development, positioning Amazonian countries as leaders in the global search for sustainability solutions. This will require dramatic acceleration of applied research and entrepreneurship, deep collaboration and learning from the best of local and global innovation, and new approaches to biodiversity-compatible scaling. This Call to Action explores how a network of science, technology, and innovation hubs can strategically catalyze and accelerate the innovation, investment, and capacities needed to achieve breakthroughs towards such a transition. The risks of not acting are great, and time is of the essence.

CALL TO ACTION 28

Figure C7.28.1. As part of the Biomas Program of The Good Food Institute - Brasil, researchers at the Brazilian Corporation for Agricultural Research - EMBRAPA and the Brazilian Federal Universities of Maranhão (UFMA) and Ceará (UFC) worked with traditional nut harvesters to develop a meat replacement made from the seeds of the babassu palm (Attalea speciosa). Such efforts can expand economic opportunities for local communities while providing nutritious foods that can replace value chains causing environmental harm. Photo credit: Guilhermina Cayres.

The Facts

- TThe Amazon's biodiversity and local knowledge hold enormous, and largely untapped, sustainable economic potential: 84% of Amazonian trees are useful to humans[1]; over 1000 species each are used for food[2] (**Figure C7.28.1**) and medicine, respectively.
- Tropical forest-compatible products exported from the Brazilian Amazon account for only 0.2 percent of the USD177 billion global market[3].
- Amazonian institutions in Brazil train graduate students at rates orders of magnitude lower than institutions outside the Amazon[4].
- Amazon states' GDP and Human Development Index are among the lowest in their respective countries.

- Only four Amazonian countries are listed among the top 100 innovation centers worldwide[5], and over 90% of indicators for innovation ecosystems are concentrated in large cities outside of the Amazon region[5].

Global/Regional and Synergistic Connections

- Expanded production of açaí via industrial monocultures has impacted biodiversity and ecosystem services[6] (see Chapter 6), even as açaí palms are naturally hyperabundant in Amazonian forests. Meanwhile, although processed açaí sorbet sells in bulk for up to USD 7 per pound, traditional açaí collectors earn around USD 0.20 per pound[7].

- When biodiversity-based products are exported, the value is almost always added elsewhere. Of over 43,000 global patents mentioning Amazonian plants filed through 2022, only 9% are registered both in Brazil and internationally[8].

Map C7.28.1. Locations of science, technology, and innovation (STI)-related institutions and urban centers in the Amazon ecoregion. Most of these institutions are clustered in a few large cities. There is a noticeable absence of STI-related institutions in small cities or in areas with high deforestation pressure. A network of innovation hubs should strategically locate institutions across the Amazon to catalyze broad and sustainable economic opportunities for rural and urban Amazonians in both remote and high pressure areas.

The Solutions Space

Selected Key Opportunities

- Follow the example of The Breakthrough Effect[9] to identify and catalyze positive tipping cascades for outsized impact in an uncertain future. Strategically identify hub focal topics around local and systemic breakthrough opportunities and industries.

Collaborative Efforts

- **Design the hub network to accelerate innovation** and build business capacity for broad economic opportunity in small Amazonian cities (see **Map C7.28.1**). One of few existing examples is the Centro de Inovação Aces Tapajós (CIAT), inaugurated in Santarem, Pará, in 2023 as a result of a public-private, innovation-focused partnership. While this hub has supported promising socio-bioeconomy-related efforts, its founders and supporters have also promoted infrastructure and commodity-based development that have harmed Indigenous People and Local Communities. This tension underscores the complexity of these partnerships and the need for robust participatory governance, transparent accountability, and safeguards to prevent the reinforcement of harmful extractive development under the guise of sustainability.

- **Build deep collaboration across diverse institutions and geographies:** The Center for Amazonian Science and Innovation – CINCIA works with national and international research institutions to build regional capacity to address impacts of "wildcat" gold mining in Peru.

Positive Efforts for Scaling

- **Use hubs to incentivize innovation and infrastructure** for connected, aggregated, and added-value supply chains that connect ecosystems to urban processing centers across the Amazon region, as accomplished by the RECA project in Brazil[10].

- **Build the pipeline of research to sustainable enterprise at scale:** Fundação Certi's Jornada Amazonia nurtures enterprises and builds entrepreneurial capacity at institutions across the Brazilian Amazon.

Best Practices

- Develop Amazonian countries as leaders in key emerging industries and sustainable economic opportunities. For example, the Biomas Program of the Good Food Institute Brasil supported research on sustainable, plant-based proteins rooted in Amazon and Cerrado biodiversity (**Figure C7.28.1**).

- Invest in research and development for novel, value-added products that can position Amazonian countries as leaders in emerging markets while accelerating regenerative socio-bioeconomies: The Amazon Biobusiness Center (CBA) in Manaus, Brazil, is seeding new sustainable industries, including bioplastics and alternative proteins, from scalable Amazonian products.

- Elevate local innovation and efforts, while incorporating the best lessons from international experience, such as those of DARPA[11] and the African tech hubs[12]. Example: Open Innovation programs, such as Conservation X Labs' Con X Tech Prize—the Amazon can accelerate innovative solutions while building novel collaborations that increase the capacities of all participants.

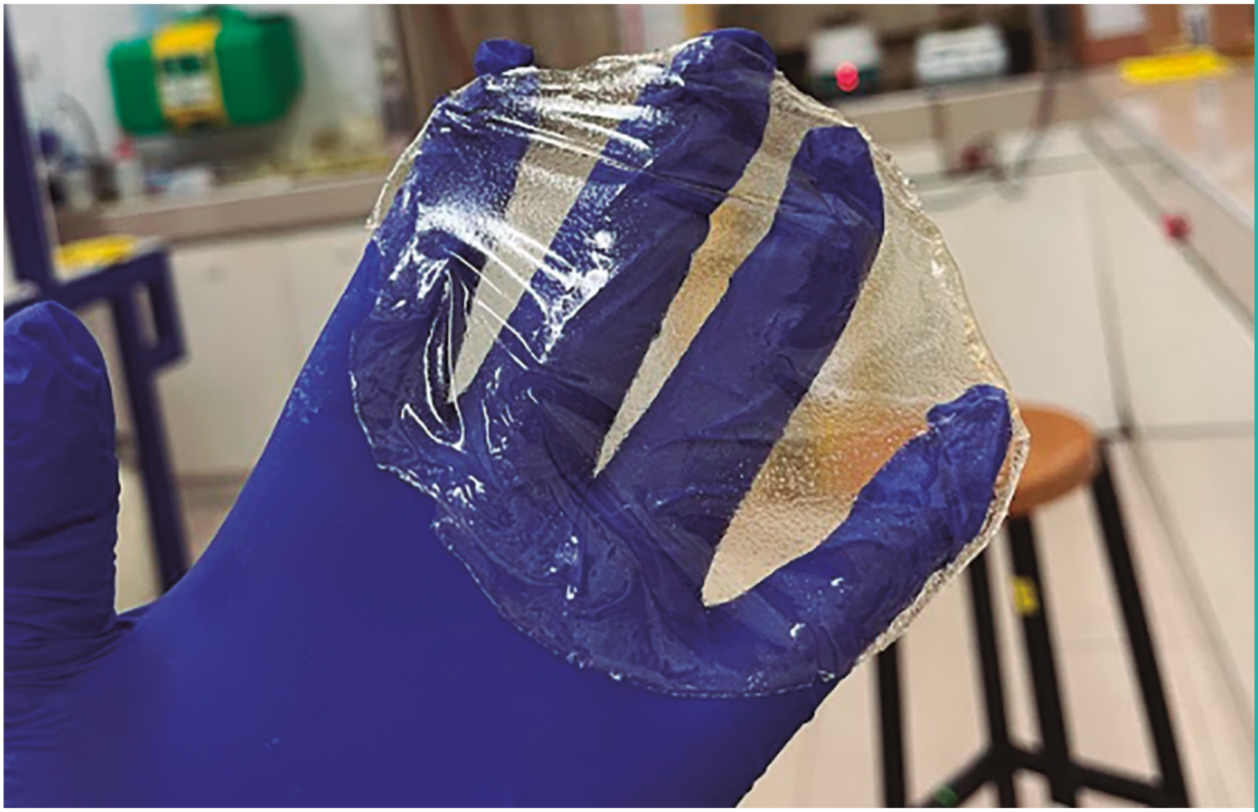

Figure C7.28.2. Patch Healing is an example of a high-tech replacement material derived from Amazonian biodiversity and local knowledge. A revolutionary advancement in burn treatment, Patch Healing leverages the healing, anti-inflammatory, and antimicrobial properties of Huito extract (Genipa americana L.). Developed by Peru-based Biogenia SAC working with Universidad Privada Norbert Wiener and Universidad Nacional de Ingeniería, Patch Healing was a winner of the open innovation Con X Tech Prize: The Amazon. Photo credit: Biogenia SAC.

Recommendations

- **Convene a coalition of key partners, including Indigenous and local knowledge-holders as equal collaborators,** to design and fund a network of innovation hubs for the Amazon (see roadmap[13]).
- **Engage private sector and financial institutions from the outset,** and innovate new financial mechanisms to support both the hubs and the associated economies.
- **Coordinate existing efforts around regional opportunities, systemic principles, and breakthrough opportunities** to achieve a network with impact larger than the sum of its parts.
- **Incorporate the best of local and international innovation approaches and institutions,** including deep collaboration, high-risk/high-reward models, open innovation, and experiences from the Global South.
- **Incentivize and prioritize applied research, including development of cutting-edge tools and methodologies** in biotechnology, synthetic biology, genomics, and artificial intelligence, among others, to add value to Amazonian products (**Figure C7.28.2**).
- **Dramatically expand effort, capacity, and opportunity,** for broad engagement with rural and urban Amazonians.
- **Strategically apply innovation to address technological, logistical, and seasonal bottlenecks** to create viable and sustainable supply chains for ecosystem-based, value-added products. Incentivize "research-to-enterprise" pipelines.
- **Engage transdisciplinary teams to develop scientific, social, and economic innovation to support solutions and build the necessary enabling environment,** including policy innovations and new mechanisms to return value to communities and intellectual property holders.

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CHAPTER 8

Knowledge Connectivity in the Amazon: Bridging Scientific, Technological, Indigenous, and Local Perspectives for Sustainable Development

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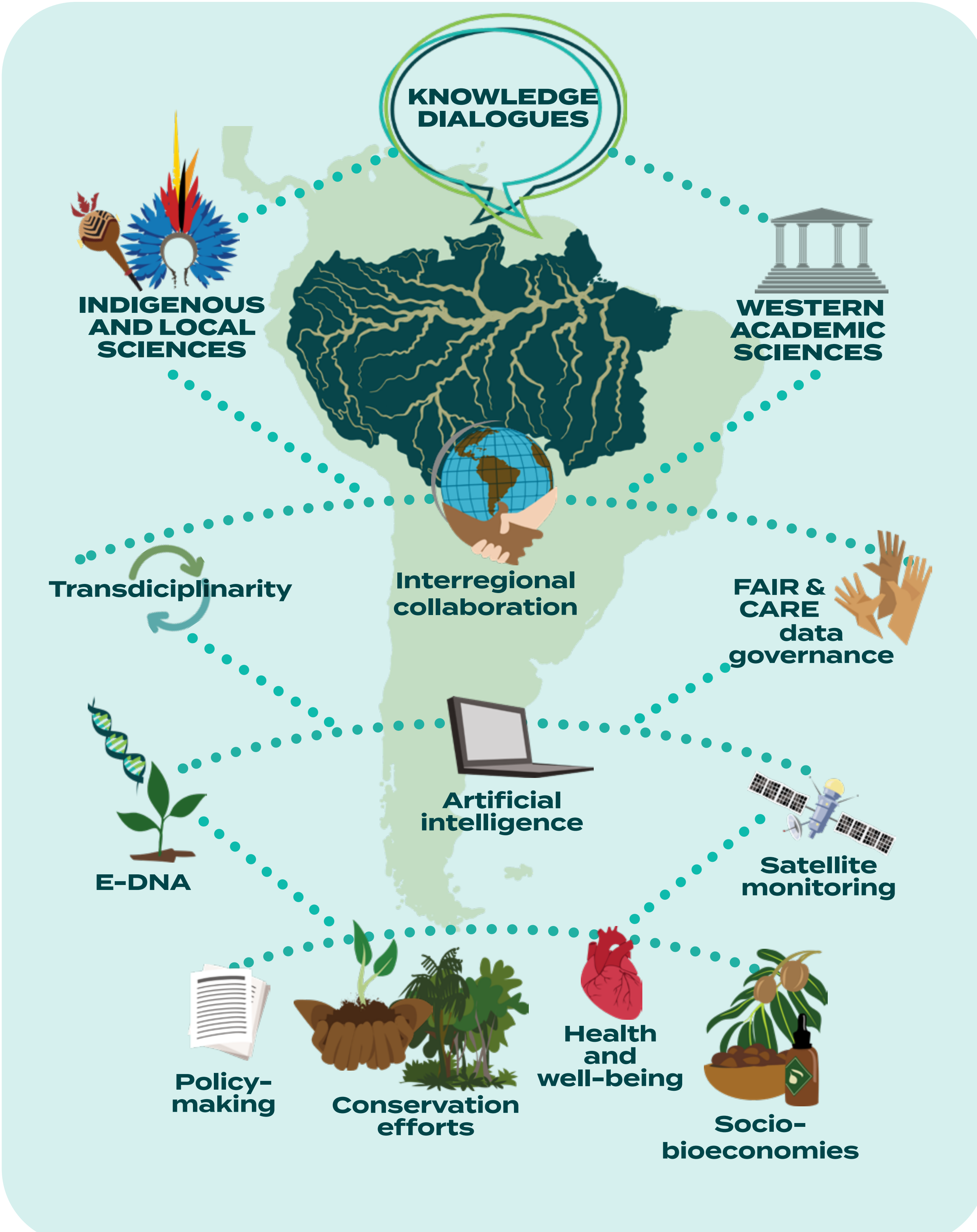
Abstract

This chapter explores the connectivity of science and technology in the Amazon Basin, with particular emphasis on the integration of Indigenous and Local sciences (ILS) and Western academic sciences (WAS). It argues that fostering knowledge connectivity—i.e., links and feedbacks between worldviews, epistemologies, methodologies, technologies, and institutions—is essential to addressing the region's socio-environmental challenges and catalyzing a transition toward a resilient and sustainable future. The chapter reveals structural asymmetries in knowledge systems, including the underrepresentation of Indigenous and Afrodescendant Peoples and Local Communities (hereafter IPs & LCs) contributions, fragmentation across national efforts, and the limited visibility of locally produced research. It emphasizes the need to transform how knowledge is produced, valued, and funded in the Amazon, integrating Indigenous epistemologies and methodologies and their academic counterparts, securing equitable benefit sharing, and reinforcing territorial rights through participatory and transdisciplinary research. Furthermore, it discusses the potential for connecting ILS with emerging technologies to enhance biodiversity monitoring, detect environmental degradation, and support evidence-based policymaking, including satellite imagery, environmental DNA (e-DNA), and artificial intelligence (AI). The chapter advocates for capacity building, digital infrastructure, and data governance aligned with the FAIR (findable, accessible, interoperable, reusable) and CARE (collective benefit, authority to control, responsibility, ethics) principles to ensure ethical and effective knowledge use and equitable benefit sharing. Finally, the chapter proposes criteria for evaluating Amazonian science through a contextual lens, including the participation of Indigenous and Local Communities' scientists, transdisciplinarity, technology transfer, and societal relevance. By centering plural knowledge systems and equity, the Amazon can become a global model of knowledge-led sustainable development.

Keywords

The Amazon, Indigenous and Local sciences, Science, technology and innovation policy, knowledge dialogues, socio-bioeconomy.



Graphical Abstract. Network of knowledge in the Pan-Amazon that integrates academic sciences and Indigenous and Local sciences and applies key strategies — transdisciplinarity, data governance, interregional collaboration — and emerging technologies such as e-DNA, satellite monitoring, artificial intelligence to guide conservation and sustainable development.

1. Introduction: Toward Pluralistic Knowledge Connectivity in the Amazon Basin

The Amazon Basin is a strategic frontier for knowledge generation and the application of innovative technologies. Home to 10%–15% of the planet's biodiversity and serving as a cradle of cultural innovation, the basin is a key site for understanding the complex relationships between people and nature[1,2].

The Amazon's knowledge production systems have evolved over more than 10,000 years, shaped by a relatively stable climate and ecological conditions[2,3]. Often rooted in anthropocentric, utilitarian, and Euro-American worldviews, conventional scientific knowledge systems fall short in addressing the region's complex realities. To uphold the values of "living well" (*buen vivir*; see Chapter 5), adaptability, justice, equity, and the safeguarding of rights, the Amazon must rise to this challenge: to generate strategic knowledge about the basin and the biome — in both Indigenous and Local sciences (ILS) and Western academic sciences (WAS) — to foster inclusive, accessible, and innovative solutions[4].

This chapter presents an overview of the Amazon's knowledge production systems. It highlights their potential to respond to some of the most urgent issues of our time: climate change, biodiversity loss, and the need for a socio-bioeconomy grounded in healthy standing forests, living rivers, and the cultural richness of Amazonian Peoples[5,6]. Furthermore, we also explore the key strategies and instruments required not only to strengthen science and technology in the region but also to reshape the way knowledge is produced. This includes strengthening local research institutions, fostering interregional collaboration, facilitating transdisciplinary research, and creating meaningful dialogues between ILS and WAS (**Figure 8.1**).

Finally, this chapter argues for a new kind of knowledge in the Amazon — one that radically opposes the formation of scientific monocultures and fosters connectivity between worldviews, knowledge systems, methodologies, and technologies[7]. The problems we face, as an Amazon and globally, will not be solved by repeating the same frameworks and practices that caused them.

BARRIERS				
Lack of regional integration	**Invisibility of local research**	**Exclusion of indigenous sciences**	**Lack of digital infrastructure**	**Chronic underfunding**
SOLUTIONS				
research programs and academic exchange initiatives among Amazonian countries	Value research not only for international journal publication but also for contributions to society	Institutionalize knowledge dialogues as a permanent mechanism for integrating Indigenous and Local sciences and Western academic sciences	Foster local technological ecosystems and innovation networks under FAIR and CARE principles	Secure long-term national funding lines for Amazon-focused science with binding allocation targets

Figure 8.1: Barriers hampering Amazon Scientific Knowledge Systems and solutions supporting it. FAIR stands for findable, accessible, interoperable, reusable; CARE stands for collective benefit, authority to control, responsibility, ethics.

2. Amazon's Diverse Knowledge Production System

2.1. What are Indigenous and Local Sciences?

Grounded in empirical experiences and oral transmission, Indigenous and Local Sciences (ILS) refers to the diverse scientific empirical inquiries of Indigenous and Afrodescendant Peoples and Local Communities (hereafter IPs & LCs). Any kind of scientific empirical inquiry emerges from a protocol—an attitude about how to approach the world. While WAS may approach the world as the sum of resources that are managed by humans, Indigenous scientists express protocols of experimentation, prediction, and environmental feedback in which humans share responsibilities within collectives of human and non-human beings (see Chapter 5)[8]. ILS offer critical contributions to sustainable solutions, in areas such as including ecosystem restoration, the development of inclusive and regenerative bioeconomies (see Chapter 7), territorial governance, social technologies, food security, and the integration of human and planetary health[9].

Among the Indigenous Peoples of the upper Rio Negro in Brazil, for instance, the world is not singular but plural. Numerous agents govern the relationships of kinship, communication, negotiation, and the exchange of goods and technologies. Through ceremonial practices led by specialists or knowledge holders, Indigenous communities ensure that these socio-ecological networks function cyclically and remain resilient. This complex understanding of the presence and distribution of resources speaks to broader environmental and ecological contexts and dynamics, offering substantial insights into both ecological and evolutionary processes and grounding scientific research in local priorities[10,11].

Box 8.1. Amazon guardians made invisible: The role of Indigenous women in the survival of traditional knowledge.

Indigenous women play a fundamental role in the construction, preservation, and transmission of traditional knowledge. This knowledge, intimately linked to territory, ancestral medicine, food security, and spirituality, forms the backbone of the life systems of Indigenous Peoples and of nature's protection[12]. In this regard, the Inter-American Court of Human Rights has recognized in an advisory opinion that "the knowledge of Indigenous women is decisive for maintaining cultural identity, managing risks and the effects of climate change, protecting biodiversity, achieving sustainable development, and building resilience to extreme events"[13].

In territories such as the province of Pastaza, in the Ecuadorian Amazon, Indigenous women not only ensure the material and symbolic reproduction of life through their care for *chakras* (traditional agro-productive systems; also spelled *chagras*) and their domestic and community work, but also take a leading role in organizational processes to defend the territory against the violent advance of extractive industries. As expressed in a testimony from the collective *Mujeres Amazónicas Defensoras de la Selva*, "women are between the crying child and the harvest," revealing the work overload they face and their centrality in community sustainability[14].

However, the key role of Indigenous women continues to be made invisible or delegitimized. The same advisory opinion of the Inter-American Court of Human Rights warns that Indigenous women environmental defenders face multiple forms of violence arising from their gender and ethnic origin, including gender stereotypes, criminalization, harassment, and threats to their families[13]. Recognizing their strategic role and ensuring their effective protection is imperative for the realization of human rights, the rights of nature, and the sustainability of the global fight against climate change.

2.2. Connecting Worldviews: A Path to Transformative Change

Building genuine partnerships and establishing spaces for knowledge dialogues with Indigenous Peoples and Local Communities (IPs & LCs) — including their sciences and philosophical systems — is essential to ensure that scientific efforts in the Amazon are meaningful, inclusive, and rooted in community-defined values, responsibilities, and goals[15,16].

As Gregório Mirabal, an Indigenous leader from the Kurripako People points out

> [...] the effort must be to bring these two approaches together and enable genuine collaboration. That is both a challenge and an opportunity. In some cases, Indigenous knowledge identifies plants with superfood potential or healing properties—key examples for the bioeconomy. This knowledge can help scientists discover what might otherwise take 5 to 10 years of research. And if Indigenous knowledge were empowered with the tools of modern science, the result would be a relationship of mutual strengthening[17].

Bridging knowledge systems requires more than technical collaboration: it challenges academic scientists to understand and engage with other forms of empiricism and explanations beyond the frameworks of WAS. Indigenous worldviews do not separate subject from object or culture from nature; instead, they observe and perceive multidimensional patterns and connections across spatial and temporal cycles[9]. Indigenous worldviews rely on communal and spiritual validation and avoid dichotomies. In contrast, the WAS seeks to understand the universe through analytical and reductionist methods, using statistical and causal relationships[18]. Therefore, the WAS approach carries the risk of oversimplifying multiple realities by reducing complex issues to binaries, potentially distorting the depth and richness of ILS[19].

Collaboration across diverse knowledge systems can catalyze transformative change, but only if these systems are fully respected as integrated cultural wholes, encompassing knowledge, practices, values, and worldviews[20]. Recognizing and honoring these knowledge systems as integral to IPs' and LCs' struggles for self-determination is essential to advancing truly sustainable and equitable development, particularly in areas where such intercultural dialogues are already yielding positive outcomes such as:

- **Conservation and combating deforestation:** IPs of Latin America predominantly inhabit forested areas. Moreover, Indigenous Territories account for ~28% of the region and contain significant portions of the remaining mature forests[21,22]. Importantly, about a quarter of the region is also designated as Protected Areas (in addition to Indigenous Territories), and there are overlap zones between them. These governance frameworks collectively underpin biodiversity conservation, carbon storage (≈10%–20% of global forest carbon), and community well-being amid high deforestation rates[23].

- **Territorial management and governance:** Across the Amazon Basin, IPs & LCs develop territorial and environmental management plans to sustainably manage their lands. Built through participatory mapping and research led by Indigenous specialists, these plans weave traditional knowledge with conservation objectives and local development goals[24] (see Chapter 5).

- **Ecology and management:** Locally generated knowledge — including ethnobiological studies and local ecological knowledge — has greater impact when shared across scales, linking community realities to regional and global decision-making[25-27] (see Call to Action 20, Chapter 6).

- **Health:** ILS offers rich insights into traditional diets and plant-based medicines, supporting healthier alternatives to processed food systems (see Chapter 3). Cultural connectedness also contributes to lower risks of suicide and obesity, reinforcing the value of traditional food and knowledge systems[28,29].

- **Climate adaptation and mitigation:** IPs & LCs in the Amazon have long practiced fire management, agroforestry, and water conservation to adapt to climate variability, sustain ecosystem resilience, and reduce carbon emissions[30,31] (see Chapter 6).

A growing number of collaborative research initiatives involving Indigenous communities have also developed outside university settings, through partnerships between nongovernmental organizations (NGOs), Indigenous organizations and communities, and government agencies (**Table 8.1**).

Table 8.1. Research and innovation initiatives integrated with Indigenous and Local sciences (ILS) and traditional knowledge of the Amazon.

INITIATIVE	MAIN OBJECTIVE	IMPACTS OR RESULTS
The Amazon Revealed project, Brazil[32]	LiDAR technology is used to map archaeological sites in areas threatened by deforestation together with seeking guidance with communities that live in these territories.	Archaeological remains indicate that the human presence in the rainforest is much more ancient than previously thought.
Da Tribu Biojewelery company, Brazil[33]	Centering sustainability in products and processes, valuing IPs' & LCs' knowledge and social technologies.	Built a community-rroted supply chain to produce biodegradable pieces, reconciling economic value capture with respect for communities, their social technologies, and the environment.
Bahserikowi'í, Center of Indigenous Medicine of Amazonia, Brazil[34]	Create a community-led space where Indigenous specialist healers practice and cultivate knowledge, offering care and teaching while dialoguing with public heatlh services.	It supports cultural resilience and offers Indigenous patients more culturally meaningful and holistic healthcare options, establishing a lasting reference or Indigenous medicine.
ACITAM-SINCHI pilot on Geographich Indications (GIs) and Collective Marks, Colombia[35]	Affirm Indigenous and Local Sciences' sovereignty by creating community-defined GIs and collective marks that embed sustainable biodiversity-use practices.	Co-developed GIs and collective-mark frameworks that let communities set terms for circulation and benefits of their knowledge in biodiversity-based products.
Inter-institutional coordination around the cassava value chain, Colombia[35]	Co-design a cassava value chain that elevates indigenous cultivation and processing and links it to supportive institutions and markets.	Aligned roles across regional agencies and communities, improving processing and commercialization while amplifying visibility of Indigenous social technologies.
Organizational strengthening for GI adoption, Colombia[35]	Strengthen community leadership and producer organizations so families can govern how knowledge travels through GI/collective-mark value chains.	Built local capacity and producer structures across indigenous Territories, enabling fairer participation in value chains.
Participatory co-design workshops, Bolivia[36]	Participatory methodologies were used to identify problems, objectives, and lines of action to discuss strategies for the protection of archaeological assets in the municipality of Trinidad.	The involvement of members of the Municipal Council in the protection of an archaeological site that was discovered during the construction of a drinking water infrastructure system.

2.3. Improving Dialogues: Three Strategies to Strengthen Collaboration and Knowledge Exchange

A wide range of methodological approaches and tools have been used in over 39 Amazonian initiatives to organize *knowledge dialogues*, collaborative processes that bring together knowledge production systems to inform action[37]. These have included project-level experiences, such as bottom-up participatory research design and intercultural research programs, as well as more specific tools, such as participatory mapping, games, video/photographic tools and other methods to facilitate and catalyze IPs & LCs stakeholder participation[38,39]. The impact and performance of knowledge dialogues depend on the objective of the initiative or project and the type and level of involvement of the actors[40,41].

By blending WAS and ILS, a multi-evidence approach helps align different types of scientific evidence, enabling more holistic and effective management of Amazonian ecosystems amid rapid environmental and social changes[9,41-44]. Knowledge dialogues reveal both convergences and divergences between knowledge systems, so it is essential to emphasize complementarities, synergies, and cross-fertilization of information from different sources, scales, and methods for the success of these dialogues.

Concrete actions and policies can strengthen the environment for cooperation, dialogue, and transdisciplinary exchange among Indigenous, Local, and academic knowledge systems. This requires overcoming power asymmetries, inequalities, and mutual unawareness in intercultural dialogue processes, factors resulting from the marginalization and exclusion that IPs & LCs have historically experienced. Below are some key areas where action is especially impactful:

- **Interweave ILS into research programs and initiatives:** In Brazil, the 5th National Conference on Science, Technology and Innovation (CNCTI) provided guidelines to overcoming barriers to integrating ILS into science, technology, and innovation (ST&I) policies. These include the creation of institutional mechanisms to incorporate ILS into research and postgraduate programs and also the expansion of funding for government and nongovernment initiatives that actively include ILS.

- **Ensure horizontal cooperation and equity in knowledge dialogues:** Including community members as co-researchers can reinforce conditions of horizontal cooperation and equity without reducing or decontextualizing culturally specific knowledge[16,27].

- **Develop a legal framework integrating scientific and cultural policies:** Developing strategies that bring together ILS, nature-based solutions, and creative economies requires a legal foundation tailored to the national social realities. Legal instruments to protect and promote cultural heritage in ST&I must explicitly encompass both tangible and intangible assets linked to the knowledge systems of Indigenous and Traditional Peoples and Communities.

3. Academic Knowledge in the Amazon

3.1. Fragmented Knowledge, Strategic Potential: Research in the Amazon Today

Scientific and knowledge production in the Amazon remains fragmented, dispersed, and difficult to fully map. In Brazil, for example, much of the region's research is funded through Coordination for the Improvement of Higher Education Personnel and National Council for Scientific and Technological Development, at the federal level, and by state foundations, e.g., Amazonas Research Foundation and Amazon Foundation for the Support of Studies and Research, which primarily support posgraduate dissertations and thesis. However, these outputs are often stored in poorly structured institutional repositories, and the absence of Digital Object Identifiers (DOIs) makes it difficult to track their reach and impact.

Moreover, many Latin American researchers lack sufficient support for English-language publication, creating barriers to visibility in international journals. Research focused on local knowledge and communities is often published in Portuguese or Spanish and follows less-standardized publication formats, limiting its visibility in global academic databases. To gain a comprehensive understanding of scientific knowledge production in the region, it is essential to include books, monographs, and especially theses. However, this remains a complex task due to the fragmented, underfunded, and poorly integrated state of data sources.

Within these limitations, it is possible to conduct mapping exercises of scientific production based on specific criteria, using global publication databases such as Dimensions, Web of Science, or SciELO. For example, the Dimensions database has been used to analyze research output that originated in the Brazilian Amazon between 2018 and 2023, specifically selecting publications that included the keywords “Amazon,” “Bioeconomy,” “Sustainable Development,” or “Innovation”[45]. This mapping exercise indicated that federal universities have been the leading institutions in scientific output, with the Federal University of Pará and the Federal University of Amazonas ranking first and second, with 23,310 and 9,020 publications, respectively. Research institutes play a complementary role, often producing the most highly cited and impactful studies. Notable examples include the Brazilian National Institute for Amazonian Research, the Evandro Chagas Institute, the Emílio Goeldi Museum of Pará, and the Mamirauá Institute for Sustainable Development (IDMS). The analysis also reveals that, despite the limited number of active research institutions in the Amazon, when considering the number of doctoral programs, scientific activity in the region is robust with respect to topics relevant to the bioeconomy. Research output in this field grew by 22.3% between 2007 and 2011, and by 19.7% between 2012 and 2016. Overall, research output increased by 75% from 2007 to 2021. These results point to a gradual and increasing rise in the engagement of the Amazonian research community in issues critical to the region’s future. According to the study’s authors, the rise in publications is also an indicator of the growing specialization of Amazonian institutions in bioeconomy-related research topics — and their increasing impact.

Another indicator used to assess advances in research is the number of patent registrations. The number of bioeconomy-related patents in Brazil rose from 202 (2007–2011) to 628 (2017–2021), marking a 310% increase after a decade. Yet, Amazonian institutions’ participation in these patents, while increasing from 3.3% to 8.8% (2007-2021) remains limited considering the Legal Amazon holds 13.7% of the Brazilian population and produces substantial research output. In other words, the Brazilian Amazonian research community continues to be excluded from the economic returns of the national bioeconomy value chain, revealing a gap between academic research and its transformation into products and services.

The scientific output in the Amazon basin was also assessed, with specific focus on ecological research conducted between 1998 and 2005[46]. The results showed that most of the research took place in three regions: Manaus, southeastern Peru, and eastern Ecuador, with approximately 31% of all papers coming from four field stations in those regions. These three countries (Brazil, Ecuador, and Peru) accounted for 80.4% of all Amazonian research collected. Brazil is a leading country in terms of scientific output. However, this fact should be viewed in the context of two important considerations: first, Brazil encompasses the largest portion of the Amazon (approximately 60%); and second, when productivity is normalized by publications per square kilometer, it ranked as the least productive country in the region during the period.

We also quantified the research output of Amazonian-based institutions by observing trends in scientific production and cross-country collaboration from 1990 to 2024, using selected keywords about the Amazon in relation to biodiversity, conservation, bioeconomy, or clean energy, in the Web of Science database (without excluding institutions based outside the Basin). This exercise resulted in a concise collection of 953 documents, normalized by highest citations and by each country's share of the Amazon basin. The data reveal strong international cooperation in terms of co-authorship on the topics identified through the selected keywords. Brazil hosts the majority of institutions in this sampled network, appearing 576 times, followed by the United States (335) and the United Kingdom (100), which have authors co-authoring the studies in the sample (Figure 8.2). This pattern likely reflects a tendency to prioritize collaboration with countries outside the Amazon, rather than fostering cooperation among Amazonian nations. Among the 10 most recurring countries in the sample, four are from the Amazon region: Brazil (576), Peru (80), Colombia (78), and Ecuador (53).

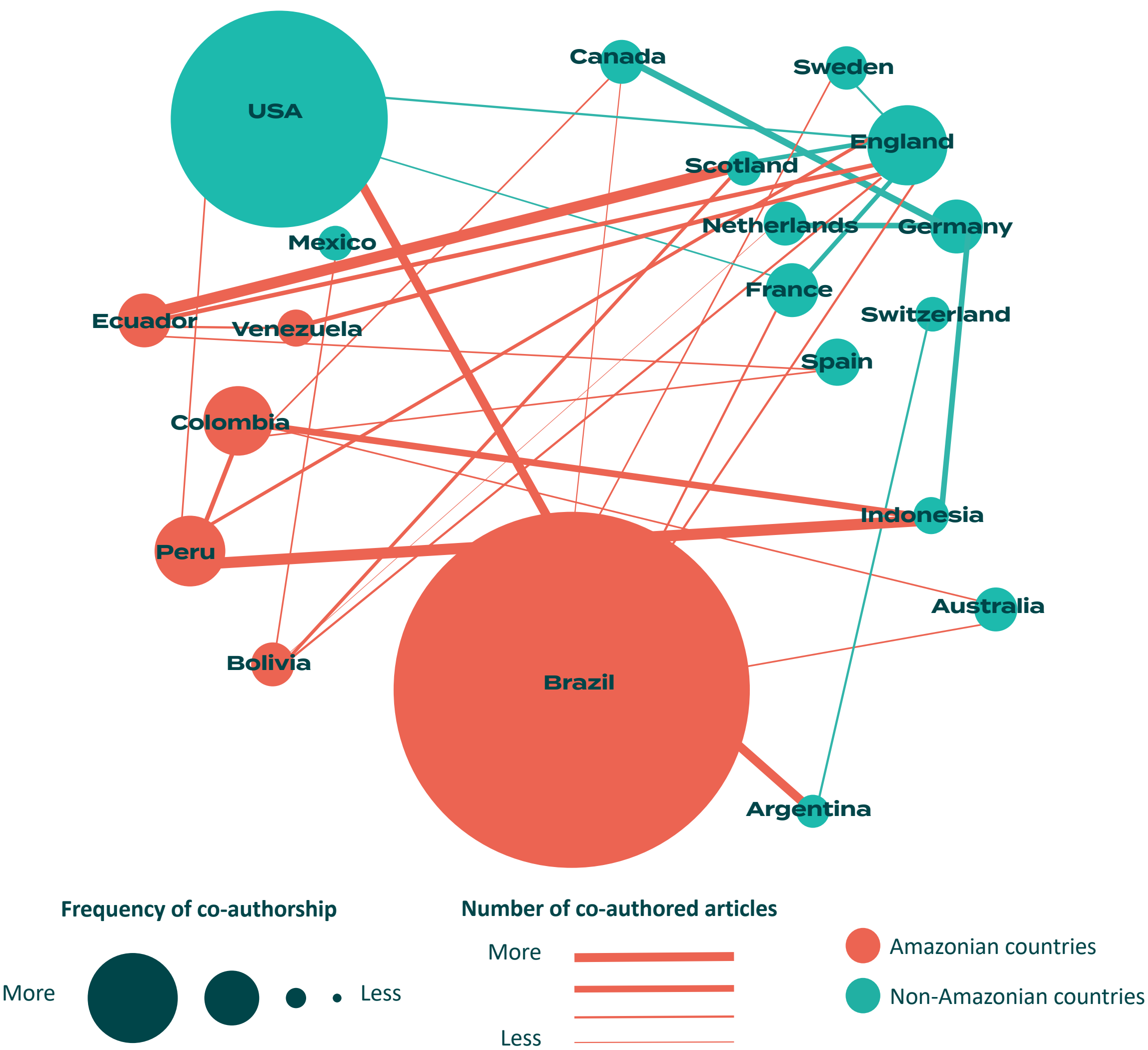


Figure 8.2: Network of international co-authorship on Amazonian science (1990–2024). This network was constructed from bibliographic data retrieved from the Web of Science (WoS)[A]. Lines represent co-authorship links between countries, and line thickness indicates the intensity of collaboration. Node size is proportional to the citation frequency of each country, and labels show country names. Brazil appears as the most frequent actor in the sample, with strong ties to the United States, France, and England. However, collaboration among Amazonian countries remains limited compared to partnerships with institutions from the Global North.

In terms of institutional affiliations, Brazilian public institutions also stand out in the selected sample. However, in this particular exercise, the most cited institution is based outside the Brazilian Legal Amazon region: the University of São Paulo (USP), appearing 99 times across the documents sampled. On the

A The dataset includes publications explicitly mentioning the Amazon and associated strategic keywords related to biodiversity, conservation, bioeconomy, and clean energy. Records were proportionally sampled to reflect contributions from Amazonian countries, resulting in a sample of the 953 most cited documents with participation of institutions from Amazonian countries. This figure shows the top 20 countries represented most frequently among the sampled documents. Data was processed in CiteSpace (version 6.4.R1) using temporal slicing in five-year intervals, and co-authorship networks were extracted at the country level. The resulting tables were exported and refined in Gephi (version 0.10).

other hand, the findings also highlight the importance of research institutions such as INPA and Brazil's National Institute for Space Research (INPE), appearing 69 and 66 times, respectively. Additionally, the data underscore the complementary role of a state-owned company in scientific research, Embrapa, which appears 72 times.

Finally, Encalada et al. integrated geographic information systems with data on the presence or absence of research centers, universities, environmental and social NGOs, and climate stations from national institutes operating in the Amazon Basin[47]. They also assessed scientific linkages between these institutional types and the research topics on which they converge. As a result, they identified high levels of collaboration in two Andean basins in Peru and Colombia, one in Bolivia, and basins in the middle and lower Brazilian Amazon. However, medium to low levels of collaboration predominate across most of the basin (**Figure 8.3**). While assessing interregional scientific collaboration in the Amazon Basin remains a challenge, the evidence presented here strongly suggests the existence of fragmented knowledge systems across the region.

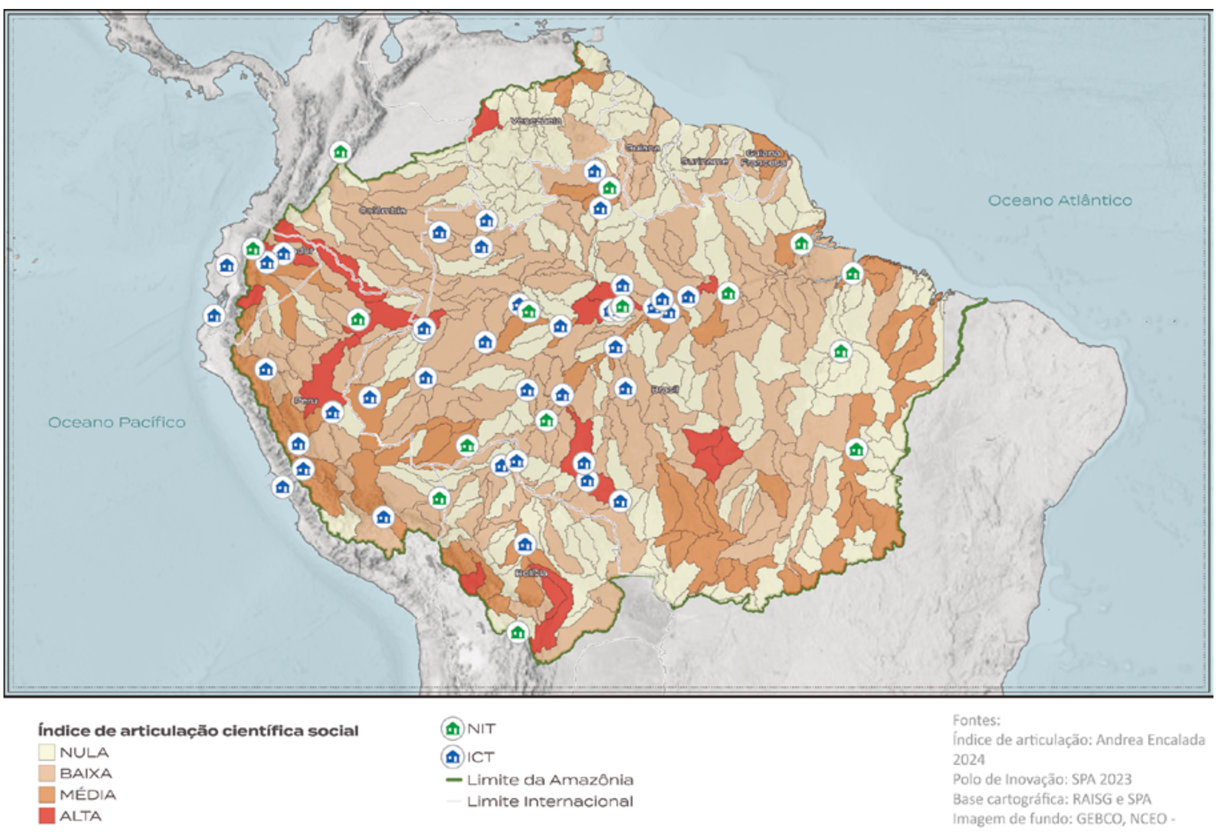


Figure 8.3. Distribution of Technological Innovation Center (NIT) and Scientific and Technological Institution (ICT) present in the Amazon Basin, and scientific articulation index at the basin level. Most of the Amazon shows null or low values for scientific articulation[50].

3.2. Science for Whom? Five Criteria for Evaluating Amazonian Science

Given the challenges outlined above, assessing Amazonian knowledge networks remains a strategic priority for the region. To achieve this, one fundamental question must first be addressed: for whom is knowledge being produced in the Amazon?

Answering this question is essential for developing metrics and indicators that align with the intended goals and, most importantly, for identifying where and how to seek the information needed. Applied research, in particular, should be designed around well-defined challenges with proven relevance and impact for Amazonian societies. To ensure alignment with public priorities, it is important that government entities, the private sector, and IPs & LCs are involved in the design, implementation, and evaluation of such projects.

In the Brazilian Amazon, applied research that focuses on the management of socio-environmental impacts and emphasizes broad participation in society has demonstrated its relevance. Examples such as an improvement in açaí farming (Embrapa, see Chapter 6) and the participatory management of pirarucu (IDSM, see Chapter 7) have delivered proven benefits in terms of income and return to society. In relation to health, a malaria control project (the Oswaldo Cruz Foundation, Fiocruz) significantly reduced cases in participating municipalities[48-50].

Developing a science assessment framework for the Amazon region that responds to its social specificities and ecological complexity requires the incorporation of criteria to measure the impact of knowledge production on nature conservation and well-being for the region. The following are particularly relevant:

- **Quality of knowledge dialogues and interweaving with ILS:** It is possible to monitor the progress of meaningful participation by IPs & LCs in the development of cutting-edge science through co-authorship analysis, a method widely used for research evaluation around the world.

- **Transdisciplinarity in knowledge production:** Transdisciplinary research occurs when actors from different scientific fields, policy arenas, and areas of practice co-evolve their understanding of socio-ecological issues, allowing knowledge domains to remain open and interactive; such types of research can also be tracked by co-authorship analysis.

- **Development and consolidation of Amazonian scientific collaboration networks:** One priority for enabling cooperation between research institutions of the Pan-Amazon is to increase inbound and outbound researcher mobility using existing institutional mechanisms as stepping stones (e.g., the Alliance for a Sustainable Amazon's internships in Peru and the discontinued Science Without Borders program in Brazil).

- **Evolution of science–society dialogues:** Making research findings accessible and actionable increases the chances of their use in decision- and policymaking. Summarized formats, such as policy briefs and technical notes, should be encouraged or even incentivized and should be acknowledged as outputs within science evaluation frameworks.

- **Knowledge and technology transfer:** Beyond patent registration, measurable dimensions of knowledge and technology transfer include collaborations with businesses and the extent to whch research contributes to the development of new ventures, such as startups, NGOs, community-based initiatives, and cooperatives.

4. Technologies Supporting Knowledge Construction and Conservation in the Amazon

Technologies play a fundamental role in supporting knowledge construction in the Amazon by enabling a deeper understanding of its vast biodiversity, ecological processes, and cultural landscapes. In the following sections, we highlight technologies with high potential for impact — provided they are adapted to the realities of the Amazon and its peoples, their needs, cultures, and traditional practices **(Figure 8.4)**.

4.1. Remote Sensing

Satellite monitoring has become an indispensable tool for environmental governance in the Amazon. Brazil's programs PRODES (Program for the Calculation of Deforestation in the Legal Amazon) and DETER (Real-Time System for Detection of Deforestation) provide annual deforestation rates and real-time alerts to support law enforcement[51-54] (see Call to Action 1, chapter 1,). The use of optical and radar imagery (e.g., Landsat and Sentinel) enables detection of deforestation even under cloud cover, as well as detection of more subtle processes such as selective logging[55,56]. Satellite data has also been key to detecting illegal mining, forest degradation, and deforestation[53,54, 57-59]. Despite these advances, monitoring systems still lack consistent and comprehensive integration with IPs & LCs' needs, worldviews, and ethics. In this sense, future initiatives should connect to local leadership to effectively use and further develop remote sensing technologies in a respectful and egalitarian way.

4.2. On-the-Ground Sensors and the Use of Artificial Intelligence

Environmental DNA (e-DNA) is an emerging, noninvasive tool that enables biodiversity monitoring through traces of genetic material found in environmental samples, such as water or soil. It allows for the detection of rare, invasive, or undocumented species and provides cost-effective insights into ecosystem health[60]. Applications in the Amazon have included assessments of endangered mammal co-occurrence and identification of 28 fish taxa in forest streams, many of them potentially unknown to science[61,62]. This is crucial in a region where biodiversity remains vastly underestimated due to limited access and coverage[63,64]. However, realizing its full potential requires overcoming barriers such as insufficient genetic reference databases and the need for scalable data processing[65]. Strategic investments in digital infrastructure and open-access platforms are essential to harness e-DNA for conservation, health, and sustainable development in the Amazon (see Call to Action 29 of this chapter).

Artificial intelligence (AI) also offers powerful tools to support decision-making by identifying patterns and generating insights from large datasets. In the Amazon, AI is already improving species identification through genetic data analysis, enhancing biodiversity monitoring via drones and acoustic sensors, and expanding participatory science through platforms like Merlin Bird ID and iNaturalist[66-69]. In the sustainable bioeconomy sector, AI helps map tourism impacts, discover bioactive compounds, and design biorefinery models that align biodiversity use with innovation[70-72].

Despite its potential, AI in the Amazon must be adapted to local socio-environmental conditions and supported by a reliable infrastructure. Building local capacities and investing in local AI industries are key to ensuring technological sovereignty and relevance[73]. Additionally, data gaps driven by limited interoperability, underfunding, and the region's ecological complexity can skew results and perpetuate inequalities[74]. Addressing these gaps is necessary for AI to serve inclusive and sustainable development.

Figure 8.4: *Emerging technologies, such as satellite monitoring, AI, and e-DNA, have positive applications in conservation, territorial management, citizen science, and the strengthening of socio-bioeconomies.*

4.3. Citizen science, data governance, benefit sharing, and open knowledge

One of the most exciting aspects of these technological innovations is their potential to foster broader participation of citizens and local communities in the scientific research process. Citizen science is a growing field that seeks to integrate public concerns and knowledge into research through participatory methods, contributing to large-scale environmental monitoring[75-77]. But to bridge knowledge production with democratic values, it is essential to raise ethical and political questions about how citizen-generated data is used, especially in light of the FAIR principles for scientific data management and stewardship (findability, accessibility, interoperability, and reusability) and the CARE Principles for Indigenous Data Governance (collective benefit, authority to control, responsibility, and ethics) (see Call to Action 29).

Data sovereignty is a key concept in discussions around data collection, storage, and use. Historically, biodiversity research has often reproduced colonial and extractivist logics[78]. Similarly, relying on the infrastructure of large transnational corporations for data storage creates risks of biopiracy and data use that may violate the rights of IPs & LCs. Finally, open science practices and open-source initiatives—including open software, data, models, and hardware—are key to supporting the democratization of scientific knowledge and technological tools. By removing economic and technical barriers, they enable more researchers, institutions, and local communities to access, use, and develop these resources. This openness fosters innovation and accelerates scientific progress, allowing experts to adapt, improve, and share solutions tailored to specific needs.

5. Conclusions

Amazonian knowledge systems are vibrant yet constrained by fragmentation and weak data infrastructure, limited collaboration across Amazonian countries, underfunding, and persistent power asymmetries that erase IPs & LCs' contributions, with gaps between research outputs and innovation returns (e.g., patent filings). Furthermore, reliance on Global North platforms threatens data sovereignty.

As pathways forward, Amazonian countries should recognize and institutionalize permanent knowledge dialogues between ILS and WAS, ensuring full and informed participation, intellectual property protection, and fair benefit sharing. Enhancing ST&I in the region demands strengthening research budgets, establishing long-term national funding lines, and reinforcing Pan-Amazonian collaboration via joint programs, transdisciplinary projects, and academic exchanges, with generation of societal benefit valued alongside publications. To ensure digital sovereignty, investments in local technological infrastructure and formative processes are essential, including territorially adapted technologies and regional data centers. Finally, adopting FAIR- and CARE-aligned data governance and promoting citizen science platforms are fundamental to ensure that science is made by and for the Amazon, not merely about it. With these principles and priorities in mind, we can ensure that the Amazon's own knowledge leads, so that Amazonian sciences can assist in charting a pathway to a more sustainable future for the world.

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Promote Ethical, Fair, Sovereign, Inclusive & Locally-Driven Technology Development

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Photo credit: John Jairo Bernal / Resguardo Indígena Yauará

The Overview

In the Amazon, technology holds the power to either entrench inequality — deepening dependency, erasing Indigenous and Local Knowledge Systems, and extracting data for profit elsewhere — or to strengthen sovereignty, uplift Indigenous innovation, and co-create just conservation futures. Success relies on equity, transparency, and inclusive participation in how technology is developed and applied[1]. Conservation is being transformed by technological innovations, such as satellite monitoring[2, 3, 4], environmental DNA[5], acoustic monitoring, camera traps and artificial intelligence (AI)[3,6,7]. These technologies can support a thriving regional sociobioeconomy in the Amazon — but only if they are shaped by and fully respect local knowledge and priorities.

CALL TO ACTION 29

The Facts

- Pre-Columbian Amazonian cultures created technologies adapted to local conditions that significantly expanded food production. These practices now inform approaches to urban planning, waste management, and land use[8].

- Recent technologies remain poorly adapted to the Pan-Amazon, where tropical climate and insect intrusion compromise equipment. The combination of extremely high biodiversity and substantial data gaps hinders the development of AI models for biodiversity monitoring.

- Limited infrastructure and scarce technical training limit the adoption of novel technologies in the Pan-Amazon.

- Biodiversity data and technological resources are centralized in institutions far from the Amazon, excluding local actors from decision-making, authorship, and the resulting benefits.

- Data from biodiversity-rich regions is often extracted and sent to institutions in the Global North for model development. These models, built on Southern resources, are frequently credited to Northern institutions, which may commercialize them or restrict access, reinforcing extractive and inequitable dynamics.

Global/Regional and Synergistic Connections

- Limited local infrastructure and technical training in tropical regions from Latin America to Africa and Asia perpetuate dependency on external expertise, undermining the capacity for region-driven environmental solutions and sustainable development goals.

- Around the world, there is a significant gap between the biological and sociological sciences and the engineers developing new technologies, which often leads to tools that are poorly aligned with ecological needs, lack local relevance, or fail to consider social and ethical dimensions.

- However, established and emerging global agreements on climate and biodiversity (e.g. Paris Agreement, Kunning-Montreal Global Biodiversity Framework) and on the intellectual property of IPs and LCs (e.g. ILO's Convention on Indigenous and Tribal People, Nagoya Protocol, WIPO's Treaty on Intellectual Property, Genetic Resources and Associated Traditional Knowledge) are opportunities to open pathways to align funding, research and technological innovation with socioecological needs of tropical regions.

Benefits

• Scientific transparency and efficiency • Interdisciplinary • Visibility and impact of research • Stimulation of applied solutions • Social and epistemic justice • Autonomy and self-determination • Positive relationships between science and society.

Figure C8.29.1. What are FAIR and CARE principles? While FAIR focuses on data usability and accessibility, and CARE on rights and ethics, the two can be aligned — FAIR providing technical standards and CARE ensuring governance and equity in data use.

The Solutions Space

Selected Key Tools

- **Applications like Science Brief, iNaturalist and eBird** are examples of how technology transforms community-generated data into curated public information, fostering participatory science. To truly support locally-driven knowledge and conservation, such tools must be adapted and embedded within community-based participatory science programs that reflect local priorities, governance, and ways of knowing. Resources like the Data Ethics Toolkit offer critical guidance for embedding ethical data practices in these efforts — emphasizing consent, data sovereignty, and benefit-sharing.

Positive Efforts for Scaling

- **Computer Vision for Ecology Workshops:** The workshops have brought together participants from ecology, computer science, and related fields to co-learn concepts, tools, and languages. This mixed format encourages interdisciplinary collaboration, and has led to shared projects that integrate ecological questions with technological solutions.

- **The WILDLABS platform:** has built a global community of over 7,500 members across 120 countries, connecting conservationists, technologists, and researchers to co-develop solutions for biodiversity challenges. It fosters interdisciplinary collaboration through forums, resources, and events focused on conservation tech. Initiatives like the Women in Conservation Technology Programme further promote inclusive, skill-building participation.

- **Global Indigenous Data Alliance:** promotes FAIR and CARE principles (**Figure C8.29.1**) in Indigenous Data Governance. Additionally, it offers resources and orientations to implement these principles in different contexts.

- **GBIF task group on Indigenous data governance:** Composed of Indigenous and non-Indigenous experts, this Global Biodiversity Information Facility (GBIF) task group is developing norms that safeguard Indigenous rights and interests in biodiversity data.

- **Forest Development and Biodiversity Hubs:** An initiative of the Colombian Ministry of Environment that seeks to curb deforestation by transforming active deforestation fronts into territories of conservation and sustainable forest use. Building on this vision, Colombia's Humboldt Institute has promoted community biodiversity monitoring. Communities are fully involved in defining monitoring objectives, designing protocols, and analyzing results to strengthen knowledge and stewardship of their lands.

Major Recent Governmental Efforts

- **Through Law 13.123/2015**, Brazil mandates prior informed consent and outlines mechanisms for monetary and non-monetary compensation for data usage from Indigenous, Traditional and Local communities. Other Amazonian countries show varying levels of legal development in this area. Peru has enacted Law 27.811 to protect Indigenous collective knowledge, including benefit-sharing provisions. Ecuador and Colombia recognize Indigenous rights, but lack detailed regulatory frameworks or benefit-sharing mechanisms. While these laws are important, they often treat IPs and LCs primarily as data sources or beneficiaries. To achieve technological justice, IPs and LCs must be recognized as innovators and co-creators. This means going beyond consent to include them in the co-design and governance of technologies.

Recommendations

- **Support the development of local technological infrastructure and promote the sovereign collection and management of Amazonian data and knowledge.** Invest in community-led innovation, training, and tools that enhance regional capacity for data governance. This will enable the development of tools adapted to the unique representation of Amazonian biodiversity and its social contexts.

- **Promote open-science practices and open-source initiatives in line with the CARE principles.** Open-source approaches offer free access to cutting-edge tools and knowledge, fostering collaboration, reducing reliance on expensive proprietary systems, and empowering local innovation, capacity building, and inclusive problem-solving — especially in context-specific challenges.

- **Foster mutual knowledge exchange and co-creation between scientific communities and local knowledge holders.** Support the development of inclusive platforms and institutional mechanisms that allow for sustained, equitable collaboration between scientists, engineers, and indigenous or local communities. This should aim to blend knowledge systems to co-develop solutions that are context-specific, culturally appropriate, and socially legitimate.

- **Implement training programs that combine workshops in environmental monitoring technologies** (e.g., acoustic sensors, GIS, AI tools) with foundational scientific and data-management skills, ensuring local stakeholders can independently collect, analyze, and apply biodiversity data in Amazonian conservation efforts.

- **Promote equitable collaborations and partnerships.** Foster open access to data, tools, and models while ensuring transparent agreements from the outset regarding credit attribution, data ownership, and the use of results. This includes recognizing all contributions—technical and non-technical—and encouraging shared publications and outputs. Projects should adopt horizontal structures where decisions are made collectively and inclusively.

- **Foster interdisciplinary collaboration.** Encourage collaboration among ecologists, sociologists, and engineers through interdisciplinary networks, workshops and mutual training. Promote accessible user interfaces to operate novel technological tools, and develop educational resources in local languages to ensure broader inclusion and usability.

- **Monitor and communicate metrics regarding** Science and innovation investment, Technological progress, Technology adoption, Socioeconomic impact based on Global Innovation Index' concepts and methodology

Key Recent Literature

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Fund, Connect, and Strengthen Science for a Living Amazon

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Photo credit: Miguel Monteiro (left), Paulo Brando.

The Overview

Developing a sustainable future for the Amazon that conserves the environment and promotes well-being requires a solid foundation in science, technology, and innovation (ST&I), with strong regional research centers shaped by local priorities. The Amazon faces major challenges in ST&I that must be addressed in this decade: chronic underfunding, fragmented regional coordination, reliance on international resources, unsatisfactory training and retention of qualified personnel, sharp inequalities, and lack of local leadership in project design. These barriers undermine the transformation of research into tangible opportunities with social impact. The central issue is determining how to design and implement strategies that strengthen the Amazon's scientific institutions and their ability to lead research agendas, while also nurturing dialogue sensitive to local demands and knowledge systems.

The Facts

- Among Amazonian countries, investment in ST&I remains critically low. With the exception of Brazil—where national investment peaked at 1.37% of gross domestic product (GDP) in 2015—investment has stayed below 0.5% of national GDPs, on average[1]. This aligns Amazonian countries with other economies heavily reliant on international funding for research[2].

- Even in Brazil, less than 4% of national ST&I funds have been directed to the Amazon region. In other countries, regional allocations remain opaque.

- Brazil's North, home to most of the Amazon, has around 6,600 PhD-level researchers, compared to over 60,000 in the Southeast[3].

- Brazil has ~903 researchers per million inhabitants (as of 2014), Ecuador 400 (2014), Venezuela 180 (2023), Colombia 90 (2017), and Bolivia 63 (2021)[4].

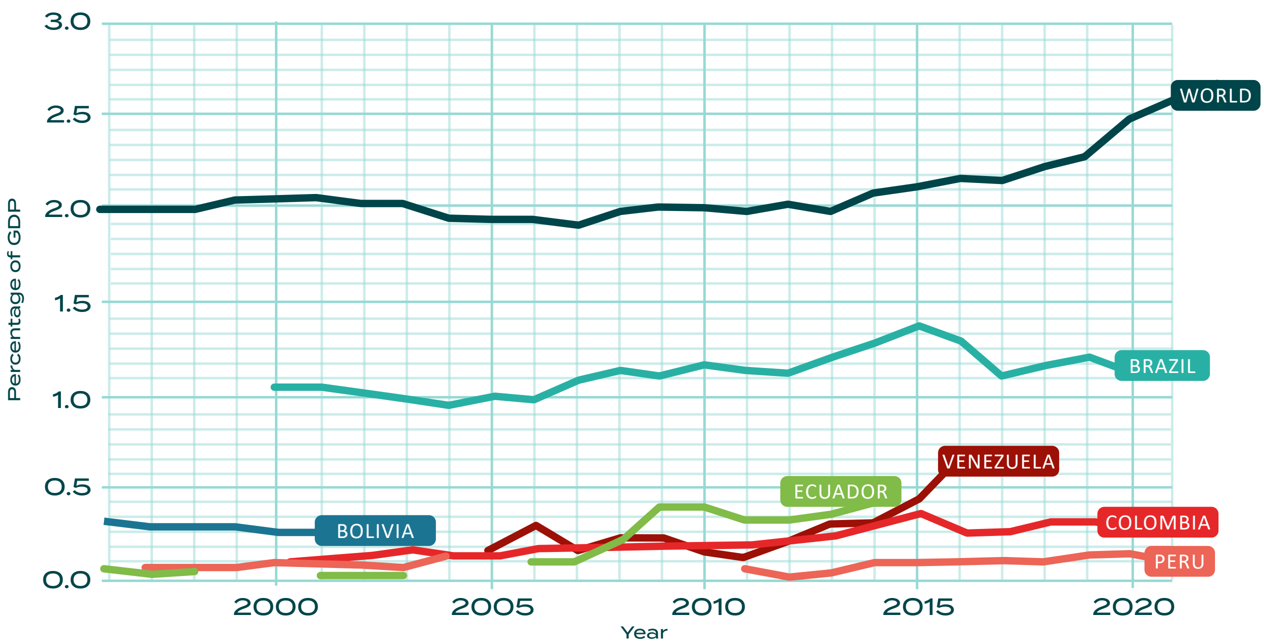

Figure C8.30.1. Research and development expenditure (% of gross domestic product, GDP) for several Amazonian countries. From 1996 to 2022, most Amazonian countries spent less than 0.5% of their own GDP on research and development. Adapted from World Bank Open Data. Data on Guyana and Suriname are not available.

Global/Regional and Synergistic Connections

- Globally, over 50% of scientific research funding comes from the US and China[2].
- The instability of international funding for science[5,6] highlights the need for Amazonian countries to cooperate and secure sustained, long-term domestic investment in ST&I.
- In the 2023 Belém Declaration of the Amazon Cooperation Treaty Organization (ACTO), the presidents of the Amazonian nations reaffirmed their commitment to joint project implementation and announced the creation of the Intergovernmental Scientific Technical Panel for the Amazon under ACTO.
- The current Brazilian presidency of the New Development Bank (NDB) offers a timely opportunity to foster partnerships led by local residents to seek funding that benefits the region, which would help to ensure local talent development and safeguard Indigenous and Local Knowledge as well as nature conservation.

The Solutions Space

Selected Key Tools

- **Amazon+10 Initiative, Brazil:** Launched in partnership with 19 state foundations for research support (FAPs) and the Brazilian National Council for Scientific and Technological Development (CNPq), the initiative supports collaborative research projects in the Brazilian Amazon, with a total investment of ~USD 18.8 million.
- **Centelha, Brazil:** The program supports 274 start-ups in the Legal Amazon, aiming to promote innovation by supporting selected projects with training, financial resources, and technical assistance to help transform innovative ideas into businesses.
- **Federal Investments in Research in Brazil:** In July 2024, the Brazilian government announced ~USD 100 million in funding for scientific and technological development programs in the Amazon through the National Fund for Scientific and Technological Development (FNDCT), which includes a dedicated program for the region, *Pro-Amazônia*[8].

- **IKI - International Climate Initiative, Germany:** Launched in 2008, IKI finances climate mitigation, adaptation, nature-based solutions, and biodiversity in emerging economies. In the Amazon, IKI supports portfolios in Brazil, Colombia, Ecuador, and Peru, with projects co-designed and implemented by Amazonian authorities and local organizations.

- **Amazon Sustainable Landscape Program:** A GEF-funded, World Bank–led regional program that brings together national projects and regional coordination to strengthen landscape connectivity, promote sustainable land management, and conserve ecosystems across the Amazon.

- **Amazon Cooperation Treaty Organization (ACTO):** ACTO has emerged with a central role in advancing science and knowledge in the region, supporting Indigenous climate initiatives and transboundary water cooperation, and revitalizing the Amazon University Association (UNAMAZ).

- **Amazonia Forever (Inter-american Development Bank- IDB):** A regional strategy agreed by authorities from Amazonian countries to coordinate investments in bioeconomy, cities, conservation, and social inclusion. Countries participate as co-proponents with shared governance.

Collaborative Efforts

- **AmazonFACE:** Involving institutions from 10 countries, this ongoing long-term CO_2 enrichment (FACE) experiment exposes mature tropical trees to projected future atmospheric CO_2 concentrations.

- **Center for Amazonian Scientific Innovation (CINCIA):** Based in Madre de Dios, Peru, CINCIA is a long-term program that brings together national and international institutions to develop sustainable solutions for tropical landscapes and public health.

- **Franco-Brazilian Center for Amazonian Biodiversity (CFBBA):** Based in Manaus, Brazil, this center aims to continuously promote and support Franco-Brazilian research dedicated to Amazonian biodiversity and received ~USD 456,000 in funding from France[9].

- **Iwokrama International Centre:** Established in 1996 under a joint mandate formed by Guyana and the Commonwealth, it operates research and monitoring in a 371,000 hectare forest, with regional partnerships (including ACTO).

- **Amazon Science and Technology Park:** Brazil and Peru are jointly developing a new cutting-edge science and technology park and innovation center in the Peruvian Amazon, linked to the Alto Solimões Science and Technology Park (PaCTAS) in Tabatinga, Brazil, and involving universities and civil society[11].

- **Amazon Tall Tower Observatory (ATTO):** ATTO is a joint long term initiative led by scientists from Brazilian and German institutions that enables continuous collection of meteorological, chemical, and biological data in the middle of the Amazon.

- **nexBio Amazônia:** This cohort-based and recurring initiative aims to bring together Swiss and Brazilian start-ups and researchers engaged in the Amazonian bioeconomy[12].

- **Bioamazonia Network:** This is a continuous regional network with a mission to integrate and strengthen Pan-Amazonian research institutes through knowledge exchange on conservation and sustainable practices.

Major Recent Governmental Efforts

- Amazonian countries have developed **strategic plans and cross-sector mechanisms focused on the bioeconomy**, highlighting the crucial role of ST&I and the need to strengthen their science and knowledge ecosystems. In Brazil, the National Bioeconomy Commission (CNBio) is responsible for the National Bioeconomy Development Plan (PNDBio)[13]. In 2024, Colombia launched the Intersectoral Mechanism for Bioeconomy, with the participation of its Ministry of Science[14]. That same year, Ecuador introduced its White Paper on Bioeconomy, integrating production, technology, and environmental aspects[15]. These examples represent institutional frameworks that provide the foundation to consolidate ST&I in the region in the short to medium term.

Recommendations

- **Establish a Pan-Amazon scientific fund for long-term research projects and capacity building,** led by the Amazonian community, with country contributions based on GDP, international co-financing, support from development banks, including safeguards against the misappropriation of resources, and an independent technical board.

- **Scale and expand successful existing financing mechanisms** to recommend resources for Pan-Amazonian countries and ensure actions specifically targeted at ST&I.

- **Secure long-term national funding lines for Amazon-focused science** with binding allocation targets (e.g., one-twelfth of FNDCT in Brazil) to ensure stable and predictable investment and retention of local talent.

- **Establish a set of impact indicators** in research assessment that goes beyond publication indexes and can adequately describe economic, environmental, and social contributions that ST&I make in the Amazonian context.

- **Ensure that Amazon-targeted and long-term project grants meet criteria of having local leadership,** funding Indigenous and Local Sciences (ILS) and scientific institutions led by Indigenous Peoples (IPs) and Local Communities (LCs), and implementing participatory evaluation and equitable benefit sharing.

- **Deploy an active science diplomacy strategy that promotes equitable bilateral and multilateral partnerships and funding,** reinforces Pan-Amazonian collaborations, accelerates resource mobilization, and upholds rights of IPs & LCs—including rights regarding free, prior, and informed consent; co-design of tools, products, and publications; data governance; intellectual property; and genetic resources.

- **Create a regional technical facility across cooperation bodies** (e.g., ACTO, UNAMAZ, Science Panel for the Amazon [SPA]) to design and submit joint Pan-Amazonian projects to multilateral funds (e.g., Global Environment Facility [GEF]) and development banks.

- **Build a network of innovation hubs,** pairing research centers and businesses to develop sustainable, technology-driven supply chains that support sustainable livelihoods with such tools as expanded fiscal incentives for research and development, REDD+ (referring to reducing emissions from deforestation and forest degradation in developing countries, plus other forest-related activities), and securitization mechanisms[16].

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Stop Epistemicide and Support Indigenous and Local Sciences for a Resilient Amazon

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Brarymi / ADOBE STOCK

The Overview

The erasure of Indigenous and Local Sciences (ILS) and other traditional knowledge systems undermines biodiversity, accelerates ecosystem collapse, and facilitates biopiracy[1]. Critical action is needed to support and value local knowledge production, protect and disseminate cosmovisions that conserve ecosystems, and promote socio-ecological innovations[2]. Integrative strategies and investments that support ILS are urgently needed as catalysts for resilient territories in the Amazon[3]. ILS are crucial for the three pillars supporting a living Amazon[4]: (i) the connectivity and functioning of Amazonian ecosystems, (ii) community-based socio-bioeconomies that support equity and well-being, and (iii) the empowerment of local institutions and governance systems.

CALL TO ACTION 31

The Facts

- Indigenous Peoples (IPs) have shaped Amazonian biodiversity by, for example, domesticating and dispersing many plant species that play key roles in biogeochemical cycles, with such actions dating back at least 12,000 years[5].
- Indigenous Territories encompass ~28% of the region, covering significant areas of the Amazon's conserved forests and exhibiting some of the lowest deforestation rates in the biome[6].
- Indigenous Territories remain among the least academically studied areas in the Amazon, and the wisdom of Indigenous specialists — who hold invaluable knowledge on biodiversity and its use — remains largely ignored by Western science and often suffers institutional erasure[7-10].

Global/Regional and Synergistic Connections

- IPs maintain cosmopolitical relationships with animals, plants, and other beings that play key ecological and cosmopolitical roles. These cosmopolitical networks connect territory-based knowledge, social traditions, and norms with biodiversity and ecosystem functioning, forming robust governance systems that involve humans and non-humans and underpin the socio-ecological integrity of Indigenous Territories[11].
- The Amazon region has the potential to become a global reference for socio-bioeconomies and other nature-based solutions that rely on diverse knowledge systems and territory-based research.
- Efforts to fund, strengthen, and integrate ILS into national science and technology agendas must guarantee direct benefits for IPs and Local Communities (LCs) living in their territories.

Figure C8.31.1. **Participatory science workshop in the Huni Kuin territory, Acre State, Brazil.** Photo Credit: Renato Gavazzi.

Figure C8.31.2. **Overlay of Indigenous Territories and Protected Areas and the distribution of Science and Technology Institutions (ICTs) and Innovation Centers (NITs) across the Amazon region.** The map highlights the potential for advancing territory-based knowledge production by integrating diverse epistemologies and methodologies.

The Solutions Space

Selected Key Tools and Collaborative Efforts

- **Living Schools**: A network of territory-based movements that protect and disseminate ILS. They provide continued financial support for educational workshops and biocultural activities that promote reforestation; agroforestry; traditional medicine and foods; and research on Indigenous history, arts, and sciences.

- **Kayapo Project**: The project connects ILS, governance and surveillance technology for participatory monitoring and territorial management against illegal mining and logging across 9 million ha of federally demarcated lands.

- **TerraIndígena Project**: This initiative involves 18 IPs from Brazil, Colombia, and Ecuador, encompassing 17 million hectares. It supports governance, environmental monitoring, and community-based bioeconomies in the Amazon region.

- **Cuencas Sagradas Amazónicas**: The Living School of the Amazon (EVA) is a training and learning space that promotes multicultural, bilingual, environmental, and political education for young leaders of the 23 IPs of the Ecuadorian Amazon.

- **The Amazon Hopes Collective**: The Kuikuro Indigenous Association of the Upper Xingu is leading a geospatial portal that combines technologies for cultural heritage mapping and socio-ecological monitoring by Indigenous communities with the long-term goal of engaging Indigenous communities, researchers, and the public in finding solutions to common socio-environmental problems.

- **Biocultural Jaguar Credits from Pachamama Alliance**: An innovative crediting approach combining territorial and biodiversity monitoring processes and blockchain technology, aimed at supporting the conservation of 10,000 hectares of critical jaguar habitats in the Ecuadorian Amazon

Major Recent Governmental Efforts

- **In Brazil, the new National Strategy for Science, Technology, and Innovation** recommends formulating legal frameworks and institutional mechanisms that support the inclusion and funding of ILS[12]. In 2024, the Colombian government issued Decree No. 1275, which recognizes IPs as environmental authorities in their territories. Bolivia and Ecuador are also showcasing advances in integrating ILS into climate action.

Positive Efforts for Scaling

- **The Pan-Amazon Network for Bioeconomy:** This multisectoral alliance promotes socio-bioeconomies inspired by IPs and LCs. The network connects diverse interested parties that share socio-ecological principles to safeguard financing. It provides a compelling example of how to develop a polycentric network that balances national agendas, ethical funding, market demands, and the values and aspirations of forest communities.

- **Biodiplomacy strategies[13]:** Diplomatic tools and agreements used to govern biodiversity, genetic resources, and bio-innovation across borders must reconcile bioeconomical aspirations for the Amazon and respect for Indigenous intellectual and territorial rights by (i) gaining prior, free, and informed consent for activities that affect IPs; (ii) ensuring their participation in development of any products or publications based on their knowledge or territory; and (iii) promoting adequate funding, positive socio-ecological impact, and the equitable and fair sharing of benefits arising from bioeconomic enterprises[10].

Best Practices

- Operationalizing a paradigm of open science that integrates ILS with emerging technologies—such as artificial intelligence (AI), e-DNA (i.e., environmental DNA), and remote sensing—requires wisdom in combining principles and tools. Best practices should be built on CARE principles (collective benefit, authority to control, responsibility, ethics) to make FAIR tools (findable, accessible, interoperable, reusable)[14]. Scientific leadership and co-design of protocols by IPs and LCs are essential for aligning technological tools with Indigenous cosmovisions and community-defined priorities.

Recommendations

- **Include Indigenous scientists in an Amazon policy platform** hosted by the Amazon Cooperation Treaty Organisation (ACTO) to guide the alignment of national legislation and strategies for transboundary cooperation with Indigenous and local sciences and locally rooted socio-bioeconomies.

- **Provide sustained funding for Indigenous-led research and innovation** via dedicated hiring and budgetary mechanisms within national science and technology agencies and the implementation of public–private co-financing instruments.

- **Adopt inclusive governance frameworks** that facilitate IPs and LCs consultation and enable the co-design of policies at the regional and national levels.

- **Promote regenerative socio-bioeconomies** grounded in biocultural approaches to sustainable innovation by supporting territorial management plans and scaling up community-based enterprises through cooperative networks and geographic indication schemes that value biocultural products.

- **Advance ethical and inclusive data governance**, ensuring digital tools like AI, e-DNA, and remote sensing respect Indigenous data sovereignty.

- **Strengthen intercultural education and research networks** by supporting Indigenous higher education institutions, promoting ILS within Indigenous Territories, and opening fair opportunities for Indigenous scholars to hold permanent positions in universities and research institutions.

- **Update legal protections against biopiracy** by strengthening and expanding access and benefit-sharing frameworks to include digital sequence information and AI-derived products, including (i) transparency standards for genomic databases, (ii) obligations for companies and institutions to disclose the origin of biological data used in innovation, and (iii) mechanisms protecting the rights and knowledge of IPs and LCs in biodiversity-rich countries[15].

Key Recent Literature

- Gebara, M.F., Ramcilovic-Suominen, S. & Schmidlehner, M.F. Indigenous knowledge in the Amazon's bioeconomy: unveiling bioepistemicide through the case of Kambo medicine. *For. Policy Econ*. **154**, 103012 (2023).
- Levis, C. et al. Indigenizing conservation science for a sustainable Amazon. *Science* **386**, 1229–1232 (2024).
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- **See full list of references here**

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