nature-based solutions

THE MARKET THAT CAN SAVE THE PLANET

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To all those who seek to
understand and preserve
life on the planet

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The whole of life is coming to terms with yourself and the natural world. Why are you here? How do you fit in? What's it all about?

David Attenborough

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Contents

Carbonext Tatuy REDD+ Project (Mato Grosso)

Foreword

Izabella Teixeira, *former Minister of the Environment of Brazil, Co-Chair of the International Resource Panel of UN Environment, Honorary Board Member of Cebri and the FHC Foundation, Senior Fellow at the Arapyaú Institute, and Board Member of BNDES*

Nature is not only a victim of climate change – it is also our greatest ally in confronting it and in providing sustainable solutions for the decarbonization of the global economy. Development challenges demand that nature be treated as a political actor, particularly in countries that hold biodiversity, material, and natural resources.

In the face of emerging challenges from the convergence of the Climate, Biological, and Digital-Technological Eras, I am convinced that the green transition we must undertake has to be inclusive and sustainable, also leveraged by nature-based solutions (NBS), with integrity and a focus on processes and results. Brazil, because of its unparalleled socio-environmental wealth, has a central role in this global agenda and can lead by articulating global solutions with pragmatism and long-term vision. But it must know how to deal with short-term trade-offs, seeking to establish robust climate transition processes that avoid setbacks and contain a past that is still in motion.

We live in a unique moment. The world increasingly recognizes that, in order to achieve the goals of the Paris Agreement, it is necessary to ensure the conservation and restoration of Nature. The protection of forest ecosystems, especially tropical ones, and of seas and oceans defines a new relationship between humanity and nature. NBS emerge as a strategic driver of this transformation: conserving our tropical forests, recovering degraded areas, promoting low-carbon and regenerative tropical agriculture, as well as fostering an innovative bioeconomy. These actions simultaneously capture carbon, preserve biodiversity and natural resources, and generate socioeconomic benefits for local communities and for Brazilian society.

Brazil, which holds more than 25% of the global potential for NBS, stands out as a provider of solutions in this field. But to realize this potential, it is imperative that we align science, public policies, and business action around a common green development project.

Since my time as Minister of the Environment, I have always advocated that the climate agenda is inseparable from the development agenda. It is not only about avoiding emissions, but about redefining our model of economic growth. If we want a less vulnerable and prosperous country, deforestation can no longer be part of our horizon of progress. Protecting the Amazon and other forest biomes is not an economic obstacle – on the contrary, it is a condition for Brazil's climate, energy, and food security.

The stability of the rainfall regime that irrigates our agricultural areas and ensures the country's water security depends directly on standing forests. Thus, conserving nature is simultaneously an environmental, economic, and social mission, as well as a technological challenge. We cannot fall into false narratives that oppose food production to environmental conservation: as this book explores, there is no prosperous tropical agriculture without preserved forest, and vice versa. The leaders of Brazilian agribusiness and family farming themselves increasingly recognize the sector's diversity and strategic role – many already understand that competitive production requires sustainability, social inclusion, less climate vulnerability, and more stable weather conditions.

Fortunately, over decades Brazil has built a solid institutional foundation to protect its biomes. Agencies such as Ibama, the Brazilian Forest Service, Inpe, among others, have developed exemplary monitoring and enforcement systems, such as PRODES and DETER, which are global references. This capacity to generate reliable, public, and timely data on deforestation has been the cornerstone of our policies and also a diplomatic asset for the country. The chapters of this book highlight the achievements of countless public servants, private agents, and civil society partners in building this environmental protection framework – an institutional heritage we must value and continuously strengthen.

Investing in science and monitoring technology, in territorial governance, and in law enforcement means investing in the trust necessary to attract financial resources, develop metrics and business models, and maintain Brazil's international credibility.

The great innovation of recent years – and the central theme of this book – is the convergence between environmental conservation/restoration and market mechanisms. Payments for environmental services and carbon markets are no longer distant utopias and have become growing realities. Several chapters illustrate pioneering projects in conservation (REDD+), reforestation (ARR), and low-carbon agriculture (ALM) that are paving the way for a green economy.

What once seemed experimental now gives rise to a sophisticated market, with highly skilled companies, solid governance, and on-the-ground diligence. These ventures prove that it is indeed possible to generate sustainable income in the territories, remunerating those who protect and restore nature and aligning the private sector with the public interest.

When traditional knowledge, science, markets, and the public sector meet with respect and transparency, we harvest valuable lessons on how to build sound and robust projects with local communities. Nothing could be fairer: Indigenous peoples and forest dwellers, who for millennia have developed sustainable ways of life in their territories, must be protagonists and beneficiaries of this new carbon economy. Ensuring strong social and environmental safeguards, fair benefit-sharing, and consultation from the outset are non-negotiable principles to give legitimacy to these projects – and the examples in this book reinforce this message.

Of course, carbon markets do not replace the direct reduction of emissions, but they are an indispensable instrument to channel climate finance at scale. I see the carbon market as a way of putting a price on what has always been invisible – the service of keeping the forest standing, ecosystems healthy, and restoring them. In doing so, we create concrete economic incentives for conservation, restoration, and agriculture, correcting the historical distortion that favored destruction. However, I insist: this market only has value if it has absolute integrity. A carbon credit is not a license to pollute, but an instrument to mobilize capital toward the decarbonization of our economy and the sustainability of development.

As I have publicly stressed, implementing business models for climate and environmental solutions requires clear rules, transparency, and mutual trust. We cannot accept a "make-believe" carbon market – it must be structured with legal certainty, a strategic vision of mitigation, and quality criteria for the carbon transacted. Integrity and credibility are the backbone of this entire system. I often say that a "carbon credit" is nothing more than the trust placed in a climate intervention that is sound, additional, and permanent.

For this reason, it is positive that there is rigorous scrutiny of projects and methodologies – constructive criticism, though sometimes harsh, has forced continuous improvement of practices, from monitoring technology to legal safeguards. Today, methodologies are more robust, registry platforms more transparent, and we see greater convergence with regulated mechanisms such as Article 6 of the Paris Agreement. This evolution is fundamental to ensuring the reliability of the activity and providing accountability to society about its results.

Challenges exist: proving additionality and permanence in projects is not trivial, and there are risks of greenwashing if there is negligence. But the answer is not to retreat, it is to improve. Just as doing nothing is a great risk, so too is doing it poorly – implementing climate solutions without integrity, scale, or permanence.

We must face difficulties with the same technical determination with which we confront climate goals. Here again, the importance of Brazil leading by example comes in. Our country has the chance to reposition itself as a reliable leader in multilateral climate diplomacy, showing the world how to combine ambition with concrete action. I see Brazil as strategically positioned to provide global climate security – whether through our forests, our clean energy matrix, our sustainable and resilient tropical agriculture, or the innovative solutions of the new green economies we are incubating.

But it is not enough to have resources and ideas; governance and internal convergence are necessary. This means bringing together government, the private sector, academia, NGOs, Indigenous peoples, local communities – all around a new green development pact. Only with institutional trust, political dialogue, and cross-sectoral cooperation will we be able to elevate these initiatives to the transformative level required.

This book shows that we have already laid the foundations of this transition. The chapters span from emblematic cases in Indigenous territories to state-level jurisdictional REDD+ initiatives; from the perspective of agribusiness engaged in regenerative practices to the legal intricacies of a functional carbon market. It becomes clear that a green, ecological, and just transition requires a mosaic of efforts: technical robustness, financial innovation, modern legal arrangements, information technology, and above all, long-term vision, political dialogue, and new business models.

It is inspiring to see that a dynamic market is forming, mobilizing billions of dollars for conservation and sustainable agriculture in Brazil – only between 2023 and 2024, it is estimated that we received about USD 1.67 billion in climate investments in these sectors. These resources are already driving measurable results: increased local income, green jobs, value chains of socio-biodiversity products, higher productivity with low emissions. These are seeds of an inclusive tropical bioeconomy, which combines cutting-edge technology and traditional knowledge to generate prosperity in the regions that most need it.

It is now up to us to fertilize this rich soil with consistent public policies and broad partnerships, so that these seeds grow and scale up. I have no illusions about the magnitude of the task – it is a monumental challenge. But I also have no doubts about our capacity. Brazil has already overcome the apparent dilemma between conserving and developing, by drastically reducing deforestation while expanding its agricultural production. We can do it again, now at new levels of ambition. Nature-based solutions, powered by an integrity-driven carbon market and the engagement of all stakeholders, can and must be the engine of an economic transformation that makes Brazil synonymous with sustainability and innovation.

This is the national project we envision: to strategically place Brazil in the global geoeconomy as a major producer of life, food, renewable energy, forest products, and sustainably managed minerals – and also as a provider of environmental services, traditional knowledge, and climate solutions for the world. In short, to turn our natural advantages into responsible global leadership. For this, it is necessary to understand nature as an ally and political actor. And to recognize that the climate issue is not only a problem of the future. It is already a problem of the present, with the barrier of a 1.5°C increase in global temperature having been surpassed in 2024. We must talk about tomorrow, beyond the future. Nature has already changed. It is necessary to understand this and accelerate the necessary transformations duly agreed with our society.

We cannot waste this historic opportunity. We have before us the tools, the ideas, and – as this work demonstrates – concrete examples of success in the most diverse corners of the country in nature-based solutions. May this book serve as an invitation and an initial map for us to walk together the path of a just ecological transition, in which climate, biodiversity, and development go hand in hand. I firmly believe that, with pragmatism and courage, without letting ourselves be paralyzed by alarmism, we will be able to build something lasting and transformative. After all, nothing solid is ever built on fear, but on the ability to face challenges head-on.

It is time for Brazil to step into the future, leading by example, inspiring confidence inside and outside our borders, and proving that low-carbon, inclusive, nature-based development is not only possible but the only viable path. We have choices to make to take care of Brazil and the world.

■

Carbonext Awa REDD+ Project (Pará)

1. REDD+ and the Value of the Standing Forest

Janaina Dallan, *Forestry engineer, Co-CEO and founder of Carbonext, member of the UNFCCC Registration and Issuance Team (RIT)*

Introduction

Behind deforestation in the Amazon lies a historically constructed logic, deeply rooted in Brazilian land policies. For decades, forest destruction was incentivized as a means of land possession and economic appreciation. The idea that "unused land is land with forest" prevailed in public policies and private practices since the military dictatorship, when a project of Amazon occupation was structured around road construction, agricultural colonization, and cattle expansion.

The forest, with its millions of years of ecological complexity, came to be seen as empty, unproductive, and even an obstacle to development. The result was a predatory occupation, based on land grabbing, informality, and a frontier economy that still dictates land market values today.

The informality of land occupation created a perverse cycle: deforestation became synonymous with proving possession, which allowed illegal occupations to later be regularized. The State, historically absent in land governance, legitimized occupations based on destruction.

The economic logic behind this is brutally simple: forested land is worth little. Deforested land, with cattle or soy, is worth much more. In Brazilian states like Pará, a forested property may be worth between BRL 1,500 and BRL 2,500 per hectare (USD 300 to 500), while the same land, converted into pasture, can be worth between BRL 8,000 and BRL 15,000 (USD 1,600 to 3,000). And in consolidated soy areas, this value can exceed BRL 20,000 (USD 4,000).

This distortion inhibits conservation. Even when environmental legislation is in force, it is rarely sufficient to compete with the immediate value generated by destruction. As reported by a rural producer in a municipality in the state of Pará: "My neighbor who deforested decades ago now owns land worth ten times more than mine – even though mine has forest, biodiversity, and captures carbon. The forest is still seen as a void."

REDD+[1] emerges as an attempt to reverse this logic: to assign real value to standing forest. But for it to work, not only financial incentives must change – it is also necessary to shift culture, land policies, perception of value, and recognition of the environmental services provided by the forest.

[1] Reducing Emissions from Deforestation and Forest Degradation is a mechanism for generating carbon credits based on the conservation of tropical forests. It provides financial incentives to protect standing forests and is implemented through individual or jurisdictional projects in voluntary and regulated markets.

1. The Role of REDD+ in Reversing the Amazon's Economic Logic

In light of the historically constructed land and economic logic in the Amazon, REDD+ constitutes a concrete attempt to change the incentives associated with forest destruction. The proposal is simple in its essence: if standing forest provides valuable environmental services to the planet – such as carbon capture, climate regulation, and the protection of biodiversity and water – then these services must be economically valued.

However, in practice, implementing REDD+ involves structural challenges. REDD+ will only be able to fulfill its role if it can ensure permanence – that is, if its benefits are sustainable over time, even after the sale of credits ends. This implies building solid regulatory structures, long-term financial mechanisms, and real economic alternatives in the territory.

Ongoing REDD+ projects show the potential of the approach – but also its limitations. In communities where illegal mining and deforestation are the only sources of income, projects have offered training, local job creation, strengthening of biodiversity-based value chains, and basic infrastructure. However, without scale and consistent support – including from the media and committed buyers – structural change does not hold.

It is important to highlight that carbon credits generated by voluntary REDD+ projects follow integrity rules and verification under methodologies such as Verra's Verified Carbon Standard (VCS) Program, operating in the voluntary carbon market, and should not be confused with mitigation outcomes officially reported under Article 6 of the Paris Agreement[2].

- REDD+ is one of the solutions to value standing forests. It transforms the logic that forest means backwardness, assigning real value to conservation.
- "My neighbor who deforested decades ago now owns land worth ten times more than mine – even though mine has forest, biodiversity, and captures carbon. The forest is still seen as a void." – Rural producer, municipality in the State of Pará
- REDD+ needs to go beyond credit sales. We need long-term structures, or it will only be a temporary solution.

2. Permanence and the Future of REDD+

The permanence of REDD+ outcomes – environmental, social, and economic – is one of the most critical issues for the mechanism's future. Successful projects can protect thousands of hectares and transform local realities, but if incentives cease with the end of credit sales, there is a risk of reversal: the return of deforestation and degradation.

This fragility has already been pointed out by various experts, who advocate for the creation of long-term support mechanisms to ensure the permanence of benefits. These include robust regulatory structures, legal frameworks integrated with public policies, and financial models that complement or replace credits, such as trust funds, results-based payments, or blended climate finance instruments.

In addition, it is necessary to generate viable economic alternatives for territories, focusing on forest-based value chains, low-carbon agriculture, ecotourism, bioeconomy, and environmental services. REDD+ cannot operate in a vacuum: it must be articulated with a new logic of inclusive territorial development.

[2] Article 6 of the Paris Agreement enables international cooperation in climate mitigation. It allows countries to trade emission reductions – known as ITMOs (Internationally Transferred Mitigation Outcomes) – provided they apply corresponding adjustments to their national emissions accounting. In parallel, voluntary projects like REDD+ can align with these structures through jurisdictional programs or regulatory mechanisms, but they operate in distinct, though potentially complementary, spheres.

In this context, it is important to recognize that the sustainability of REDD+ also depends on the solidity and clarity with which projects communicate their value to society and the market. It is not enough to expect buyers and institutions to pay for conservation: projects must present measurable, auditable, and transparent results, clearly demonstrating the benefits generated in terms of mitigation, social inclusion, and local development. This represents a challenge – and a responsibility – for climate entrepreneurs, who must evolve in technical capacity, governance, and impact communication.

Integration with jurisdictional programs[3] and with Article 6 of the Paris Agreement represents one of the main opportunities to consolidate this permanence. By incorporating REDD+ results into national mitigation commitments (Nationally Determined Contributions–NDCs) and structuring public benefit-sharing schemes, it is possible to bring scale, predictability, and legitimacy to the mechanism.

If REDD+ is to be more than a transitional tool, it must evolve into a state policy, linked to long-term development – not just as a market product. This is the key to its resilience and relevance in the climate future we want to build.

- REDD+ needs long-term solutions: regulation, stable financing, and resilient territorial economies.
- "Without a plan to sustain long-term results, any climate impact attributed to REDD+ will be temporary."

3. Communities and Real Economic Alternatives

For millions of people living in rural and forested areas of the Amazon, available economic choices are limited – and often restricted to activities that involve territorial degradation: illegal mining, predatory logging, land grabbing, and extensive agriculture. These practices are not the result of misinformation or ignorance, but of an economic system that fails to offer viable, fair, and sustainable alternatives.

REDD+ has shown, in different contexts, that it can be part of this transition. By generating financial flows linked to conservation and emissions reductions, REDD+ projects have funded initiatives that create local income, strengthen community governance, support productive value chains, and expand social infrastructure.

Successful projects demonstrate that when communities have access to technical training, collective organization, and markets for their products, they become strategic allies in conservation. Examples include the commercialization of Brazil nuts, vegetable oils, native honey, artisanal goods, and agroforestry systems (AFS). Additionally, part of the resources from REDD+ projects can be used for basic infrastructure: schools, community centers, clean energy, and health services.

This intersection between REDD+ and local economies is only possible when the project is built with the community – and not just for it. The genuine involvement of traditional populations from the project design stage, respect for social and environmental safeguards, and fair benefit-sharing are indispensable factors for the legitimacy and effectiveness of these initiatives.

Still, there are challenges: bureaucracy in fund disbursement, lack of continuous technical assistance, weakening of territorial public policies, and carbon

[3] Jurisdictional programs are subnational or national initiatives with their own targets, monitoring plans, and institutional frameworks recognized by the government. They can include multiple REDD+ projects and align them with public climate policies and national accounting mechanisms. Although they may incorporate project activities, jurisdictional programs are not defined by this inclusion.

market instability threaten the continuity of these gains. That is why REDD+ must be integrated into structural policies and backed by long-term political, financial, and institutional support.

- "REDD+ gave us an alternative. Before, it was either cutting wood or trying mining. Now we have a way to live from the forest." – Community leader in a project in Acre.
- REDD+ works when it is built with the community and not just for it. Local governance, inclusion, and fair benefit-sharing are essential.

4. REDD+ and Its Alignment with Article 6 of the Paris Agreement and Jurisdictional Programs

The integration of REDD+ with Article 6 of the Paris Agreement and jurisdictional programs represents one of the greatest opportunities – and also one of the greatest challenges – to scale up conservation with integrity and international recognition.

Article 6 of the Paris Agreement provides for mechanisms of international cooperation for emission mitigation. Through Article 6, countries may transfer emission reductions – so-called ITMOs (Internationally Transferred Mitigation Outcomes) – among themselves, as long as corresponding adjustments are applied in their national greenhouse gas inventories[4].

REDD+ can be connected to these structures, especially when embedded in jurisdictional programs – which are initiatives at the state or national level with defined targets, monitoring plans, and recognized institutional frameworks. Brazilian states such as Acre, Mato Grosso, Pará, and Tocantins are already advancing in the creation of jurisdictional REDD+ policies, seeking to align local actions with national climate commitments (NDCs).

This articulation requires advances in governance, transparency, and distributive justice. It is crucial to ensure that the benefits of international cooperation are also channeled to local actors who maintain the standing forest. It is also necessary to avoid double counting of emissions, harmonize methodological standards, and create interoperable registries.

Voluntary REDD+ projects and public programs are not competitors. On the contrary, they can be complementary. The most promising future lies in convergence: where private sector innovation joins the scale of public power. And where international commitments translate into real development for forest territories.

- Voluntary and jurisdictional REDD+ are not in competition: they can be complementary and interdependent to ensure scale and integrity.
- Integration with Article 6 of the Paris Agreement can bring predictability, legitimacy, and new resources to REDD+, as long as there is governance and distributive justice. It is important to highlight that the carbon credits generated by voluntary REDD+ projects follow rules of integrity and verification under recognized methodologies such as Verra (Verified Carbon Standard–VCS).

5. Investments, Impact, and Prospects for REDD+ in Brazil

Brazil holds more than 25% of the global potential for nature-based solutions[5], including REDD+, and is already beginning to attract significant investment volumes. Between 2023 and 2024, the country received approximately USD 1.67 billion directed to conservation, restoration, and agroecological transition projects with climate impact.

[4] This accounting alignment – known as "corresponding adjustments" – is necessary to avoid double counting of emission reductions transferred between countries [5] According to estimates by McKinsey & Company and the World Economic Forum.

These investments have produced measurable returns for both the climate agenda and the local economy. In various projects, income per hectare/year increased by 2 to 4 times compared to extensive cattle ranching, with notable results in agroforestry systems, the sustainable management of sociobiodiversity products, and environmental services.

When well implemented, REDD+ can generate per capita income of up to BRL 3,500 per year in Amazonian communities, as well as more than 200 direct jobs per project. These results reinforce that REDD+ is not only an environmental policy – but an integrated territorial development strategy.

However, to scale and ensure the permanence of results, the financial model must be improved. The latest studies propose combining patient capital, long-term contracts, stabilization funds, and public mechanisms for minimum pricing. The logic needs to shift from a short-term market to structured platforms for climate development.

Another critical area is public governance and articulation with jurisdictional programs. The alignment between projects and states – through nesting[6] – prevents overlap and strengthens national emission accounting. States such as Acre, Mato Grosso, and Pará are already in advanced stages of building these arrangements.

Lastly, Brazil's credibility as a global leader in REDD+ depends on building structures for traceability, benefit-sharing, and regulatory clarity. The absence of these elements may generate uncertainty for investors and slow the flow of capital toward conservation – which would be a missed opportunity in the face of the climate emergency.

- REDD+ is now a competitive asset – not only environmentally, but also economically and socially.
- The greatest risk is not doing REDD+ – it is doing it without integrity, scale, and permanence.

6. Pathways for Scaling, Legitimacy, and the Future of REDD+

For REDD+ to achieve scale and international legitimacy, it must consolidate its connection with regulated mechanisms such as Article 6 of the Paris Agreement. Article 6.2, which addresses bilateral transfers of mitigation outcomes (ITMOs), and Article 6.4, which establishes a global market under UN supervision, are strategic tools for allocating climate capital at scale. Well-designed REDD+ projects, aligned with jurisdictional programs and integrated into NDCs, may be eligible for these mechanisms – provided they meet criteria for additionality, permanence, safeguards, and transparency.

Some Brazilian states, such as Acre and Mato Grosso, are already developing policies and programs to value environmental assets. In Acre, for example, the ISA Carbon Program enables the generation and commercialization of carbon credits, paying for results in reducing deforestation and greenhouse gas emissions, with appropriate benefit-sharing with family farmers, Indigenous Peoples, and traditional communities. In Mato Grosso, following the logic of results-based payment through the REDD+ for Early Movers (REM) Program, resources are directed to sustainable value chains and productive inclusion. These examples show that it is possible to build a legal environment through public policies, establishing multisectoral governance focused on results and fair benefit-sharing.

[6] Nesting is the process of integrating carbon projects into jurisdictional programs, ensuring accounting coherence, coordination across scales, and clear benefit-sharing.

In this context, considering each state's jurisdictional approach and the Brazilian law regulating the carbon market, it is necessary to strengthen state-level mechanisms to include nesting with private projects in the voluntary market – ensuring greater integrity and positioning Brazil as a country that values its environmental assets. Furthermore, strengthening the connection with international markets requires Brazil to establish clear national regulatory frameworks, avoid overlap between programs and projects, and consistently communicate its climate accounting. The creation of an interoperable national registry, as planned by the federal government, is an essential step toward gaining global trust.

On the other hand, the territorial strengthening of REDD+ requires direct investment in communities and local productive initiatives. Projects that promote sustainable extractivism, forest-based crafts, the Brazil nut value chain, and agroforestry systems are showing positive results. In Pará state, quilombola communities that joined private REDD+ projects began generating income from the commercialization of Brazil nut and cassava-derived products – the latter being one of the region's staple crops. In Amazonas state, local associations began managing nurseries and selling credits with technical support, keeping an average of 70% of revenues within the community.

These stories reinforce that the forest will only remain standing if it makes economic sense to those who live in it. And that sense cannot depend exclusively on the volatile price of carbon. It is necessary to incorporate REDD+ into regional development strategies, supported by public and private funds, digital platforms for market access, and targeted fiscal incentives.

- In Pará state, quilombola communities increased household income through REDD+ by commercializing Brazil nut and cassava-derived products.

7. Evolution of Methodologies and Quality Standards in the Carbon Market

In recent years, the voluntary carbon market has undergone intense transformation, with a focus on improving environmental integrity, transparency, and the credibility of methodologies applied to projects. This evolution has been driven both by legitimate criticism and by a maturing sector that recognizes the need to strengthen transparency and the trust of buyers, governments, and communities.

In the field of REDD+ projects, there have been relevant methodological updates – such as the revisions led by the Verra standard (Verified Carbon Standard–VCS) – which have incorporated advances in dynamic baselines, deforestation risk modeling, and more robust remote sensing monitoring systems. In addition, new standards and initiatives have emerged seeking to increase transparency and align projects with international best practices. There are also new institutions being developed as registries, aiming to offer more agile, technological, and cost-efficient certification processes than the alternatives currently in operation – all aiming to lay the foundations for a long-term, efficient, and integrity-based market for standing forest compensation.

Among the highlights regarding credibility and integrity standards is the initiative of the Integrity Council for the Voluntary Carbon Market (ICVCM), which has published quality criteria (Core Carbon Principles) and mechanisms for evaluating methodologies and standards. The goal is to enable buyers to identify credits with a high level of integrity and positive impact. Another important initiative is the Voluntary Carbon Market Integrity Initiative (VCMI), which works to regulate the corporate use of credits within voluntary climate commitments.

The trend is for the market to move toward greater standardization, comparability, and credibility, with increasing use of automated MRV (Measurement, Reporting, and Verification) technologies, independent audits, and interoperability with public registries. These advances help position REDD+ as a robust instrument within an economic transition toward regenerative and low-carbon models.

- The evolution of methodologies and standards in the carbon market reinforces the legitimacy of REDD+ as a science- and transparency-based climate solution.

8. Financial Sustainability and Proper Valuation of Carbon Credits

One of the most critical challenges faced by REDD+ projects in the voluntary market is real financial sustainability, especially when aiming to go beyond the basics and implement high socio-environmental impact models. Projects certified under standards such as CCB (Climate, Community & Biodiversity) and that develop participatory life plans with the involved communities often invest in long-term, structural actions such as strengthening local governance, generating sustainable economic alternatives, environmental education, and healthcare.

These initiatives are essential to ensure the permanence of results and the social legitimacy of the project. However, they generate high operational costs – which can range from BRL 5 million to BRL 10 million per year, or the equivalent of USD 1-2 million annually, depending on the scale and depth of local engagement. With the revision of methodologies, the time required for project development, and the expected reduction in the volume of credits issued per hectare, many projects begin to face a mismatch between operational costs and potential revenue from credit sales, especially when these are sold at average market prices around USD 10 per ton.

In many cases, the amount received from the sale of credits does not even cover the basic costs of operation and monitoring – let alone structural social investments. This reality highlights the urgent need to revise the pricing of high-impact credits, differentiating them based on their additional, social, and territorial contribution beyond carbon mitigation. Without such recognition, the risk is that the most transformative and responsible projects may become financially unviable – undermining global climate ambition and confidence in nature-based solutions.

- Projects with participatory life plans and CCB standards generate high socio- environmental impact – but require investments of up to USD 2 million per year.
- Selling credits at USD 10 may not even cover operational costs, especially with more conservative methodologies.

Conclusion

Despite its transformative potential, it is important to recognize that REDD+ should not be treated as a magical solution or an end in itself. There are structural challenges that must be addressed for the achieved results to be lasting. The permanence of the benefits generated by REDD+ projects requires long-term planning, going beyond the simple sale of carbon credits. This includes the creation of stable regulatory or financial mechanisms, or the strengthening of sufficient local economic opportunities to address the structural causes of deforestation. Without this support, any climate impact attributed to REDD+ may be merely temporary.

REDD+ emerged as a response to a historical failure: the fact that, for a long time, forest conservation generated no real economic benefit for those who lived there. By proposing a logic of valuing ecosystem services, the mechanism sought to change the incentives of the forest economy, creating a concrete alternative to destruction.

However, as seen throughout this chapter, REDD+ is not a magic solution. It carries contradictions, faces technical limitations, and is under pressure to deliver greater integrity and transparency. At the same time, it is a living, constantly evolving tool – with the potential to be one of the foundations of the low-carbon economy in tropical territories.

Its success will depend on five core elements:
1. Anchoring in long-term public policies;
2. Strengthening local governance and transparency mechanisms;
3. Coherent integration into international climate mechanisms, such as Article 6 of the Paris Agreement;
4. Generation of real and lasting economic alternatives for forest peoples;
5. Building a financially viable business model that adequately recognizes and rewards high socio-environmental impact projects, with pricing that reflects their real costs and operational complexity.

Standing forests will only be truly valued when capital flows, market rules, and public policies recognize their irreplaceable role in balancing the global climate agenda and sustaining the diversity of life they support.

REDD+ can be one of the keys to this transformation – as long as it is approached with the seriousness, constructive criticism, and commitment that a safe climate future demands.
- REDD+ is not a panacea, but a powerful tool – if built with integrity, inclusion, and a long-term vision.
- Forests must be worth more standing than cut down – not as rhetoric, but as the foundation of a new climate economy.

Final Considerations

Brazil has a historic opportunity to lead a new forest economy, where conservation is a strategic asset, not an obstacle to development. REDD+, when understood as public policy, an economic instrument, and a proposal for social transformation, becomes a concrete bridge between climate justice, territorial sovereignty, and inclusive prosperity.

To achieve this, institutional courage, political patience, and long-term vision will be required. Courage to break with the predatory logic that still dictates the value of land. Patience to build governance mechanisms that respect the diversity of actors. And vision to recognize that a living forest is the foundation of a safe future – not only for Brazil, but for the planet.

More than a market, REDD+ represents a pact. A pact between past and future, between the global and the local, between capital and life. A pact that must be continuously strengthened, improved, and rooted in the realities of the forest.
- REDD+ is not an end in itself – it is a tool to rewrite the relationship between economy and forest.
- The future of the climate agenda depends on where Brazil chooses to plant its flag: in the living forest or in irreversible deforestation.

■

Carbonext Awa REDD+ Project (Pará)

2. Jurisdictional REDD+: Challenges and Horizons

Raul Protázio Romão, *Secretary of Environment, Climate and Sustainability of the State of Pará and State Attorney*

1. Introduction

1.1 Climate change and deforestation context

In debates on climate change, ecosystem protection, or economic agendas, two points quickly arise: the need for command and control to curb illegality, and the enabling of a low-carbon economic transition. They represent, respectively, an agenda of the past – still essential – and an agenda of the present, which points the way forward. Both depend on climate finance in a context of limited public budgets under pressure from the social demands of an unequal country. Here, we will discuss how a jurisdictional REDD+ (Reducing Emissions from Deforestation and Forest Degradation) strategy, if well structured, can finance ecosystem protection, promote climate justice, and stimulate new forms of sustainable land, forest, and agricultural use.

In Brazil, the climate change context is directly related to deforestation, which stands out as one of the main contemporary environmental challenges. Emissions from land-use change account for a significant share of global emissions, estimated at approximately 23% according to the IPCC (Intergovernmental Panel on Climate Change), with deforestation as the main driver of this contribution. This scenario is even more concerning in Brazil, where deforestation accounts for approximately 46% of national emissions, making it the largest single source of greenhouse gases (GHG) in the country.

The Brazilian case is particularly aggravated by the uneconomic and predominantly illegal character of these emissions. Much of the deforestation generates no significant or sustainable economic gains. A simple cross-check of the social and economic indicators of the municipalities leading in deforestation (and mining, for that matter) makes clear that we are repeating misguided choices.

Beyond the economic inefficiency of our emissions, there is an even more serious element: illegality. Since the enactment of the Forest Code in 2012, with the establishment of the cut-off date of July 22, 2008, as the limit for new deforestation – except for very restricted exceptions – Brazil has had a legal framework delimiting the advance of the agricultural frontier over native vegetation. Thus, in Brazil we have a phenomenon rarely seen in the world: carbon that is both illegal and economically inefficient. Even so, illegal deforestation persists, requiring intensified state action, which alone holds repressive authority.

In this context, strengthening command-and-control measures is essential to reduce illegal deforestation and, consequently, mitigate the climate, social, and economic impacts it generates.

1.2 Importance and urgency of tropical forest protection

From an economic perspective, we need to establish some connections often overlooked by various actors. Protecting tropical forests, especially the Amazon, is essential not only because of their unique biodiversity but also because they sustain Brazil's agricultural potential. The country has a highly productive and competitive agriculture, the direct result of 50 years of research led by Embrapa, robust public financing for the sector, and privileged climatic conditions that allow two harvests per year in the same agricultural area, the so-called double cropping. However, the stability of this climatic regime depends directly on the existence of the Amazon rainforest, since much of the rainfall irrigating Brazil's Midwest comes from flying rivers originating in the forest. Recent studies[1] indicate that significant suppression of the Amazon would have devastating consequences for the rainfall cycle, threatening the country's food security and economy.

Beyond the economic aspect, the Amazon harbors the planet's greatest biodiversity, with critical species for scientific research, the pharmaceutical industry, and other strategic sectors. Far from being a "demographic void," the region is the ancestral territory of Indigenous peoples and traditional communities that have developed sustainable and culturally rich ways of life for millennia[2]. Therefore, preserving what remains of this ecosystem is not only an urgent environmental and climate matter but also an economic and social imperative for those who live within this richness.

2. Need for Climate Finance

To ensure the effective protection of Brazil's forests, we highlight three fundamental strategic lines of investment. First, it is essential to strengthen state capacity for monitoring, environmental and land regularization, and enforcement – actions that are crucial to combating illegal deforestation and ensuring territorial governance. Second, clear economic incentives must be implemented for forest rightsholders – both traditional peoples and rural producers in general – who conserve their forests, considering that a significant share of Brazil's forest cover lies on private lands or lands of traditional peoples[3]. Finally, it is crucial to invest in a sustainable economic transition tied to land use – promoting a forest-based bioeconomy in forested territories and, in rural territories, an inclusive, productive, low-carbon agriculture.

Although a detailed analysis of the costs required for forest-protection strategies is beyond the scope of this chapter, it is vital to acknowledge a crucial limitation: traditional public financing – especially at the subnational level – is insufficient to fully meet the demands of monitoring, land regularization, and environmental enforcement. We emphasize this priority line because command-and-control is essentially a state function, as it depends directly on the police powers of public agencies. In light of this, it becomes evident that public budgets must be complemented by alternative and innovative sources of climate finance capable of filling

[1] Qin, Y. et al. (2025). Impact of Amazonian deforestation on precipitation reverses between seasons. Nature, 639, 102–108. Leal Filho, W. (2025). Managing ecosystem services in the Brazilian Amazon. Geoscience Letters. [2] Rainforest Foundation US. The Ancestral Forest: How Indigenous Peoples Transformed the Amazon into a Vast Garden. [S.l.], 2024. The Amazon was created by Indigenous peoples over. [3] Yes, there is already a legal obligation for this, and there is a valid debate on whether we should incentivize behavior that is already mandatory. Recent history has shown us that the exclusive reliance on command-and-control measures is not sufficient to ensure the permanence and stability of deforestation reduction.

funding gaps and strengthening the State's ability to fulfill its core mission of protecting forests.

3. REDD+: Basic Concepts and Premises

3.1 Incentive mechanism

How can we combine the need for additional resources for forest protection and economic transition with a mechanism that incentivizes deforestation reduction? One possible answer emerged in the early 2000s with the idea of "compensated reduction," which encapsulates the logic that GHG emissions from deforestation (and later, degradation) should be financially compensated by the international community – in other words, the costs of maintaining forests should be shared by all, under the principle of common but differentiated responsibilities.

A given country (and later we will see that subnational jurisdictions can also take part in the arrangement) that reduces its deforestation (more precisely, the emissions arising from deforestation) can receive financial compensation equivalent to that reduction. From this simple concept, countless variations of the mechanism can be derived. Below we explain the main ones.

With respect to commutativity[4], there are market and non-market approaches.

In the non-market approach, there is no equivalent exchange: payment is made for the reduction of emissions without any other consideration. It is a moral and political commitment undertaken primarily by developed countries that have historically built their wealth on fossil fuels. It is not exactly a donation, but rather a recognition of shared responsibility for the climate crisis. These payments, known as Results-Based Payments, include examples such as Pathway 1 of the international public-private LEAF Coalition (Lowering Emissions by Accelerating Forest Finance), the Amazon Fund, Article 5 of the Paris Agreement, and the international results-based program REM (REDD+ Early Movers).

In the market approach, there is a clear and equivalent exchange: a jurisdiction's quantified emissions reductions are turned into tradable carbon credits. These credits can be sold to countries or companies to offset their own emissions or resold to third parties. This is currently the most common modality. Two notes are in order: first, when countries use credits to count toward their NDCs (Nationally Determined Contributions), it must occur under Article 6 of the Paris Agreement, and such credits are called ITMOs (Internationally Transferred Mitigation Outcomes). Second, what defines the market nature is not only issuance or even transfer of the credit, but its use to offset own emissions or its resale. Thus, if jurisdictional REDD+ credits are purchased and retired without being used for compensation, this constitutes a non-market operation, as in LEAF Pathway 1, where credits are issued but taken out of circulation without offsetting emissions.

3.2 Procedure for credit generation

Credit generation in Jurisdictional REDD+ Systems follows a simple yet rigorous logic: it occurs upon measured proof of effective results in reducing greenhouse gas emissions from deforestation and forest degradation. States establish a historical emissions baseline and project reduction targets for future periods. Once a real reduction in emissions is verified against this baseline, carbon credits are generated and may be traded in voluntary or regulated markets. The revenue obtained

[4] Characteristic of contracts or obligations in which the performances undertaken by the parties are equivalent and proportional to each other, ensuring a balance between what is given and what is received.

must then be reinvested in public policies aimed at forest protection, sustainable economic development, and strengthening local communities.

The baseline is the central element for understanding the mechanism. It is simply the average emissions of a given country or state over a five-year interval. Once this average is set, the five years following the last baseline year are called the crediting or performance period. In that period, whenever a given year's emissions are lower than the baseline average, that jurisdiction will, in principle, be able to issue credits that can be converted into financial resources.

4. Structure and Functioning of a Jurisdictional REDD+ System

4.1 Main components of a jurisdictional REDD+ system

Jurisdictions play a central role in implementing REDD+ systems, particularly due to their direct responsibility for developing and executing public policies capable of reducing emissions from deforestation and forest degradation. These actions include both stringent command-and-control measures and initiatives that foster a low-emissions economy, ensuring that achieved reductions are sustainable over time.

However, for a jurisdiction to access REDD+-related financial resources, it is not enough merely to reduce emissions; a complementary legal-institutional framework is essential to confer legitimacy and transparency on the entire process. The fundamental elements of this framework include:

a) Jurisdictional emissions-reduction strategy

Each jurisdiction must clearly define its strategies for reducing forest-related emissions. Typically, these strategies include concrete actions to combat deforestation and burning, as well as to promote viable and sustainable economic alternatives that replace destructive practices.

b) Social and environmental safeguards

To protect society from potential risks arising from the implemented policies, jurisdictions must establish robust social and environmental safeguards. These measures must also ensure that the benefits of the strategies are maximized and fairly distributed, promoting social and environmental justice.

c) Reference emissions level (FREL)

Jurisdictions must formally define their historical emissions baseline, known as the Forest Reference Emissions Level (FREL). This technical document records the average emissions over a specific period and will serve as a key parameter for annually monitoring the jurisdiction's performance in emissions reduction.

d) Monitoring, reporting, and verification (MRV)

Beyond establishing the baseline, each jurisdiction must have a rigorous and transparent monitoring system capable of periodically tracking its emissions. These results must be reported clearly and submitted to independent verification processes, ensuring credibility and reliability of the reductions achieved.

e) Governance arrangement

The actors involved, their specific responsibilities, and the internal mechanisms for managing and controlling the implementation of REDD+ strategies must be clearly defined. Transparency and participation by civil society, academia, and traditional populations are fundamental, ensuring broad social legitimacy for the actions adopted.

f) Financial mechanism

To access REDD+ resources, jurisdictions must also clearly define how the receipt and financial management of such resources will occur – whether in market or non-market approaches. This mechanism must ensure that funds are used exclusively to finance new actions to reduce forest emissions.

g) Benefit-sharing

Finally, resources raised must be shared fairly and coherently with the jurisdiction's territorial composition. Benefit-sharing must directly favor Indigenous peoples, quilombola communities, extractivists, and smallholder family farmers – groups that play an essential role in conserving forests and whose territories often provide the physical basis for these strategies.

When properly implemented and integrated, these elements form a robust jurisdictional system capable not only of effectively reducing emissions but also of securing the financial resources needed to ensure forests' economic, social, and environmental sustainability.

4.2 Converting emissions reductions into tradable assets

Lastly, it is relevant to briefly address how emissions reductions become eligible to access REDD+-related financial resources. As noted above, it is important to distinguish market from non-market approaches, as each implies different processes. However, regardless of the chosen modality, all jurisdictions must, in addition to demonstrating an effective reduction in emissions, prove compliance – to a greater or lesser degree – with the legal, technical, and institutional requirements mentioned earlier.

A non-market mechanism frequently used by Brazil's federal government is implemented through the National Strategy for REDD+ (ENREDD+). The National REDD+ Commission (CONAREDD+) sets the requirements that must be met for reductions to be recognized by the United Nations Framework Convention on Climate Change (UNFCCC). In Brazil's case, for example, the Amazon Fund – operated by the National Bank for Economic and Social Development (BNDES) – was established as an eligible financial mechanism to receive REDD+ results-based payments.

Decree No. 11,548, of June 5, 2023:

Art. 2 (...) §1 The National Commission for REDD+ is tasked with coordinating, monitoring, overseeing, and revising the National Strategy for REDD+ (ENREDD+), and coordinating the development of requirements for accessing REDD+ results-based payments in the country, as recognized by the United Nations Framework Convention on Climate Change.

(...)

Art. 11. The National Bank for Economic and Social Development (BNDES), through the Amazon Fund, is recognized as eligible to access REDD+ results-based payments in the country, without prejudice to other institutions or financial mechanisms to be established in regulation by the National Commission for REDD+.

Also among the structuring measures enabling Brazil to access REDD+ resources, the country established its FREL (Forest Reference Emission Level)[5] as the benchmark for monitoring its emissions and, shortly thereafter, the InfoHub[6] as a transparency platform

[5] https://www.gov.br/mma/pt-br/composicao/secd/redd/central-de-conteudos/submissoes-de-redd-a-unfccc. [6] https://infohubbrasil.mma.gov.br/en/ [7] https://infohubbrasil.mma.gov.br/en/results-and-payments

for monitoring. Through Brazil's InfoHub, we can, for example, verify that by August 2025 the country had already raised USD 1.4 billion in results-based payments, having used 276 million tons of CO_2e in performance – i.e., greenhouse gases that the country prevented from being emitted[7]. This transparency shows that Brazil received an average of USD 5 per ton in results-based payments.

Another approach that has stood out in recent years among Brazilian states and several forest-rich countries is the ART-TREES standard (Architecture for REDD+ Transactions – The REDD+ Environmental Excellence Standard). ART-TREES sets specific criteria and technical procedures for jurisdictions to demonstrate that their emissions reductions are effective, additional relative to prior actions, and third-party verifiable. The standard also clearly prescribes rules on internal governance, monitoring, social and environmental safeguards, and benefit-sharing of the proceeds from such reductions. In this way, ART-TREES provides an objective and transparent technical and institutional framework that can support jurisdictions seeking to access financial resources via voluntary or regulated markets.

Today ART-TREES lists 27 national and subnational jurisdictions – that is, those that have already begun their registration process with the standard, the first step toward credit issuance[8].

We thus observe that, beyond reducing emissions, national or subnational jurisdictions have a duty to build robust legal-institutional structures that meet the exacting requirements set by the various internationally recognized standards or programs.

5. Funding Mechanisms

Perhaps the most common question when discussing market approaches (and in this section we focus only on this approach) is: who buys these credits, and why are they interested? Buyers and their motivations vary widely.

In short, buyers can be grouped as (a) countries, (b) private companies, and (c) multilateral organizations.

Countries may acquire credits to provide additional support toward meeting their NDCs or, voluntarily, to contribute to global efforts to mitigate GHG emissions. Credits eligible to contribute to the purchaser country's NDCs are called ITMOs (see Section 3.1), and such transactions occur in the regulated UNFCCC market under Article 6 of the Paris Agreement. These transactions remain modest today due to the early (and incomplete) stage of the article's regulation. When undertaken voluntarily, the country's primary interest is to help develop the market by creating demand, which in turn motivates jurisdictions to structure their jurisdictional arrangements.

Example: United Kingdom (COP26, 2021) – The UK government purchased credits to neutralize the residual emissions of the Glasgow conference. The official report records that the offsets purchased were CERs (Certified Emission Reductions) from the CDM (Clean Development Mechanism) and/or Gold Standard, used to offset the remaining 131,556 tCO_2e from the event. There was no NDC use under Article 6 and therefore no corresponding adjustments. The Netherlands (2023–2024), Germany, Norway, and Canada (2023) also undertook similar operations.

[8] https://art.apx.com/myModule/rpt/myrpt.asp?r=111 [9] The purchase of carbon credits does not replace companies' primary obligation to reduce their own emissions across the entire value chain. The use of high-integrity credits is accepted only to offset the residual share of emissions, those classified as hard-to-abate – difficult or impossible to eliminate with current technologies (such as certain industrial processes, cement use, or long-haul aviation).

Companies, in turn, may acquire jurisdictional carbon credits for two main reasons: (a) to offset part of their GHG emissions, especially from "hard-to-abate" processes[9]; or (b) to resell them at a premium – in this case, a typical commercial activity. Example: LEAF Coalition Pathway 3.

Multilateral organizations, especially development banks, can also participate in the market for reasons similar to those of countries or companies. They can act as demand creators, strengthening the market, or as private buyers to offset their own operations.

The World Bank has acted in the market both by purchasing offsets for its own neutrality and by backing carbon-market operations through guarantees that reduce transaction risk. The Bank's FCPF (Forest Carbon Partnership Facility) also made results-based payments in Costa Rica (2020) and Indonesia (2019). In Brazil, BNDES launched the "BNDES Carbon Credits" program in 2022 – its first systematic effort to acquire credits and incentivize generation by environmental projects, also as a form of market support.

We can clearly see a structuring and indispensable role on the demand side – providing scale and predictability to enable national and subnational efforts to build their jurisdictional systems.

6. Social and Environmental Guarantees and Safeguards

6.1 Cancun Convention

In the pursuit of incentives, it is natural that elements perceived as hurdles or constraints might be overlooked in an attempt to access resources. To prevent deforestation reduction from being pursued "at any cost," generating negative externalities for a given country or state, social and environmental safeguards were created – "guidelines aimed at maximizing positive impacts and reducing negative impacts related to REDD+ actions. They refer to the measures national governments must adopt to manage risks in the design and implementation of their actions."[10]

Each payment arrangement is free to present its own safeguards; however, it must observe Decision 1/CP taken under the UNFCCC at COP16 in Cancun, 2010.

The Cancun Safeguards therefore aim to ensure that REDD+ activities are implemented in an environmentally sustainable, socially just, and economically viable manner. They function as principles to guide countries and jurisdictions in protecting rights, promoting community participation, and ensuring that emissions reduction is accompanied by social and environmental benefits – preventing negative impacts and maximizing positive ones. They are:

a) Actions that complement or are consistent with national forest-program objectives and other relevant international conventions and agreements.

Activities must align with national legislation, public policies, and ratified international treaties. Example: a REDD+ program in Brazil must follow the Forest Code and the National REDD+ Strategy.

b) Transparent and effective national forest-governance structures, taking into account national sovereignty and legislation.

Requires clear and accessible governance systems, with information disclosure and managerial accountability.

[10] https://www.gov.br/mma/pt-br/composicao/secd/salvaguardas-de-redd

Example:publicly providing annual monitoring and program-funds use reports; establishing a climate ombuds office in the jurisdiction.

c) Respect for the knowledge and rights of Indigenous peoples and members of local communities, taking into account relevant international obligations, circumstances, and national laws, noting that the UN General Assembly adopted the UN Declaration on the Rights of Indigenous Peoples.

REDD+ actions must recognize and protect traditional knowledge and customary rights, ensuring full, informed participation. Example: a REDD+ program cannot prevent communities from carrying out traditional activities as a way to boost emissions-reduction performance.

d) Full and effective participation of relevant stakeholders, in particular Indigenous peoples and local communities, in the actions referred to in paragraphs 70 and 72 of this decision.

These groups must not only be informed; they must have an active voice in the design, implementation, monitoring, and evaluation of activities, ensuring that their perspectives, knowledge, and priorities are incorporated into decisions. Example: during the design of a jurisdictional REDD+ strategy, conduct co-creation workshops with Indigenous and extractivist representatives, ensuring their proposals directly influence measures and benefit-sharing design; in project execution, include local leaders in governance committees and participatory monitoring processes.

e) Actions consistent with the conservation of natural forests and biological diversity, ensuring that the activities referred to in paragraph 70 are not used for the conversion of natural forests but rather to encourage the protection and conservation of natural forests and their ecosystem services, and to enhance other social and environmental benefits.

Initiatives must avoid converting natural forests, preserving ecosystems and species. Example: protect areas of primary forest from clear-cutting and promote restoration of degraded forests.

f) Actions to address the risks of reversals in REDD+ results

Programs must adopt measures to avoid losing emissions reductions already achieved – e.g., due to subsequent deforestation, forest degradation, or events such as fires. Maintaining REDD+ results depends on preventive and corrective actions that ensure the permanence of carbon stocks over time.

g) Actions to reduce the displacement (leakage) of carbon emissions to other areas

Actions must prevent reduced deforestation in one area from causing increases elsewhere. Example: combine forest-area protection with economic incentives to prevent neighboring communities from deforesting nearby regions.

6.2 Free, Prior and Informed Consent (FPIC) under ILO Convention 169

FPIC is a fundamental process that guarantees the right of Indigenous peoples, quilombola communities, traditional communities, and family farmers to be informed and consulted before measures are adopted that directly affect their territories, livelihoods, and cultural practices.

In practice, FPIC involves more than formal meetings: it is a continuous process of dialogue, capacity-building, and access to information in accessible language so that communities fully understand the objectives, risks, and opportunities linked to REDD+.

Furthermore, FPIC must be inclusive and promote the participation of different social segments – such as women, youth, and elders. The process must be articulated with community management bodies – such as management councils and local associations – and include grievance mechanisms to record and address complaints.

In jurisdictional programs, the recently published CONAREDD+ Resolution No. 19 sets out two important guidelines related to consultations in the context of jurisdictional programs:

- Recognition of the role of representative entities of traditional peoples (Art. 2).
- Jurisdictional REDD+ programs must be carried out on the basis of a consultation plan (unlike REDD+ projects, which must follow community-specific consultation protocols) previously approved by the jurisdiction's climate-governance body (Art. 7).

Importantly, unlike REDD+ projects, jurisdictional programs are state-wide public policies; thus, consultations must be conducted in a regionalized manner, ensuring participation from representatives across all parts of the state.

In essence, FPIC is a pillar ensuring legitimacy, transparency, and social justice in implementing jurisdictional REDD+ programs – guaranteeing that the benefits of emissions reductions are shared equitably and that communities' territorial and cultural rights are respected.

7. Fair and Inclusive Benefit-Sharing

7.1 Overview

Benefit-sharing principles in REDD+ aim to ensure that financial resources obtained from emissions reductions are distributed fairly, transparently, and in ways tied to promoting new conservation actions. Benefits should prioritize actors who play a direct role in protecting forests, ensuring that most resources are invested in the communities that guarantee environmental integrity. This approach meets both an ethical requirement and a key integrity criterion under international REDD+ standards.

Models and criteria for fair distribution take into account territorial composition, effective contributions to emissions reduction, and the recognition of longstanding land rights – translating into predefined percentages for different groups.

The involvement of Indigenous Peoples, Quilombola Communities, Traditional Communities, and Family Farmers (PIQCTAF) is foundational to this model. These populations are not merely beneficiaries but active participants in decision-making through governance bodies and FPIC mechanisms. In addition to direct financial resources, the benefit-sharing model should incorporate indirect benefits such as training, strengthening sustainable value chains, improving community infrastructure, and expanding access to public policies.

7.2 Stock and flow in generating results

A recurring critique of REDD+ is that it pays for reductions in deforestation but not for standing forests, favoring jurisdictions with historically high forest loss. Indeed, the mechanism was designed to incentivize emissions reductions, not payments for existing stock. Thus, areas that have historically conserved their forests end up without access to resources precisely because they have little to "reduce."

Despite this logic in credit generation, in the benefit-sharing stage jurisdictions can balance distribution by considering not only the flow of reductions but also the carbon stock in each land-tenure category. Stock represents the carbon accumulated in forests and soils – like a snapshot of the existing natural capital – while flow represents the effective reduction in emissions relative to the baseline. In REDD+, only flow generates credits; however, after funds are raised, nothing prevents distributing resources with stock taken into account.

In Pará, for example, Indigenous Lands (TIs) hold large carbon stocks but experience little deforestation. Settlements, in contrast, have smaller stocks but concentrate higher pressure on forests. If distribution were based only on flow, settlements would receive almost all resources and TIs very little – creating a perverse incentive. Conversely, if based only on stock, most funds would go to TIs, ignoring real pressure on settlements. To correct this distortion, the state adopted a mixed model: 50% based on stock and 50% on flow, creating a fairer balance between conservation and deforestation pressure.

8. Challenges and Lessons Learned

Looking back, it is essential to recognize the barriers faced so far and understand how overcoming them can drive the spread of jurisdictional REDD+ systems in other Brazilian states. The readiness – or preparation – phase is decisive for a state to meet the requirements of standards such as JNR (Jurisdictional and Nested REDD+) or ART-TREES. This requires dedicated resources to build state capacities, including in-person consultations with traditional peoples and communities, creating robust social and environmental safeguard systems, setting up independent climate ombuds offices, and implementing MRV mechanisms – which often depend on external expertise.

Because such resources are substantial, they rarely come from the state treasury. In practice, they derive from donations or pre-investment by private partners. Pará, for example, received support from NICFI (Norway's International Climate and Forest Initiative) to enable its readiness, while Tocantins relied on a partnership with Mercuria Energy Trading S/A. The intense search for funding shows that the country still lacks a stable national mechanism to support state readiness. The Amazon Fund could assume this role – ensuring predictable resources and enabling other states to already be structuring their jurisdictional REDD+ systems and steadily reducing deforestation and fires.

Another challenge is the lack of internal consensus on the topic. Key concepts must be fully understood by all relevant institutional actors before advancing the debate. In the discussions preceding the Carbon Market Bill – ultimately enacted as Law No. 14,590/2023 – it became evident that understanding of jurisdictional systems was limited, resulting in provisions that generated uncertainty rather than clarity. Much of the resistance to the mechanism stems from mistaken premises and imprecise interpretations. Once these barriers – readiness financing and conceptual clarity – are overcome, the country will have a replicable model capable of confronting illegality and driving an inclusive, low-carbon Amazonian economy.

9. Future Outlook and Policy Recommendations

Looking at trends in jurisdictional REDD+, a promising scenario comes into view – provided the main technical, institutional, and governance barriers are overcome. The consolidation of integrity standards, social and environmental safeguards, and robust monitoring systems will expand access to finance, particularly from the private sector in hard-to-abate segments such as aviation, steel, and cement. In these sectors, high-integrity credits are no longer optional but a regulatory and reputational requirement, and they can represent a relevant and predictable source of revenue for jurisdictions – provided there is institutional stability, regulatory clarity, and transparent benefit-sharing rules.

Further ahead, credit values tend to rise if Brazil adopts a strategy of integration into the UNFCCC-regulated market, allowing verified reductions to be converted into ITMOs. At that stage, credits would circulate under Article 6 of the Paris Agreement, accessing higher-value interstate transactions and qualified global demand. This evolution, however, will require alignment between national targets (NDCs) and subnational performance, preventing double counting and ensuring accounting transparency. If well managed, this path would not only enhance the economic relevance of credits but also consolidate jurisdictional REDD+ as a strategic instrument of climate diplomacy and financing for forest conservation.

For this potential to be realized, Brazil must tackle key domestic challenges. Institutional actors urgently need to understand the mechanism and integrate it into public policy efficiently – turning control systems into guarantors of integrity rather than bureaucratic hurdles. It is also essential to define, within the National REDD+ Strategy, the role of subnational programs in financing forest protection. Internationally, the message must be reinforced that jurisdictional credits are instruments to accelerate climate neutrality – not licenses to pollute. This implies ensuring responsible use that complements absolute emissions reductions, in line with recommendations from the VCMI (Voluntary Carbon Markets Integrity Initiative) and the SBTi (Science Based Targets initiative).

In a letter to the future, we want to say there will be an Amazon without deforestation and illegal mining, with land and environmental regularization for all. The rights and territories of traditional peoples will be protected and respected. The forest economy will be strong and high-tech, while agriculture and livestock will be sustainable and land-use efficient. This is the project, and this is the need. But without stable, large-scale financing mechanisms, it will not be possible. Jurisdictional REDD+ is undoubtedly one of the options on the table – provided certain consensuses are established and some barriers overcome. One way or another, there is no time to waste. The turning point is now.

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Carbonext Awa REDD+ Project (Pará)

3. REDD+ in Collective Territories: Potentials, Challenges, and the Right to Understanding

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"For us, it's not just about the money or the contract. It's about helping to build the balance of the world. That's only possible if we can reflect on and understand what is being done in our name."

Almir Suruí

"Our mental models – our conceptual models of how objects work, how events take place, or how people behave – result from our tendency to formulate explanations for things. These models are essential for helping us understand our experiences, predict the outcome of our actions, and deal with unexpected occurrences. We base our models on whatever knowledge we have, whether real or imaginary, naïve or sophisticated."[1]

Introduction

The implementation of REDD+ projects (Reducing Emissions from Deforestation and Forest Degradation, plus conservation, sustainable management, and enhancement of carbon stocks) in collective territories has intensified as a response to climate crises and the search for sustainable solutions. However, the success of these initiatives depends on their ability to respect the ways of life, social organization, and the right to full understanding of the communities involved. We believe accessible communication is an essential part of the just governance of carbon projects. In this article,

[1] NORMAN, Donald A. O design do dia a dia. Rio de Janeiro: Rocco, 2006, p. 62.

we analyze this landscape from a perspective that unites territorial experience and technical knowledge.

Perhaps one of the most sensitive issues when discussing carbon credit projects in collective territories is respect for their rights, and yet what we most often see is the violation of those rights. Still, the solution is not to deprive these communities of exercising their autonomy and exclude them, preventing their direct participation in climate finance. Nor is it acceptable to exercise indirect guardianship under the pretext of supposed protection that ultimately blocks project development.

The idea is precisely to demonstrate the real potential of these territories, their capacity to implement actions that effectively bring improvements chosen by the will of their inhabitants, using resources arising from mechanisms that remunerate forest protection.

The traditional approach to environmental policy, centered exclusively on ecosystem conservation, has proven insufficient to effectively confront the advance of deforestation, especially in the Amazon. The persistence of this dynamic is intrinsically linked to social, economic, and structural factors.

Reversing this logic requires a new paradigm: policies to tackle deforestation must prioritize the populations that inhabit the threatened biomes, promoting productive inclusion, territorial planning, and the strengthening of local governance.

And this can only be achieved through instruments that guarantee autonomy, respect for rights, and the full understanding by the peoples of these territories of all conditions, so that their aspirations are realized in a just, transparent, and integrative way. The main path to these conditions is clear, accessible, and empathetic communication.

1. Shared Responsibility: Beyond the Boundaries of the Forest

Indigenous peoples and traditional communities are recognized as guardians of tropical forests and therefore essential allies in addressing the climate crisis. This mission, however, cannot be placed upon them as a solitary burden. The Amazon forests and the collective territories that sustain them are impacted by global dynamics: international commodity markets, demand for gold and timber, climate change aggravated by emissions from distant countries.

Protecting these territories is also a shared responsibility among governments, companies, civil society, and international organizations. Climate finance mechanisms – such as carbon credits from REDD+ – only fulfill their role if they reflect this co-responsibility, ensuring fair prices, predictability, and suitable conditions for traditional peoples to continue performing their historic role.

This responsibility also requires respect for the right to Free, Prior, and Informed Consent (FPIC), offering technical and legal support so communities can negotiate on equal footing, with full understanding of what is at stake. Recognizing the value of forests also means recognizing the rights of the peoples who have protected them for centuries.

When this global perspective is ignored, the risks of injustice increase. Poorly designed projects can reproduce inequalities, reinforce power asymmetries, and even compromise the credibility of carbon markets. Therefore, building fair solutions requires all actors to assume their share of responsibility in promoting equity and the autonomy of traditional peoples.

2. Intergenerationality, Intercultural Dialogue, and Multi-local Governance

This shared responsibility also demands a deep understanding of Indigenous peoples' relationship with their territories – one that transcends the present and extends across generations. Traditional knowledge, built over centuries, carries an essential intergenerationality – a continuous dialogue between past, present, and future that guides sustainable management practices, biodiversity protection, and social organization. REDD+ projects must respect and incorporate this temporal dimension if they are to be true instruments of enduring cultural and environmental preservation.

More than a simple exchange of knowledge, intercultural dialogue is a political practice of mutual recognition and redistribution of power. This active process builds trust, respect, and cooperation, capable of transforming historically unequal relationships into fair partnerships. It requires attentive listening, reciprocal adaptation, and the valuing of diverse knowledge systems, placing just governance as the central principle of REDD+ projects.

Moreover, project governance in collective territories operates across multiple levels – local, regional, national, and international – forming a complex multi-local network of actors, interests, and policies. While this complexity poses challenges, it also creates opportunities to align different decision-making scales and strengthen strategic alliances. When carried out with transparency and participation, this integration enhances the autonomy of traditional peoples and increases the effectiveness of conservation and development actions.

These dimensions – intergenerationality, intercultural dialogue, and multi-local governance – broaden the horizon of environmental, social, and cultural justice in REDD+ projects, ensuring the continuity of territories and the valuing of Indigenous ways of life.

3. The Paiter Suruí Territory: Experience and Current Reality

The Sete de Setembro Indigenous Land, located in the state of Rondônia on the border with Mato Grosso and belonging to the Paiter Suruí people, covers about 248,000 hectares, with 35 villages and a population between 1,700 and 2,000 people. The economic base is structured around the production of coffee, cocoa, bananas, and Brazil nuts, with growing participation by local cooperatives and the Metareilá Association, the people's main representative organization. Some villages have also developed ethnotourism as a culturally integrated income alternative.

Despite economic diversity, the territory faces significant structural challenges: lack of infrastructure to move products, insufficient farm equipment, limited technical support, and precarious public services. Basic education and healthcare are present in almost all villages, albeit with limitations. Women's participation stands out in both the economy and community politics. Youth, starting at age 15, begin contributing labor and, in many cases, seek access to higher education. About 60% of those who study outside return to work in the territory, though not all manage to complete their studies due to structural inequalities.

4. The Suruí REDD+ Project: Advances and Lessons

The carbon project developed by the Paiter Suruí people was pioneering. Certified in 2013, it was the first Indigenous REDD+ project validated internationally. The initiative positioned the Paiter Suruí as global protagonists in forest conservation, drawing international attention and establishing a new paradigm for carbon projects on Indigenous lands.

However, the project also revealed the profound challenges of Amazonian realities. The advance of illegal mining, pressure from timber exploitation, and internal conflicts over financial resource management hindered its continuity. Continuous technical support, transparent mediation, and sufficiently robust governance structures were lacking. These factors – along with physical and communication isolation – led to the suspension of activities.

Perhaps here lies the project's main problem: some leaders did not fully take ownership of the initiative due to a lack of effective understanding of their obligations, responsibilities, rights, and benefits. This understanding gap created space for external influences to exploit misinformation and spread distorted or even false narratives about the project, generating distrust and disengagement. This wave of opposition resulted in actions that further weakened the initiative, such as increased illegal deforestation in the territory. This shows that external influence gains strength when leaders and communities are not fully grounded in the project – without the understanding and sense of ownership necessary to defend it and manage it autonomously.

The lesson is clear: beyond technical design, REDD+ projects must be understood, controlled, and legitimized by the communities themselves.

Despite these challenges, we believe this type of project can bring important benefits by strengthening traditional sustainability systems and valuing ancestral knowledge, as well as financially remunerating conservation that has been practiced for centuries. It is a path to protect the territory, raise awareness of the collective role of an Indigenous land, and ensure that all members of the people benefit.

However, challenges arise when there is no clear governance, effective participation, and collectively built rules. Rights to benefits must go hand in hand with duties: to protect, manage, plan collectively, and share. The essence of a project like this is to build balance through dialogue between Indigenous and non-Indigenous knowledge systems, planning the sustainable use of the territory for the long term, sharing benefits fairly, and promoting economic, cultural, environmental, and political balance. This balance is what allows us to strengthen our economy, value the forest, and prioritize those who have historically always protected it.

5. Accessible Communication as a Pillar of Governance and Autonomy

The experience of the Suruí REDD+ Project highlights a fundamental aspect of equity in carbon project implementation: the right of Indigenous peoples to full understanding.

Without clear, transparent, and culturally appropriate communication – translating technical content into accessible language while respecting traditional knowledge – there is no effective participation, only formal consent. Climate justice therefore depends on communication justice.

Ensuring that Indigenous peoples understand project implications is ensuring autonomy to decide, manage, and plan their territories. This accessible communication is an instrument of justice aligned with the right to FPIC as provided in international conventions and recognized as a pillar for protecting Indigenous rights.

Protecting the forest begins with protecting Indigenous peoples' right to fully understand the projects that affect their lives and territories. Only then can dialogue between Indigenous and non-Indigenous knowledge promote a true balance among economy, culture, environment, and social justice.

Accessible communication is not merely an auxiliary tool – it is itself a structuring element of governance and autonomy for Indigenous peoples. REDD+ projects deal with complex topics: carbon, intangible assets, benefit-sharing, market risks, and contractual obligations. Translating this information into forms understandable to communities is both an ethical and practical requirement.

Fully understanding project terms – from the consultation phase under FPIC to implementation – enables peoples to make informed decisions consistent with their interests and ways of life. Well-designed communication strengthens internal and external trust, prevents conflicts, and promotes stronger, more participatory governance. It is also a path for Indigenous peoples to be genuine protagonists of the choices that impact their territories and future generations.

We must not forget that Brazil today has more than 300 Indigenous peoples and over 270 different Indigenous languages. In other words, when we talk about communication with Indigenous peoples, beyond the inherent complexity of any subject, there is a language barrier, since Portuguese is not the mother tongue. This adds yet another layer of difficulty and care that we must take when communicating with traditional populations. It is at this point that we employ tools that break these barriers, materialize concepts, and build a sense of belonging so that the right to understanding is effectively fulfilled.

6. Tools to Guarantee the Right to Understanding

Traditional populations and Indigenous peoples have a growing interest in current businesses and ventures, as large infrastructure works or programs such as REDD+ and carbon credit development initiatives encourage their participation. However, traditional contractual structures and language do not meet their needs. Often, the documents accompanying these initiatives are drafted in technical or legal language that is inaccessible, disregarding the knowledge, languages, and communicational practices of the communities. This generates informational and power asymmetries in the relationship between developers and communities.

As a result, they are often prevented from having full access to justice. Access to justice is not limited to the right to file a suit or go to court; it also involves the ability to understand and effectively exercise one's rights. The issue is so broad that it is part of the United Nations Sustainable Development Goals. Goal 16 is "provide access to justice for all."

Guaranteeing the right to understanding requires the use of specific, culturally appropriate methodologies. Accessible documents should be prepared based on processes of listening, translation, and continuous validation, respecting the communities' timing, languages, and symbolic codes.

Legal design techniques can help as tools for social justice, creating more accessible documents for Indigenous communities, other minority groups, and anyone unfamiliar with legal language. Legal design is interdisciplinary. It uses user-centered design principles to create more understandable, accessible legal documents. Plain language, infographics, flowcharts, visual storytelling, and audio versions in mother tongues are some indispensable resources.

Rather than focusing solely on the technical and formal aspects of the law, legal design prioritizes the user experience, employing plain language, visual elements, infographics, and multimodal resources to facilitate communication and interaction with complex legal content. In this way, legal design represents a way of thinking and creating legal solutions that place the user at the center of the process.

An example is the experience presented by Jeronimo Roveda et al.[2], which involved a complete redesign of a partnership contract for generating carbon credits based on deep dialogue with Indigenous communities in the Cerrado and the Amazon. In that case, the process resulted in accessible and empathetic documents built in partnership with the communities themselves and recognized internationally for their innovation[3]. This experience not only facilitated understanding of the contractual terms but also strengthened trust among all actors involved and reduced asymmetries.

This concern with clarity, accessibility, and user centrality reflects a broader trend in Brazil's Judiciary and Public Administration, which have adopted legal design as instruments to promote access to justice and reduce communication barriers. Various normative acts already recognize the importance of these practices, such as National Council of Justice (CNJ) Resolutions No. 347/2020 and No. 395/2021, which incorporate visual law into governance and innovation in judicial services, as well as state and federal provisions and ordinances – for example, TJES Provision No. 45/2021, TJDFT Joint Ordinance No. 91/2021, and DREI Instruction No. 55/2021. These normative instruments reinforce the notion that good communication is both a right and an institutional duty, and they point to a new paradigm in which legal language becomes more human, accessible, and inclusive.

With regard to traditional and Indigenous peoples, a recent resolution approved by members of CONAREDD+ (National REDD+ Commission) states in two articles:

Art. 13 – The benefit-sharing agreements and the economic, social, and environmental results – except for information that is justifiably confidential – of jurisdictional REDD+ programs, public projects, and private forest carbon projects must be made public in accessible language, ensuring transparency and social oversight [emphasis not in the original].

Art. 18 – Communities and their representative organizations shall have full access, in accessible language, to the project risk matrix, including risks associated with failing to achieve expected economic, social, and environmental results, as well as socio-economic feasibility studies, which shall be considered within the respective contracts so as to safeguard traditional ways and means of life and avoid imbalance in the contractual relationship [emphasis not in the original].

These communication tools must also be used throughout the entire project cycle, not only in the contractual phase. They should be incorporated into FPIC-style consultations, internal decision-making processes, resource governance, and results communication. The right to understanding is not an event, but a continuous process of building autonomy and protagonism.

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[2] NYBO, Erik Fontenele, ROVEDA, Jeronimo Pinotti, CUNHA, Mariana Moreno de Gusmão. Legal Design for Indigenous Communities: A case within the carbon credit Market. Journal of Strategic Contracting and Negociation. 1-12. 2023. Article reuse guidelines. sagepub.com/journals-permissions. DOI: 10.1177/20555636231184152. journals.sagepub.com/home/jsc [3] Design for a Better World Award 2022 - https://dfbwaward.com/premiado/legal-design-aplicado-a-contrato-com-comunidade-indigena/ – Currently used as reference in universities in Finland and Sweden.

7. Communication, Conflict Prevention, and Resource Management

The absence of clear communication generates insecurity and fuels internal disputes. Conversely, when project documents and terms are fully understood, risks decrease and community cohesion strengthens. Accessible communication thus functions as a conflict-prevention mechanism and as a foundation for long-term sustainability.

Moreover, it is essential to recognize that the success of any project also depends on the community's capacity to manage financial resources. This implies building, together with local leaders, transparent and participatory mechanisms for managing benefits, guided by the collective's aspirations. Clear communication is a pillar of this management because it enables everyone to understand where resources come from, how they are used, and what results are expected. This is also a way of honoring the collective memory of those who, for centuries, have protected the forest and biodiversity.

Furthermore, it boosts and organizes other projects already existing in the territory or that may emerge as a result of a REDD+ project. As noted, communication is not a phase; it is a continuous process stemming from proper, attentive listening that matures and strengthens over time. Communicating and being communicated with is an exchange that cannot be unbalanced. Misunderstanding is both a vector and a catalyst of vulnerabilities and misguided actions that permeate society at any scale. Major losses can arise precisely from a "mis-understanding" or "non-understanding."

8. Paths to the Future: Strengthening Through Understanding and Justice

Strengthening REDD+ projects in collective territories requires, above all, mutual trust and a commitment to justice. This is built on transparent relationships, accessible documents, and recognition of Indigenous or quilombola leadership. It is crucial to understand that forest conservation carried out by traditional peoples is not only a historical contribution but an ongoing effort that must be valued through adequate, fair, and permanent climate finance mechanisms.

REDD+ projects are, in this sense, one way to channel resources to those who effectively keep the forest standing. However, for them to fulfill this role fairly and effectively, they must be conducted based on listening, full understanding, respect, and autonomy. Good communication, from the earliest stages and during consultation, allows each territory to decide autonomously whether to participate, how, and under which conditions. By guaranteeing understanding, we open the way to self-determination with security, legitimacy, and dignity.

This is about overcoming a multidimensional problem rooted in the absence of effective mechanisms for listening, dialogue, and the circulation of accessible information. This absence prevents communities from having the conditions necessary to fully exercise their autonomy in defending their territories, dealing with the precariousness of public services, and confronting illicit networks that exploit territorial vulnerability. Reducing deforestation to an ecological issue ignores its effects on collective health, regional economic stability, and food security for traditional populations. In this context, forest protection is a direct consequence of development strategies grounded in social justice.

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4. Restoration in Brazil: Where We Came From, Where We Are Going

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Thiago Frias Picolo Peres, *CEO of re.green*

The objective of this chapter is to present a brief history of ecological restoration in Brazil within the national regulatory context and to analyze how the climate crisis has opened new opportunities for this activity, given its potential and readiness to scale up the removal of greenhouse gases.

1. Forest Restoration in Brazil

Restoration is not a new theme in Brazil. It was included in the former Forest Code (Federal Law No. 4,771/1965) as an instrument to offset legal reserve liabilities. This central role was maintained in the current Forest Code (Federal Law No. 12,651/2012), which establishes as one of its principles "the creation and mobilization of economic incentives to foster the preservation and recovery of native vegetation and to promote the development of sustainable productive activities."

The relevance of the issue was reinforced by the National Policy for the Recovery of Native Vegetation (PROVEG, Federal Decree No. 8,972/2017), which aims to coordinate and promote policies that induce the recovery of forests and other forms of native vegetation and to distinguish between ways of converting degraded land into forest cover.

According to PROVEG, not every conversion of degraded land into forest is classified as recovery or restoration of native vegetation. This is because the formation of a forest structure on land originally covered by degraded forest may use native or non-native species – what is called "reforestation."[1]

[1] Art. 3 For the purposes of this Decree, the following shall be considered:
I – natural regeneration of vegetation management – a set of planned interventions aimed at ensuring the natural regeneration of vegetation in an area undergoing recovery;
II – ecological rehabilitation – planned human intervention intended to improve the functions of a degraded ecosystem, even if it does not lead to the full restoration of the composition, structure, and functioning of the pre-existing ecosystem;
III – reforestation – the planting of forest species, native or not, in pure or mixed stands, to form a forest structure in an area originally covered by deforested or degraded forest;
IV – natural regeneration of vegetation – the process by which native species establish themselves in an altered or degraded area to be recovered or in recovery, without this process having occurred deliberately through human intervention;
V – ecological restoration – intentional human intervention in altered or degraded ecosystems to trigger, facilitate, or accelerate the natural process of ecological succession; and
VI – recovery or recomposition of native vegetation – the restitution of native vegetation cover through the implementation of agroforestry systems, reforestation, natural regeneration of vegetation, ecological rehabilitation, and ecological restoration.

In this context, ecological restoration is defined by PROVEG as one of the ways to promote the recovery or restoration of native vegetation, consisting of "intentional human intervention in altered or degraded ecosystems to trigger, facilitate, or accelerate the natural process of ecological succession."

Thus, ecological restoration is neither new in Brazil's territorial nor institutional context. The Restoration Observatory (ORR)[2] has already mapped 153,130 hectares of restoration, 8.76 million hectares of reforestation, and 18.58 million hectares of secondary vegetation.

The country also has a rich ecosystem of organizations dedicated to fostering, coordinating, and implementing ecosystem restoration projects, such as the Atlantic Forest Restoration Pact, the Amazon Restoration Alliance, the Cerrado Restoration Network, and the Caatinga Restoration Network, among others.

2. Restoration at Scale

Over the last three years, the profile of ecological restoration projects in Brazil has undergone some changes, with the emergence of for-profit initiatives anchored in the premise of scale, contrasting with previous initiatives focused on environmental compliance or philanthropy.

The emergence of companies such as re.green, Mombak, and Biomas – which together have already restored more than 14,000 hectares in the Atlantic Forest and Amazon in just over two years – illustrates this shift. This new chapter in ecological restoration results from the intersection of three fundamental elements of the climate agenda: (i) the need to remove GHGs (greenhouse gases), (ii) the urgency of scaling up this removal, and (iii) the intersection of climate, biodiversity, and people.

3. The Growing Need for GHG Removal

The Paris Agreement states that Parties shall "aim to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century."

In scenarios consistent with the goals of the Paris Agreement, the Intergovernmental Panel on Climate Change (IPCC) indicates that the world must reach net-zero CO_2 emissions by the early 2050s (to limit warming to 1.5 °C with little or no overshoot) and net-zero emissions of all greenhouse gases by around the 2070s.

To meet these targets, carbon removal actions must be substantially expanded. Recent scientific assessments, including the State of Carbon Dioxide Removal report[3], converge on the need to remove about 7-9 gigatons of CO_2 ($GtCO_2$) annually by 2050 in Paris-consistent scenarios. Today, the world removes approximately 2 $GtCO_2$ per year, mainly through conventional terrestrial sinks.

Nature-based solutions can provide more than one-third of the required GHG mitigation by 2030[4]. Forest restoration is one of the most relevant strategies within this portfolio, involving the sustainable management of around 2.5 billion hectares of forests, agricultural land, and pastures, and the restoration of more than 230 million hectares of natural vegetation[5].

[2] The Restoration and Reforestation Observatory (ORR) is a collective initiative platform hosted by the Brazil Climate, Forests and Agriculture Coalition, which aims to compile and improve the quality of restoration and reforestation data, monitoring the progress of the climate agreements signed by Brazil (https://observatoriodarestauracao.org.br/home). Its data are updated annually. [3] https://www.researchgate.net/profile/Oliver-Geden/publication/383025929_The_State_of_Carbon_Dioxide_Removal_2024_-_2nd_Edition
[4] https://www.pnas.org/doi/epdf/10.1073/pnas.1710465114

4. The Need for Ready and Scalable Solutions

Tropical forest ecological restoration has emerged as one of the main alternatives to meet the growing need for carbon removal. This is due to three factors: scalability potential, readiness for immediate deployment, and low cost.

The availability of degraded areas that can be converted into forests is one of the elements reinforcing this solution's scalability. Brazil, for example, with approximately 35 million hectares of degraded land, represents 15% of the global potential for natural carbon capture, with about 80% of this potential allocated to the restoration of degraded pastures. Restoring these areas could remove up to 1.5 $GtCO_2$ over 30 years[6].

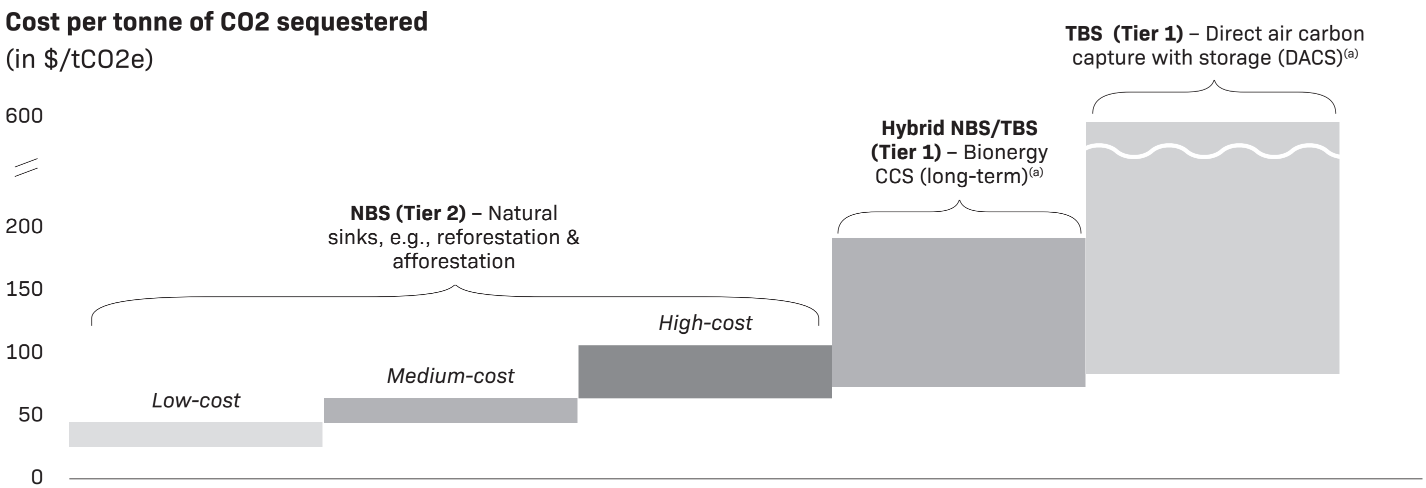
The results achieved in just over two years by the companies that pioneered the sector highlight the readiness of forest restoration. In the case of re.green, restoration has already begun on more than 12,000 hectares, with the acquisition of over 145 million seeds and the planting of nearly 6 million seedlings.

There is undoubtedly room for technological improvements and developments, but Brazil has the best conditions for these advances. National investment in Research & Development is four times greater than in other forested countries such as Indonesia (Brazil invests 1.3% of GDP versus 0.3% in Indonesia). In addition, the country hosts leading agricultural and forestry R&D institutions such as Embrapa and Esalq.

The fact that the cost of removal through nature-based solutions is substantially lower than technological alternatives further explains why tropical forest ecological restoration has gained momentum in recent years[7].

5. The Core Benefits of Ecological Restoration

The climate crisis is not limited to the greenhouse gas balance: it is also a biodiversity and social crisis. It is



Source: Goldman Sachs: Nature Magazine, IPCC; Ember Climate; Bain IP
(a) Technologies at nascent stage with large variations and uncertainty on current and future cost estimates.

[5] https://openknowledge.fao.org/server/api/core/bitstreams/ffc2794a-de82-4fe0-a851-eebdadae245e/content. [6] https://orbitas.finance/wp-content/uploads/2025/06/FINAL-Orbitas-Room-to-Grow-2025.pdf. [7] Goldman Sachs; Nature Magazine, IPCC; Ember Climate; Bain IP

essential to remember that the purpose of market mechanisms under the Paris Agreement is to promote GHG mitigation while simultaneously fostering sustainable development.

In this sense, one of the main factors driving investment in forest restoration projects is the ability to generate high-quality carbon credits alongside a wide range of co-benefits – such as biodiversity recovery, improved water security, and the socioeconomic strengthening of local communities.

Studies indicate that habitat loss and degradation are the main threats to 85% of the species on the IUCN (International Union for Conservation of Nature) Red List[8]. To reverse this trend, it is necessary to halt the conversion of natural habitats, conserve what remains, and restore degraded ecosystems. With careful spatial planning, restoring just 15% of converted areas, combined with halting new conversions, could prevent up to 60% of projected species extinctions by 2050[9]. This percentage is aligned with Aichi Target[10] 15 and reinforced by Sustainable Development Goal (SDG) 15 – Life on Land.

Ecological restoration also plays a crucial role in regulating the hydrological cycle, increasing soil water infiltration, reducing erosion, and improving aquifer recharge, as well as enhancing water availability for supply and agriculture. Forest cover also regulates the microclimate, maintaining milder temperatures and reducing evaporation, which contributes to more stable river flows – a critical factor for community water security.

Beyond environmental gains, the socioeconomic benefits are significant, both directly and indirectly. Implementing ecological restoration projects drives a wide supply chain, including seed collection, seedling and seed production, project implementation services, drone use, and project monitoring. For this reason, studies suggest that up to 42 jobs can be generated for every 100 hectares restored[11].

Globally, the cost of inaction is much higher than the cost of restoration: more than half of the world's GDP depends directly on nature[12], and the continued degradation of ecosystem services could cause losses of up to USD 10 trillion in global GDP by 2050[13]. On the other hand, every dollar invested in restoration can generate up to USD 30 in economic benefits[14].

6. Challenges to Realizing the Potential of Ecological Restoration

In today's climate crisis context, much is being discussed about the measures needed to turn the potential of millions of hectares under ecological restoration projects into reality. Challenges include expanding funding sources, strengthening guarantee mechanisms, structuring the supply chain, reviewing the tax base applicable to the restoration sector, among other structural actions.

It is important to ensure that carbon credits from forest restoration projects have access to both national and international regulated markets, considering that – as shown here – the global demand for carbon removal is growing and strategic.

[8] https://wwf.panda.org/discover/our_focus/wildlife_practice/problems/habitat_loss_degradation/?utm_source=chatgpt.com [9] Strassburg, B. B. N., Iribarrem, A., Beyer, H. L., Cordeiro, C. L., Crouzeilles, R., Jakovac, C. C., … Balmford, A. (2020). Global priority areas for ecosystem restoration. Nature, 586, 724–729. https://doi.org/10.1038/s41586-020-2784- [10] Twenty global objectives adopted in 2010, during the 10th Conference of the Parties to the United Nations Convention on Biological Diversity, held in Nagoya, in Aichi Prefecture, Japan. [11] Brancalion, P. H. S. (2022). Empregos gerados pela restauração florestal no Brasil. Revista Brasileira de Restauração Ecológica, 10(1), 45–52 [12] World Economic Forum. (2020). Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy. WEF. [13] https://www.wwf.org.uk/sites/default/files/2020-02/GlobalFutures_SummaryReport.pdf [14] https://files.wri.org/d8/s3fs-public/roots-of-prosperity_0.pdf?_gl=1*1t3k703*_gcl_au*MTUzMjA5NjYxNi4xNzU1MTE1MDI3

Brazil now has a law establishing its regulated carbon market, currently under implementation. However, further domestic measures are still needed to enable the export of ITMOs (Internationally Transferred Mitigation Outcomes) and A6.4ERs (certified emission reductions under Article 6.4 of the Paris Agreement). These assets hold high value in international markets, as they can be used by other countries to meet part of their NDCs (Nationally Determined Contributions) or fulfill mitigation commitments in specific demand-driven regimes, such as CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation).

To fully integrate into this system of international exchanges, Brazil must ensure that the emissions underlying such assets are not double-counted across multiple NDCs or by the same Party under the Paris Agreement in different commitment periods. This safeguard is ensured through the so-called corresponding adjustment, whereby both the transferring and receiving countries adjust their national emissions inventories to reflect the transaction.

This alignment is critical to expand the access of Brazilian carbon credits to international markets, thereby increasing demand for and investment in Brazilian forest restoration projects, turning potential into tangible benefits for climate, biodiversity, and the national economy.

Conclusion

Forest restoration in Brazil is at the epicenter of three urgent and interdependent agendas: combating climate change, reversing biodiversity loss, and promoting inclusive socioeconomic development. With one of the world's largest reserves of degraded land and unique natural conditions for highly efficient restoration, the country has the potential to lead a global market that will move tens of billions of dollars in the coming decades.

The structuring of this new sector faces challenges, as expected. Advances in policies to maintain forests, research and development in native forests, and financing structures suited to the type of projects are among them.

Nevertheless, the opportunities are immense. Forest restoration projects have unquestionable climate additionality, readiness for scale, and generate social, environmental, and water benefits with strong international demand. For this reason, it is essential that the Brazilian government adopt the necessary measures to ensure this becomes, indeed, a global market.

Investing in forest restoration is not only about repairing environmental damage: it is about creating jobs, ensuring water security, strengthening community resilience, and preserving species. Each restored hectare is a bridge between past and future, where reconnection with nature translates into prosperity, climate stability, and hope for future generations.

The time to act is not tomorrow. It is now. And Brazil cannot miss this historic opportunity to transform restored forests into a living legacy.

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Carbonext Awa REDD+ Project (Pará)

5. Farmland Management

Alexandre Leite, *CEO of NaturAll Carbon*

Brazilian Agribusiness and the Climate Challenge: Leadership in the Transition to a Low-Carbon Sector

Brazil is among the world's largest producers of food, fiber, and bioenergy. With a highly developed agricultural base, adapted to diverse biomes and supported by vast arable land, the country plays a strategic role in global food security. Alongside this productive leadership, Brazil has also made significant progress in reducing greenhouse gas (GHG) emissions, particularly in the agricultural sector.

In 2023, Brazil emitted approximately 2.29 billion tons of CO_2 equivalent (tCO_2e), according to SEEG (System of Greenhouse Gas Emissions and Removals Estimates). Of this total, roughly 27.5% – about 630 million tCO_2e – came from agriculture and livestock. While substantial, this figure also represents an opportunity: few countries in the world have as much potential for climate mitigation through agriculture and livestock as Brazil. With technologies already available and public policies under consolidation, it is possible to align production with sustainability.

Within the sector, livestock is the main source of emissions, accounting for about 90% of the total. In 2019, cattle raising – an area where Brazil leads the world in exports – alone generated about 540 million tCO_2e. The primary source is enteric fermentation in ruminants, a natural process that produces methane (CH_4). This methane can be reduced with innovations such as feed additives, genetic improvement, nutritional supplementation, and rotational pasture management. Manure management is another source of emissions, though smaller, and in many cases manure can be converted into renewable energy through bio-digesters.

Crop farming (grains, fibers, vegetables, and sugarcane) accounts for about 15% of sector emissions – around 90 million tCO_2e annually. The main source is the use of nitrogen fertilizers, which release nitrous oxide (N_2O) into the soil. However, Brazil has become a global reference in adopting more efficient practices, such as biological nitrogen fixation – especially in soybeans – which reduces or even eliminates the need for synthetic fertilizers. Other expanding practices include no-till farming, crop rotation, and permanent cover crops, which not only reduce emissions but also improve productivity and climate resilience.

One of Brazil's most important advances is the adoption of integrated production systems, such as Crop-Livestock Integration (CLI) and Crop-Livestock-Forestry Integration (CLFI). These systems transform degraded land into diversified, intensive, and sustainable production. CLFI has proven to be one of the most effective solutions for increasing carbon sequestration in both soils and vegetation, while maintaining or expanding food production.

Another critical point is that Brazilian agriculture is closely linked to land use. Land-use change emissions – particularly from deforestation – account for about 40% of national emissions. This trend, however, has begun to change: deforestation rates in the Amazon fell significantly in 2023, directly reducing sector emissions. Public policies such as the ABC+ Plan (Low-Carbon Agriculture) and the enforcement of the Forest Code have been decisive instruments in this process.

Brazil's trajectory is already internationally recognized. According to FAO (United Nations Food and Agriculture Organization) and the IPCC (Intergovernmental Panel on Climate Change), Brazil is the developing country with the greatest potential to reduce emissions through agriculture without jeopardizing food security. Regenerative practices such as agroforestry, rotational grazing, silvopastoral systems, and organic farming already cover millions of hectares across the country.

In addition, bioenergy – particularly sugarcane and corn ethanol, and soybean biodiesel – contributes to the country's energy transition and positions Brazilian agriculture as a key ally in transport decarbonization.

In summary, although agriculture and livestock represent a major share of Brazil's GHG emissions, they also offer one of the greatest pathways to mitigation. With a robust productive base, available technologies, and favorable soils and climate, Brazil is uniquely positioned to lead globally in the transition to climate-smart agriculture. The challenge is not only to reduce emissions but to achieve this while strengthening competitiveness, income generation, and sustainability in rural areas.

With integrated policies, effective incentives, and continuous innovation, Brazil can transform its agriculture into a true example of how to produce more and better while emitting less.

Degraded Soils and Pastures: An Opportunity for Regeneration through Agriculture

Soil is one of the most valuable resources for any nation striving to produce food sustainably. In Brazil, despite having one of the largest agricultural areas in the world, a major challenge persists: soil and pasture degradation. Yet within this challenge lies one of the greatest opportunities to advance regenerative, productive, and climate-smart agriculture.

It is estimated that more than 100 million hectares of pastures in Brazil are degraded to varying degrees. Of these, about 28 million hectares are highly suitable for conversion into productive farmland. In parallel, many cultivated areas also suffer from loss of fertility, erosion, compaction, and declining organic matter. The encouraging fact is that much of this damage is reversible – and the solutions already exist.

Part of this vulnerability stems from Brazil's tropical climate. While highly fertile in terms of biodiversity, it imposes unique challenges on soil: heavy rainfall that promotes erosion, high temperatures that accelerate organic matter decomposition, and naturally acidic, nutrient-poor soils. Without proper management, these conditions accelerate degradation, especially when soil is left bare or subjected to intensive cultivation.

Tropical agriculture, therefore, requires management models adapted to these conditions. Brazil has become a global reference in developing such tropical solutions. Practices including no-till farming, crop rotation, cover crops, crop-livestock integration, CLFI, and agroforestry systems have proven highly effective in protecting and regenerating soils. These approaches not only preserve but also restore soil fertility and structure, while increasing water retention and carbon sequestration capacity.

Brazil has already reaped important benefits from this transition. No-till farming covers more than 30 million hectares, reducing erosion and increasing productivity. CLI and CLFI, adopted on more than 17 million hectares, allow for intensified production with substantial environmental gains. Agroforestry practices are expanding in the Amazon and Cerrado, recovering degraded land with native species and commercial crops.

The federal government has also set more ambitious targets. The ABC+ Plan and the National Program for the Conversion of Degraded Pastures aim to recover up to 40 million hectares by 2033. In addition, private sector engagement through input companies, trading houses, and "green financing" initiatives are mobilizing resources and technical support for thousands of producers.

By recovering degraded lands, Brazil avoids the expansion of the agricultural frontier over native biomes, while improving efficiency, reducing emissions, and strengthening food security. Each regenerated hectare represents progress toward modern, resilient, and sustainable agriculture.

More than restoring soils, this is about rebuilding the foundation that sustains production. Regenerative agriculture is both a response to climate challenges and a new frontier of opportunity for the Brazilian countryside.

Productivity in Regenerative Systems: Producing More While Restoring

The adoption of regenerative practices in Brazilian agriculture has proven not only environmentally strategic but also a real driver of productivity gains. By regenerating soils and rebalancing production ecosystems, farmers are seeing consistent increases in yield per hectare, reductions in operating costs, and greater climate resilience.

Contrary to the belief that sustainability implies lower productivity, regenerative agriculture demonstrates the opposite: it allows producing more with fewer inputs and greater long-term stability. This is possible because regenerative practices restore the ecological processes that sustain fertility and life in the soil – organic matter, microbiology, water cycles, and permanent cover.

Research by Embrapa shows that recovering degraded pastures, when well-managed, can significantly increase forage production and animal carrying capacity per hectare, generating substantial economic gains in integrated systems. Similarly, CLFI can triple productive efficiency in underutilized areas. No-till farming, adopted on more than 30 million hectares, has drastically reduced erosion and increased grain productivity by up to 30% in some regions.

Regenerated soils also retain more water, better withstand drought, and offer greater protection against climate fluctuations, ensuring stability in adverse years. By promoting organic matter accumulation and nutrient cycling, regenerative agriculture reduces dependence on external inputs, lowering costs and increasing autonomy. The use of cover crops, green manure, and composting strengthens soils naturally, reducing the need for synthetic fertilizers and pesticides.

Another relevant dimension is access to differentiated markets. Products from regenerative systems – such as low-carbon beef, agroecological grains, or agroforestry-based foods – are increasingly valued by consumers and international buyers, translating into better prices and new business opportunities.

Regenerating soils and conserving natural resources is not only an ethical or environmental imperative but above all a smart production strategy. Each regenerated hectare is an asset: more valuable, more productive, less costly, and capable of producing superior-quality food.

With its biodiversity, climate, and tradition of agricultural innovation, Brazil is uniquely positioned to lead this new chapter in global agriculture – one that restores, multiplies, and looks to the future. Sustainable productivity is already a reality, rooted in regeneration.

Carbon Credits through Regenerative Agriculture: Brazilian Pioneering and Innovation

Brazil has taken a historic step by issuing the world's first tropical carbon credits under the VM0042 – Agricultural Land Management (ALM) methodology. The initiative, led by climate-tech company NaturAll Carbon, marked the Americas' debut in this type of certification, consolidating Brazil's role as a global reference in regenerative agriculture and nature-based solutions.

The pilot project was implemented on a farm in Mato Grosso do Sul, adopting practices such as recovery of degraded pastures, CLI, permanent soil cover, and biological fertility management. The successful issuance of credits was the result of a robust technical and scientific effort to prove both additionality and environmental integrity of soil carbon gains.

A major challenge was adapting the biogeochemical carbon quantification model to tropical conditions. Originally designed for temperate systems, the model required the creation of a monitoring, reporting, and verification (MRV) system suited to Brazilian soils and biomes, such as the Cerrado and the Amazon-Cerrado transition. Field data collection, parameter adjustments, and protocol development were necessary to accurately measure soil carbon gains in tropical environments, where nutrient cycling, organic matter, and nitrogen dynamics differ significantly.

At the heart of the modeling is the DayCent® model, one of the most respected computational tools for estimating soil carbon and nitrogen fluxes. Applying it to Brazil required detailed tropical calibration, integration of regenerative farming practices, and adaptation to local conditions of temperature, rainfall, and biogeochemical cycles. Even so, results proved promising: properties with regenerative management showed consistent soil carbon gains, providing a solid scientific basis for ALM credit certification.

Brazil's pioneering effort also relied on technologies such as precision agriculture, remote sensing, and digital MRV platforms, which enabled scaling and reduced uncertainties.

With the success of this first issuance, Brazil consolidates its leadership in the transition to certified regenerative agriculture, with potential to scale up to hundreds of thousands of hectares. Agricultural carbon credits are more than a market innovation – they are a concrete reward for those who regenerate soils, protect the climate, and cultivate a more balanced future.

The Potential of the ALM Market in Brazil

Given the more than 100 million hectares of degraded land and pastures across Brazil, the climate mitigation potential of regenerative agriculture is extraordinary.

Studies by Embrapa and international organizations indicate that regenerative practices can sequester between 0.5 and 1.5 tons of carbon per hectare per year (tC/ha/year), depending on biome, land-use history, and management. Even at a conservative rate of 1 tC/ha/year (equivalent to 3.67 tCO_2e/ha/year), regenerating 100 million hectares could remove more than 367 million tons of CO_2 equivalent from the atmosphere annually.

The potential impact on Brazilian agriculture is transformative. Livestock, responsible for around 540 million tCO_2e annually, could offset nearly half its emissions by regenerating 70 million hectares of degraded pastures – removing about 257 million tCO_2e per year. Agriculture, with about 90 million tCO_2e in annual emissions, could be more than neutralized by regenerating 30 million hectares, generating approximately 110 million tCO_2e in annual removals. This would position Brazilian agriculture as a net carbon remover, achieving "net-zero agriculture" in practice and gaining a strategic competitive edge in international markets.

In total, this represents a potential sequestration of 367 million tons per year – more than 60% of Brazil's total agricultural emissions. This combined effort could not only neutralize much of the sector's historical emissions but also establish Brazil as a global leader in soil-based carbon removals, with the capacity to issue large-scale certified ALM carbon credits.

Beyond removing carbon, regenerating these areas would also boost productivity, restore ecosystems, and promote socioeconomic inclusion in rural communities.

If properly structured, Brazil's regenerative carbon market could become both a robust source of revenue for farmers and a climate solution of global significance.

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Carbonext Ybyrá REDD+ Project (Pará)

6. Brazilian Agribusiness and COP30: Key Issues

Luiz Carlos Correa Carvalho, *President of the Brazilian Agribusiness Association (ABAG)*

"We're the first generation to feel the impact of climate change and the last generation that can do something about it."

Barack Obama, 2015

Summary

The tropical green revolution began in Brazil in the 1970s. It has been 50 years of investments in research and development to face the enormous challenge of transforming a country that used to import food and energy into one of the largest exporters of these products.

As a driver of extraordinary development in the 20th century, the developed world must integrate with what is new in the tropical world and in relevant Asian countries in the 21st century – which is likely to be labeled the century of the bioeconomy.

There are, of course, important differences to observe: countries such as those in the Association of Southeast Asian Nations (ASEAN) and Germany exhibit a high intensity of trade in goods due to their integration into cross-border manufacturing value chains. In contrast, the U.S. and Brazil, for example, show lower trade intensity than many other large economies, partly due to their large domestic markets and natural resource endowments. While Brazil's trade travels over longer geographical distances due to its significant trade with China, Germany and the United Kingdom tend to trade over shorter distances compared to other large trading economies, reflecting the relatively compact nature of European economies.

This, as a small example, illustrates the scope of the significant differences between countries, which become even deeper when considering climate diversity – regardless of a country's level of development.

For years, global policies have been under discussion in the field of greenhouse gas emissions mitigation, the foundation of what are known as climate changes, which are already showing their impacts through repeated extreme climate events in all regions of the planet.

In the midst of the fight against global warming, the marathon of global competition for food and energy security – driven by the logic of ensuring reliable supply – produces, at times, disconcerting impacts, such as the difficulty in obtaining fertilizers (for example, due to the Russia–Ukraine war) or the blackout in the

Iberian Peninsula. Similarly, products essential to new technologies (such as critical minerals, with the three largest producers accounting for 90% of the market) are not only necessary for energy, but also for sectors like aerospace, defense, and semiconductors – all evolving alongside artificial intelligence and a surging global demand for energy. This is a context in which strategic partnerships can help shift the balance in the markets.

Between the temperate world – in the Northern Hemisphere – and the tropical world – across a wide swath of the Southern Hemisphere – lies a chasm of profound differences.

For 50 years now, Brazil has been developing technologies with extraordinary and revealing outcomes regarding the advantages of the tropical world in terms of agribusiness competitiveness, including relevant sustainability and much lower carbon footprints.

Introduction

There is a long trajectory behind Brazilian agribusiness that explains how Brazil evolved from a fragile importer of food – until the 1970s – to one of the most important exporters of agricultural commodities today. It is cited in UN/FAO reports as the country most capable of expanding food supply in the 21st century.

It is interesting to note that in 1972 – at that very time – the report The Limits to Growth, published by the Club of Rome[1] under the leadership of a team from the Massachusetts Institute of Technology (MIT), was a historic milestone in global environmental debate. It presented computational models and environmental concepts that would decisively influence sustainable development policies that surged globally in the early 21st century.

Brazil responded to the first oil shock with policies aimed at reducing its foreign dependency and, at the same time, took long strides toward an environmental focus – initially by reducing local pollution and later by aligning with the global warming agenda.

The most striking milestone in this global evolution toward reducing greenhouse gas emissions was the Paris Agreement, reached at the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change on December 12, 2015, and ratified by virtually every country in the world. Expanding on the Kyoto Protocol (1997), the Agreement set the goal of limiting the rise in average global temperature to 1.5°C above 2005 levels, and defined voluntary emission reduction targets (NDCs) to be reviewed every five years. It is a binding agreement, requiring countries to report on their progress and revise their targets.

Brazil ratified the agreement in September 2016 and, in its revision, announced a 43% reduction in emissions by 2030.

Globally, according to the Intergovernmental Panel on Climate Change (IPCC), agriculture, deforestation, and land use account for 19% of global carbon-equivalent emissions – the second largest source after energy. In Brazil, according to the Greenhouse Gas Emissions Estimation System (SEEG) from the Climate Observatory, agriculture is responsible for 25%, land use (including deforestation and land-use change) for 45%, and energy (generation and use) for 18%. In Brazil's case, agribusiness is present in all three of these emission sources, which gives it a significant role in discussions on targets, climate, and essential public policies – a topic of great relevance for COP30, in Belém, Brazil.

[1] International organization founded in 1968 by scientists, economists, industries, and former political leaders concerned about the future of the planet. Today, it remains focused on issues such as the energy transition, regenerative economy, and others.

COP30

The defining features of COP30 include a focus on financing mechanisms for sustainable innovation, the acceleration of the viability of the global carbon market, and the valorization of essential environmental assets, such as forests, the recovery of degraded lands, the energy transition, along with other key topics like biofuels.

Agribusiness, which plays a relevant role in the discussion of carbon emissions, must have its relationship with the carbon market analyzed, aiming at the development of metrics and effective integration into the trade of CO_2 credits, positioning it as an important agent of transformation within the expected agenda of adaptation and mitigation of climate change.

Accounting for 25% of Brazil's GDP, Brazilian agribusiness is, at the same time, vulnerable to climate change and a strategic sector both for food security and the energy transition. Therefore, its transition to sustainable practices is essential, combining productivity, resilience, and climate neutrality. To achieve this, beyond operational practices and carbon emission mitigation, global and national public policies are fundamental to scale up investments and integrate agribusiness into carbon and ecosystem services markets.

Focused on this theme, it is essential to establish the view of Brazilian agribusiness as part of the solution, leading this low-carbon agriculture and livestock, and ensuring a sustainable future for the sectoral production chains.

A modern regulatory framework, investments in research and development (R&D), and the transformation of discussions into actions will be necessary.

Agriculture, Livestock, and Integration

Developed by Embrapa (Brazilian Agricultural Research Corporation), the Integrated Crop-Livestock-Forestry system (ILPF, in Portuguese) gave sectoral competitiveness to the vast block of land in the Cerrado, a very significant biome for Brazil.

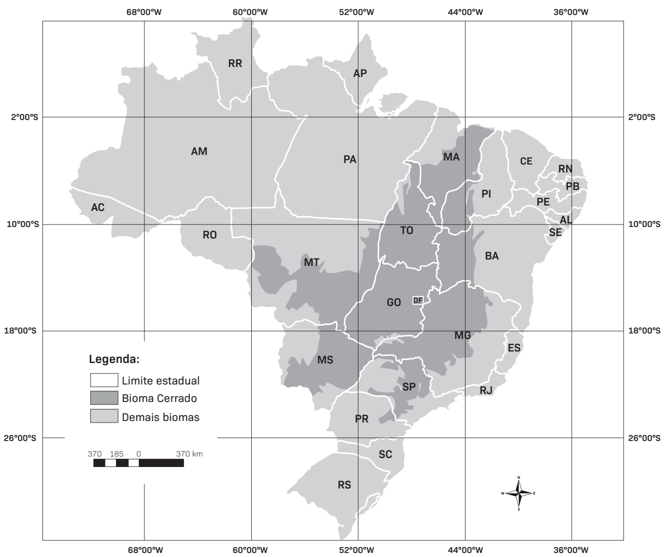


Figure: Map showing the location of the Cerrado and other biomes in Brazil. Source: Ministry of the Environment and Brazilian Institute of Geography and Statistics – IBGE, 2005.

The soils in this biome are sensitive, poor in chemical nutrients, and depend on what is called biodynamics in these lands – that is, intense microbial life that must necessarily be present in them.

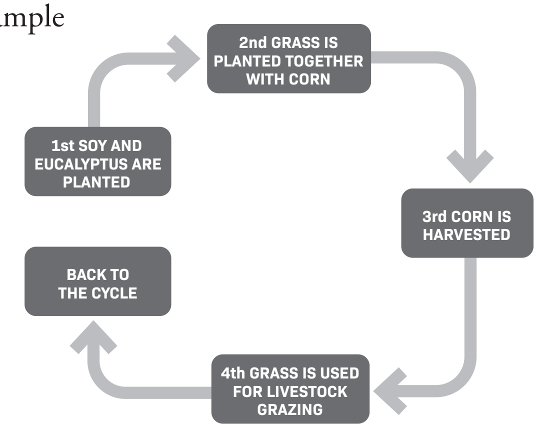
For a long time, using temperate-world technology, these soils produced little and became degraded. Today, the vast majority of this problem is found in extensive pastures.

This reality clashes with a current narrative, intensely debated among Europeans, with their Green Deal program, and Latin Americans, especially Brazilians, who defend the essential and necessary use of intensive agriculture, in contrast with the old European environmentalist concept favoring extensive agriculture.

This is a relevant topic with extremely different comparative metrics. A clear example is that Brazil, in the Cerrado and other biomes, produces 2 to 3 crops per year on the same land. Obviously, this entails a greater use of crop protection products in terms of volume, but lower rates per unit of product generated. This leads to Brazil having a statistical production area of 70 million hectares, while in reality using only 56 million hectares – a concept nicknamed “land-saving”.

Thus, the integration of crops, livestock, and forestry aims precisely at creating soils that gain more life through their intensive use, involving different types of crops, pastures, and forests, which in this case generate not only wood, but also shade, and consequently, animal welfare.

Example



Agriculture, Bioenergy, and Integration

History shows us that during World War II, Brazil faced serious difficulties in importing fuels. Dependent on this product, which it was unable to import, and with experience in the production of ethanol from sugarcane, Brazil had already reached 40% ethanol in gasoline by the 1940s. With the first oil shock in the early 1970s, Brazil launched PROALCOOL alongside a process of investments that began in 1972 in the then sugar-alcohol sector, through the Institute of Sugar and Alcohol (a federal agency extinguished in 1992), aiming to replace gasoline.

The impact of gasoline substitution in Brazil was, and still is, impressive . No other country in the world has achieved these results. The so-called Otto Cycle (gasoline, natural gas, and ethanol) in Brazil includes about 50% of total ethanol (anhydrous ethanol in gasoline and hydrated ethanol as fuel).

When considering all renewable sources – that is, biomass (biofuels), hydropower, firewood, and charcoal, as well as others (such as black liquor) – renewable energy in Brazil reaches nearly 50% of total energy used in the country (49.1% in 2023). Meanwhile, Brazil’s electricity matrix is composed of 88.2% renewable sources.

Along with ethanol came biodiesel and, subsequently, electricity cogeneration through sugarcane bagasse, biogas, and now, biomethane.

Here we record another completely distinctive impact from Brazil, which is the industrial integration for ethanol, produced from sugarcane (75%) and corn (25%). These are flexible plants that allow corn ethanol to use sugarcane fiber as energy in the industrial process, greatly reducing the carbon emissions of corn-based ethanol produced in Brazil, while also adding value.

Strategic Biomass

Among all that is said and done globally, the results of ongoing innovations have a strong impact on the development and sovereignty of countries. In the case of the energy transition, Brazil clearly has competitive advantages derived from biomass, which have emerged since the 1970s – with ethanol and all that followed, such as biodiesel, bioelectricity, biogas, among others – in the wake of urgency created by the oil shocks, driven by creative talent and economies of scale, both rare in the global bioenergy sector.

Brazil's value chains connected to the energy transition – whether directly or indirectly – must be encouraged to diversify and grow. This effort should aim to ensure a stable and secure supply of renewable energy, while promoting competitiveness and sustainability. Achieving this will require balanced and consistent public policies that stimulate investment and attract international capital. In fact, regarding this point, international partnerships will be essential both for opening secure markets and for technological development.

Biomass, here termed strategic, is situated in the 21st century within the logic of bioeconomy priority, aiming for sustainability and industrial value aggregation through its full and integrated use. There is no doubt that it represents an essential path given its competitive capacity and already scaled-up production, generating true biorefineries with effective biocompetitiveness in Brazil.

Among the many aspects to mention, biomass and its products and by-products have shown great versatility for various needs:

- Food and bioenergy, integrated, will provide health, well-being, and sustainability to the planet and its inhabitants;
- In the transportation sector (road, air, and sea) with low emissions, various agricultural crops and livestock by-products (such as tallow) will, through different technologies, be in healthy competition, decisively contributing to the logic of the circular economy;
- Investments in R&D, logistics, and infrastructure will be essential to these goals for a continental country with enormous opportunities like Brazil.

Main recommendations for positive sectoral actions would certainly include:

- The stimulated integration between competitive agricultural crops and biorefineries, at large scale;
- Creation of mechanisms and incentives for innovation and gains in competitiveness, both for producers and for companies of vehicles, machinery, and equipment, and for the large-scale use of bioelectricity;
- Open markets, which are fundamental to encourage a greater supply of food and bioenergy, with global mechanisms in the carbon market and well-characterized metrics suited to the different climatic conditions on the planet.

Carbon Market

The creation of a Brazilian carbon market will be an important factor for essential investments in the fight against global warming, which, in addition to mitigating greenhouse gas emissions, will also generate jobs and opportunities.

A regulated market for primary agricultural production is extremely complex due to the subjectivity in setting parameters for carbon credits. It is understood, therefore, that the regulated market should be characterized by the cap and trade model (in which companies that emit less than their limit sell that credit), within a robust certification process to avoid double counting, with a cutoff line in time for what is called carbon additionality, whether for this market or the voluntary one.

A regulated market includes allowances (or quotas) as well as offsets – that is, verified emission reductions. The connection with the voluntary market occurs through the definition of permissible compensation percentages and the specification of the types of offsets that will be accepted in the system.

It is necessary to accelerate the development of projects aimed at reducing greenhouse gas emissions. This market will be fundamental.

Final Considerations

COP30 is an opportunity for Brazilian agribusiness to change the external narratives about it – whether well-intentioned or not – while at the same time making explicit its relevance as a solution to climate change, given its competitive mode of production and use, in terms of productivity, sustainability, socioeconomic impacts, and its relevance as a market-based approach rather than one based on government intervention.

In a moment of great uncertainty, helping to ensure the supply of food and renewable energy, through agro-industrial integration and across different productive chains, is highly relevant and a hallmark of Brazilian agribusiness.

It is essential to join efforts between countries, as already done in the private sectors of Mercosur, in pursuit of agreements and alliances, as part of a sensible public policy in favor of a more balanced future. COP30 has a relevant role in elevating this process.

Innovation, professional training, and investments will certainly help accelerate humanity's interest and actions in fighting global warming.

The creation of a global and Brazilian carbon market will be a fundamental factor for the necessary investments aimed at mitigating greenhouse gases.

Biomass will be an essential component of the global renewable energy movement, whether for reducing emissions, ensuring energy security, or ensuring food security. This makes it an essential product. Innovations in air and maritime transport, with renewable fuels, will be essential to sustainable mobility, as long as biofuels are supplied on a large scale and at low cost.

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Carbonext Tatuy REDD+ Project (Mato Grosso)

7. Nature-Based Carbon Markets: From Structural Challenges to the Data-Driven Future

Luciano Corrêa da Fonseca, *Co-CEO of Carbonext*

1. Scaling and Integrity of the Voluntary Carbon Market

The scaling of the voluntary carbon market (VCM) through nature-based solutions (NBS) has emerged as a central challenge in the architecture of global climate finance. While the Paris Agreement (2015) and subsequent developments have emphasized the role of forests and land use in achieving climate stabilization, the operationalization of large-scale, high-integrity NBS projects remains uncertain. Demand for carbon credits is projected to multiply by a factor of 15 by 2030[1], yet supply from forest conservation, reforestation, and regenerative agriculture has been slow to match expectations.

The lack of scalability is often attributed to concerns about integrity. This includes criticisms of project methodologies, weaknesses in registries' governance, and persistent opacity in financial and social benefit-sharing arrangements.

However, attributing the lack of scale solely to methodological disputes underestimates the structural and operational bottlenecks facing the sector. Challenges include inefficient project operations lacking standardization and making little to no use of modern technology, limited access to structured project finance, inefficient allocation of risks, insufficient technology integration in monitoring systems, and a fragmented ecosystem of service providers. Addressing these issues is equally essential if the VCM is to move beyond pilot projects and reach the scale necessary to contribute meaningfully to net-zero pathways.

2. Core Structural Dimensions of the Market

Beyond integrity debates, much of the voluntary carbon market's challenge seems to lie in its structural foundations. If NBS projects are to move from scattered pilots into investable, large-scale assets, several dimensions likely need to evolve together. These can be thought of as essential areas of progress of a more mature market:

[1] McKinsey (2021). A blueprint for scaling voluntary carbon markets to meet net zero.

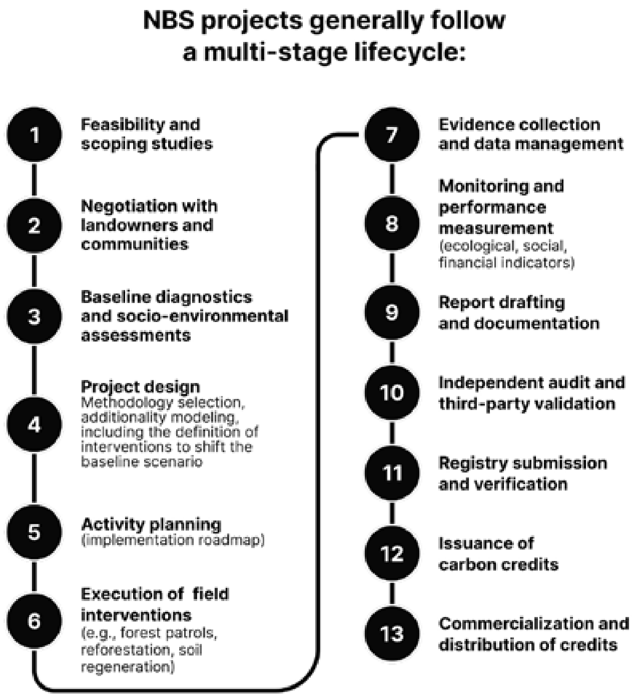
1. **Operational processes** – standardizing how projects are designed, executed, monitored, and audited.
2. **Technology integration** – embedding geospatial analytics, Artificial Intelligence (AI), blockchain, and IoT (Internet of Things) to improve operational processes, transparency and overall efficiency.
3. **Capital structure of projects** – who finances development, under what risk-return profile, and through which instruments.
4. **Risk allocation** – how permanence, leakage, and delivery risks are distributed among landowners, developers, financiers, and offtakers.
5. **Use of proceeds** – ensuring that revenue streams are fairly distributed across all stakeholders including landowners, investors, service providers, local communities, and long-term forest governance.
6. **Pricing mechanisms** – designing models that are both economically grounded (e.g., opportunity cost of land) and aligned with demand-side expectations for integrity.

How these dimensions are addressed will influence costs, development timelines, and credit quality. More importantly, they may decide whether the VCM stays niche or begins to scale into a market with real weight in global climate finance.

3. Operational Processes and Embedded Technology

3.1 Project Lifecycle and Key Actors

Nature-based projects may look different in practice, but most follow a similar journey. It usually starts with feasibility studies and negotiations with landowners or communities, then moves through diagnostics, project design, and activity planning. From there, interventions are implemented on the ground – forest patrols, reforestation, soil regeneration – followed by evidence collection, monitoring, reporting, and audits. Finally, credits are registered, verified, issued, and brought to market.



Along the way, a wide range of actors are involved: landowners, developers, data providers (satellite firms, drones, in-situ sensors), field partners, auditors, registries, and brokers or marketplaces. What's striking is that there is no single standardized model for how these responsibilities are shared. Each project tends to reinvent its own arrangements, which adds complexity and cost.

3.2 Current Practices and Limitations

Despite the rapid growth of the VCM, the operational backbone often still looks old-fashioned. Field data is collected manually, results are managed in Excel spreadsheets, and monitoring reports end up as static PDFs or Word files. This analog style slows everything down, raises transaction costs, and increases the risk of inconsistent data. In many ways, it reflects how young this market is compared to more established commodities like oil or soy, where standardized processes and infrastructure have been built over decades. Until these bottlenecks are overcome, scaling will remain difficult.

3.3 Technology as a Game-Changer

Emerging trends point to a transition toward digital MRV (Measurement, Reporting, Verification) ecosystems, in which developers reposition themselves as integrators coordinating a network of specialized providers. Technologies being deployed include:

- Satellite remote sensing and drone monitoring for real-time land cover change detection.
- IoT-enabled field sensors for forest cover, soil carbon, water cycle and biodiversity tracking.
- IoT-enabled interfaces for data collection within communities to support the diagnosis, implementation and monitoring of socio-economic development projects.
- AI and machine learning to process data, predict risks (e.g. deforestation, sequestration), and produce diagnostic and monitoring reports. Blockchain-based registries for immutable tracking of credit issuance and transfers.
- Digital platforms showcasing carbon projects and delivering tech-based net-zero solutions, from GHG (greenhouse gas) measurement to embedded credits and real-time offsetting.

These innovations can lower costs, reduce lead times for verification, and provide buyers with greater confidence in the integrity of credits[2]. Over time, digital infrastructure may enable interoperability between registries, opening the door for secondary trading markets and derivatives.

4. Capital Structures and Risk Allocation

When it comes to scaling NBS projects, questions of capital and risk are also very important. Who provides the upfront capital? Who absorbs the risk if credits aren't delivered? And how revenues are shared may strongly influence whether projects stay niche or grow into something investable at scale. At the same time, these financial choices ultimately affect the communities, landowners, and landscapes that make the projects possible.

4.1 Cost Categories

The costs of a carbon project can usually be grouped into a few broad areas:

- **Data collection:** studies, field work, satellite imagery, and geospatial monitoring.
- **Technical work:** baseline modeling, methodology application, and data integration.
- **Impact activities:** interventions on the ground such as patrols, reforestation, or soil regeneration.
- **Registration and validation:** audits and registry fees.
- **Commercialization:** marketing, brokerage, and legal structuring

Different project types carry different profiles. ARR (Afforestation, Reforestation, and Revegetation) tends to be more expensive on the execution side because of planting and long-term maintenance. REDD+ (Reducing Emissions from Deforestation and Forest Degradation) and ALM (Agricultural Land Management) often cost less upfront, but they require significant investment in monitoring and community engagement over time.

4.2 Financing Models

Currently, projects are financed through three primary channels:

- **Landowner-financed models:** Landowners cover technical costs, and developers typically retain ~10% of generated credits.
- **Developer-financed models:** Developers assume Capex (Capital Expenditures), retaining 30–50% of credits.
- **Offtake-financed models:** Corporate buyers pre-finance projects via long-term purchase agreements, locking in credit delivery at predetermined prices.

[2] Goldstein, A., Turner, W. R., Spawn, S. A., et al. (2021). Protecting irrecoverable carbon in Earth's ecosystems. Nature Climate Change

While project finance structures, Special Purpose Vehicles (SPVs), debt-equity blends, and specialized investment funds are emerging, they are not yet dominant. Their expansion will depend on greater standardization of methodologies and reduced uncertainty in credit delivery.

In practice, each model has trade-offs. Landowner-financed approaches may work best where owners have the liquidity and long-term commitment to conservation. Developer-financed models allow projects to move forward without upfront local capital but concentrate risk heavily on developers. Offtake agreements can give projects early financial stability, but they lock in prices and shift much of the upside to corporate buyers.

4.3 Risk Allocation

Currently, performance risks (failure to deliver credits due to fire, illegal logging, or underperformance) fall disproportionately on the party financing development. Insurance markets for carbon projects remain underdeveloped, though early pilots are testing parametric insurance for forest fires and climate-related risks. Similarly, derivative products to hedge against carbon price volatility are nascent but could become mainstream as liquidity deepens[3].

A mature ecosystem will require risk-sharing mechanisms, where financiers, developers, insurers, and buyers align on structured allocation of risks. This is analogous to infrastructure project finance, where credit enhancement tools (guarantees, insurance, blended finance) enable institutional capital to participate.

One way to mitigate performance risk is through a waterfall structure – a mechanism that distributes cash flows in order of priority. The sequence should reflect each stakeholder's level of involvement and the extent to which their livelihoods are impacted by the project, ensuring fairness while preserving long-term stability.

5. Use of Proceeds and Stakeholder Remuneration

5.1 Stakeholder Alignment

Equally important as payment order is defining each stakeholder's share and the logic behind it.

- **Landowners:** compensated for the opportunity cost of foregone land use. A relevant benchmark is annual land lease values, typically ~3–5% of total property value in Brazil.
- **Developers and specialized service providers:** remunerated with margins >20% to incentivize high-quality project design and innovation.
- **Financiers:** requiring risk-adjusted returns often above 20% real per year, consistent with high-risk, early-stage investments.
- **Local communities:** compensated directly (for restrictions on economic practices such as hunting or logging) and indirectly through long-term investments in alternative livelihoods, infrastructure, and bioeconomy development.

5.2 Social Dimension and Justice

Projects, particularly REDD+, frequently intersect directly with local communities that rely on forests for their livelihoods. Without proper benefit-sharing, communities in situations of economic vulnerability may continue to engage in deforestation or unsustainable practices[4]. Ensuring social safeguards, gender inclusion, and participatory governance is therefore not only a matter of justice but also a precondition for ecological permanence.

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[3] Taskforce on Scaling Voluntary Carbon Markets (TSVCM). (2021). Final Report. [4] Busch, J., et al. (2019). Carbon markets and the cost of forest conservation. Nature Climate Change.

Long-term success requires creating conditions for bioeconomy transitions, where communities derive income from non-timber forest products, ecotourism, or regenerative agriculture. Short-term compensation (akin to indemnities) may bridge the transition but must be complemented with structural investments.

Note: While social safeguards and livelihood improvements are critical for long-term project legitimacy, private carbon developers are not best positioned to act as socioeconomic development agencies. Developers must ensure robust safeguards, transparent benefit-sharing, and respectful engagement, but the delivery of broader community development outcomes requires deep expertise, consistent governance, and mandates that lie more naturally with governments or specialized civil society organizations. This division of roles helps ensure community outcomes are delivered effectively, while allowing developers to focus on the technical, financial, and environmental complexities of project execution.

6. Carbon Credit Pricing Mechanisms

6.1 Opportunity Cost Benchmarking

One of the recurring challenges in carbon markets is how to set a fair and transparent price for credits. Unlike commodities such as oil or soy, carbon credits don't have a long history of standardized benchmarks. Prices often fluctuate widely depending on negotiations, buyer perception, or the type of project. This creates uncertainty both for landowners deciding whether to conserve and for investors assessing the financial stability of projects.

A useful way to cut through this complexity is to start with something very concrete: the opportunity cost of land use. Put simply, landowners will compare the returns they can make from conservation with what they could earn from other activities – cattle ranching, agriculture, logging, or leasing. If conservation does not at least compete with these alternatives, it will never scale.

This logic can be translated into a simple framework for pricing, where carbon credit values are tied to land opportunity cost plus the direct costs of developing and maintaining projects. Expressed conceptually, the price of a carbon credit can be written as:

$$P_{credit} = \frac{OC_{ha} + C_{dev} + C_{impact} + C_{fin}}{C_{gen}}$$

Where:
P_{credit} = price per carbon credit (USD/tCO2e)
OC_{ha} = opportunity cost per hectare (USD/ha/year)
C_{dev} = technical development costs (USD/ha/year)
C_{impact} = impact actvity costs (USD/ha/year)
C_{fin} = fincancing costs (USD/ha/year)
C_{gen} = number of credits generated per hectare per year (tCO2e/ha/year)

The key component, OC_{ha}, reflects the annual return from alternative land use (e.g., cattle ranching, agriculture, or timber extraction). In the Amazon biome, for instance, Brazilian law permits legal deforestation on up to 20% of a rural property. This implies that only a fraction of the total area represents the true deforestation risk (AdefA_{def}Adef). Therefore, the effective opportunity cost can be expressed as:

$$OC_{ha} = \frac{R_{alt} \times A_{def}}{A_{tot}}$$

Where:
R_{alt} = annual return from the alt.landuse (e.g., cattle ranching)
A_{def} = area legally subject to deforestation (ha)
A_{tot} = total property area (ha)

With this conceptual framework established, we can now turn to a practical example. In the Amazon-Cerrado frontier, average cattle ranching yields are approximately USD 60/ha/year[5]. Applying the 20% legal deforestation threshold, the effective opportunity cost falls to USD 12.5/ha/year when spread across the entire property.

Adding technical development, impact activity, and financing costs, and assuming a 50/50 revenue split with landowners when they do not finance the project, the total revenue stream should reach ~USD25/ha/year.

Dividing by the number of credits generated (as determined by deforestation risk models and additionality methodologies) yields a per-credit reference price.

This approach is theoretically sound because the total revenue per hectare is anchored to the opportunity cost of the property itself, which reflects its underlying economic viability. Opportunity cost captures factors such as land productivity, location, and ease of access (logistics), all of which determine the potential returns from alternative land uses. Importantly, these same factors are closely correlated with deforestation risk: the more economically attractive a property is for exploitation, the greater the pressure it faces from deforesters.

By linking carbon credit pricing to opportunity cost, the model aligns financial incentives with the true economic dynamics of land use, ensuring that conservation becomes a competitive alternative to deforestation.

In an ideal setup, each rural region would have an index (eg. created and managed by Embrapa[6]) indicating its predominant land uses and expected returns. Project developers could then use this benchmark to demonstrate the opportunity cost of their land and set carbon credit prices that fairly reflect it.

The real power of this model comes once opportunity cost becomes a practical reference for carbon credit sales. In that scenario, landholders naturally weigh the returns from conservation (via credits) against those from ranching or agriculture. This creates a direct link, almost like a communicating vessel, between agricultural commodity prices and carbon credit prices, since both compete for the same land. As a result, the market itself (whether through free pricing or more structured mechanisms) acquires the ability to balance production and conservation, aligning economic incentives with environmental outcomes.

In the end, opportunity cost provides the anchor, while trading platforms, market liquidity, and integration into compliance frameworks supply the mechanisms for transparent price discovery and adjustment within an open market system.

7. Outlook: Market Trends and Opportunities

Once the structural foundations of carbon projects are in place, the next challenge is scaling. This depends not only on standardization and operational efficiency, but also on the adoption of new technologies, financial tools, and governance models that can expand reach and credibility:

- **Developers as integrators:** Developers evolving into ecosystem integrators, not only coordinating specialized actors across the value chain but also owning digital platforms that enable efficient and scalable interaction among stakeholders.

[5] An IMAZON study on the Green Cattle Ranching Project in Paragominas (Amazon) estimated profits of about BRL 300 per hectare per year at 15 arrobas/ha productivity (IMAZON, 2010). As this is used only as an illustrative example, the values have not been updated. [6] Embrapa (Brazilian Agricultural Research Corporation) is a state-owned company under Brazil's Ministry of Agriculture, focused on agricultural research and innovation.

- **Digital MRV integration:** Embedding geospatial analytics, AI, IoT, and blockchain throughout the project cycle – from diagnostics to execution, monitoring, and verification – to reduce costs, accelerate timelines, and strengthen credibility.
- **Financial innovation:** Expansion of project finance funds, insurance products, and derivatives to mobilize institutional capital and mitigate performance risk.
- **Community engagement:** Developers should uphold safeguards and fair benefit-sharing, but broader socioeconomic development is best handled by governments or specialized civil society organizations.
- **Convergence with compliance markets:** Partial integration of voluntary credits into compliance regimes (e.g., Article 6 of the Paris Agreement, Carbon Offsetting and Reduction Scheme for International Aviation, or CORSIA), creating stronger price signals and market depth.

If these trends materialize, the VCM could evolve from a fragmented, trust-deficient ecosystem into a financially mature market infrastructure, comparable to established commodity and infrastructure sectors. This would unlock the scale required for NBS projects to meaningfully contribute to the global net-zero transition.

Beyond these immediate trends, there is a broader horizon emerging: the role of NBS projects not only as providers of carbon credits, but also as sources of structured data for artificial intelligence systems.

8. Looking Ahead: Soon It Will Be All About AI-tokens

The reflections that follow are not a scientific study, but an early attempt to think through the intersection of NBS and AI. As I've spent time working and reflecting in both fields, certain connections have appeared that, to me, feel both natural and potentially transformative.

This chapter is an attempt to map those connections. It uses concepts like "AI-tokens" and "knowledge domains" less as precise technical categories and more as lenses for understanding how data from nature might interact with the digital economy. I recognize that experts in AI, economics, or environmental science would frame things differently, with more rigor and nuance. What I offer here is just a perspective, a way of looking at what might be emerging.

8.1 From Carbon Credits to Data Credits

The intersection between NBS and AI possibly represents one of the most underexplored yet potentially transformative opportunities in the global economy. Traditionally, NBS projects have been understood primarily through the lens of environmental conservation and carbon markets. However, their role as generators of structured, real-world data situates them at the heart of a new paradigm: the tokenization of knowledge for AI systems.

AI relies on four core inputs: computation (chips), algorithms, energy, and data. Of these, data is the most domain-specific and context-dependent. Data, when structured and transformed into tokens (the functional units of AI understanding), becomes the critical bottleneck and enabler of AI's performance.

Once processed, these tokens unlock new forms of AI-enabled intelligence. This intelligence does not remain confined to the digital sphere – it flows back into human systems, shaping decisions, industries, and social structures. In practice, this means:

- **Agriculture and Resources:** optimizing yields, monitoring soil health, and predicting deforestation risks.
- **Manufacturing:** enabling precision production and reducing waste through predictive maintenance.
- **Finance and Governance:** improving climate risk modeling, compliance monitoring, and policy design.
- **Science and R&D:** accelerating drug discovery, energy innovation, and material science.

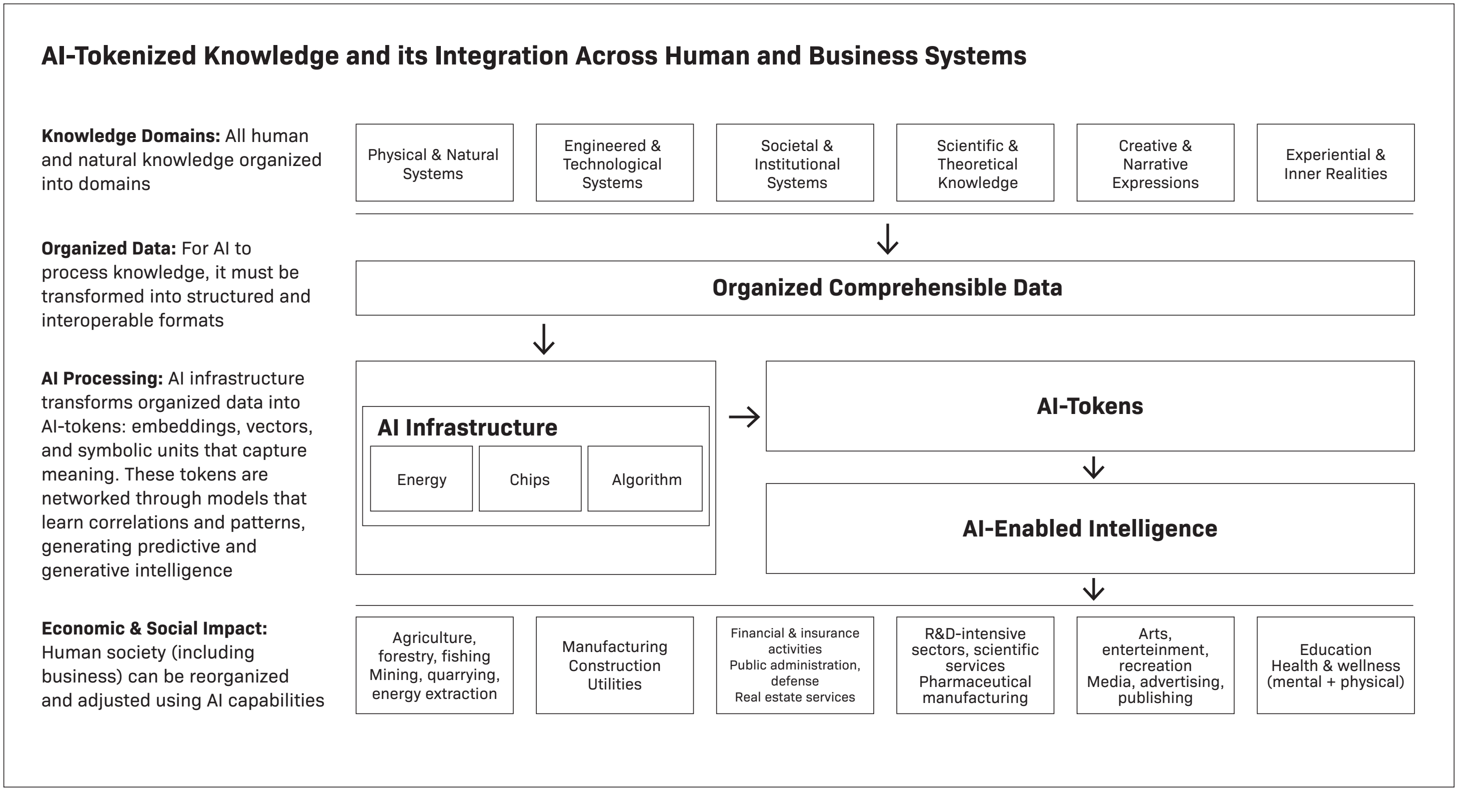
- **Arts and Media:** transforming cultural production, design, and communication channels.
- **Health and Education:** personalizing learning, advancing diagnostics, and supporting public health systems.

In this sense, the intelligence derived from nature-linked data extends far beyond environmental markets. It becomes a form of infrastructure that permeates nearly every sector. Nature-based projects, by producing both carbon credits and structured environmental data, stand at the gateway of this transformation: enabling not just climate mitigation, but also a new layer of digital value creation that drives economic and societal change. Insights from the physical world reorganize how we produce, govern, and innovate. This is the broader horizon the diagram below seeks to illustrate.

AI, Tokenized Knowledge, and the Integration of Nature Data Across Human and Business Systems

NBS projects can be seen as naturally generating vast datasets on forest cover, biodiversity, soil chemistry, water cycles, and community interactions. These datasets, once digitized, verified, and organized, can be transformed into AI tokens, creating a parallel form of asset alongside carbon credits.

In this view, carbon credits monetize the environmental service of avoided emissions or sequestration, while AI tokens derived from NBS projects might monetize the informational service of structured knowledge extraction from nature. This dual pathway suggests that NBS may be understood not only as environmental assets but also as knowledge infrastructure for the digital economy.



8.2 Knowledge Domains and the Role of Nature

As listed above, knowledge can be approached as belonging to six broad domains:

1. Physical & Natural Systems
2. Engineered & Technological Systems
3. Societal & Institutional Systems
4. Scientific & Theoretical Knowledge
5. Creative & Narrative Expressions
6. Experiential & Inner Realities

Currently, Physical/Natural domains represent about 15% of AI's tokenized knowledge base[3]. With advances in IoT sensors, remote sensing, and environmental monitoring, this share could grow to 25% over the next decade. Such growth reflects a structural shift: as AI models increasingly integrate real-world environmental data for climate modeling, resource management, and sustainability applications, nature becomes a foundational anchor of truth in AI training.

8.3 Linking Tokens to Economic Power

Mapping knowledge domains to economic activity suggests a similar rebalancing in GDP contribution. Today, Physical/Natural domains account for ~10% of global GDP. By applying token-growth projections, their share could rise to ~20% within the decade[7]. This indicates that environmental data, once tokenized, may shape macroeconomic structures in ways comparable to the industrial revolutions of the past.

Entities that control large-scale, structured environmental datasets – particularly those emerging from NBS projects – could therefore rival the strategic importance of today's core AI infrastructure (chips, cloud, algorithms). Ownership of these data flows may define the geopolitics of AI as much as semiconductor or energy supply chains currently do.

8.4 Strategic Implications for Investors and Developers

The convergence of NBS and AI opens a dual-investment thesis:

- Environmental preservation thesis: NBS projects generate verified carbon credits and deliver biodiversity, water, and social co-benefits.
- Data infrastructure thesis: The same projects structure physical-world data into tokens, which can be monetized in AI ecosystems.

This convergence creates a scenario where NBS projects evolve into "dual-purpose assets", producing both carbon credits and AI tokens. In this sense, they may become as strategically valuable as traditional AI infrastructure.

8.5 The Coming Era of AI-Tokens

In the long run, the evolution of carbon markets may be seen as the first stage of a larger transition: from commoditizing emissions reductions to commoditizing structured knowledge of the physical world. Carbon credits represent the environmental value of NBS; AI tokens represent their informational value. Together, they define a new class of natural–digital hybrid assets.

In such a scenario, NBS projects equate to the bridge between the physical world and the AI-driven digital economy. As the world digitizes further, and as AI demands exponentially more real-world data, this bridge becomes invaluable. Soon, it will not only be about carbon credits – it will be all about AI-tokens.

■

[7] The percentages presented here are based on exploratory desk research and should be interpreted as indicative rather than definitive figures.

Carbonext Tatuy REDD+ Project (Mato Grosso)

8. Addressing Systemic End-Game Risk Ensuring Long-term Solutions for Carbon Markets

David Antonioli, *founder of Transition Finance, strategic advisor to a number of companies and founding CEO of Verra*

Background

Carbon markets face a systemic risk – the lack of planning around what happens when carbon credit sales end. We can call it end-game risk[1]. Originally, carbon credits were created to mitigate the costs of complying with regulations that limited greenhouse gas (GHG) emissions. They were part of a broader framework intended to drive climate action, with the expectation that countries would eventually regulate emissions economy-wide. Over time, projects that generated carbon credits would be integrated into these regulatory systems.

As a result of this broad understanding, a lot of effort was dedicated to creating the rules that governed the creation and monitoring of carbon credits, to make sure they represented real emission reductions and removals. These efforts continue today, as illustrated by the development of new carbon crediting programs promising better ways to ensure quality and the advent of the Integrity Council for the Voluntary Carbon Market (ICVCM), which serves as a quasi-regulator for quality assurance.

Yet, almost no attention has been given to what happens when revenue from the sale of carbon credits stops. Now that the carbon market, especially the VCM, has evolved to exist outside of any regulatory framework, this question takes on added significance. Left unaddressed, failure to plan for what happens when carbon finance ends poses systemic risks to the market and to the environment. For example, projects whose only or main revenues depend on the sale of carbon credits could find their ability to operate severely jeopardized if there are no plans to ensure their long-term operational viability. Nature-based Solutions (NBS) face a particularly daunting challenge; the ceasing of project

[1] Another way of defining this is through the use of the term “durability”, which has gained traction in carbon markets. However, I prefer to use “end-game risk” as it, in my view, frames the challenge more starkly, ideally with a view to resolving it sooner rather than later

operations could result in significant volumes of carbon being released back to the atmosphere.

No existing GHG crediting program explicitly addresses end-game risk, creating a systemic risk for carbon markets. Fortunately, this is a solvable problem. In addition, successfully addressing end-game risk could help reframe the purpose of carbon markets, from simply generating tonnes of carbon for the sake of offsetting to driving the green transition in key sectors of the global economy.

Understanding the Challenge and Proposing Solutions

Not all carbon projects face the same end-game risk, especially given the wide range of project types that currently get financed through carbon markets. A useful framework for thinking about this challenge is to break out project types into two categories: (1) those that need early-stage capital but can eventually stand on their own economically; and (2) those that will likely continue to be entirely dependent on carbon finance because they have no other way to sustain themselves. Each of the sections below discusses these categories and suggests some solutions.

Category 1: Projects with an underlying economic rationale

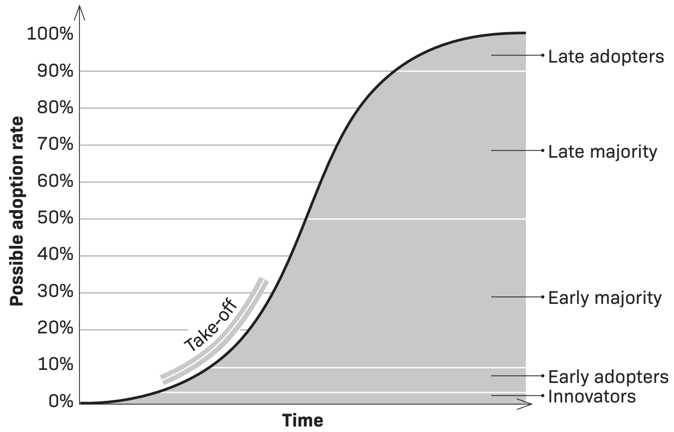
Many project types financed through carbon have a long-term underlying economic rationale but need bridge financing in the beginning to overcome high costs, technical risks, general skepticism about the innovation and/or immature markets and supply chains. For these projects, carbon finance can serve as a catalyst that drives long-term adoption of innovative climate solutions. Examples of such projects include cold recycling of asphalt, battery storage, green hydrogen, biochar, agroforestry, and regenerative agriculture including soil and carbon enhancing fungi.

- **Cold recycling of asphalt.** Traditional hot-mix asphalt (HMA) is resource- and energy-intensive, generating substantial GHG emissions. Cold recycling of asphalt can cut emissions by 70–80% by reprocessing up to 90% of asphalt on-site at ambient temperatures. However, cold recycling requires costly equipment and faces opposition from entrenched industry players who have significant influence over procurement processes. In the US, only about 15 of over 2,400 paving contractors offer cold recycling. Carbon finance could fund the adoption of this innovative technology, support training, and enable cold recycling to gain enough traction such that it can compete with HMA on a cost basis.

- **Biochar.** The development of a successful biochar industry depends on demonstrating the technology and building an entirely new supply chain. It is, for example, common knowledge that the first time one builds a new factory there are going to be huge inefficiencies that can be squeezed out of the system, mostly by tweaking designs and considerable trial and error. While the first few facilities will not be economically viable, over time they will increase their efficiency and therefore financial viability. Building a supply chain also has its challenges given the need to identify the correct input material (e.g., agricultural or timber residues?) and final buyers, likely to be farmers but could end up being other entities altogether such as cement factories exploring the use of biochar as an input to the production process. Carbon finance can play a critical role in building domestic biochar industries, and it is plausible to consider that at some point the biochar industry could stand on its own, providing a valuable new product to the market.

A theoretical framework that can be useful for thinking about these projects is based on Dr. Everett Rogers' Diffusion of Innovations theory that describes how new technologies spread – from innovators to early adopters, early and late majorities, and laggards – often following an S-curve of adoption, as illustrated in the figure below. A key element of the curve is that there is an inflection point where new solutions "take off", meaning they can stand on their own.

S-CURVE OF ADOPTION

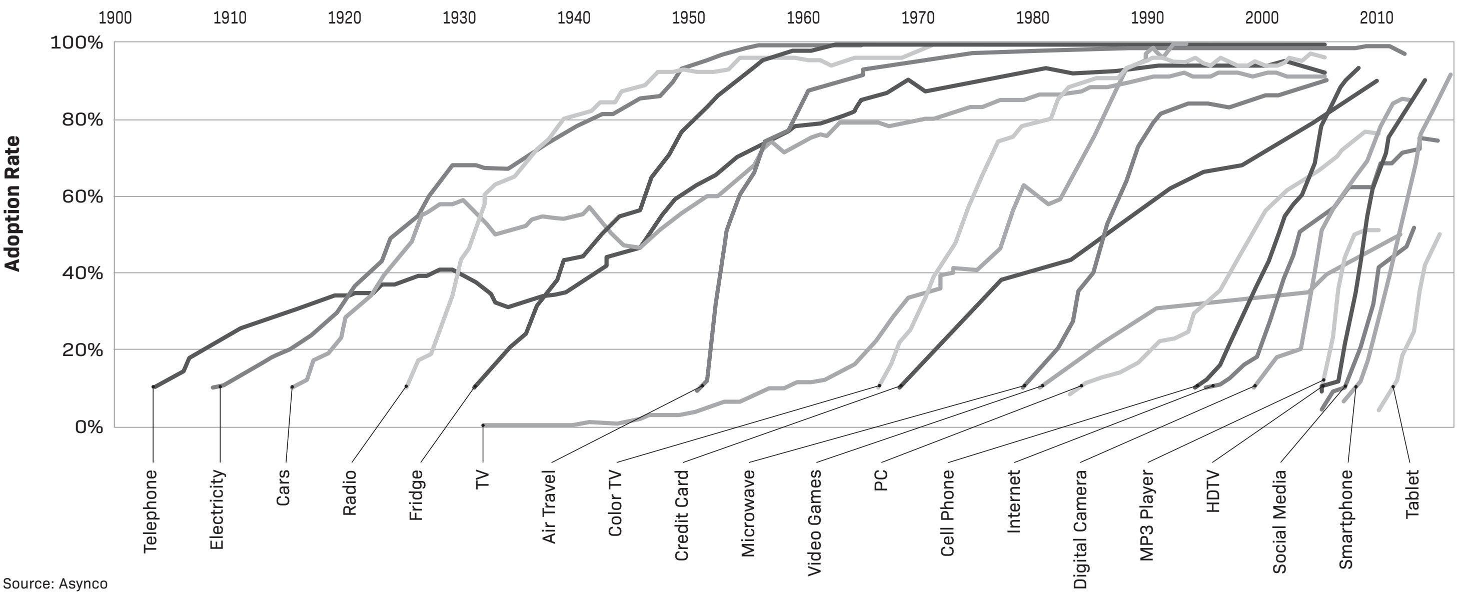


Source: www.pinnaxis.com

Indeed, a number of technology innovations have followed a similar pattern, as outlined in the figure below.

The S-curve of adoption makes intuitive sense. At low market penetration rates, it is unlikely that proponents of new practices or technologies have addressed many of the barriers to adoption, such as reducing costs of production, building the necessary technical capacity, and sufficiently socializing the innovations to overcome initial fears and concerns. In the examples set out above, low market penetration rates could stifle the adoption of these innovations and end up undermining their potential. Even worse, insufficient market penetration could result in backsliding where the innovations simply do not gain sufficient traction and end up being abandoned.

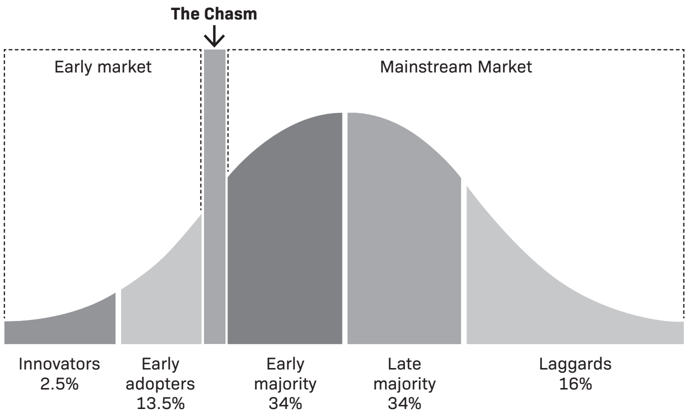
Dr. Geoffrey Moore built on Rogers' theory and wrote Crossing the Chasm, which focused on the significant challenges products face in going from early to mainstream markets. Dr. Moore quantified the point at which new technologies or practices gain sufficient



Source: Asynco

traction in the marketplace and are able to compete on their own. In general, this divide tends to happen between the Early Adopters and the Early Majority, once a technology has penetrated at least 16 percent of the market. According to Moore's research, this is a particularly difficult barrier to cross. The figure below illustrates key features of this important and powerful work.

DIFUSION OF INNOVATIONS THEORY AND THE CHASM



Source: http://amithhousedesign.com/models-predicting-future-geoffrey-moores-crossing-chasm/

The above framework could therefore be one way to address end-game risk for projects that can eventually stand on their own. Specifically, carbon finance can be designed such that it can help overcome the obstacles new technologies or practices face, leading to long-term transformations in particular sectors of the economy.

A framework that approved projects based on market penetration could also help address two other concerns that bedevil the carbon market.

- First, it would clearly set out the time when new projects should not be approved, because they no longer need additional support. This would be a tremendous improvement on the current process for making this determination, which is still largely reliant on the Additionality Tool and which leaves the question about when to no longer approve new projects to be decided on the basis of individual projects. Given the numerous opportunities project developers have at making their arguments, this then becomes a fraught process that ends up creating confusion and seeding lots of uncertainty.

- Second, such a framework could resolve the all-or-nothing dynamic that prevails in carbon markets, meaning that projects either issue a whole credit for every tonne of CO_2e that is avoided or removed, which ends up raising the stakes when considering when projects are no longer considered additional. In reality, the conditions facing the very first project will be very different than the conditions facing later projects, especially those that are being approved when questions are starting to be raised about their additionality. Why then, not begin to discount the credits projects receive once they get closer to the market penetration threshold? This would allow for the market to gradually wean itself from depending on carbon finance, and would also incentivize early action before the discounts kick in.

Category 2: Projects without an underlying economic rationale

Many project types financed through carbon do not have a long-term underlying economic rationale nor any other means of maintaining their operations once their crediting period ends. For these projects, carbon finance can serve as a catalyst that introduces new technologies and practices, including critical capital equipment, but failure to secure long-term support would likely mean shuttering operations. Examples of such projects include industrial gas capture and destruction, plugging of orphaned oil and gas wells, carbon capture and storage (CCS), direct air capture (DAC), forest conservation and forest restoration that does not have any element of agroforestry or improved forest management.

I can think of two possible solutions for these kinds of projects, and they can be complementary to each other. Under the first, governments could commit to taking over responsibility for project operations once there are no more revenues from the sale of carbon credits. This would be done in exchange for the early investment and early action carbon markets would bring to the table. The truth is that most governments tend to lack either the resources and/or the political will to regulate sectors of their economy. Carbon finance can provide that early investment, especially to cover the more capital-intensive and therefore costly equipment needed to control GHGs (e.g., destruction facilities for refrigerants). Carbon finance can also provide political cover to governments because it generates immediate benefits for host country governments in the form of direct foreign investment which translates into technology, jobs and training. In addition, it helps the country align with the targets of the Paris Agreement, and in the end reduces the costs of achieving those goals.

With this framing, one could envision that host countries could make commitments to enforce and/or enact laws or regulations to stop GHG emissions, or promote removals, once carbon projects have worked through to the end of their crediting periods. Such commitments could apply to both VCM and Article 6 projects, and would mean governments can reap the benefits of investment today while having time to both line up the resources and build the capacity and institutions they need to ensure regulation in the long run. In short, such commitments would enable host country governments to crowd in investment into sectors they are keen to address, but for which they currently do not have resources or know-how.

Of course, any long-term commitment to control GHGs will likely require resources, which leads to the second potential solution: the creation of trust funds managed by either governments or independent third parties to underwrite the project activities out into the future, after the revenues from the sale of carbon dry up. Such trust funds have been used effectively to fund long-term projects in a whole host of situations, so why not use them for carbon projects?

A trust fund could be created with regular contributions from the sale of credits while the carbon project is operational. In the case of Nature-based Solutions (NBS), the long timeframe of those projects (e.g., 30-40 years) provides ample time to build up a robust resource base that could support long-term project operations[2]. Furthermore, the contributions to the trust fund need not cost a lot. In fact, they could pay for themselves because having a trust fund to back up a long-term commitment for the protection of habitat paid for with carbon would significantly reduce the permanence risk projects face. In turn, projects that have addressed end-game risk would have lower buffer contributions, which would free up resources for the project, including to create the trust fund.

[2] The American Forest Foundation is developing a concept that is very similar to this called the Permanence Trust.

Conclusion

End-game risk is not just an operational oversight – it is a structural vulnerability that undermines the long-term credibility of carbon markets. Without clear pathways for sustaining climate benefits after crediting ends, the market risks losing both environmental integrity and stakeholder trust. This is especially critical for NBS, where the collapse of operations could erase decades of carbon gains in a matter of years. By anticipating and planning for the eventual end of carbon finance, we can turn a looming liability into an opportunity to strengthen the role of carbon markets in the broader climate transition.

Addressing this challenge requires differentiating between projects that can eventually stand on their own and those that will always need ongoing support. For the former, targeted carbon finance can serve as a bridge to full market adoption, guided by frameworks like the Diffusion of Innovations and market penetration thresholds. For the latter, solutions such as government regulation, potentially combined with dedicated trust funds, can provide the stability needed to maintain operations once the carbon crediting ends. These approaches not only mitigate systemic risk but also ensure that early investments continue delivering climate benefits well beyond the life of a carbon project.

If implemented, these strategies could redefine the purpose of carbon markets – from a short-term mechanism for generating offsets to a long-term driver of structural change. By building durability into market design, we not only safeguard the investments made today but also ensure that the climate gains we achieve are locked in for future generations. The question is no longer whether we can address end-game risk, but whether we have the foresight and will to act before it becomes a crisis.

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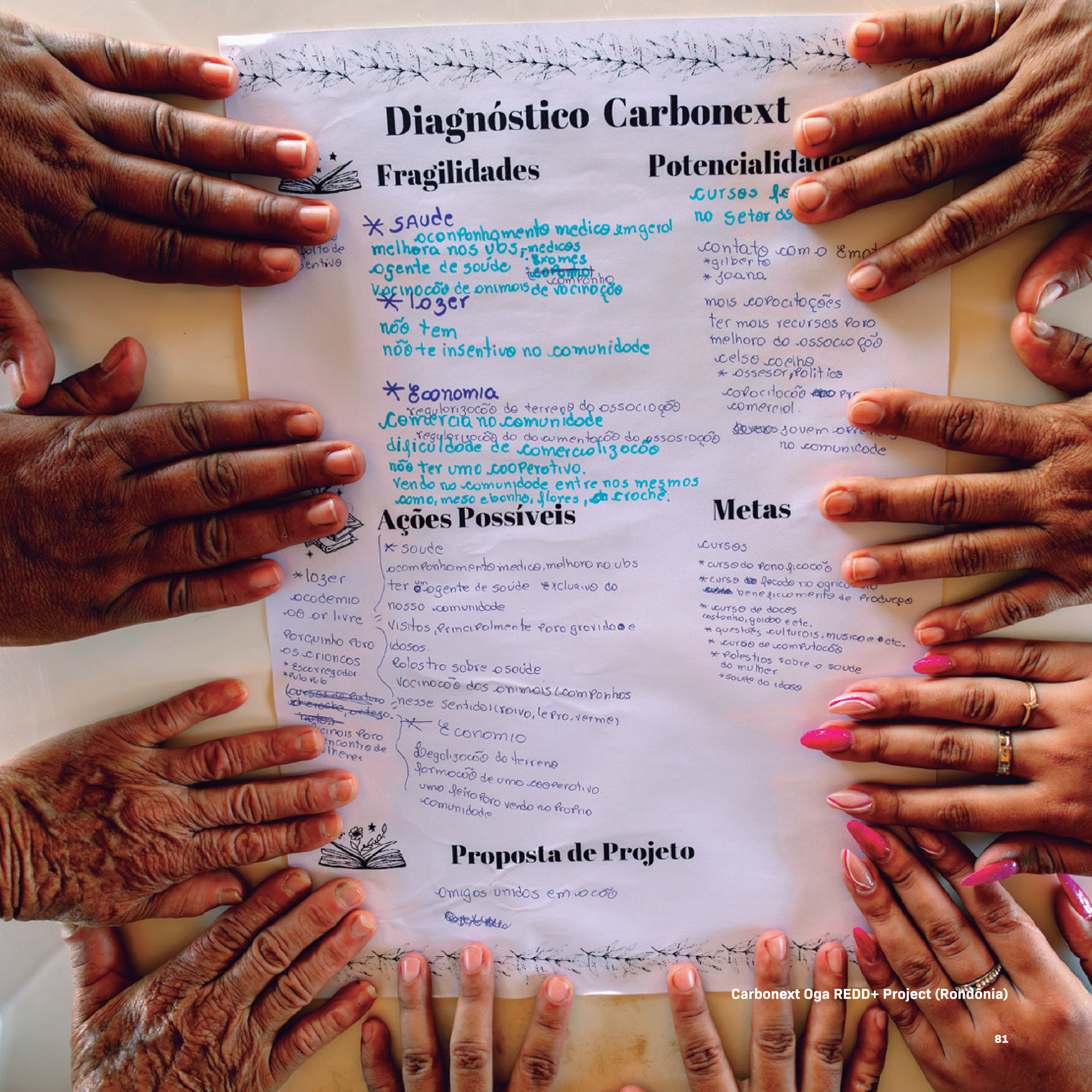

Carbonext Oga REDD+ Project (Rondônia)

9. The Legal Landscape in Brazil and Worldwide

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Introduction

In December 2024, the National Congress approved Law No. 15,042, which establishes the Brazilian Greenhouse Gas Emissions Trading System (SBCE), with the purpose of regulating the carbon market in Brazil. This is long-awaited legislation, whose transformative potential will depend on the infralegal regulation still being developed, as well as the effective coordination among the various public and private entities involved in its implementation. Despite this normative progress, the national landscape is still permeated by regulatory uncertainties.

Among the main challenges are: (i) the definition of technical and legal criteria for the approval of projects and methodologies; (ii) the governance structure of monitoring, reporting, and verification (MRV) systems; (iii) the coordination between the regulated and voluntary markets; and (iv) compatibility with international standards and requirements. The absence of clear and operational rules undermines legal predictability and discourages investments in climate initiatives at the scale required.

The context becomes even more complex in light of structural factors that compromise market effectiveness. Brazil faces historical land tenure obstacles, such as cartographic overlaps, precarious and vulnerable records in extrajudicial registries – some under state intervention due to irregularities – as well as ownership uncertainties and land-use conflicts. These factors impose significant challenges to legal certainty and the long-term feasibility of projects in the carbon market.

Although not exclusive to the climate sector, such difficulties gain prominence in this context, given the high dependence of the carbon market on reputation, integrity, and trust. The credibility of climate assets is crucial to attract financing, ensure environmental integrity, and guarantee international acceptance. Moreover, the fact that the regulatory framework is still in the structuring phase increases sensitivity to these risks, making their careful and pragmatic handling indispensable. The scenario becomes even more challenging when considering Brazil's unique position as home to the largest tropical forest on the planet, with a predominantly renewable energy matrix and significant potential for carbon credit generation.

On the one hand, this condition grants us protagonism and leadership potential; on the other, it subjects us to international scrutiny that sometimes exceeds reasonable limits.

It is equally relevant to consider that different interpretations and regulatory understandings, even when originating outside the country, can significantly impact the domestic market. A striking example is the set of non-tariff barriers arising from European rules, such as the European Union Deforestation Regulation (EUDR). Regulation No. 1115, by restricting the import of products originating from deforested areas, directly interferes in our territory by imposing obligations that do not align with the Brazilian legal framework. This is because the regulation disregards the distinction between legal and illegal deforestation – a fundamental concept in our legislation. Moreover, by unilaterally imposing due diligence and traceability obligations, the European regulation ends up interfering with domestic land-use regimes and environmental rules, disregarding Brazil's sovereignty and legal framework.

In this context, a direct examination of the intersection between Law No. 15,042 and the international mechanisms established under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement is required. Such analysis demands a critical look at the national environmental protection legal framework, particularly forest law, in order to understand the normative space in which the debate on the climate variable is situated.

This interpretive exercise requires familiarity with the national legal framework, especially the National Environmental Policy (Law No. 6,938/1981), the Forest Code (Law No. 12,651/2012), the National Policy on Climate Change (Law No. 12,187/2009), the Biodiversity Law (Law No. 13,123/2015), among other related statutes. It also requires legal sensitivity to integrate the climate variable into the three pillars of sustainable development – economic, social, and environmental – as outlined in Articles 170 and 225 of the Federal Constitution.

The 1988 Constitution unequivocally enshrined Brazil's vocation for environmental protection and the pursuit of sustainability. Its text is recognized as one of the most advanced in the world in environmental matters. However, even before its promulgation, the country already had a robust framework aimed at conservation and environmental protection.

In 1981, spurred by the existence of state-level environmental protection laws, such as those in Rio de Janeiro, São Paulo, and Bahia, Law No. 6,938 was enacted, establishing the National Environmental Policy, consolidating important environmental protection guidelines in Brazil.

The Forest Variable

In the field of forest protection, Brazil was a pioneer. The first Forest Code dates back to 1934 and reflected, at the time, a strategic concern with the conservation of timber stocks for energy generation. Although still based on a predominantly utilitarian logic, it already introduced restrictions on predatory forest use – an innovation given the international context then prevailing.

In 1965, Law No. 4,771 established a new legal regime for the protection of forests and other forms of native vegetation, now under a more conservationist perspective. The concepts of Legal Reserve (RL) and Permanent Preservation Areas (APP), until then addressed under a preservationist approach, became part of a legal model that combined environmental conservation with rational use of natural resources. At that point, Brazil had already consolidated itself as a normative reference in forest protection.

The Forest Code was amended in 1989 and later revised and updated in 2012 with the enactment of Law No. 12,651. This new legislation sought to balance environmental conservation objectives with the need to ensure agricultural production and socioeconomic growth. It reaffirmed the pillars of protection and provided greater clarity to instruments such as the Rural Environmental Registry (CAR), the Environmental Regularization Program (PRA), and Legal Reserve compensation mechanisms.

The Federal Constitution, complementing this advanced system – both in general, through the National Environmental Policy, and in forestry, through the Forest Code – brought important principled advances.

Regarding forest issues, the Constitution consolidated a system that had already been taking shape previously, with the enactment of Resolution No. 10 of the National Environmental Council (CONAMA), which introduced the idea of institutionalizing the protection of areas beyond RLs and APPs, such as parks and Environmental Protection Areas (APAs).

This is the explicit provision that the Public Authority must define specially protected territorial spaces, as established in Article 225, § 1, item III, of the Federal Constitution. These spaces correspond to Environmental Conservation Units, now regulated by Law No. 9,985/2000, which established the National System of Nature Conservation Units (SNUC).

Conservation Units may be under public or private ownership – as in the case of Private Natural Heritage Reserves (RPPNs) – and, alongside RLs and APPs, constitute essential instruments for forest conservation.

This framework is complemented by specific legislation, such as the Atlantic Forest Law (Law No. 11,428/2006), which imposes stricter rules for forest management in one of the country's most threatened biomes.

Thus, the system established by the Constitution, together with the legal regimes for forest protection and the definition of specially protected territorial spaces, ensures significant conservation of Brazil's biodiversity heritage, in line with the international commitments assumed by the country.

There are also important advances in recognizing the differentiated protection of traditionally occupied territories. The Constitution grants special protection to Indigenous peoples' lands, which, by their very vocation, constitute important forested areas. The management of these territories is regulated by the National Policy on Environmental Management of Indigenous Lands (PNGATI), established by Decree No. 7,747/2012.

Other traditional communities – such as quilombolas, riverine peoples, artisanal fishers, and Afro-descendant communities – have also come to enjoy specific normative protection. The National Policy for the Sustainable Development of Traditional Peoples and Communities (PNPCT), created by Decree No. 6,040/2007, recognizes the cultural, territorial, and collective identity of these groups and establishes guidelines for their inclusion in environmental and development public policies.

When addressing the carbon market, it is essential to recognize these instruments as an inseparable part of the national climate legal context, particularly regarding legal certainty, the protection of territorial rights, and respect for sociocultural diversity.

Thus, a significant portion of Brazilian territory is under constitutional and legal protection, ensuring the conservation of a substantial share of national biodiversity.

State laws complement this framework, adding local perspectives to forest conservation and environmental sustainability.

Brazil therefore possesses a sophisticated legal model, oriented toward sustainability, which – if fully implemented – is capable of promoting environmental conservation, respecting collective rights, and fostering the development of solutions consistent with the climate transition.

The Legal System and the Specific Treatment of the Climate Variable

Since the United Nations Conference on the Human Environment in 1972, Brazil has positioned itself as a leading voice in international sustainability debates. At that time, still focused on defending the right to social and economic development, the country sought to balance this objective with the growing demands for environmental conservation, mostly driven by European countries.

At the United Nations Conference on Environment and Development (ECO-92), held in Rio de Janeiro, fundamental milestones of global climate governance were established, such as the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), and the Rio Declaration on Environment and Development. These instruments enshrined the need to seek a balance between the economic, social, and environmental pillars of sustainability.

It is important to stress that the principles established in these documents do not rank the dimensions of sustainability. On the contrary, they advocate for the harmonious integration of the three dimensions, so that sustainability is achieved as the result of balance among them, and not through the unilateral imposition of one over the others.

Between ECO-92, the creation of the Kyoto Protocol (1997), and the formalization of the Paris Agreement (2015), Brazil made significant advances in its domestic legal framework. Of note during this period is the enactment of Law No. 12,187/2009, which established the National Policy on Climate Change (PNMC).

Under the terms of the Federal Constitution, the Public Authority must grant "differentiated treatment according to the environmental impact of products and services and their production and delivery processes" (Art. 170, VI), paving the way for the adoption of incentive, stimulus, and inducement policies for the control of greenhouse gas (GHG) emissions.

The PNMC reinforces this role of the State as a driver of the climate transition. Article 5, item VII, of the law defines as one of its guidelines "the use of financial and economic instruments to promote mitigation and adaptation actions to climate change."

However, the application of these instruments in Brazil is still limited. The tradition based predominantly on the command-and-control model, combined with the limited strategic use of tax and financial mechanisms, restricts the potential of these instruments to foster innovative climate solutions.

The few successful experiences demonstrate the positive potential of these mechanisms. Still, there is a tendency to use them punitively, through taxation of environmentally harmful activities, rather than promoting positive incentives. An example is the discussion on the so-called "sin tax," included in the tax reform proposal, which adopts a revenue-oriented approach more focused on compensating for negative externalities than on fostering sustainable alternatives.

Article 6 of the Paris Agreement

Article 6 of the Paris Agreement regulates three mechanisms of voluntary international cooperation aimed at implementing Parties' Nationally Determined Contributions (NDCs).

Two of these mechanisms relate to the carbon market: Articles 6.2 and 6.4. Both allow the transfer of emission credits generated from mitigation outcomes achieved by projects in one country to another. The third mechanism, provided for in Article 6.8, addresses non-market approaches, involving alternative forms of cooperation among countries.

Article 6.1 establishes that all these mechanisms must have as their primary purpose the enhancement of climate ambition in the implementation of NDCs, simultaneously promoting sustainable development and environmental integrity.

Focusing on the creation of instruments to incentivize the reduction of GHG emissions, Article 6.2 authorizes a Party that has exceeded its targets to transfer this surplus, in the form of a credit, to another Party. The unit of measurement of this credit is the ITMO (Internationally Transferred Mitigation Outcome). To ensure environmental integrity, a rigorous accounting system is required, with corresponding adjustments, so as to avoid double counting of emission reductions.

Article 6.4, considered the successor to the former Clean Development Mechanism (CDM) under the Kyoto Protocol, allows both public and private actors to generate certified emission credits. These credits can be used to meet targets established in NDCs or for other international purposes. COP29 defined important guidelines for this mechanism, including rules for methodology approval, transition of CDM projects, operationalization of the registry, and technical oversight.

Article 6 in Recent COPs

International carbon trading gained clearer contours from COP26, held in 2021, when Parties established the regulatory foundations for operationalizing the mechanisms under Article 6. At COP27, progress was made in developing rules on operational transparency, registry functioning, and governance structure.

It was, however, at COP29, held in Baku, that a significant milestone was reached in implementing carbon markets under the Paris Agreement. Most technical pending issues were resolved, consolidating the central elements for the functioning of market mechanisms.

Within the scope of Article 6.2, definitive formats were approved for public and multilateral authorizations of ITMOs, guidelines for corresponding adjustments were defined, and the use of the United Nations international registry was formalized, aiming to ensure greater transparency and traceability in bilateral transfers.

Regarding Article 6.4, procedures were established for the submission of projects and methodologies, initial criteria for removals were approved, and rules were defined for the transition of projects from the former CDM. The responsibilities of national authorities were also reinforced, and conditions were created for countries to advance their domestic regulatory frameworks.

With these advances, the concrete operationalization of carbon markets under the Paris Agreement finally became feasible, closing a long stage of negotiations and offering greater legal certainty and predictability for the agents involved.

Brazil's Response to Advances in Negotiations

In parallel with international negotiations, and not without intense debate, the Brazilian Legislature approved in 2024 Law No. 15,042, which establishes the legal framework for the regulated carbon market in Brazil and its interface with the voluntary market.

The new legislation institutes the Brazilian Emissions Trading System (SBCE), with the allocation of quotas (CBEs) for sectors obliged to reduce GHG emissions and the possibility of partial compensation through Verified Emission Reduction Certificates (CRVEs).

Of particular note is a point of special relevance: the law imposes obligations on domestic industry, even though this sector represents a minority share of Brazil's GHG emissions. Such legislative choice raises questions as to its reasonableness, especially in light of other more impactful drivers, such as illegal deforestation and noncompliance with the Forest Code and Conservation Units legislation. This mismatch is even more evident considering Brazil's predominantly clean energy matrix.

Thus, the establishment of reduction targets for the industrial sector seems more closely linked to the need to ensure international competitiveness in the face of regulatory barriers – such as the European Union's Carbon Border Adjustment Mechanism – than to the direct fulfillment of Brazil's NDCs.

The law also recognizes the existence of the voluntary market and provides for the possibility of converting credits generated in that scope into CRVEs, provided the following requirements are met: (i) origin in methodologies accredited by the SBCE managing authority; (ii) independent measurement, reporting, and verification in accordance with approved methodologies; and (iii) registration in the SBCE Central Registry.

Landowners with REDD+ or forest restoration projects may choose to remain in the voluntary market, outside the jurisdiction of the SBCE, through an opt-in or opt-out mechanism, provided that the project is not located in territory under the system's mandatory jurisdiction.

As for Brazil's participation in the international market regulated by Article 6 of the Paris Agreement, the law requires that credits used for international transfers of mitigation outcomes be registered as CRVEs, with prior authorization from the competent national authority and the necessary corresponding adjustments to avoid double counting.

It will be up to the Interministerial Committee on Climate Change (CIM) to define the conditions for such transfers, respecting the multilateral climate regime and Brazil's international commitments. The CIM will also establish the procedures and limits for these transfers based on the Annual GHG Emissions Estimates published by the Ministry of Science, Technology, and Innovation, ensuring alignment with national targets.

Law No. 15,042/2024 thus represents an important regulatory advance, structuring the Brazilian carbon market in line with the instruments set forth in Article 6 of the Paris Agreement. Such alignment enables Brazil to expand its presence in the international market, attract investments, and align market instruments with national and global climate goals.

However, one point of concern is the implementation schedule of the law, which allows up to five years for its full regulation. This timeframe may compromise the effective contribution of the Brazilian regulated market to the 2030 climate targets. During this period, the voluntary market will likely continue to play a relevant role, especially in the forestry sector and in ongoing jurisdictional or private projects.

Given this, it is essential that the Brazilian State act proactively in creating effective economic instruments for incentive, stimulus, and inducement of GHG emissions reductions – not only in the forestry sector but also in industry, infrastructure, and logistics – always from an integrated perspective of environmental, social, and economic aspects.

In this context, defining a business model that is financially sustainable and that balances the three bases of sustainability – environmental, social, and economic – is an indispensable condition to ensure the continuity and legitimacy of climate projects in Brazil, as well as their effective contribution to the global commitments assumed by the country.

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Carbonext Awa REDD+ Project (Pará)

10. Amazon as a Development Platform: the Natura Case

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Geraldo Aleandro, *senior sustainability manager at Natura*

Over the past 25 years, Natura has created in the Amazon a new way of producing, based on care for nature, on science and technology, and on fair partnership with forest peoples. The results of this experience point to a new model of development for the region, with lessons that can be replicated in other regions of the country and the world.

Founded in 1969, Natura is a Brazilian company with a global presence, a leader in cosmetics in Latin America. In 2000, we began an innovative, nature-based experience in the Amazon that was at once a new business and a socio-environmental project. Acting simultaneously on structuring supply and generating demand, we created value flows that, in addition to being profitable as a business, benefit people, communities, and the forest.

The project began with a new line of cosmetics – Ekos, launched that year – and with the first partnerships with communities to obtain Brazil nuts, the first of our Amazonian bioactives. The heart of the initiative is our relationship with these communities, marked by deep mutual learning, over the long term, with objectives that are fundamentally meant to go far beyond the commercial transaction.

In 25 years, the program, later named Natura Amazônia, expanded to 45 extractivist and smallholder communities located along the entire extent of the Amazon, from the foothills of the Andes in Ecuador to its easternmost edge in Maranhão. As a result, there are already 2.2 million hectares of forest protected, avoiding the emission of hundreds of millions of tons of carbon, and benefiting more than 10,000 Amazonian families, who extract from the forest 46 different inputs from biodiversity, driving the company's growth while at the same time expanding its positive impact.

For us, this experience proves that there is another way to produce – a responsible capitalism based on generating value by strengthening natural systems and the human communities connected to them. Brazil's renewable natural resources and biodiversity give it major competitive advantages over the entire world, and on that basis it can build a development model in which the restoration of biomes and of the atmosphere goes hand in hand with the generation of economic opportunities and the reduction of inequalities.

Supply and Demand Simultaneously

The innovation of Natura's model is the integration of communities, nature, and science into our value chains, with simultaneous attention to supply and demand, so as to produce flows that generate value, productivity, and competitiveness.

The demand side largely runs through our Amazon headquarters, the Ecoparque located in Benevides, in the state of Pará. That is where our soap factory is, producing more than half a billion soaps per year to supply all of Latin America. The Ecoparque was conceived to host an ecosystem of industries, startups, and teaching and research centers, connected to our value chains, in the midst of 150 hectares of preserved forest. Our innovation center operates there, where cutting-edge science is conducted, drawing on the forest's traditional knowledge to turn Amazonian bio-ingredients into desirable, high-performance products that generate revenue to feed the entire cycle and to further expand positive impact and its reach.

The supply side is entirely structured in the forest, in win-win partnerships with local communities of smallholders and extractivists. With them we have created quality relationships, with very frequent visits and careful listening to the needs and potentials of each place, in order to be able to chart a long-term project. We support these communities in formalizing themselves as cooperatives or associations, in finding financing, in accessing other income streams – through carbon credits, for example. We provide training, plan production, and transfer technology.

In 20 of these communities there are already agro-industries in operation, built in harmony with the forest, producing butters and oils to add value to forest inputs. A good example is the Ataic factory (Association of Agro-extractivist Workers of Ilha das Cinzas), built on stilts in the Marajó Archipelago, in Pará, with cutting-edge technology powered by solar energy and stored in batteries, designed and supplied by another partner, the Brazilian multinational WEG, specialized in industrial infrastructure. With the industry, local families obtain additional income gains of around 60%, as well as achieving greater autonomy and earning income throughout the entire year, since they work with non-perishable products.

To drive this model, Natura joined with partners and launched an innovative financial mechanism that combines philanthropic resources with returnable credit – a blended-finance structure – to structure sociobiodiversity value chains. The philanthropic side, conceived together with Funbio (the Brazilian Biodiversity Fund), raised BRL 13.5 million in its first round for training programs on regenerative cooperative practices, the promotion of women's and youth leadership, as well as improvements to processing units.

The credit side, created in partnership with the securitization company Vert, financed annual harvests with BRL 13 million granted to associations and cooperatives that supply sociobiodiversity inputs, benefiting 3,860 families in the Amazon. The success of the undertaking can be measured by the repayment rate of these loans: 100%.

This cycle between supply and demand generates prosperity for the entire value chain. In the communities, it not only increases income, but also stability, predictability, and autonomy. Another positive aspect is that the generation of opportunities keeps young people in place, reducing the appeal of rural exodus and of destructive activities. This creates a strong incentive to protect nature, since it is directly connected to the community's livelihood, driving lasting social transformations in the territory.

In an academic study on Natura's mode of operation in the region, recently published in the journal Management Science[1], the authors conclude that "the analysis of the mechanism suggests that increased reforestation and decreased deforestation occurred because Natura aligned the interests of local communities with those of forest conservation." Well aligned, the flows of life in the Amazon are powerful enough to keep everything healthy, including the business.

A fundamental premise of this model is the correct valuation of all impacts generated. Natura collaborated with partners such as the Capitals Coalition to develop an open management tool called IP&L (Integrated Profit and Loss). IP&L records all gains and losses of value, not only financial ones. Human, social, and natural impacts are also counted and converted into monetary values, so as to enable management to see the business, including its externalities. Thanks to IP&L, we were able to verify that for every dollar invested in the Amazon Program, USD 9.40 are generated in socio-environmental benefits.

Long-Term Partnerships

The key to making this model work and produce impact is that it is entirely structured around long partnerships, with the constant pursuit of learning and mutual enrichment. Since the beginning, in 2000, we have been looking for ways to share the benefits of this trade with the communities, remunerating traditional knowledge and the contribution to the genetic heritage of the inputs we use – this long before Brazil's Law on Access to Genetic Heritage and Associated Traditional Knowledge, approved in 2015, to which we contributed.

Long-term alliances, supported by technical assistance, turn local knowledge into productivity and, under joint governance, pave the way to attract co-financiers and maintain a flow of investments in the territory, as well as to create new sources of resources. For example, one of our partner cooperatives, Reca, in Rondônia state, today is able to generate even more income from the sale of forest-conservation carbon credits than from the inputs it supplies to us.

Another long-standing partnership is the one we established with Camta (the Tomé-Açu Mixed Agricultural Cooperative, Pará state). In an alliance that also included Embrapa (the Brazilian Agricultural Research Corporation), over 13 years we jointly developed a new agroforestry system to produce oil-palm trees amid the living ecosystems of the forest.

Palm oil, also known as dendê oil, is the most widely used vegetable oil in the world because of its desirable characteristics – it has low cost, is stable, resistant to high temperatures, and can be processed to become odorless and tasteless. It is the main input of the cosmetics industry, contributing 70% of the mass of our soaps. It is also essential for various other industries, especially the food industry, its largest consumer. The problem is that almost all global palm-oil production is done in monoculture, a system linked to deforestation that generates several socio-environmental harms. Until the beginning of this century, there was a perception

[1] "There Is No Planet B: Aligning Stakeholder Interests to Preserve the Amazon Rainforest". Anita M. McGahan, Leandro S. Pongeluppe. 23/8/2023. Access link: https://pubsonline.informs.org/doi/10.1287/mnsc.2023.4884 Accessed in Aug. 2025.

worldwide that it was impossible to produce palm at scale without these negative consequences.

Over the years of partnership with Camta and Embrapa, it became clear that regenerative palm oil is not only possible – it is more profitable, more productive, and more advantageous for producers than monoculture. In this new agroforestry system, the Oil-Palm SAF, the oil-palm trees are combined with subsistence species such as cassava, squash, banana, rice, and beans, and also with other species with economic value, such as açaí, cupuaçu, cocoa, andiroba, and some trees that provide valuable timber. Thus the ecosystem is restored, attracting animal species and capturing an amount of carbon even higher than that of a mature forest.

It is not only nature that benefits. Farmers' income is also significantly impacted. Over the 25-year cycle, we calculate that it increases by 40% with the implementation of the system. The addition of other activities reduces dependence on a single market, giving resilience and stability to the operation, and spreads income much more evenly throughout the year. The system significantly reduces food insecurity and lowers the cost of subsistence. Over time, thanks to the presence of long-cycle species and the gradual enrichment of the soil, production revenue increases more and more – the opposite of what happens in a degenerative system, which quickly exhausts soils and loses productivity.

In recent years, we have begun to expand this production – in 2025, we reached 650 hectares of Oil-Palm SAF (Sustainable Aviation Fuel), implemented in degraded forest areas such as abandoned pastures and former monocultures. But the potential of this innovation goes far beyond, if we consider the size of the global palm-oil market – around 80 million tons per year – and the large availability of degraded land in the Amazon.

The Future Belongs to the Sociobioeconomy

Over the last century, oil and other fossil inputs were the source of energy for fuels, of materials for industry, and of ingredients for medicines, foods, and cosmetics. Organized in concentrated value chains, this model generated significant gains, but also environmental externalities, such as emissions and residues in the air, soil, and waters, which today systematically pressure natural systems. In this context, the transition to bio-based value chains gains relevance – chains that capture carbon instead of emitting it, are much more distributed, and are anchored in territories and in long-term relationships.

Caring for the planet requires implementing a model that restores living systems and makes them the basis of a new economic-industrial complex that is a driver of social inclusion and economic progress. Over the course of our work in the Amazon, we have become convinced that this model can have at its base the sociobioeconomy, which is the production of value from the harmonious interaction between living nature and the communities that live in it and from it. With advances in science and innovation, the sociobioeconomy can offer growing alternatives to what today depends on oil and other fossil inputs.

If this is one of the keys to the future, then the Amazon has the potential to occupy a position of global relevance in this new era, since nowhere else is there so much natural wealth and so many communities deeply connected to natural ecosystems. But the path from the present to that imagined future is full of obstacles. Today, the logistical, regulatory, and fiscal landscape is frankly unfavorable to the sociobioeconomy.

Agricultural financing standards were historically structured around monoculture. This model has a consolidated track record and predictability, while new forest arrangements or nature-based solutions still lack these references, which restricts the flow of credit to such initiatives, even in the face of evidence of their feasibility and impact. Much of the Amazon lacks land regularization, which creates risks, complexities, and high costs for anyone operating there. As if the logistical difficulties – expected in a naturally challenging region with a great lack of infrastructure – were not enough.

For the world to be supplied by the solutions offered by the forest, intensive capital will be necessary, public and private, national and international, with significant investments in science, infrastructure, technology, education, communication, and transport. Today, a disproportionate share of Brazil's investment in science and technology is still concentrated in the state of São Paulo. In addition, the number of patents linked to the sociobioeconomy remains relatively very low – these proportions need to change.

In the last 25 years working in the Amazon, we have found that the model we helped to develop delivers results, but that does not mean it is finished. What we have achieved is a beginning, but we still have much to learn from the forest and its inhabitants and much to accomplish in this immense region. Perhaps the greatest contribution we can make, for now, is to draw the attention of the country and the world to the potential that is within our reach.

Realizing this potential of the sociobioeconomy depends on many companies choosing to travel this new path, orienting their axis of innovation and their value chains toward nature. The 45 forest communities with which we have established partnerships are the seeds of a model that needs to reach thousands of them, in the Amazon and in many other biomes.

We believe that our contribution can inspire a new development project for the region and for Brazil – one that is far more inclusive and sustainable in the long term, based on what the country has that is most extraordinary: its sociobiodiversity. Its people, its nature.

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Carbonext Awa REDD+ Project (Pará)

11. The Legal Nature of Environmental Assets: The New Frontier

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Introduction

The consolidation of environmental assets as intangible legal assets opens a new frontier in law and global regulation. What were once externalities invisible to the economy are now recognized as assets endowed with title, transferability, and economic value, circulating in both voluntary and regulated markets.

This chapter examines the legal nature of environmental assets along three axes: (i) their classification under civil and economic law, including the notions of civil fruits and defeasible (resolutive) ownership; (ii) international harmonization standards, such as the multilateral mechanisms of the Paris Agreement (Article 6) and International Institute for the Unification of Private Law (UNIDROIT)'s recent study; and (iii) the role of Brazilian legislation, in particular Federal Law No. 15,042/2024 establishing the Brazilian Emissions Trading System (SBCE), Federal Law No. 14,119/2021 on the National Policy for Payment for Environmental Services (PSA), and Federal Law No. 13,493/2017 (Green GDP).

It also analyzes the integration of environmental assets into national economic accounts and into the financial system's regulatory frameworks (Securities and Exchange Commission of Brazil, CVM, and Central Bank of Brazil), highlighting accounting and system-interoperability challenges. It argues that the legal recognition of environmental assets is essential not only for market security and integrity but also for the robust and integrated juridification of environmental assets, enabling the protection of natural capital to become a central pillar of a new green and inclusive economy.

Natural Capital's Economic Value

The debate on the legal nature of environmental assets now occupies a central position at the intersection of law, economics, and climate policy. Whereas environmental protection once relied primarily on command-and-control instruments, the present moment demands that natural capital be assigned economic value. This capital – understood as the stock of natural resources (forests, water, soil, biodiversity) – not only sustains the basis of life but also generates continuous flows of environmental products (tangible, such as timber from sustainable management or bioactives) and environmental services[1] (intangible, such as carbon sequestration, water regulation, pollination, and habitat conservation).

The Brazilian Federal Constitution of 1988, in Article 225[2], established the environment as a common good of the people and essential to a healthy quality of life, imposing on the Government and on society the duty to defend and preserve it. This constitutional foundation underpins subsequent normative evolution – from the Forest Code (Federal Law No. 12,651/2012[3]) and the National Policy on Climate Change (Federal Law No. 12,187/2009[4]) to the current consolidation of environmental assets as autonomous legal instruments.

Internalizing environmental services – formerly perceived as positive externalities without market value – has inaugurated a new category of legally cognizable assets: environmental assets. They manifest the effort to transform diffuse benefits of nature into measurable, transferable rights capable of economic circulation. A crucial question follows: how should the law classify these assets so as to ensure both legal certainty and environmental integrity?

Over the past two decades, a discernible shift has occurred from disparate measures to a structured regulatory framework. Key milestones include the UNFCCC (United Nations Framework Convention on Climate Change); the Kyoto Protocol (1997), which introduced Certified Emission Reductions (CERs[5]) recognized under international law; the Paris Agreement (2015)[6], which established cooperative approaches under Article 6.2 (Internationally Transferred Mitigation Outcomes, ITMOs) and a crediting mechanism under Article 6.4 (emissions reductions); and – sector-specifically ICAO's CORSIA (2016)[7], which set global offsetting standards for international aviation. Most recently, the Glasgow Climate Pact[8] (COP26, 2021) finalized the Article 6 rulebook – detailing integrity safeguards and accounting requirements for both the 6.2 cooperative approaches and the 6.4 mechanism – thereby underscoring the imperative of interoperability across markets.

At the national and regional levels, the European Union pioneered with the EU ETS (2003)[9], the world's first emissions trading system, recognizing carbon credits as regulated proprietary rights. Subsequent initiatives – including California's Cap-and-Trade Program (2012), China's national ETS (2017), and the United Kingdom ETS (2021) – have expanded the compliance landscape; for comparative surveys, see Boyd et al.[10] In

[1] BRAZIL, Federal Law No. 14,119, of Jan. 13, 2021 (National Policy for Payment for Environmental Services – PSA) (defining environmental services and providers). [2] Constitution of the Federative Republic of Brazil art. 225 (1988). [3] BRAZIL, Federal Law No. 12,651, of May 25, 2012 (Forest Code). [4] BRAZIL, Federal Law No. 12,187, of Dec. 29, 2009 (National Policy on Climate Change – PNMC). [5] Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 11, 1997 (introducing CERs under the CDM). See also BOYD; STRECK; VIOLA; PROLO, Carbon Markets and Law (OUP 2022). [6] UNFCCC, Paris Agreement (2015), art. 6 (cooperative approaches under art. 6.2 and the art. 6.4 mechanism). [7] ICAO, CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation), Assembly Resolutions initiating the scheme (2016). [8] UNFCCC/CMA, Decision 2/CMA.3 (Guidance on Cooperative Approaches under Article 6.2) & Decision 3/CMA.3 (Rules, Modalities and Procedures for the Article 6.4 Mechanism), Glasgow (COP26, 2021). [9] EUROPEAN UNION, Directive 2003/87/EC (establishing the EU ETS). [10] Emily BOYD; Charlotte STRECK; Eduardo VIOLA; Caroline PROLO, Carbon Markets and Law (Oxford: OUP, 2022). [11] BRAZIL, Federal Law No. 15,042, of May 27, 2024 (establishing the SBCE; defining CRVEs and CBEs).

Brazil, normative development consolidated with Federal Law No. 12,187/2009 (National Climate Policy) and Federal Law No. 14,119/2021[1] (National Policy for Payment for Environmental Services), reaching a new milestone with Federal Law No. 15,042/2024[11], which created the Brazilian Emissions Trading System (SBCE) and established CRVEs (Certificates of Verified Emission, Reduction or Removal) and CBEs (Brazilian Emission Allowances) as regulated legal instruments capable of circulating in the domestic market.

A parallel development concerns environmental – economic accounting. Since the 1990s, multilateral bodies – including the United Nations, Organisation for Economic Co-operation and Development, and World Bank – have advanced the System of Environmental-Economic Accounting (SEEA[12]) to integrate environmental and macroeconomic statistics. In Brazil, Federal Law No. 13,493/2017[13] ("Green GDP Law") formally mandated the development of growth indicators adjusted for environmental variables. This statutory turn recognizes that conventional GDP does not record natural-capital depletion or the social costs of degradation, thereby creating distortions and obscuring negative externalities.

A broader policy current – reflected in the G20 and the Kunming-Montreal Global Biodiversity Framework (2022)[14] – points toward internalizing negative environmental externalities within national accounts (including GDP). Operationally, this implies recognizing the economic value of emissions, biodiversity loss, soil erosion, and freshwater degradation on both balance-sheet and flow statements. This transition poses significant measurement and reporting challenges: (i) how to value environmental intangibles; (ii) how to recognize and classify ecosystem services in corporate and national accounts; and (iii) how to ensure consolidation and reconciliation across registries to prevent double counting or value overlap.

At this juncture, the debate over environmental assets – and their methodologies for recording, auditing, and pricing – connects directly to national accounts. The same emissions reduction that is treated today as a credit in a carbon market may, in the future, also be incorporated into the calculation of GDP adjusted for natural capital. The challenge, therefore, is to design legal and accounting frameworks that ensure methodological integrity, avoid inconsistencies, and secure international comparability.

This trajectory demonstrates that the juridicity of environmental assets is no longer a hypothesis or academic construct but a normative reality, incrementally built by both international law and domestic legal orders. It is a movement of progressive juridification of the climate, in which emissions reductions and environmental services cease to be intangible externalities and come to be recognized as autonomous legal assets, protected and regulated by laws, regulations, and multilateral treaties10.

From a conceptual standpoint, environmental assets are distinct from the physical asset itself – forest, river, soil – because they are intangible and depend on measurement, report and verification (MRV) to exist legally. They are rights derived from ecosystem services, formalized through instruments or certificates whose value

[12] United Nations et al., System of Environmental-Economic Accounting (SEEA) Central Framework (2012) and SEEA Ecosystem Accounting (2021). [13] BRAZIL, Federal Law No. 13,493, of Oct. 19, 2017 (Green GDP Law). [14] CBD, Kunming–Montreal Global Biodiversity Framework (2022); see also G20 Leaders' Declarations highlighting natural-capital accounting. [15] BRAZIL, Civil Code, Federal Law No. 10,406, of Jan. 10, 2002, arts. 95–96 (civil fruits).

rests on the integrity of the underlying environmental asset. The law is therefore called upon to classify this new object. Are these assets closer to incorporeal assets? Could they be considered civil fruits of natural capital, as contemplated in Articles 95 and 96[15] of the Brazilian Civil Code? Might they constitute a new category of environmental receivables?

This trajectory is reflected in a kind of transmutation of the legal nature of the same emissions reduction. One metric ton of CO_2 equivalent is, at its origin, an environmental service – a diffuse climate benefit of conservation or restoration. When certified by private standards, it becomes a voluntary carbon credit, taking on the features of a tradable intangible asset, suitable for Emission Reduction Purchase Agreements (ERPAs[10]) and potentially treated as a civil fruit of natural capital when deriving from private property. In Brazil, once it complies with SBCE methodologies (Federal Law No. 15,042/2024[11]), it may be qualified as a CRVE, a regulated compliance asset; depending on the form of offering, it may even be characterized as a security, under Federal Law No. 6,385/1976[16] and CVM interpretations (CVM Resolution No. 175/2022; Guidance Opinion No. 40/2023[16]). Finally, if authorized by the State and accompanied by a corresponding adjustment to the NDC (Nationally Determined Contribution), that same reduction may later be recognized as an ITMO6 under Article 6 of the Paris Agreement.

This trajectory underscores the imperative of systemic interoperability. A physical emissions reduction is not, by itself, sufficient: greenhouse-gas accounting must be consistent, double counting prevented, chain-of-title and registration made clear, and valuation aligned with the credit's climate function. Interoperability[8] must be climatic, legal-regulatory, accounting, and technological so that the circulation of credits does not erode their legitimacy.

From a civil-law perspective, understanding these assets as incorporeal assets reinforces the need to apply the bundle of rights constituting property – exclusion, use, enjoyment, and disposition. A nuance arises, however: this is a defeasible (resolutive) ownership[15], because its validity depends on the maintenance of the integrity of the underlying environmental service. The disruption of the ecosystem may entail the loss of the credit's validity, aligning these assets more with the logic of a conditional right than with absolute ownership.

On the financial front, the evolution is equally notable. Through Resolution No. 175/2022, Guidance Opinion No. 40/2023[16], and Circular Letter SSE No. 6/2022, the CVM has opened space for carbon credits to compose investment-fund portfolios (FIDCs, FIPs), reinforcing their nature as eligible assets. The Central Bank of Brazil, with BCB Resolution No. 151/2021, CMN Resolution No. 4,943/2021[17], and BCB Resolution No. 139/2021[17], has incorporated climate risks into prudential regulation, linking them to the Social, Environmental, and Climate Responsibility Policy (PRSAC).

The challenge, therefore, is to consolidate a regime that combines legal certainty, environmental integrity, and economic efficiency. This entails four priorities: (i)

[16] CVM, Resolution No. 175, of Dec. 23, 2022 (investment-fund framework); CVM, Guidance Opinion No. 40, of Oct. 11, 2023; CVM/SSE, Circular Letter No. 6, of June 28, 2022 (securities treatment for carbon credits/receivables). See also BRAZIL, Law No. 6,385, of Dec. 7, 1976 (CVM Law). [17] BCB, Resolution No. 151, of Sept. 15, 2021 (GRSAC); CMN, Resolution No. 4,943, of Sept. 15, 2021 (risk management); BCB, Resolution No. 139, of Sept. 15, 2021 (PRSAC). [18] IFRS Foundation/ISSB, IFRS S1 (General Requirements for Disclosure of Sustainability-Related Financial Information) & IFRS S2 (Climate-Related Disclosures) (2023).

strengthening interoperable registries and chains of title; (ii) aligning accounting and disclosure with IFRS/ISSB[18]; (iii) developing robust regulation to protect rights and the legitimacy of the creation, management, and issuance of environmental assets; and (iv) ensuring fair benefit-sharing with local communities and Indigenous and traditional peoples.

Brazil occupies a distinctive regulatory position. By standardizing multiple dimensions of natural capital into tradable environmental assets and implementing an end-to-end architecture – MRV, issuance, registration/chain-of-title, secondary trading, clearing/settlement, retirement – aligned with the Article 6 rulebook[8], IFRS/ISSB[18] disclosure, and CVM/BCB supervision[16], the country is positioned to serve as a reference jurisdiction for climate governance and carbon-market infrastructure.

This leadership can be further reinforced by full implementation of the Green GDP Law (Federal Law No. 13,493/201713), which inserts the environmental dimension into national economic statistics, enabling negative externalities to be incorporated into official development indicators. Advancing toward a unified legal statute for environmental assets – combined with environmental accounts integrated into GDP calculations – will consolidate the value of natural capital not only in financial markets but also in the macroeconomic indicators that guide public policies and strategic investment decisions.

Ultimately, this means shaping a new legal-economic paradigm in which environmental assets cease to be merely instruments of offsetting or market titles and become structuring pillars of a green and inclusive economy. The new frontier is not merely recognizing the economic value of natural capital, but endowing it with a clear, solid, and interoperable legal regime that allows emissions reductions and other environmental services to move legitimately from the ecological to the financial plane, from the local to the global.

This is the path for environmental assets to fulfill their historical promise: to reconcile environmental integrity with economic logic, transforming nature protection into a central axis of the new economy and of climate geopolitics.

■

Glossary of Terms and Acronyms

Environmental asset – Intangible right associated with an environmental/ecosystem service (e.g., one ton of CO_2 avoided, a hectare of preserved forest), subject to registration, title, and trading.

Natural capital – Stock of natural resources (forests, water, soil, biodiversity) that generates flows of environmental goods and services.

CBEs (Créditos de Compensação de Emissões) – Credits regulated by Law No. 15,042/2024 for mandatory compliance compensation within the SBCE.

CERs (Certified Emission Reductions) – Emissions reduction credits created by the Kyoto Protocol (1997) under the Clean Development Mechanism (CDM).

CORSIA – ICAO's global scheme (2016) establishing offset standards for international aviation.

CRVEs (Créditos de Redução Verificada de Emissões) – Credits regulated by the SBCE (Law No. 15,042/2024), tradable in the national market, linked to measured and verified emissions reductions.

CVM (Comissão de Valores Mobiliários) – Brazilian Securities Commission, the federal authority regulating the capital markets, including potential characterization of carbon credits as securities.

ERPAs – Emission Reduction Purchase Agreements used in both voluntary and compliance markets.

EU ETS – European Union Emissions Trading System created in 2003, a pioneer in regulating carbon credits as proprietary rights.

IFRS/ISSB – International standards guiding disclosure and recognition of environmental assets.

Intangible – Incorporeal good without physical materiality but with economic or legal value.

Systemic interoperability – The ability of different systems (climate, legal, financial, technological) to recognize and validate the same credits or assets without loss of integrity or duplication.

ITMOs – Internationally Transferred Mitigation Outcomes under Article 6 of the Paris Agreement.

MRV – Measurement, Reporting and Verification practices ensuring integrity of reductions or services.

NDC – Nationally Determined Contribution under the Paris Agreement.

Green GDP – Brazilian framework (Law No. 13,493/2017) calling for development of growth indicators adjusted for environmental variables.

PSA – Brazil's National Policy for Payment for Environmental Services (Law No. 14,119/2021).

SBCE – Brazilian Emissions Trading System (Law No. 15,042/2024).

SEEA – UN/OECD/World Bank methodology integrating national accounts and environmental statistics.

UNIDROIT – International Institute for the Unification of Private Law, drafter of the 2023 Draft Principles on the Legal Nature of Verified Carbon Credits.

VCCs – Voluntary Carbon Credits issued by private standards (Verra, Gold Standard, ART TREES).


Capivara (Hydrochoerus hydrochaeris)

12. Climate Additionality and Integrity in Carbon Projects

Diana Rodriguez-Paredes, *NBS technical advisor at Shell*

Luiz Fernando de Moura, *Technical Director at Carbonext*

Introduction

In a context of growing climate urgency, carbon projects have gained prominence as tools to mitigate greenhouse gas (GHG) emissions. They provide a complementary solution to public policies by channeling private investments into actions that promote environmental conservation, sustainable land use, and the development of productive alternatives. However, for these projects to genuinely contribute to global climate stability, they must be technically and environmentally additional and robust, as well as socially fair.

This chapter aims to explore the technical and conceptual foundations that underpin the credibility of NBS (Nature-Based Solutions) voluntary carbon projects: the logic of emissions and removals quantification, the demonstration of additionality, the importance of permanence of generated reductions, and the overall integrity of the projects. The chapter also addresses the instruments and organizations that support the market in adhering to high-quality standards. Understanding these pillars is essential for anyone involved in or interested in this evolving market.

What is Carbon Quantification?

Beyond carbon dioxide (CO_2), other gases also contribute to the greenhouse effect. Their impact is converted to that of CO_2, yielding the CO_2 equivalent (CO_2e), considering their Global Warming Potential (GWP, see examples in Figure 1). In the case of CH_4 and N_2O, these are important gases to be considered in NBS projects as they could be emitted during biomass burning. N_2O is also associated with the use of nitrogen-based fertilizers.

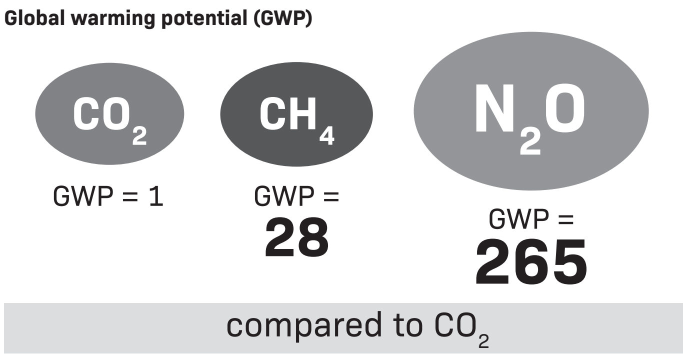

Figure 1. Global warming potentials (GWP) for examples of greenhouse gases

Carbon quantification is the technical process of measuring how much CO_2 (or CO_2e) is avoided, reduced, or removed from the atmosphere through a project (see Figure 2).

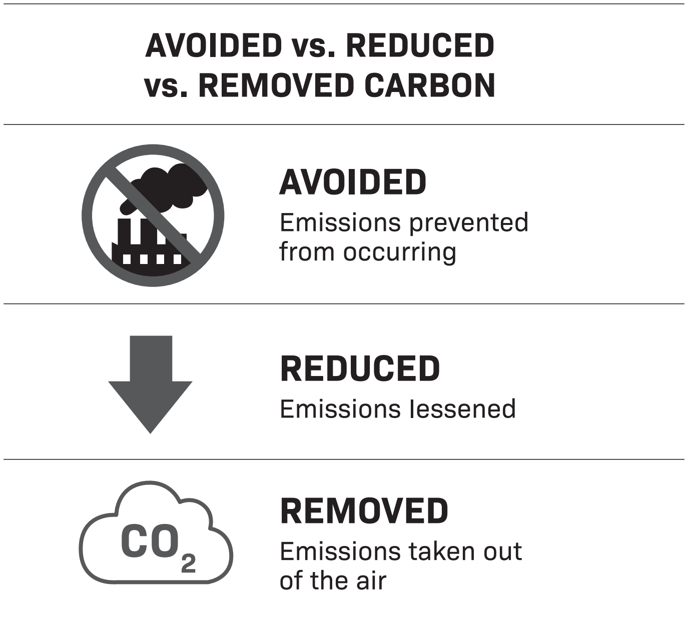

Figure 2. Approaches of carbon projects to mitigate emissions or reduce the presence of greenhouse gases in the atmosphere.

This quantification may involve direct methods, such as forest inventories and sensor-based monitoring (e.g. band-type electronic dendrometers, point dendrometers, for continuous diameter measurements), or indirect methods, such as mathematical modeling and remote sensing analysis.

The baseline concept

For quantification of its additional benefits, every project must define a baseline – a reference scenario representing what would occur in the absence of the project intervention. The project's effectiveness is then measured by the difference between the baseline scenario and the project scenario (Figure 3).

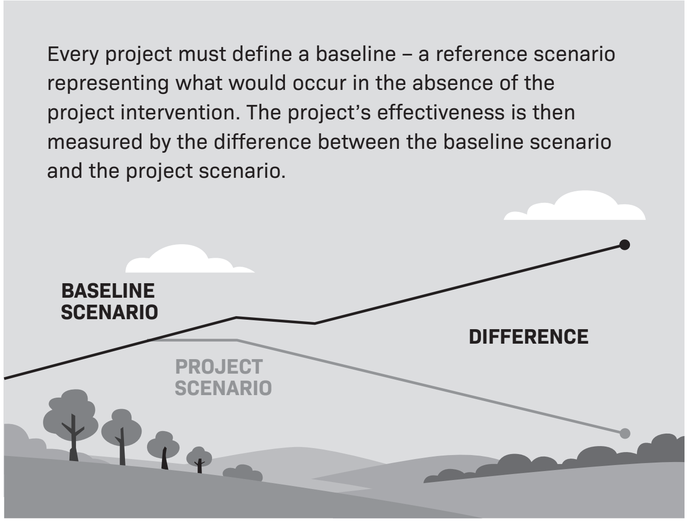

Figure 3. Schematic concept of the baseline compared with the project benefit scenario.

The estimation of carbon credits generated by a project is based on the net balance of reduced emissions or sequestered carbon, after adjustments for project emissions, leakage, and non-permanence risks. Given the incidence of these deductions, it is essential to exercise caution when conducting preliminary estimates to assess a project's viability. These deductions must be anticipated and incorporated into the analysis, rather than relying solely on the gross benefits of a project activity. These are the key components:

1. Carbon Benefits - Emission Reductions/Removals

This is the core of the project. It refers to the amount of GHGs that were not emitted or were removed from the atmosphere compared to a business-as-usual baseline scenario and that are attributed to the implementation of the project. NBS carbon projects include:

- REDD+ projects (Reducing Emissions from Deforestation and Forest Degradation) estimate emissions reduced through prevented deforestation as expected in a business-as-usual scenario.

- ARR projects (Afforestation, Reforestation, and Revegetation) estimate carbon sequestration in biomass and soil from planted trees.
- ALM projects (Agricultural Land Management) estimate carbon stock changes and emission reductions through improved agricultural practices such as reduced tillage, cover cropping, nutrient management, and agroforestry.
- IFM projects (Improved Forest Management) estimate emission reductions and enhanced carbon sequestration by modifying forest management practices to increase carbon stocks in existing forests, such as extending rotation ages, reducing harvesting intensity, or conserving previously harvested forests.

2. Project Emissions

These are GHG emissions directly associated with project activities within the project area, such as fuel combustion for field operations (e.g., logistics, mechanized operations, power generators), emissions from controlled burning, extraction of commercial timber under sustainable forest management or methane/N_2O emissions in agricultural projects. If material, these must be monitored and subtracted from gross reductions/removals to calculate the net gain.

3. Leakage

Leakage occurs when project activities cause emissions outside the project area, either directly or indirectly (e.g., deforestation shifts beyond protected zones; land-use changes in surrounding areas triggered by the project). A deduction (in tons of CO_2e) is applied based on modeling, historical estimates, or specific monitoring.

4. Non-Permanence Risk and Buffer

Land-use and forestry projects face the risk that reduced emissions or removed carbon may not remain stored over time, due to different variables such as fires, degradation, or legal instability (e.g., legal changes making certain practices mandatory and resulting that those practices become not additional).

To address this, a percentage of net reductions/removals (reductions/removals after the deduction of project emissions, baseline and leakage) is set aside in a buffer pool, a collective reserve managed by the certifier (e.g., Verra, Gold Standard).

The estimate is based on risk tools (e.g., Verra's AFOLU Risk Tool), standard discounts (e.g., GoldStandard), or other specific methodological provisions, in case of other standards.

Additionality: The Heart of Credibility

Additionality is one of the most important – and also most debated – pillars of carbon project integrity. It addresses the key question: does the project only occur because of carbon credits? If the project would have taken place without carbon revenues, it is not additional and thus should not generate valid credits. In other words, the additionality analysis assesses whether the carbon project scenario is truly distinct from the baseline.

Additionality can be assessed through several complementary lenses:

- **Legal:** The project must not be legally required.
- **Financial:** The project is not financially viable without carbon revenues.
- **Technical or Institutional Barriers:** The project overcomes real-world implementation challenges.
- **Behavioral:** The project represents an uncommon practice in the region.

Without additionality, a project may generate credits for emission reductions that would have occurred in the absence of the project. While these reductions may be real, they cannot be attributed to the project's intervention, thereby undermining market integrity and diverting investments from truly impactful climate solutions.

Permanence: Ensuring Long-Term Impact

Carbon projects must ensure that carbon stocks are maintained over time. This is particularly important for NBS projects for which risks of reversal (e.g., fire, land invasions, future deforestation, or management failure) compromise the environmental validity of the credits.

Therefore, the best practices dictated by independent bodies such as the Integrity Council for the Voluntary Carbon Market (ICVCM) or even Art 6.4 (United Nations Framework Convention on Climate Change, UNFCCC) require strategies to mitigate these risks:

- Non-permanence risk assessment;
- Mandatory contributions to a buffer pool (a credit reserve acting as collective insurance);
- Continuous monitoring and periodic audits;
- Potential credit replacement mechanisms in case of loss (e.g., insurance).

Technology-based projects (e.g., renewable energy, methane capture from landfills) usually have lower reversal risks but must still ensure continuous operation.

Environmental and Social Integrity of Projects

A high-integrity project delivers on its promises while respecting the environment, human rights, and local communities. This entails:

- Environmental integrity: Accurate measurement, conservative baseline, risk management;
- Social integrity: Active community engagement, Free, Prior and Informed Consent (FPIC), accessible grievance mechanisms;
- Co-benefits: Income generation, inclusion of women and youth, biodiversity conservation.

Good practice requires the demonstration and monitoring of social and environmental safeguards (e.g., working conditions, human rights, environmental impacts), thereby strengthening project governance and reducing risks related to social and environmental issues. Projects that ignore social impacts or concentrate benefits among a few actors lose legitimacy and face growing resistance from buyers and regulators.

Sustainable Development Goals

Good practice requires a minimum number of Sustainable Development Goals (SDGs) to be addressed and some standards offer complementary certifications that enhance social and biodiversity outcomes (e.g., Verra's Climate, Community & Biodiversity Standards, or CCB, and Sustainable Development Verified Impact Standard, or SD VISta).

SDG 13 ("Take urgent action to combat climate change and its impacts") is intrinsic to the climate objectives of these projects. Integrating other SDGs into project design is not only desirable but strategic: it aligns the project with global best practices, enhances local legitimacy, builds resilience to social and reputational risks, and creates pathways for multidimensional, transformative impact beyond mere carbon accounting.

With regard to Rights Recognition and Social Inclusion (SDGs 1, 5, 10, 16), well-structured projects must account for customary rights, collective lands, gender equality, and participation of traditional peoples and local communities. Instruments such as FPIC are practical tools to achieve these aims.

Adopting SDGs linked to collective and sustainable benefits (SDGs 2, 8, 12) encourages projects to develop sustainable economic alternatives (e.g., forest value chains, regenerative agriculture, or community-based tourism), promoting food security (SDG 2) and decent work (SDG 8).

Likewise, integrating SDGs related to participatory governance and institutional strengthening (SDGs 16, 17) fosters the establishment of local governance structures (e.g., community councils, deliberative forums), transparency, accountability, and conflict resolution.

The Role of Methodologies and Standards in Carbon Projects

Certification standards and methodologies serve as the "rules of the game" in carbon markets, offering the technical guidance and minimum criteria every project must meet to ensure predictability, comparability, transparency, and environmental and social integrity. The credibility of the quantification relies heavily on the methodology chosen.

Organizations such as Verra (USA), Gold Standard (Switzerland), and Climate Action Reserve (USA), to mention a few, function as certifiers, responsible for developing and publishing methodologies and for validating and verifying projects through accredited third parties.

What Are Methodologies?

Methodologies are normative documents that standardize how to calculate, monitor, and report GHG emission reductions or removals for a specific project type (e.g., reforestation, REDD+, regenerative agriculture, etc.).

They ensure that reported climate impacts are measurable, additional, verifiable, and permanent – the pillars of environmental integrity.

What Do Standards Require?

These standards and methodologies impose a set of technical and procedural requirements, generally summarized as:

- Clear definition of scope, boundaries, and baseline: The type of intervention, the exact geographical area, and the baseline scenario must be defined.
- Demonstration of additionality: The project must prove that GHG reductions or removals would not have occurred spontaneously, whether due to economic, legal, or practical reasons.
- Monitoring plan: A robust, detailed plan specifying how and when data will be collected, verified, and reported (including environmental, social, and carbon parameters).
- Conservative and methodology-compliant calculations: Emission reduction or removal calculations must follow the methods outlined in the applicable methodology, using conservative approaches to avoid overestimation. Appropriate deductions must also be quantified, such as project emissions, the non-permanence buffer and leakage discounts.
- SDGs and environmental and social safeguards: Many standards require projects to identify SDGs they contribute to and to assess and mitigate potential social and environmental impacts.
- Third-party validation and verification body (VVB): Every project must undergo initial validation and periodic verifications by independent auditors accredited by the certifier.
- Public reporting and regular audits: Transparency is mandatory. Key documents (e.g., Project Description, Monitoring Report, Validation and Verification Reports) are published on registries like Verra Registry for public and technical scrutiny, including through public consultations.

Ongoing Methodology Updates

Over time, methodologies undergo regular updates to:

- Incorporate new scientific and technological advances (e.g., remote sensing, dynamic models, AI);
- Respond to increasing integrity and co-benefit demands in voluntary and regulated markets;

- Address emerging climate, social, or regulatory risks;
- Align with global frameworks (e.g., Paris Agreement Article 6, Integrity Council for the Voluntary Carbon Market, Science Based Targets initiative).

This evolution ensures that carbon credits remain robust, reliable, and accepted by discerning buyers, while raising the technical standard of projects globally.

Changes Toward Greater Integrity: The Case of the Core Carbon Principles

The Integrity Council for the Voluntary Carbon Market (ICVCM), an independent non-profit governance body that works to establish and maintain worldwide standards for integrity in the voluntary carbon market, created the Core Carbon Principles (CCPs) to establish a minimum quality benchmark for carbon credits. The CCPs function as a cross-cutting quality seal, applicable to any standard (e.g., Verra, Gold Standard, Architecture for REDD+ Transactions) seeking alignment with the best global practices.

The 10 key pillars of the CCPs are:

- **Effective Governance:** Carbon-crediting programs must be well-managed, transparent, and accountable, with strong oversight and conflict-of-interest policies. Effective governance builds the foundation for a high-integrity carbon market by ensuring that crediting systems are credible, reliable, and free from undue influence.
- **Tracking:** Credits must be uniquely identified, securely recorded, and tracked to prevent double counting or fraudulent claims.
- **Transparency:** All key information (e.g., methodologies, project data, verification reports) must be publicly available and easy to access (registry).
- **Third-Party Validation and Verification:** Projects must be assessed by independent, qualified validators/verifiers to ensure credibility and accuracy.
- **Additionality:** Projects must demonstrate that their climate benefits (emission reductions or removals) would not have occurred without the project.
- **Permanence:** Carbon benefits must be durable. If there's risk of reversal (e.g., forest fires), mechanisms like buffer pools must be in place to manage it.
- **Robust Quantification:** Emissions reductions/removals must be measured using conservative, science-based methods that avoid overestimation.
- **No Double Counting:** Credits must not be claimed more than once – by any country, company, or person – for the same benefit.
- S**ustainable Development Benefits and Safeguards:** Projects must contribute to sustainable development and protect environmental and social rights, including human rights and biodiversity.
- **Contribution to net-zero transition:** Projects must result in positive carbon impacts and avoid any actions that are incompatible with the objective of achieving net-zero GHG emissions by mid-century.

Most methodologies and standards are currently being revised to meet CCPs. Institutional buyers and platforms like CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation[1]) may soon only accept CCP-aligned credits. Thus, low-integrity projects or those with methodological flaws risk exclusion from premium markets. The CCPs are redefining quality criteria in the voluntary carbon market and represent an essential step toward a more reliable, environmentally sound, and socially just system.

[1] CORSIA is a global climate initiative led by the International Civil Aviation Organization (ICAO) to address greenhouse gas emissions from international flights. It aims to help the aviation sector achieve carbon-neutral growth from 2020 onward by requiring airlines to offset the growth in emissions above 2020 levels.

The Role of Carbon Ratings

High-quality projects implement good practices in terms of quality criteria (e.g., clear additionality, community engagement, robust monitoring, swift risk responses etc.). In contrast, controversial projects often fail to document baselines, exaggerate benefits, or neglect social impacts.

Carbon ratings agencies are independent institutions that assess the quality, integrity, and risk of credits generated by projects in voluntary carbon markets. Leading agencies include Sylvera, BeZero, Calyx Global, and Renoster. They typically evaluate additionality, quantification accuracy (i.e., effective accounting of emissions/removals from baseline, project activities, leakage etc.), non-permanence risks, leakage risks, methodological compliance, governance robustness, general safeguards, SDG contributions, and legal issues. Many of these criteria are directly linked to the logic defined in the CCPs. These assessments offer a "second opinion" for institutional buyers, reducing information asymmetry and providing comparable ratings (e.g., A, B, C, or numeric scales) to support investment decisions.

Ratings influence capital flows: institutional investors and climate funds use them to define purchasing criteria. Thus, ratings are seen as instruments that can potentially improve transparency due to its independent and integrity-oriented cause.

Low-rated projects suffer market devaluation due to perceived high risk, questionable additionality, poor governance, among other poor-quality criteria. Conversely, high-rated credits are seen as more trustworthy, lower-risk, and impactful, attracting demand from reputation-conscious corporate buyers and achieving premium CO_2e prices.

Conclusion

Attention to carbon quality has increased greatly in response to criticism about the validity/credibility of projects to deliver the actual carbon benefits they claim (e.g., inflated baselines or weak calculations that result in overestimations).

In an attempt to set clear guidance on high-quality projects, organizations such as ICVCM have defined key quality criteria related to governance, emissions impact and sustainable development. Key criteria to consider in terms of emissions impact involve quantification (including monitoring), additionality, permanence, baseline, and leakage, which form the technical foundation of carbon projects.

High-quality carbon projects deliver climate mitigation benefits considering social and environmental safeguards to demonstrate no negative impact, and have the potential to contribute to sustainable development. The latter is demonstrated by identifying, monitoring and reporting on the SDGs that project activities relate to.

An important part of the credibility of the carbon credits includes effective governance, traceability, transparency and third-party validation and verification. Certification standards have become a key factor for the market as they create processes, methodologies and guidance for estimating climate mitigation impacts. Under the growing concern about quality of projects, rating agencies are gaining traction as third-party organizations that help the public assess the quality of carbon projects.

It is important for professionals in the sector and the general public to understand key quality criteria to be able to increase the demand for high-quality credits not only as a differentiator but as a commitment to our future.

■

Carbonext Awa REDD+ Project (Pará)

13. The Tropics and Agribusiness: Building Blocks for a Powerful Solution

Ingo Plöger, *Brazilian entrepreneur, president of the Latin American Business Council (CEAL) and vice-president of the Brazilian Agribusiness Association (ABAG)*

The Planet's Growing Overload

The world has roughly 50 billion hectares of surface area. Of that, two thirds are water and one third is land. Of this one third of land, one third is arable land (5 billion hectares) and the remainder comprises deserts, ice, natural forests (4 bn ha), cities, roads, etc.

Of the arable land (5 billion hectares), two thirds are pastures and one third (1.5 billion hectares) is used for crops.

Today, humanity – 8 billion people – consumes around 10 billion tons from agriculture. Of those 10 billion, 60% are for food and 40% for non-food products (fibers, cotton, pulp, fuels, leather, rubber, etc.).

The consumption of animal proteins is no more than 1 billion tons – i.e., less than 10% of agricultural production and 16% of food. Yet two thirds of the areas are devoted to pasture, while the food base (cereals, tubers, fruit) uses only one third of the cultivated area. Over the course of human development, pastures came to dominate the area used to supply protein to the population. FAO research shows that the world's preferred food is proteins, but storage is a critical factor because they are perishable.

Food has always been a security issue for governments. Scarcity leads to food insecurity and quickly to instability in governance. Food security prioritizes the production of staples (cereals and tubers), followed by proteins, which are more expensive and problematic to produce and supply.

Pastures are also a concern because they require a great deal of land and are the first step toward desertification. In the latest UNCCD (United Nations Convention to Combat Desertification)[1] report, two thirds of the world's pastures are degraded, causing losses of USD 300 billion per year. Between 2015 and 2019, there were 100 million hectares degraded, affecting 3.2 billion people, with 1.3 billion directly exposed to degradation.

[1] UNCCD https://www.unccd.int/sites/default/files/2025-02/2424286E.pdf

Little is said about the disproportionality between pastureland, demand for animal proteins, and the risk of desertification. There is enormous developmental room to explore. In Gaia Principle[2] terms, desertification is the greatest danger to the planet.

Another relevant point is attention to non-food products. We often associate agriculture with food and energy security (biofuels). However, 40% of non-food agricultural production goes to household energy (firewood) in low-income countries with little electrification or natural gas distribution.

Another growing demand is for biofuels (ethanol, biodiesel). In integrated industries, biomass is used for cogeneration, as in the food, pulp, and ethanol industries. The paper and pulp industry is growing due to paper replacing fossil-based materials in packaging and lifestyle changes. Per-capita tissue consumption is 25 kg/year in the U.S., 15 kg/year in Europe, 6 kg/year in Latin America, under 5 kg/year in China, and below 5 kg/year globally. It's easy to imagine this demand growing as countries' economies develop.

Products such as cotton replace synthetic fibers, and natural rubber replaces synthetic rubber. Growth in this non-food segment of natural products is outpacing that of edibles. We will also see demand for sustainable aviation fuel (SAF) and marine fuels, as well as bio-origin pharmaceutical and chemical inputs.

Agriculture as a Solution to Climate Change

Natural forests are in photosynthetic balance: they produce and absorb oxygen and carbon dioxide. Photosynthesis is an endothermic biochemical process – i.e., it needs heat from light. Natural forests are not the "lungs of the world," but the "refrigerator of the world." Growing forests absorb heat and carbon dioxide to form roots, trunks, and leaves, and they produce oxygen – thus being both "lungs" and "refrigerator." Phytoplankton are the oxygen producers, so more credit should go to the oceans than to forests.

Natural forests cover nearly one third of the earth's surface (about 4 billion hectares), with 50% concentrated in five countries: Russia (0.8 bn ha), Brazil (0.5 bn ha), Canada (0.35 bn ha), the U.S. (0.31 bn ha), and China (0.22 bn ha). The largest tropical forests are in Brazil, Indonesia, and the Democratic Republic of Congo. The value of natural forests lies in their power for biodiversity, preservation of springs and waterways, and the evapotranspiration in photosynthesis that generates "flying rivers" which irrigate other regions.

Cropland occupies one third of arable land, producing cereals, tubers, vegetables, fibers, with the remaining two thirds used for pasture. Protein production is increasingly confined, requiring less area and achieving high productivity. However, it needs grains such as corn and soybeans for feed, so industrial intensity must be correlated with the area needed to plant those crops. Soy's value is tied to animal protein because of its energy and protein content.

If, until a few decades ago, the biggest problem with animal protein was preservation, today modern processing makes it viable. Until the start of this century, protein was preserved through salting, curing, or smoking. Today, global cold chains make this a high-demand solution.

Humanity will likely number 11 billion people by 2050. The demand for food security will rise. Countries in crisis will need to increase local production through connectivity, knowledge, and productivity. This will be

[2] Developed by the scientist James Lovelock, according to whom the entire surface of the Earth, including life, is a superorganism

a general theme, even if the trend does not assert itself in the short term due to the rollback of globalization.

Protein solutions will also lie in local economies, but with a growing development of international supply. International trade in food products accounts for no more than 8% of world production. While grains (especially soy) are increasingly competitive for supplying animal protein production, other cereals will only cover shortfalls, not serve as the mainstay. Therefore, domestic markets will remain a priority for a long time. On the other hand, the trend toward non-food agriculture will become more evident in globalization. The need for biofuels and other fossil-substitute products of biological origin will grow faster than the world economy.

The challenge posed by these structural trends will be to use land and increase productivity without touching native forests. Solutions will come from science and technology in connecting the countryside – bringing digital processes to farms, which will become "open-air factories." Public policies can steer degraded land toward Crop-Livestock-Forestry Integration (CLFI/ILPF) or toward improved productivity in cattle management. In both cases, upfront investment in restoration will be essential, turning year-one capex into opex for the following years.

Land degradation will be the main focus, and farmers will first choose less degraded lands. Recovery of the most degraded areas will certainly be led by players like Israel, which restores areas considered desert. Between these and less severe cases, we will see all kinds of variation, experiments, and innovations.

Farmers depend deeply on their land – on soil quality, seed, knowledge, and innovation. No serious farmer disrespects Nature, because it would undermine their very existence. Their solutions contribute to life's processes, maintaining and developing their own livelihood and that of others, expanding productive area and the broader Gaia system.

Many entities and sectors sought to contribute to COP30 in Belém. The Brazilian Agribusiness Association (Abag) held a symposium with experts and stakeholders in tropical agriculture: producers, finance, policymakers, academia, and consumers. The suggestions were developed and debated, resulting in a document[3] inviting agriculture in all countries to take part in solution-oriented debates, because agriculture is more a solution than a problem for the environment and climate change.

Global and Local Efforts and Sovereignty in Climate Change

The United Nations Conference on Environment and Development (Rio-92 or Earth Summit) was an important global step toward climate solutions. Various concepts and measures were adopted worldwide, and the definition of sustainability was universalized as economic, social, and environmental development. Note that this definition wasn't obvious: developed countries wanted to focus on the environmental pillar, and Brazilian leadership ensured that the economic and social pillars were included in the final definition. Three decades later, ESG (Economic, Social, Governance) began to supplant the sustainable development concept, adding governance and dropping the economic pillar.

The U.S. never fully embraced Europe's ESG concept, but it imposed itself globally. In the Trump II era, ESG lost salience in the U.S., reverting to a competitiveness-first principle without constraints. Nonetheless, over these decades, consumers around the world have

[3] https://abag.com.br/wp-content/uploads/2024/11/solucoes-climaticas-da-agropecuaria-a-caminho-da-cop30.pdf

adopted a more socially and environmentally responsible mindset – an attribute for products and services that is here to stay. How much should be regulated or incentivized is the contemporary question.

The European Union overreached on environmental regulation in recent years and now faces a steep economic bill that the public is unwilling to pay. Europe's environmental movement has perceived its limitations. Through the Draghi Report on EU Competitiveness[4], the European Commission is seeking a new balance among the social, environmental, and economic pillars. The Commission brought the most elaborate and sophisticated climate-change concepts into international relations. In establishing its Green Deal, it sought to speak with one voice at COP26 in Glasgow.

The EU set internal measures to offset carbon and defined each country's decarbonization targets through 2050. But after the elections, a Parliament with greater green representation internationalized the Green Deal, setting rules for those who wish to export to Europe. The EUDR (EU Regulation on Deforestation-Free Products) emerged, regulating purchases of products linked to deforestation. Likewise, CBAM (the EU Carbon Border Adjustment Mechanism) regulates imports of products that embody fossil energy. These measures were decreed unilaterally and create problems for European buyers, who are the ones held accountable.

Europe's recession shows that multiple extreme measures left industry unable to adapt in time, leading to falling sales and unemployment. A classic example is the auto sector. The EU decreed that as of 2035 only electric vehicles could be produced, not combustion vehicles. Subsidies for EVs were cut in 2024, and combustion vehicles are fined for CO_2 emissions above quotas. The result: consumers returned to combustion cars – which can no longer be produced beyond the quota – and new EV plants sit idle. Over-regulation triggered a recession in the auto sector.

Evidently, this policy's Technology Assessment shows the side effects are worse than the primary objective. The same will occur with EUDR and CBAM, and the question is how the EU will escape this trap without "losing face."

In Brazil, the government and Congress crafted rules that encourage production of vehicles that emit less fossil carbon, and any technology aiming at that target will be preferred. Innovation steps in to make the difference in biocompetitiveness.

After Rio-92, many international agreements were signed, such as the Kyoto Protocol and the 2015 Paris Agreement. They set targets and compensatory measures for developing countries. COP29 in Azerbaijan defined procedures, but not the amount to be paid, and COP30 should seek that understanding.

Since Rio-92, debate has grown about transferring national sovereignty to international bodies.

It's not the first time agreements have transferred sovereignty to higher-credibility, enforceable instances, as with the WTO (World Trade Organization) and WHO (World Health Organization). This is how countries negotiate and establish fair balances today – a new sovereign competence to avert a greater harm. When we once again invoke "sovereignty," in fact we shrink the common good of humanity to the national common good – a step backward. This isn't only about environmental sovereignty; Europe has also invented "food sovereignty" to justify protectionist measures.

[4] https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

Excess on all sides leads to deadlock. On one hand, by unilaterally bringing its concerns about deforestation through EUDR and CBAM, the EU overreached by failing to recognize regional particularities and differing legislation, imposing its vision and methodology. On the other, the American unilateralism of Donald Trump II – taxing importers for any reason deemed just for the U.S. – puts power politics on the table, disregarding balance among parties.

This new international setting is unfavorable to sustainable long-term agreements. Each will seek the greatest potential self-interest. The system we had – WTO, IMF (International Monetary Fund), and World Bank – were governance arenas where countries like Brazil called for changes and reforms. Under current circumstances, a system emerging from power politics will have American, European, and Chinese predominance. There will be alignment pressures that will only partially work: the powerful will exert influence, and the less powerful will adapt as best they can.

Using game theory, while powerful countries choose MAXIMIN (maximize minimum gains), developing countries will choose MINIMAX (minimize maximum losses). In this game we will have a more unequal and insecure world. Climate will not be the top priority and will weigh less than the economic and social.

However, with a more aware world and more attentive consumers/voters, purchase decisions will continue to factor in social justice and environmental issues. There will be a price to pay for this global awareness. Socially, having no bad news about a product or service is essential, because reputation has a price – in stock value, on the shelf, in credit, in talent retention, and in preference.

On the environmental side, the game will have to bring in a new component: biocompetitiveness[5].

Biocompetitiveness and the Tropical Economy

The U.S. will follow the path of competitiveness, as will Europeans. While Americans compete first and then see if there was harm, Europeans look first at potential harm and bar operations if there is suspicion. It's always been this way. American risk principles differ from European ones: Americans foster competition, believing free enterprise makes the difference. Europe invented the precautionary principle, which bans beforehand, reducing innovative and competitive power as it tries to shield consumers from any imaginable danger. This debate is visible in AI and social-media issues. Pragmatic China adopts whatever is convenient.

Thus, the competitiveness game is on, and countries need to choose their paths.

In that game, those who can add attributes that offer value to the consumer will win preference – not only on price, but especially on attributes. Assigning value through product sustainability will necessarily require demonstrating those additionalities.

The great advantage for those who have biocompetitiveness on their side is needing less investment and getting faster returns, becoming a relevant competitor when consumers choose. Whenever you invest in your true vocation, you end up better off – thanks to motivation, resilience, and lower spend.

Biocompetitiveness looks very favorable in a tropical world. The Tropics have photosynthetic power three times higher than temperate climates. In other words, plants tend to grow and produce at an accelerated pace,

[5] Expression coined by Caio Carvalho at the Abag Congress in 2023.

since both winter and summer continue to be productive seasons, unlike temperate climates.

For many decades, agricultural technologies and know-how used in the Tropics came from temperate countries. Only in recent decades have innovations in soil management, seed, planting, harvesting, and processing driven agricultural productivity to record after record in tropical production.

Understanding of tropical realities is only beginning. With digital innovations in the field – dependent on connectivity for procedures that still operate at small scale – productivity will rise markedly in coming years. So will traceability, to ensure origin and quality.

In many cases, tropical farms have three different crops in a single year – corn, sorghum, and soy, for example – which require different attention and equipment, bringing huge logistical challenges. These equations signal investment potential and expanding markets.

In livestock and animal proteins, the historical issue of storage and spoilage is solved by end-to-end cold chain logistics. Today Brazil provides differentiated cuts according to religious cultures or customs – in time, with quality, and at competitive prices. These are more than strong signs that biocompetitiveness is linked to the strength of tropical nature.

Regarding non-food products, a major structural demand continues in fibers and biofuels. If current demand is on the order of 100 billion liters of biofuels, with the advent of SAF and marine biofuels, talk is of doubling production within 10 years. Tropical countries will find in biocompetitiveness a path to development.

Certainly the “land use” argument will arise – that by producing non-food outputs there won’t be enough land for them. Yet, as noted, two thirds of the world’s areas are pasture and 40% are degraded, with desertification risk. By seeking alternatives in these lands, we will have a double sustainability rationale: substituting fossil resources and reducing desertification.

We must still pursue, within biocompetitiveness, rigorous and credible metrics. This is a field where the short term is no friend, but perseverance and a science-based search for the truth of facts can make a significant difference. Preserving tropical forests, beyond being indispensable, will have to prove economically viable for those who steward them.

As already shown, mature tropical forest reduces heat through photosynthesis, but this is not factored into compensations. That calculation needs to be made and reflected in tradable assets on the carbon exchange. Cattle don’t eat petroleum; we should not assign to ruminants the blame for methane emissions, but rather credit them with biogenic methane emissions, which are part of a desired cycle. These and other truths require less narrative and more goodwill to listen to science and research – to move beyond pre-fabricated models divorced from context and reality.

Alliances must be built on trust and credibility. In a highly polarized and dogmatic world, this will be the task of true visionaries and leaders who serve humanity’s noblest principles: preserving living things with dignity and respect. Perhaps COP30 will show us where these allies are – less in the spotlight, more in the work of understanding and cooperating, listening, recognizing, helping, and setting examples. We have many such visionaries in Brazil and around the world. May we bring them together for our common purpose.

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14. Family Farming and Agroforestry: An Alliance that Feeds and Regenerates

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Introduction

In a world where food and nutritional security and climate change intertwine, agroforestry emerges as a powerful response capable of addressing contemporary challenges. Far beyond a simple cultivation technique, it is a production model that integrates trees, shrubs, agricultural crops, and sometimes animal husbandry, in the same area. This coexistence, planned and built by family farming, reproduces the complexity of natural ecosystems, generating a web of interactions with economic, social, and ecological benefits.

Family farming is responsible for producing most of the diversified food consumed worldwide, and finds in agroforestry a strategic ally. Examples of agroforestry systems include cocoa and coffee cultivation under the shade of native trees, and the combination of fruit species such as açaí and cupuaçu in the Amazon, araucaria and yerba mate in the Atlantic Forest, and also pequi and various other species in the Cerrado. In the recovery of degraded areas, it is possible to use vegetables in the first years, which are gradually replaced by the planting of trees that provide food and shelter. Crop diversification allows farmers to have multiple sources of income, reducing vulnerability to pests or market crises.

The socio-bioeconomy approach values forest and biodiversity-based products, but also brings a deep concern for people and social development. This includes the generation and provision of environmental goods and products for consumption, commercialization, climate regulation, support of biogeochemical cycles, and recreation, including forest restoration and conservation, management of agroforestry systems, among other issues[1].

Activities based on standing forests and local knowledge generate a gross domestic product of at least BRL 12 billion per year in the Brazilian Amazon[2]. Well-managed agroforestry systems can have a total productivity higher than monocultures, combining the harvest of several products. In addition, the presence of trees improves soil quality, increases water retention, and creates a favorable microclimate, making properties more resilient to extreme climate events.

This chapter aims to present the creation and development of the National Program of Productive Forests (PNFP) as an initiative that seeks to foster agroforestry systems in family farming from the perspective of socio-bioeconomy. The information gathered here brings the experience of the authors, who act as managers of the program at the Ministry of Agrarian Development and Family Farming (MDA). The PNFP was the MDA's priority agenda for COP30, and arrived at the conference with field initiatives and a promising future, with a significant amount of non-reimbursable resources, which makes the program one of the largest productive restoration initiatives underway on the planet.

1. The Conception of the National Program of Productive Forests

With the beginning of President Lula's government in 2023, the MDA was reestablished. This ministry is the result of a process of recognizing the existence of various rural social segments that were not being adequately contemplated by government actions. In view of this fact, it was created in 1999 and extinguished after the impeachment of President Dilma Rousseff[3]. The new structure of the MDA brings an important concern with the socio-environmental agenda. Among other definitions, Decree 11.396 of 2023 defines the competence to support the formulation of public policies with emphasis on the development of agroforestry systems, agrosavanna[4] systems, and other polycultures with a tree component[5].

At the beginning of its management, the MDA, under the coordination of Minister Paulo Teixeira, received political leaders, members of non-governmental organizations and social movements, among other actors, who highlighted the need for Brazil to develop public policies capable of responding to the country's development challenges in the context of COP30 being held in Brazil. Instituto Escolhas[6], for example, presented to the MDA a study according to which the recovery

[1] ABRAMOVAY, R. et al. Opportunities and challenges for a healthy standing forest and flowing rivers bioeconomy in the Amazon. In: NOBRE, C. A. et al. Amazon Assessment Report (UN-SDSN), 2021. doi:10.55161/UGHK1968. [2] NOBRE, C.A. et al. (2023) New Amazon Economy. São Paulo: WRI Brazil. Report. Available online at: www.wribrasil.org.br/nova-economia-da-amazonia. https://doi.org/10.46830/wrirpt.22.00034 [3] MATTEI, Lauro. A política agrária e os retrocessos do governo Temer. OKARA: Geografia em debate, v. 12, n. 2, 2018. [4] Restoration technique associated with an agroecological social technology adapted to the Cerrado biome, which seeks to integrate food production, ecological and productive restoration, and the appreciation of traditional knowledge. [5] BRAZIL. Decree no. 11.396, of January 21, 2023. Approves the Regimental Structure and the Demonstrative Framework of Commissioned Positions and Trusted Functions of the Ministry of Agrarian Development and Family Farming and reallocates and transforms commissioned positions and trusted functions. Available at: https://www.planalto.gov.br/ccivil_03/_ato2023-2026/2023/decreto/d11396.htm. Accessed in August 2025. [6] Instituto Escolhas. Como a bioeconomia pode combater a pobreza na Amazônia? 2023, p. 16. Available at: https://escolhas.org/wp-content/uploads/2023/04/SumarioBioeconomiaPobreza_Final.pdf. Accessed in August 2025.

of 5.9 million hectares of forests in Pará would have the potential to generate BRL 13.6 billion in revenue and reduce poverty in the state by 50%.

Recognizing the transformative potential of these systems, the MDA developed a first proposal of what would be the productive restoration agenda in family farming, built with the objectives of producing food, generating income, and restoring ecosystems. This proposal, called Productive Forests, was disclosed and debated during the event Amazon Dialogues 2023, held from August 4 to 6 of that year in Belém, capital of the state of Pará. The event included plenary sessions by the federal government and activities organized by civil society and academia. From these dialogues, the proposal was improved and validated. The MDA then began to implement a first project that could demonstrate the proposal in practice and be ready to be presented at COP30 as an initiative of the Brazilian government.

2. The Inaugural Project in Pará

At the end of 2023, the MDA and the Ministry of the Environment and Climate Change (MMA) developed the inaugural Productive Forests project, which serves 1,680 families in 21 areas in the state of Pará, including 18 agrarian reform settlements, 2 marine extractive reserves, and 1 quilombola territory. This initial stage promotes agroforestry systems, reinforcing the government's commitment to linking healthy food production with environmental recovery and social inclusion. In total, BRL 15 million are being invested between 2024 and 2026. The initiative has the participation of the National Agency for Technical Assistance and Rural Extension (Anater), the Brazilian Agricultural Research Corporation (Embrapa), the Federal University of Maranhão (UFMA), and the Institute of Colonization and Agrarian Reform (Incra).

The project structure was built from five components that interact with each other: 1. Technical Assistance and Rural Extension (Ater); 2. Rural Credit; 3. Community Nurseries and Seed Banks; 4. Forest Houses; and 5. Popular Units of Technological Reference.

Ater is the core of the proposal. The beneficiary families received during two years specialized technical assistance from professionals who guide the implementation of agroforestry systems in family farming areas. Each technician serves about 40 families in individual activities (with the family) or collective ones (with the group of families and/or the settlement).

The partners supported by Ater will assist in the implementation of Technological Reference Units (URTs) located on a farmer's land or on public land that serves as a practical model to demonstrate and validate technologies, in order to disseminate the experience to the farmers involved in the project. Leadership over this initiative in the inaugural project has been carried out by Embrapa, which works in technical-scientific monitoring and advisory. The URTs need seedlings and seeds to be taken to the field. In this way, community nurseries and seed banks are structures that provide the necessary genetic resources, but also serve as a space for learning and sharing knowledge about seed conservation and seedling production.

The project includes numerous training and capacity-building actions. For this, the implementation of Forest Houses was planned, as a reference space for training activities. The project does not build new facilities, but rather helps equip existing structures of associations, schools, cooperatives, among other community spaces in the communities. Rural credit, in turn, is accessed with the support of Ater, and provides the necessary resources for the implementation of agroforests on farmers' land. Currently, the Family Farming Crop Plan has several lines that finance agroforests and socio-bioeconomy with favorable conditions.

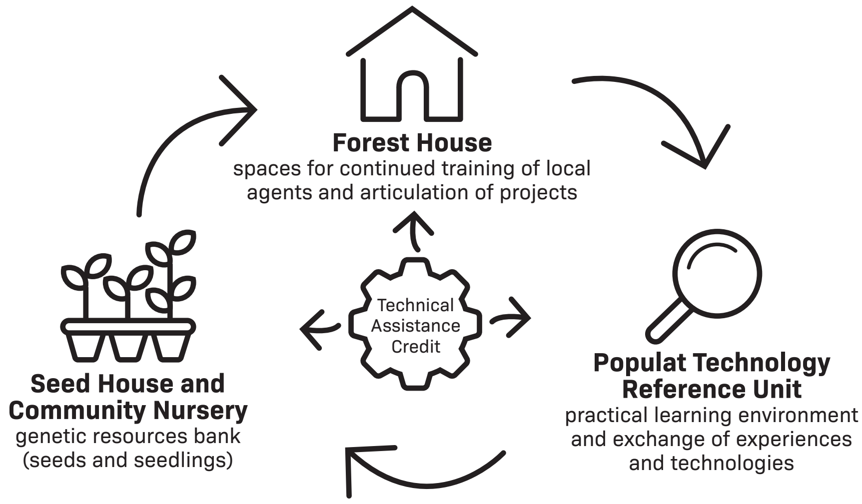

Figure 1 presents the components of the inaugural project and their interrelation.

3. The Institutionalization and Scaling of the Program

With a view to institutionalizing the initiative, on July 3, 2024, Decree 12.087 was published, establishing the National Program of Productive Forests[7]. The normative act is one of the important steps for the officialization of the public policy and aims to regulate the matter in observance of the principles of public administration[8]. The decree establishes as the objective of the PNFP the recovery of areas that were altered or degraded for productive purposes, with a view to the environmental adjustment and regularization of family farming and the expansion of the capacity to produce healthy food and sociobiodiversity products. The normative act defines the nine instruments through which the implementation of the program will occur.

In parallel with regulation, new forms of program financing were sought. In partnership with the initiative "Restore Amazon," led by the National Bank for Economic and Social Development (BNDES), a call for proposals was launched in March 2025 for ecological and productive restoration in settlements located in the Amazon, in the amount of BRL 150 million. The call covers the states of Acre, Amazonas, Rondônia, Mato Grosso, Tocantins, Pará, and Maranhão. Each project will have resources of approximately BRL 5 million, which will be used for the implementation of agroforestry systems, with the purchase of seeds, seedlings, and equipment needed for nurseries, as well as the training of cooperatives and associations, the carrying out of research and technical services for monitoring and maintenance of restored areas.

The Socio-Environmental Fund of Caixa Econômica Federal, in partnership with the MDA, launched in June 2025 the call "Regenerative Agriculture," which allocates BRL 50 million to the PNFP. The resources are intended for the states of Acre, Maranhão, Mato Grosso, Pará, and Rondônia, which have a high concentration of family farmers and agrarian reform settlements.

[7] BRAZIL. Decree no. 12.087, of July 3, 2024. Establishes the National Program of Productive Forests. Available at: https://www.planalto.gov.br/ccivil_03/_ato2023-2026/2024/decreto/D12087.htm#:~:text=DECRETO%20N%C2%BA%2012.087%2C%20DE%203,Programa%20Nacional%20de%20Florestas%20Produtivas. Accessed in August 2025. [8] TCU - Federal Court of Accounts. Política Pública em Dez Passos. Brasília, 2021. 36 p.

In addition, the planning of MDA's actions foresees for the 2025 and 2026 budget the use of BRL 37.4 million to expand the initiatives to the states of Acre, Amapá, and Maranhão.

The ongoing PNFP initiatives total BRL 252.4 million. The federal government expects the program to help consolidate agroforestry as a State policy, ensuring the necessary support so that more farming families can transition to more resilient and profitable production models. Thus, the aim is not only to encourage sustainable production, but also to restore degraded areas, strengthen sociobiodiversity value chains, and promote social justice in rural areas.

Perspectives of agroforests in a sustainable future
The PNFP is a very recent initiative, which in a short time managed to secure significant resources for its execution. It is aligned with President Lula's objectives of ending hunger in Brazil, generating income for workers, and advancing the environmental agenda. In addition to the implementation of agroforestry systems in the field, the evolution of the program should work on other related topics, such as the program's relationship with environmental services.

Agroforests are productive systems that contribute to the generation of environmental services. By recovering degraded areas, planting trees, and cultivating the land in an integrated way, the family farmer is, in practice, providing ecological benefits for the whole society. These systems contribute to climate regulation by sequestering carbon from the atmosphere, and to biodiversity conservation by creating refuges for fauna and flora.

Agroforestry systems have demonstrated a high carbon sequestration capacity, similar to native forests and higher than pastures and conventional agricultural production systems[9]. Unlike monocultures, which emit large amounts of carbon into the atmosphere due to intensive use of machinery and fertilizers, agroforestry systems act as carbon reservoirs.

In this context, payment for environmental services (PES) emerges as a fundamental mechanism to financially reward farmers for these actions. By receiving an amount for the carbon that their agroforest sequesters, family farmers are not only compensated for their work but also encouraged to continue investing in sustainable practices. Law 14.119/2021, which established the National Policy for Payment for Environmental Services, opens a promising path for agroforestry to be recognized and valued not only as a way of producing, but as a way of caring for and restoring life on the planet.

The synergy between agroforestry, family farming, and PES shows us a future in which food production goes hand in hand with environmental conservation, creating productive and regenerative landscapes capable of feeding everyone and, at the same time, regenerating natural ecosystems.

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[9] CRESPO, Aline Marchiori; SOUZA, Maurício Novaes; DA SILVA, Maria Amélia Bonfante. CICLO do Carbono e Sistemas Agroflorestais na Sustentabilidade da Produção Agrícola: REVISÃO de LITERATURA. Incaper em Revista, p. 6-19, 2023.

Deforestation frontier in Paragominas (Pará)

15. History and Challenges of the Carbon Market

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Introduction

The emergence of the carbon market is a response to the growing recognition of the climate emergency and the environmental responsibility that countries, companies, and individuals have proactively begun to assume.

It consists of two intercommunicating parts: the regulated and the voluntary. While the regulated market follows legal frameworks and national commitments, the voluntary market flourishes as a decentralized and dynamic initiative, where the primary motivation is reputational, strategic, and often anticipatory in relation to future regulatory requirements.

This chapter presents a historical, economic, and strategic analysis of the carbon markets, offering insights into future perspectives and challenges.

The Regulated Market

The Kyoto Protocol is widely recognized as a turning point in the history of international climate policy. Created according to the principles established by the United Nations Framework Convention on Climate Change (UNFCCC), the protocol was officially adopted on December 11, 1997, during the 3rd Conference of the Parties (COP3), held in Kyoto, Japan. After years of negotiations and the need to secure ratification by a minimum number of countries responsible for a significant share of global emissions, the treaty entered into force on February 16, 2005.

The main objective of the Kyoto Protocol was to confront, in a concrete and coordinated way, the challenge of climate change caused by human activities, especially the emission of greenhouse gases (GHG). To this end, the protocol established legally binding emissions reduction targets for countries considered developed or undergoing accelerated industrialization, based on the principle of common but differentiated responsibilities.

This principle recognizes that while all countries share the responsibility of protecting the global climate, industrialized countries bear a greater historical burden, as they have been the main emitters since the Industrial Revolution. Therefore, they were the first to assume reduction commitments, whereas developing countries did not have mandatory targets during the first phase of the protocol.

The Kyoto Protocol acknowledged that the cost of emissions reductions varied among countries and sectors. To make achieving the targets more efficient and economically viable, the treaty created three market-based mechanisms, also referred to as flexibility mechanisms. These instruments enabled developed countries to reduce emissions in locations where it was more cost-effective and efficient, while preserving the environmental integrity of the global system.

1. Clean Development Mechanism (CDM)

The CDM was conceived as an instrument of cooperation between developed and developing countries, allowing the former to finance emissions reduction projects in the latter in exchange for carbon credits known as Certified Emission Reductions (CERs). The mechanism enabled developed countries (with reduction targets) to invest in emissions reduction projects in developing countries, generating CERs. Each CER corresponds to one tonne of CO_2e avoided from projects that could involve renewable energy, energy efficiency, waste management, among others. Moreover, CERs could be used to fulfill part of the targets of Annex I countries, i.e., developed nations and those with economies in transition, which assumed binding commitments for GHG emission reductions.

By 2020, over 8,000 CDM projects had been registered, covering more than 100 countries.

Despite its numerical success, the CDM was criticized for failures in additionality, concentration of projects in a few countries, negative local social impacts, and market volatility. These criticisms generated reflections that would shape the new market mechanisms under the Paris Agreement.

2. Joint Implementation (JI)

Joint Implementation (JI) was conceived with the aim of promoting cooperation among developed (Annex I) countries to fulfill their emissions reduction targets.

Unlike the CDM, which involved cooperation between developed and developing countries, JI focused exclusively on countries that already had reduction commitments under the Protocol, meaning that both the investor country and the host country had mandatory emissions targets.

A common example: a Western European country such as Germany invested in modernizing residential heating boilers in Ukraine and used the generated CERs to meet part of its target under the Kyoto Protocol.

Although JI was not as popular as CDM, it provided valuable lessons regarding the need for robust oversight and emissions accounting mechanisms.

3. Emissions Trading (Cap and Trade)

The Emissions Trading mechanism, also known as Cap and Trade, was one of the main innovations of the Kyoto Protocol, enabling countries with mandatory emissions reduction targets to meet their commitments in an economically efficient way.

This system is based on the principle that total emissions of a group of countries or sectors are capped, but emission allowances can be freely traded – creating a market for negotiable permits.

The EU ETS (European Union Emissions Trading System) is the primary example of Cap and Trade implementation. Established in 2005, it was the world's first carbon market and currently covers around 40% of EU emissions.

The system operates as follows:
- The annual emissions cap is gradually lowered over time to align with the EU's climate objectives.
- Emission allowances (EUAs – European Union Allowances) are allocated: partially free for sectors susceptible to carbon leakage; partially via auction, where companies purchase allowances in the market.
- If a company fails to surrender sufficient allowances, it is fined € 100 per excess tonne, in addition to being required to offset the remaining emissions.

Within this system, a progressive reduction of the emissions cap was established, starting at an annual reduction rate of 1.74% until 2020; then 2.2% for 2021–2023; 4.3% between 2024–2027; and 4.4% from 2028 onward.

With the 2023 revision of the EU ETS Directive, the system now targets a 62% emissions reduction by 2030 compared to 2005 levels.

The Cap and Trade mechanism became a key component of EU climate policy and a global benchmark for regulated carbon markets. It played an essential role in shaping other markets such as those in California, South Korea, and China, and laid the conceptual groundwork for Article 6.2 of the Paris Agreement – addressing international transfers of mitigation outcomes (ITMOs) – demonstrating how market instruments can support international cooperation and global climate ambition.

The Need for a New Agreement

Over time, it became evident that the Kyoto Protocol, adopted in 1997 and in force from 2005, was insufficient to deal with the growing complexity and urgency of the global climate problem. Although it represented a historic milestone by establishing legally binding emissions reduction targets for developed countries, its framework revealed structural weaknesses that compromised its effectiveness over time:
- The growth of emissions in developing countries – such as China, India, and Brazil – which did not have binding targets under the Kyoto Protocol, created an imbalance between countries with formal obligations and those without.
- The absence or withdrawal of key countries from the Kyoto Protocol, such as the United States, significantly weakened its legitimacy and scope.
- Excessive rigidity in the Protocol's legal structure made it difficult to incorporate adjustments and new approaches, including adaptation, climate finance, and technology transfer.

It was in this context that, after years of negotiation, countries arrived at the adoption of the Paris Agreement at COP21 in 2015. The new treaty represented a paradigm shift by:
- Establishing voluntary, nationally determined contributions (NDCs), yet monitored transparently;
- Including all countries, with common but differentiated responsibilities and respective capacities;
- Promoting greater integration among mitigation, adaptation, climate finance, and technology cooperation;
- Creating innovative market and non-market mechanisms under Article 6, overcoming the limitations of the old CDM.

Thus, the Paris Agreement emerged not merely as a replacement, but as a profound restructuring of international climate governance.

Paris Agreement: Structure, Ambition, and Universality

Unlike the Kyoto Protocol, which imposed reduction targets only on developed countries, the Paris Agreement adopted a universal approach: all signatory countries – currently 196 – must present their own mitigation targets (NDCs), reflecting their respective capacities and circumstances.

The central goal of the agreement is to keep the global average temperature increase well below 2°C above pre-industrial levels, with efforts to limit the warming to 1.5°C – considered the safer threshold according to IPCC reports. To achieve this goal, countries must progressively strengthen their climate ambitions in five-year cycles.

Entry into force occurred in record time: in less than a year, on November 4, 2016, the Agreement achieved the minimum ratification by countries responsible for more than 55% of global emissions. This accomplishment reflected the urgency recognized by global leaders following the intensification of extreme climate events in the early decade.

Since then, the Paris Agreement has guided global climate action. The NDCs submitted up to 2020 demonstrated progress, but remain distant from the 1.5°C trajectory.

With the Paris Agreement, global climate governance entered a new era: participatory, progressive, and centered on voluntary national action supported internationally.

Brazil's Position and the Challenges of Global Implementation

Brazil has played an active role in multilateral climate negotiations, especially in the context of the Paris Agreement and the regulation of Article 6. With a relatively clean energy matrix – mainly based on renewables – and a robust track record of CDM projects, the country has a solid technical and institutional foundation to act both as a provider and as a buyer of carbon credits.

Moreover, Brazil has been negotiating bilateral agreements for the future transfer of ITMOs and has expressed interest in registering projects under Article 6.4, concerning corresponding adjustments to avoid double counting. The experience accumulated in REDD+, bioenergy, regenerative agriculture, and waste management projects places the country in a strategic position to lead the practical implementation of market mechanisms. However, the major challenge will be aligning domestic policies with the international commitments undertaken, ensuring credibility and environmental integrity.

Future climate governance will require more than good intentions and ambitious targets. It will demand functional mechanisms, multilevel coordination among governments, companies, civil society, and multilateral institutions, and a genuine commitment to climate justice.

The Voluntary Market

In the 1990s and 2000s, pioneering initiatives arose aimed at voluntary emissions compensation. The American Carbon Registry (ACR), founded in 1996; Gold Standard, in 2003; and Verra, in 2005 – today the world's largest carbon project certifier – all emerged during this period. They sought to enhance the integrity of voluntary reductions by demanding independent verification, additionality definitions, and standardized quantification methods.

The creation of these standards was a direct response to growing demand from companies and investors for reliable tools to demonstrate proactive climate action. Many corporations sought to go beyond legal obligations and reduce or offset their emissions, but there were no clear criteria for what constituted a "valid reduction" or a "reliable credit."

Phases of the Voluntary Market

In its early decades, carbon credits were traded bilaterally between buyers and sellers, with little or no contractual standardization. Large companies seeking to align their sustainability strategies with tangible actions led the way by purchasing credits directly from specific projects.

These contracts were typically based on trust and required rigorous evaluations of additionality and project integrity. The absence of organized exchanges and low liquidity meant each negotiation was practically customized. However, this flexibility enabled business model innovation and the emergence of specialized marketplaces, which later gave rise to climate tech companies.

The voluntary market was never completely isolated from regulatory mechanisms. During the Kyoto Protocol era (2005–2012), many CDM projects also served as the basis for corporate voluntary commitments in non-obligated countries. This interconnection created a hybrid space where the same tonne of CO_2 could be registered across multiple tracking systems.

This interoperability expanded project scale and enabled greater international circulation of environmental assets. However, it also raised the challenge of avoiding double counting and encouraged the development of tracking mechanisms.

As the Kyoto Protocol expired and no new global regulatory framework existed until the Paris Agreement took effect, the carbon market entered a contraction period. Low demand, regulatory uncertainty, and an oversupply of credits from the previous cycle led to asset devaluation and project suspension. The halt of international investment flows into emissions reduction projects particularly affected developing countries, where CDM had spurred numerous initiatives.

This dormant period was exacerbated by the prolonged effects of the 2008 global economic crisis, which significantly reduced companies' appetite for voluntary climate commitments. With squeezed margins, many sustainability plans were postponed or shelved, and investments in offset projects ceased to be a priority. The perception that the carbon market offered neither stability nor financial return also deterred institutional investors and climate funds.

Still, some visionary organizations maintained their investments in the voluntary carbon market, proving crucial for its later recovery. Organizations that remained active – consolidating methodologies, community engagement, and technical expertise – were highly valued in the market's new phase beginning in the 2020s.

The entry into force of the Paris Agreement in 2020 marked a new inflection point in global climate governance. Although an operational structure for the international carbon market was still lacking, the Agreement defined a clear, collective goal: limiting global warming to 1.5°C, with each country responsible for presenting and reviewing its NDCs. This new benchmark pressured the private sector to align its decarbonization strategies with science-based targets.

Simultaneously, the COVID-19 pandemic – despite its profound social and economic impacts – opened space for a global reflection on resilience, systemic risk, and the role of companies in building a sustainable future.

In this new context, carbon credits ceased to be seen as symbolic compensation tools and took on a more strategic role. Companies began valuing projects with proven climate and social benefits, supported by satellite monitoring, complementary certifications, and alignment with the Sustainable Development Goals (SDGs). The narrative of "compensation" shifted toward that of "climate contribution," signaling a deep change in corporate mindset and in the maturity of the voluntary market.

A New Scenario: Major Transactions

From 2021 onward, the voluntary carbon market reached an unprecedented milestone. The convergence of climate urgency, the advance of ESG agendas in corporations, and the institutional maturity of certification standards resulted in explosive growth in both the volume and diversity of projects and transactions.

According to Ecosystem Marketplace data, the voluntary market exceeded USD 2 billion in transacted value in 2022 alone, led by the strong entrance of institutional investors, banks, and major corporations.

Alongside the expansion of corporate climate commitments – such as Net Zero targets – there was a qualitative shift in demand: interest in carbon removal credits (CDRs), considered more rigorous from a climate standpoint, grew exponentially. Technologies like biochar[1], direct air capture (DAC), and reforestation began gaining prominence and commanded significantly higher prices, ranging from USD 20 to USD 1,000 per tonne – much above the average for conventional reduction credits.

Thus, the sector achieved more than numerical expansion: it consolidated a new era for the voluntary market, based on technical sophistication, climate credibility, and the intersection between impact and financial return.

Future Perspectives and Challenges

The future of the voluntary market strongly depends on its ability to deliver climate integrity and environmental credibility. With regulatory advancement, the use of voluntary credits will be closely monitored, requiring transparency and alignment with national commitments (NDCs) to maintain their role as a legitimate climate solution.

The emergence of frameworks such as the ICVCM Core Carbon Principles, which define criteria for integrity and transparency in credit issuance, and the VCMI Claim Code, which guides credible corporate use of credits, has added important quality benchmarks to the market, helping distinguish high-quality credits.

Although the voluntary carbon market has historically operated in parallel with the regulated market, the boundary between the two has begun to blur with the emergence of hybrid programs – such as CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation), implemented by the International Civil Aviation Organization (ICAO).

CORSIA is the first global regulated offsetting mechanism targeted at a specific sector: international aviation. In force since 2021, the program requires airlines to offset emissions exceeding 2019 levels in their international operations, using carbon credits approved through rigorous technical processes. The main phases are:

- Pilot phase (2021–2023) – voluntary, with participation from over 100 countries;
- First phase (2024–2026) – still voluntary, but with broader geographic coverage;
- Second phase (from 2027 onward) – mandatory for all countries with significant international air traffic. CORSIA distinguishes itself by using credits from standards traditionally used in the voluntary market – such as Verra (VCS), Gold Standard, American Carbon Registry (ACR), and Climate Action

[1] Biochar is charcoal produced through the pyrolysis of biomass, that is, by heating organic matter under conditions of little or no oxygen. This technique transforms plant-based residues (such as agricultural waste) into a material rich and stable in carbon, with the potential to store it for hundreds or thousands of years.

Reserve (CAR) – provided they meet ICAO's specific criteria. This creates technical interoperability between the two markets, whereby voluntary projects can be eligible for regulated use depending on methodology, start date, governance, and traceability. A key element is the corresponding adjustment, which ensures that any credit used under CORSIA is subtracted from the host country's national emissions inventory, preventing double counting and maintaining environmental integrity across both markets.

Looking ahead, the next five years will be decisive for setting the foundation to reach net zero by 2050. Under the Paris Agreement, 2030 is the first critical checkpoint, when global emissions must be reduced by nearly half to keep a 1.5°C trajectory within reach. This creates both challenges and opportunities for carbon markets. The demand for higher integrity and more rigorous accounting will test the credibility of both voluntary and regulated mechanisms. A maturing market with clearer standards and strong governance will provide the scale and trust needed to mobilize capital at unprecedented levels.

Looking toward 2050, the long-term opportunity lies in consolidating carbon markets as a fully interoperable system that blends voluntary and compliance approaches. Mechanisms such as CORSIA show how credits can already cross between systems, and by mid-century this interoperability will need to expand to ensure global coverage and liquidity. The challenge will be to manage environmental integrity while avoiding risks of double counting and misaligned incentives across jurisdictions. If this is achieved, carbon markets will be positioned as a cornerstone of the net zero transition, channeling finance into nature-based solutions, removals, and technological innovation at a scale that matches the ambition of the Paris Agreement.

Conclusion

The voluntary carbon market has followed a non-linear path, evolving from a decentralized experiment to a strategic ecosystem for the global climate transition. Its resilience was tested by regulatory and economic crises, but its capacity for reinvention positions it as one of the pillars of climate action.

In the coming years, its success will depend on its ability to balance integrity with scale, accessibility with traceability, and innovation with regulation. If it manages to overcome these challenges, the voluntary market can play a fundamental role in achieving the Paris Agreement goals and enabling sustainable business models.

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Carbonext Tatuy REDD+ Project (Mato Grosso)

16. Strategic Convergence for Conservation, Climate, and Territorial Development

Julie Messias e Silva, *executive director of the Nature-based Solutions Brazil Alliance*

Brazil occupies a singular position on the global environmental agenda. In addition to its vast territorial expanse, it holds a natural and sociocultural heritage of inestimable value. The Amazon, in particular, concentrates much of this shared responsibility. With the largest tropical forest in the world, the region regulates the rainfall regime across South America, is home to hundreds of Indigenous peoples and traditional communities, and contributes decisively to planetary climate stability.

However, this enormous potential still contrasts with structural obstacles. Despite institutional and regulatory advances, the pace of implementation of conservation policies and the recovery of degraded areas remains insufficient in the face of the scale of the challenge. Brazil's NDC (Nationally Determined Contribution), revised in 2022, sets important targets, such as net emissions neutrality by 2050 and a 53% reduction in emissions by 2030 relative to 2005. But its effectiveness depends on interlinked factors of legal certainty, federative coordination, engagement of the productive sector, and qualified social participation.

In the Amazon, these challenges intensify. Pressure for territorial expansion, the advance of illegal activities, and the absence of structuring policies for sustainable development demand a new pact among states, municipalities, the private sector, and local communities, guided by an agenda of socioenvironmental integrity, valuing the standing forest, and generating real opportunities in the territory.

The scale of the challenge is great, but the opportunity to lead a global transformation from Brazil's biomes is even greater. What is at stake is Brazil's ability to mobilize its biodiversity, its institutional strength, and the wealth of its territories in favor of a development model that unites conservation, inclusion, and prosperity.

In this context, it is essential to reflect: how can we build development strategies that articulate environmental conservation, social justice, and economic dynamism, ensuring that these strategies materialize through coordinated actions among governments, the productive sector, and civil-society organizations?

The interaction among the public sector, the private sector, and organized civil society emerges as a strategic key to answer this question. It is a complex articulation that involves different institutional cultures, distinct rationalities, and unequal operating rhythms, but which, when well structured, enables concrete, legitimate, and lasting advances. Recognizing the challenges of this cooperation is part of the process, as is identifying the points of convergence to conserve the biomes, face climate change, and support the communities that live in and protect the country's most strategic territories.

The public, private, and social-organization sectors have their own trajectories and rationalities. The public sector responds to legal frameworks, operates under institutional oversight, and must be accountable to society. It is subject to political cycles and, often, to structural limitations that hinder the continuity of strategic policies. Even so, it is chiefly responsible for formulating public policies and defining national and state priorities.

The private sector, in turn, operates with goals associated with investment risks, a focus on efficiency, innovation, and regulatory stability. In recent years, it has given traction to the transition toward a production model oriented to global commitments and new regulations, leading concrete initiatives of sustainability and socio-environmental responsibility.

Civil-society organizations, for their part, have historically acted as defenders of rights, overseers of public power, and promoters of social innovation in vulnerable contexts. They seek to represent the plurality of voices in society.

Beyond the cultural and institutional differences among the sectors, there are structural barriers that still limit the effectiveness of cross-sector collaboration. One of the main obstacles is legal uncertainty, frequently fueled by abrupt changes in contracts, regulatory frameworks, and public policies at each new electoral cycle. This instability compromises the predictability needed to build lasting partnerships and long-term projects.

Another recurring challenge is the fragility of spaces for dialogue and participation. Many forums and councils lack adequate structure, effective representation, or real capacity for articulation among different actors. This weakens consensus-building and discourages social and institutional engagement. Added to this is the asymmetry in access to resources and in decision-making spaces.

In addition, the absence of replicable and efficient financing models that integrate public, private, and philanthropic resources in a coordinated manner hampers the scalability of solutions. Isolated or one-off initiatives, however well-intentioned, tend to have limited impact without a stable financial arrangement.

In the territories, obstacles multiply. Overlapping projects, low articulation among institutions, lack of consolidated information, and limited local technical capacity make the implementation process more complex and slower. These challenges, however, do not make cooperation unviable. On the contrary, they underscore the need for it to be intentional, planned, and supported by clear mechanisms of governance, transparency, and co-responsibility.

The interaction among these worlds requires constant dialogue, mutual recognition and a willingness to build bridges. It is necessary to recognize that these sectors are not competitors with one another, but interdependent parts of a broader system of socio-environmental governance.

Climate Investments and the Role of Partnerships

Advancing the climate agenda requires more than good intentions and well-structured plans. It requires implementation capacity, cross-sector articulation, and access to consistent, long-term financial resources. Article 9 of the Paris Agreement establishes that developed countries must provide financial support to developing countries as part of global commitments to mitigate and adapt to climate change. However, the distance between the commitments undertaken and the effective flows of financing is still significant.

According to the Organisation for Economic Co-operation and Development (OECD)[1], the volume of international climate financing remains below the target of USD 100 billion per year promised since 2009. This directly affects the ability of countries with high social and environmental vulnerability, such as Brazil, to meet their climate targets and promote a just transition in their territories. The gap is not only budgetary, but institutional, since it involves challenges of access, execution, and governance.

Multilateral mechanisms such as the Green Climate Fund (GCF) and the Global Environment Facility (GEF) were created to operationalize international support to developing countries, as established in the Paris Agreement. The GCF has sought to make feasible structuring projects with mitigation and adaptation potential in strategic territories. In Brazil, the Floresta+ Amazônia program stands out, approved in 2021 with GCF financing. The program has been allocating about USD 96 million to strengthen conservation actions and encourage sustainable production in the Legal Amazon, in coordination with states and local communities.

The GEF, in turn, operating in more than 180 countries, has supported strategic projects focused on biodiversity, climate change, and ecosystem restoration. A relevant example is the Amazon Sustainable Landscapes (ASL) Initiative, which works to promote integrated and sustainable landscapes in the eight Amazonian countries, including Brazil. In the country, ASL has supported actions in Acre, Rondônia, Amazonas, and Pará, focusing on integrated territorial management, sustainable land use, and biodiversity conservation.

Within national mechanisms, the Amazon Fund has gained relevance as a tool to make conservation and sustainable-development actions in the Legal Amazon feasible. In 2023, more than BRL 3 billion were approved for projects in the states of the region. The tripartite composition of its governance – federal government, donors, and civil society – has helped ensure legitimacy, transparency, and alignment with local realities.

Another important mechanism is the National Fund on Climate Change (Fundo Clima), operated by BNDES (Brazilian Development Bank), which has sought to resume its strategic role in financing the climate agenda. With lines aimed at both the public and private sectors, the fund has supported projects in sustainable urban mobility, energy efficiency, low-carbon agriculture, and the rational use of natural resources. The recent reactivation of its reimbursable lines opens space for companies to also access financing focused on innovation, energy transition, and nature-based solutions.

[1] OECD, Climate Finance Provided and Mobilised by Developed Countries in 2013–2022. Access link: https://www.oecd.org/en/publications/2024/05/climate-finance-provided-and-mobilised-by-developed-countries-in-2013-2022_8031029a.html Accessed in Aug. 2025

Although most climate resources in Brazil have traditionally been directed to the public sector and organized civil society, there is a growing movement to bring public funds closer to the private sector. Initiatives that combine reimbursable and non-reimbursable financing, public-private partnerships, and blended-finance mechanisms have the potential to expand the reach of public policies and attract new investments.

These experiences indicate that the volume of resources is essential, but not sufficient, pointing to the urgency of structuring financial mechanisms that combine public, private, and philanthropic resources. Coordination among these sources – through hybrid funds, integrated calls for REDD+ (Reducing Emissions from Deforestation and Forest Degradation), ARR (Afforestation, Reforestation, and Revegetation), and ALM (Agricultural Land Management), and results-based payment mechanisms – can enhance the reach of investments and generate multiplier effects in the territories.

The Private Sector as Part of the Solution

In recent years, companies and investors have been taking on an increasingly prominent role in the global environmental agenda, especially in the face of international regulatory pressures and corporate carbon-neutrality commitments. According to a UN report[2], more than 1,700 companies have already established formal net-zero targets, many of them anchored in offsetting strategies based on natural climate solutions. This movement has driven interest in carbon projects that deliver measurable mitigation results aligned with recognized standards of environmental and social integrity.

In Brazil, this scenario has stimulated growth in the voluntary carbon market, with an emphasis on forest initiatives. Data from Ecosystem Marketplace indicate that, between 2020 and 2023, the country accounted for approximately 20% of the global volume of forest credits issued in voluntary markets, which highlights the attractiveness and technical potential of Brazilian initiatives.

In this context, the private sector has significantly expanded its role in forest-carbon projects and sustainable land-use management in Brazil. Initiatives based on REDD+, ARR, and ALM have gained scale in various regions of the country, especially in the Amazon, the Cerrado, and the Atlantic Forest. It is estimated that, in 2025, more than 100 projects certified by internationally recognized standards, such as Verra (VCS), are operating in Brazil.

In the Legal Amazon, private REDD+ projects already contribute to protecting millions of hectares of native forest in areas under different land-tenure regimes – private lands, concessions, and properties with recognized sustainable use. In addition to avoiding significant greenhouse-gas emissions – in some cases, more than 1 million tonnes of CO_2e per year – these projects generate concrete effects in the territories by investing in environmental education, basic infrastructure, strengthening local governance, and supporting community-based value chains. Working in partnership with traditional communities and Indigenous peoples has proved decisive for the legitimacy and sustainability of these initiatives.

ARR projects, in turn, have gained relevance in degraded areas, especially in ecological-transition regions

[2] UNITED NATIONS, Moving Business Forward Faster: 2024 Trends & Insights Report. Access link: https://unglobalcompact.org/library/6240?utm_source=chatgpt.com Accessed in Aug. 2025.

and low-productivity pastures. Companies, cooperatives, and producers have been implementing models of productive restoration seeking to ensure conservation, the generation of carbon credits, and food production. The integration of reforestation with native species and agroforestry systems has shown high potential to reconnect forest fragments, recover ecosystem services, and diversify small producers' income. These actions are directly aligned with national restoration targets of 12 million hectares by 2030, as established by Planaveg (National Plan for the Recovery of Native Vegetation), and with Brazil's NDC climate commitments.

In the ALM field, there has been progress in adopting low-emission agricultural practices, such as no-till, crop rotation, integrated soil management, and the recovery of degraded pasture areas. When associated with robust methodologies for quantifying carbon in soil and vegetation, these practices have been recognized by international standards and certified in the voluntary market.

It is important to emphasize that these initiatives do not operate in isolation. Many are already connected to jurisdictional programs under development in the states of the Legal Amazon, engaging with state REDD+ public policies, PES (Payment for Environmental Services) strategies, and emerging traceability systems. The creation of nesting mechanisms and clear rules of complementarity among scales – jurisdictional and individual projects – is essential to ensure integrity, avoid double counting of credits, and guarantee real benefits for the territories and their populations.

The convergence among the private sector, subnational governments, and civil-society organizations – especially in territories of high socio-environmental complexity – represents a concrete opportunity to generate scale, increase the effectiveness of actions, and consolidate Brazil as a global reference in nature-based solutions. It is a new cycle of territorial development that is more inclusive, regenerative, and oriented by measurable results.

The paths are already being laid. Robust climate-finance initiatives, the advance of projects with high socio-environmental integrity, and the growing integration between jurisdictional and private scales demonstrate that the transition is possible, provided it is supported by stable regulatory frameworks, appropriate financial instruments, and a common vision of the future. More than reconciling agendas, it is about aligning strategies and amplifying synergies. The standing forest, traditional knowledge, and nature-based solutions are not only environmental assets but pillars of a national project that recognizes its global role and values, in the present, the choices that will shape the future.

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Carbonext Ybyrá REDD+ Project (Pará)

17. The Green Revolution: 10 Million Jobs and Income Opportunities That Brazil Cannot Miss

Patricia Ellen da Silva, *partner and CEO of Systemiq's operations for Latin America, chair of the Instituto Aya and co-founder of Aya Earth Partners*

1. A New Development Cycle: Brazil as a Protagonist of the Green Revolution

In an increasingly challenging geopolitical context, the pursuit of food and energy security is reorganizing productive structures around the world. Brazil stands out as a powerhouse in the transition to a new low-carbon economy, with real potential to lead this transformation. In 2022, we began the voluntary task force to mobilize the private sector in this ecological transformation, and much of the data used in this chapter was compiled in that listening and data-gathering effort coordinated and published by Instituto Aya and Systemiq, in support of the New Brazil – Ecological Transformation Plan of Brazil's Ministry of Finance and through the UK Pact partnership with the British government.

Historically, Brazil has not surpassed the global average GDP growth barrier of 2.5% per year. In addition, the economic complexity of exports has decreased, with products that, in general, do not contribute significantly to the reduction of greenhouse-gas emissions.

The adoption of sustainable value chains can reverse this scenario, raising the average GDP growth rate from 2.5% to as much as 5.5% by 2030, which represents an increase of up to USD 430 billion, in higher value-added, low-carbon value chains.

Additionally, according to consolidated sectoral studies by the International Energy Agency (IEA) in 2024, Cities Climate Leadership Group (C40) in 2025, International Labour Organization (ILO) in 2020, International Renewable Energy Agency (IRENA) in 2024, World Economic Forum (WEF) in 2020, and ILO in 2018, new green jobs may range from 52 to 405 million globally by 2030. These figures consider mitigation activities and may potentially be higher with new adaptation activities. In Brazil, this transition has the potential to link economic growth with social inclusion, if the structural inequalities that still limit access to these new occupations – especially outside major urban centers – are addressed.

The Green Revolution for the Brazilian economy is a concrete possibility of sustainable economic growth, with inclusion and innovation. According to the updated estimate, the ecological transition can add between USD 40 and 75 billion to GDP by 2030, in the energy sector alone. This growth comes from the diversification of sources, with emphasis on SAF (sustainable aviation fuel), biodiesel, ethanol, green hydrogen, and solar and wind energy. The electric-mobility sector and the exploitation of critical minerals also represent a strong driver, potentially adding up to USD 65 billion in value added with electric vehicles, batteries, and industrial components.

In the bioeconomy, the potential is equally significant: between USD 40 and 75 billion, with emphasis on bioindustry (USD 20-39 bn), biosciences/health and biocosmetics (USD 9-18 bn), ecotourism (USD 7-9 bn), and superfoods originating from sustainable extractivism (USD 4-9 bn). Sustainable agri-food sectors such as ILPF (crop-livestock-forestry integration), exports of regenerative beef, cocoa, açaí, and mahogany can add up to USD 35 billion. Meanwhile, sanitation and green urban infrastructure can contribute an estimated USD 15 to 30 billion, while the circular economy (plastics, textiles, and recycling) adds another USD 10 to 20 billion.

The multiplier effect of these transformations can add up to an additional USD 110 billion, with indirect gains in productivity, productive inclusion, technological innovation, and territorial development. These data reinforce that the Green Revolution is, above all, an agenda of growth and economic prosperity, with strong global integration and appreciation of Brazil's ancestral diversity.

In addition to the direct impact on GDP, these value chains can generate between 16 and 28 million jobs by 2030 – in a median scenario, this represents an opportunity for 10 million direct green jobs. Combined, these chains represent a national strategy for sustainable, inclusive, and competitive development. The distribution of these opportunities must be carried out regionally, considering local vocations and the training bottlenecks identified in each territory.

2. Challenges and Opportunities of the Technological Revolution and Artificial Intelligence

Automation and artificial intelligence (AI) are transforming the world of work. The OECD (Organisation for Economic Co-operation and Development) points to Brazil as one of the countries with the highest percentage of jobs at risk in the face of AI, due to low access to quality education and the concentration of the economy in low value-added sectors. According to the GS 2023, McKinsey 2024, and ILO 2025 reports, up to 50% of Brazilian jobs are exposed to Generative AI, with 15% at high risk of substitution. However, 85% of these jobs show potential for complementarity, requiring multiple skills and urgent reskilling.

The economic complexity index is an indicator that measures a country's ability to produce and export sophisticated goods with high technological density. In 1995, Brazil was above countries such as India, Vietnam, and Malaysia. But over the following decades, this position deteriorated sharply.

Today, Brazil is among the countries with lower relative economic complexity, below economies such as Vietnam and India, which have made significant leaps in productivity, innovation, and industrialization. While China and the United States maintain high positions, and Malaysia consolidates among the most advanced, Brazil has dropped significantly in the ranking. This trajectory of loss of complexity is directly related to the economic model based on commodity exports and the absence of industrial policies articulated with innovation and workforce training. Reversing this picture requires investment in green and sophisticated value chains that allow the country to diversify its exports, increase the value added of its products, and generate more qualified jobs, as proposed by the ecological transformation matrix.

Green job opportunities in Brazil are concentrated in the strategic value chains mapped by the Ecological Transformation Task Force. These sectors may account for the creation of 16 to 28 million jobs by 2030, considering direct and indirect, formal and informal employment, in scenarios that combine public policies, private investment, and productive reorganization.

Below are the main value chains with their respective potential for generating direct and indirect jobs:

- Sustainable Aviation Fuel (Bio-SAF): 1.6-3.4 million jobs
- Critical Minerals, Batteries, and Electric Vehicles: 1.3-1.75 million jobs
- Biosciences/Health: 400-900 thousand jobs
- Cocoa: 110-135 thousand jobs
- Plastics and Textiles Circularity: 500 thousand-1.1 million jobs
- Green Urban Infrastructure: 2.2-4.4 million jobs
- Data Centers: 212–378 thousand jobs

These estimates total around 6.3 to 12 million direct and indirect jobs linked to the mapped green value chains, contributing to a new pact of productive inclusion and environmental regeneration.

Beyond volume, the quality of the jobs stands out: many with formal contracts, high technological content, and remuneration above the average. This represents a reversal of the low value-added logic prevalent in the Brazilian economy in recent decades. These occupations also have potential for territorial strengthening, as they bring together innovation, traditional knowledge, and local vocations, as in the cases of forest extractivism, family farming, and regional bioindustries.

3. From Artificial Intelligence to Ancestral Intelligence: Brazil's Great Opportunity

The future of green work lies not only in technology laboratories, but also in territories, forests, agroforestry systems, and regenerative value chains. The intersection between AI and traditional knowledge represents a new frontier of development for Brazil. Between 2006 and 2020, formal green jobs grew by 30.8%, and support jobs for these activities increased by 38.4% (DIEESE, 2022)[1]. Today, green jobs account for 8.7% of formal employment ties in Brazil, according to UNICEF.

The so-called "ancestral intelligence" brings together local knowledge, environmental regeneration, and social innovation. It represents the ability to design solutions that not only generate jobs, but also regenerate territories, reduce inequalities, and increase local economic complexity. This is where Brazil can differentiate itself on the global stage.

When considering emerging value chains such as superfoods (with emphasis on sustainable cocoa), urban adaptation, and bioplastics, we see strong synergy between natural vocations and the capacity for inclusive income generation. The biosciences/health sector, for example, can catalyze the integration of biotechnology and traditional knowledge of Brazilian biodiversity, generating high value-added pharmaceutical and cosmetic products with strong appeal in international markets.

[1] DIEESE. (2022). Empregos Verdes e Sustentáveis no Brasil: baixa e estável participação, alta concentração regional e menor remuneração média. Departamento Intersindical de Estatística e Estudos Socioeconômicos. (Data elaborated from RAIS/MTE)

The challenges imposed by the Technological Revolution are not limited to the substitution of functions. They reveal a structural mismatch between workforce training and the new demands of the market. Between 2022 and 2023, global demand for green skills grew by 22.4%, while supply grew by only 12.3%[2]. This gap can compromise the potential of the ecological transition. In Brazil, this scenario is aggravated by informality and by an educational system that still does not respond quickly to transformations in the labor market.

Moreover, the curricula of technical and higher-education programs remain outdated and weakly connected to the real demands of emerging green value chains. Institutions such as Senai (National Industrial Training Service) and Senar (National Rural Training Service) have been trying to fill this gap, but still in a fragmented way. The country lacks a robust national policy for training in green skills that brings together the ministries of Education, Environment, Labor, and Science and Technology. The advance of AI and automation also imposes the need for training in new digital and social competences, such as systems thinking, collaboration, and solving complex problems.

Ancestral intelligence is also a strategic response to the low resilience of the Brazilian economy to external shocks. The recovery of sustainable ways of life, together with the bioeconomy and regenerative agriculture, offers pathways to integrate economic value, social inclusion, and environmental balance. For example, value chains such as agroforestry cocoa in Pará, macaúba in the Cerrado, and artisanal fisheries in mangroves show strong potential to generate income and preserve ecosystems. These activities are among the few that combine the generation of formal jobs with traditional knowledge, and often with female or community leadership. This shift also represents a new economy based on ties to the territory, in which development does not require displacement or cultural loss.

4. What Must Be Done: 3 Fronts to Unlock the 10 Million Opportunities

To capture the potential of the Green Revolution, Brazil needs to act on three fronts:

i. Public policies for training and innovation:

In the field of public policy, the establishment of a national strategy with an official definition of green jobs and skills is recommended. This policy should contain clear goals for professional training, regionalized investments, impact criteria, and inclusion indicators. The integration of tools such as territorial input–output matrices and data from the informal market can improve diagnostics and increase the effectiveness of actions.

- Ampliar e territorializar a formação técnica em setores verdes, com destaque para os programas do Sistema S e iniciativas como o FEP Bioeconomia (Fundo de Estruturação de Projetos do BNDES).
- Expand and regionalize technical training in green sectors, with emphasis on the programs of the "S System"[3] and initiatives such as the BNDES Project Structuring Fund for the Bioeconomy (FEP Bioeconomia).
- Update curricula with content on AI, sustainability, and entrepreneurship, aligning technical and higher education with the real demands of the market.
- Recognize traditional knowledge as formal qualifications, valuing the knowledge of Indigenous peoples, quilombola communities, and traditional communities.

[2] WORLD ECONOMIC FORUM, Green job vacancies are on the rise – but workers with green skills are in short supply, 2024. Access link: https://www.weforum.org/stories/2024/02/green-jobs-green-skills-growth/?utm_source=chatgpt.com Accessed in August 2025. [3] The S System is a group of Brazilian private, non-profit organizations created and maintained by industry and commerce sectors to provide professional training, social services, and support for innovation and competitiveness.

ii. Business action and investment in green value chains:

In the private sector, the role of companies will be decisive in making productive restructuring feasible. Green value chains require integrated planning, investments in infrastructure, and long-term contracts. Companies working with reverse logistics, reforestation, fleet electrification, and precision agriculture have already shown that it is possible to combine financial returns with positive socioenvironmental impact. Finally, engagement from the philanthropic sector, universities, and local networks will be essential to develop capacities in territories that are currently neglected.

- Structure emerging value chains, such as bioenergy and superfoods, based on regional vocations.

- Encourage the formalization and training of productive cooperatives and grassroots entrepreneurs.

- Integrate social and environmental criteria into public procurement and tax-incentive policies.

iii. Subnational governance and territorialization:

Real transformation happens in the territory and, therefore, territorial action through local governments, as well as cooperatives and local development agencies, becomes essential for the successful structuring of new value chains and the densification of existing ones.

- States and municipalities should lead green development plans aligned with the Ecological Transformation Plan.

- The example of Pará, with the Amazon bioeconomy, shows how local strategies can generate jobs and income based on regional vocations.

- Philanthropy, the private sector, and local governments should work in partnership to unlock these value chains in a decentralized and inclusive way.

5. Conclusion: a Country Ready to Reinvent Itself

The Green Revolution is not a distant project; it is a concrete possibility to rebuild Brazil based on its strengths. We have the natural resources, diversity, human potential, and vocation to lead a new low-carbon economy that is fairer and more regenerative.

This transformation requires courage to move from the extractivist model to higher value-added value chains, with technological innovation, productive inclusion, and respect for our ancestral intelligence. Artificial intelligence can amplify capacities, but it must be at the service of a national project. Green jobs, distributed throughout the national territory, can guarantee dignity, income, and belonging for millions of Brazilians.

The challenge now is to turn this potential into reality. With coordination among the public, private, and social sectors, with structured policies for professional training, targeted investments, and territorial action, it is possible to open up to 10 million employment and income opportunities by 2030.

It is not just about responding to the climate crisis, poverty, or unemployment; it is a decision about the country we want to be. A Brazil that protects its forests and its people. That innovates without excluding. That grows without destroying. That generates value with justice. This is the choice before us. And the future is watching.

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Carbonext Awa REDD+ Project (Pará)

18. Deforestation in the Amazon and the Tipping Point

Pedro Côrtes, *Full Professor at the Institute for Energy and Environment and the School of Communications and Arts, University of São Paulo (USP)*

In 2018, Thomas E. Lovejoy and Carlos Nobre published the article "Amazon Tipping Point" in Science Advances, drawing attention to the concept of a tipping point. It represents a point beyond which deforestation and degradation would reach a level where the Amazon rainforest would lose its capacity for self-regeneration. This point corresponds to an area between 20% and 25% of the deforested territory. Once this point was reached, the forest would progressively transform into something between the Brazilian Cerrado and the African savanna, a process known as savannization. Estimates indicate that accumulated deforestation across the Amazon rainforest is close to 20%.

The idea spread that if the total deforested area reached between 20% and 25%, the forest would collapse due to the difficulty in recirculating the moisture so vital to the maintenance of this biome. As deforestation progresses at varying speeds, climate fluctuations become more pronounced, indicating that we are approaching a critical tipping point. Unprecedented droughts and rainfall far above normal – even for a rainforest – show that the normal equilibrium is in the process of breaking down. Could it be?

The Amazon Rain Cycle

To better understand how moisture recirculation works in the Amazon forest – a tropical rainforest – it is necessary to determine the source of the water that supplies the Amazon.

Fundamentally, this water originates in the equatorial Atlantic Ocean. In that region, winds blow from east to west, transporting oceanic moisture to the equatorial zone of the South American continent. There, this moisture precipitates as rain, irrigating the deep subsoil. The large Amazonian trees, which have deep roots, drain the deep subsoil and replenish atmospheric moisture through a process known as evapotranspiration.

As a result, the rain cycle repeats itself – hydrating the deep subsoil and reintroducing moisture into the atmosphere – always with winds carrying this moisture westward. This process is what keeps the rainforest alive.

Upon reaching the Andes, some of this moisture manages to bypass that mountain range, precipitating as snow in the higher reaches. The melting of the ice sheet helps feed the headwaters of Amazonian rivers. A significant portion, however, literally curves and is initially distributed, like a fan, to the central region of the country and the southeast. It then continues to southern Brazil and also irrigates Paraguay, Uruguay, and northern Argentina. These flows of wind and moisture are called Flying Rivers.

It is interesting to note that during more intense periods of fires, episodes of so-called black rain (rain laden with soot) were frequent in states such as São Paulo (southeastern Brazil), Paraná, Santa Catarina, and Rio Grande do Sul (all in southern Brazil). The soot from the fires served as an "excellent" marker of the Amazonian origin of these rains. Of course, this is a simplified model, but it serves to explain how rainfall dynamics occur in the Amazon region.

When large trees are cut down, the forest loses its ability to recycle rainwater stored underground and replenish atmospheric moisture. The winds continue to blow, but without transporting the humidity needed to supply other regions and the forest itself.

Has the Point of No Return Been Passed?

A study published in 2023[1] shows how the arc of deforestation is configured, crossing the boundaries of the Amazon rainforest from the Brazilian Northeast to the northern part of the Central-West region. Since the estimated deforestation rate is around 25% – the same value considered the breaking point – it is worth considering that it functions as a trench that prevents the replenishment of atmospheric moisture, precisely by removing large-scale vegetation.

Therefore, deforestation across the entire Amazon does not need to be between 20% and 25% for the forest to enter a savannization process. It is enough for a wide strip, crossing the entire forest, to create a trench that prevents the replenishment of moisture in the forest. This process has not only already happened but is also expanding, with a new arc of deforestation expanding the original area, as shown in Figure 1.

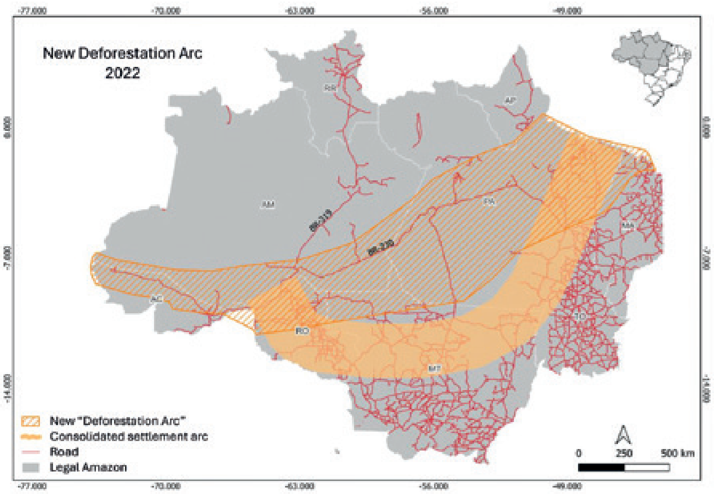

Figure 1 – Arc of Deforestation – Source: "Urban network and pioneer fronts…", see footnote1

Rain falls across this large deforested area, but the absence of large trees significantly reduces the replenishment of moisture in the atmosphere. As a result, east-west winds continue to circulate, but carry less moist air, reducing their ability to generate rainfall in the forest and other areas of Brazil and the South American continent.

[1] Urban network and pioneer fronts in the South of Amazonas state: Transamazônica (BR-230) and Manaus-Porto Velho (BR-319) highways, Ana Beatriz Castro de Jesus, Thiago Oliveira Neto, Fredson Bernardino

The Lack of Water in Large Reservoirs

One way to assess the impact of Amazon deforestation on rainfall is to analyze the inflow into the reservoirs of large hydroelectric plants in Brazil. Inflow represents the amount of water that naturally flows into a system, taking into account the contributions from rainfall and springs. In short, inflow is the water that nature provides, without human interference.

At the University of Porto (Portugal), researcher Fernanda Massaro Leonardis developed the study "The impact of Amazon deforestation on electricity generation in Brazil," under the supervision of Pedro Luiz Côrtes and António José Guerner Dias. The research concluded that the advance of deforestation is already compromising the flow of 11 hydroelectric plants located in central Brazil. These plants were chosen for their location, under the influence of the Flying Rivers, and also because they have no other plants or dams upstream controlling the water flow. Therefore, the water the reservoirs receive is what nature provides, without direct human interference.

Figures 2, 3, and 4 present updated results of this research, featuring condensed data from three hydroelectric plants: Emborcação, Furnas, and Itumbiara. In each figure, two lines stand out. One in blue shows the average inflow until the end of the first decade of this century. The second, red, shows the average inflow after the end of the first decade and the beginning of the second.

A significant reduction in inflow can be noted, a situation that can be attributed to Amazonian deforestation and the loss of moisture in the Flying Rivers. As mentioned, other plants are experiencing a similar situation, all reported in the study above.

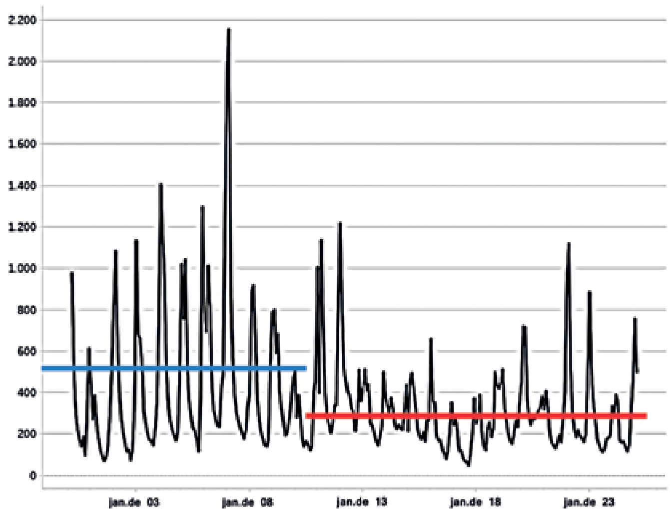

Figure 2. Emborcação Hydroelectric Plant. Variation in inflow (m³/s) between March 2000 and February 2025 – Source: National Electric System Operator - ONS.

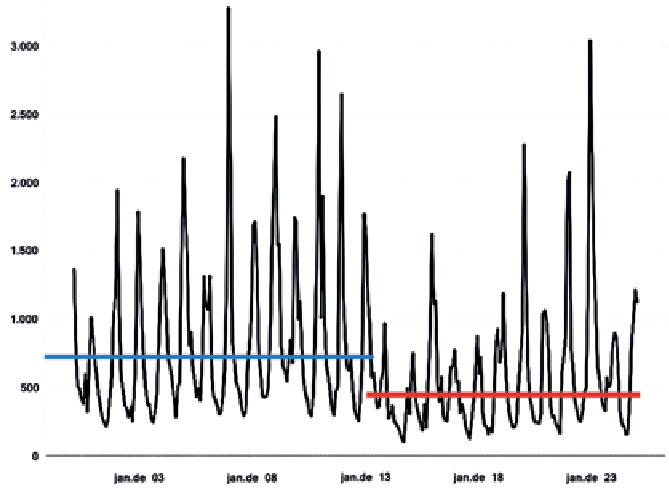

Figure 3. Furnas Hydroelectric Plant. Variation in inflow (m³/s) between March 2000 and February 2025 – Source: National Electric System Operator - ONS.

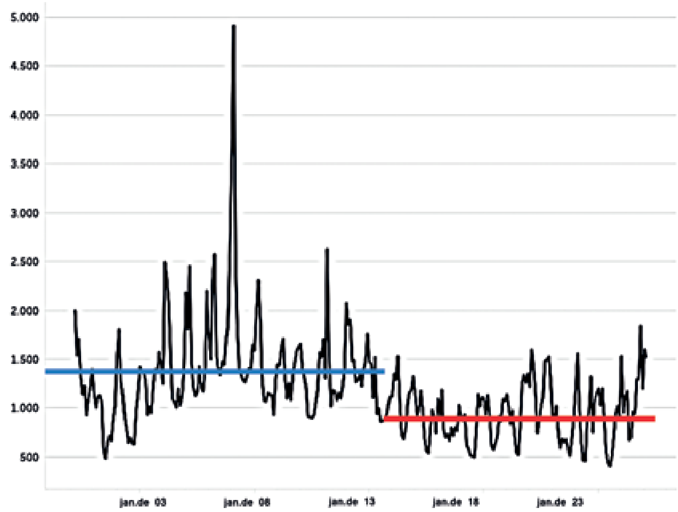

Figure 4. Itumbiara Hydroelectric Plant. Variation in inflow (m³/s) between March 2000 and February 2025 – Source: National Electric System Operator - ONS.

In the São Paulo Metropolitan Region, which encompasses more than 20 million people in the country's largest city and its surrounding municipalities, the Alto Tietê System, one of the region's primary water supply reservoirs, faces a similar issue. Over the past few years, there has been a consistent decline in rainfall, which has been systematically below historical averages. Much of the rainfall that supplies this system originates from moisture transported by the Flying Rivers.

These are examples of the consequences of reduced inflows into large reservoirs resulting from the cumulative deforestation of the Amazon rainforest. Although the deforestation rate has undergone significant reductions, it is essential to note that since intense deforestation began in the 1970s, there has never been zero deforestation or net deforestation. Therefore, this degradation has been accumulating for decades, generating significant climate repercussions.

Conclusion

The concept of a point of no return was crucial in highlighting the potential for a highly alarming scenario if deforestation continues. There is evidence that this point may have already been surpassed, as demonstrated by the results summarized here and the research conducted by researcher Fernanda Massaro Leonardis. Suppose we assume that the point of no return has not yet been reached, based on the accumulated rate of deforestation in the Amazon as a whole. In that case, we run the risk of being subjected to leniency, even though we are close to the limit, as if we still have some time left. However, it is considered that this limit has already been reached in the so-called arc of deforestation, and that this large area constitutes a trench that blocks the recirculation of atmospheric moisture.

As we move toward a situation in which the forest loses its capacity for self-maintenance due to reduced rainfall, significant environmental change will occur. We will feel the impacts of climate change that will extend across the central-southern region of the country, where much of Brazil's economic activity is carried out and where a large portion of the population resides. The consequences will also affect Paraguay, Uruguay, and northern Argentina. Inaction and delay in solving problems can be extremely harmful.

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Carbonext Awa REDD+ Project (Pará)

19. Forests – From Extractivism to Global Leadership

Nelson Barboza Leite, *agronomist and forester*

Introduction

The history of forests in Brazil is also the history of the country's own economic, social, and environmental formation. Since the beginning of colonization, brazilwood symbolized predatory extractivism and the unrestrained exploitation of natural resources. Without management, regulation, or concern for the future, forests were seen as obstacles to occupation and as an apparently infinite stock of timber and other forest products (IBGE, 2019).

Over the following centuries, this logic of exploitation continued with successive cycles of devastation: timber for shipbuilding, charcoal, agricultural expansion, and cattle ranching. The Atlantic Forest was reduced to fragments. In the Cerrado, conversion into farmland advanced rapidly. And the Amazon, to this day, remains under constant pressure (ISA, 2025).

In recent decades, however, Brazil has begun an important transformation. Society has come to understand that forests are much more than timber. They represent biodiversity heritage, a factor of climate balance, and, increasingly, a driver of sustainable economic opportunities (MMA, 2025). Our territory harbors six major biomes, each with distinct ecological, climatic, social, and economic characteristics. Each of them represents not only a natural heritage but also concrete opportunities for the development of regional bioeconomies, provision of ecosystem services, creation of green jobs, and social inclusion (NOBRE et al., 2020).

This diversity gives Brazil a strategic role in the global agendas of forests, biodiversity, climate, water security, and the development of a low-carbon economy (UNEP, 2021).

1. Characterization of the Different Brazilian Biomes

Brazil harbors one of the greatest ecological diversities on the planet, distributed among continental biomes and a coastal-marine biome. Each biome has its own characteristics of vegetation, fauna, climate, relief, and socio-environmental dynamics, reflecting the vast variety of natural landscapes and ways of life existing within the national territory. Understanding these biomes is essential to valuing Brazil's natural heritage, guiding conservation policies, and promoting the sustainable use of resources.

1.1 Amazon – Global Climate Pillar and Symbol of Biodiversity

The Amazon covers about 49.29% of the national territory, approximately 4.2 million km². It is the largest continuous tropical forest in the world, harboring more than 40,000 plant species, 2,200 fish species, 1,300 bird species, and over 400 mammal species (IBGE, 2019; MMA, 2025).

In addition to its unparalleled biodiversity, the Amazon is one of the planet's main climate regulators, influencing rainfall patterns throughout South America and playing an essential role in the global carbon cycle (WWF, 2025).

Its potential for forest-based bioeconomy is enormous: it includes products of sociobiodiversity (oils, fruits, fibers, active ingredients), biotechnology, and environmental services (NOBRE et al., 2020).

1.2 Atlantic Forest – Wealth of Biodiversity and Restoration

Originally covering more than 1.3 million km², today the Atlantic Forest preserves about 12% of its original extent (SOS MATA ATLÂNTICA, 2023). Still, it is one of the world's biodiversity hotspots, with about 20,000 plant species and a high rate of endemism.

The region harbors about 70% of the Brazilian population and concentrates much of the country's economic activities, which worsens conservation challenges (MMA, 2025). Forest restoration initiatives, creation of ecological corridors, and Payment for Environmental Services (PES) projects have been developed as strategies to restore the landscape and promote sustainable development (WWF, 2025).

1.3 Cerrado – Brazil's Water Tank and Cradle of Savanna Biodiversity

With more than 2 million km², the Cerrado is the largest tropical savanna in South America and the second largest vegetation formation in Brazil, covering about 24% of the national territory (IBGE, 2019). It is also the most biodiverse savanna in the world, with approximately 12,000 plant species and rich terrestrial fauna.

The Cerrado is essential for the country's water security, as it harbors the headwaters of major river basins such as the São Francisco, Tocantins, and Paraná (MMA, 2025). The adoption of agroforestry systems, low-carbon livestock, and practices for restoring degraded areas are fundamental for its preservation (EMBRAPA, 2020).

1.4 Caatinga – Exclusively Brazilian and a Laboratory of Solutions for the Semi-Arid

The Caatinga is the only biome that is exclusively Brazilian, occupying about 850,000 km² (MMA, 2025). It has vegetation adapted to drought and surprising biodiversity, with more than 4,500 plant species and several endemic species (EMBRAPA, 2020).

It has high potential for production chains adapted to the semi-arid, such as honey, herbal medicines, and bioenergy. Policies to combat desertification and encourage agroecology make the Caatinga a field of innovation for living with the semi-arid climate (ISA, 2025).

1.5 Pantanal – Floodplain and World Heritage

The Pantanal, with about 150,000 km², is the largest floodplain on the planet and extends across the states of Mato Grosso and Mato Grosso do Sul (UNESCO, 2025). With a high density of fauna per square kilometer, it is home to jaguars, giant otters, and jabiru storks, among other emblematic species.

Its potential for ecotourism, PES projects, and sustainable cattle ranching is internationally recognized (WWF, 2025).

1.6 Pampa – Natural Grasslands and Countryside Biodiversity

Located in southern Brazil, mainly in Rio Grande do Sul, the Pampa covers about 63,000 km² (IBGE, 2019). It is characterized by native grasslands and open vegetation with significant biodiversity of grasses and groundcovers.

The sustainable management of native pastures, traditional extensive cattle ranching, and rural tourism are alternatives for sustainable development in this biome (EMBRAPA, 2020).

2. Natural and Planted Forests – A Heritage for Sustainable Development

The diversity of Brazilian biomes reflects a wide vegetation cover, ranging from dense forests, savannas, grasslands, caatinga vegetation, and wetlands. According to the most recent MapBiomas data (2023), approximately 59% of Brazil's territory still maintains some type of native vegetation cover, predominantly forest formations, mainly in the Amazon.

Natural forests occupy about 480 million hectares, representing approximately 56% of Brazil's total area. Most of this is concentrated in the Amazon, but there are also significant remnants in the Atlantic Forest, Cerrado, Caatinga, and Pantanal (FAO, 2020; IBGE, 2023). These forests provide essential environmental services such as climate regulation, biodiversity protection, and water supply (Millennium Ecosystem Assessment, 2005).

In addition to natural formations, Brazil also stands out worldwide for its planted forest silviculture. Currently, the country has approximately 10.6 million hectares of planted forests, predominantly with species such as eucalyptus and pine, according to the Brazilian Tree Industry – Ibá (2024). These areas are responsible for highly productive and sustainable forest production, supplying the demand for timber, paper, pulp, biomass, and other products, with reduced pressure on native forests (EMBRAPA, 2021).

The combination of conserving natural forests and responsibly managing planted forests represents one of Brazil's greatest differentiators on the global stage. In addition to strengthening the forest economy, this integration is strategic for the country to advance in climate goals, ensure water security, protect biodiversity, and develop a bioeconomy capable of generating jobs, social inclusion, and regional development (OECD, 2022).

3. Forest Management – Legal and Institutional Framework

Before understanding the advances and challenges faced by the Brazilian forestry sector, it is essential to know the legal and institutional framework that underpins its management. The construction of this normative and organizational base reflects the evolution of the perception of the strategic value of forests – not only as a source of resources but as an environmental, social, and economic asset of the country.

3.1 Evolution of the Legal Framework

Forest management in Brazil is the result of a legal and institutional base that has been consolidating over decades, reflecting the growing appreciation of forest resources as a strategic asset for sustainable development, biodiversity conservation, and tackling climate change (Vianna et al., 2020).

The trajectory of Brazilian forestry legislation began as early as the imperial period, with the Land Law of

1850, which, although focused on land tenure, already brought reflections on the use of natural resources.

The initial milestone of a modern forest policy came with the first Brazilian Forest Code, instituted in 1934 (Decree No. 23,793). This pioneering document recognized the social function of forests, established the requirement of authorization for vegetation cutting, and created the foundations for the protection of water sources (Diegues, 2000).

In 1965, Brazil advanced with the enactment of a new Forest Code (Law No. 4,771/1965), which introduced fundamental concepts such as Permanent Preservation Areas (APPs) and Legal Reserves, creating instruments that began to guide the conservation and sustainable use of forests (Cavalcanti, 2017).

The early 2000s brought institutional and legal strengthening of environmental protection, with emphasis on:

- Environmental Crimes Law (Law No. 9,605/1998): Established administrative and criminal sanctions for environmentally harmful conduct.
- National System of Nature Conservation Units – SNUC (Law No. 9,985/2000): Structured the different categories of protected areas in Brazil (MMA, 2021).

A new milestone came in 2012, with the approval of Law No. 12,651/2012 (New Forest Code), which maintained the principles of environmental protection but introduced modern management and regularization instruments, such as:

- Rural Environmental Registry (CAR)
- Environmental Regularization Program (PRA)
- Economic incentives for the conservation of native vegetation, in synergy with Payment for Environmental Services (PES) policies (Soares-Filho et al., 2014).

Currently, initiatives such as Law No. 14,119/2021, which established the National Policy on Payment for Environmental Services (PNPES), and the debate on the Regulated Carbon Market indicate the continuous evolution of a legal framework increasingly integrated with global sustainability and climate agendas (OECD, 2022; MMA, 2023).

3.2 Institutional Structure of Forest Management

The institutional structure for forest management in Brazil has undergone profound transformations over the past decades:

- 1967 – IBDF (Brazilian Institute for Forestry Development): The first federal agency dedicated exclusively to forest management.
- 1989 – IBAMA (Brazilian Institute of Environment and Renewable Natural Resources): Centralized inspection, environmental licensing, and monitoring (IBAMA, 2022).
- 2006 – Brazilian Forest Service (SFB): Responsible for forest concessions, promotion of sustainable production, and coordination of the CAR (SFB, 2023).
- 2007 – National Public Forests Policy: Consolidated forest concessions for sustainable use.
- 2019 – Transfer of the SFB to the Ministry of Agriculture (MAPA): Strengthened articulation with agribusiness and the forest bioeconomy.
- Ministry of the Environment and Climate Change (MMA): Since 1992, the central body of Brazilian environmental policy. In 2023, it once again incorporated the issue of Climate Change.
- 2023 – New National Secretariat for Forests and Territorial Development (MMA): Reinforces forest governance and expands the formulation of public policies for the sustainable use of forests.

The trajectory of Brazilian forests, marked by a past of predatory exploitation and by recent advances in conservation and sustainable use, places the country in a prominent position in the global agendas of biodiversity, climate, and bioeconomy. With a unique forest heritage, a robust legal framework, and institutions in constant improvement, Brazil has the opportunity to transform its natural resources into drivers of sustainable development, social inclusion, and environmental leadership. The future of Brazilian forests will depend on the ability to reconcile production with conservation and to build an inclusive and resilient green economy.

4. The Technological Leap of Forest Activities

One of the great milestones in Brazil's forestry trajectory was the development of modern silviculture. What began with isolated initiatives in the 1960s has, in recent decades, transformed into one of the largest and most competitive forestry sectors in the world (SOUZA et al., 2020).

Thanks to scientific research, technological innovation, and private investment, Brazil today leads in the productivity of planted forests. Species such as eucalyptus and pine reach wood growth rates far above the world average, with average productivities exceeding 35 m^3/ha/year for eucalyptus and 30 m^3/ha/year for pine, in some regions (IBA, 2024).

This revolution counted on the protagonism of research and technological development institutions such as Embrapa Florestas (founded in 1978), which plays a fundamental role in the development of management technologies, genetic improvement, precision silviculture, and forest restoration (EMBRAPA, 2023). Other prominent institutions include the Institute for Forestry Research and Studies (IPEF), created in 1968, and the São Paulo Forestry Institute, which since the 1940s has conducted studies on silviculture, soils, and forest ecology (IPEF, 2022; IF-SP, 2020).

Public universities, such as the Federal University of Viçosa (UFV), the University of São Paulo (USP/ESALQ), the Federal University of Paraná (UFPR), and the Federal University of Santa Maria (UFSM), played an essential role in training thousands of forestry engineers and researchers. Their graduate programs generated knowledge applied to genetic improvement, forest nutrition, pest and disease management, as well as socio-environmental aspects of silviculture (FERREIRA & LEITE, 2019).

Another important milestone was the introduction of eucalyptus cloning and genetic improvement techniques in the 1990s, which resulted in more productive trees adapted to different edaphoclimatic conditions and more resistant to pests and diseases (BRAZILIAN PULP AND PAPER ASSOCIATION – BRACELPA, 2014). The integration between universities, research centers, and private companies created a virtuous cycle of innovation that increased the sector's competitiveness.

In addition to planted forests with exotic species, Brazil has also advanced significantly in research with native species and in the sustainable management of natural forests, especially in the Amazon, Atlantic Forest, and Cerrado (SCHWARTZMAN et al., 2013).

Sustainable forest management (SFM) projects gained momentum in the 1980s and 1990s, with emphasis on the National Institute for Amazonian Research (INPA), created in 1952, which led the first experiments in logging management in the humid tropical forest (INPA, 2021).

The São Paulo Institute for Technological Research (IPT), since the 1960s, has also contributed with studies on the technological properties of native woods (IPT, 2020). In the 2000s, the Tropical Forest Institute (IFT) and the Institute for Forest and Agricultural Management and Certification (Imaflora) began to work strongly in training communities and implementing good management practices (IMAFLORA, 2022).

Research began to include topics such as:
- Reduced Impact Logging (RIL) techniques (PINHEIRO et al., 2018)
- Growth and yield modeling for native species (SILVA et al., 2017)
- Spatial and logistical harvest planning
- Monitoring technologies using satellites, drones, and remote sensors (FREITAS et al., 2020)
- Restoration of degraded areas with native species

The development of public policies, such as the National Policy on Sustainable Forest Management, and the strengthening of instruments such as the Sustainable Forest Management Plan (PMFS), expanded the adoption of good practices in natural forests (MMA, 2023).

Another highlight was the advancement of forest certification, with the arrival in Brazil, in the 1990s, of the FSC (Forest Stewardship Council) system, followed by CERFLOR (Brazilian Forest Certification Program), which reinforced the technical, social, and environmental requirements for responsible management (FSC BRASIL, 2024).

Currently, Brazil has millions of hectares under sustainable management, both planted and natural forests, and is internationally recognized as one of the most advanced countries in the application of science and technology to the forestry sector (FAO, 2022).

This technological and institutional development laid the foundation for the consolidation of a modern and competitive forest industry in Brazil.

5. The Market for Forest Products and Byproducts

The Brazilian forestry sector represents one of the pillars of the national bioeconomy and has gained increasing prominence in international trade. According to data from the Brazilian Tree Industry (Ibá, 2024), the cultivated tree sector generated, in 2024, annual revenues exceeding R$130 billion, considering the forest-based production chain, which includes pulp, paper, wood panels, charcoal, biomass, and various timber products.

The direct participation of the forestry sector in the Brazilian Gross Domestic Product (GDP) is estimated at about 1.2%, but its multiplier effect on the economy is even more significant, considering the entire value chain – from planting to industrial processing and export (Ibá, 2023). In addition, the sector generates approximately 2.5 million direct and indirect jobs, with a strong presence in inland regions and areas of lower industrial development (FAO, 2022).

5.1 Brazil's Participation in the Global Market and Comparison with Competitors

When analyzing the global market for industrialized forest products (including sawnwood, pulp, paper, and wood panels), the following leaders in export value stand out, according to FAO (2023) and ITTO (2023):
- Canada: approximately 12% of global exports.
- China: about 9%, with strong presence in processed wood and paper.
- United States: around 8%, with emphasis on sawnwood and paper.
- Sweden: approximately 7%, focused on paper and construction timber.
- Finland: about 6%, especially in paper and pulp.
- Brazil: with a share of about 5.5%, being one of the five largest global exporters, with strong concentration in pulp and packaging papers.

While the Nordic countries and Canada have a predominantly natural forest base (slow-growing conifers), Brazil stands out for the high productivity of its planted forests, with much shorter growth cycles (6 to 7 years for eucalyptus), in addition to lower production costs (Embrapa Florestas, 2022; Ibá, 2024).

Another Brazilian differentiator is the accelerated growth of exports in recent years, putting the country on a trajectory of market share gains in segments such as pulp, paper, reconstituted wood panels, and forest biomass (BNDES, 2023).

5.2 Industrial Structure and Segments of the Brazilian Forestry Sector

a. Pulp and Paper

Brazil is the world's second-largest pulp producer, with production exceeding 20 million tons annually (Ibá, 2024). Exports surpass US$8 billion per year, with main destinations being China, the European Union, and the United States. The country accounts for about 16% of global pulp production, in a global market worth approximately US$40 billion annually (Pöyry, 2021).

In the paper sector, Brazil's share is more modest, around 2% of the global market, while China, the United States, and Germany lead with more than 10% each (FAO, 2023). However, there is room for growth, especially in packaging papers, a segment driven by e-commerce and demand for sustainable packaging (PwC, 2022).

b. Wood Panels

Brazil is Latin America's largest exporter of wood panels, such as MDF and MDP, with exports exceeding US$500 million per year (ABIMCI, 2023). In the global market, valued at around US$150 billion, Brazil holds about 2% share, while China, Germany, and the United States concentrate about 45% of world production and exports (ITTO, 2023).

c. Solid Wood (Sawnwood and Plywood)

The solid wood segment (sawnwood and plywood) generates more than US$1.5 billion in annual exports. Brazil stands out in the supply of pine plywood, accounting for about 10% of world trade in this product (ABIMCI, 2023). The global solid wood market moves more than US$250 billion per year (FAO, 2022).

d. Wood-Derived Chemicals (Resins and Tannins)

Although less representative in total values, the wood-chemical segment, such as resins, tannins, and plant extracts, has gained ground in international markets (Embrapa Florestas, 2021). The global market for this segment exceeds US$20 billion annually, with major concentration in China, the United States, and India. Brazil still has a share of less than 1% but with growth potential, especially due to demand for bio-based inputs in the chemical and cosmetics industries (CNI, 2023).

e. Non-Timber Forest Products (NTFPs) and Natural Forests

In addition to planted forests, Brazil's natural forests are beginning to gain strategic prominence. Opportunities include:

- Valorization of NTFPs: items such as essential oils, seeds, fruits, nuts, resins, and fibers, with a growing market in the food, cosmetics, and herbal medicine sectors (WRI Brasil, 2022).
- Sustainable Forest Management: international demand for certified tropical timber (FSC and PEFC) has been growing, especially in Europe and North America, driven by regulations such as the EUDR – European Union Regulation on Deforestation-Free Products (EU, 2023).
- Environmental Services and Carbon Market: natural forests are becoming assets for carbon sequestration, biodiversity protection, and water regulation, opening space for payments for ecosystem services (OECD, 2022).

5.3 Global Competitiveness and Structural Challenges

Brazilian competitiveness in the forestry sector is based on factors such as:

- Favorable climate.
- High productivity per hectare.
- Short growth cycles.
- Advanced technology in genetic improvement, management, and industry.
- Low production costs, especially in pulp (Embrapa, 2022; Ibá, 2024).

However, the sector still faces logistical challenges, such as deficiencies in port infrastructure, insufficient railway network, and high domestic transport costs (IPEA, 2023). Another growing challenge is pressure for traceability, certification, and socio-environmental compliance, especially due to new European Union and other developed economies' regulations.

Investments in logistics, information technology, blockchain traceability, and satellite environmental monitoring are underway to strengthen Brazil's position (CNI, 2024).

5.4 New Frontiers for Growth and Trends

The global transition to a low-carbon economy creates a window of opportunities for the Brazilian forestry sector. The main trends include:

- Expansion of the packaging paper market, replacing plastics.
- Growth of bioenergy and second-generation biofuels.
- Development of cellulose-based textile fibers as an alternative to cotton and synthetic materials.
- Advancement in the production of biomaterials, nanocellulose, and forest bioproducts.
- Engineered wood for civil construction (e.g., CLT – Cross Laminated Timber).
- Payments for ecosystem services and voluntary/regulated carbon markets (WEF, 2023; McKinsey, 2022).

Projections indicate that Brazil is in a position to double its share in global forest product exports in the medium term – 15 to 20 years – provided that investments in infrastructure, technology, traceability, and governance continue to advance (BNDES, 2023). Brazil is clearly positioned to transition from a traditional, commodity-based model to a role as a leader in the global bioeconomy, offering innovative, sustainable, and high value-added solutions.

6. Forests and Climate and Biodiversity Policies

In addition to their productive and economic role, Brazilian forests have come to occupy a central place in global climate and biodiversity agendas.

6.1 Evolution of Environmental and Climate Public Policies in Brazil

In recent decades, Brazil has consolidated one of the most advanced legal and institutional frameworks related to climate, biodiversity, and forest management.

The integration of forests into climate public policies has become progressively more evident since the 2000s.

Among the main milestones, the following stand out:

- Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) – Launched in 2004, it reduced Amazonian deforestation by more than 80% by 2012, helping Brazil to meet, ahead of schedule, its voluntary emission reduction targets by 2020.
- National Policy on Climate Change (PNMC) – Established by Law No. 12.187/2009, formalized Brazil's commitments to emission reduction and established instruments such as the National Greenhouse Gas Emissions Inventory (Brazil, 2009).
- Rural Environmental Registry (CAR) – Created by the Forest Code (Law No. 12.651/2012), it became a strategic tool for monitoring land use and complying with environmental legislation, with georeferenced

data from more than 6.5 million rural properties, covering about 90% of the country's registrable area (MMA, 2023; Brazilian Forest Service, 2024).
- National Plan for the Recovery of Native Vegetation (PLANAVEG) – Launched in 2017, it defines strategies to recover 12 million hectares of native vegetation by 2030, a goal assumed by Brazil in its Nationally Determined Contribution (NDC) under the Paris Agreement (MMA, 2017).

These policies also have direct effects on biodiversity, by promoting the maintenance of natural habitats, the creation of ecological corridors, and the reduction of pressures on threatened species (ICMBio, 2023).

6.2 Participation of Forests in Climate Targets

Brazil's natural and planted forests play a central role in the country's national climate mitigation targets. The Land Use, Land-Use Change, and Forestry (LULUCF) sector has historically been responsible for much of Brazil's emissions, but it also concentrates the greatest carbon sequestration opportunities.

Recent data from SEEG – the Greenhouse Gas Emissions Estimates System – indicate that, in 2023, the forestry sector accounted for approximately 48% of Brazil's total GHG emissions, but also for about 80% of the potential for emission reductions, mainly through controlling deforestation and forest restoration (SEEG/OC, 2024).

Brazil's main targets include:
- Reduction of 43% of GHG emissions by 2030, compared to 2005 levels (Brazil, 2020).
- Recovery of 12 million hectares of native forests.
- Restoration of 15 million hectares of degraded pastures.
- Integration of 5 million hectares with agroforestry systems.

Beyond carbon, these actions bring relevant co-benefits for biodiversity conservation, expanding areas of native vegetation and reinforcing ecosystem connectivity (IPAM, 2023).

6.3 Advancement of Payments for Environmental Services (PES)

With Law No. 14.119/2021, Brazil officially established the National Policy for Payment for Environmental Services, creating a legal framework that encourages rural landowners and traditional communities to conserve and restore native vegetation areas (Brazil, 2021).

State programs, such as the Bolsa Verde Program (PA) and the Water Producer Program (SP and other states), have already distributed resources to thousands of families, encouraging conservation practices (ANA, 2023).

In 2024, the National Environment Fund and the Amazon Fund together allocated more than R$600 million to PES initiatives (BNDES, 2024; MMA, 2024).

Other instruments of note:
- Brazilian Emissions Reduction Market (MBRE) – In the regulatory phase, it will establish rules for the official carbon credit market in the country (Chamber of Deputies, 2024).
- Amazon Fund – Has already raised more than R$3.4 billion since 2008, financing more than 100 conservation and sustainable development projects (BNDES, 2024).
- Green Rural Credit – New financing lines tied to environmental performance are being implemented by BNDES and Banco do Brasil (Banco do Brasil, 2024).

In addition to emission mitigation, these initiatives have direct impacts on biodiversity protection, by promoting the conservation of natural areas and the recovery of habitats.

7. Opportunities and Responsibilities: Brazil as a Forest Power

The current challenge is to strengthen institutional capacity, reinforce environmental governance, and promote public policies that integrate forest production, biodiversity conservation, and social inclusion.

Brazil has real conditions to assume global leadership in:

- Sustainable wood production
- Restoration of degraded areas
- Biodiversity protection
- Provision of nature-based solutions to address the climate crisis (WEF, 2020; IPCC, 2023).

In recent years, the country has consolidated a solid foundation in this direction:

- There are about 10 million hectares of planted forests (IBÁ, 2024), supplying one of the most efficient production chains in the world, with average productivity above 35 m^3/ha/year for eucalyptus and 30 m^3/ha/year for pine.

- The Rural Environmental Registry (CAR) already covers more than 6.2 million properties, covering approximately 90% of the expected area, according to the Brazilian Forest Service (SFB, 2025).

- In the restoration of degraded areas, the goal of restoring 12 million hectares by 2030, set in the National Plan for the Recovery of Native Vegetation (PLANAVEG), already has projects underway in several regions (MMA, 2023).

- In conservation, Brazil maintains more than 66% of its original native vegetation preserved and 18% of its territory protected by Conservation Units (UCs), according to MapBiomas data (2024).

The valorization of environmental services is advancing with the legal framework of the Payment for Environmental Services (PES) (Law No. 14.119/2021), which opened new opportunities to remunerate producers and communities that maintain or restore native vegetation, contributing to climate regulation, the protection of water resources, and biodiversity conservation.

However, achieving this potential requires:

- Strategic planning
- Investment in science and technology
- Strengthening of institutions
- Strong and active institutional representation

The forestry sector, with all its branches – conservation, production, environmental services – needs to position itself as a strategic State agenda.

In this context, it is timely and necessary to rescue and update successful initiatives of the past – such as the Floram Project. Conceived in the 1980s within the Institute of Advanced Studies (IEA) of the University of São Paulo (USP), Floram was an innovative program that sought to promote the reforestation of millions of hectares, prioritizing degraded areas and those with low agricultural aptitude (USP/IEA, 1989). Its differential was the multidisciplinary scientific basis, articulating reforestation with sustainable regional development.

The Floram Project had as one of its main architects the renowned geographer and environmental thinker Professor Aziz Nacib Ab'Saber, who coordinated a select group of scientists, professors, researchers, and representatives of the productive sector. With his integrated territorial vision, Ab'Saber was decisive in formulating a proposal that combined geoscientific knowledge, ecological criteria, and a focus on social inclusion (Ab'Saber, 1982; Leite, 2021).

The group coordinated by Aziz advocated for a national forest restoration strategy that respected the specificities of each Brazilian region, taking into account soil suitability, climate regimes, and the ecological vocation of ecosystems. The project envisioned the establishment of regional forestry hubs, economic incentives, integrated public policies, and massive investment in science, education, and technical assistance.

The proposal was bold and pioneering, anticipating in a visionary way many of the concepts that today are pillars of sustainability, bioeconomy, and ecological restoration (Sá, 2020; Strassburg et al., 2020).

Although Floram was not fully implemented, its foundations remain current and extremely relevant. Given today's challenges – climate change, the transition to a low-carbon economy, and the valorization of ecosystem services – resuming a national strategy inspired by Floram is a strategic urgency.

It is time for a new forest pact, bringing together the State, the productive sector, universities, and civil society. Brazil can, and must, assume a global leadership role in the forestry and climate agenda, combining environmental conservation, the creation of green jobs, and international competitiveness.

The future of Brazilian forests depends on the decisions being made now. According to the World Economic Forum, the global market for nature-based solutions could move more than US$10 trillion by 2030, with the potential to generate around 400 million jobs (WEF, 2020).

Brazil, with its territorial scale, biological diversity, and sustainable production capacity, has all the conditions to be a protagonist in this new green economic scenario.

Brazilian society faces the historic opportunity to transform a legacy of exploitation into a new cycle of sustainable development and global leadership, integrating conservation, forest production, social inclusion, and technological innovation.

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Carbonext Awa REDD+ Project (Pará)

20. Public Forests, Carbon, and the Bioeconomy: Turning Challenges into Climate Assets

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Introduction

Brazil faces a key challenge: how to turn its vast forest legacy into an engine of development without sacrificing the ecological integrity that sustains climate, biodiversity, and local livelihoods? Forest concessions emerge in this context as a strategic point of convergence between public policy, markets, and civil society– an instrument capable of anchoring economic value in conservation and restoration, while putting forest carbon at the center of a low-carbon bioeconomy. This is the guiding idea of this chapter: to show how sustainable management and new restoration models with a carbon component become levers to transform vulnerable public forests into enduring climate and social assets.

Drawing on the institutional experience of the Brazilian Forest Service (SFB) – responsible for the concession and governance of federal public forests – in close dialogue with organized civil society, represented by technical partners such as Imaflora, the chapter explores the evolution of concessions, their recent legislative and institutional innovations, and the integration of the carbon agenda as a new source of revenue and impact. It is a story of synergy: the public sector provides legal certainty, structure, and scale; civil society actors contribute best practices, certification, integrity modeling, and connections to national and international markets; together, they redefine what it means to “use the forest”– no longer as appropriation, but as productive and regenerative stewardship.

The chapter is organized along three main fronts. First, we outline the historical and institutional context of forest concessions in Brazil, including the role of land-use planning and the effects on preventing deforestation and land grabbing. Second, we analyze the recent turn that incorporates carbon as a legitimate asset within these arrangements – the legal and regulatory change that opened the door to carbon credits in management concessions and, especially, in restoration concessions. Finally, we present the new generation of flagship projects, focusing on the Bom Futuro National Forest (FLONA), its hybrid restoration-and-conservation design, its selection logic and climate-justice model, and the expected developments to expand scale and impact in Brazil's bioeconomy.

In short, this chapter combines official data, recent regulatory milestones, project studies, and field experience to offer an integrated view. The perspective is deliberately hybrid: public policy and technical know-how are interwoven with certification practices, social participation, and market dynamics, reflecting the fact that truly scalable climate solutions arise from collaboration among the state, society, and the private sector.

The Role of Forest Concessions in Bridging Forest Governance and the Carbon Agenda

Created in 2006, SFB structured the federal government's main strategy for transforming public forests into spaces of sustainable management with legal certainty and a long-term value outlook – demonstrating, early on, the economic potential of keeping the forest standing instead of relegating it to an institutional vacuum and illegal appropriation. The institutionalization of forest concessions changed the paradigm: the forest ceased to be treated merely as a resource to be exploited or a territory to be "tamed" and came to be recognized as a renewable asset whose responsible management can generate jobs, income, ecosystem services and, fundamentally, ensure its integrity. This model combines technical planning with accountability and participation mechanisms, creating a legitimate, long-lasting presence in areas historically fragile from a governance standpoint.

From 2008 to 2025 (the year this book was prepared), the federal government granted approximately 1.3 million hectares of federal public forests to sustainable private management, through 23 concession contracts in 9 National Forests (FLONAs). As a result, local communities benefit from job creation, infrastructure investments, and transfers of resources to state and municipal governments. In 2024, for example, concessions enabled the SFB to transfer BRL 27 million in revenues to states and municipalities (especially in Pará and Rondônia), demonstrating the economic potential of keeping the forest standing.

Over this period, Brazil elevated the climate agenda to the center of its public policies and strategic development projections, recognizing that conservation, sustainable use, and forest restoration are inseparable pillars of any consistent emissions-reduction pathway. This is reflected in the SFB's 2024-2027 Multi-Year Plan (PPA), which set national strategic performance indicators, including reductions in greenhouse gas (GHG) emissions and in Amazon deforestation.

In this context, the SFB expanded its traditional focus – from sustainable forest-management concessions that derive revenue from timber sales – to an innovative new front: forest concessions aimed at restoring degraded areas with revenue from generating carbon credits. This initiative aligns Brazilian forest policy with a low-carbon bioeconomy and the Paris Agreement commitments, signaling a strategy in which environmental conservation and sustainable development advance together.

At this intersection, forest concessions gain a new dimension: they cease to be mere management instruments and become platforms that integrate carbon logic into the bioeconomy. The synergy between the state's forest-governance framework – via SFB – and the incorporation of climate value into concession operations paves the way for a model in which conserving also strengthens climate commitments, attracts integrity-oriented investment, and generates measurable socio-environmental returns. This articulation underpins the proposal to turn public forests into levers of a low-carbon bioeconomy.

Deforestation Pressure in Public Forests and the Strategic Response of Forest Concessions

Despite normative and institutional advances, vast expanses of public forests in the Amazon remained for years without a defined designation, becoming highly vulnerable to illegal occupation, land grabbing, and deforestation. Today, about 49.5 million hectares of public forests in the Legal Amazon – an area the size of the state of Bahia – still lack a formal use designated by the public authority. These undesignated areas are prime targets for environmental crime: between 2019 and 2021, 51% of all deforestation in the Amazon occurred on public lands, with nearly 30% concentrated in Undesignated Public Forests. Irregular appropriation almost always precedes clearing: 61% of large tracts of these forests appear improperly registered as private properties in the Rural Environmental Registry (CAR) by land grabbers. In April 2024 alone, 2,100 hectares of these areas were deforested, underscoring the urgency of a robust state intervention to break the cycle of illicit appropriation and forest loss.

In this fragile, high-pressure scenario, forest concessions emerge as one of the most effective instruments for land-use ordering and valuing standing forests. By transferring – through public tender and under technical management plans – the management of a public forest to a concessionaire committed to sustainable practices, the public authority establishes ongoing presence in the area, deters irregular occupations, and creates economic incentives aligned with conservation. This model not only prevents deforestation and land grabbing; it also redefines the logic of forest use, privileging lawful actors, excluding illegitimate ones, and turning the forest into a renewable asset with social, environmental, and economic value for local economies and for the global bioeconomy. The forest ceases to be an "empty" space to be occupied and becomes a good whose value depends directly on its integrity.

The Public Forest Management Law (Law No. 11,284/2006) structures these incentives, distributing concession benefits in a decentralized manner and linking them to governance and sustainable-use practices. In National Forest concessions, a significant share of concession payments flows beyond the federal sphere: 40% to ICMBio, 20% to the state, 20% to the municipality, and 20% to the National Forest Development Fund (FNDF) – provided environmental councils are functioning and resources are applied to actions that promote sustainable use and local development. This financial architecture builds a foundation of shared responsibility and subnational returns, strengthening territorial value chains and amplifying concession impacts.

More recently, concession notices have incorporated "ancillary obligations": an additional, contract-defined financial obligation that directs resources to public-interest projects linked to the area and neighboring communities. This approach ensures that the enhanced value of the environmental asset flows back as shared benefits – not only to the granting authority but also to traditional communities and nearby Indigenous Peoples. Ancillary obligations finance initiatives in conservation, environmental monitoring, wildfire prevention and response, recovery of degraded areas, applied research, technical training, and socio-productive inclusion. In many contracts, specific clauses reserve up to

30% of resources for initiatives defined jointly with Indigenous communities, strengthening collaboration and advancing an agenda of environmental justice and co-management.

Thus, forest concessions do more than brake deforestation: they become a vector of structural transformation, integrating governance, economy, and territorial justice. By internalizing value in standing forests and creating redistribution and participation mechanisms – such as ancillary obligations – they contribute to a climate bioeconomy in which forest protection and local development are part of the same long-term equation.

Carbon Credits in Forest Concessions: From Prohibition to Adoption as a Lever for Restoration and Conservation

Until 2023, Brazilian law prevented federal forest concessions from capturing direct value from carbon stored in – or emissions avoided by – native forests. The Public Forest Management Law (Law No. 11,284/2006) expressly prohibited including the commercialization of credits from avoided emissions in natural forests as part of the concession's scope, leaving the climate potential of these public areas significantly underutilized. In theory, there was an exception for restoration projects in degraded areas, but it was never operationally regulated and, as a result, none of the 22 concession contracts signed up to that point incorporated carbon revenues – neither as a core activity nor as an ancillary source.

This picture changed structurally with the approval of Provisional Measure No. 1,151/2022, which, when converted into Law No. 14,590 of 2023, revoked the provision in the Public Forest Management Law that barred commercialization of carbon credits derived from avoided emissions in natural forests. The new law created legal space for concession contracts to provide for the transfer of the title to carbon credits from the granting authority to the concessionaire during the concession term, allowing the latter to market those credits and associated environmental services, subject to safeguards and conditions set out in the tender.

With the legal change, an innovative, strategic proposal emerged: using concessions to implement ecological restoration projects in degraded areas where carbon sequestration becomes a legitimate source of revenue. In these arrangements, the concessionaire assumes technical and financial responsibility for restoring native vegetation and, as recovery occurs, accesses the credits generated by the increased carbon stock – integrating into their accounts the logic of a low-carbon bioeconomy and creating a paradigmatic case of land-use reversal.

In parallel, sustainable forest-management concessions also began to benefit from the new legal architecture via REDD+ projects (Reducing Emissions from Deforestation and forest Degradation). When a concessionaire can demonstrate – using robust methodologies and recognized baselines – that their operations reduced deforestation compared to the expected scenario, it becomes possible to certify and market the credits corresponding to avoided emissions, adding a climate component to the traditional management logic.

Formal incorporation of carbon into concessions was consolidated by Decree No. 12,046 of June 5, 2024 (World Environment Day), which regulates Law No. 11,284/2006 and explicitly establishes the rights to generate and commercialize credits for environmental services – including carbon – within forest concessions. The decree also allowed existing contracts to be amended to include the carbon component where feasible, opening a window of opportunity for current sustainable-management concessionaires to broaden their scope by providing additional conservation services and capturing climate value.

This normative and institutional transition positions forest concessions as hybrid platforms: simultaneously instruments of territorial ordering and presence, and vehicles for the economic internalization of the climate benefits of conservation and restoration. The ability to generate and market carbon credits turns "keeping the forest standing" into a revenue source compatible with climate commitments and integrity markets, strengthening the narrative that forest protection and economic development can converge in a resilient bioeconomy.

Bom Futuro National Forest (FLONA): The First Restoration Concession with Carbon

The choice of Bom Futuro FLONA was strategic: created in 1988 and located in the Amazon, in the state of Rondônia, this protected area has historically suffered invasions and illegal logging. It is estimated that about 14,000 hectares of its 98,000 hectares (roughly 14%) have already been deforested and require restoration. The remaining forested portion needs protection against further degradation. In other words, the challenge is twofold: to restore lost forest and to conserve what remains, bringing the area's ecological integrity back.

The concession model designed for Bom Futuro reflects this dual objective. The tender, released for public consultation in 2024, structured the concession in two area blocks and set a 40-year contract term. Concessionaires will be primarily obligated to restore degraded hectares (planting native species and fostering natural regeneration) and to ensure conservation of native forest areas, preventing new illegal deforestation. In return, they may commercialize the future carbon credits resulting from tree growth and from maintaining the restored forest carbon stock. These credits will be the project's main revenue source.

Unlike traditional management concessions, where the winner is the one offering the highest payment to the government, the restoration concession's selection criteria sought to balance returns and benefits. The government's priority is environmental and social, not fiscal. The concession fee was kept low so that revenues earned by concessionaires are channeled to restoration and ancillary obligations (social and environmental actions). In other words, instead of demanding high payments for the area, the tender rewards proposals that allocate more investment to restoring the forest and engaging local communities.

Project studies estimate that restoring Bom Futuro FLONA could capture around 6 million tons of CO_2 over the coming decades. As forest regrowth is verified and certified, these carbon credits can be sold on the international voluntary market – where demand is growing among companies committed to net-zero targets. Gross revenue on the order of BRL 1.2 billion over 40 years is projected for concessionaires, against an estimated BRL 600 million in restoration and protection costs – showing economic viability in the modeling, especially if carbon prices remain at higher levels. For added prudence, calculations used a conservative credit price and included risk buffers (reserve credits) for adverse events.

A key differentiator of the Bom Futuro project is social inclusion and Indigenous participation in the model. The FLONA borders the Karitiana Indigenous Territory and, during the concession's preparation, the Brazilian Forest Service visited the territory to consult the Karitiana people, who support the initiative. The tender grants extra points to companies that commit to hiring Indigenous professionals and purchasing seedlings and seeds from local villages, valuing traditional knowledge in restoration. In this way, the concession also becomes a climate-justice mechanism, channeling benefits to those who have historically protected the forest.

Once awarded, the Bom Futuro experience will serve as a showcase and template for other areas. The goal is not only to restore a critical area in Rondônia's Amazon region, but also to prove the concept that investing in regenerating devastated public forests can generate financial returns and numerous co-benefits (climatic, economic, social). The initiative has already attracted investor and environmental-company interest. At least five corporate groups expressed interest during market sounding, including international carbon-trading firms and Brazilian companies in reforestation and environmental services. The presence of experienced players suggests confidence in the project's feasibility and an expectation that Amazon-origin credits (considered "high-integrity" if well monitored) will achieve strong market pricing.

Next Steps – Future Outlook

The path opened by Bom Futuro FLONA will be replicated and expanded over the next few years through a robust agenda of new restoration concessions with a carbon component. The 2024-2027 Forest Granting Multi-Year Plan (PPAOF) makes 32 federal public forest units available for concession: 24 for sustainable forest management and 9 for restoration of degraded native vegetation. Candidates for restoration with carbon include other National Forests in the Legal Amazon – such as Altamira and Jamanxim – which together have over 110,000 degraded hectares. This expansion reflects a commitment to converge conservation, restoration, and climate in a concession portfolio that unites carbon-sequestration potential and ecosystem-service generation.

In parallel, traditional management concessions also advance in synergy with climate goals. In May 2025, the award of the Jatuarana FLONA in the state of Amazonas – with 453,000 hectares dedicated to sustainable management out of a total 570,000 hectares – increased the federal area under concession by 35%, signaling renewed momentum. With the sum of new management and restoration tenders, Brazil aims to deliver about 5 million hectares under concession by 2027 – nearly quintupling current scale and reinforcing its leadership in public-private partnership models for conservation in the tropics.

To enable this ambition, SFB has strengthened strategic partnerships. In 2024, the SFB, the IDB (Inter-American Development Bank), and BNDES (Brazilian Development Bank) signed a Technical Cooperation Agreement to provide financial support and structure concession projects. BNDES has already committed to structuring 11 concessions – totaling 2 million hectares – with an expectation of mobilizing BRL 6 billion in private investment. Since 2023, Imaflora has served as a technical partner to the SFB, conducting economic-financial modeling, feasibility studies, and revenue-sharing proposals, and is also supporting the state of Amazonas in implementing its first state forest concession.

In sum, Brazil is transforming historical challenges – such as deforestation and land grabbing in public forests – into opportunities for innovation through concessions. By anchoring economic value in forest carbon, the country signals a new cycle of prosperity based on a low-carbon bioeconomy, where conserving and restoring forests becomes good business. Initiatives like Bom Futuro FLONA point to a promising path: using the forest without destroying it, ensuring that our natural wealth helps confront the climate emergency and promotes fairer, more sustainable development – locally and globally.

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Carbonext Ipoá REDD+ Project (Amazonas)

21. The Importance of Monitoring Selective Logging by Means of Remote Sensing

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Introduction

The Brazilian Amazon contains the largest tropical forest on the planet and is one of the main targets of deforestation and forest degradation. Although clear-cut deforestation is widely monitored by remote sensing systems, selective logging poses an additional challenge due to its subtle and fragmented nature.

In this chapter, we discuss the importance of monitoring selective timber extraction as a strategic tool to curb illegal activities, ensure compliance with Sustainable Forest Management Plans (PMFS), and promote more effective environmental governance in the Amazon. We also address how identifying and tracking these activities can support more effective enforcement actions and help combat the illegal timber market.

History of Monitoring by Remote Sensing

The use of satellite imagery to monitor deforestation in Brazil began in 1988 with the creation of PRODES (Project for Monitoring Deforestation in the Legal Amazon), developed by the National Institute for Space Research (Inpe)[1]. In 2004, the Real-Time Deforestation Detection System (DETER) was launched to generate near-daily alerts in support of environmental enforcement.

[1] Inpe. PRODES Project. http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes

Initially focused on the Amazon, these systems evolved to monitor Brazil's other biomes as well, providing essential information to Ibama and other environmental control institutions.

The Dynamics of Degradation and Selective Logging

Studies have shown that deforestation is often preceded by processes of forest degradation[2], with selective logging and the use of fire as the main forms of degradation that alter vegetation structure without necessarily eliminating all forest cover.

Unregulated selective logging that ignores forest management principles plays a central role in this dynamic, as the economic value of tropical timber drives the illegal timber market[3]. High-value timber species are removed first, and the profits from timber sales often finance subsequent deforestation and the conversion of forest to pasture or cropland, as illustrated in Figure 1.

Given this scenario, satellite monitoring of selective logging emerges as an essential tool to anticipate deforestation and enable preventive actions by enforcement agencies. By identifying early signs of human intervention – such as the opening of skid trails and clearings – it is possible to forecast the occurrence of deforestation[4] and allow enforcement bodies to act preventively. This approach increases the effectiveness of actions, reduces damage to the ecosystem, and contributes to the more efficient application of public resources dedicated to environmental protection.

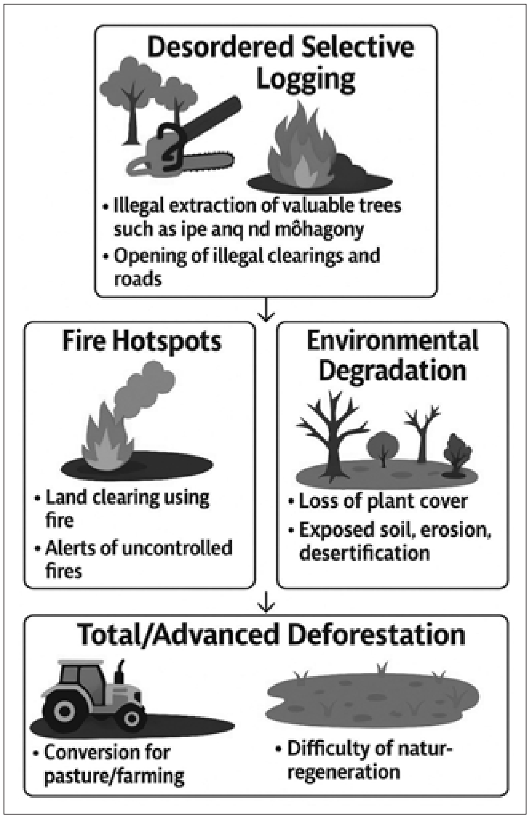

Figure 1: General flow from unregulated selective logging to deforestation.

Sustainable Forest Management

Sustainable Forest Management (SFM) is a recognized instrument for reconciling conservation and forest production. It is an alternative that seeks to ensure the rational use of forest resources, guaranteeing that the forest remains standing and able to regenerate for future uses. As defined by Law No. 11,284/2006, SFM is the "administration

[2] Matricardi, E. A. T. et al. (2020). Long-term forest degradation surpasses deforestation in the Brazilian Amazon. [3] Brancalion, Pedro H. S. et al. Fake legal logging in the Brazilian Amazon. Science Advances, 4(8), eaat1192, 2018. DOI: https://doi.org/10.1126/sciadv.aat1192. [4] Diego Menezes, João Mourão, and Clarissa Gandour (2021). Sob a Lupa do DETER: A Relação entre Degradação e Desmatamento na Amazônia. https://www.climatepolicyinitiative.org/pt-br/publication/sob-a-lupa-do-deter-a-relacao-entre-degradacao-e-desmatamento-na-amazonia/

of the forest to obtain economic, social and environmental benefits, respecting the sustaining mechanisms of the ecosystem under management and considering, cumulatively or alternatively, the use of multiple timber species, multiple non-timber products and by-products, as well as the use of other forest goods and services."

In practice, SFM allows low-intensity timber extraction, observing cutting cycles of 30 to 35 years. In Brazil, management plans allow the removal of up to 30 m^3/ha, which represents fewer than six trees per hectare. Forest Management Units (UMF) are subdivided into Annual Production Units (UPA), which are harvested in rotation over decades. This rotation allows the forest to regenerate between interventions.

Forest management alters less than 15% of the managed area[5], including trails, clearings, and minimal infrastructure (roads, log decks, camps). It is a way of using the forest that generates economic, social, and environmental benefits while allowing it to recover before the next use. This mechanism is internationally recognized in instruments such as the United Nations Sustainable Development Goals (SDGs). SDG 15 sets targets for the conservation, restoration, and sustainable use of terrestrial ecosystems, including forests. SFM is a sustainable activity and simulates the forest's natural dynamics, as mature, senescent trees fall, opening gaps for younger trees to occupy.

However, despite the positive potential of forest management, the system has often been defrauded to launder illegal timber, undermining its credibility and effectiveness. Various irregularities have been identified in areas with approved harvesting. The main ones include: (i) overestimation of timber volumes by falsifying tree dimensions; (ii) recording fictitious trees in inaccessible areas or of no commercial value; and (iii) improper use of timber credits to legalize wood from prohibited areas such as Protected Areas and Indigenous Lands.

In light of this, monitoring selective logging by means of remote sensing tools has become important to ensure the proper execution of authorized Sustainable Forest Management Plans (PMFS) and to identify selective logging in unauthorized areas. Strengthening remote monitoring of selective logging is an important strategy to ensure the integrity of forest management instruments and to combat the diversion of natural resources in the Amazon.

Systems for Monitoring Selective Extraction

In response to these challenges, the Selective Logging Detection system (DETEX) was created in 2008 by Inpe in partnership with the Brazilian Forest Service (SFB) to monitor the occurrence of selective timber extraction in Sustainable Forest Districts[6]. DETEX is a system designed to monitor logging activity in the Amazon. It detects subtle changes in forest cover typical of selective logging that are not captured by traditional deforestation systems such as PRODES or DETER.

One advantage of DETEX is that it uses free, medium-resolution imagery such as Landsat (30-meter resolution). Using images of the same forest area at different times, it applies a change-detection technique based on pixel-by-pixel comparison between a reference image and a current image. The technique detects trails and clearings associated with selective logging by identifying fractions of bare soil. The focus is on logging activity (selective extraction).

[5] Rodrigues, D. A., de Souza Macul, M., Oliveira, A. H. M., Amaral, S., Rennó, C. D., & Escada, M. I. S. (2019). Análise dos sistemas DEGRAD e DETEX em áreas de fronteira agropecuária da Amazônia. In: Proceedings of XIX Brazilian Symposium on Remote Sensing, São José dos Campos, Brazil. URL: https://proceedings.science/sbsr-2019/papers/analise-dos-sistemas-degrad-e-detex-em-areas-de-fronteira-agropecuaria-da-amazonia. [6] Lochs, C. J., & Matricardi, E. A. T. (2019). Estimativa de impactos da extração seletiva. Ciência Florestal.

Another technique adapted to evaluate timber extraction is NDVI (Normalized Difference Vegetation Index), a spectral index calculated from vegetation reflectance in the near-infrared (NIR) and red bands. Widely used for monitoring vegetation and plant health, NDVI captures changes in biomass and can identify alterations caused by events such as fire, drought, and logging. However, DETEX is more efficient for identifying selective logging, as it can detect subtler degradation patterns associated with logging activity. Image processing in the DETER system is performed through the Linear Spectral Mixture Model (LSMM) to estimate the proportion of soil, shade, and vegetation in each pixel of the image used. As a result, soil-fraction, vegetation-fraction, and shade-fraction images are generated. The ratio between the soil-fraction and vegetation-fraction images produces the DETEX image.

Figure 2: DETEX image, highlighting roads, log decks, and clearings. Source: SFB

Although DETEX techniques can be applied to free images such as Landsat and Sentinel, the process is time-consuming and requires trained geoprocessing technicians. Cloud cover is a limitation because it hinders image processing. In some regions of the Amazon, it is common to obtain only one or two cloud-free images per year. To properly monitor a sustainable forest management plan, multiple images per year are ideal.

An alternative to the cloud problem is the use of radar imagery to detect selective logging[7]. However, this type of image requires even more specialized professionals and investment in research to train algorithms capable of performing detection.

With the advent of satellite images with high spatial and temporal resolution, cloud cover has ceased to be a significant limitation. Since 2018, the SFB has used Planet imagery to monitor forest management plans in public forests under forest concession regimes.

This type of imagery enables semi-automated alerts and integration with other technologies such as LiDAR (Light Detection and Ranging) to serve as remote inspections of management plans, validating field information without necessarily dispatching teams on site. However, airborne LiDAR data are costly, and satellite LiDAR (GEDI) does not offer sufficient resolution to monitor at the level of individual trees.

Selective logging alerts based on Planet imagery (Figure 3), adopted by the SFB for monitoring management plans in public forests under concession, show high robustness and reliability[8], allowing very secure assessment of whether the logged trees recorded in control systems match field reality. One example of a control system is the Concession Chain-of-Custody System

[7] Kuch, N. et al. (2021). Assessment of ML techniques for selective logging detection using SAR images. Remote Sensing. https://doi.org/10.3390/rs13173341. [8] Oliveira, M. A. et al. (2025). Monitoring sustainable forest management plans in the Amazon. Remote Sensing Applications. https://doi.org/10.1016/j.rsase.2025.101535

(SCC), which controls all stages of forest management, recording everything from tree felling, bucking, and log transport to processing at the first mill. All SCC data are georeferenced, enabling the use of remote monitoring tools to validate the data.

The main challenge is to expand this alert-based control system for selective logging to all management plans in the Amazon, especially those on private properties and at smaller scales. Such monitoring can significantly reduce enforcement costs for environmental agencies, since PMFSs are spread across vast areas with difficult travel logistics.

Economic Impacts of Illegal Selective Extraction and Degradation

Studies have shown that the rate of degradation (unregulated selective logging, burn scars, and degradation) in the Amazon has exceeded the rate of deforestation[2].

Figure 3: Selective logging alerts from Planet imagery: (a) Newly managed area; (b) Selective logging alerts; (c) Detail of alerts in clearings and roads. Source: SFB

YEAR	BURN SCAR	DISORDERLY SELECTIVE LOGGING	GEOMETRIC SELECTIVE LOGGING	DEGRADATION	DEFORESTATION	MINING
2016	18,194.50	787.83	467.12	3,408.32	2,834.23	15.14
2017	15,500.01	654.78	514.68	1,926.71	3,499.12	52.41
2018	6,253.05	465.71	1,121.81	3,242.56	4,867.18	85.59
2019	8,557.88	1,633.74	1,307.30	1,970.59	9,071.53	105.64
2020	15,172.49	1,951.35	1,600.39	1,503.45	8,318.03	100.14
2021	3,180.69	2,755.81	1,319.92	1,897.40	8,098.60	121.46
2022	11,992.30	2,386.91	1,416.00	2,217.83	10,214.60	64.52
2023	8,092.79	2,485.23	2,083.19	2,717.14	5,056.65	99.76
2024	50,792.16	1,609.24	1,629.93	2,999.23	4,118.65	65.78
TOTAL	**137,735.87**	**14,730.61**	**11,640.33**	**21,883.24**	**56,078.89**	**711.06**

Source: DETER: https://terrabrasilis.dpi.inpe.br/app/map/alerts?hl=en

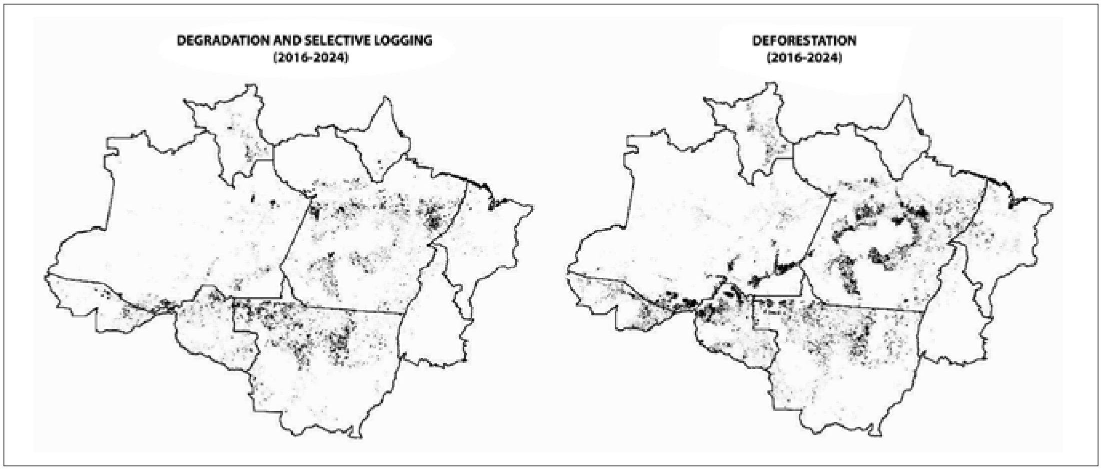

Figure 4: Areas of degradation and selective logging versus deforestation in the Amazon, between 2016 and 2024. DETER-B data.

According to data from Inpe's DETER-B, degradation and unregulated selective logging (i.e., not selective logging under SFM) totaled 3.6 million hectares (36.6 km²) between 2016 and 2024. Deforestation in the same period totaled 5.6 million hectares. In Figure 4 it is possible to see that degraded areas and deforestation generally occur in neighboring or overlapping areas.

As noted earlier, degradation can be a stage that precedes deforestation. However, in many cases it occurs in non-converted areas, mainly in protected areas and Indigenous lands. Illegally extracted timber does not generate shared economic benefits for society, as it is an informal activity that harms the environment.

If all degraded area (3.6 million hectares) had been managed sustainably, it could have produced up to 94 million cubic meters of logs from 2016 to 2024. In this calculation, burn-scar areas were disregarded. These scars typically occur after removal of the most valuable timber. Natural fire in humid forest areas is an uncommon phenomenon[9].

According to the International Tropical Timber Organization (ITTO)[10], the average log price in Brazil in June 2025 is USD 124 for Amazonian species in general. Therefore, the country lost about USD 11.7 billion over the last nine years due to forest degradation.

Future Trends and Potential Applications

The future of forest degradation monitoring points toward systems that are more precise, frequent, and accessible. With the emergence of new sensors and higher spatial and temporal resolution imagery, the trend is for degradation monitoring to enable additional practical applications.

Whether by optical sensors, radar, laser (LiDAR), or the combination thereof, the expectation is that in the near future it will be possible to measure variation in forest biomass caused by degradation.

This will allow better monitoring of sustainable forest management plans, preventing the generation of

[9] Ray, David, Daniel Nepstad, and Paulo Moutinho. "Micrometeorological and Canopy Controls of Fire Susceptibility in a Forested Amazon Landscape." Ecological Applications 15(5) (2005): 1664–1678. bit.ly/3DlepO9. [10] ITTO (2025). Tropical Timber Market Report, Vol. 29(12), June. https://www.itto.int/direct/topics/topics_pdf_download/topics_id=8379&no=1

timber credits to launder wood illegally extracted from other areas. Monitoring selective logging alone already provides some degree of SFM validation, as shown earlier; however, it still does not allow assessment of logging intensity.

Another application will be quantifying carbon emitted to the atmosphere as a result of forest degradation. Quantifying this type of emission is important to understand its impact on climate change mitigation strategies.

The use of artificial intelligence (AI) can revolutionize analyses of forest degradation data, providing greater speed and quality, including the possible identification of illegally extracted tree species. AI applications in processing large volumes of data and documents will allow the detection of fraud in forest transport documents, such as automatically identifying inconsistencies among routes, times, and volumes. Predictive models with supervised and unsupervised learning can help forecast areas most likely to experience illegal selective logging and identify temporal and spatial degradation patterns to guide preventive enforcement actions.

Conclusions

Monitoring selective logging by means of remote sensing technologies is a key piece in protecting the Amazon rainforest. It enables preventive actions against deforestation.

Likewise, it is an important tool for monitoring sustainable forest management plans, as it allows the remote tracking of activities and thus helps prevent the laundering of timber credits that finance illegal deforestation.

Forest degradation generated estimated economic losses of USD 11.7 billion from 2016 to 2024, impoverishing Brazil’s forests and making them less attractive for sustainable forest management. Less attractive forests become more susceptible to conversion to other land uses, such as pasture and agriculture, reducing the potential for forest management in the Amazon.

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Carbonext Awa REDD+ Project (Pará)

22. Monitoring Deforestation and Forest Degradation: Advances, Challenges and Strategies for Climate Protection in Brazil

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Introduction

The protection of tropical forests, especially the Amazon, is one of the fundamental pillars of Brazil's strategies to mitigate the climate crisis, consolidating the country as a central actor in international mitigation agendas. With the largest extent of tropical forest on the planet, Brazil plays a global leadership role in biodiversity conservation and carbon storage. Monitoring deforestation and forest degradation has been consolidated as a strategic tool to inform public policies, guide enforcement actions, and support compliance with international agreements signed by the country, such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD).

Aiming to reduce degradation, deforestation, and the carbon emissions associated with these processes, initiatives such as the 17 Sustainable Development Goals (SDGs), the Reducing Emissions from Deforestation and Forest Degradation mechanism (REDD+), the

Nationally Determined Contributions (NDCs), and Nature-based Climate Solutions (NbCS) have been established. The SDGs, launched in 2015, represent the main global plan to integrate human well-being, environmental protection, and economic development by 2030. REDD+ offers incentives for conservation and sustainable forest management, while the NDC reaffirms Brazil's climate commitments under the Paris Agreement, which include reducing 48% of emissions by 2025 and 53% by 2030, achieving neutrality by 2050. NbCS, in turn, propose actions of conservation, restoration, and management of natural ecosystems, combining mitigation and CO_2 removal.

The contribution of deforestation and forest degradation monitoring to the fulfillment of Brazil's NDC under the Paris Agreement is undeniable. Brazil has set a national target of reducing net greenhouse gas emissions by 67% by 2035 compared to 2005. The goal of achieving zero illegal deforestation by 2030 reinforces the role of remote sensing technologies as essential allies in the transition to a sustainable and resilient development model. Brazil's commitment to the global climate agenda therefore necessarily involves the ability to generate reliable, timely, and public data on land cover and use in national biomes.

Initiatives that integrate satellite imagery with high spatial and temporal resolution, combined with advanced algorithms and automatic mapping techniques, have gained prominence in monitoring deforestation and forest degradation (Wagner et al., 2023). Approaches based on deep learning have improved the detection of vegetation disturbances, allowing for more accurate identification of spatial patterns associated with forest degradation drivers, surpassing the accuracy of conventional monitoring systems.

Over the past decades, Brazil has stood out for the robustness, transparency, and reliability of its satellite monitoring systems, such as PRODES and DETER, which not only precisely track the dynamics of vegetation loss and degradation but also promote full access to data, enabling engagement from different sectors of society. This trajectory has allowed Brazil to influence the international debate on climate, forests, and land use. As such, forest monitoring in Brazil is internationally recognized as one of the most advanced in terms of operational and technological capabilities. This prominence is largely due to the scale and importance of the country's forest resources, which grant Brazil a strategic position in the global scenario and reinforce the need for robust and continuous monitoring systems.

This chapter addresses the historical evolution of deforestation and forest degradation monitoring systems in Brazil, highlighting key technological advances, existing challenges, and future prospects.

1. Historical Evolution of Deforestation and Forest Degradation Monitoring

Deforestation is defined as the conversion of primary forest into another type of land use, particularly pasture and agriculture. In the Brazilian Amazon, the deforestation process involves the complete removal of forest cover by clear-cutting, generally followed by burning, with the objective of establishing agricultural or livestock activities.

Forest degradation corresponds to the partial removal of vegetation, altering fundamental characteristics of the forest such as canopy cover, density, and biomass, without ceasing to be recognized as forest. This process originates mainly from human activities and, progressively, leads to the reduction of ecosystem services, biodiversity loss, and increased carbon emissions, with the main drivers related to illegal logging and forest fires, as represented in Figure 1.

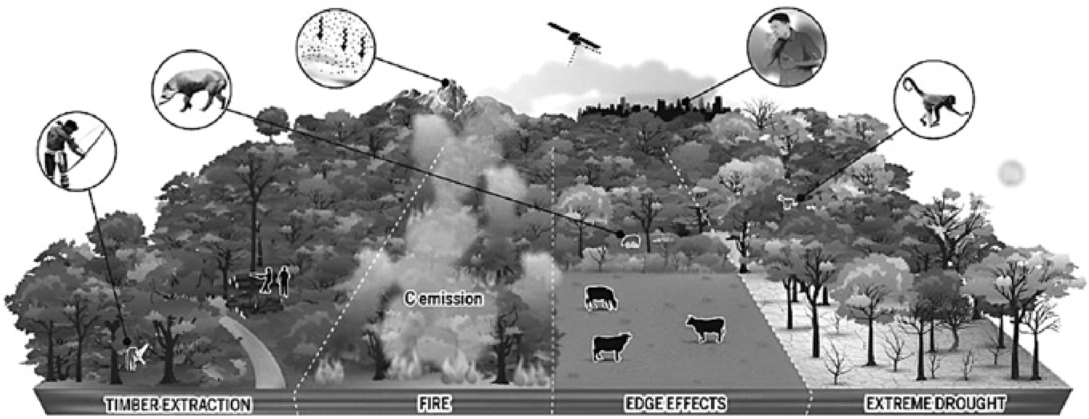

Figure 1. Processes of degradation in the Amazon, their drivers, disturbances, and local and remote impacts. Factors such as logging, fire, and extreme droughts cause losses of carbon and biodiversity and affect both those living in the forest and distant populations. Source: Adapted from Lapola et al. 2023.

Brazil's trajectory in satellite environmental monitoring dates back to the late 1970s, with the first reports of Amazon deforestation produced by INPE and the former IBDF, which in 1988 became systematic monitoring through the Amazon Deforestation Monitoring Project (PRODES), coordinated by the National Institute for Space Research (INPE). PRODES uses medium-resolution optical sensor imagery, such as those from the Landsat and Sentinel missions, to map annually deforested areas of primary forest and is the official monitoring system of the Brazilian government to report annual deforestation rates. With annual updates and consistent historical series, the system has become a global reference in forest monitoring.

Following PRODES, other complementary systems emerged, such as DETER in 2004, designed to detect deforestation in near real time to support environmental enforcement actions, providing daily deforestation alerts, and DEGRAD, developed to map areas in the process of deforestation where forest cover had not yet been fully removed. The DEGRAD system was incorporated into the DETER system in December 2016, and forest degradation began to be monitored on a daily basis. TerraClass, in turn, seeks to classify land use and cover in deforested areas of the Amazon – such as agriculture, pasture, natural regeneration, and urban areas– contributing to the understanding of territorial pressure drivers. Table 1 summarizes the official programs for monitoring deforestation, forest degradation, and land use.

Year	System	Institution	Goal
1988 - today	PRODES	INPE	Annual deforestation monitoring
2004 - 2014	DETER MODIS	INPE	Near real-time alerts
2015 - today	DETER WFI	INPE	Near real-time alerts
2007 - 2016	DEGRAD	INPE	Forest degradation identification
2009 - today	TerraClass	INPE/EMBRAPA	Classification of land use in deforested areas

Table 1. Deforestation and forest degradation monitoring programs conducted by the National Institute for Space Research.

The institutionalization of these systems consolidated Brazil's leadership in the field of forest monitoring, with important milestones such as public data access, methodological standardization, and the adoption of evidence-based public policies. The conceptual distinctions between deforestation and degradation are fundamental for improving monitoring systems. Deforestation implies the suppression of forest cover, with replacement by another land use. Degradation, on the other hand, refers to the functional and ecological loss of the forest, often retaining part of the vegetation cover. This differentiation imposes methodological challenges and uncertainties in official documents, since degradation tends to occur more diffusely, subtly, and is difficult to detect, especially in areas of selective logging or after fire events.

Figure 2 illustrates the methodological workflow used in INPE's monitoring of deforestation and degradation, based on satellite images processed by segmentation algorithms and subsequently validated by interpreters. This process results in maps of deforested areas (in yellow), providing essential inputs for various applications, such as the calculation of deforestation rates and alerts on deforestation and degradation. This integration between remote sensing technology and specialized analysis ensures greater reliability of information, consolidating Brazil as an international reference in forest monitoring.

According to Almeida et al. (2022), until 2021 the annual deforestation rate mapped by PRODES reported all types of clear-cutting in a single class "de-

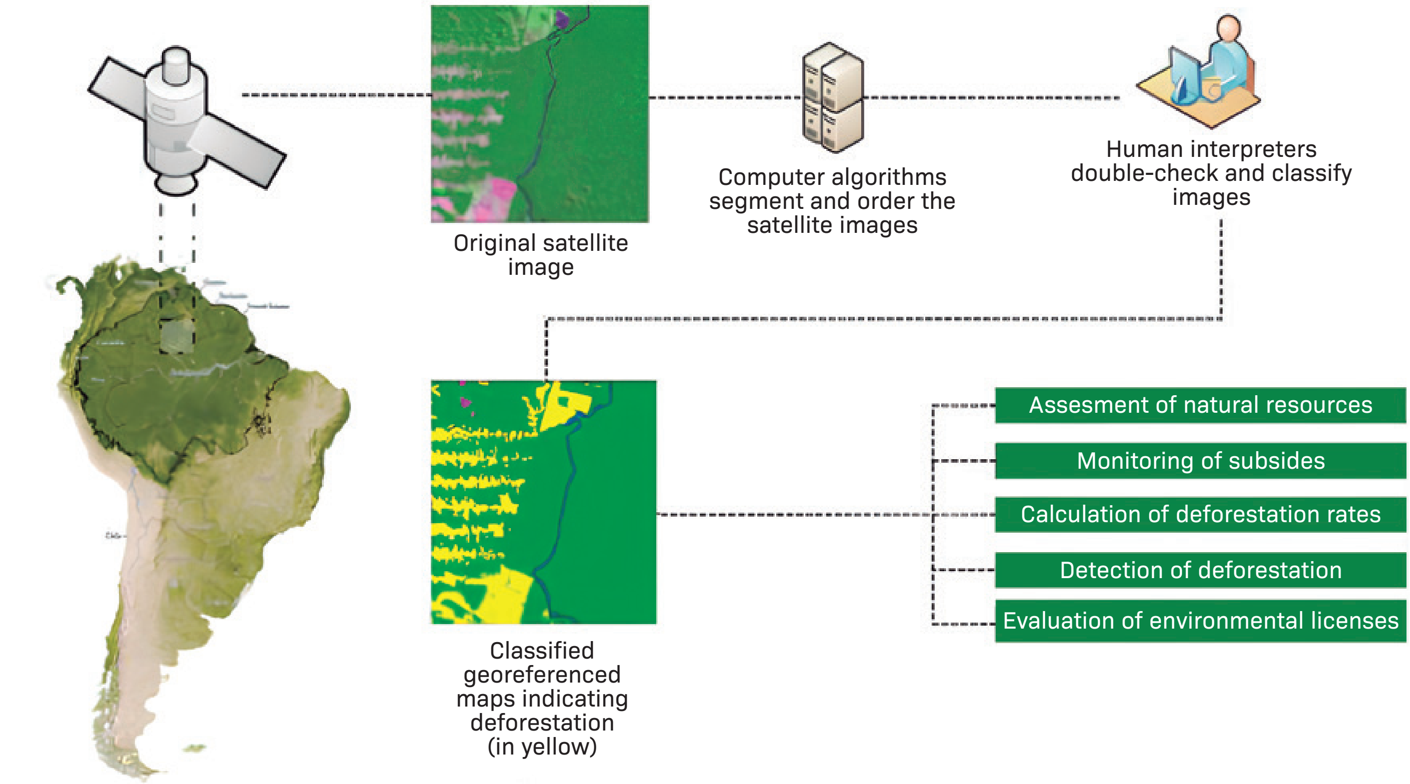

Figure 2. Schematic representation of the functioning of PRODES and DETER. Source: Rajão and Hayes, 2009.

forestation." As of 2022, the rate also began to include "deforestation by progressive degradation." Thus, the "clear-cut deforestation" class aggregated all polygons where complete forest removal occurred over a short period, between the previous year and the current year, identifying in satellite imagery areas with exposed soil, herbaceous vegetation, burning, or mining. Meanwhile, the "progressive degradation deforestation" class aggregates polygons of deforestation detected in forests that had been degraded in previous years by fire or selective logging, with canopy collapse being detected in the observed year.

INPE also operates the Burned Area Program, which monitors and detects fire hotspots throughout Brazilian territory, including the Amazon, distributing daily data such as hotspot location, fire risk, and mapping of burned areas.

Brazil also has other monitoring platforms coordinated by institutions and organizations, such as the Ministry of Justice and Public Security, through the Brasil MAIS Program (Integrated and Secure Environment), which uses commercial imagery from the high-resolution PlanetScope constellation to generate change detection alerts to monitor Brazilian territory; the Deforestation Alert System (SAD) developed by Imazon in 2008 to report monthly forest degradation and deforestation in the Amazon; and the Logging Monitoring System (Simex), also developed by Imazon and based on satellite images to assess Forest Management Plans and map areas subjected to logging in the region.

In this context, it is also worth mentioning the MapBiomas network, created in July 2015 by NGOs, universities, laboratories, and technology startups to carry out annual land cover and land use mapping, in addition to monthly monitoring of water surface and burn scars with data dating back to 1985. The diversity of systems with different purposes and methodologies strengthens transparency and public access to data in Brazilian society.

The mapping of disturbances related to deforestation and degradation has been explored by Brazilian research since the mid-1990s. Initially, the main methods used involved Landsat imagery, spectral mixture models, and visual identification of disturbances. Automation of this process began with the advent of machine learning and the advancement of remote sensing as a science, being directly linked to new computational techniques and more modern sensors. Today, modern systems involving deep learning, LiDAR data, and neural networks represent the state of the art in deforestation and forest degradation monitoring.

2. Challenges in Detecting Forest Degradation

Despite the advances, monitoring deforestation and forest degradation faces technical, institutional, and financial challenges. Among the main obstacles is the limitation of optical sensors, whose effectiveness is reduced during periods of intense cloud cover, especially in the Amazon rainy season. This compromises the timely detection of critical events such as fires and illegal selective logging.

The Forest Reference Emission Level (FREL) is an essential instrument to ensure that Brazil's carbon emissions from deforestation and forest degradation are reported annually and to enable the effective insertion of the country in programs such as REDD+. In the 2023 document, forest degradation is defined as the reduction of carbon stocks in remaining forest areas in the Amazon biome caused by disturbances such as forest fires and uncontrolled logging. Estimates are based on data from DETER, which provides the extent of uncontrolled logging and burn scars in vector format (shapefile). The historical limitation of data meant that degradation was initially ignored in FRELs and still remains restricted to the Amazon. The current scenario highlights that it is still necessary to improve the identification of degraded areas, precisely so that Brazil can meet climate commitments and produce more robust estimates in official reports.

Forest degradation remains underreported. Selective logging, a common practice in undesignated public lands, represents one of the most difficult forms to detect by conventional optical satellites, due to its fragmented nature and the ephemeral character of the disturbance. Degradation can reach greater extents than deforestation in certain periods, contributing significantly to greenhouse gas emissions.

Qin et al. (2021) highlight that degradation accounted for 73% of total biomass loss, while deforestation represented only 27%, a significant difference at the regional scale. Degradation and forest disturbances account for nearly half of emissions, demonstrating the relevance of this often underestimated component. By July 2025, DETER had issued 7,086 deforestation alerts, corresponding to 2,625.72 km², while for forest degradation the system issued 6,789 alerts, totaling an area of 5,812.05 km².

Silva Júnior et al. (2021) report, and point to discussions during the 26th United Nations Climate Change Conference (COP26), that forest fires and edge effects accounted for 88% of gross deforestation emissions in the Brazilian Amazon between 2003 and 2015. The authors warn that countries must broaden the climate agenda to consider forest degradation and incorporate such estimates into future commitments to reduce emissions.

Another critical point is the pressure on public lands, especially those still undesignated, which become targets for land grabbing, predatory exploitation, and criminal burning. Weaknesses in land governance and the challenges of effective State action in these areas reinforce the importance of more precise and integrated territorial alert and surveillance systems. The shortage of technical and financial resources also threatens the continuity of strategic programs. Budget instability and the undervaluing of scientific institutions put at risk the maintenance of infrastructure and the training of specialized personnel. Even so, practical success cases reinforce the relevance of monitoring.

In this sense, the role of governmental environmental institutions is fundamental to combating environmental crimes that actively contribute to the increase of deforestation and forest degradation.

3. Strategies for Climate Protection in Brazil

The increasing complexity of territorial and forest dynamics in the Amazon and other Brazilian biomes requires integrated strategies that consider deforestation and forest degradation as interdependent parts of the same phenomenon of vegetation cover loss. This approach is fundamental to identifying forest change processes, from subtle disturbances to complete vegetation removal, enabling more effective mitigation policies consistent with the international commitments assumed by Brazil.

The adoption of new remote sensing technologies and methods that allow mapping and monitoring the extent of disturbances related to forest degradation, combined with field measurements, must be adopted to reduce the uncertainties associated with estimates of degraded forest area, in order to establish a continuous monitoring system capable of providing forest degradation rates, similar to the annual deforestation rate calculated by PRODES.

The future of satellite monitoring in Brazil can be structured into three strategic axes: technological innovation, institutional collaboration, and scale expansion. The combination of optical and radar sensors (multi-sensor), images at different spatial and temporal resolutions (multiscale), and the integration of terrestrial, aerial, and space observation platforms (multiplatform) has expanded the capacity for detection and continuous operational monitoring. Technologies such as Synthetic Aperture Radar (SAR) are especially valuable for detecting degradation, due to their sensitivity to forest structure and ability to penetrate clouds, which are frequent in the Amazon rainy season.

Artificial intelligence and machine learning-based tools have been successfully tested in the automatic classification of targets and patterns associated with deforestation and degradation, such as road openings, logging yards, and clearings. At the same time, collaborative initiatives among federal, state, civil society, and international cooperation institutions have the potential to strengthen local capacities and promote the strategic use of information.

The consolidation of interinstitutional networks, involving federal, state, and municipal agencies, universities, research centers, and civil society, is crucial to expanding analytical capacity and ensuring cross-validation of data. With this, the development of solutions for participatory monitoring, the training of priority municipalities, and the creation of situation rooms are examples of how monitoring can be expanded, democratized, and oriented toward action.

Achieving the goal of zero deforestation by 2030 – through the elimination of illegal deforestation and the compensation for the legal suppression of native vegetation and the greenhouse gas emissions resulting from it– requires, in parallel, strategies for quantifying forest degradation that need to be incorporated into national policies and international agreements.

The involvement of the private sector is crucial for Brazil to drastically reduce deforestation according to the deadlines and parameters established in international agreements, being fundamental for the country's development to be truly based on a sustainable economy. Companies, especially those directly or indirectly linked to the exploitation and use of natural resources, such as those in the food, cosmetics, pharmaceutical, and construction sectors, have a shared responsibility and strategic interest in ensuring the conservation of Brazilian biomes, especially the Amazon. By adopting practices such as supply chain traceability, investing in sustainably sourced biomaterials, and eliminating deforestation from their processes, companies not only mitigate reputational and regulatory risks but also ensure the continuity of their businesses, securing the availability of essential raw materials for future generations.

Beyond the operational sphere, the role of companies extends to their capacity for influence and innovation, making them agents of large-scale positive transformation. By directing investments to conservation projects through mechanisms such as carbon credits, economically supporting traditional communities that live sustainably in the forest, and developing green technologies that add value to standing forests, such as forest concessions, the private sector significantly amplifies the impact of preservation actions. This complements governmental and civil society efforts, generating large-scale environmental benefits such as climate regulation and biodiversity maintenance, while at the same time building brand value and creating market opportunities aligned with the demands of increasingly conscious consumers regarding the finitude of natural resources.

The existence of monitoring systems with technical maturity and global credibility offers enormous added value to production chains, which need to use such information to consolidate business activity grounded in environmental responsibility. In a world without borders for information production, it is important to incorporate official and reliable information into the flow of private production chains, thus ensuring a sustainability foundation for the production of goods and services based on natural resources.

4. Final Considerations

Monitoring deforestation and forest degradation in Brazil constitutes one of the main tools for the country's environmental and climate governance. The history of innovation, transparency, and strategic use of data places Brazil in a position of international leadership. However, challenges persist, especially given the need to expand the capacity to detect forest degradation, biodiversity reduction, address land tenure pressures on traditional populations, and ensure continuous resources for the maintenance and improvement of official monitoring systems.

The climate goals established in the Paris Agreement, the target of zero illegal deforestation by 2030, and the growing international demand for concrete results make it indispensable to strengthen monitoring and enforcement structures. Investing in science, technology, and cooperation means investing in forest protection and climate resilience.

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Carbonext Caapii REDD+ Project (Pará)

23. Contributions on Land Governance in the Legal Amazon

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Introduction

Brazil's territorial extent and the complexity of its regional contexts have led land governance to incorporate analytical elements that go beyond the spatial realization of economic policy. Regional imbalances caused by the geographic concentration of economic sectors become evident when we look at the configuration of the country's so-called developed regions. In the South and Southeast – and later in the Center-West – the relationship between land tenure structure and economic structure is more consolidated and advanced. By contrast, the North and Northeast show less consolidation of land tenure. These regions concentrate the largest areas of territorial disputes and conflict and, consequently, lower economic development. This reality is reflected across the different states of the Legal Amazon.

The boundaries of the Legal Amazon were defined by the territorial delineation established by Complementary Law No. 124 of January 3, 2007; its land area covers just over 500 million hectares – approximately 59% of Brazil's territory. Within it lie the states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins, Mato Grosso, and 79% of Maranhão. Across these states there are 772 municipalities, some so large that they exceed the size of certain European countries.

This continental scale makes sound land governance considerably more difficult, and many land rights are neither legally recognized nor documented. The region bears the marks of federal interventions that identified and brought vast stretches of land into the public domain, establishing public and private "allocations" over time – many left unfinished – thus fostering uncertainty and land conflicts that persist to this day.

From a land-governance perspective, the region still contains a stock of undesignated public lands and unallocated public lands (public lands not set aside for a specific use) that have yet to be identified and incorporated into the public estate. Added to this stock is the limited capacity of both federal and state governments to manage these public assets, resulting in serious environmental and land-tenure problems. This tenure category registers the second-highest deforestation rates in the Legal Amazon, surpassed only by agrarian settlement projects. Irregular occupations multiply, land grabbing spreads, regularization fails to reach occupants who meet legal criteria, pressure mounts on traditional communities, and environmental crimes such as deforestation and burning accumulate.

Local particularities rooted in entrenched historical processes increase the challenge of implementing proper land governance. Any robust and effective analysis of land-use and occupation trends on public lands in the Amazon necessarily requires federal cooperation – federal, state, and municipal governments working, within their institutional and legal mandates, on a cooperative agenda that converges technically and juridically, integrating databases and actions across territories.

For the federal government, the first question is the limit of its competence, given that states and municipalities hold title to part of the lands located in the Amazon. Therefore, the federal government must build local political coordination to enable integrated territorial action at different levels of solution. Overlaps in titling processes or even cross-allocations of state tenure categories over federal areas (and vice versa) exemplify the lack of integration that generates legal uncertainty on the ground.

Beyond institutional integration, the challenge of carrying out sound territorial governance hinges on knowledge – one of the Brazilian state's principal shortcomings. At all levels – federal, state, and municipal – the absence of a multipurpose land administration system prevents detailed understanding of the territory. Fragmented cadastres for rural properties generate uncertainty and fertile ground for fraud.

This lack of cadastral integration is one of the major villains in the process. There is dissonance among the georeferenced property cadastre, the national rural cadastre, the environmental cadastre, tax cadastres, and the property registry, revealing a complete mismatch of data that decisively affects land-governance processes. In addition to these discrepancies in federal official databases, there is no synergy with state and municipal land and environmental datasets. The federal government has been working to address these issues, but much remains to be done.

Beyond respecting the competencies of the federative entities, effective land governance requires access to land-registry information. When registry data are not accessible in an intelligible, spatialized form integrated with other cadastres, legal uncertainty grows.

It is not possible to govern an unknown territory, nor to ensure the territorial rights of traditional peoples and communities – who are in the most vulnerable situations – without information. Tracking and analyzing land occupation and use, social structures and arrangements, land-market dynamics, and human–environment interactions will only be possible with continuously updated information, consistent with a multipurpose database organized within an integrated, multi-agency land administration system that spans federative levels and branches of government.

1. Federal and State Competencies in Land Tenure Arrangements in the Amazon

In colonial Brazil, unworked "sesmarias" (land grants) were to be "returned" to the Portuguese Crown – hence the term "terras devolutas" (unallocated public lands). With the 1850 Land Law, unallocated public lands came to include all lands not under private ownership and not earmarked for public use. Under the 1891 Constitution, unallocated public lands were assigned to the states, with the Union retaining only those needed for national defense.

Decree-Law No. 1,164/1971 revisited the federalization of unallocated public lands, this time along built, under-construction, and planned highways. The 18 highways mentioned– many never built– totaled nearly 24,000 km, returning roughly 480 million hectares to federal domain, deemed indispensable for national security and development. Law No. 6,383/1976 enabled the incorporation of unallocated public lands to the Union when public-records searches found no private property, and it regulated the legitimation of possession for occupants who made public lands productive through their own and their families' labor. Large tracts were thus incorporated during this period.

Federalization of unallocated public lands had a strong impact on the states of the Legal Amazon. Pará, for example, had more than 70% of its unallocated public lands transferred to the Union. Acre lost control over almost all of its public lands, and Rondônia saw practically its entire territory federalized. Only Amazonas – crossed by few roads – retained control over most of its lands. In 1987, Decree-Law No. 2,375 revoked the earlier decree, returning unallocated public lands to state ownership, except those already registered to the Union or otherwise subject to existing legal relationships. These shifts in ownership across the Legal Amazon have fostered uncertainty and land conflicts that persist to this day.

It is also important to note that unallocated public lands still exist today at both federal and state levels; actions to identify and incorporate these lands remain essential in order to:

1. **Reduce land conflicts:** unclear ownership fuels disputes among traditional communities, farmers, companies, and the State.

Spatial distribution of federal public tracts in the Legal Amazon.

Source: Ministry of Agrarian Development.

2. **Support socioeconomic development:** regularization can unlock investment in infrastructure, agriculture, livestock, and other productive activities.

3. **Advance environmental conservation:** many unallocated public lands are crucial for conservation (ecosystems, water resources, biodiversity); unresolved tenure hinders conservation policy.

4. **Enable land regularization:** regularization is essential to secure possession and use rights for traditional communities – Indigenous Peoples, quilombolas, and riverine communities– bolstering legal security and social well-being.

Accordingly, incorporating unallocated public lands remains an action with significant socioeconomic and environmental impacts. The Brazilian State should separate public land from private land through the processes of identification, discrimination (legal delimitation), incorporation, and registry of unallocated public lands. Given the vast territory and the public sector's limited capacity to order and control land tenure, discrimination of all federal and state unallocated public lands remains unfinished. This explains why a significant share of land in Brazil still lacks well-defined property rights.

At the state level, identifying and incorporating unallocated public lands is a state responsibility. As with the Union, states must take appropriate steps to delimit and incorporate public lands in line with their own legislation. To carry out these actions, states rely on their land institutes. Amazonas, Acre, Rondônia, Roraima, Pará, Maranhão, Amapá, Tocantins, and Mato Grosso all have specific bodies – institutes, agencies, or secretariats – for this territorial agenda, playing roles analogous to INCRA (the National Institute for Colonization and Agrarian Reform) at the federal level.

As with federal public lands, which still require better-qualified databases, state public lands follow the same pattern. None of the Legal Amazon states has a platform to visualize their lands – only spreadsheets and textual information. In Amazonas, for example, only a list of 127 tracts (glebas) is available; in Pará, a 2021 table covers 115 municipalities with 13,170,388.73 ha incorporated. These sources are minimally interactive, outdated, and lack key attributes.

This lack of transparency in state land agencies severely compromises integrated action on the agenda of public-land allocation – whether for public or private purposes – reducing the efficiency of land-governance policies.

Once public lands have been incorporated and separated from private lands, the State must proceed to allocate them properly – both to regularize individual or collective possession and to establish other tenure categories such as agrarian settlements and protected areas. In this regard, states have issued norms on the management of public lands and on the discrimination and incorporation of state unallocated public lands, aligned with federal practice.

2. Federal Public Land—Designated and Undesignated: From Management to New Allocations

In 2003, the Permanent Interministerial Working Group (GPTI) was established to propose and coordinate actions to reduce deforestation in Brazil's biomes. In 2004, the GPTI's work led to the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm), which already highlighted territorial-ordering problems in the Amazon.

In 2009, Brazil formalized a voluntary commitment under the UNFCCC (United Nations Framework Convention on Climate Change) to reduce greenhouse-gas emissions – goals attainable only with sustained, significant deforestation reduction in the Amazon. This required an all-of-government approach, especially from the Ministries of Agrarian Development and of the Environment, which jointly took the lead on land and environmental regularization in the region.

These initiatives signaled a shift in the management of federal public lands in the Legal Amazon. The federal government began to gain better knowledge of the land-tenure fabric of federal public lands already incorporated and of unallocated public lands yet to be delimited, incorporated, and registered to the Union.

Thus, Interministerial Ordinance MDA/MMA No. 369 of September 4, 2013 created the Technical Chamber for the Allocation and Land Regularization of Federal Public Lands in the Legal Amazon (CTD), later regulated by Decree No. 9,309 of March 15, 2018.

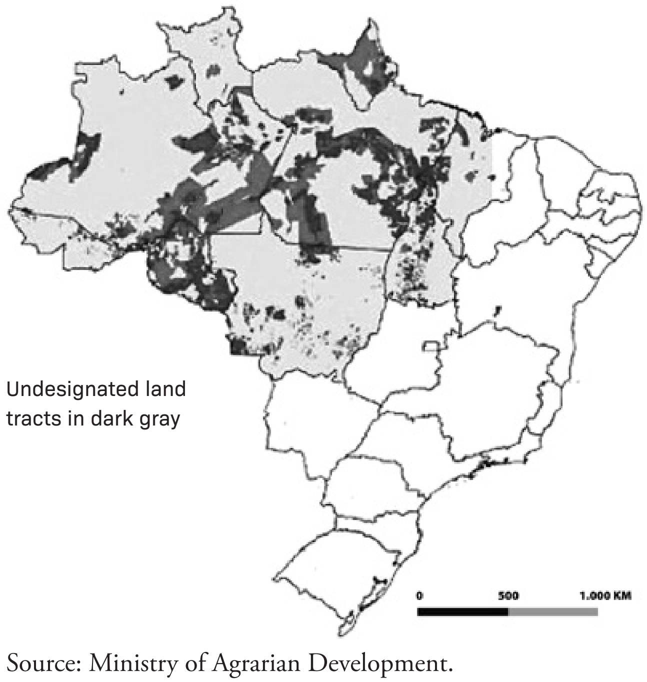
As of 2023, now under the Ministry of Agrarian Development and Family Farming (MDA), the Chamber comprises the following deliberative bodies: Ministry of the Environment (MMA), Ministry of Indigenous Peoples (MPI), Secretariat of Federal Assets (SPU), INCRA, the Brazilian Forest Service (SFB), ICMBio, and FUNAI; and advisory members: the Ministry of Justice and Public Security and the Ministry of Racial Equality. In short, the Technical Chamber reviews and decides on the allocation of federal public lands for public policies related to:

- Indigenous Lands;
- Protected Areas (Units of Conservation);
- Quilombola Territories;
- Territories of other Traditional Peoples and Communities;
- Agrarian Reform;
- Forest Concessions;
- Land Regularization.

Currently, the CTD is regulated by Decree No. 10,592 of December 24, 2020, updated by Decree No. 11,688 of September 5, 2023, which – besides adapting to the new ministerial structure – better aligns with existing laws on public-land allocation. The Chamber now includes deliberative and advisory members (as above), consults the National Defense Council, and returns coordination and the Executive Secretariat to the MDA. The Chamber's new operational workflow, set out in its Internal Rules (Resolution No. 1 of January 22, 2024), also provides for specific working groups – three at the time of this document's preparation.

Operationally, the original wording of Decree No. 10,592/2020 assigned INCRA to indicate the tracts to be regularized for consultation, thereby prioritizing the public interest over the private. The new wording assigns the agency to indicate tracts not yet consulted, i.e., to be allocated, revising the focus. Other features remain: a 60-day review period (extendable) for agencies; monthly ordinary meetings; release of areas to land regularization under Law No. 11,952 in the absence of other agencies' interest; and the requirement that each agency with allocation competence keep its interest layer in the Land Management System (SIGEF) up to date. This last point is essential to safeguard the public interest, since INCRA's Land Governance Platform – which issues documents and titles – automatically queries these layers and denies applications in cases of overlap. As of now, the CTD still has 48,252,653.47 ha to be discussed and allocated within federal public lands.

Spatial distribution of federal public tracts and undesignated federal public areas in the Legal Amazon.



Source: Ministry of Agrarian Development.

With respect to federal public lands, information is available via the Terras do Brasil Platform[1], which publishes the main land-tenure figures for the Amazon. It lists 2,141 federal public tracts totaling 123,948,606.64 ha. It also reports: 155 Quilombola Territories (2,009,815.9 ha); 148 Federal Units of Conservation (67,554,026.07 ha); 388 Indigenous Lands (118,665,683.99 ha); and 2,811 Agrarian Settlement Projects (34,926,448.73 ha). Information on private rural properties located in the Legal Amazon is also available: as of August 2025 there were 220,974 certified private rural properties, totaling 131,408,202.95 ha.

3. The Allocation Problem: Created but Unfinished Allocations; Precarious Destinations

Allocation of public lands intersects directly and indirectly with several public policies – chiefly land regularization and environmental regularization. After public lands enter the public estate, the State selects areas for specific allocation, in order to meet demands for recognizing the territories of traditional peoples and communities, creating protected areas, promoting agrarian reform, and regularizing individual or collective possession.

Allocation involves several steps and is often left unfinished. These incomplete procedures aggravate legal uncertainty. Allocation (afetação) is an early step in which specific purposes are assigned to public lands. Protected Areas created by decree, for instance, are "allocated" at creation; however, this must be followed by expropriation or removal of private lands and possessions within their boundaries and by the proper annotations in land registries.

Failure to complete every step of the allocation process generates legal uncertainty for private properties and good-faith occupants whose situations are otherwise consolidated on the ground. A process is considered complete when all steps have been concluded: creation, registration of the allocated area to the Union, de-allocation where applicable, compensation or regularization of affected occupants. Many public areas are not in this condition.

Similar difficulties occur across tenure categories, often producing overlapping claims among Quilombola Territories, Units of Conservation, Indigenous Lands, Agrarian Settlements, and federal public tracts. These overlaps hinder land governance. The absence of a consistent, well-integrated land database exacerbates conflicts even among government bodies.

When it comes to individual land regularization – potentially transferring public assets to private hands – the situation is even more serious. Research by the Center for Management and Innovation in Family Farming at the University of Brasília (CEGAFI/UnB) indicates that roughly 80% of issued titles lack a completed allocation process – missing evidence of payment, release of resolutory clauses, and registration of titles with proper notation of the public estate.

Compounding this, a significant share of titles were issued in the 1970s–1990s and lack vectorized graphic information, making it exceedingly difficult to define boundaries between allocated and unallocated areas.

Another complicating factor is the condition of land-tenure archives, which are mostly physical and poorly preserved. A comprehensive records-recovery effort is urgently needed. Beneficiaries should be summoned to present documentation proving titling, payment, release of clauses, and registry; thereafter, these data must be entered into existing official databases. Efficient land governance is impossible without ensuring interoperability

[1] https://terrasdobrasil.mda.gov.br

among existing systems and harmonization of concepts and procedures across responsible bodies.

These elements must be in order so that public policies can be effectively applied – guaranteeing the rights of good-faith occupants to be regularized individually, and of traditional communities to be regularized collectively – while safeguarding original territorial rights and meeting urgent environmental needs in an era of climate change.

Proper allocation of public lands should primarily aim to generate legal certainty for all beneficiaries, public and private. Unfinished allocations directly undermine what we refer to as allocation, since in practice it has not been concluded.

4. Weaknesses in Land Governance in the Legal Amazon

In discussing weaknesses in land governance in the Legal Amazon, our goal is not to exhaust the topic but to raise key questions that make the difference between advancing public land-allocation policies and maintaining the status quo.

1. **Absence of an integrated land administration system.** Brazil lacks an administratively integrated system that articulates the many institutions working on land issues, together with a multipurpose, interoperable land cadastre that aggregates cadastral and registral information. This gap seriously compromises the efficiency of public and private allocation processes, especially in the Amazon.

2. **Unfinished allocations create chaos.** Purchase-and-sale contracts grounded in invalid titles; heated land markets trading precarious or void titles; renegotiation risks; lack of compensation; state titles issued over federal lands and vice versa; overlapping interest layers. All of this hampers sound governance, opening space for illegalities and land-tenure fraud.

3. **Undelimited and unincorporated unallocated public lands.** There is a clear perception of weak governance over public lands – particularly unallocated public lands – at both state and federal levels. As a large share of public lands falls into this category, these areas are prone to private appropriation through possession. The perpetuation of this process sustains the State's lack of control over its lands and land policies, undermining efforts to improve governance.

4. **Shifting legal frameworks.** In Brazil, frequent changes to the legal bases governing land tenure create significant uncertainty. New laws are constantly proposed – or existing ones challenged – calling administrative acts into question. Legislation on Indigenous land demarcation, for example, is continually contested, hindering proper policy implementation. Likewise, there are recurrent attempts to amend Law 11,952/2009 (land regularization), proposing new temporal cut-offs and criteria. Such changes disrupt workflows, systems, and the effectiveness of land-governance agendas.

5. **Limits of registry information.** Especially in the Legal Amazon, there is a generalized lack of notarial/registry information, which erodes confidence in records of private land rights due to limitations in the property-registry system. This is compounded by inaccuracies in public-land information, which often fails to reflect actual allocations already made.

6. **Lack of geospatial information on allocations.** Regardless of type – public or private – there is often a mismatch between a geospatial representation of a property and its land-registry record. The result has been more territorial disputes and cadastral problems such as duplicate entries and "stacked" (overlapping) polygons in both cadastres and registries.

5. Considerations and Recommendations

Although occupation of the Amazon predates the arrival of the Portuguese Crown, multiple attempts to regulate the process have been made. Various federal and state plans, programs, and actions have been implemented over time without proper, in-depth evaluation of their outcomes. Unsurprisingly, many issues remain unresolved.

Implementation of any public policy – whether public or private allocation – must follow all stages, including monitoring and evaluation, with recalibration as needed. Based on the reflections above, we offer the following contributions to more adequate land governance in the Legal Amazon:

1. Carry out collective land regularization as a guarantee of territorial and environmental rights for traditional peoples and communities.

Collective land regularization is vital for policies that identify, delimit, and title the territories of traditional peoples and communities. Ensuring the rights of Indigenous Peoples and quilombolas – as well as other traditional communities – is fundamental to maintaining their sociocultural development and preserving their relationships with territory and the environment. Programs such as Territórios da Floresta, promoted by the Ministry of the Environment and Climate Change and the Ministry of Agrarian Development and Family Farming, are essential to securing collective territorial guarantees and should be strengthened and even expanded.

2. Carry out individual land regularization.

Both the federal government and the states must advance the individual regularization of occupations that meet legal requirements, upholding the socio-environmental function of land use, promptly allocating public lands, strengthening legal security and land/environmental status of properties, reducing deforestation and land grabbing, and complying with environmental law.

3. Do not reward environmental offenders with land titles.

Current law allows regularization only for properties consolidated before 2008. Occupations established and deforested after that are not eligible. In addition to this requirement in Law No. 11,952/2009, Decree No. 10,592/2020 provides that only occupations with an active Rural Environmental Registry (CAR), no environmental embargo, and only partial overlap with "type B" public forests may be regularized. The law also allows title cancellation within ten years if resolutory conditions are unmet. The legal framework sets criteria not only at issuance but also post-titling. However, monitoring is very weak, effectively leaving compliance with contractual clauses to the discretion of beneficiaries.

4. Identify legacy titles issued by states and the federal government.

A thorough search of archives, fonds, land ledgers, and administrative case files at INCRA and state land agencies is essential to establish the actual number of titles issued and assess their legality. Validity analysis can substantially affect states' land-tenure structure: in places where titling was expected to have produced private properties, process weaknesses may mean such lands remain public domain despite private allocations. This review is necessary, as is vectorizing these documents to locate them spatially. When academic research shows that 80% of issued documents lack information confirming their legality, this action becomes fundamental for territorial governance.

5. Integrate land cadastres into a single administration system.

It is essential to develop a multipurpose, integrated land-administration system based on graphic and textual information, so the federal government, states, and municipalities can identify existing public lands and define optimal allocation strategies. Territorial knowledge is fundamental, and only institutional integration together with a transparent, public, user-friendly system can deliver significant advances in land-governance agendas. Property-registry offices must be included, as access to registry information is one of the greatest challenges.

In sum, the challenges to effective land governance in the Legal Amazon are considerable, complex, and involve multiple public and private interests. It falls to federal, state, and municipal governments to engage cooperatively with this agenda and propose solutions. At the same time, society must demand results and public-sector efficiency in implementing policies for the proper allocation of lands.

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Carbonext Awa REDD+ Project (Pará)

Closing Thoughts

Lourival Sant'Anna, *Director of Communications at Carbonext*

At the end of the extraordinary journey through the chapters of this book, I would like to share some perceptions it has inspired in me.

First, the immense pride I felt, as a Brazilian citizen, in learning about the achievements of countless public servants who have dedicated their time, talent, and energy to building the system for protecting Brazil's biomes – from legislation to the creation of various types of protected areas, their monitoring, and enforcement. The seriousness, competence, and commitment of professionals from institutions such as the Ministry of the Environment, Ibama, the Brazilian Forest Service, Inpe, Inpa, the Ministry of Agrarian Development, Incra, BNDES, and many others highlighted throughout this book is truly remarkable.

We are constantly reminded of the illegal activities that devastate our biomes. This pain and ongoing concern – which, of course, must indeed mobilize us – sometimes prevent us from perceiving and valuing the impressive protection system Brazil has built over many decades. This is the institutional foundation we must build upon, valuing and improving what already exists, and above all, the professionals at the heart of this construction.

Their call for the acquisition of more sophisticated monitoring and geoprocessing systems must be heard.

Second, I would like to draw attention to the rich experience of the great Indigenous leader Almir Suruí. He is an example of the foresight that emerges when traditional knowledge, nature, the market, and the public sector come together. The experience of his enterprise in the Sete de Setembro Indigenous Land in Rondônia, combined with the expertise of legal design, brings essential lessons about the care required to build robust, integral projects with traditional communities.

This brings me to the third lesson of this book: how the private sector can take part in the monumental task of conserving the forest and other biomes, in partnership with government and civil society.

Natura's experience, as a pioneer in developing this business model, is foundational: in its Amazon Program, which involves 45 forest communities in producing inputs for cosmetics, for every dollar invested, USD 9.40 is generated in socio-environmental benefits. One of its partner cooperatives in Rondônia today generates more income from selling forest-conservation carbon credits than from the raw materials it supplies to Natura.

Our generation has both the privilege and the grave responsibility of building regulatory, technological, economic, and social solutions for generating environmentally sustainable income in the territories.

It is a monumental challenge. But, as many chapters in this book demonstrate, we have already laid the foundations of this structure, and are beginning to raise its walls. Payments for environmental services in general, and carbon credit projects in particular, are no longer utopian. A large and sophisticated market is taking shape, with companies that bring together high expertise, solid governance, and complex on-the-ground due diligence. It is an activity 100% dependent on credibility. That is what a "carbon credit" means: trust in an intervention that is integral, additional, and permanent.

Given the complexity and sensitivity of this intervention, it is natural that criticism has arisen – some pertinent, others less so. In any case, scrutiny has been vital, however painful and at times unfair, for the sector's maturity. Methodologies have been refined, as have institutional and legal arrangements, to ensure the reliability of this activity and its continuous accountability to society, as it should be.

Up to now, REDD+ has been the most intensely scrutinized, with serious doubts raised about its integrity, additionality, and permanence. Proving that an intervention prevents deforestation of a given area – and consequently avoids a given amount of carbon emissions – or ensures its sequestration is no trivial task. But we cannot allow ourselves to become complacent in the face of difficulties. Conserving the forest and other biomes is the most important task, because their loss is irreparable in terms of climate, biodiversity, and traditional cultures and knowledge.

The emergence of ARR is extremely welcome, given the vast extent of already deforested and degraded areas. If we can not only stop destruction but also recover what has been lost, we will move more quickly in the desired direction. ARR cannot be seen as a substitute for REDD+. They must walk hand in hand. First, because we will never be able to recreate the immeasurable richness contained in natural biomes. Second, because every successful ARR project eventually becomes a REDD+ project, to conserve the replanted area.

ARR's potential is immense, being an intuitive modality whose credibility is established with far less effort than REDD+. Its additionality is undisputed. It is a highly labor-intensive activity, bringing a very positive economic externality: the creation of quality jobs in territories that are in great need of them. A whole value chain is born with ARR, starting with seed collection and cultivation, moving on to planting, and then to the care required for growth, consolidation, and conservation.

All nature-based solution modalities interact with agribusiness, as sources of complementary income for landowners and as contributions to the rainfall regime on which the production of food, pulp, and energy depends. But ALM is, by excellence, the meeting point between agriculture and the fight against climate change. The enthusiasm surrounding regenerative agriculture is fully justified, especially in Brazil, where practices such as no-till farming, crop rotation, and crop-livestock-forest integration have long been a reality, thanks to national technological development and the generosity of our climate and nature.

It is no coincidence that a Brazilian company, NaturAll Carbon, was the first in the Americas – and one of the first in the world – to certify an ALM methodology at Verra. The potential for productivity increases, carbon removal, and income generation is formidable. Regenerative agriculture represents a transformation potentially comparable to the Green Revolution.

Given all this, Brazil faces some urgent tasks. The first is to organize its land tenure system. Land tenure disorder benefits a few, through corruption and illegal appropriation, and harms the entire country. A 2022 law mandates the digitalization of property records in all notary offices. It must be implemented.

Similarly, georeferencing databases must be unified to end discrepancies around land boundaries – and with them the legal uncertainty surrounding projects. We must also reach regulatory clarity regarding contracts between Indigenous Peoples and project developers, with the participation of public authorities, so we can unlock the immense potential for remunerating the environmental services provided by these peoples.

What we have here is the outline of a national project: strategically positioning Brazil in the global geo-economy as a major producer of food, renewable energy, sustainably harvested forest products and minerals, traditional knowledge, clean water, and greenhouse gas storage and removal. This is Brazil's vocation – its "bio-competitiveness"– just as it is for many other nations around the world.

We do not have the right to squander yet another historic opportunity – which may well be the last. This book seeks to be an invitation, as well as the sketch of a map, for us to walk this path together.

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