New Economy for the Brazilian AMAZON

WRI BRASIL

THE NEW CLIMATE ECONOMY
The Global Commission on the Economy and Climate

Research Coordination

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Reviewers

The authors would like to thank the experts who reviewed this report, formally or informally, at different stages throughout its development process (in alphabetical order): André Baniwa, Antonella Mazzone, Caio Koch-Weser, Carlos Muñoz Piña, Elizabeth Farina, Fabíola Zerbini, Fernanda Boscaini, Gustavo Pinheiro, Henrique Evers, Henrique Roncada, Itamar Melo, Joaquim Levy, Julio Alves, Laize Sampaio, Lara Caccia, Laura Malaguzzi Valeri, Luiz H. Calado, Maritta Koch-Weser, Monika Roper, Patricia Pinho, Paulo Amaral, Pedro Frizo, Robin King, Rodolpho Zahluth Bastos, Sâmela Sateré-Maué, Luiz Antonio Lindau and Vanessa Perez.

Suggested Citation

Nobre, C.A. et al. (2023) *New Economy for the Brazilian Amazon*. São Paulo: WRI Brasil. Report. Available at: www.wribrasil.org.br/nova-economia-da-amazonia

https://doi.org/10.46830/wrirpt.22.00034en

Imprint

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Design and Layout
Nektar Design (nektardesign.com.br)

Cover photo
Valdemir Cunha/Greenpeace

June 2023

COORDINATION

WRI BRASIL

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The Global Commission on the Economy and Climate

PARTNERS

FINANCIAL SUPPORT

Acknowledgements

This report was led by the WRI Brasil and The New Climate Economy teams and produced in collaboration with more than 75 researchers from various Brazilian regions, and organizations, which we thank for their technical and institutional support: NAEA-UFPA, NEREUS-USP, FIPE, CENERGIA-COPPE-UFRJ, IPEAD-CEDEPLAR-UFMG, IPAM, IDESAM, Contas Abertas Association and Amazon Concertation.

Financial support from Instituto Clima e Sociedade (iCS), the Danish Ministry of Foreign Affairs, the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection of Germany, Instituto Arapyaú, Good Energies Foundation, and the Climate and Land Use Alliance (CLUA) was vital for the conduction of the study.

We thank all the people who contributed to the research at different stages. Among them, the people interviewed at Acampamento Terra Livre (ATL) and throughout 2022, as well as the consultants who enabled the production of this report.

The following list should not be taken as exhaustive, but exemplifies people who shared their time and knowledge (in alphabetical order): Adilson Joanico Baniwa, Adriana Lobo, Ana Terra Yawalapiti, Anderson Rogerio Lopes, Angela Mendes, Antônio Araújo da Silva Apurinã, Beptuk Kayapó, Berta Pinheiro, Bia Saldanha, Camila Carolina, Carina Pimenta, Cira Moura, Crisanto Rudzö Tseremey'wá, Danilo Igliori, Demetrio Tiriyo, Denison Duarte dos Santos, Edilson Martins Melgueiro, Edivan Silva de Carvalho, Edmilson dos Santos Oliveira, Eduardo Correa Tavares, Eduardo Malta, Elcio Filho Manchineri, Erika de Paula Pedro Pinto, Evaldo Bruno Martins, Fábio Heuseler Ferreira Leite, Fabricia Sabanê, Florinda Tuyuka, Francineia Fontes, Genilson Guajajara, Gustavo Fontenele, Hélio Jorge da Cunha, Izabella Teixeira, Janete Martins Iana, Joaquim José Martins Guilhoto, Johannes van de Ven, Jucleison do Santos Aniká, Kreusa Nunes André, Lindalva Felix Zaquri, Luciane Rodrigues, Lucimar Souza, Manoel Serrão Borges de Sampaio, Marago Ikpeng, Marcela Rodrigues, Marcelo Furtado, Marek Hanush, Mário Fadell, Masawãkatxi Apurinã, Mauri Kurio Boe, Narciso Pantoja, Neuraci Charles, Olavo Kamuu Dan Wapichana, Oremê Ikpeng, Oyago Suruí, Paulo Moutinho, Renata Cordeiro, Renee Pineda, Rodrigo Junqueira, Samia Apurinã, Samuel Lima Pereira Arara, Sandra Regina, Saulo de Tarso Vale Bente, Sebastião Krahô, Sérgio André Castelani, Shirley Amairé, Suely Araújo, Tari Kayabi, Tatiana Schor, Terekwyi Gavião, Tilho Nascimento Felix Arara, Tuíre Kayapó, Tutuma Ikpeng, Valmir Ortega, Vanuza Guajajara, Viviane Romeiro, Waduwabati Suya, Wagner Katamy and Walmyr Tapirapé.

We are also grateful to the communication and engagement teams at WRI Brasil and The New Climate Economy (in alphabetical order): Alex Simpkins, Andrea Mendez, Bruno Calixto, Bruno Felin, Cristina Bodas, Fernando Correa, Guilherme Cutrim, Lais Assumpção, Jenna Ellingson, Joana Oliveira de Oliveira, Karoline Barros, Laio Teixeira, Madhavi Ganeshan, Nate Shelter, Pandora Batra, Sara Ascher, Yelena Akopian, the entire WRI Brasil team, WRI, The New Climate Economy and partner organizations.

Sustainable production by families associated with Central das Associações Agroextrativistas of the Manicoré River, in the state of Amazonas, who are working to create the Sustainable Development Reserve (RDS) of the Manicoré River. Photo: Nilmar Lage/Greenpeace.

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List of acronyms

ABC+ Plan	Low Carbon Agriculture Plan (Plano de Agricultura de Baixa Emissão de Carbono, acronym in Portuguese)
AFS	Agroforestry System
AMIT	Amazon Institute of Technology (Instituto de Tecnologia da Amazônia, acronym in Portuguese)
ANR	Assisted Natural Regeneration
APP	Permanent Preservation Area
ATEG	Technical and Managerial Assistance (Assistência Técnica e Gerencial, acronym in Portuguese)
ATER	Technical Assistance and Rural Extension (Assistência Técnica e Extensão Rural, acronym in Portuguese)
ATG	Animal Transport Guide
BASA	Banco da Amazônia
BAU	Business as Usual Scenario, same as Reference Scenario
CAPDA	Committee for Research and Development Activities in the Amazon (Comitê Das Atividades de Pesquisa e Desenvolvimento na Amazônia, acronym in Portuguese)
CAR	Rural Environmental Registry (Cadastro Ambiental Rural, acronym in Portuguese)
CBI	Climate Bonds Initiative
CEDEPLAR-UFMG	Center for Regional Development and Planning at Universidade Federal de Minas Gerais (Centro de Desenvolvimento e Planejamento Regional da Universidade Federal de Minas Gerais, acronym in Portuguese)
CENERGIA-COPPE-UFRJ	Environmental and Energy Economics Center, Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering of Universidade Federal do Rio de Janeiro (Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia da Universidade Federal do Rio de Janeiro, acronym in Portuguese)
CGE	Computable General Equilibrium
CRA	Agribusiness Receivables Certificate (Certificado de Recebíveis do Agronegócio, acronym in Portuguese)
CRI	Real Estate Receivables Certificate (Certificado de Recebíveis Imobiliários, acronym in Portuguese)
DEGEE	Greenhouse Gas Emission Rights (Direitos de Emissão de Gases de Efeito Estufa, acronym in Portuguese)
DOM	Dynamic Optimization Models
ESG	Environmental, Social and Corporate Governance
FCO	Center-West Region Constitutional Fund (Fundo Constitucional do Centro-Oeste, acronym in Portuguese)
FDIC	Credit Rights Investment Fund (Fundo de Investimento em Direitos Creditórios, acronym in Portuguese)
FFS	Forest Support Scenario (Cenário de Sustentação Florestal, acronym in Portuguese)
FIPE-USP	Institute of Economic Research Foundation of Universidade de São Paulo (Fundação Instituto de Pesquisas Econômicas da Universidade de São Paulo, acronym in Portuguese)
FLR	Forest and Landscape Restoration
FNO	North Region Constitutional Fund (Fundo Constitucional do Norte, acronym in Portuguese)
FT-BTL	Fischer-Tropsch Biomass-to-Liquids
FUNRURAL	Rural Worker Assistance Fund (Fundo de Assistência ao Trabalhador Rural, acronym in Portuguese)

FWA	Fixed Wireless Access
GDP	Gross Domestic Product
GEM	General Equilibrium Models
GHG	Greenhouse Gases
GO	Gross Output
$GtCO_2$	Gigaton of carbon dioxide
GWp	Global Warming Potential
HDI	Human Development Index
IBGE	Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, acronym in Portuguese)
IBRAM	Brazilian Mining Institute (Instituto Brasileiro de Mineração, acronym in Portuguese)
ICLF	Integrated Crop-Livestock-Forestry System
IDESAM	Institute for Conservation and Sustainable Development of the Amazon (Instituto de Conservação e Desenvolvimento Sustentável da Amazônia, acronym in Portuguese)
IEMA	Institute of Energy and the Environment (Instituto de Energia e Meio Ambiente, acronym in Portuguese)
IIOAS	Interregional Input-Output Adjustment System
IIOM	Interregional Input-Output Matrix
IIOM-LAM	Interregional Input-Output Matrix for the Legal Amazon
INPE	National Institute for Space Research (Instituto Nacional de Pesquisa Espacial, acronym in Portuguese)
IOM-Alpha	Input-Output Matrix of Alpha Accounts
IPAM	Amazon Environmental Research Institute (Instituto de Pesquisa Ambiental da Amazônia, acronym in Portuguese)
IPCC	Intergovernmental Panel on Climate Change
IPEA	Institute of Applied Economic Research (Instituto de Pesquisa Econômica Aplicada, acronym in Portuguese)
LAM	Brazilian Legal Amazon
LCA	Agribusiness Credit Bill (Letra de Crédito do Agronegócio, acronym in Portuguese)
LCI	Real Estate Credit Bill (Letra de Crédito Imobiliário, acronym in Portuguese)
LR	Legal Reserve
MAPA	Ministry of Agriculture, Livestock and Food Supply (Ministério da Agricultura, Pecuária e Abastecimento, acronym in Portuguese)
MBRE	Brazilian Market for Carbon Emission Reduction (Mercado Brasileiro de Redução de Emissões de Carbono, acronym in Portuguese)
Mha	Million hectares
MRV	Monitoring, Reporting and Verification System
$MtCO_2$	Million tons of carbon dioxide
NAEA-UFPA	Center for Advanced Amazonian Studies at Universidade Federal do Pará (Núcleo de Altos Estudos Amazônicos da Universidade Federal Pará, acronym in Portuguese)
NDC	Nationally Determined Contribution
NEA	New Economy for the Amazon
NT	No-tillage systems
OTCA	Amazon Cooperation Treaty Organization (Organização do Tratado de Cooperação Amazônica, acronym in Portuguese)
PES	Payment for Environmental Services
PLANAVEG	National Plan for the Recovery of Native Vegetation (Plano Nacional de Recuperação da Vegetação Nativa, acronym in Portuguese)

PNAE	National School Meals Program (Programa Nacional de Alimentação Escolar, acronym in Portuguese)
PNGATI	National Policy for Territorial and Environmental Management of Indigenous Lands (Política Nacional de Gestão territorial e Ambiental de Terras indígenas, acronym in Portuguese)
PNPSA	National Policy for the Payment of Environmental Services (Política Nacional de Pagamento por Serviços Ambientais, acronym in Portuguese)
PON	Passive Optical Networks
PPBio	Bioeconomy Priority Program (Programa Prioritário em Bioeconomia, acronym in Portuguese)
PPCDAm	Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia Legal, acronym in Portuguese)
PROAGRO	Agricultural Activity Guarantee Program (Programa de Garantia da Atividade Agropecuária, acronym in Portuguese)
PRONAF	National Program for Family Farming Strengthening (Programa Nacional de Fortalecimento da Agricultura Familiar, acronym in Portuguese)
PSR	Rural Insurance Program (Programa de Seguro Rural, acronym in Portuguese)
REDD+	Reducing Emissions from Deforestation and forest Degradation
REF	Reference Scenario, same as Business as Usual

Stilt houses in a stream in the Educandos neighborhood, Manaus, state of Amazonas. Photo: Guentermanaus/Shutterstock.

SBGE-GEE	Brazilian Greenhouse Gas Emissions Management System (Sistema Brasileiro de Gestão de Emissões de Gases de Efeito Estufa, acronym in Portuguese)
SBTi	Science Based Target initiative
SIN	National Interconnected System (Sistema Interligado Nacional, acronym in Portuguese)
SINARE	National System for the Reduction of Greenhouse Gas Emissions (Sistema Nacional de Redução de Emissões de gases de efeito estufa, acronym in Portuguese)
SNCR	National Rural Credit System (Sistema Nacional de Crédito Rural, acronym in Portuguese)
SUDAM	Amazon Development Superintendence (Superintendência do Desenvolvimento da Amazônia, acronym in Portuguese)
SUFRAMA	Manaus Free Trade Zone Superintendence (Superintendência da Zona Franca de Manaus, acronym in Portuguese)
tCO_2	Ton of carbon dioxide
TFP	Total Factor Productivity
STE	Technological Support Scenario (Cenário de Sustentação Tecnológica, acronym in Portuguese)
TWh	Terawatt-hour
VA	Value-added
VER	Verified Emission Reduction

Family farming fruit harvest in Apuí, Amazonas.
Photo: Dereck Mangabeira/IDESAM.

Foreword

The coming decades will define whether the Amazon – home to more than 28 million inhabitants, 198 indigenous peoples, and harboring the most biodiverse forest, the largest freshwater reservoir and the largest tropical bloc for climate regulation on the planet – will become the great catalyst for Brazil's low-carbon economy. Or whether, in the opposite direction, the Amazon will reach an irreversible point of degradation, deepening current inequalities and jeopardizing the stability and competitiveness of the country's entire economy.

How to guide the Legal Amazon towards a decarbonization trajectory, transforming the region's economy so that it grows, generates opportunities, values local cultures and environmental assets, while fighting inequality and deforestation? This question motivated the 76 researchers who signed the New Economy for the Amazon report.

The study combines different techniques and knowledge to present a unique depiction of the Legal Amazon's current economy, bringing to light the region's economic and environmental relations with the rest of Brazil and the world. The study focuses on carbon-intensive sectors that must change course in order to become a relevant part of a standing forest economy, more suited to the challenges of this century.

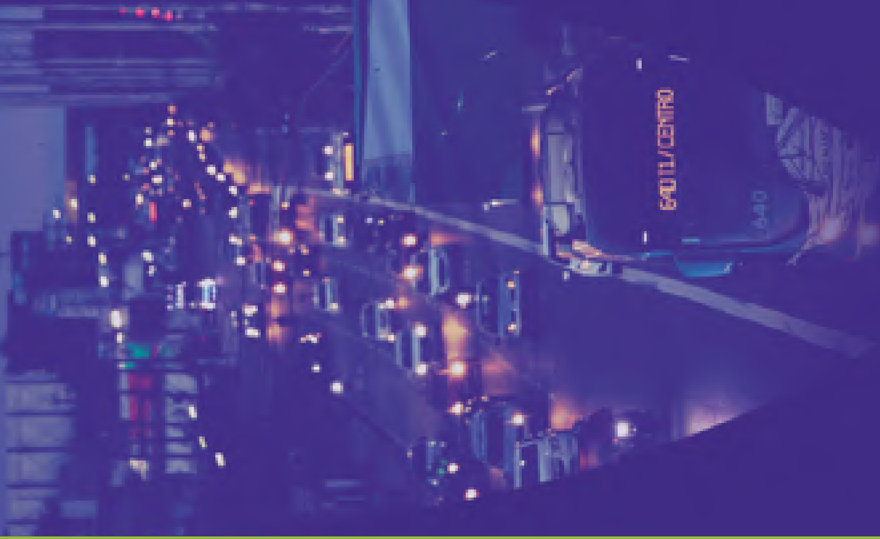
The study further explores the role of the bioeconomy, revealing a vigorous activity hitherto invisible to conventional instruments used to measure economic activity. Although it is based on the secular form of production of the original peoples, constantly innovated by local technologies developed in Amazonian villages, rural areas and cities, the bioeconomy remains underestimated in terms of its current impact and future potential. The work provides visibility to these activities, demonstrating their relevance as a solution for the region's future economy.

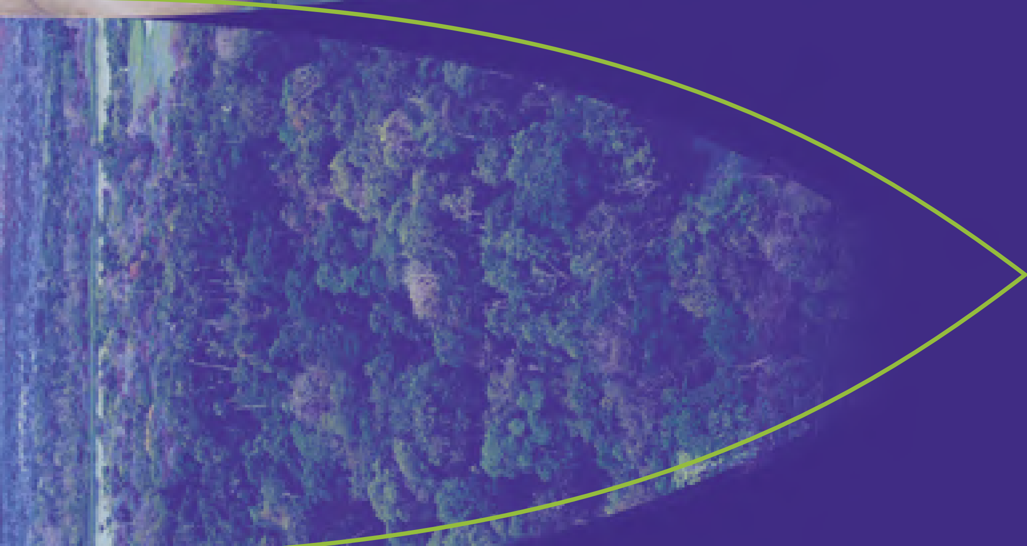
The report also assesses the economic performance of the Legal Amazon under different scenarios, comparing the current trajectory, which has been driving degradation, with alternative decarbonization scenarios, especially in the agricultural, livestock and energy sectors.

More than comparing GDP and job creation results, as economic performance is traditionally assessed, the New Economy for the Amazon gives shape to a qualitative analysis of that which is wanted for the future – and there is no future for Brazil without the Amazon. The results show that it is impossible for the country to reach its Paris Agreement targets and contribute to curbing global warming without eliminating deforestation in the Amazon. Even assuming that deforestation is eliminated, it will still be necessary to restore large areas of the forest and adopt new ways of generating and consuming energy, whether in rural or urban areas.

This report proposes a transition that generates quality jobs and opportunities for the region's citizens, while driving important changes in the rest of the country. The New Economy for the Amazon can be the great catalyst for the decarbonization of the entire Brazilian economy and the greatest opportunity for economic and social development in the country's contemporary history.

Fernanda Boscaini
Executive Director of WRI Brasil





EXECUTIVE SUMMARY

Highlights

The Amazon rainforest is on the cusp of a crucial tipping point following decades of extensive deforestation that would have widespread ramifications for Brazil's people and economy, and the global climate.

A new analysis of various scenarios for the Brazilian Amazon's economy through 2050 finds that a deforestation-free, low-carbon pathway delivers the largest and most equitable economic growth for the region and for the whole country. This scenario — called the New Economy for the Brazilian Amazon — includes several major yet achievable transformations: zero deforestation, expanding the Amazon's bioeconomy to sustainably produce goods, expanding forest restoration, adopting low-emissions agriculture and livestock practices, and decarbonizing Brazil's energy mix.

This scenario would produce significant economic, jobs, and climate benefits for Brazil. By 2050, the Brazilian Amazon economy's GDP would grow by BRL 40 billion (US$8 billion) above the business-as-usual reference scenario, while adding 312,000 additional jobs. Brazil would also have 81 million more hectares of standing forests compared to business-as-usual and reduce its emissions by 94%, meeting its Paris Agreement climate target.

The investments to finance this transition are 1.8% of Brazil's national GDP per year, just 0.8% more than the reference scenario, or an additional BRL 2.56 trillion ($513 billion) by 2050.

The Amazon would be the great catalyst for the decarbonizing the entire Brazilian economy, as investments would flow throughout the country.

*All values primarily estimated in BRL at 2020 prices, and converted to US$ at the exchange rate of US$ 1 = BRL 5, which is the weighted average exchange rate over the last 60 months.

Context

The Brazilian Legal Amazon (LAM), an area covering almost 60% of the Brazilian territory, holds the most extensive and biodiverse forest in the world, the largest freshwater reservoir and the most important climate regulating forest block on the planet, embracing a significant part of the Cerrado biodiversity hotspot. It is home to 28 million Brazilians, 198 indigenous ethnic groups from almost 50 language families. Despite its unique cultural and biological richness, LAM has suffered a chronic process of degradation, with 83 million hectares of primary forests having been cleared, jeopardizing its capacity to absorb carbon and provide ecosystem services - such as climate regulation and rainfall irrigation - for which there are no economically viable substitutes on such a large scale, for the own Amazon and surrounds economy, especially agriculture and livestock.

Climate change negatively impacts the forest and the economy, disproportionately affecting the poorest and already vulnerable populations. In addition to forest degradation and erosion of biodiversity, reducing the conditions of subsistence of traditional populations, climate change has a direct impact on agriculture, which is highly dependent on rainfall, as 96% of planted areas and 99% of pastures in Brazil do not have any irrigation systems in place (IBGE, 2019). The poorest people are the biggest victims of food price fluctuations resulting from crop failures and shortages due to systemic weather events such as droughts and floods. Living in areas at risk, with poor sanitation and without adequate assistance, the poor are also primarily affected by increases in flash floods, landslides, and epidemics.

Stopping deforestation and curbing global warming are crucial for the people of Amazon and beyond. Achieving the Paris Agreement goals and reducing emissions to curb global warming to 1.5°C requires investments of around 2% of global GDP per year – until stability in greenhouse gas (GHG) concentrations in the atmosphere is achieved (Stern, 2015). Exceeding the 1.5°C threshold considerably increases the investments needed to adapt and replace carbon-intensive processes, as well as increases the costs of recovering from more severe climate impacts, which may require up to 9% of global GDP per year (Guo, Kubli, & Saner, 2021).

Late afternoon in the Ver-o-Peso market, in Belém, state of Pará. Photo: Nayara Jinknss/WRI Brasil.

Brazil's role in containing global warming is vital and will require shifting to an economy that is free of deforestation and forest degradation, with low-carbon agricultural, livestock and industrial production. Brazil emitted about 67 gigatons of carbon dioxide ($GtCO_2$) over the past 30 years (SEEG, 2022). To meet the Paris Agreement goals and curb global warming to 1.5°C, this study estimates that the balance of Brazil's emissions between 2020 and 2050 (carbon budget) cannot exceed 7.7 $GtCO_2$. In the Legal Amazon, net emissions cannot exceed 1.4 $GtCO_2$ by 2050, which corresponds to a 96% reduction compared to the 36 $GtCO_2$ emitted over the past 30 years.

The New Economy for the Brazilian Amazon

The New Economy for the Brazilian Amazon (NEA-BR), an initiative by WRI Brasil in partnership with Brazilian research institutions and organizations from different regions, recognizes that advancing economic and social development combined with climate mitigation calls for profound changes in Brazil's economy. The initiative positions the Amazon as the great catalyst for these changes across Brazil. This report shows that investments in conserving and expanding natural assets, strengthening the bioeconomy, and shifting agriculture and livestock production and the energy mix to low-carbon models in the Legal Amazon (LAM) would result in a stronger economy, with better performance than that based on the continued expansion of carbon-intensive activities. The structural changes of the transition to the NEA led by the Amazon would reach the entire Brazilian economy through the flows of investments, inputs and products exchanged between regions, leading the country towards the decarbonization of its entire economy.

The NEA study pioneered the integration of multiple economic models developed by different research groups in the country to build a comprehensive analysis of the LAM's current economy and outline different scenarios for its future economy. Different econometric techniques were combined, with the development of Inter-regional Input-Output Matrix (IIOM-LAM), General Equilibrium (GEM) and Dynamic Optimization (DOM) Models coupled to

Combu island, Belém, Pará.
Photo: Nayara Jinknss/WRI Brasil.

Figure SE 1 | The New Economy for the Brazilian Amazon report

THE CURRENT LEGAL AMAZON ECONOMY IIOM-LAM	PERSPECTIVES FOR THE LEGAL AMAZON ECONOMY IN 2050 Economic models (GEM, DOM and IOM-Alpha)	THE NEW ECONOMY FOR THE BRAZILIAN AMAZON Bioeconomy, agriculture and livestock, mining, infrastructure, and financing
The Inter-regional Input-Output Matrix of Legal Amazon (IIOM-LAM) with 27 regions allowed the analysis of regional economic relations, as well as with the rest of Brazil and foreign trade. Furthermore, it segmented the forest sector into logging (native wood and timber) and non-timber forest products (native seeds, fruits, leaves, resin etc).	The combination of General Equilibrium Models (GEM), Dynamic Optimization (ODM) and the Bioeconomy Input-Output Alpha Matrix (MIP-Alpha) enabled multisectoral analysis and scenario projections for the economy of the Legal Amazon up to 2050, incorporating environmental assets and greenhouse gas emissions in an unprecedented way.	In-depth discussions on: • the main land use sectors (responsible for 94% of greenhouse gas emissions in the Legal Amazon), • the changes required in the energy matrix (4% of emissions) • necessary investments for the New Economy for the Amazon.

Source: Elaborated by the authors.

computable modules of land use changes, and Input-Output Alpha Accounts Matrix (IOM-Alpha) for the bioeconomy. The work enables the analysis of the peculiarities of the LAM, the characteristics of its different regions, their trade flows, inputs, products, emissions and deforestation incorporated into them.

The methodological choices for the coupling and interaction of analytical models have some limitations. Although the NEA's originality offers a new perspective for the assessment and planning of the LAM's economy, there are limits and restrictions inherent to the models and interpretation of results, such as: (1) underestimation of potential positive effects generated by gains in human capital or technological progress on economic performance, (2) undervaluation of the degradation and depletion of natural resources, (3) undervaluation of ecosystem services, (4) underestimation of the current bioeconomy and, therefore, of the future bioeconomy, particularly in the secondary and tertiary sectors, and (5) non-spatially explicit economic results.

NEA's analytical approach

The NEA adopts the boundaries of the Brazilian Legal Amazon as its study area. The Amazon biome covers approximately 6.2 million square kilometers in eight countries in South America and in French territory, approximately 60% of which is in Brazil. The LAM, on the other hand, is a legal delimitation that includes the entirety of the Brazilian Amazon Basin, encompassing the tropical forest and adjacent Cerrado areas. Instituted by Law N. 1.806/1953, it amounts to 5 Mkm^2 – 59% of the Brazilian territory. With about 28 million inhabitants (Ipeadata, 2022) and an average Human Development Index below 0.58 (Firjan, 2020), it fully covers the states of Acre, Amazonas, Amapá, Pará, Rondônia, Tocantins and Mato Grosso, in addition to Maranhão in its portion west of the 44th meridian.

The LAM is a mosaic of forest and savannah environments, with unique cultural and biological richness. With dozens of ecosystems managed by native peoples for more than 10 thousand years, the indigenous population of the LAM currently stands at nearly 600 thousand people from 198 ethnic groups and 49 language families (ISA, 2023) (Museu Emílio Goeldi, 2023). Forest management, agriculture and manufacturing techniques bring together a profusion of traditional knowledge about medicinal drugs, cosmetics, food, fibers, infrastructure materials and energy, still unknown to science, but commonplace in the original economy – or indigenous bioeconomy – characterized by its capacity to support the environment and respect for intangible assets that are inseparable from production.

The LAM houses the most extensive and biodiverse forest in the world, also encompassing a significant part of the Cerrado biodiversity hotspot. The largest tropical carbon stock in the world, the Amazon stores 120 GtC above ground (Gatti et al., 2021), equivalent to twelve times the annual emissions resulting from global economic activities (Valsecchi do Amaral et al., 2017). The LAM is responsible for recycling between 6.3 and 7.4 trillion cubic meters of water per year through the so-called "flying rivers", which irrigate the Brazilian center-south and is the region's most important service provided to the agribusiness, hydroelectric power generation, industry and sanitation sectors in the country and the Southern Cone (Baker et al., 2021). Over the past 30 years, the land use and energy sector has accounted for nearly 98% of all cumulative LAM emissions. They are, therefore, the focus of this report.

Despite its relevance and role in the economy, the Amazon is approaching a point of no return due to its current trajectory of accelerated degradation. About 83 million hectares of primary forests have already been deforested in the Amazon (Prodes, 2022b). Considering the entire LAM, approximately 23% of the original cover has already been deforested, with 59 million hectares of primary forests and Cerrado areas deforested in the last 36 years (Mapbiomas, 2022c). The continuity of this process is leading to a point of no return (Nobre et al., 2016), with changes in the carbon cycles that cause the region to become a net carbon emitter, which happens when its capacity to absorb falls below its own emissions (Gatti et al., 2021).

Main results

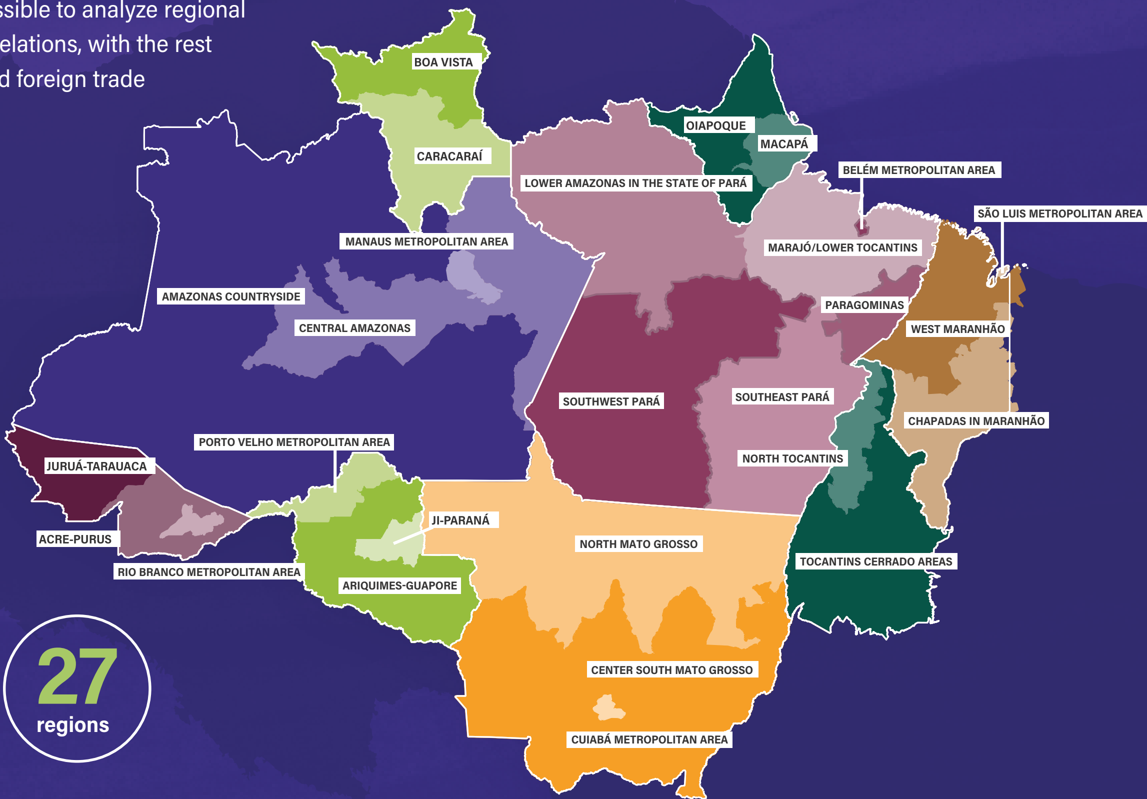
The Legal Amazon's current economy

The LAM's current economy runs a deficit in commercial transactions and a surplus in emissions, with highly carbon-intensive transactions. Under the current economic arrangement, the region is a large stock of land that supplies low value added (VA) inputs to the national and international economy, exporting primary products and purchasing qualified goods and services with higher value added. The use of IIOM-LAM shows that, in 2015 – the most recent data available – the LAM's trade flows with the rest of Brazil resulted in exports of BRL 355 billion ($71 billion) and imports of BRL 469 billion ($94 billion), with a BRL 114 billion ($23 billion) deficit. On the other hand, emissions of 863 $MtCO_2$ were generated in the LAM to meet internal and external demands, with deforestation of around 1.5 million hectares. The complete IIOM-LAM is available at www.wribrasil.org.br/publicacoes/nova-economia-amazonia-nea.

River transport in Combu island, in Belém, Pará.
Photo: Nayara Jinknss/WRI Brasil.

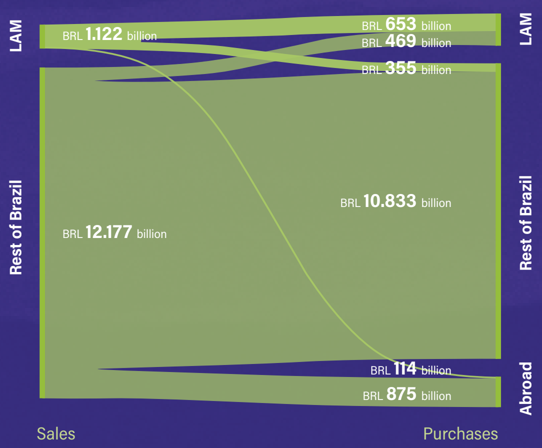
Figure SE2 | The current Legal Amazon economy revealed by IIOM-LAM

The development of an Input-Output Matrix for 27 regions of the Legal Amazon, defined by their technological trajectories, made it possible to analyze regional economic relations, with the rest of Brazil and foreign trade

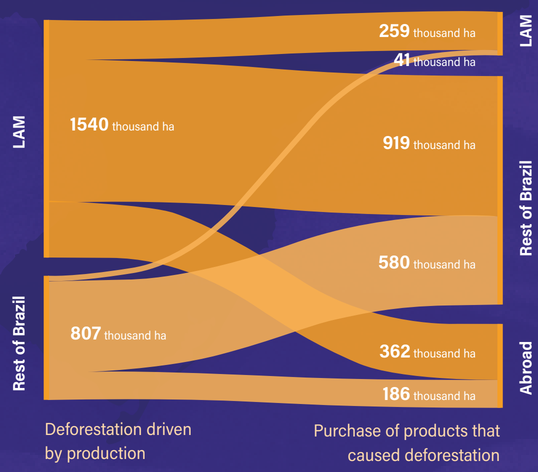


27 regions

The Legal Amazon imports more than it exports, generating a COMMERCIAL DEFICIT...



...And its exports are linked to MUCH HIGHER DEFORESTATION RATES



By selling basic products and purchasing goods and services with higher added value, the Legal Amazon economy has a BRL 114 billion deficit in commercial transactions.

BRL 114 billion **US 23 billion**

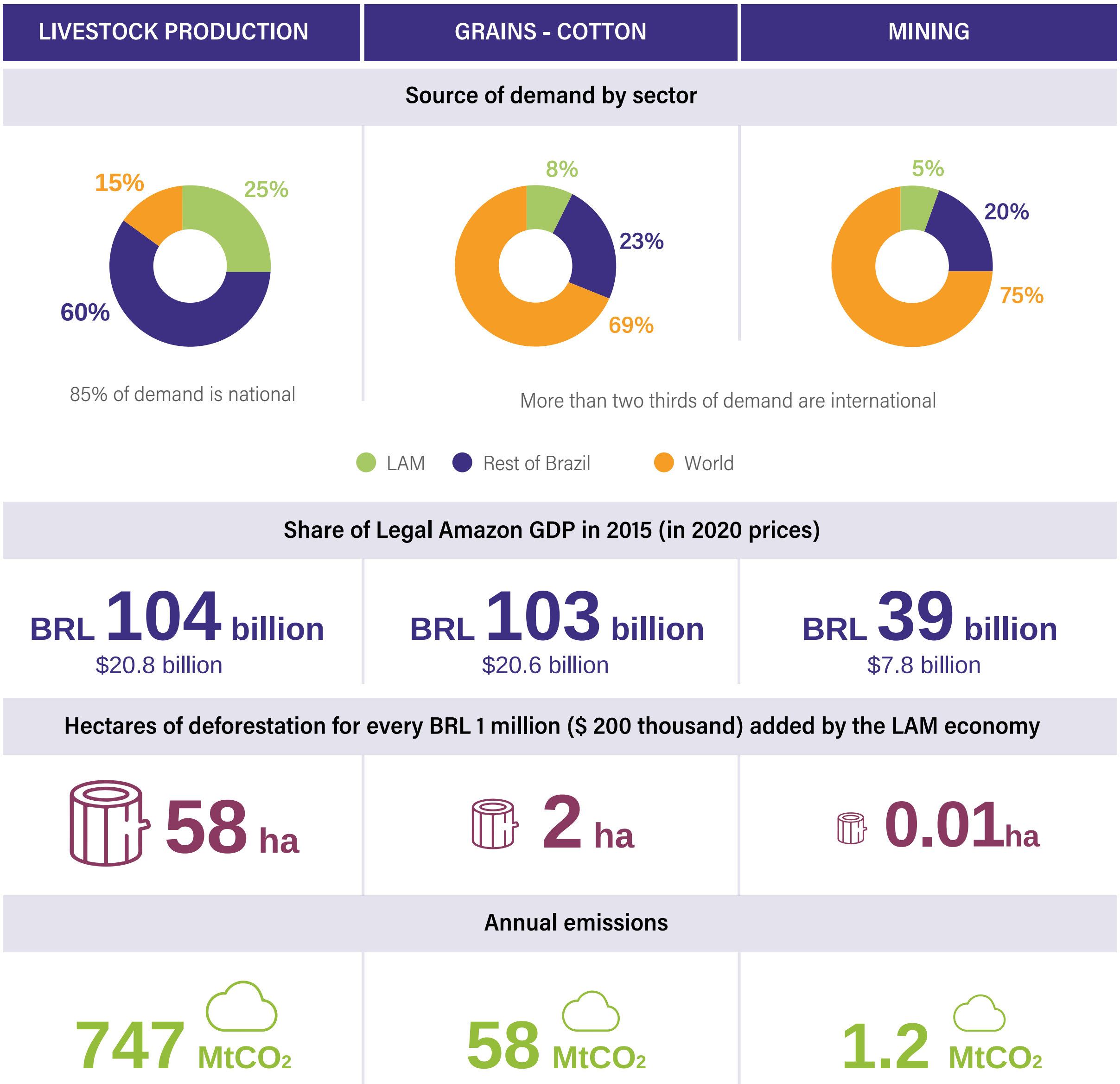
83% by external demand

More than 83% of deforestation in the LAM is stimulated directly or indirectly by existing demand from the rest of Brazil and abroad.

Note 1: trade flows at basic prices in the year 2015, according to the IIOM-LAM (at 2020 prices).
Note 2: Deforestation incorporated into commercial transactions per one thousand hectares.
Note 3: Results of this study.
Source: Elaborated by the authors.

More than 83% of deforestation in the LAM originates from demand arising from the rest of Brazil and from foreign trade. Deforestation is often assessed from the perspective of supply, that is, which productive sectors are promoting the replacement of forests by other land uses. The IIOM-LAM makes it possible to see the deforestation phenomenon from the perspective of demand as well, identifying the sources of incentives for the productive sectors to engage in deforestation. In the IIOM-LAM, the breakdown by origin of demand indicates that, while 46% of the LAM's VA is stimulated by existing demand from outside the region, 83% of deforestation is triggered by this external demand, as the region's exports are characterized by low VA and intensive deforestation. Only 12% of deforestation observed today in the LAM results from direct, indirect and induced stimuli from the region's internal demand. In absolute terms, of total deforestation in the LAM in 2015, 919 thousand hectares were induced by demand from the rest of Brazil, 362 thousand hectares by international demand and 259 thousand hectares by demand from the LAM region.

Figure SE 3 | **Analysis of deforestation and emissions by LAM sector and source of demand**



Note: Results of this study.
Source: Elaborated by the authors.

The Legal Amazon's economy in 2050

Using General Equilibrium (GEM) and Dynamic Optimization (DOM) models, four different scenarios were outlined for the LAM's economy in 2050, combining two restrictions to the allocation of production factors and technological choices: control of total GHG emissions and control of deforestation. In the **Business-as-Usual Reference Scenario (BAU-REF)** scenario, no restrictions were applied. In the **Technological Support (STE)** scenario, deforestation was not restricted, but the condition was imposed that total emissions by 2050 could not exceed the estimated limit of 7.7 $GtCO_2$ for compliance with the Paris Agreement's 1.5°C scenario, forcing the optimization of energy technologies in support of the decarbonization of the economy. The opposite was done in the **Forest Support (SFL)** scenario, with deforestation restricted to zero, but no limits imposed on any other emission sources in the economy, forcing the optimization of land use. Finally, in the scenario for the **New Economy for the Amazon (NEA)**, the two restrictions were applied, combining optimization of land use and the energy mix to achieve the goal of maintaining net accumulated emissions in Brazil at 7.7 $GtCO_2$ between 2020 and 2050.

Figure SE 4 | Window to the future: economic scenarios

The study projects scenarios for the economy of the Legal Amazon until 2050 combining restrictions on emissions and deforestation

Note 1 : In order to meet the emission targets established in the Paris Agreement and curb global warming to 1.5°C, this study estimated that the balance of emissions in Brazil between 2020 and 2050 (carbon budget) cannot exceed 7.7 $GtCO_2$.
Note 2: Results of this study.
Source: Elaborated by the authors

Without restrictions on deforestation, Brazil will not be able to meet its climate targets. Eliminating deforestation is also insufficient – it is necessary to combine it with the decarbonization of agriculture, livestock production and the energy mix. The persistence of the carbon-intensive economy represented by the BAU scenario would result in accumulated emissions of 43.6 $GtCO_2$ by 2050. The STE scenario, on the other hand, failed to produce a viable mathematical solution, which illustrates the impossibility of meeting the Paris Agreement targets without restricting deforestation. No combination of technological and energy packages from other sectors of the economy would be able to neutralize the emissions resulting from changes in land use. The SFL scenario shows that, even with zero deforestation in Amazon, the Brazilian economy would emit 21.1 $GtCO_2$ by 2050, a figure almost three times higher than the target. In the NEA scenario, emissions were restricted to the target of 7.7 $GtCO_2$, which would lead to the optimization of land use, increase in agricultural and livestock productivity through the intensive use of capital and labor, decreased pressure on native vegetation and restoration of 24 Mha in favor of carbon sequestration and the bioeconomy. In this scenario, LAM emissions were estimated at 1.4 $GtCO_2$ by 2050.

Qualified GDP and a larger number of inclusive jobs, especially in bioeconomy, are major advantages of the transition to the New Economy for the Amazon. The national GDP in 2050 in the BAU scenario was estimated at BRL 14.432 trillion ($ 2.88 trillion) at 2020 prices, while in the NEA scenario, this indicator is slightly higher, BRL 14.658 trillion ($ 2.93 trillion). In the LAM, the GDP in the BAU scenario was estimated at BRL 1.301 trillion against BRL 1.340 trillion in the NEA scenario ($260 billion against $268 billion). **Under the NEA scenario, around 312 thousand additional jobs would be created in the LAM alone**, with 365 thousand new jobs in the bioeconomy, and another 468 thousand new jobs in restoration, replacing jobs in carbon-intensive chains. In these chains, more than 91% of current positions are held by minority groups such as black and indigenous people. In the NEA scenario, the jobs held by these groups fill about 18.7 million positions (81% of the total), with 345 thousand additional jobs compared to the BAU. By the end of 2050, the NEA's GDP would produce less than one fifth of the total emissions in the BAU scenario and an additional 81 Mha of native vegetation, with a 19% larger forest carbon stock, generating savings that contribute to climate negotiations, attract financing and generate essential ecosystem services for production.

The investments required to finance the transition to the NEA amount to BRL 2.56 trillion ($513 billion) by 2050 (additional to the BAU scenario). Investments in LAM were estimated at BRL 3.36 trillion in the BAU scenario (1.0% per year of national GDP) and BRL 5.92 trillion in the NEA scenario (1.8% per year of national GDP) by 2050 ($672 billion and $1.184 trillion, respectively). Of the additional BRL 2.56 trillion in the NEA scenario, BRL 659 billion ($132 billion) would be applied to reestructure land use through technical changes to intensify production of the agricultural, livestock, bioeconomy and restoration sectors; BRL 410 billion ($82 billion) to low-carbon energy and another BRL 1.49 trillion ($298 billion) to infrastructure. Investments would not be restricted to the LAM, given the intricate input-output relationship between the region and the rest of the country, implying harmonization of standards, products and processes. **The Amazon would be the great catalyst for the decarbonization of the Brazilian economy**.

Oil production from andiroba seeds in the riverside community of Bauana, in Carauari, Amazonas. Photo: Ricardo Oliveira.

Figure SE 5 | Benefits of the New Economy for the Amazon

Maintaining the standing forest and reducing emissions represent an opportunity to strengthen the Amazon's economy.

An unprecedented combination of data and models enabled the assessment of economic, social and environmental results that demonstrate the benefits of the New Economy for the Amazon compared to the current trajectory by 2050.

BENEFITS

ENVIRONMENTAL AND CLIMATE-RELATED

+22 Mha* of restored forests

+81 Mha OF STANDING FOREST

59 Mha of avoided deforestation

WATER

13% reduction

in water loss due to surface runoff

Higher penetration of water into the soil increases the resilience of agricultural and livestock production to water stress and reduces the risk of flooding

SOIL FERTILITY

-16% nitrogen **-18% phosphorus**

lower soil nutrient loss

Savings in fertilizer replacement costs from BRL 46 to 8.7 billion over 30 years

EMISSIONS

94% less

net carbon emissions

Emissions reduction of

35,9 GTC » Brazil

24,2 GTC » LAM

CARBON

19% more

carbon stock

Environmental asset to back carbon credits, climate negotiations and attract financing

*In the NEA scenario, 24 Mha are restored and in the Reference (BAU), 2 Mha was estimated, the total difference between the scenarios is 22 Mha.

Note: All data in this figure are additional values of the New Economy for the Amazon (NEA) scenario compared to the reference scenario (BAU-REF), results of this study.

Source: Elaborated by the authors

ADVANTAGES OF THE NEA

BENEFITS

ECONOMIC AND SOCIAL

+BRL 40 billion

$ 8 billion

IN THE LEGAL AMAZON'S GDP

saldo de

+312 thousand

additional jobs in the region

BIOECONOMY

higher GDP, reaching

$ 7.7 billion

JOBS

More sustainable jobs replacing occupations linked to deforestation. 833 thousand additional jobs in the bioeconomy and restoration sectors

MULTISECTOR

Growth in all sectors, including agriculture, livestock production, mining and bioeconomy, with less land and more labor and capital

CITIES

Cities assume a vital role in the development and innovation of the bioeconomy, as they are the platform for the circular and proximity economy for standing forest products

ADDITIONAL INVESTMENTS FOR THE TRANSITION

Low carbon agricultural and livestock production	$ 88.4 billion
Bioeconomy and restoration	$ 43.4 billion
Energy matrix	$ 82 billion
Infrastructure	$ 298 billion

The Amazon would be the catalyst for Brazil's low-carbon economy.

Bioeconomy

The bioeconomy proposed by the NEA is one that evolves with the forest standing and the rivers flowing. The Amazon bioeconomy must be able to adjust to the biome's biocapacity, building upon economic activities that do not disrupt the complex ecological balances that guarantee the health of the forest and rivers on which the population depends, combining tradition and innovation, as a bioecological bioeconomy (Costa and Fernandes, 2016) (Costa et al., 2022). This bioeconomy already exists, but it is partially invisible in national accounts due to the high level of informality and the inadequacy of official methods for capturing indicators.

The bioeconomy revealed by the new indicators is thriving in the LAM. Even with limitations inherent to the collection of primary data and traceability of informal activities, the bioeconomy already generates an annual Gross Production Value (GPV) of BRL 15 billion ($3 billion) in the LAM. The application of the IOM-Alpha method reveals that the bioeconomy is a vector of strong dynamism in the proximity economy, with great capacity to generate local production and employment. Assessments based on the IOM-Alpha show that the region's bioeconomy, encompassing only 13 primary products (for which there are reliable data), currently generates BRL 9.5 billion in VA, a GDP of approximately BRL 12.1 billion and a wage bill of BRL 1.89 billion across the chain or, $1.9 billion, $2.4 billion and $378 million, respectively (primary, secondary and tertiary sectors). Pará emerges as the leader of the bioeconomy, accounting for 73% of the LAM's wage bill. The LAM's IOM-Alpha is available at at www.wribrasil.org.br/publicacoes/nova-economia-amazonia-nea.

In the scenario of transition to the NEA, the bioeconomy emerges as an important GDP component. Despite data and projection limitations – this study was limited to only 13 primary products and their derivatives from the secondary and tertiary sectors –, in the NEA scenario, the bioeconomy's GDP in the LAM will reach BRL 38.5 billion ($7.7 billion) in 2050, or 2.8% of the regional GDP, employing 947 thousand people, around 4% of the total number of jobs in the entire region. In the BAU scenario, the GDP of the bioeconomy would be close to BRL 22.3 billion ($4.5 billion), generating around 592 thousand jobs.

Figure SE 6 | The bioeconomy is larger than current instruments can measure

The Matrices Conventional Input-Output matrices do not allow any differentiation between the standing forest economy from the deforestation economy.

The separation of these sectors through the IIOM-LAM, added to the innovations of the IOM-Alpha, allow us to see the thriving economy of the forest and its peoples, invisible to current instruments.

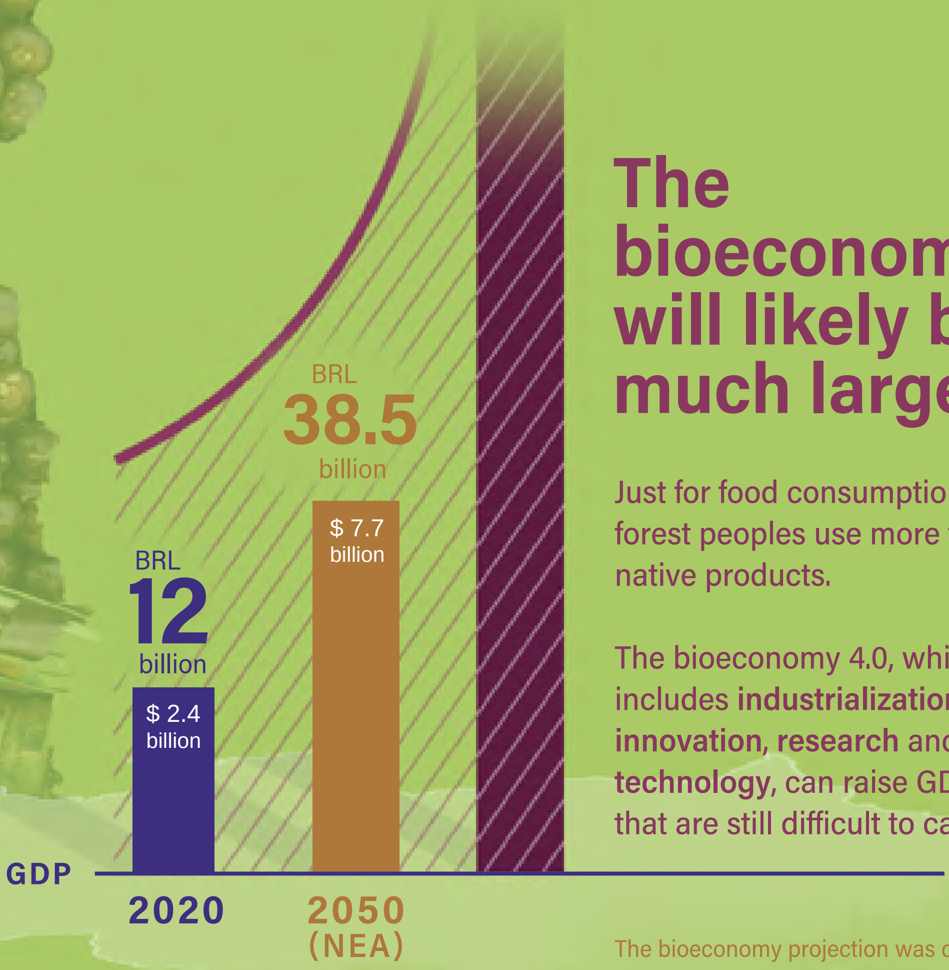
THE METHODOLOGIES USED IN THIS STUDY ENABLE:

The segmentation of the forest extraction sector into **destructive** (which implies felling that irreversibly damages the mother plant) and **non-destructive** (which assumes the maintenance of the plant and, on a large scale, the forest), in addition to **silviculture.**

The inclusion of the **secondary** and **tertiary** sectors, especially **individual entrepreneurs** with a description of activities related to the bioeconomy

The differentiation of **monocultures** of Amazonian products from small production systems, such as **agroforests.**

LAM'S BIOECONOMY GDP



The bioeconomy will likely be much larger

Just for food consumption, the forest peoples use more than 270 native products.

The bioeconomy 4.0, which includes **industrialization, innovation, research** and **technology**, can raise GDP to levels that are still difficult to calculate.

The bioeconomy projection was carried out based on only **13 native products** for which reliable data is available:

- açaí fruit
- açaí palm heart
- cocoa
- nuts
- babassu coconut
- babassu oil
- cupuaçu
- honey
- rubber
- buriti
- urucum
- copaíba
- andiroba

BIOECONOMY SECTORS ANALYZED

PRIMARY

BRL **1.92** billion
US$384 million

Extraction and agro-extraction

may take place through non-destructive extraction or production via sustainable systems, such as agroforestry

SECONDARY

BRL **3.98** billion
US$796 million

Artisanal and industrial

processing includes everything from the açaí beater to large pulp factories

TERTIARY

BRL **9.15** billion
US$1.8 billion

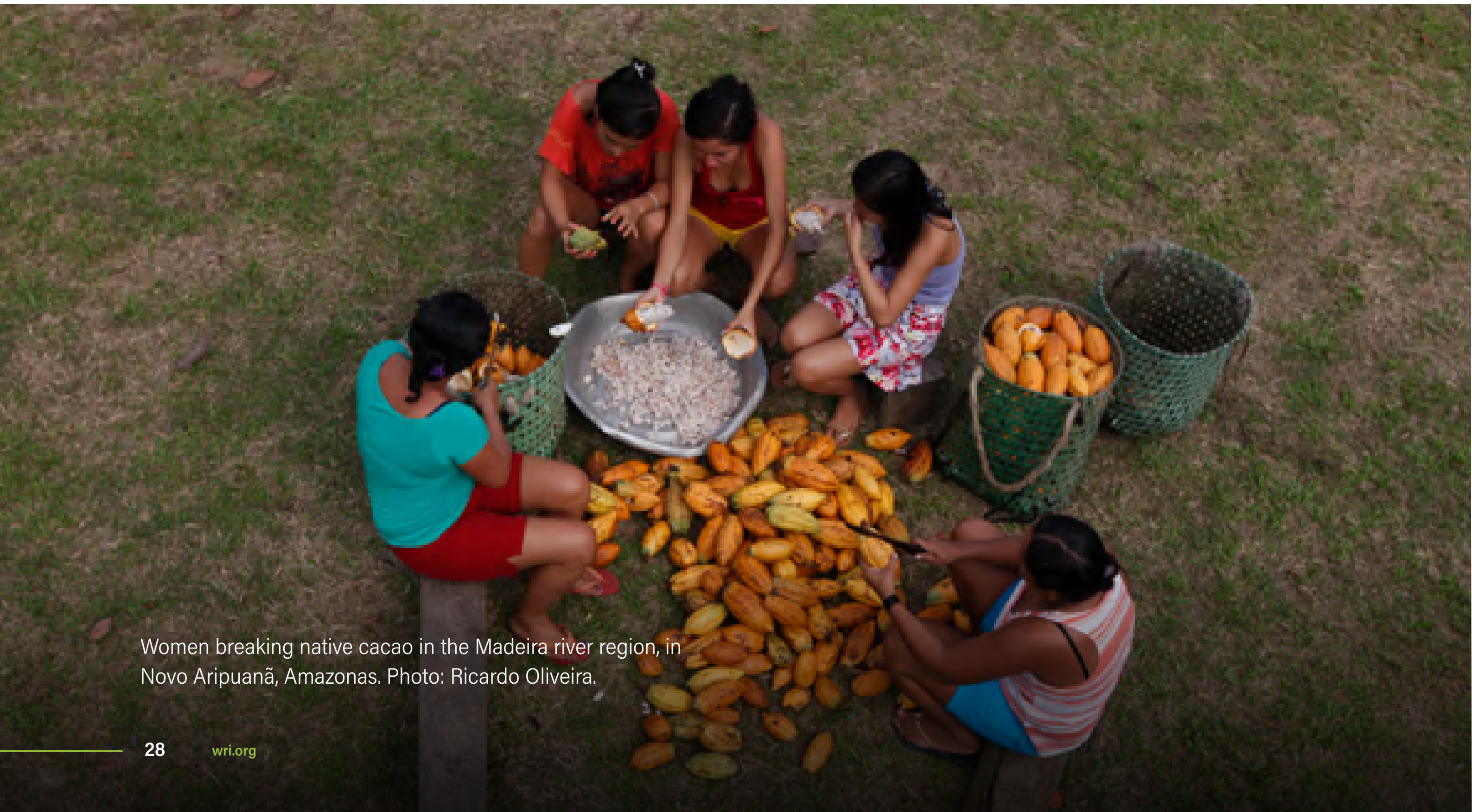
Trade, services and final consumption

From the Ver-o-peso market, in Belém, to the beaches in California

The bioeconomy will likely be much larger than indicated above. Research shows that the indigenous peoples of the Amazon have an extremely diverse diet, with up to 270 items used daily in cooking, compared to less than 30 items used by non-indigenous groups in the same region (Mesquita, Barreto, 2015; Skeltis, 2019). On a daily basis, they use up to 85 species of trees and more than two hundred herbs for food or medicine supplementation (Levis et al., 2018), and ingest about 30 species of insects – the food of the future – as a source of vitamins and iron (Roche et al., 2008). Because each ethnic group has its own food preferences and taboos, the resources available in the forest are spatially heterogeneous and as numerous as biodiversity, which reinforces the hypothesis that the Amazon Forest itself, in good measure, is the result of persistent and millenary autochthonous forest management (Levis et al., 2017).

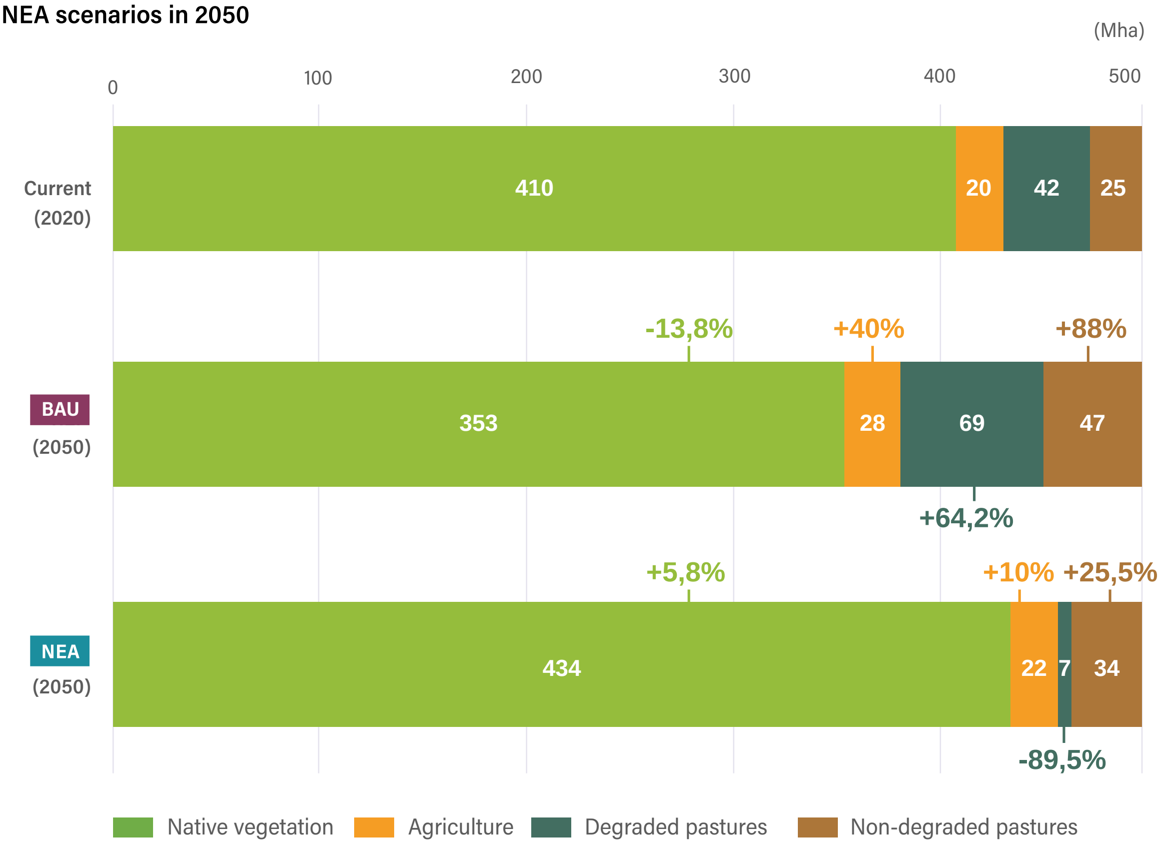
The bioeconomy scaling strategy that generates the best social, environmental and economic results for the NEA is based on the replication and expansion of productive arrangements already existing in the territory: inclusive, diverse and based on local ability and intelligence. The bioeconomy growth should take place through the multiplication of production arrangements that are typical or under development in the territory, which are labor intensive, based on forest products or the restoration of native vegetation, and which combine local solutions with the adaptation of efficient technological innovations. The transformation of primary products and their insertion in markets depend more on the ability to add local value and their capillarity in the territory than on a technological revolution. The bioeconomy is also vital for the generation of ecosystem services for which there are no substitutes that are economically viable or sufficiently available to meet productive demands, especially from the agricultural and livestock production sector.

The indigenous economy is based on community elements and benefit sharing, which are essential to the bioeconomy. The productive processes of the indigenous economy are generally structured around individual initiatives, organization into associations, cooperatives, collectives and groups of producers or family initiatives – often led by women. They combine food cultivars, medicinal herbs, dyes and textile products, as well as handicrafts and other cultural manifestations. Benefit sharing is a hallmark of the indigenous economy, following concepts of justice that encompass not only distribution based on work or knowledge of productive processes, but also recognition of different social roles and solidarity with excluded people. Decisions are always based on the gathering of collective resources and dialogue with ancestral heritage.



Women breaking native cacao in the Madeira river region, in Novo Aripuanã, Amazonas. Photo: Ricardo Oliveira.

Figure SE 7 | Land use and land cover classes in the base year 2020, in the BAU and NEA scenarios in 2050



Note: Results of this study.
Source: Elaborated by the authors.

Agriculture and livestock production

The agriculture and livestock production sector accounts for a large portion of the LAM's economy and must become free of deforestation and forest degradation to ensure its relevance by 2050. In the NEA scenario, higher land productivity, less susceptibility to water stress, and less soil fertility loss would boost agricultural and livestock production, allowing the sector to grow by substituting land for capital and labor. A productive reorganization would result in a more productive, resilient, deforestation-free and low-carbon agricultural and livestock production sector. With a more efficient land use and no deforestation and degradation, water loss from runoff would recede by 13%, protecting these activities from water stress, and nitrogen and phosphorus losses would decrease by 16% and 18%, respectively, reducing costs with fertilizers and generating savings in the range of BRL 4.6 - 8.7 billion ($920 million to $1.7 billion) over 30 years.

The three biggest challenges for agriculture and livestock production in the transition to the NEA are: (1) the strategic use of land; (2) the productive intensification and mainstreaming of low carbon emission practices, and (3) the fight against rural inequality. The strategic use of land reflects a focus on recovering degraded pastures, both for livestock production and agriculture and forest restoration activities, in addition to increasing the areas with integrated and agroforestry systems. The productive intensification and mainstreaming of low carbon emission practices are guidelines for the sector's adaptation to climate change, specifically outlined by the country's low carbon emission plan for the sector ("Plano ABC+"), while the fight against rural inequality must be tackled mainly through family farmers' unobstructed and privileged access to credit, risk mitigation instruments, customized technical and managerial assistance, including for bioeconomy products, and differentiated, institutional markets with denomination of origin.

Investments to finance the transition of agricultural and livestock production would exceed those estimated for the BAU scenario by about BRL 442 billion ($88 billion). The mainstreaming of low carbon emission practices and the intensification of agriculture and livestock activities should occur exclusively in consolidated degraded and anthropized areas, with a focus on the adoption of bio-inputs and integrated production systems (integrated crop-livestock-forestry and agroforestry systems, especially with native species). Agricultural and livestock production activities in the NEA scenario would maintain their share in the LAM's GDP compared to the base year 2020, receiving substantially higher investments to promote the transition, but simultaneously generating savings in fertilization replacement costs resulting from the erosion of ecosystem services observed in the BAU scenario. Investments in the agriculture chains in the NEA scenario are 25% above the figures in the BAU scenario, while investments in livestock production would be 84% higher in the NEA, reflecting the effort to generate productivity gains that offset the significant loss of pasture area.

Mining

Mineral assets are indispensable for the global energy transition and for building a low-carbon economy infrastructure. However, mining costs and benefits must be internalized and better distributed. Industrial mining in the LAM already generates approximately BRL 39 billion ($7.8 billion) in GPV and 113 thousand jobs. The region has reserves of global significance that are already measured, such as 18% of tantalum, 11% of niobium, 9% of manganese and tin, in addition to other significant reserves, such as 8% of aluminum ore (metallurgical bauxite) and 4% of iron ore. The industry has advanced in precautionary practices and has been making progress in the adoption of environmental, social and corporate governance (ESG) criteria. However, current social and environmental impacts, such as exposure of the population to substances harmful to health, risks of disasters with tailings, territorial disorder following the end of the mining extraction cycle, pollution of groundwater and watercourses are negative externalities that need to be addressed. The exploitation of essential minerals for the transition must go beyond ESG practices and prioritize the well-being and safety of local populations and their natural resources, essential for their ways of life, translated into direct investments to promote environmental quality, the bioeconomy and regenerative productive systems that are compatible with local aspirations.

Infrastructure

The main energy solution for the NEA scenario is the implementation of photovoltaic systems, whether in floating systems on existing hydroelectric dams or on degraded pastures close to transmission structures, optimizing the installed capacity of the National Interconnected System (SIN). Together, these systems would generate 55% of the 131 TWh that will be demanded by the LAM in 2050 under the NEA scenario. Hydroelectric power plants, currently responsible for 85% of the installed capacity in the LAM, do not expand in the NEA scenario. Belo Monte would have been the last major hydroelectric power project in the region. The burning of agricultural, urban and bioeconomy waste, such as açaí pods, would be able to generate another 14TWh. This ideal approach to isolated systems would replace, in 2050 alone, the equivalent of 359 million liters of diesel, reducing emissions by almost 1.5 $MtCO_2$ and boosting the local economy.

As for the transportation sector, the required energy in the NEA scenario would reach 133 TWh in 2050, while in the BAU scenario it would stand at 188 TWh. In the NEA, the energy demands of passenger and cargo transportation by road, hybrid waterway and air fluvial systems would be met as follows: 54% by second and third generation biofuels, 40% by renewable electric energy and only 6% by fossil fuels. Differently, in the BAU scenario, 82% would come from fossil sources, 16% from biofuels and only 2% from electricity. Additionally, no new high-speed roads would be built, but replaced by hybrid waterway transportation systems. While emissions in 2050 would amount to 38 $MtCO_2$ in the BAU, in the NEA scenario they would only reach 17 $MtCO_2$.

Heavy traffic in Av. Torquato Tapajós in Manaus, Amazonas. Photo: Bruno Kelly/WRI Brasil.

Financing

A significant expansion in the supply of financing will be necessary to reach the investment volumes required to decarbonize the global economy, and in Brazil this will be no different. Studies on the dimensioning of investments required to decarbonize the global economy have converged to rates close to 2% of GDP per year (Stern, 2015), while the values effectively applied have been around 0.1% in the most optimistic estimates (Guo, Kubli and Saner, 2021). Filling the gap in order to reach levels close to 2% of GDP requires a disruption in trends and a displacement in the supply curve, given the steep 590% increase that needs to take place by 2030 to reach the required level (Naran et al., 2022). There are no references on the gap between investment and financing needs for Brazil.

Investments of BRL 2.56 trillion ($513 billion) will be needed to finance the NEA transition. Brazil needs to invest around 4.5% of GDP per year over the next 25 years to guarantee a stock of infrastructure and minimize risks of economic constraints (Frischtak, Mourão, 2017). In the present study, investment needs corresponding to 1.8% of GDP were estimated to finance the transition to the NEA. Although those investments would not necessarily be additional to the formation of a stock of infrastructure – which could be expanded under a decarbonized energy and agricultural/livestock production mix–, the highly competitive environment to access financial resources adds to the challenge.

On the other hand, the do-nothing costs could be much higher. In the GEM models used in this study, the reference scenario for the LAM's economic growth does not include opportunity costs of the technologies employed in the NEA scenario, nor do-nothing costs, which reduce GDP in the reference scenario (BAU) due to chronic and acute effects of climate change. Worldwide, projections indicate that the cost of not curbing warming below 2°C should range between 4% and 18% of global GDP by 2048 (Guo, Kubli and Saner, 2021). If the do-nothing penalties suggested for Brazil's GDP by the Swiss Re Institute are applied, the additional investments of BRL 2.56 trillion ($513 billion) for the transition would, in the most conservative economic estimates, be less than half of the costs of not promoting the transition.

Table SE 1 | **Investments according to the scenarios between 2030-2050 (US$ billion)**

		BAU	NEA
STRATEGIC LAND USE		198.5	330.3
Agriculture		122.6	153.0
Livestock Production		69.0	127.0
Bioeconomy		2.6	8.0
Restoration		4.3	42.2
ENERGY AND INFRASTRUCTURE		472.7	853.7
Electricity		188.6	267.5
National Interconnected System	Wing Generation	39.1	39.8
	Solar Generation	14.8	15.0
	Biomass	15.4	72.0
	Other Sources	86.6	86.6
Local Systems	Solar Generation	32.6	53.8
	Waste	0.0	0.3
Biofuels		2.8	7.0
Passenger Road Transport		0.8	2.3
Cargo Road Transport		1.4	3.1
Hybrid Water Transport		0.3	0.8
Air-fluvial Transport		0.3	0.8
Induced Infrastructure		281.3	579.2
TOTAL		671.2	1,184.0

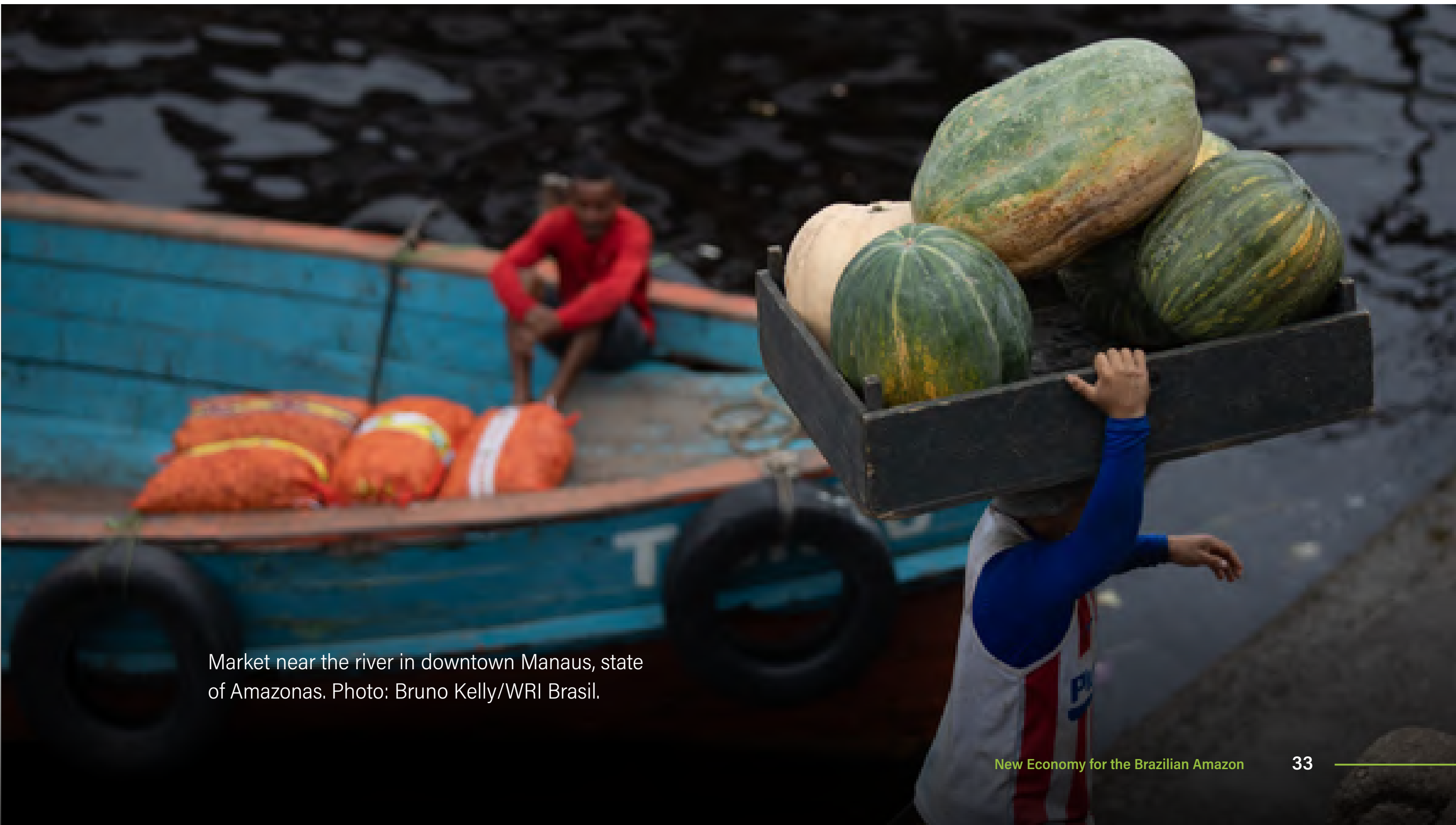
Note: Results of this study.
Source: Elaborated by the authors.

Recommendations

The public sector must assert its allocative and distributive roles to signal the directions to be taken by the economy going forward. Although renewable energies, such as solar, are already competitive, they are still penalized and distorted by the maintenance of subsidies to fossil fuels, whose extinction should be the main guideline for public sector actions. Brazilian subsidies to fossil fuels over the past decade amounted to almost US$ 222 billion (Inesc, 2022), corresponding to 60% of the investments needed to change the energy mix under the NEA scenario. In agriculture and livestock production, if the total volume of funds managed by Plano Safra (the government's agriculture and livestock production financing program) were earmarked to investment projects aligned with Plano ABC+, the annual average volumes of rural credit available for investment in the LAM would be enough to cover (if replicated over the 30-year period) almost 40% of the investment needs under the NEA scenario.

The private sector needs to increase its capacity for innovation and become a driver of the new economy. Between 2013 and 2020, approximately BRL 61 billion ($12.2 billion) in green bonds were issued in Brazil, of which 50% financed energy projects, while 25% went to land use projects, 10% to transportation projects, 4% to construction projects, 4% to projects involving water resources, 4% to projects involving waste and 3% to the industrial sector (CBI, 2021). Many corporations have been investing in decarbonization, largely following criteria relating to actions with positive impacts on the ESG spheres, which are difficult to account for. The volume of associated shares traded on the stock exchange reached around BRL 2 billion ($400 million). It is true that public sector signaling is essential to ensure safety, but there is already enough information for the private sector to take the lead in the race for innovation and adaptation of the economy to the needs of decarbonization.

Employ instruments and methods that enable the adequate assessment of the LAM's social and economic development. Adoption of Input-Output Matrices capable of segmenting activities typical of the Amazonian economy and its different regions offer a technically robust and replicable alternative. Accounting techniques for generally undersized monetary flows, as revealed by the IOM-Alpha for the bioeconomy chain, are essential to break with the undersizing bias connected with these activities, which prevent their relevance from being recognized and, therefore, adopted as part of the solution through the circular and proximity economy.



Market near the river in downtown Manaus, state of Amazonas. Photo: Bruno Kelly/WRI Brasil.

Establish clear milestones in the conceptualization of bioeconomy plans and programs that are compatible with products, processes and productive structures that protect the standing forest, biodiversity and knowledge of indigenous peoples and traditional populations. The bioeconomy is not to be confused with low-carbon agriculture and livestock production, although they are complementary in the transition to the NEA. The entire structuring of systems for promotion, innovation, research and development of products and processes must be based on the concept of standing forests and flowing rivers as bioeconomy pillars, safeguarding and promoting the fair distribution of benefits to people and communities that hold traditional knowledge. **Sustainable economy should be prioritized in indigenous territories with their peoples as protagonists**, with actions that promote the exchange of knowledge, technical and financial support, valuing traditional knowledge and involving political representations of indigenous peoples. Indigenous professionals must lead the planning and operation of production chains, from production to commercialization.

Eliminating subsidies or promoting cross-subsidies from fossil fuels to energy from renewable sources with an emphasis on solar generation and second-generation biofuels is essential to the decarbonization of the economy. As shown in this study, the volume of subsidies to fossil fuels in Brazil, in the last decade alone, amounted to a value equivalent to half of what is needed to structure the energy mix under the NEA scenario. Differentiated taxation in favor of electric vehicles, public transport concession policies aimed at fleet electrification, regulation that leads to the progressive growth of the volumetric content of biodiesel produced in deforestation-free areas that are compliant with the Soy Moratorium and reduction of docking fees for vessels with batteries and biofuels are other points to be addressed by fiscal policies in order to promote the decarbonization of transportation in the region.

Redirect the availability of rural credit, gradually transforming the Plano Safra into a Low Carbon Emission Agricultural Plan (ABC). Currently, only 3% of all credit for investment in agriculture and livestock production in the LAM coming from Plano Safra is earmarked to low carbon emission practices. As demonstrated in this study, if the current volume of loans granted in the LAM were annually applied only to low-carbon agriculture and livestock production, it would be enough to finance 40% of the investments necessary for the transition of this sector to the NEA. We endorse the recommendations of the Brazilian Coalition on Climate, Forests and Agriculture (2022), in particular its recommendation to increase funds that authorize the payment of interest rate equalization on rural financing granted under the Plano Safra for low-carbon agriculture and livestock activities, in addition to including private investment funds that finance credit lines aligned with the ABC+ and Pronaf ABC+ programs.

Re-establish the role of the public sector in territorial management and governance. Reestablish the Plan for the Prevention and Control of Deforestation in the Amazon and support the updating of State Plans for the Prevention and Control of Deforestation; resume the allocation of

public forests for conservation, Indigenous Lands and sustainable forest management; reestablish the territorial security of protected areas (Indigenous Lands and Conservation Units) and support the forest-based economy in these areas; implement the National Plan for the Recovery of Native Vegetation (Planaveg) and support state programs for the restoration of landscapes and native vegetation; and structure the jurisdictional Reduction of Emissions from Deforestation and Degradation (REDD+) systems of the Amazon states.

Restore governance and guarantee the investments of the Amazon Fund. The Amazon Fund, in addition to providing support for command-and-control actions, indigenous communities and the implementation and analysis of the Rural Environmental Registry (CAR), must play a vital role in the development of the bioeconomy. Fund resources can both initiate the structuring of new chains and generate scale gains for existing chains and businesses. Among the possible actions are priority investments in enterprise management, technical and management assistance, access to markets, working capital, logistics, technology and provision of specialized services.

Create a methodological framework and taxonomies for the financial and capital markets on the requirements for green investments in the Amazon that promote the reduction of emissions and the preservation of biodiversity. A legal framework for the carbon market in Brazil is thus necessary, based on a broad discussion with society about the earmarking of subsidies, leading to their progressive shift from carbon-intensive activities to the development of new technologies and the implementation of low emission productive practices throughout the economy. There are many potential sources of funds, both domestic and international. These sources must be accessed and give rise to a new mainstream financing model.

Ka'apor people of the Indigenous Land Alto Turiacu, in northern Maranhão, install cameras for autonomous monitoring of their territory in areas threatened by illegal loggers. Photo: Lunae Parracho/Greenpeace.

Residents of extractive and fishing communities in the Bailique Archipelago, state of Amapá, during a training course on photovoltaic solar energy. Photo: Diego Baravelli/Greenpeace.

INTRODUCTION

INTRODUCTION

Developing the Legal Amazon (LAM), to ensure the coexistence of healthy forests with competitive and inclusive economic activities, requires refuting paradigms that oppose environmental conservation to economic growth and valuation of natural assets to production increase. It also requires the understanding that Gross Domestic Product (GDP) growth and job and income creation are indispensable, but need to be qualified by an economy that is resilient to challenges posed by climate change and capable of reducing social inequalities.

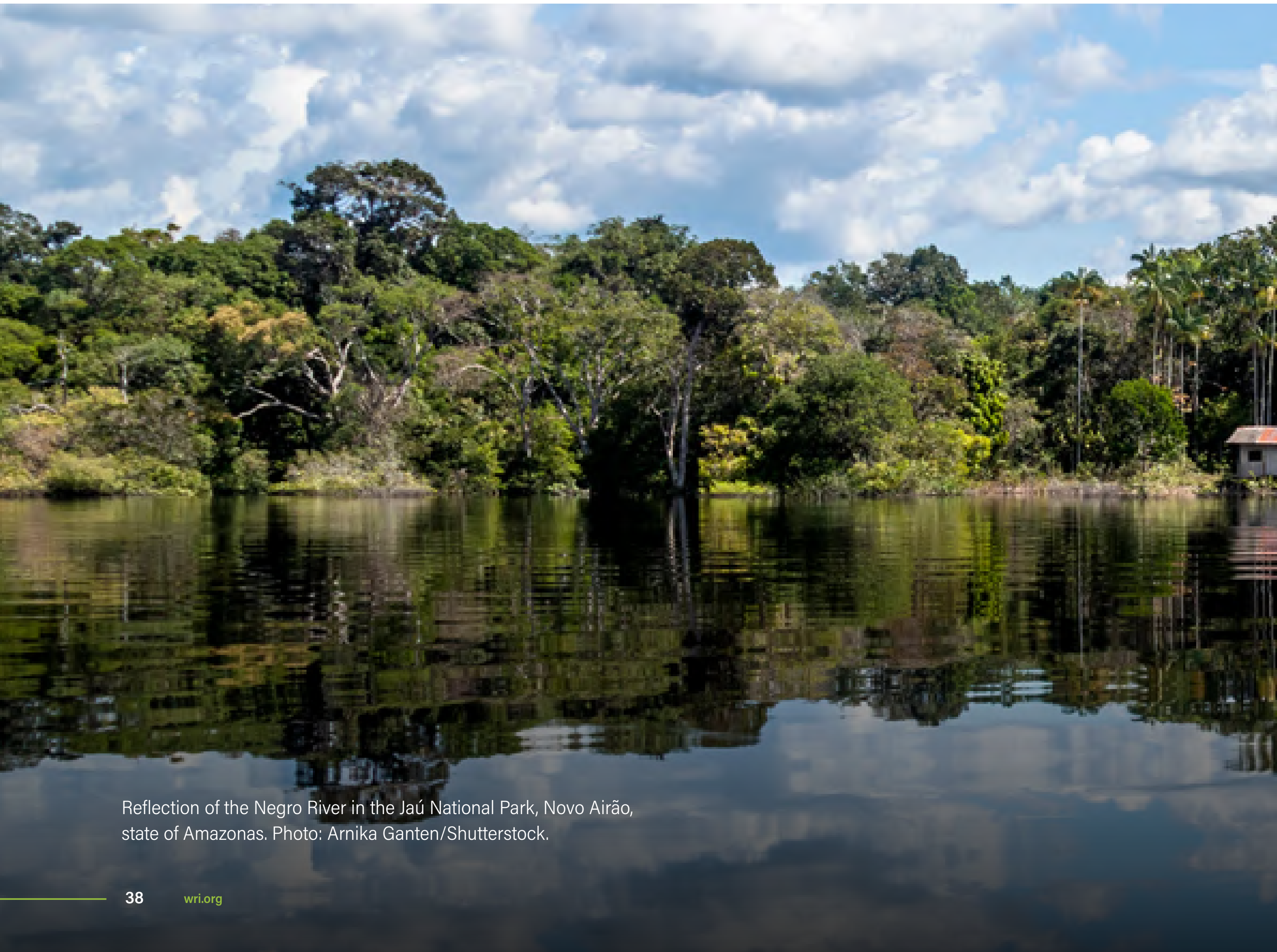
The structuring of a New Economy for the Brazilian Amazon (NEA-BR) needs to first accommodate the expectations of the region's 28 million inhabitants, a highly diverse population with conflicting interests. The strong economic link between the LAM and the rest of Brazil will require that incentives for change be associated with national and regional policies, reducing information asymmetries, and encouraging economic agents across the country to support this development approach. It is important that this approach continues to shape international relations and be strengthened by the exogenous stimuli, whether in terms of foreign trade flows or promotion of innovation. Harmonization of rules, products and processes is essential.

Overcoming barriers to follow this path is not just a matter of technical and institutional innovation capacity. It is necessary to firmly address territorial planning, guarantee the rights of indigenous and traditional peoples, universalize basic sanitation services, overcome housing deficits, advance in the fight against hunger and rural and urban poverty, and promote wellbeing, equity, and sustainability as conditions for any development model.

A new economy for the Brazilian Amazon, based on the appreciation of the region's natural and social assets and the generation of inclusive jobs and opportunities for the region, will be the great catalyst for the decarbonization of the entire Brazilian economy and constitutes the greatest opportunity for economic and social development in the country's contemporary history.

The Amazon biome and the Legal Amazon

This report adopts the boundaries of the Legal Amazon (LAM) as its analytical delimitation. The Amazon biome covers approximately 6 million square kilometers (Mkm^2) in nine South American countries, of which 60% located in Brazil. The LAM, on the other hand, is a legal delimitation that includes the entirety of the Brazilian Amazon Basin and adjacent Cerrado areas. Instituted by Brazilian Federal Law No. 1,806/1953, which defined the area of activity now assigned to the Amazon Development Superintendence (Sudam), it covers 5 Mkm^2 – 59% of the Brazilian territory. With around 28 million inhabitants, it fully covers the states of Acre, Amazonas, Amapá, Pará, Rondônia, Tocantins, and Mato Grosso, as well as the state of Maranhão in its portion west of the 44th meridian.



Reflection of the Negro River in the Jaú National Park, Novo Airão, state of Amazonas. Photo: Arnika Ganten/Shutterstock.

The LAM is a mosaic of forest and savanna environments managed by native peoples for more than 10 thousand years. It is the largest tropical carbon stock in the world, storing 120 billion tons of carbon above ground (Gatti, et al., 2021), which is equivalent to twelve times the annual emissions resulting from global economic activities. It is also responsible for recycling between 6.3 and 7.4 trillion cubic meters of water per year through the so-called "flying rivers" (Baker et al., 2021).

The forest produces half of its own rainfall and 35% to 45% of the rainfall that irrigates the country's Center-South, which is the most important service provided by the forest to the agribusiness, hydroelectric power generation, industry and sanitation sectors in Brazil and the Southern Cone. The reduction of the forest and increased frequency and intensity of fires already have a direct impact on agriculture, which is highly dependent on rainfall, as 96% of planted areas and 99% of pastures in Brazil do not have any irrigation systems in place (IBGE, 2019).

Despite its richness and its role in the economy, the Amazon is approaching a point of no return due to its current trajectory of accelerated degradation (Nobre et al., 2016).

About 83 million hectares of primary forest have already been deforested in the Amazon.

Considering the entire LAM (including Cerrado areas), approximately 23% of the original cover has already been deforested, with 59 million hectares of primary forests and Cerrado areas deforested over the past 36 years (Mapbiomas, 2022c). The continuity of this process is leading to changes in water and carbon cycles, prolonging droughts and causing the region to become a CO_2 net emitter, which happens when its capacity to absorb carbon falls below its own emissions, thus adding risks to the competitiveness of agricultural and livestock activities (Gatti et al., 2021).

Figure 1 | **Current portrait of the Legal Amazon**

The **Legal Amazon** holds the most extensive and biodiverse forest in the world, and is also the largest freshwater reservoir and the most important forest block for climate regulation on the planet. However, degradation already causes parts of the Legal Amazon to emit more carbon than they are able to absorb. Continuity of this trend could lead to a point of no return of ecosystem collapse.

People

213 million in Brasil

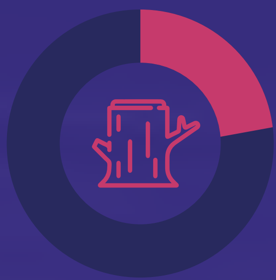
28 million in the Legal Amazon

+75% in urban areas

600 thousand indigenous people from 198 different ethnicities

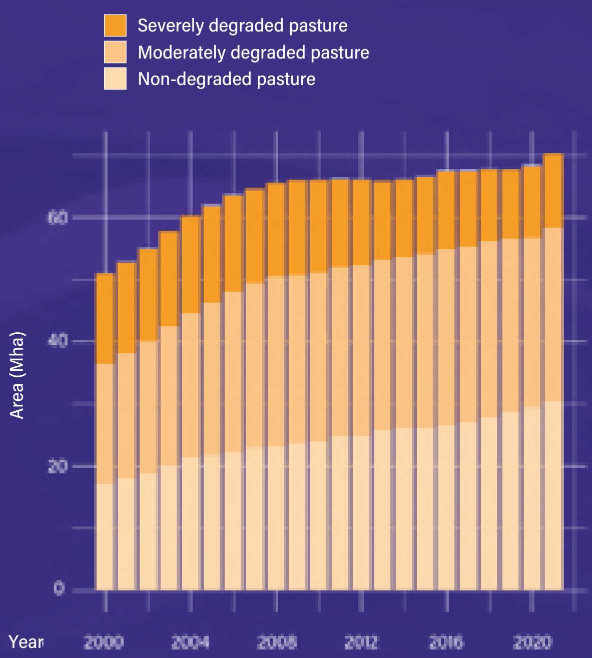
Degradation

59 million hectares of primary forests and savannas deforested in the last 36 years

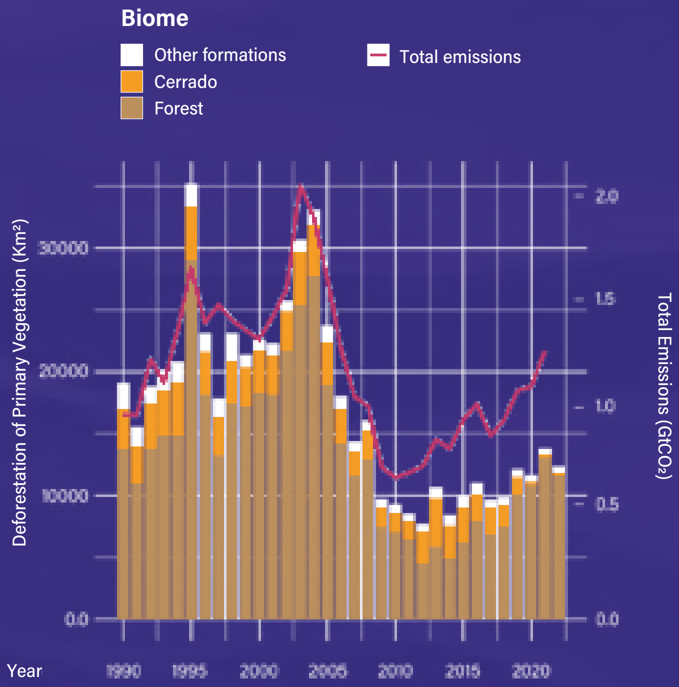


Around **23%** of the Legal Amazon has already been deforested

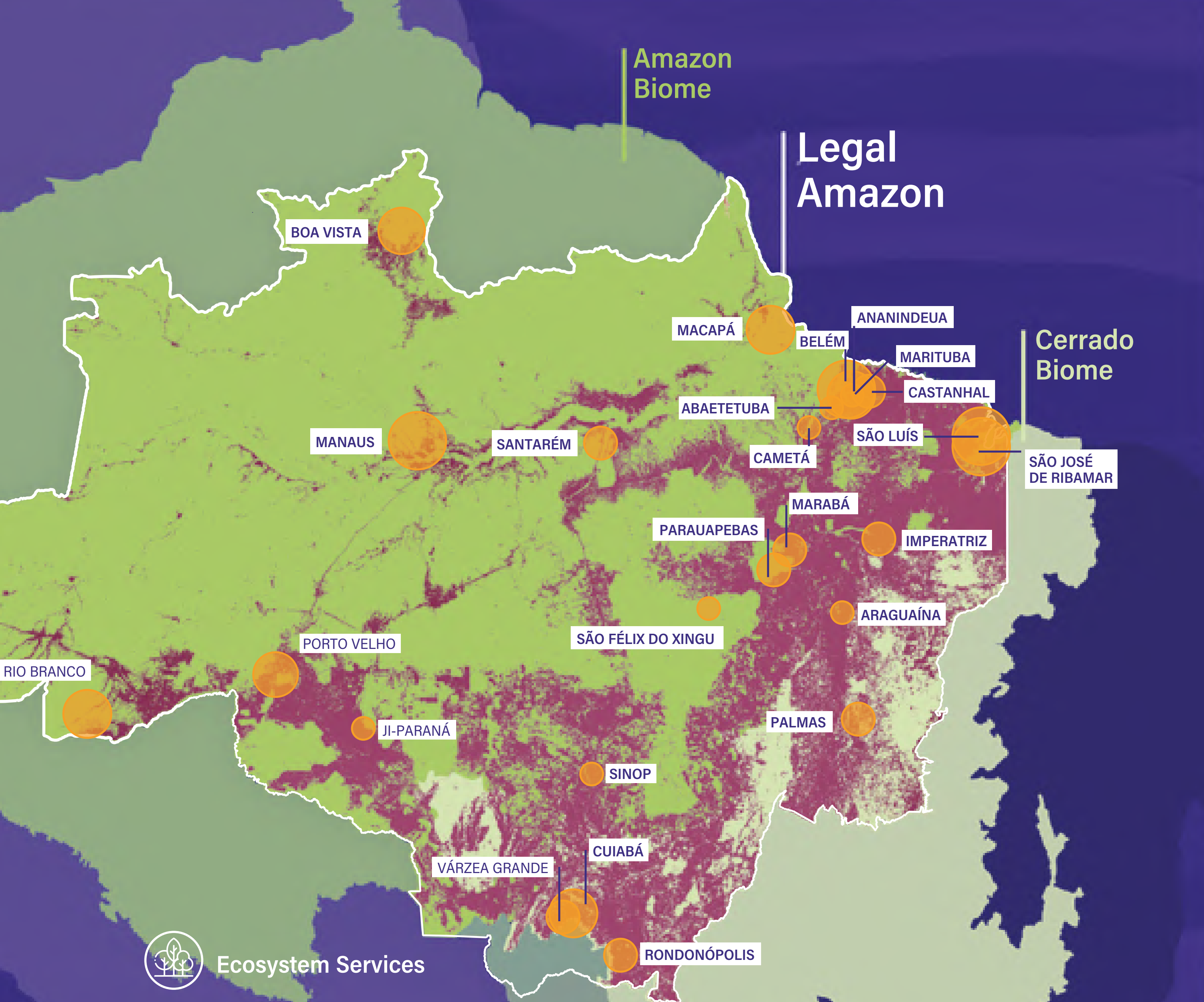
Evolution of degraded pastures



Evolution of deforestation and CO_2 emissions



Source: Created by the authors based on Baker, et al. (2021), IBGE (2019), Ipeadata (2022), ISA (2023), Gatti, et al. (2021), Mapbiomas (2022c), Mapbiomas (2021), Museu Emílio Goeldi (2023), Nobre et al. (2016), Prodes (2022b), SEEG (2022), Valsecchi do Amaral, et al. (2017).

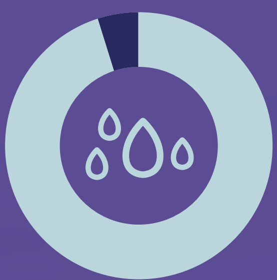


Ecosystem Services

120 billion
tons of above-ground carbon are stored by the Amazon, equivalent to 12 times the global economy's annual emissions

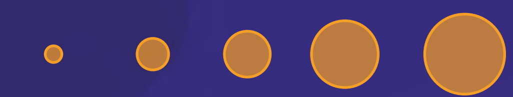
Around
7.3 trillion
of water per year are released by the transpiration of forest trees in the so-called "flying rivers"

The forest produces
35% to 45%
of the rainfall that irrigates the country's Center-South



+95%
of planted and pasture areas in Brazil do not have irrigation systems in place, and depend on rainfall

Total population in the municipality



Accumulated deforestation (2000 - 2021)

The Legal Amazon as a catalyst for Brazil's low-carbon economy

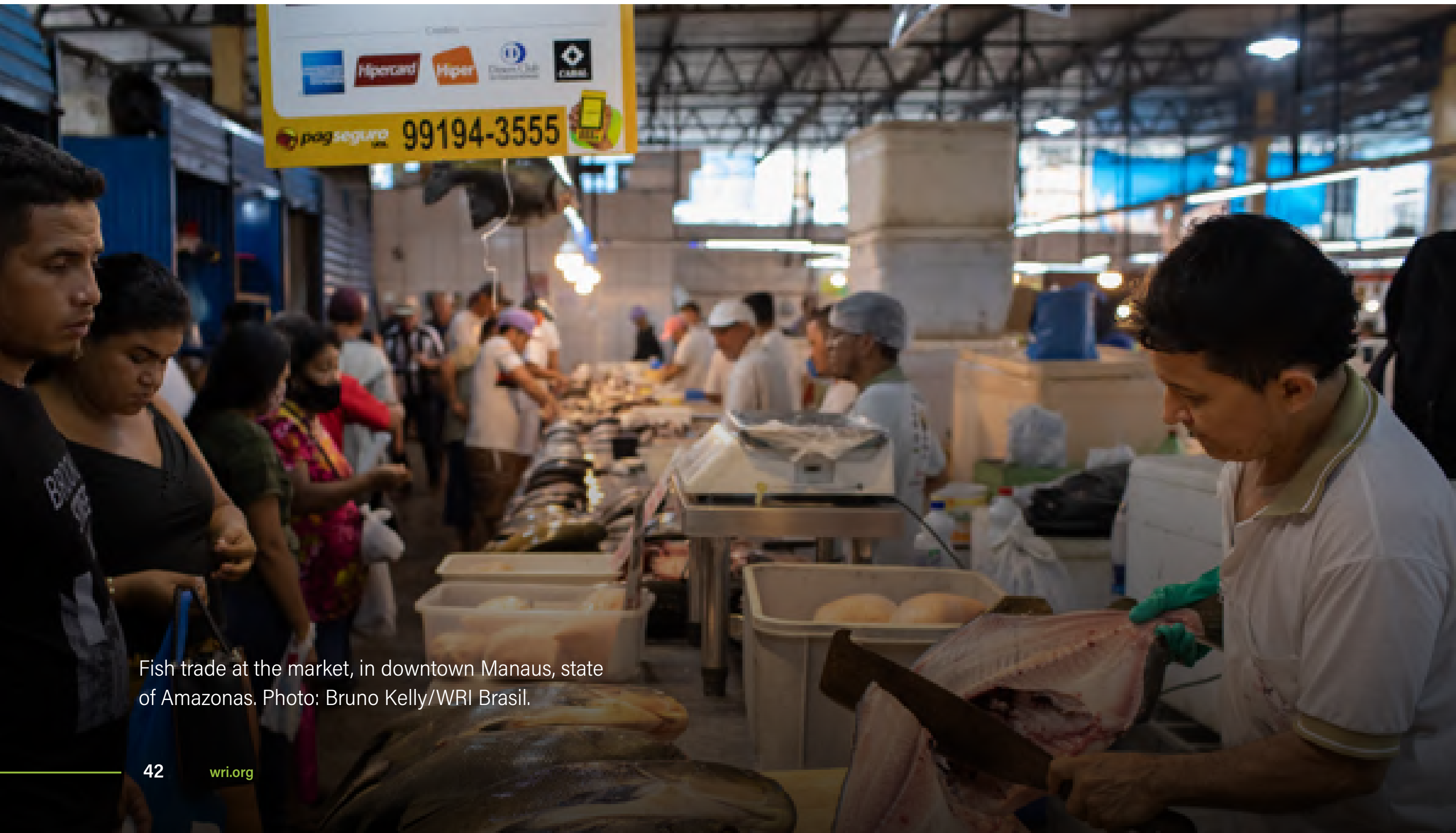
Climate change is increasing the frequency and intensity of acute events such as heavy rains, heat waves and droughts, while also causing chronic and systematic temperature increases. The Intergovernmental Panel on Climate Change (IPCC), which brings together nearly two hundred experts to assess current knowledge on climate change, already considers it unlikely that global warming is curbed below 1.5°C, which in itself calls for investments of around 2% of global GDP in decarbonization. Exceeding this limit causes disproportionately greater impacts, with remediation costs that could range from 4% to 9% of global GDP per year (Guo, Kubli and Saner, 2021).

Recognizing the importance of curbing global warming, 196 countries, including Brazil, have joined the Paris Agreement, commiting to reduce GHG emissions that cause climate change. Countries establish their own targets, known as Nationally Determined Contributions (NDCs), which must be updated periodically. Brazil has agreed to reduce its GHG emissions by 50% by 2030, using 2005 as base year.

Considering this trajectory, it was estimated in this study that Brazil's accumulated net emissions (carbon budget) to limit warming to 1.5°C and comply with the Paris Agreement by 2050 should total 7.7 $GtCO_2$.

The LAM currently accounts for 53% of Brazil's total GHG emissions. When considering only national emissions resulting from agriculture, livestock production and land use, the region's contribution increases to 67%. Since 1990, the LAM has already emitted around 38.1 $GtCO_2$, of which 32 $GtCO_2$ stem from land use change, 4.7 $GtCO_2$ from agriculture and livestock production, and 1.1 $GtCO_2$ from the energy sector, including transportation.

Over the past 30 years, land use and the energy sector have accounted for nearly 98% of all accumulated emissions in the LAM. They are, therefore, the focus of this report.



Fish trade at the market, in downtown Manaus, state of Amazonas. Photo: Bruno Kelly/WRI Brasil.

The New Economy for the Brazilian Amazon

The NEA-BR represents the collective effort of different academic schools, research institutions and researchers from several Brazilian universities to rethink the trajectory of the Amazon's economy. The study was organized into three parts.

The first part seeks to characterize the LAM's economy and forecast scenarios for 2050. In Chapter 1, the diagnosis is carried out with the support of the Interregional Input-Output Matrix for the Legal Amazon (IIOM-LAM), which was developed in partnership with the Institute of Economic Research Foundation of the University of São Paulo (FIPE-USP), allowing for a comprehensive characterization of the LAM's economy, with a focus on land-use intensive sectors. Chapter 2 develops scenarios using General Equilibrium Models (GEM) and Dynamic Optimization Models (DOM) coupled with Computable Land Use Change Modules, developed in partnership with the Environmental and Energy Economics Center of Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering of the Federal University of Rio de Janeiro (CENERGIA-COPPE-UFRJ) and the Center for Regional Development and Planning at the Federal University of Minas Gerais (CEDEPLAR-UFMG), with the aim of forecasting different scenarios for the LAM's economy, comparing the economic, environmental and social results expected for 2050.

In the second part, the main sectors of the transition to the NEA-BR are explored in more depth. Chapter 3 presents a broad discussion on bioeconomy, highlighting results from the Input-Output Alpha Matrix (IOM-Alpha), which was developed in partnership with the Center for Advanced Amazonian Studies at the Federal University of Pará (NAEA-UFPA). It also discusses the role of forest restoration and the relevance of indigenous peoples and their economy – as stated by the indigenous communities themselves – as vital factors for the transition to the NEA-BR. Chapter 4 discusses the role of low-carbon agriculture and livestock production in the new economy and the main challenges to be faced in replacing land with more capital and labor. Chapter 5 presents a brief debate on the relevance of mining in the just transition and the environmental and social impacts that need to be mitigated for the industry to adapt to a low carbon pattern. Chapter 6 details the necessary changes in the energy sector resulting from the models used in Chapter 2, as well as the associated infrastructure to achieve decarbonization by 2050. Chapter 7 provides considerations on the main financing axes for the transition.

Finally, Part 3 wraps up the study, outlining the main conclusions and recommendations. This report aims to present to national and subnational decision makers, members of civil society and investors a pathway for the region's economic transition until 2050, exploring viable, beneficial, and sustainable development alternatives for the Brazilian Amazon and its population.

Varieties of Amazonian peppers ready for sale at the Ver-o-Peso market in Belém, state of Pará. Photo: Nayara Jinknss/WRI Brasil.

The current and future

PART **1**

AMAZON ECONOMY

PART 1

Part I of this report discusses the main characteristics of the LAM's current economy and discusses them in relation to recent literature that criticizes the deforestation-intensive economic growth model and its social and environmental effects.

Chapter 1 discusses the LAM's current economy from the perspective of the results obtained with the IIOM-LAM. Although this matrix enables the assessment of 67 sectors of the region's economy, the report focused only on sectors or chains that simultaneously meet two criteria: (1) relevance to the formation of Gross Output (GO), Gross Domestic Product (GDP) and Value-added (VA); and (2) impact on GHG emissions. The sectors that meet these conditions were selected based on the IIOM-LAM results, which coincide with the specialized literature.

Discussions on exaustive plant extraction (timber, firewood and charcoal) and non-exaustive plant extraction (non-timber forest products)[1] are also introduced, as they are part of marginalized value chains, different from the mainstream activities that have benefited from extensive government and institutional support. in the LAM's current economy, whose roles in the NEA need to be more deeply debated. The IIOM-LAM, developed in partnership with FIPE-USP, is the instrumental framework for Chapter 1 and is available at the www.wribrasil.org.br/publicacoes/nova-economia-amazonia-nea.

Chapter 2 demonstrates how economic growth combined with conservation and expansion of environmental assets can lead to the transition to a low-carbon economy, generating GDP and jobs at levels above those that could be achieved with the persistence of growth linked to deforestation.

By using GEM and DOM models, coupled with Computable Land Use Change Modules, projections were made for GDP, job creation and emissions intensity expected for the BAU-REF scenario (characterized by persistent deforestation). This scenario was compared with two alternatives: economic growth without deforestation (SFL scenario) and economic growth without deforestation and simultaneous increase in vegetation cover dedicated to bioeconomy (NEA scenario). The GEM models were developed by CENERGIA-COPPE-UFRJ and coupled with the Regional Equilibrium Models with land use, developed by CEDEPLAR-UFMG.

Ver-o-peso market in Belém, state of Pará.
Photo: Michel Dantas.

CHAPTER 1

The main sectors of the **CURRENT ECONOMY**

Structurally, the LAM's economy is characterized by regional production specialization (especially of carbon-intensive, low value-added agricultural and mineral commodities), high participation of public administration services in GDP formation, a deficit in trade transactions with the rest of the country, high levels of informality in the job market, lower professional qualifications, and wages below the national average. The thriving local economy, mediated by cities and based on biodiversity products and creative technologies, has its relevance overshadowed by conventional sectors and is hidden by informality. This economy will be explored in Part 2 of this report.

According to official data, more than 50% of jobs are informal, a percentage that is well above the national average of 35%. Considering rural jobs, informality rises to no less than 80%, compared to 60% in the rest of Brazil. The region also shows lower female participation in total employment, holding only 36% of total positions, an indicator that is also below the national average of 42% (Amazônia 2030, 2020). On the other hand, the participation of black, brown, and indigenous people in total employment in the LAM is above the national average, at almost 80%, while this group holds 74% of total jobs in the national economy.

Although these are striking structural characteristics, there is evident spatial heterogeneity in the LAM's economy. This heterogeneity, which can be assessed by classical economic instruments, is analyzed through the IIOM-LAM, developed in partnership with FIPE-USP.

Based on the 2015 national Input-Output Matrix made available by the Brazilian Institute of Geography and Statistics (IBGE)[2], all IIOM-LAM results refer to 2015 and allow: (1) measuring the interconnection between sectors and regions, including exports, (2) measuring direct, indirect and induced sectoral impacts on GO, GDP, Value-added (VA), employment and income creation (Guilhoto, 2011) and (3) measuring negative impacts of economic activities, such as GHG emissions and deforestation (Haddad and Araújo, 2021).

The IIOM-LAM, developed exclusively for this study, also offers two important methodological contributions to advance the understanding of the LAM's economy: the regionalization – meaning the design of new and more socially conscious subregions within state lines – and segmentation of products obtained from forest management.

The regionalization depicts the LAM's heterogeneity, in addition to highlighting sectoral and regional exchanges. 27 different subregions[3] were defined by economic, demographic and morphoclimatic attributes, which were combined by a non-hierarchical clustering method (Kent, Jensen Kongsted, 2014), based on the technological trajectories of land use and occupation observed over the past 35 years (Costa, 2016). Among the 27 regions, six urban agglomerations were highlighted: those formed by the conurbation of municipalities in a metropolitan region and named after their respective capitals: Belém (PA), Manaus (AM), São Luis (MA), Cuiabá (MT), Porto Velho (RO) and Rio Branco (AC). The following figure illustrates the proposed regionalization.

The other innovation is the segmentation of products obtained from forest management, whose activities, albeit antagonistic and competing, appear aggregated and without distinction in the

Box 1 | Interregional Input-Output Matrix for the Legal Amazon (IIOM-LAM): methodological aspects

The IIOM-LAM was generated using the Interregional Input-Output Adjustment System (IIOAS) method. The IIOAS is a hybrid method that combines data made available by official agencies with non-census techniques to estimate unavailable information. The main advantages of this method are its consistency with information from the national input-output matrix and the flexibility of its regionalization process. For further details, see Haddad, Gonçalves Júnior and Nascimento (2017).

Consider the intersectoral and interregional economic flows for two hypothetical regions L and M and two sectors *i* and *j*, represented as:

Z_{ij}^{LL} money flow from sector *i* to sector *j* in region *L*;
Z_{ij}^{MM} money flow from sector *i* to sector *j* in region *M*;
Z_{ij}^{LM} money flow from sector *i* in region *L* to sector *j* in region *M*; and
Z_{ij}^{ML} money flow from sector *i* in region *M* to sector *j* in region *L*.

Note that Z_{ij}^{LL} and Z_{ij}^{MM} are intraregional flows and Z_{ij}^{LM} and Z_{ij}^{ML} are interregional flows.

Thus, it is possible to assemble the matrix $Z = \begin{bmatrix} Z_{ij}^{LL} & Z_{ij}^{LM} \\ Z_{ij}^{ML} & Z_{ij}^{MM} \end{bmatrix}$

Considering this, the interregional input-output model can be written as $X_i^L = Z_{ii}^{LL} + Z_{ij}^{LL} + Z_{ii}^{LM} + Z_{ij}^{LM} + Y_i^L$ where Y_i^L and X_i^L represent the final demand and output of sector *i* in region *L*.

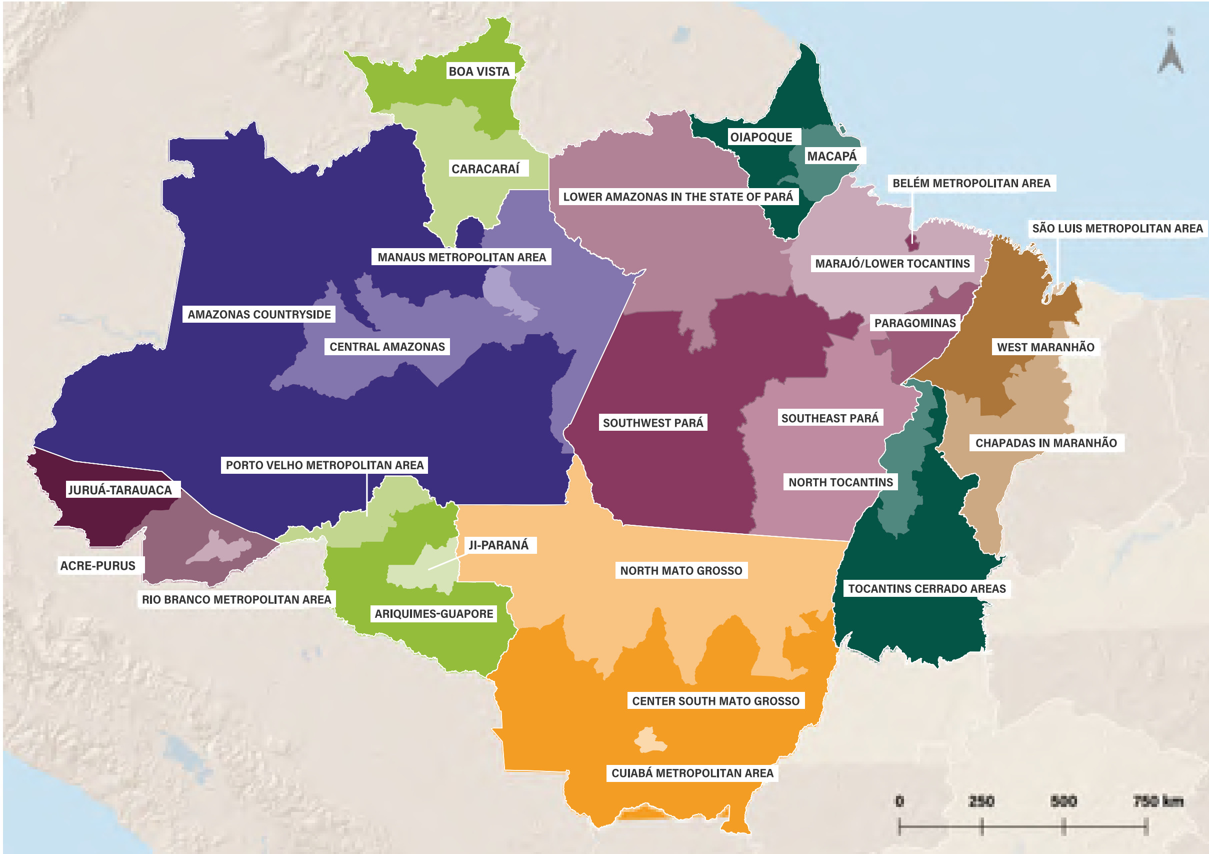
The technical production coefficients can be defined as $A^{LL} = Z^{LL}(\hat{X}^L)^{-1}$.

The same must be done to find A^{MM}, A^{ML} *and* A^{LM}.

Finally, the input-output system can be defined as $X = (I - A)^{-1}$ and $Y = BY$ where *B* represents the Leontief inverse matrix.

*Wassily W. Leontief developed the Input-Output theory and was awarded the Nobel Prize in Economics in 1973.

Figure 2 | Legal Amazon regionalization for the IIOM-LAM



Source: Authors..

original IBGE matrices (2018). The IIOM-LAM distinguishes three forest management sectors: (1) non-destructive plant extraction, consisting of non-timber products, (2) destructive plant extraction, based on the production of non-planted native timber, firewood or charcoal, and (3) foresty, which consists of the deliberate planting of forest monocultures.

To ensure that the first two sectors exclusively comprised extraction activities[4], identical or similar items produced by permanent agriculture, such as planted acai palms or rubber tree crops, were allocated in the IIOM-LAM to the agriculture sector. All the remaining 66 sectors and products followed the original IBGE classifications, resulting in 67 sectors, 129 products and services and 31 regions, 27 of which located in the LAM, in addition to the other 4 Brazilian regions (the Northeast, except municipalities in Maranhão belonging to the LAM; Central-West, except Mato Grosso; South and Southeast regions)

1.1 Productive interdependence and sectoral clusters revealed by the IIOM-LAM

The use of IIOM-LAM identified that LAM's GDP in 2015 stood at BRL 497 billion at current prices, or BRL 646 billion at 2020 prices by the implicit GDP deflator ($ 99.4 bilion and $ 129.2 billion respectively. Henceforth, all values will be expressed in 2020 dollars at the exchange rate of US$ 1 = BRL 5, which is the weighted average exchange rate over the last 60 months). International exports amounted to $ 19.2 billion or 11.6% of the country's total, which is equivalent to 15% of the LAM's GDP. The regions with the highest export rates are in Mato Grosso and Pará, with a highlight to the central-southern portions of Mato Grosso, the leader in soybean production, and the southeastern portion of Pará, with its mineral extraction industry.

Income, represented by per capita GDP, is close to the national average of $ 7.54 thousand only in the center-south of Mato Grosso and in the Manaus agglomeration, where it is supported by the industrial and services economy promoted by the Manaus Free Trade Zone. In the other 25 regions, income is below the Brazilian average, with the poorest regions located in rural Amazonas, western Maranhão and the Marajó-Baixo Tocantins area in Pará. On the other hand, it is precisely in these three regions that the non-destructive non-timber products economy prevails, where the level of informality is above the LAM's average. Associated with this economy, these three regions also show the highest relative participation of black and indigenous people in the job market.

The tripod that characterizes the economy of the Amazon – public administration, non-tradable goods and services and specialization in low value-added export commodities – results in a smaller interregional trade than that represented by external

Table 1 | Value-added incorporated into trade transactions between the Legal Amazon's regions and the rest of the country (in BRL billion)

			Destination														
			R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15
Origin	R01	Porto Velho Metropolitan Area	0	121	345	18	24	58	196	80	93	33	14	47	73	28	24
	R02	Ji-Paraná	47	0	224	8	6	13	79	24	33	11	4	17	27	11	9
	R03	Ariquemes-Guaporé	116	188	0	19	12	26	219	46	68	21	8	40	73	24	24
	R04	Rio Branco Metropolitan Area	32	28	90	0	31	273	106	76	61	14	9	12	38	14	13
	R05	Juruá-Tarauaca	10	6	16	7	0	5	28	33	8	3	1	5	8	2	3
	R06	Acre-Purus	19	14	32	52	4	0	38	10	9	5	1	7	9	3	4
	R07	Manaus Metropolitan Area	427	172	487	155	75	112	0	342	2.167	427	175	411	404	214	244
	R08	Amazonas Countryside	23	14	34	10	12	5	69	0	17	10	2	22	22	7	10
	R09	Central Amazonas	43	23	59	15	5	8	1.591	31	0	46	12	52	64	23	25
	R10	Boa Vista	12	10	29	4	5	7	217	27	79	0	135	12	29	11	8
	R11	Caracaraí	3	2	5	1	0	1	51	2	6	40	0	3	3	1	1
	R12	Belém Metropolitan Area	26	26	83	8	15	20	124	75	108	28	14	0	1.793	88	146
	R13	Marajó/Lower Tocantins	39	27	76	15	7	10	130	34	53	24	7	823	0	56	128
	R14	Lower Amazonas In The State Of Pará	17	14	40	5	4	6	82	26	61	12	5	45	144	0	84
	R15	Southwest Pará	14	10	30	5	3	4	61	14	25	13	2	118	113	46	0
	R16	Southeast Pará	37	25	72	12	8	12	153	32	57	23	6	438	710	82	230
	R17	Paragominas	5	4	11	2	1	2	31	5	13	3	1	97	191	10	25
	R18	Macapá	5	5	17	2	4	5	61	23	40	20	8	37	84	26	18
	R19	Oiapoque	1	1	3	1	1	1	12	3	5	3	1	6	13	5	3
	R20	North Tocantins	7	7	20	2	2	4	48	13	20	5	2	57	116	17	38
	R21	Tocantins Cerrado Areas	17	18	53	5	6	9	90	29	43	10	5	94	184	31	57
	R22	São Luis Metropolitan Area	20	18	58	6	11	14	107	49	74	18	8	187	421	63	77
	R23	West Maranhão	26	18	53	7	7	9	124	31	48	18	5	317	397	50	119
	R24	Chapadas In Maranhão	18	10	28	4	3	5	88	14	23	8	3	105	148	22	68
	R25	Cuiabá Metropolitan Area	44	61	200	14	18	32	285	82	121	27	15	63	171	57	57
	R26	Center South Mato Grosso	94	117	365	31	25	46	614	109	181	47	21	165	317	90	103
	R27	North Mato Grosso	39	50	151	12	12	20	242	52	83	24	10	105	169	48	54
	R28	North	966	567	1.664	253	233	324	3.714	1.119	1.619	491	192	2.592	4.645	1.062	1.948
	R29	Southeast	3.722	2.476	7.513	1.469	1.052	1.579	19.104	4.422	6.794	2.319	842	8.211	12.899	3.660	4.753
	R30	South	1.295	932	2.743	533	362	555	5.570	1.525	2.249	823	295	2.676	4.019	1.164	1.504
	R31	Midwest	523	419	1252	204	154	220	2.047	573	853	356	124	1.104	1.934	463	615
		Imports	6.507	4.395	13.172	2.460	1.802	2.677	30.436	7.639	11.516	3.989	1.454	14.583	23.496	6.348	8.821

Note: Results of this study.
Source: Authors.

transactions. The use of the IIOM-LAM indicates that the LAM's trade with the rest of Brazil, of which 75% takes place with the Southeast region, resulted in $71 billion in exports and $ 94 billion in imports, with a $ 23 billion deficit. Table 1 indicates the VA incorporated into trade transactions between the LAM's regions and the rest of the country.

The relatively smaller size of the interregional market (among the LAM's regions) is supported by the literature and is generally attributed to the combination of low population density and income level, the significant scarcity of medium-sized cities, the long distances between urban centers and the dispersion of population centers (Chein and Procópio, 2022). The road network developed since the 1960s explains the dynamics of emergence and expansion of cities, creating exit routes to the edges of the Amazon, contrary to what was previously performed by river routes that favored the penetration of population centers.

R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	R26	R27	R28	R29	R30	R31	EXP	VA (TOTAL)
52	11	18	5	13	34	21	46	33	37	193	98	1.033	2.692	1.280	575	103	16.280
18	4	8	2	6	15	15	18	12	28	98	38	415	1.185	583	264	226	6.885
48	8	19	4	16	37	44	40	25	86	279	97	953	3.222	1.686	729	1354	19166
23	5	10	3	6	17	16	25	18	12	65	38	467	1.047	527	243	13	9.491
5	1	4	1	2	4	7	7	4	6	19	8	114	327	151	96	8	3.059
7	1	4	1	4	7	8	7	4	17	43	14	155	563	344	145	29	3.620
444	65	290	49	85	239	422	332	192	371	835	422	7.399	14.377	6.376	3.415	1.383	70.285
16	4	14	2	6	14	18	16	10	26	76	27	363	1.381	706	274	57	8.095
46	8	40	5	12	32	50	35	25	54	153	59	1.097	3.244	1.509	560	206	16.091
14	3	22	6	4	10	14	18	11	7	32	18	306	758	373	168	28	10.425
2	0	4	1	1	2	2	2	1	4	9	3	50	195	110	40	5	1.845
442	185	91	27	94	179	270	615	256	44	199	132	3.322	4.184	1.764	1.098	590	42.485
319	92	85	14	75	139	286	370	143	76	248	129	2.499	5.401	2.283	1.333	4.750	35.677
84	16	34	6	17	35	66	69	40	32	90	53	819	1.827	732	420	1.294	12.392
106	17	27	4	24	44	51	69	38	35	93	44	949	1.686	821	469	404	10.711
0	137	78	10	173	247	251	463	197	92	254	158	3.250	6.014	2.581	1.563	12.743	46.009
111	0	11	2	17	25	73	105	23	12	38	23	467	988	363	202	1.073	6.480
37	9	0	97	10	22	24	42	24	9	35	22	630	1.340	709	242	472	14.687
6	1	43	0	1	3	5	6	3	2	6	4	94	259	132	43	31	2.065
162	24	15	3	0	121	71	109	87	17	56	31	923	1.513	613	442	227	9.225
223	33	28	7	118	0	101	169	129	44	172	87	2.075	4.102	1495	1.451	1.564	24.948
242	65	50	14	58	122	0	792	294	30	159	101	3.850	3.414	1.474	778	1.717	31.227
333	100	50	9	104	157	575	0	230	59	162	90	3.161	4.498	2.068	990	2.191	30.939
171	31	23	4	73	96	212	230	0	39	92	51	1.829	2.631	1.127	550	2.333	17.090
142	26	36	10	30	99	83	116	85	0	1360	345	2.313	5.852	2.250	1.923	606	31.349
280	41	63	13	63	190	171	186	129	753	0	749	4.531	13.491	5.436	3.973	15.048	67.850
131	19	33	7	34	84	87	91	60	176	669	0	2062	5.285	2.339	1.353	4.660	27.635
4.199	665	1.235	256	1.004	2.479	4.587	5.169	3.239	1.634	4.989	2.460	0	131.399	45.557	29.696	29.689	892.957
13.016	2.127	3.844	803	2.931	9.008	9.033	10.630	7.041	6.902	25.961	11.174	250068	0	339.699	164.905	386.129	3.561.218
3.888	608	1.367	283	910	2.549	2.715	3.262	2.062	2.350	8.260	3.696	67039	254.189	0	46.200	115.329	1.130.247
1.815	300	632	135	596	1.933	1.166	1.674	1.105	1.310	4.792	1.747	35052	91.720	30.767	0	22.829	539.555
22.918	3.701	7.078	1.476	5.442	15.969	17.501	20.736	13.447	12.196	44.002	19.077						

The LAM's strong economic link with the rest of the country and the world, evidenced by the role of exports and imports (domestic and international) in the trade flow, is rooted in geopolitics. The mobilization of land, labor, and capital in the LAM, whether ostensibly guided, as during the military dictatorship, or driven by public investments in infrastructure, tax incentives and private risk exemption after 1985, followed the dynamics of exogenous drivers of development (Loureiro, 1992; Becker, 2005; Loureiro, 2022). The highly informal local economy, which generates work (not necessarily employment) and income (not necessarily wages) is not captured by conventional methods.

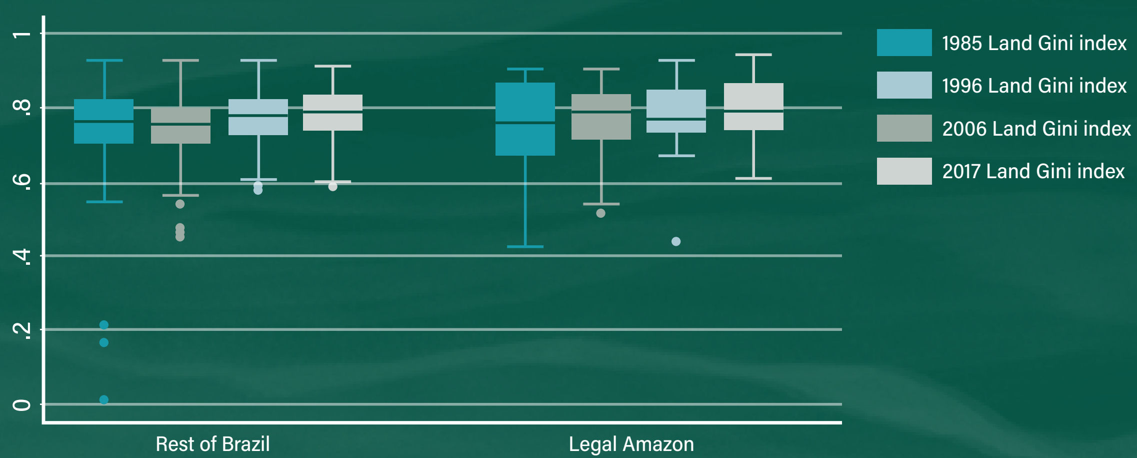
Box 2 | The structural problem of land tenure inequality: distribution of the "land factor"

Land tenure inequality in the LAM has remained unchanged over the past 40 years. Starting with the composition of Comparable Minimum Areas at the municipal level and subsequent aggregation into Minimally Comparable Mesoregions and based on ten classes of groups of rural establishments' total area directly comparable between census surveys, it is possible to conclude that, according to land Gini index calculations, land inequality persists: 0.74±0.13 in 1985, 0.76±0.10 in 1996, 0.78±0.10 in 2006 and 0.80±0.10. Statistically, it does not differ from the land tenure structure of the rest of the country, which posted indexes of 0.75±0.13, 0.75±0.09, 0.78±0.07 and 0.78±0.07, respectively.

Importantly, despite all the Amazon's peculiarities, from the level of illegality to the vast availability of land, land tenure inequality has only reproduced the land tenure dynamics observed in the rest of the country, which is undeniably a structural problem that goes beyond regional diversity. The chart below depicts the distribution of land Gini indexes.

Inequality has persisted despite the significant difference in deforestation, with 35 Mha in the Amazon and 14 Mha in the rest of Brazil between 1985 and 2017, which also refutes the rhetoric that deforestation is a necessary evil to fight land tenure inequality.

Chart Q2 | Distribution of land Gini indexes in the Legal Amazon and the rest of Brazil

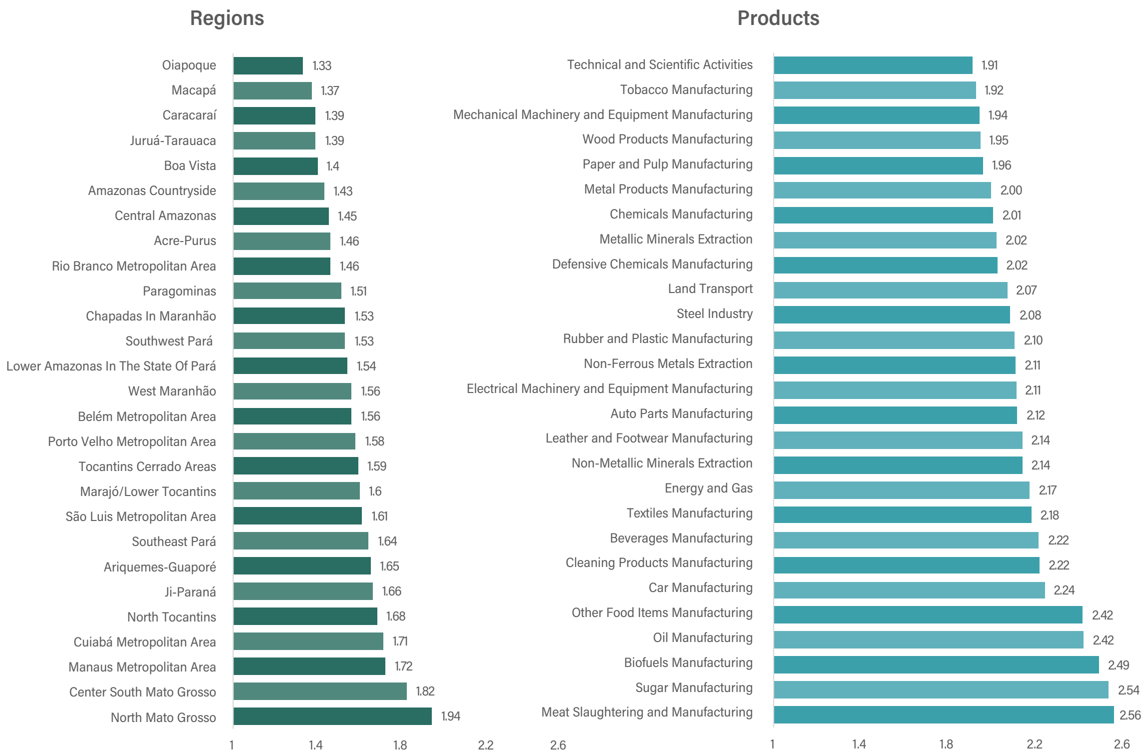


Note: Results of this study.
Source: Authors.

The IIOM-LAM makes it possible to calculate the multiplier effect or to measure regional and sectoral production responses to national demand shocks (marginal increments). Not coincidentally, the regions with the highest multipliers were the central-southern portion of Mato Grosso (1.94), northern Mato Grosso (1.82), and the Manaus agglomeration (1.72). These regions act as the main points of entry and exit for economic flows between the LAM and the rest of Brazil, as well as for international trade.

In terms of sectors, the greatest multiplier effects are found in the production of goods with high demand from markets outside the LAM (domestic and international), especially meat production (2.6), biofuels (2.5) and oil refining (2.4). In the sectoral breakdown by product, considering those with the highest GO, exported items also stand out, such as cotton (2.9), processed beef (2.8), corn (2.7), soybeans (2.3), metallic minerals (2.0) and cattle livestock (1.9). Chart 1 shows the regional production multipliers of the LAM's 27 regions and main products.

Chart 1 | Regional production multipliers of the Legal Amazon's 27 regions and main products



Note: Results of this study.
Source: Authors.

Despite the export sectors' high multiplier effects and economic strength, particularly agriculture, livestock production and mining, the analyses based on the IIOM-LAM show that these are not key sectors. Technically, a key sector is able to drive economic growth by simultaneously stimulating upstream and downstream chains, acting as a sectoral center both in the purchase and sale of inputs and outputs (Guilhoto, 2011).

Agriculture, livestock production and mining in the LAM, besides the fact that they are not key sectors, show similar dynamics both in relation to the LAM's productive structure and in relation to their connections with the national structure, which reinforces the idea that this an economy strongly shaped by exogenous stimuli.

Agriculture (soybean and other temporary and permanent crops) is relevant in output supply, but not as a demander of inputs from other internal sectors. Production is high, but the sector is not productively inserted into the economic structure as it does not foster upstream chains, given its role as exporter of primary commodities. In contrast, meat production, metallic mining and the steel industry depend on intersectoral supply, meaning they are significant buyers of outputs but not suppliers of inputs to downstream chains. On the other hand, cattle livestock production, non-metallic mining and iron mining are characterized by sectoral independence, with weaker connections in their respective upstream and downstream links.

1.2 Value chains and source of demand

The sectoral view, as presented earlier, is important for economic planning because it allows the quantification of monetary flows of inputs and outputs in the productive structure and mensuration of intersectoral linkages with their direct and indirect effects. Politically, it is an important negotiation tool for weighing competing expectations that may emerge between major segments or different sectors within the same chain, for example, in negotiations between producers, manufacturers and retailers (Delgado and Mills, 2020).

Alternatively, the value chain perspective is more intuitive and offers an outlook that transcends sectorization, treating in an aggregate manner the flows of the primary sector (producers) and the secondary sector (manufacturing industry) and their productive linkages with the tertiary sector (trade and services in domestic demand and exports). To meet the need to examine the major wealth generators and their environmental impacts in the LAM's current economy, sectors were aggregated and analyzed from a chain perspective, as follows.

1.2.1 The cotton and grains chain

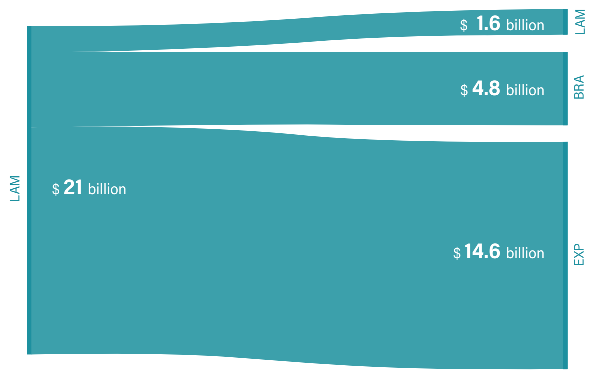
The cotton and grains chain is intensive in land use and is considered in this study as including soy, corn, cotton, and semi-manufactured and manufactured oil products (in the IIOM-LAM, about 11% of the oils are of animal origin; and as such they are included in this chain).

This chain has experienced rapid growth in the LAM since the 1980s (Abiove, 2022a). Regarding the harvested area, the LAM's share in the country's total grew from 9% to 34% between 1980 and 2021 (IBGE, 2021c). The LAM currently holds 23% of the national installed capacity for processing, refining and bottling vegetable oils (Abiove, 2022a).

The IIOM-LAM results indicate that, in 2015, the chain employed around 690 thousand people in the region, of whom 260 thousand (37.7%) had formal jobs. The GO, considering the economic flows between sectors and regions, totaled $ 21 billion, with GDP at $ 8.7 billion.

Of the total GO, only $ 1.6 billion (8%) stemmed from local demand (intermediate and final demand), $ 4.8 billion (23%) from the rest of Brazil and $ 14.6 billion (69%) from international demand, as illustrated in the chart below.

Chart 2 | Source of demand for products of the cotton and grains complex chain produced in the Legal Amazon (in $)



Source: Authors.

The VA incorporated into this chain's trade transactions in the LAM was estimated at $ 4.8 billion, of which 9.7% originated from regional demand, 33% from demand from the rest of Brazil and 57% from international demand.

The coupling of the IIOM-LAM with mathematical vectors of deforestation information, as described in Box 8, Coupling of the IIOM-LAM and deforestation and emissions vectors, made it possible to estimate the VA incorporated into transactions vis-à-vis deforestation and associated emissions, shedding light on the deforestation intensity and carbon intensity of the economy, following the source of demand flows.

It was estimated that, in 2015, the economic transactions of the grains and cotton chain in the LAM induced the emission of approximately 58 $MtCO_2$, with direct deforestation of 86 thousand hectares. Emissions and deforestation induced by external demand and incorporated into international exports amounted to around 33 $MtCO_2$ and 49 thousand hectares deforested, representing 57% of the total.

Deforestation and emissions in the chain may be underestimated, as the data used in the IIOM-LAM refer to 2015, when the Soy Moratorium was still relatively operative. In fact, the Soy Moratorium, an agreement that established that financing and purchase of soybeans were carried out exclusively with producers whose areas had been deforested until 2008, led to a drastic reversal of the deforestation trend in the past decade: while in years prior to the moratorium approximately 30% of the soybean expansion occurred via deforestation, in the subsequent years it dropped to less than 6%, with the grains complex expanding primarily over open pastures until 2008 (Gibbs et al., 2015; Abiove, 2022b).

However, the official report from the Soy Working Group (Grupo de Trabalho da Soja; GTS, from its initials in Portuguese) shows that the moratorium has been losing adherence, with non-compliant areas increasing from 12 thousand hectares in 2012 to 147 thousand hectares in 2020. While deforestation in the LAM increased by 135% during the period, soybean expansion in violation of the moratorium rose by 1,100% (Soy Working Group - GTS, 2018; Abiove, 2022b).

Box 3 | Illegality in the grains chain

Land use and occupation in the LAM are significantly exposed to interference from illegal activities, which contaminate the grains chain, considering that these irregularities are systemic in the region.

Unlike others, the irregularity that affects the chain relates to the ownership and concession of rural properties, given that agriculture is the final stage in the deforestation cycle[5]. Land tenure disputes are very relevant in this context and arise from the uncertain status of a large number of rural properties in the Amazon. This happens due to the complex historical legal framework that regulates the issue and is sometimes contradictory[6], but above all, as a result of the practice of land grabbing (BNDES, 2022). Land grabbing is defined as the appropriation of land through mechanisms involving the falsification of documents. In many cases, this process involves the illicit appropriation of public lands by means of the expulsion of informal settlers or traditional communities[7].

For the NEA to be successful, territorial planning issues need to be properly addressed and resolved. The continuous and widespread practice of land grabbing, fueled by the successive enactment of new land regularization laws and uncertainties regarding land ownership, hinders the region's development by generating insecurity for investors and producers.

Currently, there are initiatives by subnational governments that seem promising, such as the Amazônia Agora plan[8], as well as actions by other institutions, such as the Amazônia Protege program led by the Federal Public Prosecutor's Office[9]. However, the Federal Government needs to invest in monitoring of data inserted by rural landowners into the CAR system[10] and in the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm), so that new areas are not added to the deforestation cycle.

1.2.2 Cattle livestock production chain (beef and dairy products)

Livestock production is the historical activity driving frontier expansion in the LAM (Valverde, 1967; Fearnside, 1986; Shukla, Nobre and Sellers, 1990; Skidmore et al., 2021). From 1985 to 2021, the region absorbed nearly 54% of the net growth of the national cattle herd. While in the rest of Brazil the cattle herd grew from 116 to 160 million, in LAM it jumped from 12 to 64 million over the same period, with GO rising almost 1000%. In the last 20 years alone, cattle slaughter increased by 140%, with an addition of 1.9 million tons of prepared carcasses, alongside a 1.4 billion-liter increase in milk production (IBGE, 2021a, 2021b, 2022).

Buffalo farming on the banks of the Amazon River. Photo: Greenpeace.

The livestock GO chain (cattle livestock production, dairy and meat sectors) has been estimated at $ 21 billion with a $ 8.9 billion GDP, employing 2 million people, of whom 600 thousand have formal jobs.

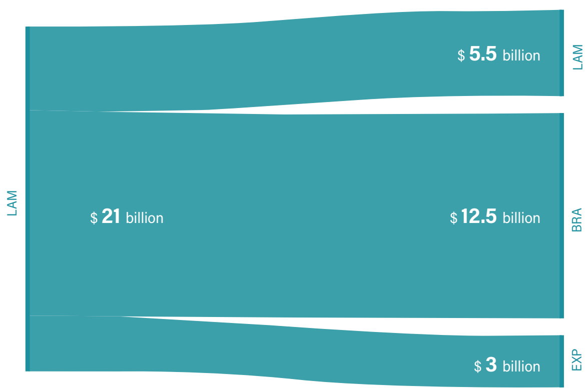
Looking at the production breakdown by source of demand, the IIOM-LAM reveals a very different scenario from that outlined for the cotton and grains complex chain: 25% of the LAM's livestock production is sold within the LAM, 60% to the rest of Brazil and only 15% destined for foreign trade, as shown in the following chart.

The VA incorporated into these trade transactions has been estimated at $ 5.5 billion, of which 17.8% come from regional demand, 59.5% from demand from the rest of the country and 17.4% from international demand. Vector analyses of deforestation show that in 2015, economic transactions in this chain led to the emission of 783 MtCO$_2$, with direct deforestation of 1.4 Mha of primary and secondary vegetation.

Emissions and deforestation incorporated into commercial transactions with the rest of Brazil reached around 483 MtCO$_2$ and 886 thousand hectares, representing 61.6% of the total.

The results indicate the need to change common interpretations of the role of consumer markets in the expansion of livestock production in the LAM and the negative impacts of deforestation. They also measure, for the first time, the size of the different markets, revealing how much effort needs to be exerted in each of them. The focus shifts to local and regional demand, but mainly to domestic demand, different from the cotton and grains chain. Although external demand is not the main driver of livestock production in the region, it still plays a significant role, influencing the adoption of sectoral trends and practices, such as traceability throughout the value chain, for example.

Chart 3 | Source of demand for products from the cattle livestock production chain in the Legal Amazon (in $)



Source: Authors.

Box 4 | Illegality in the cattle livestock production chain

Livestock production is the economic sector most exposed to illegality. Since 1985, of a total of almost 59 Mha deforested in the LAM including primary and secondary forest and savanna vegetation, approximately 83% have been converted into pastures. In 2020 alone, 75% of deforested areas in public forests were converted into pasture, totaling 2.6 Mha of illegal deforestation (Salomão et al., 2021). Considering the years 2019, 2020 and 2021, almost 95% of new pastures were illegally formed (Mapbiomas, 2020; 2021b; 2022a).

The dynamics of deforestation and replacement of forests with pastures can be observed in satellite images and is a consequence of an expansion model that assumes the incorporation of new areas into the production process. Deforestation and conversion into pastures can be interpreted as a rationalized strategy of accumulation of pasture areas to accommodate rotational herd management or, in other cases, inflation-protected savings with more liquidity than the forest itself (Furtado, 2005; Costa, 2010; Brito et al., 2019). Land speculation, as a strategy for asset appreciation, is also an important driver of deforestation.

Therefore, territorial planning is of utmost importance in the fight against deforestation associated with livestock production in the region. In this sense, the Rural Environmental Registry (CAR), implemented by Brazilian Federal Law No. 12,651/2022 (Forest Code), constitutes an essential tool for territorial management and fighting illegal deforestation. However, this instrument is flawed. Currently, there are CAR registrations for public lands and overlapping registrations. This is due to the fact that only 100 thousand registrations have been completed, representing only 1.5% of CAR registrations in Brazil (Coalizão, 2022; Soares, Pereira and Pucci, 2021; Waisbich et al. 2022).

For the agriculture and livestock production sectors to comply with environmental legislation, command and control policies must be strengthened to better support the inspection and application of sanctions to potential offenders.

Despite advances in voluntary regularization to fight the spread of illegality in the meat chain, recent studies indicate that large slaughterhouses and retail networks still experience failures in supplier traceability, with many suppliers located in protected and/or deforested areas (Wasley and Heal, 2019; Phillips et al., 2019; Phillips, 2020a; 2020b; Campos, 2019; Bourscheit et al., 2021; Amazon Watch, 2019; Neves, 2020; The Economist, 2020; Amnesty International, 2020; Global Witness, 2020).

In this sense, the complexity of the meat production chain and the absence of an efficient traceability system for cattle converge to create a scenario of vulnerability in the sector, which struggles to establish monitoring, especially of indirect suppliers – breeding and rearing –, leaving the meat market exposed to the presence of animals of illegal or irregular origin.

Despite being considered the most effective way to control cattle herds, individual tracking is not commonly implemented in Brazil. It is only required for exported production.

In the domestic market, the Animal Transit Guide (Guia de Trânsito Animal; GTA, from its initials in Portuguese) is the document used for control and inspection of the livestock activity. However, the information contained in this guide is not public, which makes inspection difficult. Moreover, direct suppliers are not required to submit guides for previous links, which enables the concealment of the animal's origin (Garcia-Drigo, Souza and Piatto, 2021). This framework is unable to curb the practice of "cattle laundering", allowing animals from different origins (legal and illegal) to be transported to the same farm and subsequently acquired by slaughterhouses without information about any potential irregular origin.

It is worth noting that the importance of the Brazilian market for the demand for cattle livestock products and the vulnerability of the sector to contamination by illegally sourced products reinforce the need for sanitary, fiscal, and environmental traceability systems (Coalizão Brasil, 2020), but with specificities, particularly at the state and interstate levels, as the main source of demand is the domestic market.

In this regard, it is important to highlight state-level tracking initiatives, such as the Selo Verde platform in the State of Pará, aimed at monitoring and assessing sustainable agricultural and livestock development policies and fighting illegal deforestation in the state.

Illegal wood logs such as kapok tree, cedar, mahogany, itauba and sandbox tree seized in the Santo Antônio Community, in Manacapuru, state of Amazonas. Photo: Ricardo Oliveira.

1.2.3 Destructive and non-destructive plant extraction chains

In 2015, the GO of non-destructive extraction (non-timber products) in the LAM amounted to approximately $ 256 million, corresponding to 83% of the national total. The value chain, comprising the inputs and outputs transactioned by the sector – including direct and indirect impacts – generated a GO of $ 298 million, a GDP of $ 234 million, a VA of $ 187 million and a production multiplier effect of 1.52.

Although the figures are modest when compared to conventional activities, the chain already shows a GO that is not far from the economy of deforestation and destructive extraction, estimated at $ 394 million, but with a slightly lower internal net multiplier effect. The IIOM-LAM made it possible to analyze that for every $ 200 thousand in non-timber products, an additional $ 33 thousand are generated within the LAM via the supply chain, and another $ 70.8 thousand by induction in the rest of Brazil. Thus, 32% of the direct and indirect impacts of this activity are internalized by the LAM. However, in the economy of deforestation, represented by timber products, internalization is slightly lower, at 31%, with $ 44 thousand added to the LAM and $ 98.4 thousand to the rest of Brazil for every $ 200 thousand of timber products produced in the LAM.

The non-timber extraction value chain generates 52 thousand direct and indirect jobs within the LAM (excluding production leakage to the rest of Brazil), of which 92% are held by black or indigenous people[11], which differs slightly from the 57 thousand jobs in the destructive extraction economy, where 90% of workers belong to these racial groups.

The IIOM-LAM also reveals that only 7% of the non-timber product chain's GO in the LAM stems from local demand. This counterintuitive result can be explained by registration inconsistencies. While conventional sectors such as livestock production, soy production and mining have very detailed official data describing and characterizing activities and products, with dozens of specific classes and subclasses, the data available for the plant extraction industry are limited to 79 related activities (across the three sectors) and even then, descriptions are generic and ambiguous (IBGE, 2023).

Without the necessary traceability for the linkage of flows in the construction of the matrices, many activities were excluded from the analyses.

The IIOM-LAM also excluded products obtained from agro-extraction, agroforestry systems and intercropped polyculture, as well as the various artisanal or industrial manufacturing arrangements that derive from them. The lack of statistical data can lead to the underestimation of the sector, especially regarding products consumed locally and in informal markets. Non-destructive extraction has been neglected by official statistics, which will be detailed addressed in Chapter 3.

A careful analysis of Brazil's Statistical Yearbook (Anuário Estatístico do Brasil; AEB, from its initials in Portuguese) since 1936 reveals that, in fact, biodiversity products in the LAM have gradually been omitted from production and trade records, either through aggregation or substitution, while substitute or similar products, particularly soy and cotton vegetable oils and fibers, have experienced a steep growth.

Based on data from the yearbooks, it is possible to estimate that, in 1940, the Amazon produced $ 260 million in non-destructive forest products, $ 28.6 million in locally manufactured native vegetable oils and $ 157 million in exports of non-timber plant products. During that time, beef production in the Amazon did not exceed $ 71.6 million (AEB, 1947). In 2021, in contrast, the LAM's non-destructive forest production reached $ 420 million, of which $ 182 million corresponding to exports (Secex, 2022), while the cattle herd reached 64 million head, up from 2.8 million in 1940. In that year, there was no record of soybean production in the LAM, while today it covers an area of 13.9 Mha and accounts for 35% of total soybean production in Brazil.

Although the rapid expansion of livestock and soybean production in the LAM justifies the detailed registration of its products and activities, according to official data, the non-timber forest economy has remained virtually constant over the past 80 years, despite the fact that the LAM's population, the major consumer of these products, has increased tenfold during the same period.

At the same time, timber products are even more difficult to track, with two particularities adding up to the registration problems already pointed out: the generalization of wood species' names, especially those from the Atlantic Forest, and the high rate of illegality, which is a common practice in the LAM (Sassine, 2022a; 2022b; Toledo, 2022).

Box 5 | Illegality in timber product extraction

Illegal timber extraction is the first significant component of the "deforestation cycle". This practice consists in the removal of certain trees from public or private forests – native forests and successional formations – without forest management authorization issued by a competent environmental agency, such as the Timber Harvesting Authorization (Autex at the federal level or Autef in the states of Mato Grosso and Pará) (Brasil, 2012; Imazon, 2021).

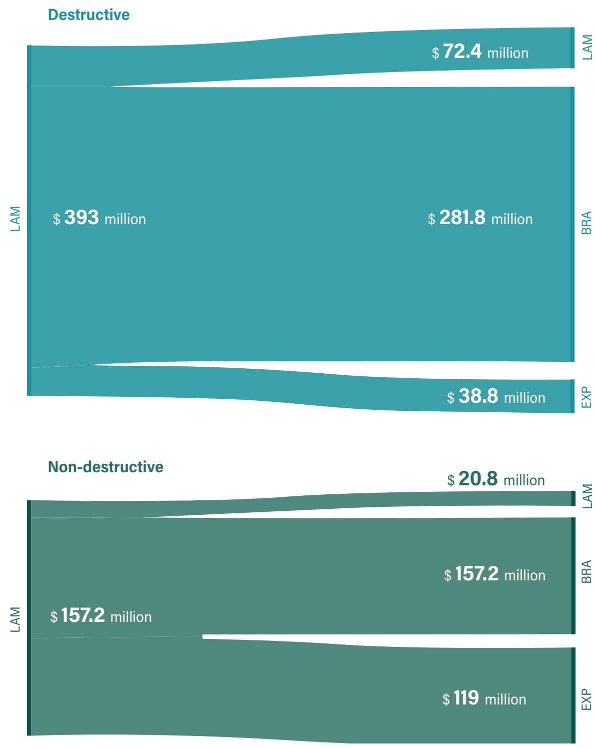
Between August 2019 and July 2020, timber extraction reached 464 thousand hectares (Imazon, 2021). Over half of this total (234 thousand hectares) took place in Mato Grosso, where 38% of the detected extraction was unauthorized, indicating illegal activity (Imazon, 2021). In Pará and Roraima, illegal extraction reached 55% of the total area (Imazon, 2021). In other states, this percentage is also significant, reaching 13% of total extraction in Amapá, 8% in Rondônia, and 26% in Amazonas (Imazon, 2021).

The fight against the criminal practice of illegal timber extraction calls for stronger state intervention through allocation of public lands, effective monitoring by environmental agencies, application of strict sanctions and effective collection of fines (Soares, Pereira and Pucci, 2021; Waisbich et al., 2022; MPF, 2015; Angelo et al., 2014).

Despite all the methodological limitations, the effort to break down the forest management sector into timber (destructive) and non-timber (non-destructive) has proven valuable, not only for estimating the size of these contrasting markets but also for verifying that, at least in terms of demand from outside the LAM, while the timber market is primarily driven by domestic demand in Brazil, non-destructive products show a very similar breakdown into domestic and international markets for the portion formalized and captured by the IIOM-LAM, as shown in Chart 4.

Vessels decorated with typical Amazonian lettering, moored at the Ver-o-Peso market in Belém, state of Pará. Photo: Nayara Jinknss/WRI Brasil.

Chart 4 | Source of demand for products from the destructive (timber) and the non-destructive (non-timber) plant extraction chains in the Legal Amazon (in $)



Source: Authors.

Vector analyses of deforestation were not applied to extraction activities. In the case of non-timber products, production activities are not dependent on standing forests, so the impact of direct deforestation can be disregarded. Indirect impacts, induced by the consumption of inputs from other sectors, were not significant, neither in terms of deforestation nor emissions.

As for timber extraction, the impacts on deforestation and emissions were not calculated because, even though this activity is explicitly dependent on deforestation, the vector bases of Mapbiomas (2022b) do not allow the identification of areas directly converted by timber extraction exclusively, which is a fundamental condition for linking the land use class to the economic activity sector. Alternative estimates of deforestation induced by or associated with livestock production, for example, were not used, as their results are not comparable with the other sectors (Boekhout van Solinge, 2014; Condé, Higuchi and Lima, 2019).

Box 6 | The role of Conservation Units and Indigenous Lands in the fight against deforestation

The creation of protected areas, especially Indigenous Lands and Conservation Units, results from the struggle of indigenous peoples and the recognition of the need to protect natural resources, which gained significant momentum after the 1988 Constitution. While Indigenous Lands in the LAM covered 7.5 Mha in 1985, they totaled 111 Mha in 2017. Conservation Units followed a similar trajectory: their areas increased tenfold between 1985 and 2017, soaring from 13 Mha in 1985 to 127 Mha in 2017 in the LAM.

These protected areas have effectively fulfilled their role in recognizing indigenous rights, conserving biodiversity and curbing deforestation. From 1985 to 2017, there was a total deforestation of 36 Mha in the LAM, while deforestation in protected areas amounted to 351 thousand hectares, representing 1% of the total.

Figure Q6 | Evolution of ratification of protected areas and accumulated deforestation

Source: Authors.

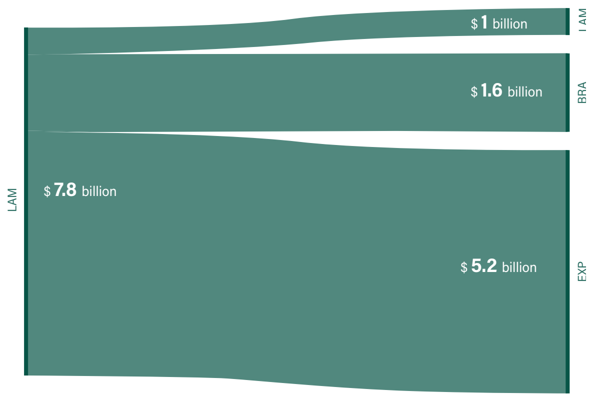
1.2.4 The mining chain

The mining chain refers in this study to all activities associated with mining production, excluding coal extraction, oil extraction, oil refining and biofuels, but including non-metallic minerals, non-ferrous metallic minerals and iron ore. As is the case with livestock production, this is a chain that deserves attention due to its exposure to informal labor practices and illegality. The results of the IIOM-LAM primarily reflect large-scale industrial mining, particularly of metallic and non-metallic minerals used as inputs in the steel and chemical industries. Small-scale mining focused on precious metals and diamonds, whether legal or illegal, is not considered in the IIOM-LAM, even though it occupies a larger area than industrial mining in the region (Mapbiomas, 2021a; 2022b). Illegal small-scale mining, permeated by violence, foreign currency flight and tax evasion (Wagner et al., 2019), albeit not the object of this study, poses a significant obstacle to the implementation of the NEA by creating a situation of insecurity and instability in the region.

Industrial mining is a chain that generates approximately $ 7.7 billion, a GDP of $ 3.9 billion and just over 113 thousand jobs. The VA incorporated into commercial transactions was estimated at $ 2.9 billion, of which only 5.4% originated from regional demand, 17.9% from demand from the rest of Brazil and 76.7% from external demand.

Four regions are responsible for more than 92% of GO in the mining chain: southeastern Pará with 69%, followed by the Lower Amazon region in Pará with 9%, Paragominas (PA) with 7% and western Maranhão with 7%. In these regions, the chain accounts for 47%, 33%, 23% and 6% of their respective GDPs and 61%, 37%, 18% and 3% of their respective exports.

Chart 5 | Source of demand in the mining chain in the Legal Amazon in 2015 (in $)

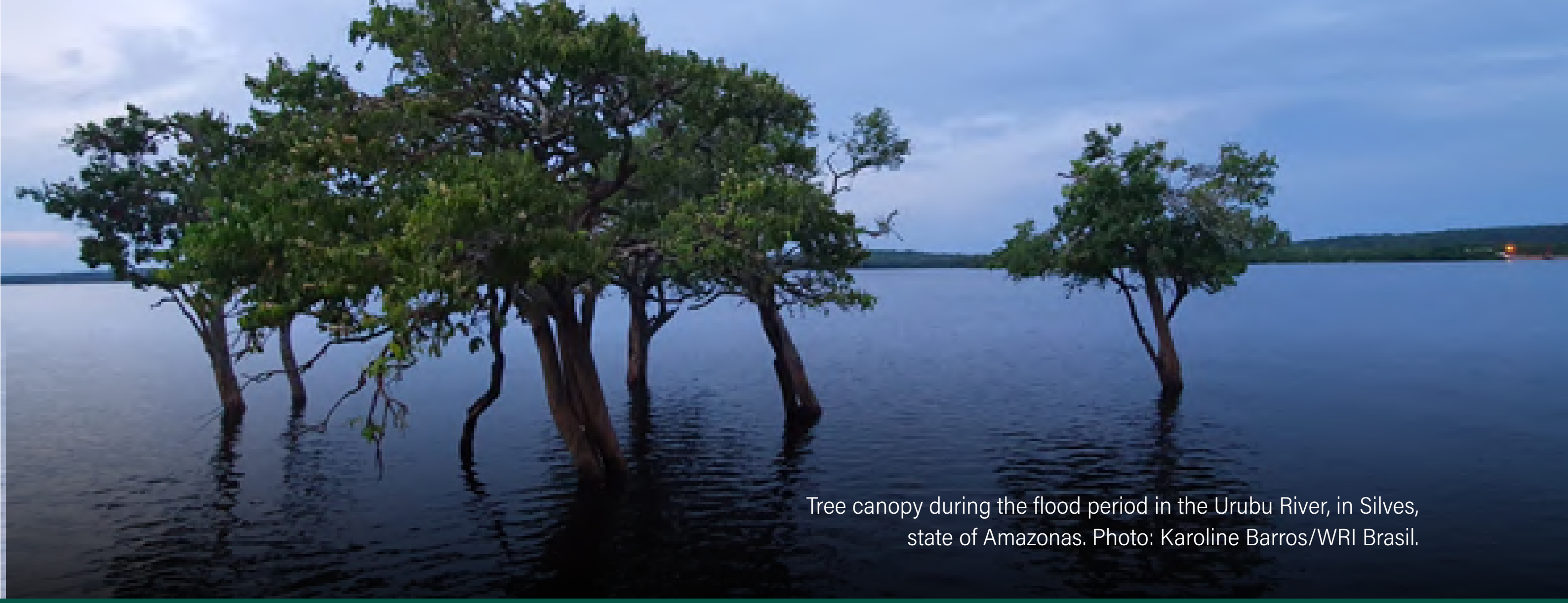


Note: Results of this study.
Source: Authors.

Metallic and non-metallic mining, both relevant sectors for the LAM, also play a connecting role with urban agglomerations, either through product flows or the circulation of inputs and services necessary for production. However, studies indicate that potential benefits are constrained by losses in tax collection. Throughout the LAM, a 75% income tax exemption is granted to large companies, in addition to a 25% to 32% reduction in freight costs for machinery, equipment and input imports (Sudam, 2016; Maurício, Morlin and Callegari, 2022).

Vector analyses of deforestation reveal that, in 2015, economic transactions in the mining chain produced emissions of 0.7 $MtCO_2$, with direct deforestation of 3.5 thousand hectares of primary and secondary vegetation. Emissions and deforestation incorporated into international trade transactions amounted to 0.57 $MtCO_2$ and 3.2 thousand hectares, representing 89% of the total.

The production multiplier effect stands at 2.5. Despite its significant growth, mining provided only a slight increase in job creation in the state of Pará, with formal jobs rising from 1.6% in 2000 to 1.9% in 2020 (MTE, 2020).



Tree canopy during the flood period in the Urubu River, in Silves, state of Amazonas. Photo: Karoline Barros/WRI Brasil.

Box 7 | Illegality in the mining chain

Illegal mining, especially the extraction of gold, precious stones and cassiterite, has escalated significantly in the LAM. Sonter et al. (2017)[12] concluded that, between 2005 and 2015, mining caused 11,670 km² of deforestation, representing 9% of the total forest loss in the Amazon. Manzolli et al. (2021) estimate that, between 2019 and 2020, 174 tons of gold were traded in Brazil, 38% of which with unknown origin, 28% showing signs of irregularities and only 34% appearing to be legally sourced.

According to Mapbiomas (2021a; 2022b), small-scale mining already accounts for 68% of the total area occupied by mining in the Amazon. Between 2010 and 2020, small-scale mining increased by 495% in Indigenous Lands and by 300% in Conservation Units. According to the Federal Public Prosecutor's Office (MPF), mining has progressively ceased to be characterized by small autonomous miners and become an activity funded by medium to large investments. In fact, according to the Foreign Trade Association (FTA), the initial investment for mining activities ranges from $ 12 thousand to $ 400 thousand, indicating the presence of organized crime (MPF, 2020).

Despite the difficulty in dismantling the organizations and tracking financial resources, the location of small-scale mining is detectable by satellite images. The biggest problem, according to the MPF (2020), is that the National Mining Agency (ANM) does not supervise mining permits, and there is no reliable database on gold volumes extracted from a particular deposit, final buyers, or the destination of the gold.

Neves and Folly (2021) also list factors that contribute to the persistence of illegal mining: the lack of a computerized monitoring system, the use of handwritten and carbon-copy sales receipts for these products and physical storage of these receipts by buyers. The lack of electronic control makes it impossible to cross-reference data or control the use of mining permits.

The Brazilian Mining Institute (IBRAM), on the other hand, states that the main damage caused by small-scale and illegal mining is reputational, as it negatively affects the image of players in the sector who comply with legislation, followed by damage to competitiveness, as illegal activities do not bear the environmental, labor, and fiscal costs associated with legal compliance.

In order to curb illegal mining, the State, both at the federal and subnational levels, must invest in on-site inspection and introduce changes that bring more transparency to the mining chain and hold financial institutions (Securities Distributors – DTVM) accountable for purchasing minerals from irregular sources.

1.3 Value chains and pressure on deforestation

Trade with other regions in Brazil and with other countries generates wealth and employment, but it also leads to deforestation and GHG emissions in LAM. In classical economic theory, the indirect effects of development, known as externalities, can be priced and incorporated into the production system through monetary measures, such as fees charged to the agent causing the environmental impact (Pigou, 2017).

However, this charging practice is controversial and economically inefficient. In the face of the current climate crisis, the polluter pays principle is subjected to the precautionary principle, which involves identifying externalities in advance in order to correct them during production and not circulation, merely through a charging of fees (Baumol, 1988; Wibisana, 2006). As well argued by Castelani (2013), deforestation in the Amazon has been treated by economic theory as primarily a supply problem, thereby underestimating the role of demand in the production dynamics. Understanding the demand forces driving deforestation is vital for the transition to the NEA.


View of the port area of Manaus, state of Amazonas. Photo: Bruno Kelly/WRI Brasil.

Box 8 | IIOM-LAM coupling and deforestation and emissions vectors

The value-added and deforestation incorporated into trade flows are based on the hypothetical extraction proposed by Los, Timmer and de Vries (2016) and adapted to the interregional context by Haddad, Gonçalves Junior and Nascimento (2017). This approach measures the domestic amount of value-added and deforestation included in a region's exports by coupling the input-output matrix with deforestation vectors initially assigned to land-intensive sectors (Mapbiomas, 2022b). Emissions are obtained from the large sectors available in the Greenhouse Gas Emission and Removal Estimation System - SEEG (2022). In this technique, V is a vector containing the variable of interest (value-added or deforestation) and v is the calculated coefficient, as the ratio between the variable of interest and the regional and sectoral production value. $\tilde{v}_1$ is defined as the sectoral coefficients for region 1 (v_1) and zero for the others: $\tilde{v}_1=[v_1, 0, ..., 0]$.

To estimate the amount of value-added or deforestation generated by domestic production attributed to exports (to the rest of Brazil and international markets), a hypothetical situation is considered in which region s, in this case region 1, stops exporting to region r while keeping the rest of its economic structure unchanged. That is, the respective blocks A_{rs} and y_{rs}, in the matrices of technical coefficients and final demand, respectively, are defined as zero:

$$A^* = \begin{bmatrix} A_{11} & \cdots & A_{1n-1} & 0 \\ A_{21} & \cdots & A_{2n-1} & A_{2n} \\ \vdots & \ddots & \vdots & \vdots \\ A_{n1} & \cdots & A_{nn-1} & A_{nn} \end{bmatrix}$$

$$Y^* = \begin{bmatrix} y_{11} & \cdots & y_{1n-1} & 0 & e_1 \\ y_{21} & \cdots & y_{2n-1} & y_{2n} & e_2 \\ \vdots & \ddots & \vdots & & \vdots \\ y_{n1} & \cdots & y_{nn-1} & y_{nn} & e_1 \end{bmatrix}$$

The variable of interest (value-added or deforestation) generated by domestic production in region 1, incorporated into trade flows with region r, V_{1r}, is defined by:

$$V_{1r} = v_1 - \tilde{v}_1 . (I - A^*)^{-1} . Y^* . i$$

Where i is a summing vector.

The same strategy can be used to measure domestic production induced by foreign exports in each domestic region. In this case, the hypothetical final demand (Y^{**}) is specified as if there were no demand for exports (e):

$$Y^{**} = \begin{bmatrix} y_{11} & \cdots & y_{1n-1} & y_{1n} & 0 \\ y_{21} & \cdots & y_{2n-1} & y_{2n} & e_2 \\ \vdots & \ddots & \vdots & & \vdots \\ y_{n1} & \cdots & y_{nn-1} & y_{nn} & e_n \end{bmatrix}$$

To calculate $V_{(1r\_e)}$, only a portion of the final demand matrix should be extracted, while preserving the original matrix of intermediate technical coefficients:

$$V_{1r\ e} = V_1 - \tilde{v}_1 . (I - A)^{-1} . Y^{**} . i$$

$V_{1r\ e}$ is the variable of interest (value-added or deforestation) associated with domestic production induced by external exports. For regions that mainly operate in upstream segments of the production chains, such as exporters of natural resources V_{1r_e} tends to represent a significant portion of the regional total.

The deforestation vector v was initially calculated as every area with natural vegetation that, at the pixel level (30m x 30m), remained classified as natural vegetation between 2012 and 2014, but was reclassified to a same class of agricultural or mining use between 2015 and 2017, using the Mapbiomas collection 6 database. All reclassifications of native vegetation to pasture were considered deforestation attributed to the livestock production sector, in the same way that reclassifications to soybean, sugarcane, rice, orange and coffee production were attributed to these respective sectors. The "other temporary crops" and "other permanent crops" classes were attributed to the agriculture sector. Deforestation from mining was proportionally distributed according to production volume (in weight of raw material) for the sectors of ferrous and non-ferrous metallic minerals and non-metallic minerals. To determine the production by weight of raw material, type of mineral and location, a bibliographic and statistical survey was conducted. It applies to the Emissions vector (E).

It is worth noting that, in general, the LAM's transactions, both with the rest of Brazil and international trade, are concentrated around deforestation-intensive products, as observed in the assessed chains.

In absolute terms, of total deforestation in the LAM in 2015, demand for the region's production from the rest of Brazil accounted for 919 thousand hectares (58%), while international demand accounted for 362 thousand hectares (25%) and regional demand for 245 thousand hectares (17%).

Deforestation comprised loss of forest and non-forest, primary and secondary vegetation (Mapbiomas, 2022b).

Despite corresponding to lower absolute deforestation, international demand transactions were the most deforestation intense. For every $ 200 thousand exported by the LAM, 4.90 hectares were deforested in the LAM in 2015, an intensity 45% higher than that observed for LAM's transactions with the rest of Brazil, which totaled 16.85 ha/$ million. The deforestation intensity of trade inside the LAM was estimated at 17 ha/$ million. When considering the VA incorporated into transactions instead of GO, the deforestation intensity of international exports was estimated at 23 ha/$ million, compared to 24.5 ha/ $ million for the rest of Brazil and only 4 ha/$ million for the LAM's internal transactions.

The livestock production chain plays a fundamental role in emissions and deforestation. Because livestock production is responsible for over 93% of deforestation in the LAM, and over 85% of the sector's demand comes from the domestic market, the deforestation intensity and carbon intensity in transactions inside the LAM and between the LAM and the rest of Brazil are much higher than the effects of international demand.

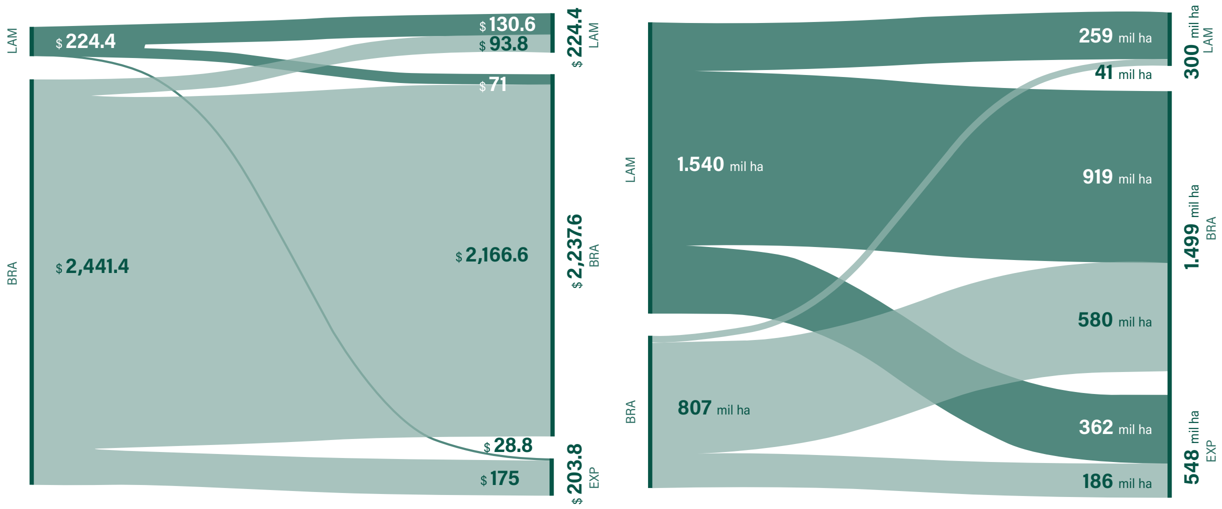
In this context, as a result of sectoral linkages in the value chain, the IIOM-LAM enabled the estimation that for each additional $ 1 million in total demand for the sectors linked to livestock production in the LAM, 290 hectares area deforested for the formation of new pastures. Considering the demand-related effects in the processed beef sector, an additional 40 hectares of deforestation occur as an indirect effect of livestock production and associated inputs.

The impact of the cotton and grains sector, by contrast, is much less pronounced, as it generates deforestation of approximately 10 hectares for every $ 1 million added, in this case with significant participation of the international market. Importantly, the IIOM-LAM in this report uses 2015 as base year, a time when the Soy Moratorium was fully operative and deforestation was at historical lows. At that time, less than 6% of soybean expansion took place in areas deforested after the 2008 cut-off date. Currently, however, with the agreement losing ground – as shown by an 11-fold increase in areas noncompliant with the cut-off date (Abiove, 2022b) – the sectoral impact is presumably much higher (Gibbs et al., 2015). Analysis of data from Mapbiomas suggests that deforestation already accounts for 10% of the net soybean expansion in the Amazon and up to 45% in Cerrado areas in the Matopiba region (Mapbiomas, 2019).

In mining, by contrast, less than 0.5 hectare of deforestation is observed for every additional $ 1 million, although the environmental impact is much more critical in terms of exposure to pollutants and violence in indigenous lands.

Finally, considering the aggregate of the LAM's economy with all 67 sectors and expecting a high concentration of non-tradable goods and services (such as public administration and education and health services), the deforestation intensity of the LAM's trade transactions stands at 15 hectares deforested for every $ 1 million traded, as illustrated in Chart 6.

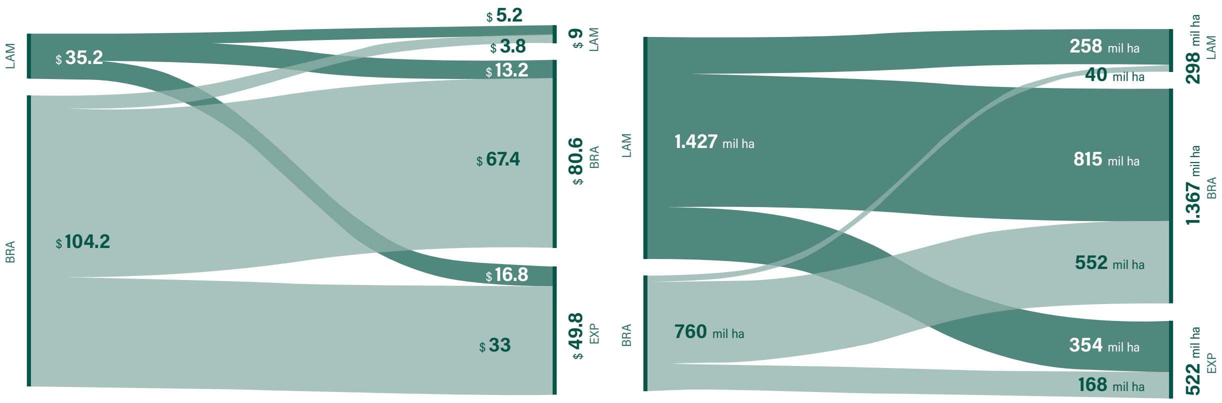
Chart 6 | Trade Value at basic prices by source of the demand ($ billion) and deforestation (in thousand ha)



Source: Authors.

Considering only the large chains analyzed in this section (cotton and grains, livestock production and mining), the intensity rises to 75 hectares for every $ million traded, corroborating the high rate, especially in the commodities chains.

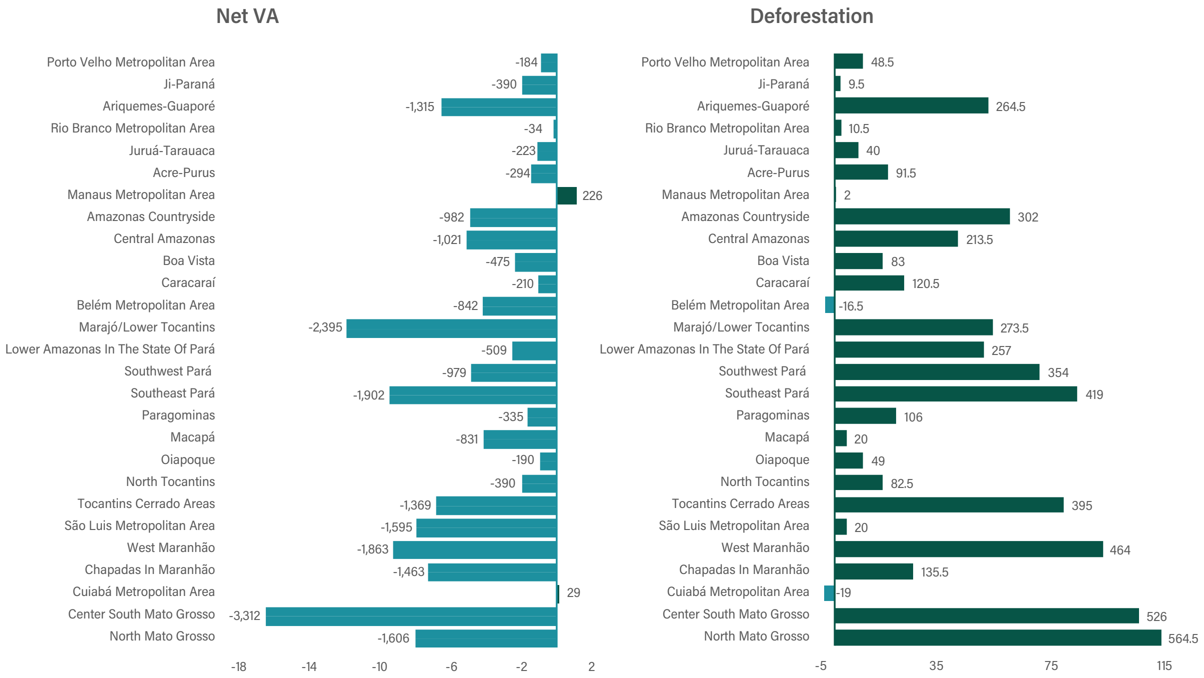
Chart 7 | Trade Value at basic prices by source of the demand ($ billion) and deforestation (in thousand ha) in the cotton and grains, livestock (beef and dairy) and mining chains



Source: Authors.

Although deforestation intensity varies among regions and the composition of trade transactions also differs among them, the phenomenon that combines a deficit VA in transactions and a surplus in deforestation incorporated into trade is widespread in the LAM and present in virtually all regions, except for the urban agglomerations of Manaus and Cuiabá. Chart 8 illustrates the case.

Chart 8 | Net VA ($ million) and deforestation (in ha per $ million) incorporated into trade between the Legal Amazon and the rest of Brazil



Source: Authors.

It is evident that urban agglomerations present dynamics that are typical of economies strongly based on the tertiary sector, thus relatively less intensive in deforestation. Additionally, the IIOM-LAM results show that the largest internal trade flows in the LAM occur precisely between these urban agglomerations and their surrounding regions.

The Manaus agglomeration and the neighboring central Amazonas region respond for the largest trade flow in the LAM, totaling $ 1.3 billion in 2015 and $ 440 million in VA incorporated into trade transactions. Belém and the contiguous region of Marajó-Baixo Tocantins follow, with approximately $ 782 million transacted in 2015 and $ 523 million in VA incorporated into bilateral trade transactions. Finally, the third largest volume of internal flows in the Legal Amazon, between the Cuiabá agglomeration and the central-southern portion of Mato Grosso, stands at $ 781 million, with $ 403 million in VA incorporated in 2015.

As will be seen in more detail in Chapter 3, cities, especially large urban centers, play a vital role in the development of the bioeconomy. As consumers of regional products, they are also major drivers of small-scale shipbuilding industries, technical and creative innovations in machinery used in local manufacturing, as well as home to thousands of points of sale for biodiversity-based products. Large cities are the main promoters of the proximity and circular economy, presumably more robust with its own surroundings.

However, despite the strong connection between urban agglomerations and their neighboring areas, the IIOM-LAM identified a less common phenomenon in the economy, albeit not surprising for the LAM. Except for Manaus, the urban agglomerations' production structure is not very integrated with the rest of the LAM and even with the rest of the country, with less intense interregional and national trade flows than other regions in the Amazon, such as northern Mato Grosso and southeastern Pará.

By using the hypothetical extraction method, it was possible to estimate that although the six urban agglomerations account for 28% of the population, 31% of the jobs and 37% of GDP in the LAM, their impacts on many sectors do not exceed 10%, especially in deforestation-intensive sectors.

Box 9 | Identification of sectors, chains, or regions by hypothetical extraction

The hypothetical extraction method involves excluding the trade flows of a particular region or sector in the input-output structure (Dietzenbacher, Linden and Steenge, 1993).

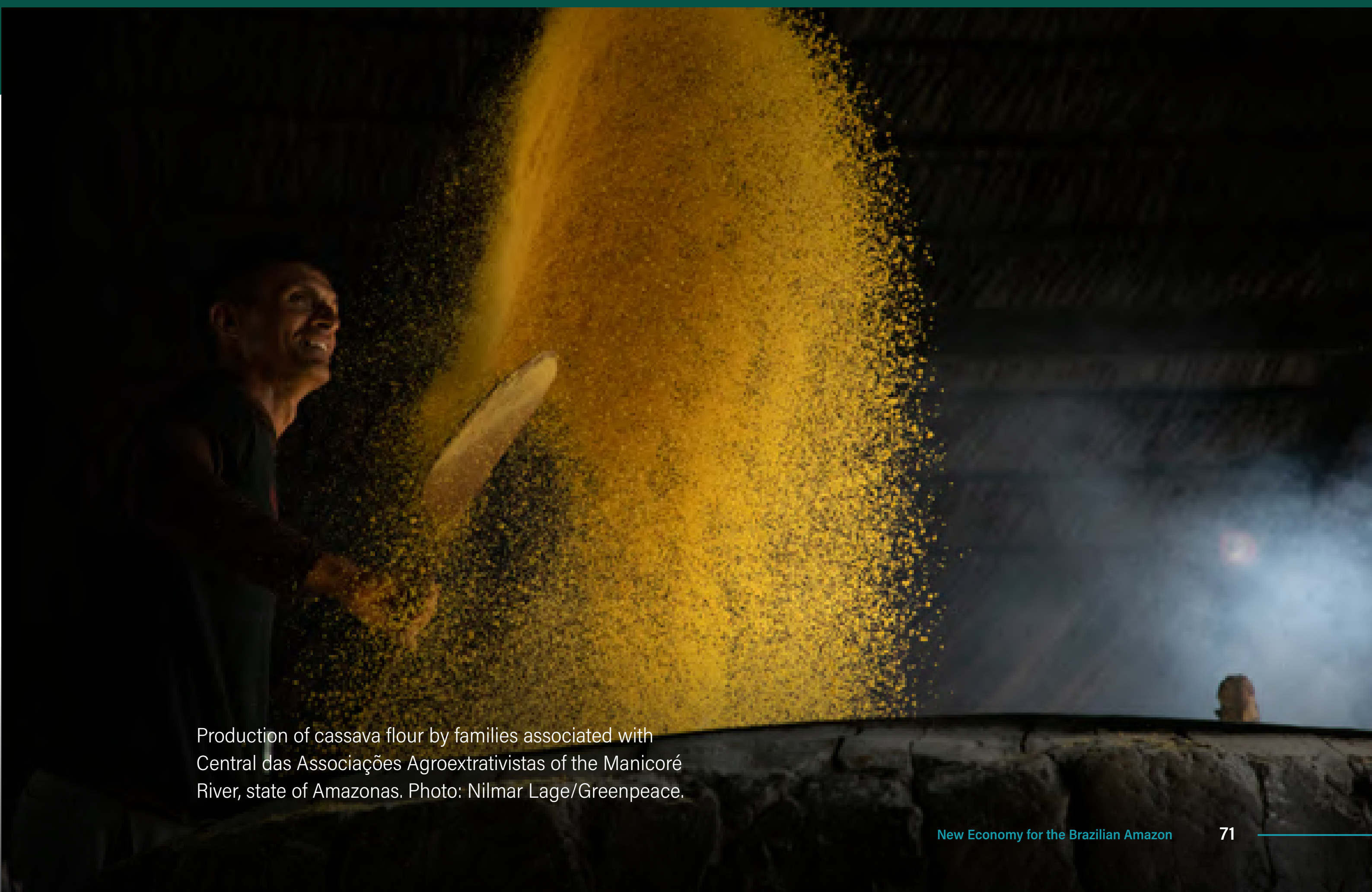
The purpose of this method is to quantify how much the total production of a given economy with n sectors (or m regions) could change if a sector or region, say the j-th sector, were removed from such economy. The extraction shows both the direct and indirect losses associated with the extraction of the sector or region and is modeled in an input-output matrix by replacing the trade flows with "zero" in both the row and column of matrix *A* of the respective sector or region that will be extracted from the model, which results in matrix $\bar{A}_{(j)}$. The same procedure is performed for the final demand vector, generating a new vector $\bar{f}_{(j)}$ for the reduced final demand (that is, without sector *j*). Production in the reduced economy (that is, without sector *j*) will be given by $\bar{x}_{(j)} = (I - \bar{A}_{(j)})^{-1} \bar{f}_{(j)}$.

In the complete model, with the production and consumption of all n sectors, the total demand of the economy is given by: $x = (I - A)^{-1} f$.

Therefore, after the extraction is performed, the impact on the economy is measured by $T_j = i'x - i'\bar{x}_{(j)}$, where *i* is a summation vector and T_j is the aggregate measure of loss in the economy – the decrease in total production if sector *j* "disappears". In other words, it is a measure of the relative importance of sector *j* or the total leakages of that sector.

The impact analysis measures the production loss in which the first term on the right side of the equation, $T_j - i'x$, is not included in the original production of x_j. If x_j is omitted, then $(i'x - x_j) - i'\bar{x}$ would be a measure of the importance of sector j for the other sectors of the economy. In both cases, normalization by dividing the results by total production, $i'x$, and multiplying by 100 produces the following estimate of the percentage decrease in total economic activity: $\bar{T}_j = 100[i'x - i'x_{(j)}]/(i'x)$.

For further details, see Miller and Blair (2009).



Production of cassava flour by families associated with Central das Associações Agroextrativistas of the Manicoré River, state of Amazonas. Photo: Nilmar Lage/Greenpeace.

Table 2 | Impacts of urban agglomerations on the LAM's economy

Sector	Description	Impacts on the agglomerations				Impacts on the rest of LAM			
		Value added (BRL million 2020	Indirect taxes (BRL million 2020)	Jobs (thousand)	Deforesta-tion (ha)	Value added (BRL million 2020	Indirect taxes (BRL million 2020)	Jobs (thousand)	Deforesta-tion (ha)
1.	Agriculture	311	-6	15	310	719	17	21	1,423
2.	Livestock Production	880	40	52	42,182	458	44	36	35,401
3.	Forestry and Fishing	509	10	16	0	198	4	10	1
4.	Coal Extraction	189	18	2	0	77	6	1	0
5.	Oil Extraction	266	26	0	0	521	50	1	0
6.	Iron Ore Extraction	12	1	0	0	52	3	0	3
7.	Metallic Minerals Extraction	42	8	0	17	135	22	0	64
8.	Meat Production	891	187	13	0	55	12	1	0
9.	Sugar Refining	0	0	0	0	1	0	0	0
10.	Other Food Items	1,407	213	50	0	73	12	2	0
11.	Beverages	4,648	643	20	0	19	3	0	0
12.	Tobacco Manufacturing	0	0	0	0	0	0	0	0
13.	Textiles	30	6	3	0	5	1	0	0
14.	Clothing Industry	154	24	19	0	1	0	0	0
15.	Leather and Footwear	155	19	1	0	4	1	0	0
16.	Wood Products	328	41	17	0	132	17	6	0
17.	Paper and Pulp	265	39	4	0	5	1	0	0
18.	Prints and reproduction	557	53	8	0	6	1	0	0
19.	Oil Refining	1,864	1,872	1	0	0	0	0	0
20.	Biofuels	22	3	0	0	44	6	0	0
21.	Chemicals	563	131	2	0	33	9	0	0
22.	Defensive Chemicals	93	22	1	0	3	1	0	0
23.	Cleaning Products	164	37	4	0	1	0	0	0
24.	Pharmaceuticals	183	16	1	0	0	0	0	0
25.	Rubber and Plastic	1,253	239	17	0	18	3	0	0
26.	Non-metallic Minerals	733	90	19	0	203	25	5	0
27.	Steel Industry	291	40	2	0	81	12	0	0
28.	Non-ferrous Metals	1,251	182	3	0	134	26	1	0
29.	Metal Products	1,996	231	19	0	56	6	1	0
30.	Computer and Electronic Equipment	5,469	2,011	38	0	6	2	0	0
31.	Electrical Machinery and Equipment	736	148	12	0	0	0	0	0
32.	Mechanical Machinery and Equipment	1,590	245	8	0	3	0	0	0
33.	Automobiles	7	3	0	0	0	0	0	0
34.	Auto Parts	154	28	4	0	0	0	0	0
35.	Transport Equipment	3,478	683	24	0	39	8	0	0
36.	Furniture	1,762	162	27	0	7	1	0	0
37.	Maintenance Equipment	436	51	20	0	25	3	1	0
38.	Energy and Gast	5,095	769	10	0	220	22	0	0
39.	Water and Sewage	1,587	134	19	0	33	2	0	0
40.	Construction	18,765	2,725	630	0	207	30	6	0
41.	Trade	26,598	1,520	678	0	1,144	68	28	0
42.	Land Transport	7,147	863	198	0	227	33	4	0
43.	Water Transport	1,856	316	13	0	23	4	0	0
44.	Air Transport	317	315	3	0	2	2	0	0
45.	Mail and Storage	2,335	209	36	0	64	5	1	0
46.	Housing	655	45	15	0	13	1	0	0
47.	Food Industry	5,512	502	304	0	8	1	0	0
48.	Print and Edition	229	47	6	0	2	0	0	0
49.	TV Radio and Film	959	150	10	0	30	5	0	0
50.	Telecom	1,386	224	6	0	19	3	0	0
51.	Systems Development	1,549	123	17	0	8	1	0	0
52.	Finance, Insurance and Pension	5,542	364	27	0	177	11	1	0
53.	Real Estate Agencies	28,891	380	15	0	53	1	0	0
54.	Legal and Accounting	2,749	155	46	0	270	15	4	0
55.	Architecture, Engineering and P&D	1,485	75	26	0	32	2	0	0
56.	Other professional, scientific and technical activities	735	81	14	0	34	4	1	0
57.	Non-Real Estate Rent	1,081	58	15	0	43	2	1	0
58.	Other Administrative Activities	5,201	322	193	0	16	1	1	0
59.	Security	1,547	68	52	0	28	1	1	0
60.	Public Administration	23,798	422	230	0	114	2	1	0
61.	Public Education	8,633	71	128	0	23	0	0	0
62.	Private Education	2,855	194	110	0	7	0	0	0
63.	Public Health Services	2,103	47	39	0	0	0	0	0
64.	Private Health Services	4,280	394	115	0	2	0	0	0
65.	Arts and Entertainment	536	35	39	0	4	0	0	0
66.	Membership Orgs. and other Personal Services	2,506	278	171	0	18	2	1	0
67.	Domestic Services	2,561	0	306	0	0	0	0	0

Source: Authors.

These results shed light on urban agglomerations' limited capacity to stimulate the economy of the rest of the LAM in conventional sectors, either because they concentrate the technology and value-added sectors without spreading their benefits to the region or because they have little demand for products from the rest of the LAM, which are mainly concentrated in a few low value-added commodities. Table 2 shows the estimated impacts of the 6 clusters on the LAM economy, divided between impacts on the economy of the clusters themselves (100%) and the rest of the LAM regions (<10% on average).

Urban agglomerations also experience their own challenges as hubs lacking in non-tradable basic goods and services that need to be urgently addressed in the transition to the NEA. The Amazon's large cities have the lowest human development index (average HDI of 0.61) and per capita income ($ 4.6 thousand) in Brazil (Firjan, 2020). The Social Vulnerability Indexes of the LAM's metropolitan regions range from low, in Cuiabá, to high, in Manaus, with a municipal Social Progress Index that is 14% lower than the national value (Santos et al., 2021). In 2020, 10.8 million people in the LAM were below the poverty line (Neri, 2022), of whom 2.2 million resided in the regional capitals. Amazonian cities are among the most violent in the country, accounting for 21% of the 45 thousand homicides registered in Brazil in 2019, and youth death rates exceeding four times the national average (90 per 100 thousand inhabitants in Belém and 80 in Manaus) (Ipea, 2019a).

The population faces poor sanitary conditions on a daily basis. Less than 15% of residents have access to sewage collection services and less than 10% have access to treated sewage, which implies the discharge of pollutants amounting to 19 billion liters of sewage per year, often polluting the population's water and food sources, as well as causing health damages of around $ 20 million per year. In the largest river basin in the world, 10.4 million people suffer from lack of access to treated water (Instituto Trata Brasil, 2022).

The investments in sanitation required for the universalization of water and sewage services in the LAM stand at around $ 6.6 billion, to be applied over the next 20 years (Instituto Trata Brasil, 2022) or $ 343 million per year, which is equivalent to less than 0.3% of the region's GDP. Actual investments in sanitation, however, have been 25 times smaller. An extreme case is Porto Velho, which invested less than 0.1% of its GDP in sanitation, or less than $ 1 per inhabitant in 2020, with average investment over the past two decades around 52 times below the required levels.

Large urban centers in the region, such as Manaus (photo), play a crucial role in the development of the bioeconomy. Photo: Bruno Kelly/WRI Brasil.

Table 3 | Main indicators estimated by the IIOM-LAM for the urban agglomerations and other regions in the Legal Amazon

Region	Description	2015 GDP (BRL million)	VA Net Balance incorporated into trade (BRL million)	Production Multiplier	Carbon Stock (Pg)	Net balance of trade-associated deforestation ha/BRL million)	Jobs (thousand people)	Black and Indigenous (% jobs)
R01	Porto Velho Metropolitan Area	14.370	-714	1.58	2.39	9.68	302	75.4
R02	Ji-Paraná	5.933	-1.498	1.66	0.26	1.92	141	67.3
R03	Ariquemes-Guaporé	16.261	-5.065	1.65	0.68	52.91	429	66.6
R04	Rio Branco Metropolitan Area	8.258	-135	1.46	1.21	2.07	188	78.8
R05	Juruá-Tarauaca	2.458	-858	1.39	1.63	8.04	63	82.6
R06	Acre-Purus	2.907	-1.131	1.46	0.14	18.27	103	85.0
R07	Manaus Metropolitan Area	67.346	871	1.72	5.77	0.40	1.171	79.1
R08	Amazonas Countryside	6.375	-3.782	1.43	22.28	60.41	193	91.0
R09	Central Amazonas	12.847	-3.929	1.45	0.20	42.66	377	91.7
R10	Boa Vista	8.726	-1.834	1.4	1.35	16.59	204	84.9
R11	Caracaraí	1.517	-815	1.39	2.18	24.05	35	86.8
R12	Belém Metropolitan Area	38.233	-3.243	1.56	2.09	-3.31	981	80.1
R13	Marajó/Lower Tocantins	29.945	-9.219	1.6	0.61	54.74	979	88.6
R14	Lower Amazonas In The State Of Pará	10.180	-1.962	1.54	3.19	51.40	345	88.5
R15	Southwest Pará	9.073	-3.767	1.53	5.88	70.83	349	81.5
R16	Southeast Pará	38.164	-7.318	1.64	7.51	83.83	991	82.2
R17	Paragominas	5.305	-1.293	1.51	0.01	21.20	200	84.0
R18	Macapá	12.186	-3.199	1.37	1.85	3.96	279	80.8
R19	Oiapoque	1.675	-729	1.33	0.54	9.81	38	88.0
R20	North Tocantins	7.799	-1.502	1.68	1.54	16.46	200	80.0
R21	Tocantins Cerrado Areas	21.131	-5.268	1.59	0.30	79.04	515	80.5
R22	São Luis Metropolitan Area	29.405	-6.144	1.61	1.39	-4.02	824	77.7
R23	West Maranhão	25.554	-7.709	1.56	0.98	92.82	1.161	85.3
R24	Chapadas In Maranhão	14.062	-5.626	1.53	0.01	27.20	781	82.7
R25	Cuiabá Metropolitan Area	27.495	109	1.71	3.92	-3.77	425	73.2
R26	Center South Mato Grosso	56.752	-12.751	1.94	6.30	105.16	900	67.4
R27	North Mato Grosso	23.171	-6.185	1.82	0.03	112.93	384	60.8

Source: Authors.

Despite their numerous typically urban problems yet to be tackled and their limited potential due to such imminent needs, urban agglomerations have an important role to play in a new economy, as they are centers of excellence in scientific and traditional knowledge that is exclusive to the Amazon and will be the subject of detailed analysis in later chapters of this report. The LAM's cities are vitally important as major hubs of production, consumption and innovation based on local products, still highly informal.

Nature-based solutions such as natural infrastructure – conservation, management, and restoration of ecosystems – could mitigate floods and thermal discomfort to which the poorer populations are more exposed, in addition to promoting a proximity economy with belts of biodiversity products deeply rooted in Amazonian cultures. Urban agglomerations can also play a pivotal role in transactions involving conventional products.

Despite their very little capacity to boost the LAM's economy in its entirety, urban agglomerations undoubtly stimulate their contiguous areas. The IIOM-LAM results show, for example, that 29% of GO transacted between Cuiabá and its surrounding region close to the center-south portion of Mato Grosso corresponds to the meat and dairy chain (agriculture and livestock production, semi-manufactured and manufactured livestock products). The same pattern is observed between the Porto Velho agglomeration and its contiguous Ariquemes-Guaporé area, where the same chain represents 16% of transactions.

This opens up a new perspective for understanding the essential role of state public policies in promoting sanitary, fiscal and environmental traceability in order to ensure safe, quality and legal products for the local population. These guarantees go beyond interstate inspection barriers and even extend to international trade.

1.4 Conclusions

The transition to the NEA requires that conventional parameters of sectoral and regional performance be assessed with the use of indicators that capture carbon intensity, deforestation and inclusion in value construction and creation of opportunities. Tools like the IIOM-LAM, with the proposed segmentation, offer a technically robust alternative that is sensitive to the LAM's heterogeneity and, when coupled with vectors that indicate deforestation and emissions, can measure the carbon intensity and deforestation intensity of economic transactions.

The results show different carbon intensity and deforestation intensity for the main chains in the LAM. They also show that demand for LAM products either comes from the rest of Brazil, as is the case of livestock production, or from foreign trade, as seen in the grains-cotton complex and mining sectors. This suggests that efforts involving fiscal, health and environmental traceability in the chains, as well as the promotion of decarbonization, require specific measures to become effective.

The adoption of segmentation for forest extraction products, as proposed in the IIOM-LAM, is indispensable in the planning for the transition, as it allows the identification and measurement of competing activities, such as destructive and non-destructive extraction. This is essential to boost the standing forest economy to the detriment of the deforestation economy.

Despite the progress achieved by segmentation, it is insufficient to capture the entire bioeconomy developed in the LAM. Combining classical analyses such as the IIOM with equally robust alternatives such as the IOM-Alpha is a better way to grasp the complexity of the LAM's economy and design the economic transition. The role of urban agglomerations illustrates this point. While the IIOM reveals that urban agglomerations have little capacity to stimulate the other LAM regions – one of the most important findings of this chapter –, they are the major drivers of the bioeconomy, as will be further discussed in Chapter 3.

Child swimming alongside an Amazon river dolphin in the Negro River, state of Amazonas. Photo: Raimundo Pacco.

CHAPTER **2**

The Amazon Economy in 2050: Window to **THE FUTURE**

Inclusive wealth, and conservation and expansion of environmental assets are key to the NEA. The region's development depends on the protection of native and traditional peoples' rights, biodiversity conservation, preservation of large forest areas, recovery of degraded areas, provision of basic sanitation services and essential ecosystem services. Supporting an economy that turns the control of emissions into its comparative advantage will depend on its ability to compete with the current economic model in its key aspects, which have mistakenly justified deforestation so far: GDP growth and job creation.

Four scenarios, which incorporate a range of emissions and deforestation restrictions, coupled with the utilization of state-of-the-art production technologies, were meticulously constructed, and analyzed. These scenarios were designed to gauge the resilience of the LAM economy when subjected to greenhouse gas emission constraints and to identify pathways for transitioning toward the New Economy for the Brazilian Amazon (NEA). We conducted a comprehensive assessment of their impact on GDP and employment, in addition to scrutinizing the consequential systemic macroeconomic dynamics, as well as the intricate interplay of energy, financial resources, land usage, and emissions.

The scenarios were designed to produce economic, employment, deforestation, and expected emissions indicators over 30 years and for the specific year of 2050, with 2020 as base year. The combination of restrictions on emissions and deforestation allowed the elaboration of four scenarios:

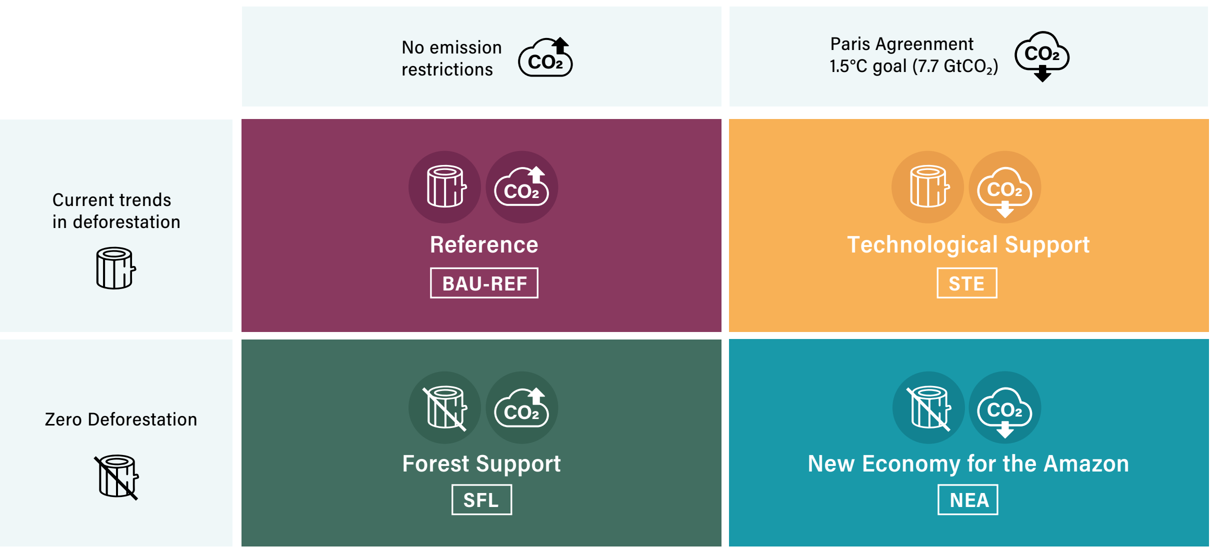
1. Business as Usual Scenario or Reference Scenario (BAU-REF) – emissions resulting from economic activity in BAU are not restricted, and deforestation is not controlled, which allows free allocation of land for agricultural activities, as directly requested by the primary sector or indirectly by other sectors. The energy mix and the technologies used in economic production follow current trends (past 10 years).

2. Technological Support Scenario (STE) – net emissions resulting from economic activity cannot end the year 2050 with a balance greater than 7.7 $GtCO_2$, in line with the need to curb global warming to 1.5°C, as per the IPCC scenario SSP1-1.9. Deforestation is not controlled, allowing free allocation of land as in the BAU scenario. The energy mix and the technologies used in economic production show marginal gains in efficiency. Variations in the use of energy inputs are incorporated in line with the assumptions of a new infrastructure that incorporates new opportunities for generation and use of energy in the region.

3. Forest Support Scenario (SFL) – opposite to the previous scenario, emissions resulting from economic activity are not initially restricted, but zero deforestation is imposed, inducing the land allocation exclusively on already deforested areas. The energy mix and the technologies used in economic production follow current trends as in the BAU scenario but may require a mix of different technologies in response to the restriction imposed by zero deforestation.

4. New Economy for the Amazon Scenario (NEA) – combines the 2 restrictions, with the targets of net emissions of 7.7 $GtCO_2$ in 2050 (IPCC scenario SSP1-1.9) while zero deforestation is imposed. The energy mix and the technologies used in economic production show marginal efficiency gains and prioritize the expansion of the bioeconomy. Variations in the use of energy inputs are incorporated in line with the assumptions of a new infrastructure that incorporates new opportunities for generation and use of energy in the region. There is an expansion of non-destructive plant extraction sectors and agroforestry systems, according to the results of the IOM-Alpha described in detail in Chapter 3, for the production of acai fruit and palm hearts, babassu coconut and oil, cocoa, Brazil nuts, cupuacu, rubber, urucum, buriti, copaiba, andiroba, pupunha palm and honey. See appendix for details.

Figure 3 | Projected scenarios



Source: Authors.

Box 10 | Inclusion of the "Land Factor" in the Models Used

"Land" is one of the primary factors of the RÉGIA-NEA model, but unlike capital and labor, it does not have inter-regional mobility. Land is divided into four classes and allocated to the following economic sectors: agriculture (14 classes), pasture (5 classes), planted forest (2 classes) and native vegetation (2 classes). Land conversion is guided by two replacement levels . First, each class is allocated to the different sectors according to the use specifically attributed by the satellite classification (example: soy) or by remuneration differential between other uses not defined by the former. Demand for land responds to changes in remuneration for each sector. It is assumed that the change in demand for land is equal to the change in supply of land. At the second level, the supply of land is given according to different uses, reflecting the dynamic adjustment in the land market. This structure will allow the land factor to move between the different categories and between year *t* and year *t + 1*, controlled through a matrix for land mobility between uses.

In REGIA-NEA, the transition matrix was built based on the methodology developed by Ferreira Filho and Horridge (Ferreira Filho and Mark, 2014). The supply of land in each category for each region increases according to the annual percentage growth rate of each use given by the transition matrix:

$$N_{k,t+1}=100 * \Delta N_{k,(t+1,t)}/N_{k,t}$$

In addition to this annual growth rate, to adjust the transition matrix for the next period, the current stock of land in *t* is distributed for the next year *t + 1*, responding to changes in land remuneration. The transition matrices are expressed in the form of probabilities that a given land use will be converted into another in the following year, modeled as a function of the profitability variation for each use:

$$S_{pkr}=\mu_{pr} \cdot L_{pkr} \cdot P_{kr}^{ßind} \cdot M_{kr}$$

Or alternatively:

$$S_{pkr}= L_{pkr} \cdot P_{kr}^{ßind} \cdot M_{kr} / \sum_k . L_{pkr} \cdot P_{kr}^{ßind} \cdot M_{kr}$$

where the subscript *r* denotes region
S_{pkr} is the participation of land type *p* that transforms into *k* in region *r*.

μ_{pr} is an adjustment variable to ensure that $\sum_k S_{pkr} = 1$.

L_{pkr} is a calibration constant that represents the initial value of S_{pkr} (given by the transition matrix).

$P_{kr}^{ßind}$ is the average unit remuneration of land type *k*.

ßind is a sensitivity parameter that measures the response of land supply to changes in remuneration.

M_{kr} is a shift variable with an initial value of *1*.

Removing the subscript r, we have:

$$S_{pk}=\mu_p \cdot L_{pk} \cdot P_k^{ßind} \cdot M_k$$

In which S_{pk} is the participation of land type p that transforms into *k*. Assuming that $N_{k,t}$ is the area of land type *k* in year *t*. Then, the area of land type *k* in year *t +1* will be:

$$N_{k,t+1}= \sum_k . S_{pk} N_{kt}$$

To model the conversion rate of natural forests, it was necessary to consider a fictitious remuneration, in this case, the End User Price Index. The transition matrix is thus adjusted annually, as is the supply of land.

Box 11 | Brazil's carbon budget: limits to emissions by 2050

The carbon budget represents the amount of CO_2 the world can still emit if it wants to stay below a given temperature. The carbon budget calculation is complex and uses a series of models that relate GHG emissions to the increase in Earth's temperature. Because of this high level of complexity, the IPCC adopts values for the carbon budget and associates them with different levels of uncertainty. Among the most common values are those that correspond to a 50% to 66% probability that the world will remain below 1.5°C, resulting in carbon budgets for the years 2020 to 2100 that are equal to 500 billion and 400 billion tons of carbon ($GtCO_2$), respectively.

Several global integrated assessment models develop long-term scenarios that use the carbon budget as their main constraint, which means that their results must necessarily correspond to emissions below the carbon budget. These models describe what the world needs to do in order to stay within such budget, or a 1.5°C temperature increase. Based on the results of these global models, it is possible to estimate Brazil's participation in the global carbon budget, which corresponds to the national carbon budget. In the BLUES model, we used the value produced by the COFFEE model for Brazil in the period 2010-2065, corresponding to -1.3 $GtCO_2$, as the national carbon budget. In this scenario, net accumulated emissions in Brazil are expected to add up to 7.7 $GtCO_2$ by 2050 and 1.4 $GtCO_2$ in LAM, which is the value considered in the scenarios.

For more information on carbon budget, see Rogelj (2021).

The scenarios' estimates were produced in four steps, expressed clockwise in the Figure 4. The first step involved the estimation of commercial and financial flows and long-term global trends in energy intensity, land use, economic growth, factor allocation and emissions, ensuring consistency with climate targets and global economic trends. Brazil's expected share in such flows and stocks until 2050 was also estimated. The models used were the TEA General Equilibrium model (Cunha, 2019, Cunha, Garaffa and Gurgel, 2020 and the COFFEE Dynamic Optimization model (Rochedo, 2016, IAMC, 2023).

Then, the results for Brazil were further detailed, disaggregated into regions and regrouped for the LAM, using the OD BLUES model (Rochedo et al., 2018; Koberle, 2018). In the third block, the following ecosystem services: carbon storage, water availability (surface runoff) and retention of sediments and nutrients in the soil, were estimated through the use of the InVest model (Natural Capital Project, 2021), and the bioeconomy's potential production was estimated in accordance with the Input-Output of Alpha accounts method (IOM-Alpha).

This information was used as input data for the GEM Regional REGIA-NEA model in the last block, along with the other macroeconomic and regional parameters, such as technical coefficients and sectoral multipliers obtained in the IIOM-LAM. The coupling of the models, with interactions and iterations, is illustrated in Figure 4.

Fundamental constraints such as gains in productivity of capital and labor factors, expected dynamics of external markets, population growth and growth in the labor supply were considered constant and identical in all scenarios. Specific constraints and attributes varied according to the scenarios, such as:

1. Areas occupied by agriculture, pastures and forests (BLUES-REGIA NEA);

2. Additional expansion of bioeconomy products (Input-Product of Alpha Accounts);

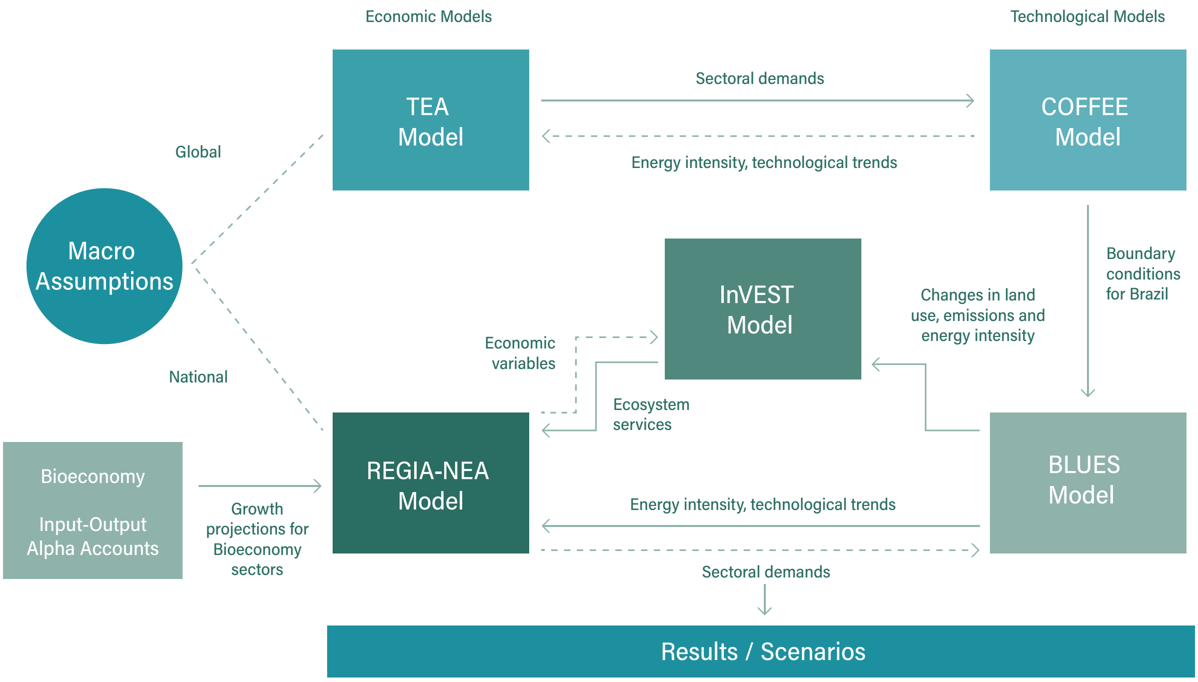
3. Land productivity gains (InVEST);

4. Productivity gains in fertilizers (InVEST);

5. Variations in the use of energy inputs by sectors in the LAM and in Brazil (TEA-COFFEE-BLUES).

The applied models combine 67 economic sectors, 51 land use classes – with special attention to temporary crops and pasture degradation gradients –, 30 energy technologies and a series of conventional macroeconomic and regional variables.

Figure 4 | Steps and interactions of the models used to estimate the scenarios



Source: Authors.

The models have limitations, which include the underestimation of the positive effects of technological progress and human capital, presumably divergent among the proposed scenarios, the undervaluation of the process of degradation and depletion of natural resources (trade-offs between consumption and preservation of environmental assets, except for carbon, runoff of water and nutrients - nitrogen and phosphorus), the inability to forecast efficiency gains and creation of technological jobs with higher value-added, or technical coefficients arising from new sectors that come to replace conventional sectors (see Appendix for more details). In the case of the bioeconomy, the only products considered were those that are already commercialized.

Despite the models' limitations, their results provide new elements to guide sectoral and regional public policies that combine economic expectations and climate mitigation. Given the iterations between the different sectors in the different scenarios, only the results of the large aggregates are presented in this chapter, as they allow a global assessment of the scenarios' performances in terms of their main economic, social and environmental indicators, while the main sectors are discussed in more detail in dedicated chapters.

The sequencing and coupling of the models produced a number of intermediate results, which serve as input data for the calculation of final results. Some of the intermediate information are relevant for understanding the scenarios' performance.

The main intermediate information is that the STE scenario failed to produce a viable solution; no mathematical convergence was found, which points to the impossibility of reconciling restrictions on emissions with no restrictions on deforestation.

This result shows that no combination of technological and energy packages from other sectors of the economy would be able to neutralize the emissions arising from deforestation linked to agricultural expansion through the unconstrained incorporation of new areas.

Even considering promising technologies yet to be implemented – for which technical coefficients and economic efficiency have already been estimated and used in the models –, Brazil would not be able to meet its climate targets or contribute to curbing global warming to 1.5°C if deforestation persists at the current magnitude.

For the viable scenarios, the main parameters resulting from the intermediate steps and which served as input data are indicated in Tables 4 to 8.

Table 4 | LAM productive structure at the level of the major sectors (% relative share in GDP) in base year 2020, and projected for 2050 according to the BAU, SFL and NEA scenarios

		Sectors - large aggregates								
Estate	Scenario	Agriculture	Livestock Production	Bioeconomy*	Extraction Industry	Food Industry	Manufacturing Industry	Electricity, Cooking Gas and Sewage	Public Administration and services	Other services
AC	2020	2.1	4.1	0.4	0.0	5.4	1.8	7.4	13.0	65.7
	BAU	1.9	4.2	0.4	0.0	5.9	2.1	7.1	12.5	65.9
	SFL	2.4	4.3	0.4	0.0	5.8	2.1	7.0	12.4	65.7
	NEA	2.2	4.8	0.3	0.0	5.8	2.0	7.1	12.4	65.4
AM	2020	1.0	1.6	1.3	2.5	3.4	31.2	3.5	7.1	48.3
	BAU	1.1	1.4	1.4	2.4	3.4	31.5	3.3	6.8	48.7
	SFL	1.1	1.4	1.4	2.4	3.4	31.5	3.3	6.8	48.7
	NEA	1.0	1.3	1.4	2.4	3.4	31.1	3.6	6.8	49.0
AP	2020	0.8	4.7	1.1	2.8	1.0	1.4	11.8	7.8	68.8
	BAU	0.8	4.5	1.1	2.9	1.0	1.5	11.3	7.6	0.0
	SFL	0.8	4.4	1.1	2.9	1.0	1.5	11.3	7.6	69.3
	NEA	0.8	4.2	1.3	2.9	1.0	1.5	11.5	7.6	69.2
MA	2020	3.7	3.3	0.6	0.2	3.8	8.3	4.4	8.5	67.2
	BAU	4.4	3.5	0.6	0.2	3.7	8.8	4.2	8.1	66.5
	SFL	4.0	3.3	0.6	0.2	3.7	8.8	4.3	8.2	66.8
	NEA	4.1	3.3	0.6	0.2	3.7	8.6	4.5	8.2	66.8
MT	2020	23.8	5.2	0.4	0.4	18.5	5.3	2.5	5.5	38.5
	BAU	24.2	5.2	0.3	0.4	18.5	5.5	2.3	5.2	38.3
	SFL	24.3	5.2	0.3	0.4	18.5	5.5	2.3	5.2	38.3
	NEA	25.1	5.3	0.3	0.4	17.9	5.3	2.5	5.2	38.0
PA	2020	2.0	3.6	2.7	9.4	8.7	7.2	3.4	8.7	54.4
	BAU	2.1	3.8	2.8	8.8	9.1	7.5	3.3	8.3	54.3
	SFL	2.2	3.6	2.8	8.8	9.1	7.5	3.3	8.3	54.3
	NEA	2.0	3.1	4.9	8.6	8.7	7.2	3.4	8.2	53.8
RO	2020	2.5	6.8	0.3	0.4	20.1	3.6	8.1	7.2	51.0
	BAU	2.4	7.2	0.2	0.4	21.2	3.8	7.5	6.8	50.5
	SFL	2.6	6.9	0.2	0.4	21.1	3.8	7.5	6.9	50.6
	NEA	2.4	9.3	0.3	0.3	19.8	3.4	7.7	6.8	50.0
RR	2020	2.4	4.9	0.6	0.0	1.8	1.6	13.9	10.6	64.1
	BAU	2.5	5.1	0.6	0.0	2.0	1.8	13.3	10.3	64.4
	SFL	2.6	5.0	0.6	0.0	2.0	1.8	13.3	10.3	64.4
	NEA	2.5	4.8	0.6	0.0	2.0	1.8	13.5	10.3	64.5
TO	2020	8.8	5.5	0.2	0.7	11.4	4.0	4.1	9.3	56.0
	BAU	9.0	6.3	0.1	0.7	11.8	4.5	3.8	8.8	55.0
	SFL	9.2	5.8	0.1	0.7	11.8	4.6	3.8	8.9	55.2
	NEA	8.8	6.3	0.1	0.7	11.5	4.4	4.0	8.9	55.3

* Bioeconomy only in the primary sector. Considering food industry, manufacturing industry and other services, the bioeconomy's share ranges from 1.1% to 7.9% of the GDP.
Source: Authors.

Table 5 | Estimated five-year variations (%) in land productivity and fertilizer use in relation to base year 2020, under the BAU, SFL and NEA scenarios

Brazilian State	BAU		SFL		NEA	
	Land	Fertilizer use	Land	Fertilizer use	Land	Fertilizer use
Acre (AC)	-3.78	-14.66	-4.29	-0.91	0.14	0.08
Amapá (AP)	-1.24	-1.62	-1.33	-0.33	4.21	1.59
Amazonas (AM)	-4.06	-2.58	-1.79	-0.40	0.42	0.24
Maranhão (MA)	-2.22	-1.82	-3.05	-0.55	0.67	0.08
Mato Grosso (MT)	-5.33	-4.63	-2.54	-0.73	0.43	0.08
Pará (PA)	0.66	7.44	-1.06	-0.39	1.47	0.73
Rondônia (RO)	-3.32	-1.70	-1.63	-0.31	0.65	0.26
Roraima (RR)	-4.48	-1.91	-1.56	-0.40	1.25	0.88
Tocantins (TO)	-0.07	-0.54	0.02	-0.03	1.58	2.38

Source: Authors.

Table 6 | Five-year variations (%) in the coefficient of energy use in production compared to base year 2020, under the NEA scenario

State	2025	2030	2035	2040	2045	2050
AC	0.53	1.24	2.39	3.71	6.42	11.66
AP	0.03	0.08	0.15	0.3	0.44	1.13
AM	0.23	1.02	2.63	6.9	12.57	31.2
MA	0.02	0.19	0.6	1.57	3.35	5.83
MT	-0.01	0.13	1.22	2.66	4.54	6.92
PA	-0.02	0.29	1.04	2.9	5.85	13.38
RO	0.09	1.25	3.26	9.36	16.39	39.11
RR	0.21	0.39	0.71	0.95	1.25	3.08
TO	-0.01	0.1	0.83	1.77	2.98	4.54

Note: Variations not applicable to other scenarios.
Source: Authors.

Table 7 | Annual variations (%) in agricultural production and factor productivity compared to base year 2020, under the NEA scenario

State	Annual variation in production (%)	Annual variation in productivity (%)		
		Land	Capital	Labor
AC	3.6	3.9	3.3	2.7
AP	2.5	2.8	2.1	1.9
AM	2.6	3.0	2.3	1.7
MA	2.8	3.1	2.4	2.0
MT	2.7	2.6	2.4	1.7
PA	2.8	2.6	2.3	1.6
RO	2.4	2.8	2.0	1.7
RR	2.5	2.9	2.1	1.6
TO	2.5	2.9	2.0	1.4
LAM	2.7	3.0	2.3	1.8

Source: Authors.

Table 8 | Area occupied (in Mha) by the main classes of land use and land cover, in five years, under the BAU, SFL and NEA scenarios

Scenario	Mha	Native vegetation	Agriculture	Planted forests	Degraded pastures	Non-degraded pastures	Integrated systems	Agroforestry systems
BAU	2020	410	18	1	42	25	1	0
	2025	403	19	0	48	27	1	0
	2030	394	20	0	52	30	1	0
	2035	384	22	0	57	34	1	0
	2040	374	22	0	61	38	1	0
	2045	363	23	0	66	43	1	0
	2050	353	25	0	71	47	1	0
SFL	2020	410	18	1	42	25	1	0
	2025	409	19	0	40	27	2	0
	2030	409	21	0	35	30	2	0
	2035	409	23	0	32	31	2	0
	2040	409	24	0	27	34	2	0
	2045	409	26	0	24	35	2	0
	2050	409	28	0	21	37	2	0
NEA	2020	410	18	1	42	25	1	0
	2025	409	18	1	42	25	2	1
	2030	410	18	1	38	28	2	1
	2035	413	17	1	33	30	2	1
	2040	418	17	1	25	32	2	1
	2045	426	16	1	16	33	3	2
	2050	434	16	1	7	34	3	2

Note: The same class may present different compositions and productivity between the scenarios due to different production functions and specific technological packages.
Source: Authors.

2.1 Estimates of economic aggregates

If the Technological Support scenario (STE) did not return viable results, the Forest Support (SFL) scenario indicated that zero deforestation in the LAM without restricting deforestation in other regions, and without decarbonizing the energy mix, would also be insufficient to achieve climate goals, generating net emissions of 21.1 $GtCO_2$ by 2050, almost triple the carbon budget for Brazil.

When comparing the BAU and NEA scenarios, with the STE not yielding results and the SFL falling short of the 1.5°C climate target, the LAM's GDP in 2050 was estimated at $ 260 billion in the BAU and $ 268 billion in the NEA. Over 30 years, the NEA would accumulate $ 146 billion more in GDP than the BAU.

Such results demonstrate that deforestation is not only unnecessary for economic growth in the LAM, but its persistence reduces the potential efficiency in the use of factors and, therefore, productivity, resulting in lower economic growth when compared to any other scenario that assumes zero deforestation.

Another important point is that the differences in economic transactions between the scenarios have a residual impact on the economy of the rest of Brazil. This indicates that, although demand from outside the Amazon is the main driver of deforestation in the LAM, through imports of low-value-added but carbon-intensive commodities, the elimination of deforestation would not affect the performance of the Brazilian economy, with deforestation-intensive processes being replaced by low carbon alternatives. The tables below indicate the five-year GDP estimates by state in the different scenarios.

Investments are not determined in advance in the models, but result from solutions applied to optimize resource allocation, including differences in the technologies' productivity and emission contraints.

Table 9 | **Five-year GDP in the LAM and Brazil estimated in the BAU and NEA scenarios (in $ billion)**

BAU	2025	2030	2035	2040	2045	2050
AC	3.64	4.06	4.50	4.94	5.43	5.99
AP	4.05	4.51	5.00	5.49	6.05	6.69
AM	24.40	27.41	30.61	33.80	37.38	41.28
MA	22.50	25.36	28.43	31.53	35.03	38.57
MT	32.61	37.11	41.92	46.74	52.10	57.96
PA	41.15	46.16	51.51	56.86	62.87	69.53
RO	10.82	12.23	13.72	15.20	16.85	18.67
RR	3.35	3.73	4.14	4.55	5.03	5.56
TO	9.16	10.37	11.67	12.97	14.42	16.02
LAM	151.68	170.95	191.51	212.07	235.15	260.27
Brazil	1.672.72	1.886.78	2.115.43	2.344.02	2.600.99	2.886.40

NEA	2025	2030	2035	2040	2045	2050
AC	3.72	4.18	4.66	5.14	5.64	6.29
AP	4.14	4.62	5.14	5.64	6.18	6.88
AM	24.90	28.09	31.49	34.77	38.20	42.41
MA	22.91	25.86	29.03	32.11	35.33	39.39
MT	33.31	38.10	43.26	48.32	53.60	60.12
PA	42.00	47.31	53.00	58.51	64.28	71.54
RO	11.05	12.54	14.12	15.65	17.25	19.26
RR	3.42	3.83	4.26	4.69	5.14	5.73
TO	9.34	10.61	11.96	13.28	14.67	16.41
LAM	154.79	175.13	196.93	218.11	240.29	268.01
Brazil	1,699.62	1,917.37	2,149.94	2,381.58	2,640.45	2,931.58

Source: Authors.

The investments required for the NEA transition were estimated at $ 513 billion by 2050 (additional to the BAU scenario).

Of this total, $ 131.7 billion would be applied to sectors directly and indirectly related to strategic land use, through technical intensification of agricultural and livestock production and related activities, the bioeconomy and restoration. Another $ 381 billion would be applied to changes in the energy mix and infrastructure, of which $ 83 billion would be allocated to the energy sector and $ 298 billion to the industry, residential and services sectors. Examples of induced infrastructure include the expansion of waterways, adaptation of ports, airports and filling stations for recharging electric vehicles, new pipelines for biofuels transport, adaptation of electricity transmission and distribution networks, residential and industrial adaptation for solar energy production, among others.

Importantly, the models used do not allow the distribution of investments between government and private sector expenditures, nor the distinction between the amount of investments to be applied inside and outside the LAM, given the flows of inputs and products between the regions. This reinforces the need for technical standardization, legal harmonization and national commitments that guarantee structural convergence to the transition. Investments are also characterized by external and non-private costs, not including, for example, the acquisition of machinery, equipment, and investment projects to be disbursed by rural landowners, or the purchase of electric and electrified vehicles by companies. Table 10 presents the estimated investments in land use and other sectors in the different scenarios assessed. Such investments indicate additional amounts relative to base year 2020.

Table 10 | Investments accumulated over 30 years ($ billion)

		BAU	NEA
STRATEGIC LAND USE		198.5	330.3
Agriculture		122.6	153.0
Livestock Production		69.0	127.0
Bioeconomy		2.6	8.0
Restoration		4.3	42.2
ENERGY AND INFRASTRUCTURE		472.7	853.7
Electricity		188.6	267.5
National Interconnected System	Wing Generation	39.1	39.8
	Solar Generation	14.8	15.0
	Biomass	15.4	72.0
	Other Sources	86.6	86.6
Local Systems	Solar Generation	32.6	53.8
	Waste	0.0	0.3
Biofuels		2.8	7.0
Passenger Road Transport		0.8	2.3
Cargo Road Transport		1.4	3.1
Hybrid Water Transport		0.3	0.8
Air-fluvial Transport		0.3	0.8
Induced Infrastructure		281.3	579.2
TOTAL		671.2	1,184.0

Note: Investments in restoration and biofuels were estimated ex post, based on the results of the GEM and DOM models in terms of demand for increased vegetation and biofuels to meet emission constraints.
Source: Authors.

2.1.1 Job creation

Job creation follows the economy's differential growth in the comparison between scenarios, but with greater elasticity, which means that the capacity to generate additional jobs in the transition is even greater, proportionally, than the increase in GDP. In the NEA, 312 thousand additional jobs would be created compared to the BAU scenario.

For the bioeconomy, additional jobs in the NEA scenario were estimated at 623 thousand compared to base year 2020, indicating a steep increase from 334 thousand in 2020 to 957 thousand in 2050.

Almost one third of this increment would represent a replacement of current jobs in low-productivity cattle raising carried out in degraded pastures, while the other two thirds would be distributed among other sectors, replacing chains directly or indirectly related to deforestation, such as livestock production, destructive plant extraction and the furniture industry. The following table illustrates total estimated jobs for 2050 under the different scenarios and compares the bioeconomy jobs expected for the transition with base year 2020.

The superior results of the NEA transition scenario are based on the dynamics of the primary sector, with important growth in factor productivity, notably

Table 11 | Total jobs in 2050, according to scenarios, and jobs in the bioeconomy

State	Total jobs (thousand)			Jobs in bioeconomy		
	Base-year 2020	BAU	NEA	Base-year 2020	BAU	NEA
AC	395	669	700	2,882	3,548	5,146
AP	357	622	634	7,225	12,610	13,714
AM	1,860	3,130	3,147	2,3215	37,223	37,365
MA	2,850	4011	4,034	20,504	32,159	32,416
MT	1,845	4,938	4,980	10,294	8,018	17,982
PA	4,081	5,681	5,778	259,704	483,496	834,027
RO	887	1,858	1,928	2,813	4,367	4,649
RR	299	514	520	5,803	8,882	9,515
TO	751	1,465	1,479	1,317	1,949	2,231
LAM	13,323	22,889	23,200	333,757	592,252	957,045

Note: For base year 2020, data from the IIOM-LAM 2015 were considered, adjusted by regional population growth rates according to "resident population on July 1st" estimates produced by IPEA for the period 2015-2020.
Source: Authors.

in the replacement of land for labor and capital (that is, machinery and equipment and sustainable infrastructure), accompanied by gains in ecosystem services related to soil fertility. These productive effects make the primary sector more competitive and create economic gains, as well as a double environmental benefit: removal of CO_2 from the atmosphere and elimination of deforestation, ensuring the maintenance of the forest's stability. Investments in infrastructure in the transition scenario affect industrial investments associated with the primary sector, intensifying value chains in the regions.

Considering the entire LAM, the bioeconomy GDP estimated for 2050 would be around $ 7.7 billion, 73% higher than GDP in the BAU and almost three times higher than that observed in base year 2020. Also, considering that 80% of jobs in the LAM are currently held by black and indigenous people, a share that rises to 91% in the non-destructive plant extraction sectors (according to the IIOM-LAM), the bioeconomy's growth (discounting losses in other activities) would lead to the additional creation of almost 345 thousand jobs for workers in this group in the NEA compared to the BAU. While black and indigenous people would hold 18.7 million jobs in 2050 in the NEA scenario, in the BAU this number would be 18.3 million.

2.2 Estimates for emissions, deforestation and land use change

The LAM region is not only the leading GHG emitter in the country, but its share has grown over the past three decades. The LAM' share in total Brazilian emissions increased from 47% in 1990 to 53% in 2021. Considering only emissions arising from land use change and agriculture, the LAM accounts for 67% of total Brazilian emissions, up from 54% in 1990.

Between 2020 and 2050, accumulated net CO_2 emissions in the BAU scenario would amount to 43.6 $GtCO_2$, compared to 21.1 $GtCO_2$ in the SFL scenario, revealing that the 22.5 $GtCO_2$ difference could be attributed to deforestation-intensive activities and their direct, indirect and induced effects across the LAM's economy. Despite the large reduction in emissions achieved with zero deforestation in the SFL scenario, emissions would still be more than double the volume needed to reach the 1.5°C target. Adapting the economy to the restriction on land expansion would not eliminate the need to intensify decarbonization measures in other sectors in order to meet climate targets.

In the right direction, the NEA scenario foresees accumulated net emissions in the period within the 1.5°C target, which corresponds to emissions restricted to 7.7 $GtCO_2$. In the transition to the NEA, carbon-intensive sectors would drastically reduce their emissions simultaneously with the increase of native vegetation via restoration and agroforestry systems dedicated to the bioeconomy, promoting net carbon removal.

On the other hand, the transition would spark a 13.2% increase in nitrous oxide (N2O) emissions due to the acceleration of soil denitrification processes. Chart 9 illustrates the evolution of GHG emissions over the next 30 years and the comparison of the different scenarios by 2050.

Chart 9 | Evolution and total estimated emissions by 2050, under the different scenarios

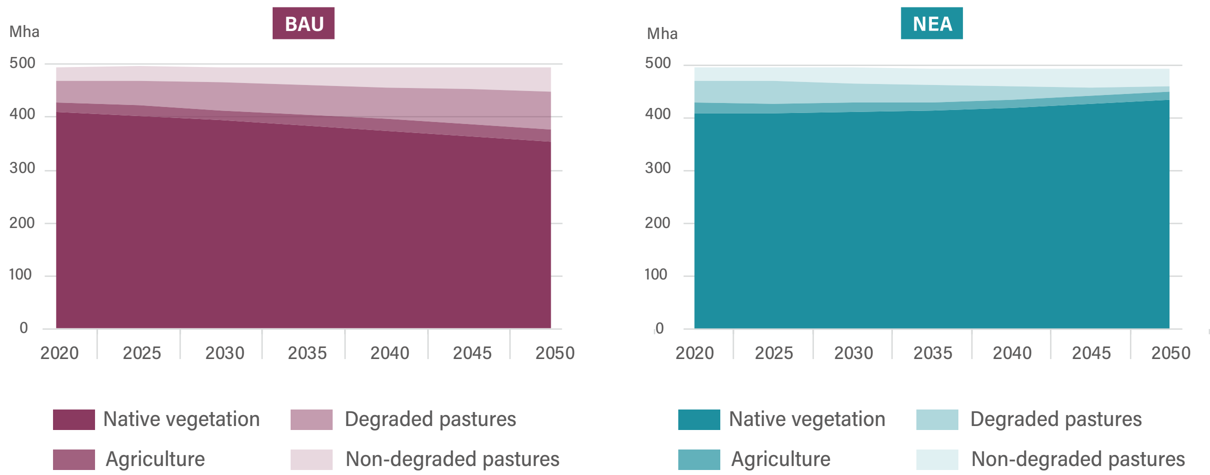
Source: Authors.

Without strategies involving mitigation (such as zero deforestation), adaptation (such as forest restoration) and integrated and labor-intensive agroforestry systems, Brazil's climate targets cannot be achieved. The fact that the STE scenario does not yield a mathematically viable solution is in itself a clear alert to the impossibility of reconciling additional land allocation via deforestation with efficient containment of emissions in other sectors and regions.

If the current trend of land incorporation via deforestation is maintained, one should expect, according to the BAU scenario, an additional pasture area in the LAM of approximately 51 Mha by 2050, reflecting growth at around 2.9% per year, with decreased productivity resulting from a combination of pastures' degradation and reduction in ecosystem services, especially due to structural loss and loss of soil nutrients. The area dedicated to agricultural production would advance to 25 Mha with a disproportionately high expansion of grain crops mainly replacing pastures and other crops, but also forests. The expected deforestation for this period would reach 59 Mha including forest and non-forest, primary and secondary vegetation, with net deforestation reaching 57 Mha, considering the restoration of just over 2 Mha.

The NEA scenario estimates that 24 Mha of native vegetation would need to be restored for carbon sequestration, in addition to zero deforestation. Chart 10 compares the main land use classes in the different scenarios.

Chart 10 | Evolution of the area covered by the main land use classes in the LAM, between 2020 and 2050, for each scenario



Note: Native vegetation includes forest and non-forest formations; and Agriculture includes integrated and agroforestry systems.
Source: Authors.

2.3 Estimates for the energy mix

Currently, 48% of the energy mix in Brazil is made up of renewable sources, compared to a low global average of 14% (EPE, 2021b). Based on energy demand, population growth and GDP data estimated in the GEM and DOM models, the total energy demand in the NEA scenario is expected to reach 211 TWh compared to 255 TWh in the BAU scenario and 169 TWh in base year 2020 (all types of energy, including fuels, converted into TWh). Considering only electricity for domestic, industrial, rural, services and transport consumption, 131 TWh would be needed in the NEA scenario, compared to 74 TWh in the BAU and 52 TWh in 2020. In the NEA scenario, 57% of the electricity mix would come from renewable sources in 2050 (Chart 11). Among these sources, hydro and solar power plants for electricity production stand out, as well as sugarcane used both for the production of second-generation ethanol and electricity from bagasse and residues - developed outside the LAM but distributed through the National Interconnected System (SIN).

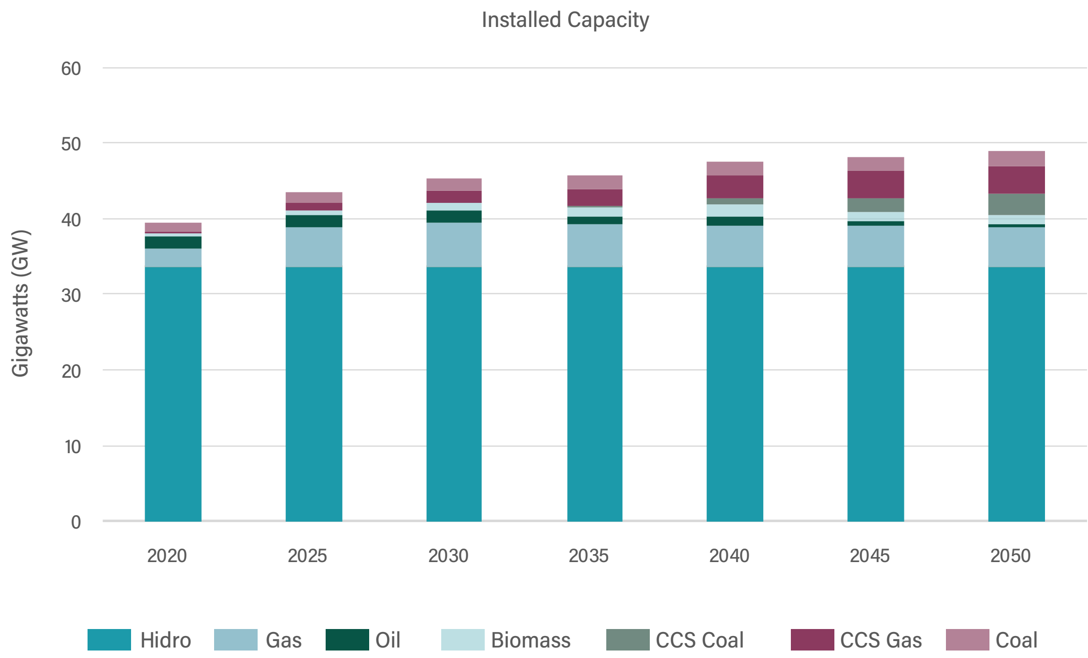
The NEA transition scenario, however, requires significant transformations in energy systems, with an impact on emissions and land use. The use of fossil fuels would suffer a significant drop, representing less than 20% of primary energy in 2050, in line with the Net Zero by 2050 report by the International Energy Agency (IEA, 2021). In parallel, there would be a significant increase in the use of biomass, including wood waste (eucalyptus and pine), agricultural waste and, in particular, waste from the bioeconomy, mainly acai pods, the disposal of which currently reaches around 1 million tons per year.

Production of cellulosic biofuels, generated from local waste biomass (acai and cocoa), would start in 2035 with small-scale plants and steadily grow until 2050, when large-scale plants would be able to replace up to 90% of LAM's fossil fuels.

Only 370 thousand hectares of planted forests would be needed, which corresponds to 1.5% of the area currently covered by degraded pastures, without the need to expand the area occupied by sugarcane dedicated to ethanol production.

Hydroelectric power plants, currently responsible for 85% of the installed capacity in the LAM, do not expand in the NEA scenario. Belo Monte would have been the last major hydroelectric project developed in the region. Alternative sources would gain relevance, especially solar energy with distributed generation in residential areas and industrial units with high electricity consumption, such as slaughterhouses and frozen food industries. SIN transmission lines would expand by 35% to accommodate the increase in electricity flow. Floating solar systems would be installed on existing hydroelectric dams in the LAM, taking advantage of transmission and distribution infrastructure, as well as ground-mounted systems in highly degraded pastures. The installed capacity in this scenario is indicated in Chart 11. Further details about the energy mix are provided in Chapter 6.

Chart 11 | Evolution of installed electricity capacity in the Legal Amazon, between 2020 and 2050, under the NEA scenario



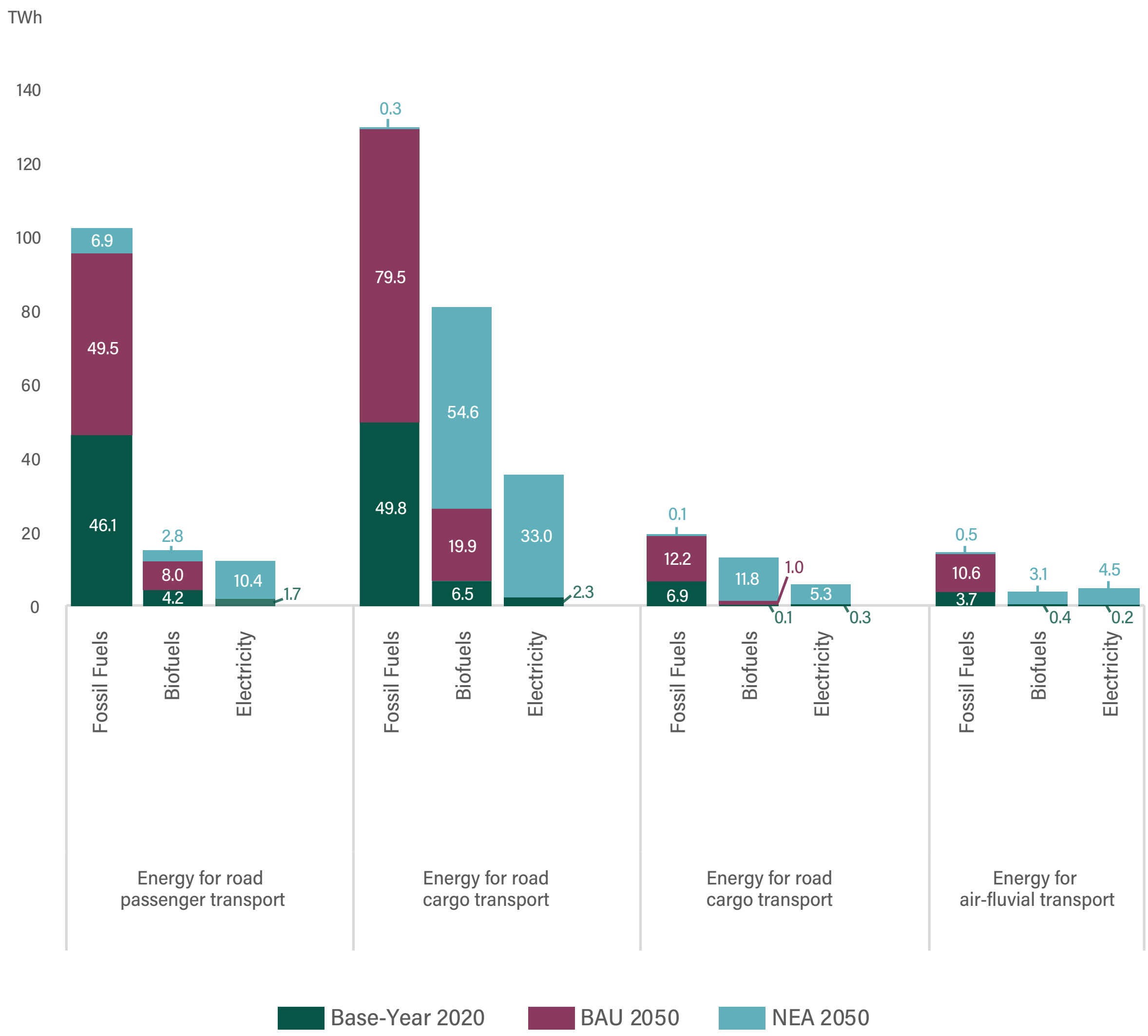
Source: Authors.

In road passenger transport, the results of the models showed that the drastic reduction in emissions imposed by the Paris Agreement's target would entail the electrification of 75% of light vehicles, 95% of motorcycles and 94% of the public transport fleet by 2050, with a concomitant 30% increase in public transport use. Such changes would result in a 2.3 M TJ decrease in energy demand and 177 $MtCO_2$, respectively, when compared to the BAU scenario.

The transition to the NEA proposes a rise in the fraction of biofuels (biodiesel and HVO) in diesel used for long distance road cargo transport from the current 10% to 100% by 2050, while short distance road transport would be progressively served by an electric fleet, at a pace at which electrified trucks represented 100% of new licenses issued in 2050. The transition scenario foresees road cargo transport requiring 197 thousand TJ from biofuels and 119 thousand TJ from electricity, while the BAU requires 366 thousand TJ from fossil sources, with avoided emissions of approximately 214 $MtCO_2$ in the NEA scenario compared to the BAU.

Hybrid waterway transport, already favored by the extensive river network and because it is the modal with the highest efficiency per ton transported (Trancossi, 2016), would be expanded and more intensively used, absorbing 20% of current road cargo transport. While the BAU scenario forecasts a demand of 49 thousand TJ for hybrid waterway transport (passengers and cargo), with 7.5% met by biofuels and the rest by fossil fuels, the transition scenario would increase demand by 26% (62 thousand TJ), with 70% met by biofuels and 30% by electrification. In the period 2020-2050, emissions of 6.92 M tCO_2 would be avoided in the NEA scenario compared to the BAU.
Air-fluvial transport, used for the selective transport of passengers and valuables, would save 8.3 $MtCO_2$ in emissions in the NEA scenario. Chart 12 illustrates the energy demand by type of fuel for each transport modality, simulated for the different scenarios and base year 2020. More details can be found in Chapter 6, dedicated to the energy mix.

Chart 12 | Energy demand (TWh) by type of fuel, for each transport modality, simulated for the different scenarios and base year 2020



Note: Results of the study.
Source: Authors.

2.4 Estimates for the provision of ecosystem services

Ecosystem services are essential for economic development, especially in the agricultural sector, which is highly dependent on climate conditions. Currently, 96% of planted areas and 99% of pastures in Brazil do not have any irrigation systems in place (IBGE, 2019).

High impact ecosystem services include carbon sequestration, which directly affects temperature and the water cycle, especially in the supply of rainwater irrigation and availability of water in the soil (surface runoff), as well as sediment retention, connected with the ability to reduce erosion, soil loss and consequent structural degradation and fertility decline.

Despite scientific consensus and industry recognition, ecosystem services continue to be neglected in decision-making processes, with insufficient assessment of their contribution to the economy. Most ecosystem services are not cash generators, but cost savers (measured by the cost of replacing such services with technology or inputs), which makes their benefits invisible in conventional economic models.

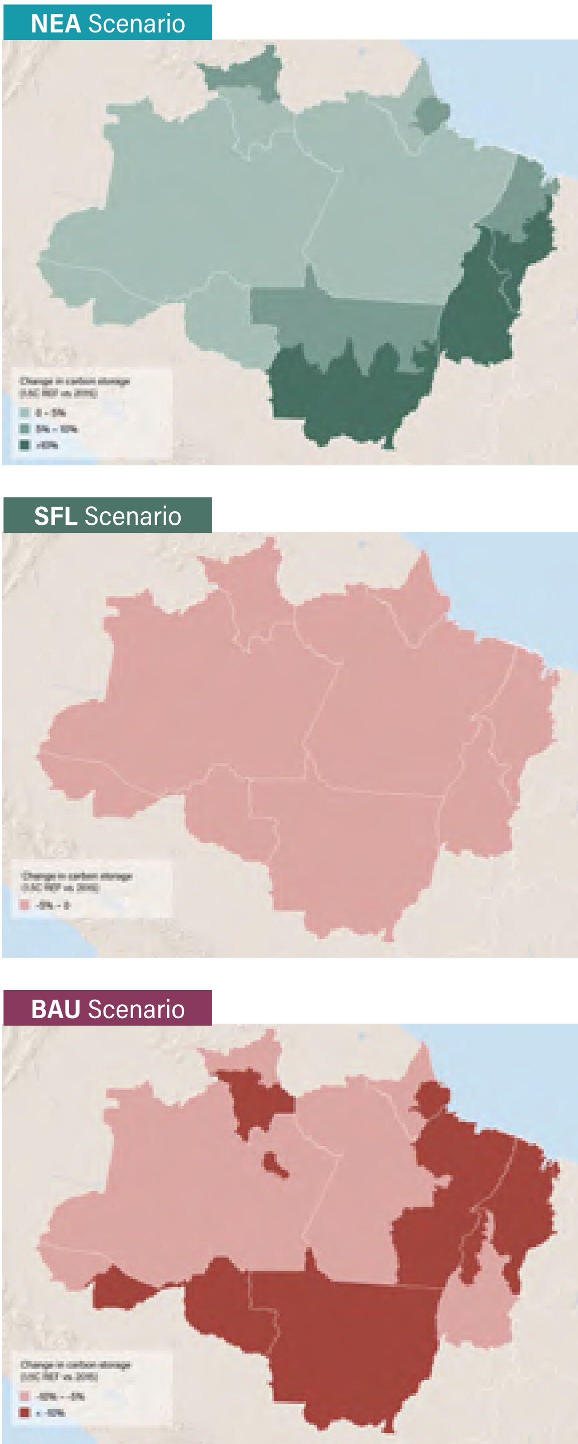
For the scenarios forecasted in this study, selected ecosystem services were estimated through the InVest tool and used as input data in the GEM models, affecting economic aggregates as vectors that alter land productivity and give rise to compensatory changes in labor and capital, and replacement costs.

2.4.1 Carbon storage

In the BAU scenario, almost 12% of the carbon storage capacity is lost between 2015 and 2050 (as in the IIOM-LAM, results refer to 2015 due to methodological limitations), while in the transition the intensive restoration of forest systems would lead to an increase of almost 5%. The differences obtained in the scenarios were not monetized, but served as input data for land allocation and emission constraints. Figure 35 illustrates changes in carbon storage across regions and scenarios, while Table 12 summarizes the aggregates.

In the NEA scenario, the carbon stock in 2050 would be 19% higher than in the BAU, driving an appreciation of environmental assets with the formation of forest carbon savings, potentially used to back current carbon credits or contribute to fundraising efforts with promises of future markets.

Figure 5 | Carbon storage change compared to 2015



Source: Authors.

Table 12 | Change in carbon storage across the study area

Scenario	Carbon storage	Variations in relation to 2015
2015	74.22	
BAU	65.34	-11.97%
SFL	73.11	-1.49%
NEA	77.84	4.88%

Source: Authors.

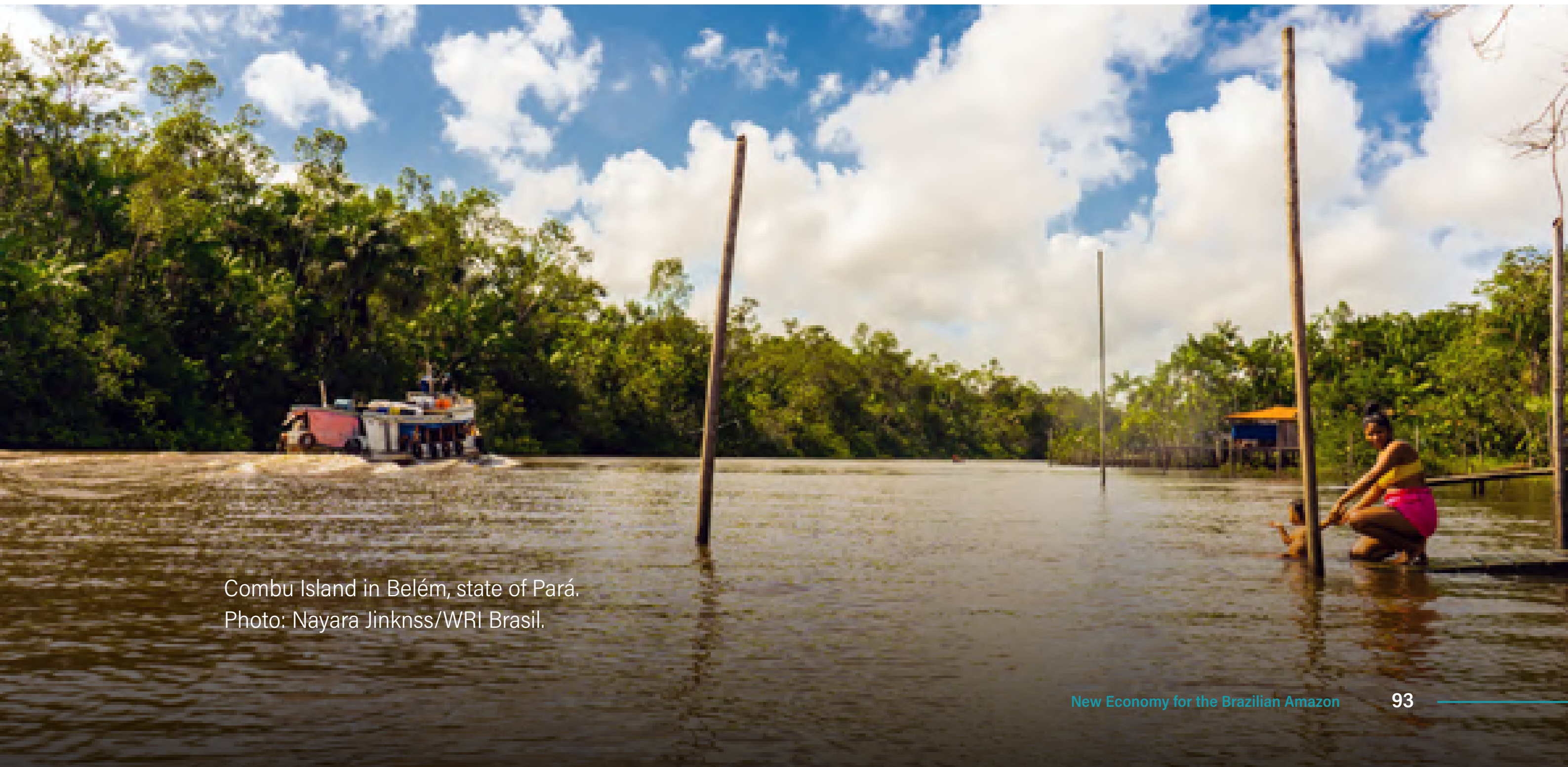
2.4.2 Availability of water (surface runoff)

The balance between total precipitation and total evapotranspiration over a period of one year determines water availability. Greater water availability is associated with greater runoff of surface water, and, consequently, greater soil erosion, less infiltration and groundwater storage, and greater risk of flooding. It is important to note that, between 1995 and 2019, the LAM suffered 8.2% of all climate damages and losses observed in the country, of which 66% were due to floods and 34% to droughts and dry spells, totaling $ 4.6 billion (constant 2021 values). Damages and losses in the agricultural sector added up to $ 2.3 billion, with $ 607 million in livestock production and $ 1.5 billion in infrastructure and energy in the region (World Bank, 2020).

In the BAU scenario, water availability would increase in all LAM regions by an average of 11% by 2050 compared to 2015. These indicators point to a higher probability of increased surface runoff with less water penetration in soil, essential for agriculture and livestock production. In the NEA scenario, water availability drops to an average of almost 4% by 2050, which means that, in 2050, a 13% difference in water availability in the LAM could be expected between the BAU and NEA scenarios.

Considering that the fight against deforestation and forest recovery would be carried out over the 30-year period at constant rates, a 6% average difference in water availability in the LAM would be seen between the BAU and NEA scenarios, making agriculture resilient to water stress in the transition, with proportional impact on remediation costs. On the other hand, as indicated by the 2050 National Energy Plan (EPE, 2020b), a decrease in water availability due to climate change could generate additional costs in the range of $ 20.6 to 37.8 billion in electricity generation in the country by 2050. The figure below illustrates changes in water availability across the different regions and scenarios, while Table 13 summarizes the aggregates.

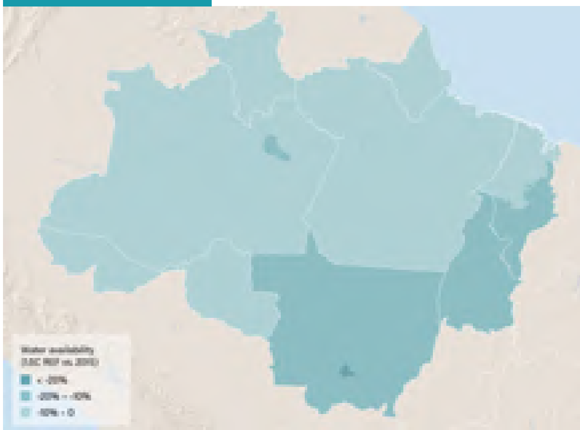
In the BAU scenario, biomass retains less water because forests have been converted to other uses, increasing the risk of flooding, waterborne diseases (Petterson et al., 2016), soil erosion and reduction in the soil's capacity to absorb water, a factor that negatively affects agricultural and livestock production.



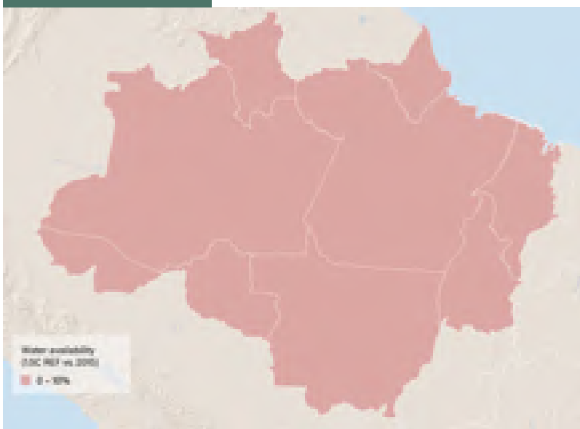
Combu Island in Belém, state of Pará.
Photo: Nayara Jinknss/WRI Brasil.

Figure 6 | Change in water availability compared to 2015

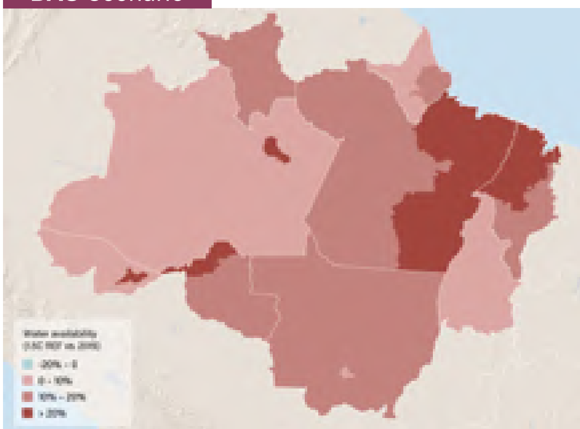
NEA Scenario



SFL Scenario



BAU Scenario



Source: Authors.

Table 13 | Change in water loss due to surface runoff

Scenario	Water availability (billion cubic meters)	Variation in surface water availability compared to 2015
2015	4,672.0	
BAU	5,181.8	10.91%
SFL	4,705.3	0.71%
NEA	4,489.9	-3.90%

Source: Authors.

2.4.3 Sediment export

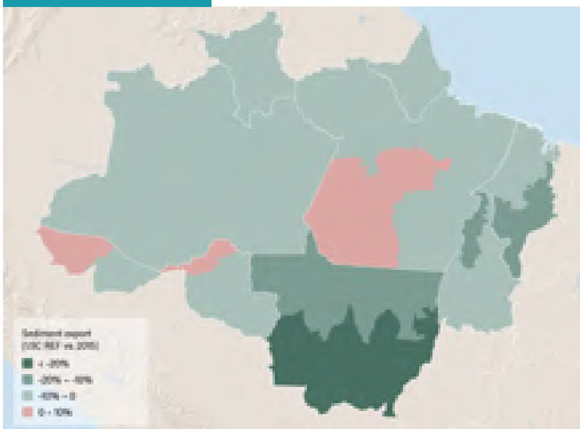
In river basins, water flow associated with erosivity and erodibility potentials cause soil loss through sediment export. Under these conditions, surface layers of soil that retain nutrients and fertilizers are carried away, causing structural and fertility loss. Projections for the BAU scenario indicate that, in 2050, an increase of up to 14% in sediment export should be expected compared to 2015, while in the NEA scenario, on the contrary, a reduction close to 15% would be observed in the same period. The figure below illustrates changes in sediment export across the different regions and scenarios.

Sediment export leads to nutrient loss and, therefore, soil fertility loss. In the NEA scenario, nitrogen and phosphorus losses are reduced by 4.9% and 5%, respectively, decreasing fertility replacement costs and making agricultural practices more efficient. Comparing the scenarios, nitrogen loss in 2050 in the NEA scenario would be 16% lower than in the BAU, while phosphorus loss would be 18% lower, reducing the need for nutrient replacement. If deforestation elimination and forest recovery efforts occurred over 30 years at constant rates, a 9% average difference between the BAU and NEA scenarios would be seen.

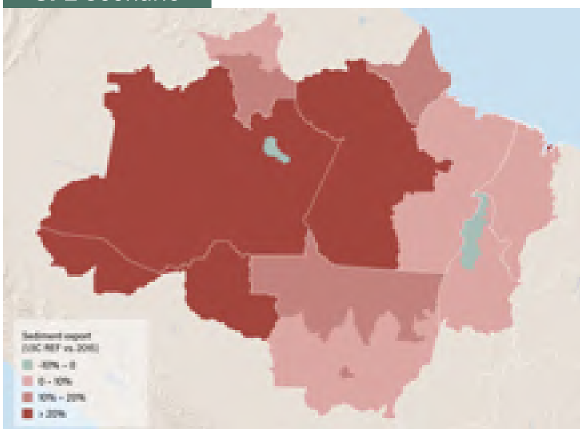
Studies show that sediment export in Brazil ranges between 600 Mt and 820 Mt per year, generating nutrient replacement costs between $ 1.8 and $ 3.4 per ton per year, 80% to 92% of which referring to nitrogen and potassium replacement (Dechen et al., 2015). Based on these reference values, avoided nutrient replacement costs in the NEA scenario compared to the BAU would be in the $ 921 million to $ 1.74 billion range over 30 years, corresponding to 30% to 56% of total fertilizer costs in the LAM in 2017 (Lense et al., 2021; Merten and Minella, 2013).

Figure 7 | Change in sediment export compared to 2015

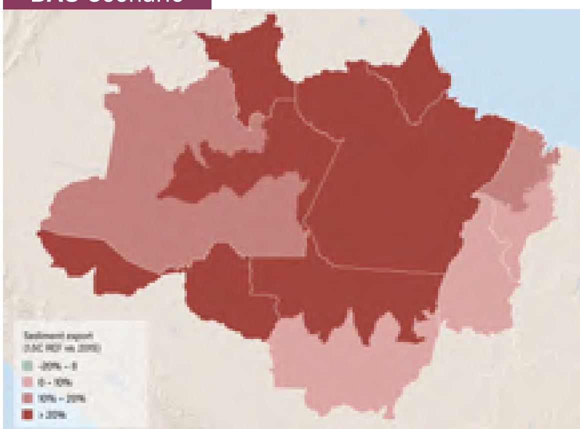
NEA Scenario



SFL Scenario



BAU Scenario



Source: Authors.

Aerial view of the forest near Manaus, state of Amazonas. Photo: Nelson Antoine/Shutterstock.

Table 14 | Change in sediment and nutrient export across the study area

Scenario	Sediment export (million tons)	Nitrogen (N) export (thousand tons)	Phosphorus (P) export (thousand tons)	Variation in relation to relative net nutrient loss (N and P)
2015	188.8	429.8	64.0	na
BAU	214.9	488.8	74.6	14.1%
NEA	160.2	408.6	60.8	-4.9%

Source: Authors.

2.5 Conclusions

The persistence of deforestation and carbon-intensive production will likely result in consistent losses in land productivity and fertilizer use in the LAM which, in addition to negatively affecting GDP, would strengthen the practice characterized by the incorporation of new land, further increasing deforestation levels. No combination of technological and energy packages tested for the other sectors would be able to neutralize emissions arising from deforestation driven by agricultural expansion under such conditions. Eliminating deforestation is essential not only to achieve the domestic and global targets to contain global warming to 1.5°C, but also to stimulate growth intensive in capital and labor at the expense of carbon-intensive production.

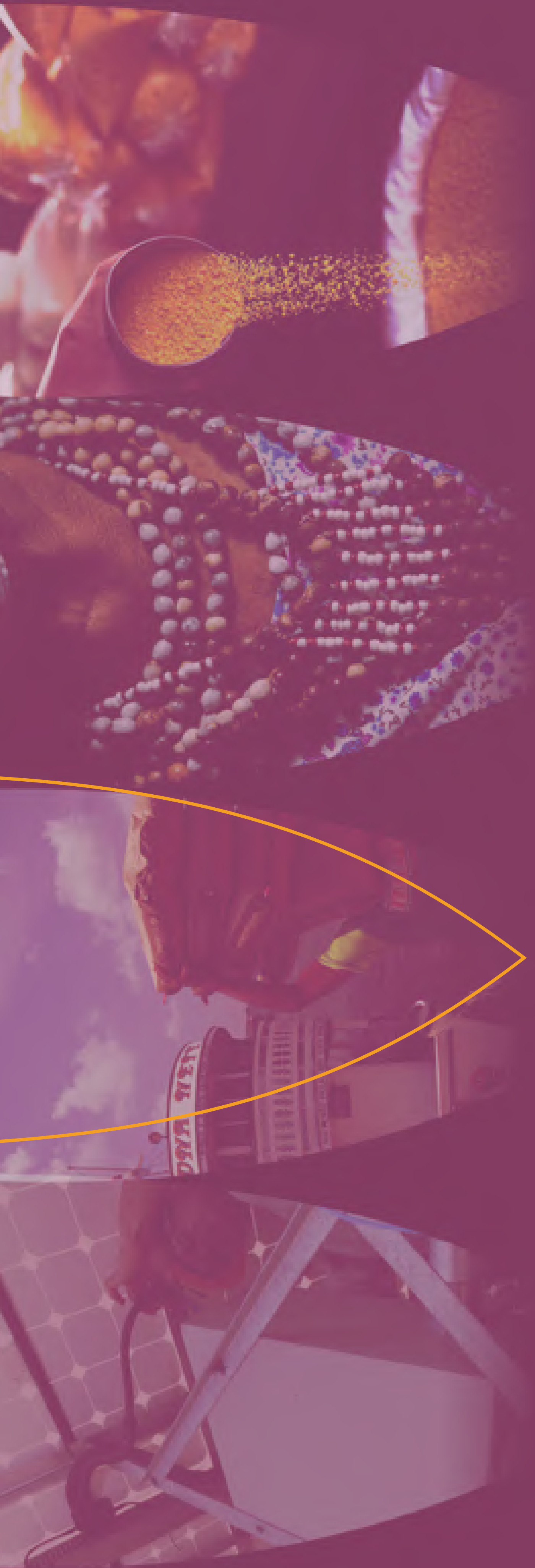
Considering three possible scenarios for the LAM economy in 2050, the scenario of transition to the New Economy for the Amazon, with the expansion of the bioeconomy, is the one that delivers the strongest economic growth and job creation. GDP in the NEA scenario, for example, would show an accumulated gain of $ 146.2 billion compared to the BAU scenario. Moreover, the NEA scenario would generate 312 thousand additional jobs compared to the BAU, mainly replacing jobs linked to carbon-intensive activities, such as logging and extensive land use, and low-productivity livestock farming.

The investments needed to finance the transition to the NEA were estimated at $ 513 billion (additional to the BAU), to be applied until 2050, of which $ 381 billion would be applied to changes in the energy mix and infrastructure induced by such changes, in addition to another $ 381 billion used in strategic land use, especially recovery of degraded pastures, integrated systems and forest restoration for the expansion of the bioeconomy and associated secondary and tertiary sectors.

Acai picker from the community of Arraiol, in the Bailique archipelago, state of Amapá.
Photo: Diego Baravelli/Greenpeace.

The New Economy for the Brazilian Amazon in

PART **2** **PERSPECTIVE**



PART **2**

As discussed in the first part of this study, the New Economy for the Amazon (NEA) generates higher GDP and more jobs than the maintenance of the carbon-intensive economy. The second part of this report deepens the discussions on the role of the main land use sectors in this transition, and further details the required changes in the energy mix and investment needs.

Chapter 3 offers a broad review of the bioeconomy. First, it reveals that bioeconomy currently generates GO of around $ 5.1 billion in the country and approximately $ 3 billion in the LAM, but is partially invisible in national accounts due to high levels of informality and the inability of official accounting methods to capture bioeconomy indicators. It shows, through the IOM-Alpha application, that the bioeconomy is a dynamic driver of the circular and proximity economy, thus with great capacity to generate production and employment multipliers - factors that served as input to the GEM models developed in Chapter 2.

The chapter also acknowledges the underestimation of the bioeconomy practices led by indigenous peoples and traditional populations. Widely practiced in the territories, the bioeconomy is poorly documented in the scientific literature, and its protagonists – indigenous entrepreneurs, associations, cooperatives, and leaders – are rarely consulted about their initiatives and challenges. Two characteristics of indigenous production can be learned from such practices, which must constitute the conditions for the development of the entire LAM and Brazilian bioeconomy: 1) bioeconomy is defined by its processes and not by products; and 2) the fair and equitable benefit-sharing.

Chapter 4 discusses the role of agricultural and livestock production in the transition to the NEA, as this sector is the main GHG emitter and the most directly affected by the availability of ecosystem services. This chapter discusses three basic conditions for the transition: strategic land use, productive intensification through mainstreaming and prioritization of low carbon emission practices, and reduction of rural inequality.

Chapter 5 briefly discusses the contribution of mining to the NEA, limited to formal mining activities, intensive in capital and focused on the extraction of minerals relevant to the current LAM economy, as well as essential minerals for emergent technologies.

Chapter 6 explores the infrastructure induced by changes in the energy mix, which respond to emissions constraints, levelized energy costs and potentialities and limits of local resources. The chapter describes, therefore, proposals based on the results of the models used, such as identified optimization solutions that would allow the convergence of economic growth with low emissions, adapted to zero deforestation and the use of local resources. Solutions are proposed that replace the prevailing idea in regional energy infrastructure of "projects in the Amazon" with the idea of "projects for the Amazon".

Closing the second part of this report, Chapter 7 reviews funding sources and modalities, guiding the construction of an investment portfolio to finance the transition to the NEA, with a focus on carbon-intensive sectors and the bioeconomy.

The Café Apuí Agroflorestal initiative, in the state of Amazonas, connects fair trade and forest conservation, with fruits planted in shaded areas and harvested by families in the region. Photo: Dai Dietzmann/IDESAM.

CHAPTER **3**

BIOECONOMY

BIOECONOMY

Bioeconomy is a disputed concept, with different definitions currently adopted in Brazil and abroad. For the Brazilian Ministry of Science, Technology and Innovation (MCTI), the term is linked to solutions in the use of biological resources (MCTIC, 2018; CGEE, 2021); for the Ministry of Foreign Affairs (MRE), the approach is focused on bioenergy (Biofuture Platform, 2018); for the Ministry of Agriculture, Livestock and Food Supply (MAPA), the concept has an important social focus, promoting family farming and traditional knowledge (MAPA, 2019).

In the private sector, the National Confederation of Industry (CNI) presents a concept of bioeconomy linked to agriculture, including medical biotechnology (Silva, Pereira and Martins, 2018)[15]. Some of the concepts already adopted for bioeconomy focus on replacing fossil inputs with biological inputs and do not take biodiversity into account. These concepts encourage low-carbon economic activities, but based on homogenization processes (Costa et al., 2022).

The bioeconomy in the LAM needs its own definition, which must include the improvement of instruments that enable the local population to lead new productive processes, promoting businesses that stimulate the circular flow of income and the proximity economy. The Amazon bioeconomy must be able to adjust to the biome's biocapacity, with development driven by economic activities that protect the complex ecological balances that guarantee the health of the forest and rivers, and that combine tradition and innovation (Costa and Fernandes, 2016; Costa et al., 2022).

3.1 The Amazon bioeconomy today

The transition process from a carbon-intensive economy to an economy that privileges the standing forest encompasses major social and technological changes, in addition to scientific, institutional, and behavioral transformations (Bergamo et al., 2022).

The bioeconomy is a key driver of deforestation-free economic growth in the Amazon. Both the IIOM-LAM, presented in Chapter 1, and the GEM, detailed in Chapter 2, were based on the total economy of the 67 sectors that make up the Brazilian economy, with special focus on deforestation-intensive chains: livestock and cotton and grains production.

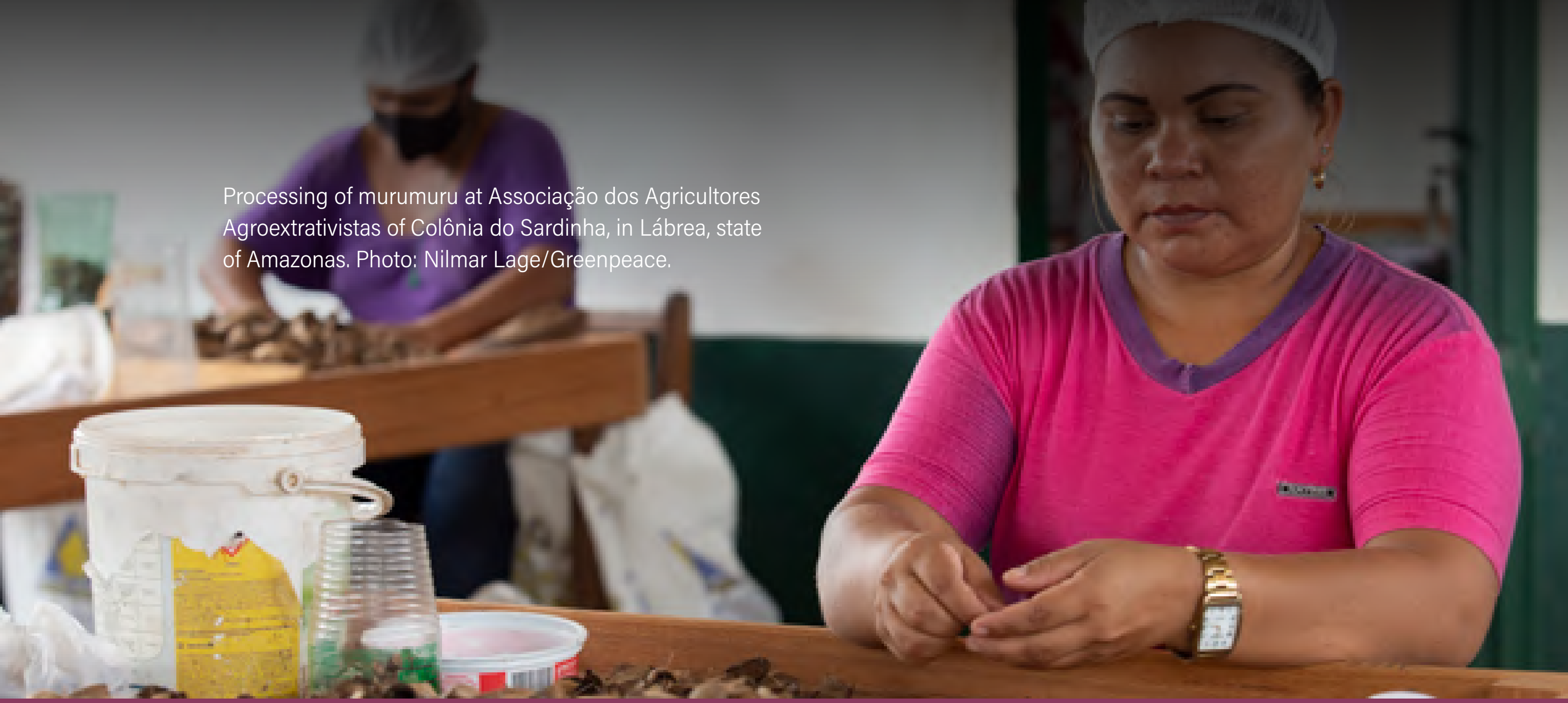
The GEM models were fed with data from the IIOM-LAM; however, the IOM-Alpha results developed by the Center for Advanced Amazonian Studies of the Federal University of Pará, available at WRI Brasil's website, were specifically used for the bioeconomy. The Alpha Accounts methodology is also based on the input-output matrix tool, but provides visibility to a thriving economy currently existing in the Amazon, otherwise invisible from the perspective of the national IOM's 67 sectors, and partially invisible to the IIOM-LAM.

Importantly, the IIOM-LAM is innovative in its capacity to measure the non-destructive plant extraction sector, containing products from the standing forest, and can be replicated using official disaggregated data available at IBGE. On the other hand, this matrix reveals only a part of the bioeconomy - that which is captured in the non-destructive extraction sector.

The IOM-Alpha is based on Leontief's classic models, as is the IIOM-LAM, but variables for agrarian structure, technological trajectories and biodiversity products are included in the "apportionment" parameters of the aggregates, allowing a more accurate view of specific transactions for certain products whose records are faulty. Exhaustive field research, as well as data from state and federal databases, complement the information that enables the construction of transacted flows between regions and along the productive chains, from the primary to the tertiary sector. On the other hand, the IOM-Alpha requires significant data collection effort, which limits both the number of products included and the regional coverage. The IOM-Alpha only considers 13 native products (acai fruit and acai palm heart, cocoa, Brazil nut, babassu coconut and babassu oil, cupuacu, honey, rubber, buriti, urucum, copaiba and andiroba). Methodological details can be found in Silva et al. (2022). A summary of the matrices' construction process can be seen in the box below.

It is important to point out, however, that the bioeconomy is much larger. Research shows that the peoples of the Amazon have an extremely diverse diet, with up to 270 items used daily in cooking, compared to less than 30 among non-indigenous groups in the same region (Mesquita, Barreto, 2015; Skeltis, 2019). On a daily basis, they use up to 85 tree species and more than 200 herbs for dietary or medical supplementation (Levis et al., 2018), and ingest about 30 insect species - the food of the future - as sources of vitamins and iron (Roche et al., 2008). Because each ethnic group has its own food preferences and taboos, the resources available in the forest are spatially heterogeneous and as numerous as biodiversity, which reinforces the hypothesis that the Amazon Forest itself, in good measure, is the result of persistent and millenary autochthonous forest management (Levis et al., 2017).

The IOM-Alpha results, considering only 13 products and 14 sectoral segments, pointed to a current Brazilian bioeconomy that generates a GO of $ 5.1 billion, with $ 2.2 billion in VA and a wage bill of $ 515 million, much higher figures than those corresponding to the non-destructive plant extraction sector accounted for in the IIOM-LAM, which generated a GO of $ 307 million (in 2015 values). In the LAM alone, the bioeconomy was estimated to generate VA of $ 1.9 billion, a GDP of $ 2.4 billion and a wage bill of $ 505 million. The total number of jobs in the LAM bioeconomy was estimated at 347 thousand, of which 84 thousand were formal positions. The following chart breaks down the results by state.



Processing of murumuru at Associação dos Agricultores Agroextrativistas of Colônia do Sardinha, in Lábrea, state of Amazonas. Photo: Nilmar Lage/Greenpeace.

Box 12 | Two antagonistic technological paradigms: the chemical-mechanical and the agro-extractive

Today, two economic models governed by different technological paradigms coexist unevenly in the Amazon. The dominant chemical-mechanical paradigm, resulting from economic policies implemented in the region over the past 70 years, is characterized by solutions that "control" nature to meet the needs of growing industrialization and urbanization (Loureiro, 2022). When applied to agriculture, it is based on the specialization of homogeneous productive systems. These solutions seek to maximize earnings based on the following factors:

1. Extensive land use and natural resources, with mechanical solutions, where land is abundant (or where land regulation allows the incorporation of forest land);

2. Intensive land use and natural resources, with (bio) chemical solutions, where access to land is limited.

For these reasons, this model is known as chemical-mechanical. Mechanization increases productivity but depends on monoculture and homogenization to gain scale, which, in turn, requires chemical inputs to guarantee support capacity, in the form of pesticides and agrochemicals. The Green Revolution[16] has consolidated this technological paradigm. Derived technologies imply a profound transformation of original nature, and high impact on biodiversity and other natural resources. In rural areas, this model sees nature as raw material or physical capital (Silva H., 2017).

The second economic paradigm is known as the agro-extractive paradigm (Costa, 2021; Costa F. d., 2008; 2009; 2014). Its technologies were developed by societies originating from the complex and diverse Amazonian ecosystem. Improved over centuries, the technological solutions in this productive paradigm aim to manage nature instead of transforming it. The techniques used increase the productivity and natural return of living productive systems. It is a paradigm that adjusts to the conditions and rhythms of reproduction and permanence of the biome[17]. In some parts of the LAM, mainly in forest areas, the agro-extractive model is an alternative to the chemical-mechanical wealth production system (Romeiro, 1998; Costa and Fernandes, 2016).

Its technologies represent a set of productive solutions based on agroecological, agro-extractive or agroforestry principles. The agro-extractive paradigm's technical and technological references approximate what Bugge, Hansen and Klitkou (2016) and Vivien (2019) identify as bioecological bioeconomy[18]. In the Amazon, the bioecological bioeconomy is adapted to the biome's support capacity and based on the pace of forest management carried out by local people and communities. It is creative and endogenous. Because it primarily depends on forest maintenance, it is better adapted to climate change and presents better results in hunger and inequality reduction (Costa et al., 2022).

Box 13 | IOM-Alpha method

According to the model, the social accounting of an economy of *k* products whose flows take place through *n* agents grouped in *m+1* positions in the productive and distributive system, in which the *m+1-th* position represents final demand, is represented by

$$X_{ij} = \sum_{i=1}^{m} \sum_{j=1}^{m+1} \sum_{v=1}^{k} q_{ijv} * p_{ijv}$$

in which *v* is the product, *j* is the sector that purchases it, and *i* is the sector that sells it.

By incrementing *g* geographical attributes and e structural attributes, the equation results from the aggregation of a number *g* * e of submatrices, each composed of

$$X_{srij} = \sum_{s=1}^{g} \sum_{r=1}^{e} \sum_{i=1}^{m} \sum_{j=1}^{m+1} \sum_{v=1}^{k} q_{srijv} * p_{srijv}$$

in which *r* would be the structural attribute (family and non-family farmers) and *s* the geographical attribute (regions). The elements of the summing matrices for the geographic attributes would be

$$X_{sij} = \sum_{s=1}^{g} \sum_{i=1}^{m} \sum_{j=1}^{m+1} \sum_{v=1}^{k} x_{rij}$$

and for the structural attributes would be

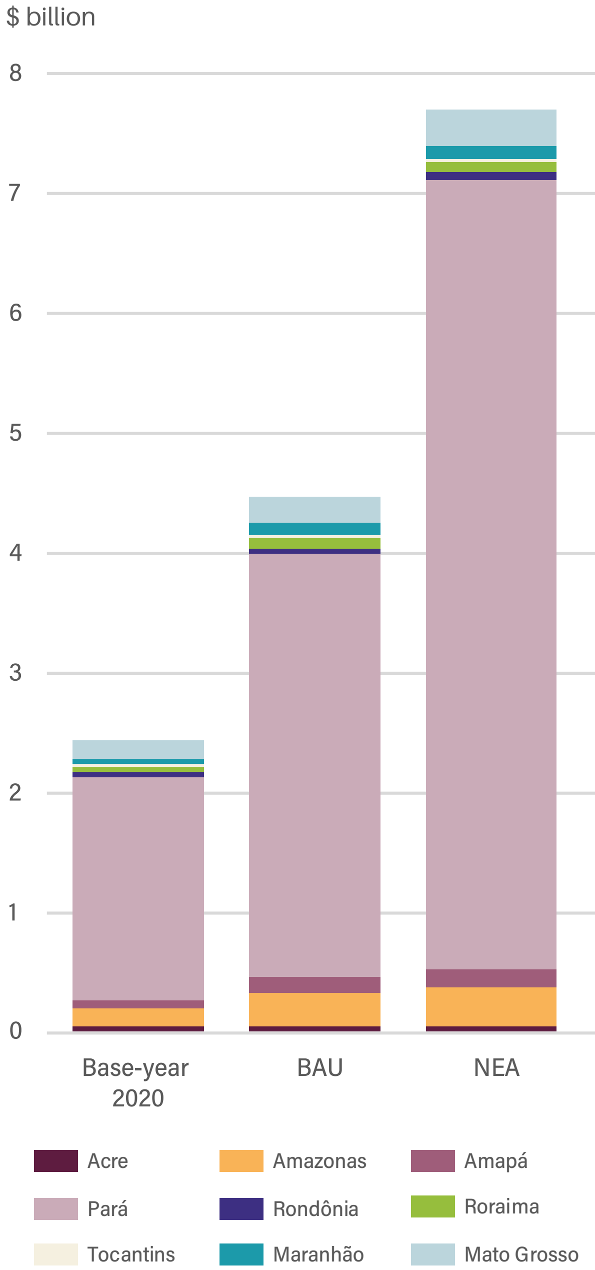
$$X_{rij} = \sum_{r=1}^{e} \sum_{i=1}^{m} \sum_{j=1}^{m+1} \sum_{s=1}^{g} x_{sij}$$

The summing matrix can be described as:

$$X_{ij} = \sum_{i=1}^{m} \sum_{j=1}^{m+1} \sum_{r=1}^{g} x_{rij} = \sum_{i=1}^{m} \sum_{j=1}^{m+1} \sum_{s=1}^{e} x_{sij}$$

where *s* are the geographic attributes (municipalities, groups of municipalities, etc.), *r* are the structural attributes (characteristics of the production modalities, characteristics of the systems, etc.) that underlie the productive structure of the economy. *q* indicates the quantity of each product transacted by agents settled in *s* under structural condition *r*. *p* refers to the basic prices at which quantity q was transacted by agents settled in *s*, under structural condition *r*. Obtaining the distribution of *q* by positions *ij* indicates the proportion of *q* that was transacted by agents *ij*.

Chart 13 | Bioeconomy GDP in the LAM states in base year 2020, and projected for 2050 under the different scenarios

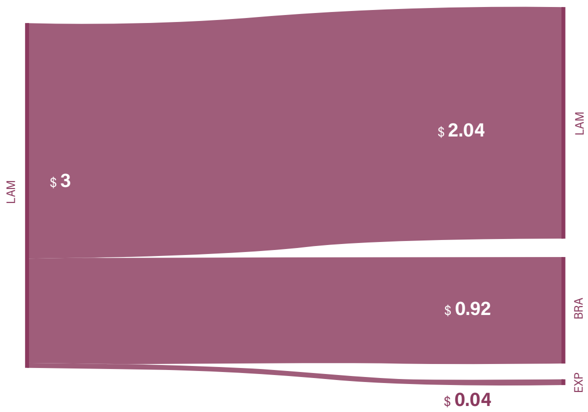


Note: Results from the study.
Source: Authors.

Two observations are relevant. First, the IOM-Alpha results show that 23% of VA is formed in local intermediate consumption and 15% in local final consumption, unlike the IIOM-LAM, which indicates that local demand holds a small share of total demand for non-destructive extraction products. This difference is explained by the fact that the IOM-Alpha has greater reach in the invisible economy, and because it includes primary sectors not restricted to plant extraction. The IOM-Alpha delves into the traceability of plant extraction products as well as those derived from agriculture and livestock activities, differentiating small production systems from monocultures of Amazonian products, while also covering occupations in the secondary and tertiary sectors, including informal activities.

The method combines the identification of formal activities (association of the Individual Microentrepreneur category with description of activities related to biodiversity products) and VA apportionment by region and productive structure. A breakdown of demand shows that 68% of GO comes from inside the LAM, 31% from the rest of Brazil and only 2% from exports, as illustrated below.

Chart 14 | Bioeconomy GO by source of demand in the LAM's economic transactions ($ billion)



Note: Results of the study.
Source: Authors.

Table 15 | IOM-Alpha for the Legal Amazon in 2020 (in $ million)

Description	Intermediate demand														Final demand				Final production
	Local system						State system				National system				Regional		National		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Households	Gross capital formation	Rest of the country	Exports	
Production	10	348	138	1	23	9	2	0	30	2	6	-	0	0	20	9	0	2	601
Rural retail	-	0	96	0	175	3	92	0	25	2	2	1	11	1	5	-	-	-	413
Local processing industry	-	-	1	1	0	1	12	0	4	1	-	1	1	211	302	-	-	9	545
Local transforming industry	-	-	-	-	1	4	-	-	0	1	-	-	-	1	9	-	-	-	16
Local urban wholesale	-	0	8	2	0	5	19	10	6	0	-	234	-	0	2	-	-	2	288
Local urban retail	26	-	24	0	-	0	4	-	-	-	-	-	-	-	50	9	-	-	112
State processing industry	-	-	-	-	-	0	-	14	12	28	-	-	-	403	101	-	13	32	604
State transforming industry	-	-	-	-	0	4	1	0	13	14	-	-	-	20	1	1	4	-	58
State urban wholesale	-	-	1	0	3	45	69	12	0	58	-	17	-	-	16	-	-	-	221
State urban retail	-	-	0	0	-	0	23	3	-	0	-	-	-	-	119	7	-	-	153
National processing industry	-	-	-	-	-	-	-	0	-	-	-	120	-	0	-	-	19	-	140
National transforming industry	-	-	-	0	4	0	3	0	72	1	-	-	60	291	-	-	2	-	434
National urban wholesale	-	-	0	0	2	14	-	-	27	22	5	0	-	14	0	-	-	-	85
National urban retail	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,438	13	1,451
Total inputs	35	349	269	4	208	85	225	41	189	128	13	373	72	942	625	26	1,476	57	5,119
Added value	566	64	275	11	79	27	379	17	32	25	127	62	12	509					
Salaries	33	33	36	1	23	9	40	4	18	12	11	36	12	126					
Profits	533	31	239	10	57	18	338	13	14	13	115	26	1	383					
Gross income	601	413	545	16	288	112	604	58	221	153	140	434	85	1,451					
Employment (jobs)	57	1	1	0	1	0	1	0	1	0	0	1	0	5					
Wage earners	4	1	1	0	1	0	1	0	1	0	0	1	0	5					

Source: Authors.

The second observation is that the bioeconomy considered in this study is restricted to currently known fresh and manufactured products from food, pharmaceutical and cosmetics industries, and to established processes and products (similar to the IIOM-LAM). Thus, because of model limitations, the study does not consider the revolutionary potential of the Bioeconomy 4.0, where the convergent use of cutting-edge technology and traditional knowledge results in the replacement of non-biodegradable inputs and development of high value-added products. In the assessment restricted to the consolidated bioeconomy, two main primary products and their secondary and tertiary chains stand out: acai and cocoa, responding for more than 85% of VA of the entire bioeconomy, and further detailed in the following sections.

3.2 Development of bioeconomy chains in the Amazon

3.2.1 The acai chain

The acai chain in the state of Pará is an example of how a local product can spark the creation and expansion of a sector. The acai berry chain generate, through the multiplication of single production units, a forest conservation system that adds value to the territory. Acai production successfully advanced in the outskirts of urban centers and rural communities, generating income for all links in the production chain as a result of innovation involving specific machinery and a heterogeneous dissemination of commercialization points. In this sense, it provides an example of an urban economic activity focused on a forest product.

Amazon cities played a pivotal role in the development of this economic activity, as mediators in the process of creation, dissemination and consolidation of innovative technologies. These innovations brought scale gains to the local economy, with expansion of input and equipment markets and increased productivity, diversity and diversification (Bartoli, 2018).

The first step in the evolution of acai's market expasion involved the mediation of knowledge held by traditional acai producers and the Belém upper classes' desire to consume the fruit without quality loss (Calzavara, 1972; Ribeiro, 2016; Rodrigues, 2006; Rogez, 2000; Silva, 2017; 2021). This interaction started in the 1950s, inspired by techniques from the 19th century. At the time, the vertical axis manual pulper was invented (Schwob, 2012), an innovative machine capable of gently processing the acai berry while preserving the fruit's locally preferred flavor. To this day, it is the most commonly used equipment among artisanal acai beaters.

This process unfolded and contributed to the expansion of acai consumption in Belém and nearby urban centers. Pulp sales points appeared, particularly on the outskirts of Pará's capital. This gain in scale contributed to the maintenance of acai consumption in the urban diets of areas with rapid population growth, such as Belém in the 1970s[19] (Silva H., 2021; Ventura Neto et al., 2020). It also led to an increase in the number of beaters and the expansion of sales to street fairs throughout the Amazon River estuary, with unchanged flavor and density characteristics (Brondízio, 2004).

The region's urban centers have thus become important mediators in the creation, dissemination, and consolidation of new technologies, allowing scale gains, expansion in input and equipment markets, increased productivity and diversity and diversification gains to the local economy. As a result, the urban centers have become hubs for the development of new infrastructure and wider access to such products and associated services, leading to growth in scale an expansion of production and commercialization of both acai fruit and pulp.

The production and distribution networks combined with the technological progress of small producers and agro-extractivists proved to be sufficiently resilient and widespread in the territory. These two characteristics are important to strengthen the production and distribution of other Amazon biodiversity products that share the same seasonally diverse productive structure, with acai processing potentially taking place alongside the production of oils, fibers, vegetable fats, etc.

As the links in the acai chain evolve and gain complexity and depth, followed in this process by acai consumption habits among the urban population of cities like Belém, a new cycle of densification and further development and expansion of the acai production and commercialization chain will take place. Which, to a large extent, has been driven by the process of expansion of the fruit's processing and consumption.

In this sense, the region's urban centers assume a dual role: on the one hand, they expand as consumer markets; on the other hand, they serve as mediation centers for the development and experimentation of new products and processes at a pace compatible with the expansion in local diversity.

The market for acai outside the Amazon gained popularity from the 2000s onwards. At that time, researchers and public managers at state and federal levels understood the strategic significance of the chain in its support to regional development based on the sustainable use of the Amazon biome. Although the bioeconomy concept was not discussed at the time, its main themes were already present in the debate.

Costa et al. (2006) pioneered an investigation of what would come to be conceived as the emergence of a new Local Productive Arrangement (LPA) for fruit processing, with the appearance of pulp industries in northeastern Pará and in the metropolitan region of Belém (Costa et al., 2010; Costa, 2012).

What may seem like no more than the expansion of a certain market was, in reality, a competitive conflict between two very different productive arrangements. On the one hand, there was an arrangement based on thousands of small production units spread across the territory that preserved pulp production techniques, meeting local preferences and generating employment and income for the population. On the other, large industrial units emerged with production processes and product presentation that followed export standards disconnected from local taste, with wealth creation escaping to other regions. Nicknamed "açaização", this productive arrangement is characterized by monoculture production, contrary to the bioecological bioeconomy principles.

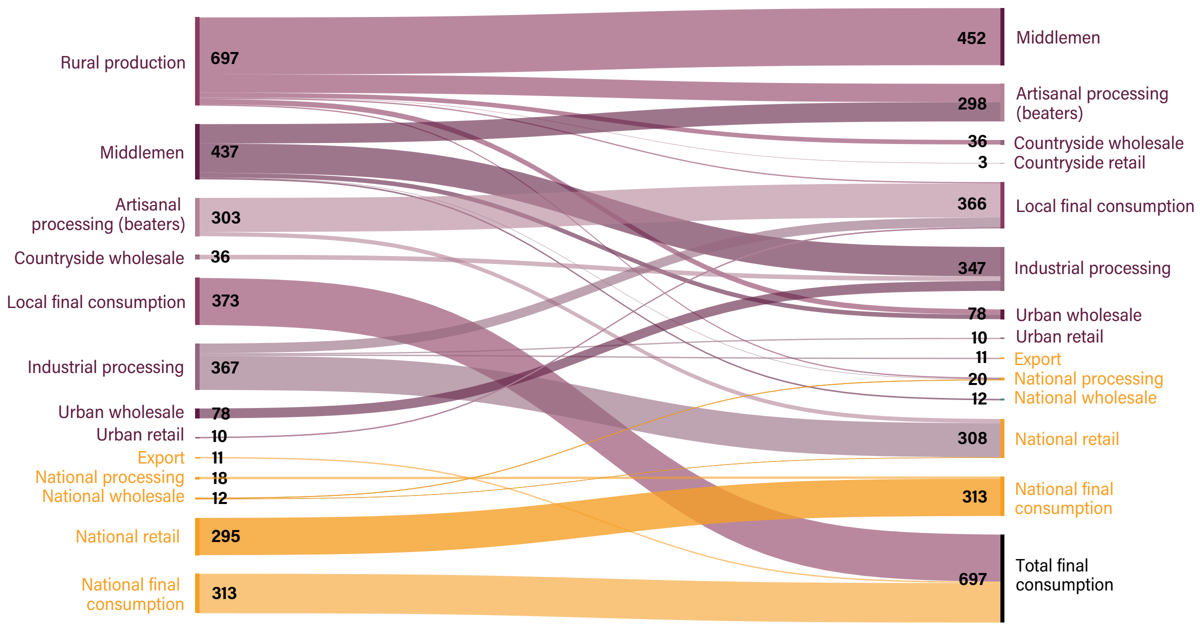
The acai chain is an example of the connection between products from the standing forest and the urban economy. Photo: Paralaxis/Shutterstock.

Production data from Vegetal Extraction and Forestry (PEVS) indicate that, in 2020, permanent crops accounted for 87% of the acai chain's GO. Vegetal extractivism corresponded to 13%. However, in a paper produced in the mid-2000s, Brondízio (2004) discussed the difficulties and uncertainties regarding the categorization of establishments and classification of acai production as extractive or agricultural. Brondízio (2004) highlighted that the persistence of extractive production and its relative importance in terms of produced volumes, combined with the inadequacy of the binary classification (extractive versus agricultural), posed challenges for a more nuanced analysis of the activity[20]. In fact, reflecting such problems, official data (IBGE, 2019)[21] available for the activity still produce limited historical series.

On the other hand, the methodology involving Matrices based on Social Accounts is capable of a more granular analysis of acai production, categorizing it differently from IBGE. The IOM-Alpha considers two concurrent production arrangements for acai. The first is focused on demand from outside the LAM while the second focuses on local supply, both of which are beneficial to the region.

Middlemen and wholesalers operating in the countryside are responsible for supplying the pulp industry, which, in turn, supplies foreign markets. The relationships between middlemen, countryside wholesalers and industrial processing companies form the productive arrangement operating in regions outside the LAM. The relationship flows between the different actors in the acai chain are shown below.

Chart 15 | Product flows of the acai pulp value chains (t)



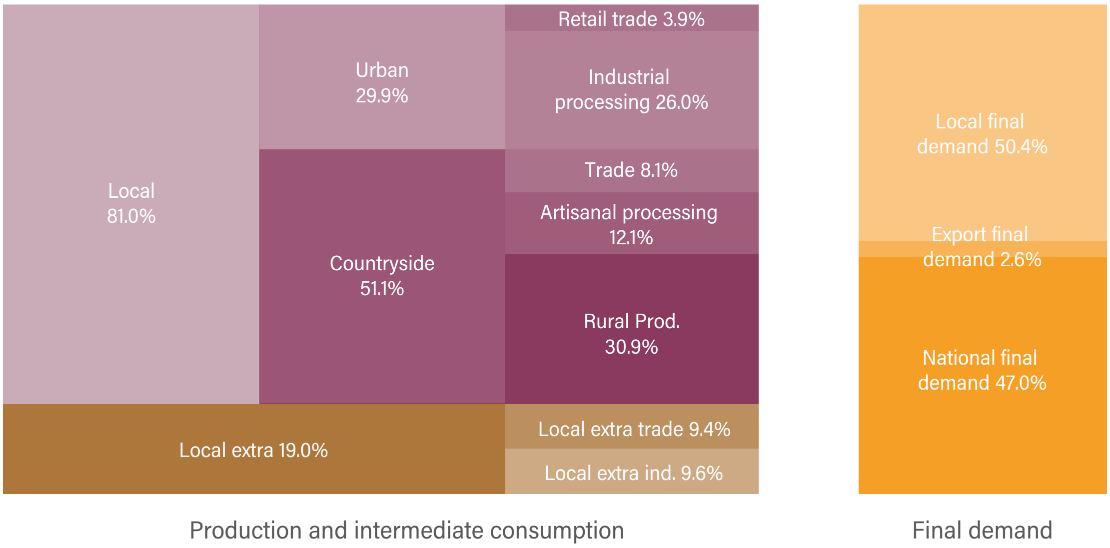
Source: Authors based on data from the Alpha Social Accounts.

The productive arrangement aimed at external markets processes 47% of total production, generating 49.6% of GO (47% in the domestic market and 2.6% in the international market). This arrangement generated VA of approximately $ 941 million. Industrial pulp processing is at its core, and is responsible for the largest share of VA in the entire chain ($ 242 million, around 25% of the total). The registration of active companies at the Brazilian Internal Revenue Service (Receita Federal Brasileira; RFB, from its initials in Portuguese) indicates that industrial processing plants are concentrated in the Guajará Integration Region, followed by Tocantins and Guamá (Belém). Urban zones allow interaction between scale and stability of consumption and densification of social and technical division of labor, and of networks of agents linked to the acai value chain.

Artisanal processing carried out by acai beaters meets 80% of the local demand for pulp, a daily consumption item in Pará. To meet the local demand, beaters purchase the fruit directly from producers or buy from middlemen their inventory that has not been sold to the industry. These interactions form an inward-focused productive arrangement.

As shown in the chart below, the inward-focused productive arrangement processes 53% of the collected fruits, corresponding to 51% of VA. Out of a total of $ 216 million, beaters are responsible for around $ 109 million. When considering the total VA of the two arrangements, it is possible to see that 81% of the aggregate is generated in the economy of the state of Pará. That is, Pará's economy, in addition to the volumes produced and consumed locally, still absorbs 49.6% of the value produced by other LAM states. Acai thus proves to be an important contributor to the dynamism of the regional economy, with a strong participation of exports. Chart 16 illustrates the relationships described.

Chart 16 | VA distribution by income and product destination in the acai fruit chain



Source: Authors based on data from the Alpha Social Accounts.

Considering the açaí economy from the perspective of job creation, there was a total of 164.4 thousand jobs in the chains and local production arrangements in 2020. Of this total, 86% were jobs in rural production. An additional 2% of jobs were created in primary intermediation, that is, middlemen. In artisanal pulp processing, the so-called beaters held 3% of total jobs. Industrial processing accounted for 3% of total positions and non-local economies for another 5%.

The intensity of the labor factor in the acai chain is positive. This fact, which at first may seem like a sign of precariousness, perhaps points to a new type of relationship with land use. This is because the transition processes of primary (agro-extractivist) production characterized by labor-intensive conditions show a higher predominance of technologies used to homogenize production and space. However, it is difficult to reconcile this homogenization process with economies based on sociobiodiversity.

In short, when analyzed from a general point of view, the acai chain in Pará meets the requirements of the Amazon bioeconomy. It has deep local roots, and applies traditional knowledge such as acai management, improving it with technological innovations such as the pulping machine. It also creates numerous and widespread jobs, most of which within the territory. Finally, it absorbs the wealth generated by the product with an additional 49.6%.

3.2.2 The cocoa chain

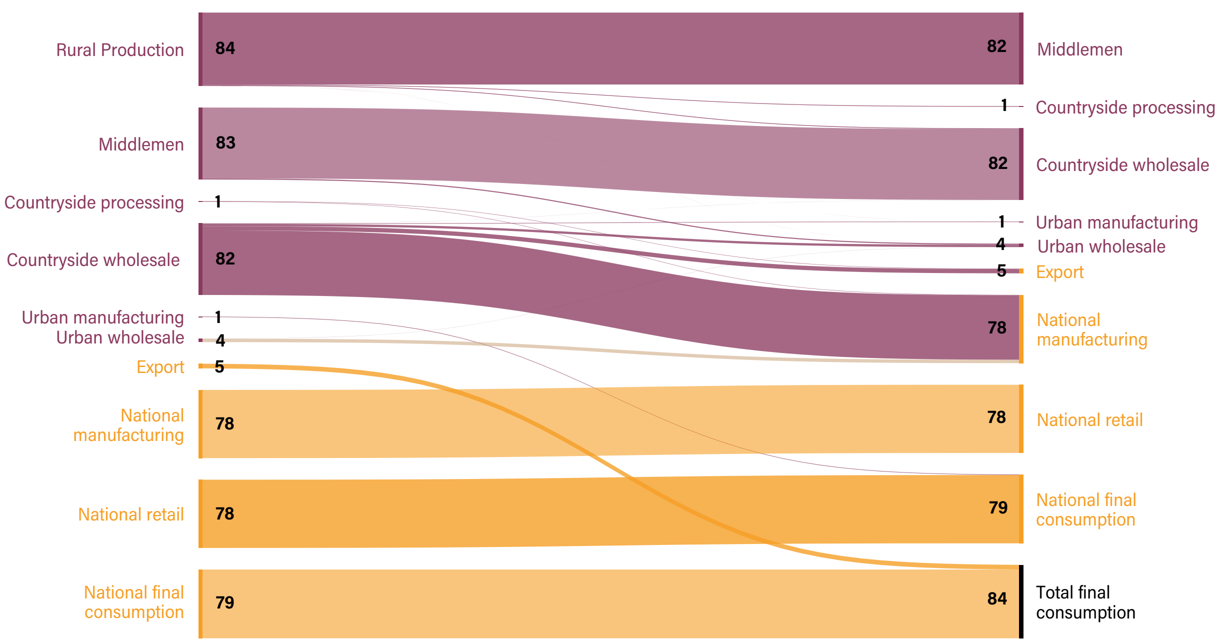
The cocoa chain depicts a forest product's economic trajectory that differs from that of acai. This chain illustrates a native product's failure, due to its production and commercialization process, to conform to a bioeconomy that values biological and social diversity and creates wealth that remains in the territory, benefiting local populations. Unlike the acai chain, cocoa-related activities do not reach all social strata and have not experienced technological improvements in fruit management and production processes.

In the Brazilian territory, cocoa is mainly produced in Pará (49%) and Bahia (45%). The 2017 Agricultural Census listed 93 thousand producing establishments in the country. Family farming plays an important role and is responsible for 75 thousand establishments. The activity employed 160 thousand people in family farming and 46 thousand in non-family farming, totaling 206 thousand workers.

In terms of volume, cocoa bean production reached 160 million tons in a harvested area of 504 thousand hectares[22]. Family farming was responsible for 57% of this total, in 51% of the area, with an average yield of 286 kg per hectare and GO of $ 118 million (55%). The cocoa plantations in the Baixo Tocantins region stand out in the state of Pará. They use native regional seeds, cultivated in shaded agroforestry systems, intercropped with other economically valuable species. In 2019, 4.1 thousand tons were harvested in 9.6 thousand hectares (428 kilograms per hectare).

In Pará, cocoa producers mainly access the value chain through middlemen operating in the countryside, who purchase 98% of beans. Local production of manufactured products, which includes chocolate, is very restricted, isolated and lacking scale effects. Thus, although small producers hold a very large share in the chain, permeability only occurs in the primary sector, in such a way that all upstream sectors funnel into large companies. Chain flows are illustrated in Chart 17.

Chart 17 | Product flows of the cocoa value chains in 2020 (t)



Source: Authors based on data from the Alpha Social Accounts.

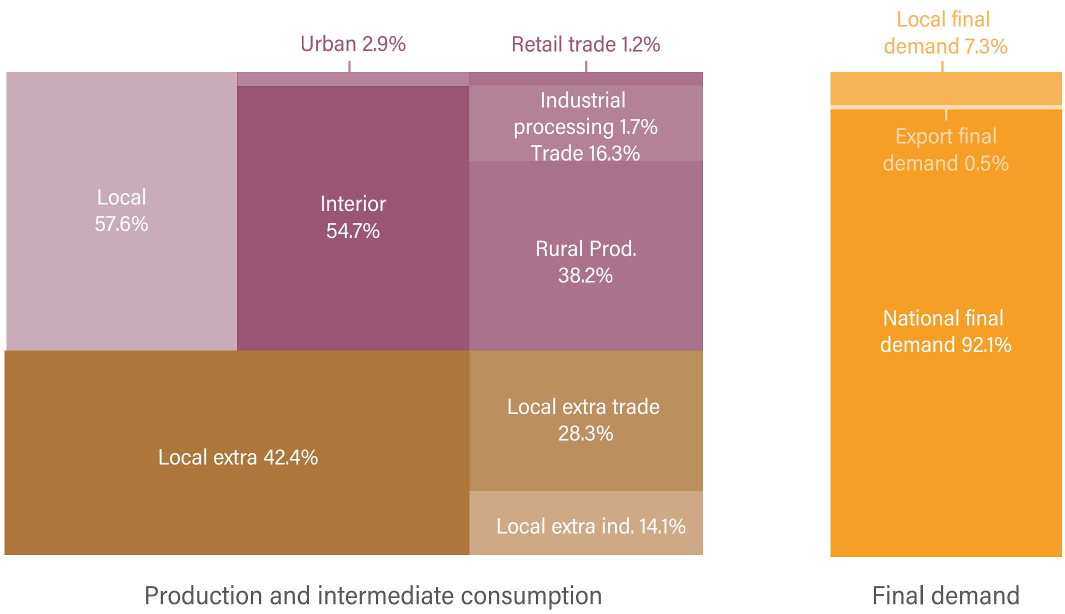
Middlemen and wholesalers act as mediators between the local economy and exports to domestic and international markets. Wholesalers lead this link in the chain. The Brazilian Internal Revenue Service's database indicates a total of 356 companies dedicated to the wholesale trade of cocoa in Pará. Almost half (48.5%) is located in the Xingu Integration Region, mainly in the municipalities of Medicilândia and Altamira. This region is followed by the Tocantins and Guamá regions, with just over 9% each. In the Xingu portion located in Pará, where production is significant, national and international traders have established milling units (Mendes, Mota e Silva, 2018).

Compared to the acai chain, the cocoa chain is less dense and less capillary. One chain's structure is almost the opposite of the other, in part because the biochemical characteristics of acai require rapid processing after harvesting. Cocoa, especially cocoa beans, do not require processing equipment with the same level of technological complexity. Not by chance, the cocoa chain's urban economy is dominated by logistical and commercial activities carried out by wholesalers. Despite the obstacles, initiatives have been emerging in the main producing regions of the state of Pará to verticalize the cocoa chain.

The domestic industry processed 93% of Pará's cocoa bean production (6% is processed by the international industry) and withheld $ 41.2 million in VA. Retail absorbed $ 123 million. Primary processing is concentrated in four large global companies, which controlled 65% of the market and two thirds of the milling capacity in the period from 2006 to 2015 (Amiel et al., 2018, p.12 apud Carimentrand, 2020). In recent years, these four groups have expanded their activities in Pará cities (Altamira, Medicilândia, Uruará and Belém), but most of cocoa processing into chocolate derivatives takes place outside the Amazon, mainly in industries located in southern Bahia and in São Paulo.

Nevertheless, the number of micro and small manufacturers of cocoa derivatives and chocolate has grown. Individual entrepreneurs predominate (96%), a group that grew by more than 13% per year over the past decade, with almost 1.3 thousand additional companies in 2019 compared to 2010. In terms of the labor market, the cocoa economy generates 98.4 thousand jobs in Pará (82% linked to rural production, 8% in local trade and industry and 10% in national trade and industry), as shown in the chart below.

Chart 18 | **VA distribution by income and product destination in the cocoa fruit chain**



Source: Authors based on data from the Alpha Social Accounts.

Drawing a parallel between the two chains, the acai chain is characterized by endogenous development, that is, the local and regional consumer market has played an important role in consolidating the product, both by creating constant demand and by expanding the market to different points of sale in Belém's outskirts and surrounding regions.

On the other hand, the cocoa chain, developed to supply exogenous demand, has not produced similar effects. Amazon cities have not played a substantial role in this case, with no significant ramifications of innovation in cocoa production and distribution processes, so that the main cocoa bean processing points are currently located outside the LAM.

3.2.3 The restoration chain

Forest and Landscape Restoration (FLR) is a globally used term that refers to a set of strategies and practices for climate change mitigation and adaptation, particularly through the restoration of ecosystems and the implementation of agroforestry systems (Chazdon et al., 2016; Alves et al., 2022). FLR is closely linked to the bioeconomy, precisely because it is based on the expansion of native vegetation cover and agroforestry systems – largely representd by acai and cocoa in the LAM.

The positive effects of FLR extend far beyond agroforestry systems. The recovery, management and conservation of ecosystems rehabilitate landscapes in the provision of ecosystem services, which are essential to economic production. FLR strategies are among the most cost-effective for carbon sequestration and storage, in addition to the provision of ecosystem services such as climate regulation and rainwater irrigation (Fagan et al., 2020).

It is globally accepted that decarbonizing the energy mix without creating new sources of carbon sequestration and storage is not enough to achieve the Paris Agreement's targets, which has sparked commitments to massive restoration of ecosystems and recovery of degraded areas. The Bonn Challenge, a global initiative launched in 2011, brings together a series of national and international commitments – with Brazil as a signatory –, aiming to recover 350 Mha by 2030. In 2020, around 170 Mha had already been globally committed to restoration, with additional 230 Mha under negotiation, combined with voluntary initiatives. These numbers indicate a clear possibility that the Bonn targets are exceeded (Fagan et al., 2020).

Soil recovery work in forest restoration.
Photo: IDESAM.

In line with the global challenge of curbing global warming to 1.5°C, as shown in Chapter 2, achieving the accumulated net emissions target of 7.7 $GtCO_2$ by 2050 – possible only in the NEA scenario – requires not only the elimination of deforestation and transformation of the energy mix, but also the restoration of 24 Mha of native vegetation in the LAM to increase the capacity to capture carbon and neutralize unavoidable emissions – such as enteric fermentation resulting from livestock production, as shown in Chapter 4, and some fossil fuel sources that remain beyond 2050. Another 1.5 Mha additional to the BAU scenario would be dedicated to agroforestry systems.

Brazil already has a legal framework in place – the Law for the Protection of Native Vegetation, the Forest Code (Federal Law No. 12,651/2012) and PLANAVEG (Brazil, 2017) – and has already assumed different global commitments that include the restoration of landscapes and forests. The first NDC, presented in 2015, foresaw the restoration of 12 Mha of native vegetation, the recovery of 15 Mha of pastures and the implementation of 5 Mha of integrated and agroforestry systems. Although the subsequent updates carried out in 2020 and 2021 do not include these targets, they remain relevant, and are required under the Forest Code and PLANAVEG. In the LAM, restoration requirements to comply with the Forest Code total approximately 6.3 Mha (2013 survey, presumably outdated), which represents only one third of the area to be restored under the NEA scenario (Imaflora, 2023).

It is important to mention that changes made in the respective law in 2012 drastically reduced the deficits in Permanent Preservation Areas (PPA) and Legal Reserves (LR) established by the previous law (Law No. 4,771/1965), consequently reducing the areas subject to mandatory restoration. In the LAM, changes in the law reduced such areas by 9.1 Mha (Soares-Filho et al., 2014). Even if legal restoration was still ruled by the previous law, commitments of 15 Mha would result, 9 Mha short of the required restoration for carbon neutralization.

Box 14 | Agroforestry systems have already achieved commercial success in the Brazilian Amazon

WRI Brasil's Verena project aimed to demonstrate the economic viability of investments in silviculture with native species and Agroforestry Systems in Brazil. The project includes the case of Cooperativa Agrícola Mista de Tome-Açu (Camta). Agricultural crops adapted to Amazon conditions through agroforestry systems are currently produced and commercialized. This model is supported by the maintenance of different crops that generate income in a given area, forming a successive production chain in the short, medium and long term, with priority to cocoa, acai and andiroba crops, but including the production of other fruit pulps, black pepper and wood species.

Source: Authors based on Batista et a. (2021).

FLR commitments exceed legal requirements and environmental targets. An IPCC report highlights that FLR is also vital for food security. The fundamental conditions for improved food security include the production of more food where there is notorious scarcity, promotion of moderate demand habits, greater efficiency in the use of production factors and strengthening of governance in all spheres of supply, demand and access to food. In the context of climate change, this implies restoring degraded areas, scaling agroforestry systems with local knowledge, inputs and preferences, prioritizing the conservation of water sources and aquifers, reinforcing the conservation and restoration of native vegetation and associated ecosystem services, disseminating low-impact agricultural practices, and scaling up incentive systems, credit and cross-subsidies for sustainable systems, as well as traceability and certification of origin schemes (Mbow et al., 2019).

As shown in the NEA scenario, eliminating deforestation, and promoting restoration create a series of economic and environmental benefits, including the increase in ecosystem services. As estimated in Chapter 2, compared to base year 2020, a 5% increase in the carbon stock, a 4% decrease in water availability and a 5% decrease in soil nutrient losses are expected. The benefits over the BAU scenario are much more pronounced, with 19% higher carbon sequestration, 13% lower surface runoff, and 16% and 18% lower nitrogen and phosphorus losses, respectively.

Economic and employment impacts would also be substantial. This report estimated investment needs around $ 42.2 billion by 2050, with the generation of 521 thousand jobs. In seed collection alone, 9.2 thousand permanent jobs would be created for indigenous people, generating income close to $ 53 million and $ 79 million in total revenue, while another 12.1 thousand permanent jobs would be created in the production of seedlings, with total gross revenue of $ 9 billion.

It should be noted that, as highlighted in Chapter 2, the investment needs and jobs created in restoration are the only exogenous values, estimated from the models' results that indicated the need to restore 24 Mha of native vegetation. Due to a technical limitation, the revenues generated by the restored forest were incorporated into the bioeconomy chain (non-destructive extractivism with productivity and prices identical to base year 2020), while the restoration implementation costs were considered external to it, but belonging to the restoration chain, as the work involved in the establishment of a forest base on which the bioeconomy is developed. In this sense, investments in restoration are identical to implementation costs (from the standpoint of demand for restoration) and revenues (from the standpoint of supply of restoration). For simplicity, restoration for commercialization of timber products was not considered.

To restore the referred 24 million hectares, Assisted Natural Regeneration (ANR) was chosen as the predominant restoration method – a method that can be limited to fencing the area in order to minimize disturbances in the regenerative process, as is the case of ANR based only on fencing, and can also include enrichment with seedlings, as is the case of ANR with enrichment. These methods are more cost-effective and suitable for the LAM in landscapes with a fragmented matrix, but with high frequency of forest remnants (see Box below). This was followed by the distribution of restoration methods of scenario 5 by Urzedo et al. (2020). Table 16 details the distribution of restoration for the 24 Mha, according to the method used.

Table 16 | LAM restoration in the NEA scenario, by restoration method

	Total planting or seeding		Assisted natural regeneration (ANR)		Total
	Total planting (muvuca)	Total seeding	ANR with enrichment	ANR with fencing	
Area (ha)	4,875,463	243,773	6,094,329	13,163,751	24,377,317
Participation	20.00%	1.00%	25.00%	54.00%	

Note: Results of this study.
Source: Authors adapted from Urzedo et al. (2020).

Demand adapted to each restoration method was estimated to define the quantity of seeds needed, with prices defined by Urzedo et al. (2020) and adjusted by the IGP-M, while the total revenue (or total cost of seeds demanded) was calculated based on the average value of $ 10.67 per kilogram of seeds, obtained in consultations with four seed networks. Table 17 shows the quantity of seeds demanded, as well as seed-related jobs and income.

Table 17 | Jobs and income related to seed collection in the NEA scenario

Restoration method (kg of seeds required)				Collection jobs	Technical, operational, commercial jobs	Total revenue ($ thousand)
Total planting	Muvuca	ANR with enrichment	ANR with fencing			
1,251,044	5,640,911	512,533	0	8,114	1,182	79,006

Note: Results of this study.
Source: Authors adapted from Urzedo et a. (2020).

The amount of required seedlings was determined by adapting Silva et al. (2015), adopting prices adjusted by the IGPM, considering benchmark values for the North Region, as well as revenue generated by the sale of 75% of seedlings at wholesale prices and 25% at retail prices. Jobs were estimated by the creation of a linear equation between jobs and production volume throughout Brazil, given the current absence of nurseries with production above 120 thousand seedlings per year in the LAM. The results are shown in Table 18.

Table 18 | Estimated jobs and revenue in the production of seedlings in the NEA scenario

Required seedlings (millions of seedlings)	Nurseries (average capacity of 120 thousand seedlings/year)	Production jobs	Technical, operational, commercial jobs	Total jobs	Total revenue ($ million)
11,749,866,794	3,264	8,904	3,221	12,125	8,963,25

Note: Results from this study.
Source: Authors adapted from Silva et al. (2015).

Box 15 | Assisted Natural Regeneration to scale up restoration in the Amazon

ANR has the potential to generate important social and economic results. The low-cost technique was used by producers seeking to recover PPA and LR areas and gain access to credit lines and markets.

In Mato Grosso, Instituto Centro de Vida together with family farmers linked to the milk, horticulture, cocoa, and coffee chains were able to access resources and obtain organic certification after regaining compliance with the Forest Code. Environmental compliance resulted in the recovery of more than 100 hectares and benefited 600 families.

Other examples of the use of ANR can be found in the municipality of Paragominas in Pará. With support from Imazon, rural landowners opted to regularize their native vegetation deficit through ANR. One of the farms expanded its restoration area from 66 to 757 hectares. The main intervention was limiting cattle access to the areas under recovery. The forest is able to regenerate when degradation pressures are eliminated.

Source: Authors based on Alves et al. (2022).

Finally, the values for the full chain were considered as the total cost per restoration method, adopting prices from Silva and Nunes (2017) at values adjusted by the IGP-M for 2020, while the total number of jobs was calculated with the labor intensity of GO in activities related to forest production, with employment based on the average number of jobs in the past five years in native and planted forest production and support to forest production (MTE, 2020) and GO of extractivism and forestry activities as measured by IBGE (2022). Table 19 presents the final results.

Table 19 | Total cost and jobs in the restoration chain in the NEA scenario

Total Planting ($ million)	Muvuca ($ million)	ANR with enrichment ($ million)	ANR with fencing ($ million)	Total ($ million)	Total jobs
15,675	11,683	131	14,757	42,246	519,648

Note: Results of this study.
Source: Authors.

For the BAU scenario, the amount of secondary native vegetation was initially estimated through regression conducted with historical time series for the 1987-2020 period in Mapbiomas (Mapbiomas, 2022), applied to this report's total vegetation results for 2050, indicating 25.7 million hectares of secondary vegetation in 2050. Subsequently, a regeneration age equal to or greater than 30 years was considered for 6.23% of this total, also according to Mapbiomas (2022), reaching a total of 1.57 Mha for ANR with fencing. For the other methods, the average amount of seeds produced in the LAM was considered, according to Urzedo et al (2020), and this average projected for all years in the period 2020 - 2050 and distributed among the other restoration methods, as carried out for the NEA scenario. Details are shown in the following tables.

Table 20 | LAM restoration in the BAU scenario, by restoration method

	Total planting or seeding		Assisted natural regeneration (ANR)		Total
	Total planting	Total seeding	ANR with enrichment	ANR with fencing	
Área (ha)	243,223	12,161	304,029	1.574,633	2,134,045
Share	11.40%	0.57%	14.25%	73.79%	

Note: Results of this study.
Source: Authors.

Table 21 | Total cost and jobs in the restoration chain in the BAU scenario

Total Planting ($ million)	Muvuca ($ million)	ANR with enrichment ($ million)	ANR with fencing ($ million)	Total ($ million)	Total jobs
1,466	1,093	12	1,765	4,336	53,271

Note: Results of this study.
Source: Authors.

Indigenous man performing traditional weaving, state of Amazonas. Photo: Leandro Reichert/Shutterstock.

3.3 Indigenous bioeconomy: a description based on the active listening of its protagonists

Despite advances in the popularization of discussions on bioeconomy, global and national debates on the subject have not sufficiently recognized the productive advances in bioeconomy led by indigenous peoples and traditional populations. This distortion needs to be remedied, considering that the sustainable economy in indigenous territories allows these peoples to continuously contribute to the preservation of natural vegetation in their territories, and to their cultural legacy. For Brazilian indigenous peoples, the word bioeconomy is just a new way of describing traditionally practiced production models, fundamentally based on the respect for nature (Costa et al., 2022).

Despite the fact that this economic modality is already practiced in such territories, it is little documented in the scientific literature, and its protagonists – indigenous entrepreneurs, associations, cooperatives and leaders – are often not consulted about their initiatives and challenges. In an effort to reduce this information and representation gap, this report presents the results of a survey that covered initiatives located in nine states of the Brazilian Amazon. This research effort seeks to complement the available literature, offering a sample record of interviews carried out with 42 indigenous people from the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, Maranhão and Tocantins. The record focuses on productive activities and the obstacles perceived by indigenous people to their performance.

Oral history research was chosen as the most appropriate way to record data from the perspective of the LAM's native peoples on the subject of economics, seeking to preserve the ideas, reasoning and expressions used by them. The interviews were conducted through semi-structured questionnaires, applied in person and online. 37 of these took place in person at the 2022 edition of Acampamento Terra Livre, an event promoted by the Articulation of Indigenous Peoples of Brazil (Articulação dos Povos Indígenas do Brasil; APIB, from its initials in Portuguese), the largest event of the national indigenous movement. The remaining questionnaires were applied online. The majority of respondents are leaders (men, women, young and old) directly involved in productionve activities developed in indigenous lands.

Respondents were heard in relation to the following topics: perceptions about the term indigenous bioeconomy, existing economic activities in indigenous territories, difficulties in consolidating these activities, perceived impacts of climate change in their territories and proposals for improving the indigenous economy in the Amazon. The following section presents the results of this process of active listening, organized according to the consultation topics.

Respondents came from different territories in eight states of the Legal Amazon, as shown in the next figure.

Box 16 | Sampling design of interviews with indigenous people

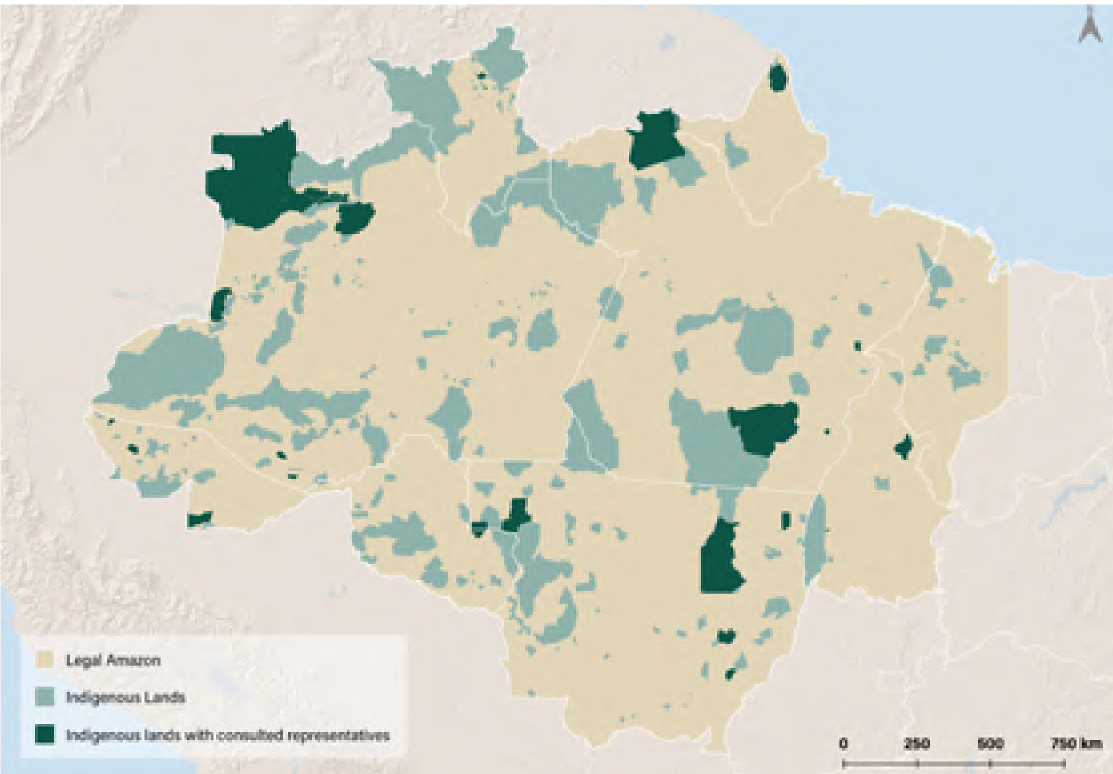
The research was not intended to be used for statistical analyses. The cultural diversity of the LAM's native peoples inhibits this type of ambition. In this sense, the sampling was determined by a search for representatives from all LAM states in the Amazon and Cerrado biomes, selecting people recognized by leaders as legitimate to speak about economy and bioeconomy matters within their territories.

The questionnaire was formulated by the indigenous and non-indigenous authors of this report, not seeking an exhaustive sample, information redundancy or saturation , but only seeking to qualify the sample and, in some cases, indicate frequencies, a useful method when applied to the study of certain groups that are difficult to be accessed, as well as for exploratory research (Vinuto, 2014). Important limitations include: (1) obtaining permission from leaders, in addition to respondents' consent; (2) time constraints related to the duration of Acampamento Terra Livre and (3) difficulty of physical and online access to potential respondents after their return to their territory.

Importantly, the information on indigenous bioeconomy presented in this report is the result of a multiplicity of perspectives and does not indicate consensus. This plurality of visions was a methodological choice in order to reflect the heterogeneity of indigenous communities. This survey intends to initially explore the subject, providing a pathway for future inquiries.

Furthermore, the interviews carried out within the scope of this study were conducted ethically and in compliance with applicable laws. For more information on these aspects, please see the annex to this report.

Figure 8 | Map of the Indigenous Lands represented by the respondents



Source: Authors.

3.3.1 Indigenous economic activities

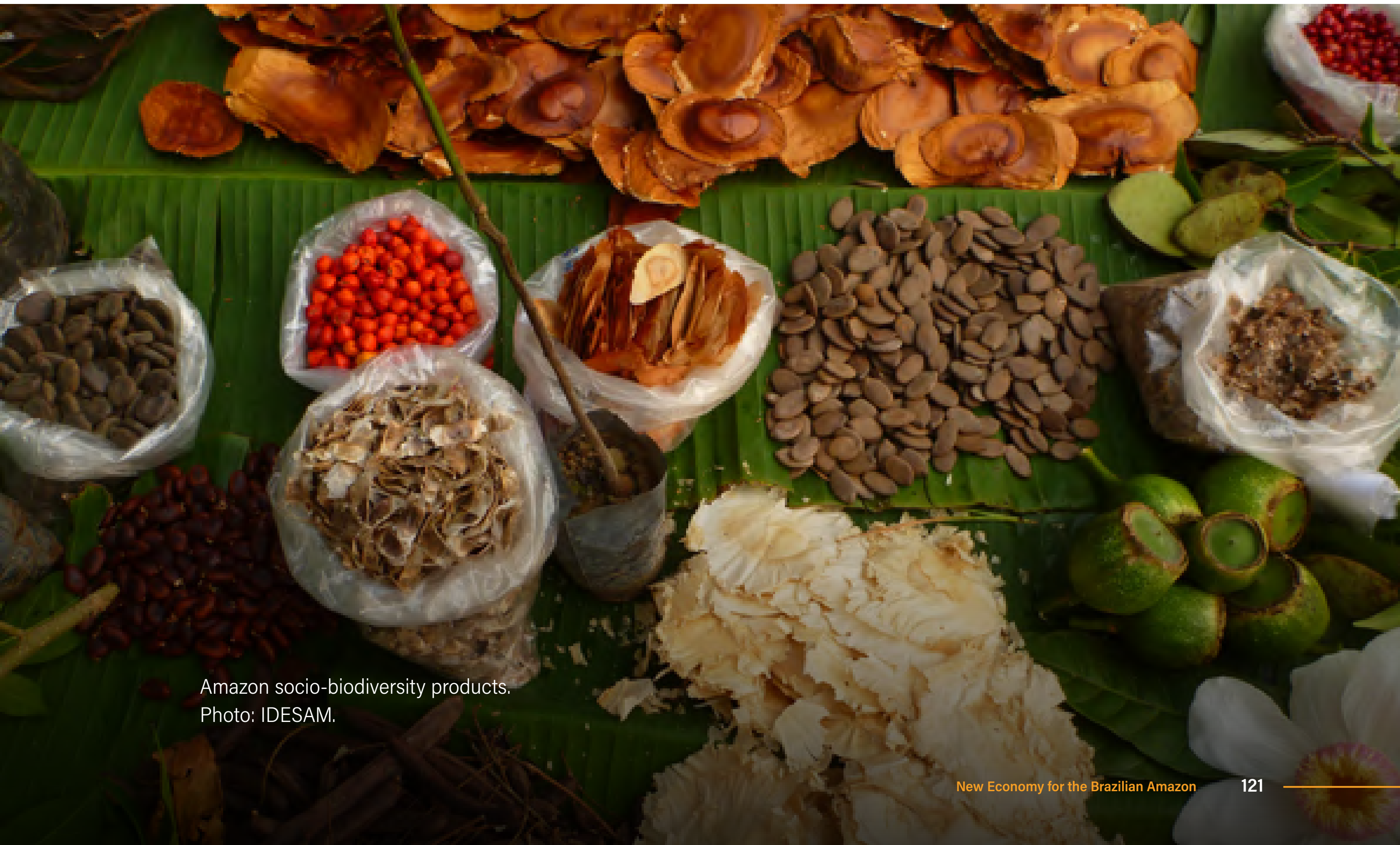
The indigenous economy in the LAM, when guided by traditional values, is defined by the production processes rather than by the products themselves, although the latter are the means by which exchanges between indigenous peoples and with non-indigenous people take place. Land is the means of production that guarantees the necessary inputs and defines the division of labor. There is a great diversity of production arrangements and roles, depending on land use and cover, gender, age and social role of the person responsible for management.

Among the mentioned economic activities, the production of food items, various non-timber forest products and handmade items clearly stand out. It is important to point out that, according to the indigenous people consulted, the distinction between products cultivated in community lands or backyards and extractivism, even between those of plant and animal origin, is well established for some peoples and very tenuous for others, often not even mentioned. Answers were organized in Table 22 to facilitate the understanding of the different types and groups of products.

The bioeconomy is not limited, therefore, to collection, agricultural production, and manufacturing, because there is always an evolutionary relationship between product and process, intertwined by the unfolding of time in nature and in the community's routine.

The productive processes are structured into three main modalities: individual or authorial initiatives; organization into associations, cooperatives, collectives and groups of producers; and initiatives at the family level. In addition to these characteristics, the respondents indicated the presence of community elements as a hallmark of the indigenous bioeconomy, such as benefit sharing, fundraising and dialogue with the ancestral collective heritage. Respondents also cited the cultivation of many varieties of cassava and the production of derivatives (flour, beiju, tapioca and curada) as important indigenous contributions to the bioeconomy of tropical forests. The relevance is not only in the nutritional value of these food items but extends to the role played by the indigenous heritage in the popular culture of the Amazon.

Reports of the main economic activities mentioned were thus collected and organized in the next table.



Amazon socio-biodiversity products.
Photo: IDESAM.

Table 22 | Economic activities mentioned

Type	Group	Responses	Items mentioned in at least 3 interviews
Type Foodstuffs	Farm products	28	Pineapple, Pumpkin, Acai, Peanut, Rice, Banana, Potato, Coffee, Sugarcane, Citrus (Orange, Lemon, Tangerine), Beans, Yam, Cassava, Watermelon, Corn and Pinecone
	Extraction products	6	Acai, Bacaba, Rubber, Buriti, Cocoa, Brazil Nut, Cocão, Babassu Coconut, Cumaru, Cupuacu, Murici, Patawa, Yawalapiti Salt, Tucuma and Urucum
	Oils	3	Andiroba, Copaiba, Pequi, Tucuma
	Beekeeping	3	various native bees
	Peppers	3	various peppers
	Hens and ducks	1	na
	Fishing and fish management	1	na
Manufactures	Handicrafts	17	na
	Flour products	17	cassava flour, cornmeal and curada
Forest Restoration	Seeds	3	na
	Seedlings and forest management	4	na
Other	Cosmetics and body painting	1	na
	Tourism	1	na
	Cryptocurrency	1	na
	Literature	1	na

Note 1: The Responses column indicates the number of participants who mentioned the group of products and services, while the most cited items column presents items mentioned at least 3 times.
Note 2: Results of this study.
Source: Authors.

The "roça" (family or community farm), when so recognized, is described as a multifunctional polyculture system in which food crops, medicinal herbs, dyes, and textile products are combined, all recognized as bioeconomy. Handicraft appears as an important cultural and economic manifestation, with a large participation of women and young people. Fruit and seed by-products collected in primary forests are often used as raw material for this activity.

Fruits and seeds can be consumed fresh, processed as oils or manufactured by cooking or roasting. These products are used for subsistence and for supplying markets outside the indigenous land. Special attention is paid to palm trees (acai, buriti, heart of palm, tucum and bacaba), almonds and nuts (Brazil nut, baru, cumaru and pequi), as shown in Table 22.

Respondents cited many sustainable initiatives that are underway in their territories. The project Rede de

Sementes do Xingu, for example, mobilizes more than a thousand seed collectors, with periodic payments equivalent to one minimum wage. This initiative, which values cultural diversity and indigenous knowledge and is focused on restoration, has the capacity to attract and apply more than $ 140 million towards the achievement of Brazilian NDC targets (Urzedo et al., 2020). The project provides technology incubators for the selection, treatment, and storage of native seeds, based on empirical creativity, with high capillarity. The purpose of the network is to increase native vegetation cover in illegally deforested areas. According to one of the respondents, the restoration economy promoted "provides enough biological diversity of seeds to form a complete forest".

Restoration with bioeconomy characteristics is a visible agenda in indigenous initiatives. The Umatalhi Project (the word means unity and respect in the Yawalapiti language) is an example. Old agricultural lands in the Tuatuari village, in the Xingu region, are being regenerated. Children participate, encouraged to plant species of great importance to their culture. The act of cultivating the forest rescues the spirit of union and respect between the ancestral generations and the Yawalapiti youth.

Among the Baniwa, Kayapó, Borari and Sabanê there are flour commercialization projects with identification of origin, contributing to the visibility and appreciation of the product. The Paiter Suruí people produces organic coffee, which is sold nationally through a partnership with coffee company 3 Corações. Another important initiative mentioned by the respondents is the Selo Origens Brasil (loosely translated as "Brazil Origin Seal'), a collaborative network focused on expanding the market for forest products and promoting the recognition of the Alto Rio Negro Agricultural System as a Brazilian cultural heritage by the Institute of National Historical and Artistic Heritage (IPHAN).

3.3.2 Main difficulties faced by indigenous peoples

When asked about the term bioeconomy, 21% of the indigenous people interviewed said they did not know the word while 31% said that, despite never having heard of it, they would like to know more about it. Only 15% of respondents claimed to know the word, even without identifying themselves as participants or promoters of the bioeconomy. On the other hand, those who said they were developing indigenous bioeconomy in their territories represent 28% of the sample.

However, the interviews showed that there is a language barrier. When the concept of bioeconomy is discussed, the indigenous people have a lot to say about it. From the perspective of indigenous peoples, bioeconomy means sustainability of natural resources and techniques, through ancestral knowledge, which results from the relationship of indigenous peoples with their territories.

Indigenous peoples understand and discuss all matters from outside their villages, but with their own terms and knowledge. Therefore, to discuss any subject, it is essential to take into consideration the reality of their territories. In addition to being guardians of local knowledge, indigenous people acquire new knowledge and adapt to situations. Thus, the productive factor of the bioeconomy is not seen as a problem and can easily fit into the daily practices and culture of these populations.

The problems belong to another dimension: logistics, commercialization, agricultural production, and connectivity. The great distances between the various indigenous lands, and between such lands and other villages or cities, make it difficult for them to travel, both in order to sell products and interact with other communities. The lack of public support for transport and high gasoline prices limit access to markets and force indigenous people to submit to intermediaries (middlemen and dealers), with low negotiating power.

Commercialization is intrinsically related to logistical issues, but it has specific aspects that need to be considered. The most frequent of such aspects is the perception that indigenous products are less appreciated and neglected over similar products sold in conventional establishments, such as markets, fruit stands and greengrocers. Another recurring perception is that resellers practice unfair prices when passing on sales proceeds or buy at very low prices. Absence of product display spaces and incipient ability to present products well (including the use of paper packaging), in addition to inhibiting the capacity for autonomy in direct sales, also appear as additional disadvantages in pricing discussions with resellers.

In terms of production, it is interesting to note that difficulties were listed only in relation to agriculture. Importantly, while some peoples cultivate labor-intensive crops with few instruments other than axes and hoes, others use equipment such as chainsaws, wagons, animal-powered plows, or even small tractors, which means that, under such conditions, barriers to access rural credit and agricultural instruments gain importance. Regardless of the intensity of labor, difficulties in accessing planting and crop management technologies were mentioned more often than the scarcity of credit and inputs, showing that technical guidance, training, and exchange of knowledge are more frequent than financial or material resources.

Other difficulties were also pointed out, such as lack of financial education, which reinforces the perception of the need for training, and restricted access to the internet, an increasingly important element both as a source of information and promoter of new opportunities. As one of the hallmarks of indigenous cultures, the term partnerships is very recurrent in discussions, and in the case of barriers to economic development, it is mentioned in connection with the lack of technical support, but also with investments in existing initiatives that lack sufficient structure and governance to achieve visibility.

Many products based on honey, dehydrated peppers, oils for pharmaceuticals and cosmetics, flours, fruit preserves, Brazil nuts and cumaru were identified as the products with the highest potential, but lacking partnerships and incentives, as well as partners or resellers from the fair trade and solidarity economy, that could support producers' advancement from homemade to commercial production conditions.

The main difficulties are listed by frequency of mention in spontaneous speech as follows.

Cassava flour at the Lábrea Municipal Market, state of Amazonas. Photo: Nilmar Lage/Greenpeace.

Table 23 | **Difficulties in consolidating economic initiatives in indigenous territories**

Topic	Description	Answers
Logistics	Low availability of means of transport and high travel costs	20
	Dependence on intermediaries (middlemen and hawkers)	9
Commercialization	Unfair prices (devaluation of products or unequal transfer by resellers)	17
	Lack of spaces for exhibition and sales	3
	Lack of adequate material for product presentation and packaging	3
Agricultural production	Shortage of planting and management technologies	4
	Difficulties in accessing rural credit	3
	High prices of agricultural materials and inputs	3
	Lack of support for certification	3
Others	Difficulties in establishing partnerships	4
	Lack of financial education	2
	Restricted access or absence of internet	3
	Lack of financial and technical resources beyond leadership	2

Note: Results of this study.
Source: Authors.

Despite the scarcity of partnerships, there are several support initiatives in place that are considered sustainable and valuable. The indigenous people interviewed mentioned the importance of agreements and collaborations with municipal bodies (mainly agriculture departments), universities (including rural extension programs), Sebrae and indigenous and non-indigenous non-governmental organizations, such as Instituto Raoni, Instituto Socioambiental (ISA), Associação Matpha and Coordenadoria Ecumênica de Serviço (Cese). There are, therefore, concrete, and inspiring experiences of indigenous bioeconomy. They encompass the management of natural lakes, agroforestry systems, traditional medicine, ecotourism, culture, and production, transport, and commercialization of various products (seeds, handicrafts, Brazil nuts, rubber latex, flour, fruits, fish, and poultry, among others).

Indigenous peoples maintain techniques, knowledge and customs that are passed on from generation to generation through informal education, outside the classroom. The only precondition is to respect the knowledge of the original peoples, who are the most able to point out the problems to be overcome for the implementation of the indigenous economy.

3.3.3 Main proposals

While conducting this study, researchers were faced with a sense of estrangement among respondents regarding the term bioeconomy and the very act of consultation on economic matters, still uncommon despite the relevance of initiatives developed by indigenous people in their territories. Although timidly, the respondents presented a series of proposals for improving their productive activities. The main message is the importance of dialogue and horizontal construction with indigenous peoples, who are the protagonists of the indigenous bioeconomy (26% of mentions). This is followed by the creation of support lines, programs, and specific initiatives to support the territories (21%). Associativism and cooperativism are also relevant as mobilization tools (15%), especially when a gender-based approach is adopted (10% of mentions).

Great emphasis is placed on the importance of building participatory dialogues on prices, raising awareness to the cultural value in the pricing of products in general, especially handicrafts. Respondents also mention the importance of improving production through easier access to production inputs, through partnerships, public tenders or access to credit, the latter still a major difficulty for indigenous peoples. For certain products, such as acai, respondents also mention the need for support to scale up production cycles and pursue certifications that add value to products generated in indigenous lands.

Copaiba oil, known for its antibiotic, anti-inflammatory and healing properties. Photo: Rodrigo Duarte/IDESAM.

It is important to consider the exchange of experiences between indigenous peoples to discuss local development from an indigenous perspective, with more systemic and non-isolated actions, including land demarcation. The indigenous economy has economic potential and an important role in supplying internal markets, and eventually even external ones, but it is different from conventional production in the way that it values and protects territories. The land – that is, the forest – is the physical and spiritual condition of existence of the indigenous people, guarantor of cultural succession, source of inputs and identifier of labor division. This bioeconomy based on processes and not just on the extraction of products needs to find ways to monetize the ancestral knowledge, cultivated and applied according to the biocapacity of the forest.

In the words of one of the respondents: “We see a lot of companies and banks financing the Amazon, and here is my criticism - I live in an Amazon that the world looks at from a satellite, which can only capture the green and the immensity of the river. Are those the most important things we have in the Amazon? The forest feeds itself, we don't. We also feed this forest with our care. I think we need to broaden these discussions. Is a tree important? Yes, but it cannot be more important than the life of a child, a woman, a young person, a grandfather, an elderly person. It cannot. So, I think you must think more broadly about these things, and above all, be able to talk to authorities, because there is a silencing process going on here in the Amazon. It is a silencing of these people's voices”.

The process of assigning value to the indigenous bioeconomy requires the participation of indigenous and non-indigenous people. Only then will it be possible to promote sustainable development through the bioeconomy, with increased access to products from the territories. All this while respecting and listening to the protagonists of this bioeconomy, which is new in name, but ancestral in its practices and values. In short, there is a collective message learned from the interviews: “There is nothing about our products without us” - a common catchphrase among the consulted indigenous people.


Apurinã crafts in Aldeia Paxiúba, in the Caititu Indigenous Land, Lábrea, state of Amazonas. Photo: Nilmar Lage/Greenpeace.

3.4 Conclusions

The bioeconomy already is an important activity in the LAM, with a GO of $ 3 billion in 2020. The IOM-Alpha methods reveal that the activity penetrates the territory, from the primary to the tertiary sector, and is a dynamic driver of the circular and proximity economy. Its expansion occurs through the multiplication of small businesses, with simple and creative technology, generating strong capillarity and capacity for inclusion.

The case of the acai chain reveals how a product, with a process based on technologies and economic relations arising from its territory, can promote economic growth by adding value and generating inclusive jobs close to the forest. In contrast, the cocoa chain, driven by exogenous demands, shows that being regional is not enough for a product to generate similar socioeconomic effects.

Productive arrangements in the bioeconomy are important when the goal is to generate inclusive jobs, capable of reducing inequalities in the access to opportunities, benefits, and wealth in the region. The expansion of the bioeconomy must occur through the multiplication of productive arrangements that are typical and already existing in the territory, intensive in labor, based on products from the forest or restoration, and that combine local solutions with the adaptation of efficient technological innovations without extrapolating the biocapacity of the forest. The bioeconomy is essential for the generation of ecosystem services for which there are no substitutes that are economically viable or sufficiently available in order to meet the productive demands of the chemical-mechanical model, especially in agricultural and livestock production.

Potential markets focused on innovation in the field of pharmaceuticals, cosmetics and other products, or the training of local populations in bio-industrialization, as proposed by the Amazônia 4.0 project (Amazônia 4.0, 2021) were not analyzed. These markets and initiatives are expected to grow and value the standing forest, but it is necessary to ensure the protagonism of local arrangements, at least in the production and distribution of raw materials, ensuring that the initiatives will have the capacity to generate jobs and income.

The indigenous bioeconomy also deserves strategic attention. Guided by traditional values, it is defined not by its products but by its production processes. The dominion over the land, or territory, is the the fundamental condition for perpetuating the means of production, labor division and existence itself.

Little documented, studied and regulated, it offers economic opportunities for communities and should be a major contributor to Brazil's main climate targets, through forest conservation or restoration. The restoration economy driven by seed networks is the best example of this.

Livestock production activities will need investments to reduce their impact on the Amazon. Photo of Caxanguá, state of Pará. Photo: A C Moraes/Flickr.

CHAPTER **4**

Agriculture and livestock **PRODUCTION**

Growth in the agribusiness sector – including agricultural and livestock production, inputs, industry and services – has a great impact on the Brazilian and LAM economy. In 2021, agribusiness generated $ 487 billion, equivalent to 27% of national GDP[23]. In the LAM, the cotton and grains and livestock chains generated around 17% of LAM's GDP (according to the IIOM-LAM). The agriculture and livestock component of the chain, that is, agricultural and livestock production in the primary sector – generated by rural producers – represented about 13% of LAM's GDP (according to the IIOM-LAM), while the sector's share of national GDP stood at 8% in the same year.

To finance expanding crops and mitigate economic and financial risks related to the activity, rural producers have had access to the wide range of instruments that make up the Safra Plan, such as below-market interest rates, direct and indirect subsidies and earmarked resources.

Among the main supporting instruments, the Minimum Price Policy, the Agricultural Activity Guarantee Program (Proagro) and the Rural Insurance Program (PSR)[24] stand out. In the market, rural producers also have access to other important instruments, such as financing via trading companies, in addition to financing via the futures market, through which the producer obtains resources to finance a harvest that is, at least in part, sold in advance.

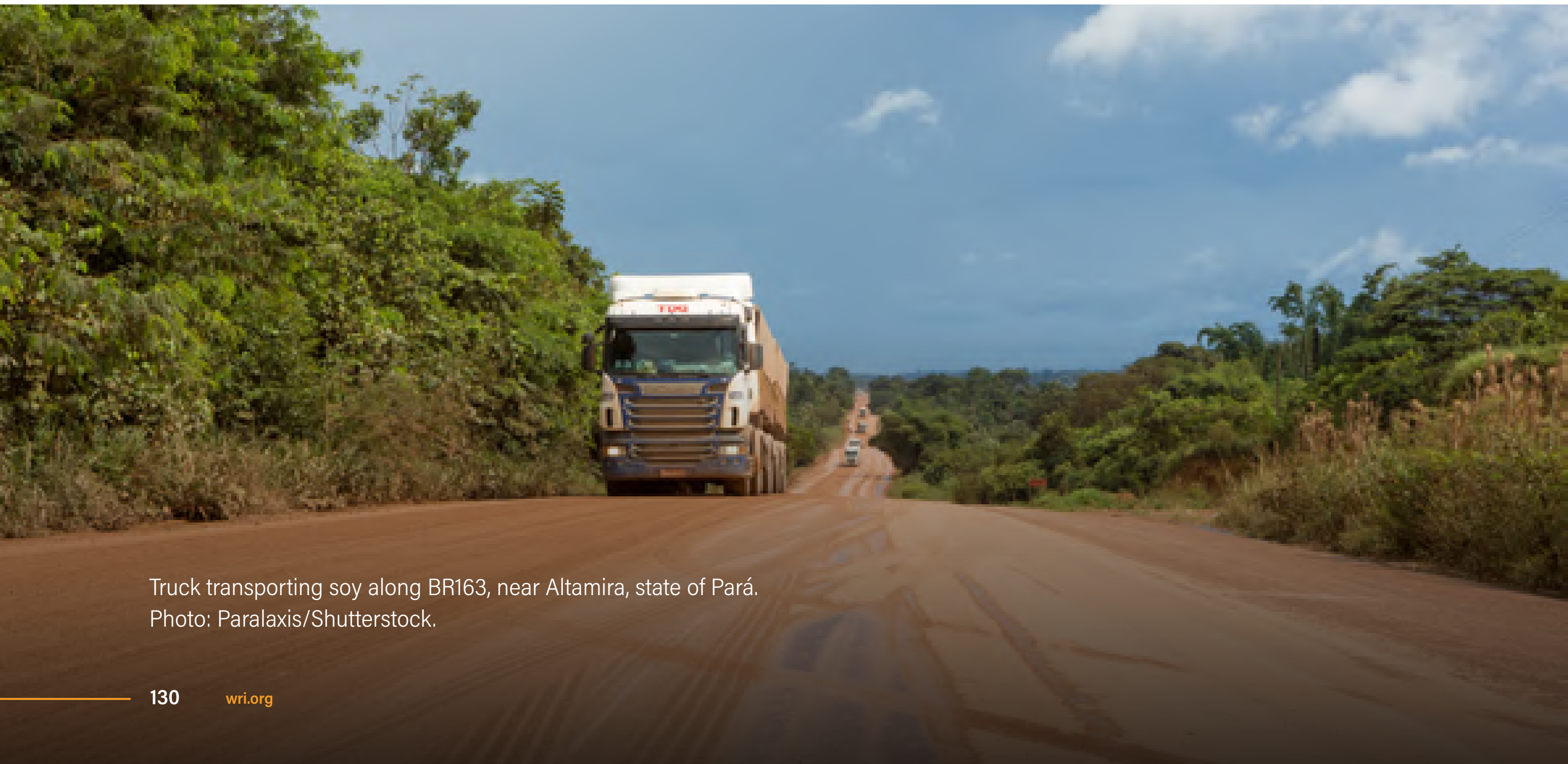
However, the chemical-mechanical model (see Box 12) is largely well-funded while emitting more GHGs and engendering deforestation, jeopardizing essential ecosystem services for the activity itself. An example is the rainfall regime, which in Brazil depends on the maintenance of forest assets, particularly the Amazon. Growing literature (Sorribas, 2016; Lima Filho, Bragança and Assunção, 2021; Mu and Jones, 2022; Silva, 2022) has reported the negative impact of changes in rainfall on agricultural production. In the region marked by the expansion of the agricultural frontier in Rondônia, Mato Grosso and eastern Pará, the loss of ecosystem services, such as the ability to regulate climate and GHG emissions, harms the profitability of soy and beef cattle, due to reduced rainfall and increased fires (Strand et al., 2018).

It is estimated that, for soy and livestock alone, the LAM offers rainwater irrigation services in the range of $ 1-3 billion per year, equivalent to 20% to 60% of national agricultural subsidies under the Safra Plan, or $ 8.7 billion considering all sources. To understand the dimension of this value, in 2022 alone, the increase in negative events in the field, such as droughts, storms and plagues, consumed approximately $ 804 million under Proagro, three times more than the amount foreseen in the federal budget at the beginning of the same year.

Under such conditions, it is essential that agribusiness intensifies the transition to low-carbon production and strategic land use. This is currently one of the most important actions to reduce risks throughout the entire agribusiness chain, and a requirement for maintaining and gaining new markets, as well as for priority and privileged access to international financing. Global conglomerates, including financial ones, have been disengaging from commercial and financing operations that contribute to climate change and the loss of socio-biodiversity.

The understanding that growth is a result of deforestation reinforces the identification of the forest as a mere “land factor” and ignores its role as supplier of inputs for climate regulation and irrigation – a dissonance that is still possible because 80% of the forest remains standing. Reversing this logic, zero deforestation, recovery of degraded pastures and forest restoration, in addition to improved ecosystem services and bioeconomy growth, would produce higher marginal gains as soon as in the medium term, as demonstrated in the scenarios of Chapter 2.

It is a strategic choice based on the reallocation of almost 42 Mha of pastures in the LAM in a stage of severe or moderate degradation (11.7



Truck transporting soy along BR163, near Altamira, state of Pará. Photo: Paralaxis/Shutterstock.

Mha and 29.8 Mha, respectively) and replacement of economic exploitation of new areas by higher concentrations of labor and capital on land that is already deforested (MapBiomas P., Annual Land Use and Land Cover Mapping in Brazil, 2022a). Considering only the areas assigned to agriculture, forestry and pastures, the LAM currently employs only half of the capital and one third of the labor employed in the rest of the country, or $ 217.4/ha/year in capital (working capital and investments) and $33.4/ha/year in labor (wages) in the LAM, against an average of 413.4/ha/year and $ 99.0/ha/year in the rest of Brazil, respectively – which includes the poorest parts of the semi-arid region (IBGE, 2019).

4.1 What needs to change in Brazilian agriculture and livestock production?

The productivity gains achieved since the Green Revolution, based on the chemical-mechanical model, contribute to the increase in GHG emissions and, consequently, to global warming. The negative impact stems from both the change in land use and the production practices used.

Production practices result mainly in the emission of methane (62.5% of the sector's total GHG) and nitrogen (37.4%), due to soil turning, use of pesticides and NPK fertilizers (based on nitrogen, potassium and phosphorus), enteric fermentation (digestion of organic materials by ruminants), animal waste management, and transport of inputs and outputs. In 2016, enteric fermentation was the main source of emissions from productive practices in the agricultural and livestock production sector (56.5%), followed by agricultural soils (36%), waste management (4.1%), rice cultivation (2.2%) and burning of agricultural waste (1.1%) (Brazil, 2020).

The technological impossibility of eliminating natural emission processes – such as enteric fermentation, for example – and the strategic decision to intensify capital and labor require that the effort to eliminate deforestation and promote forest restoration produce enough negative net emissions to offset the emissions from intensification, as demonstrated in the NEA scenario in Chapter 2.

Thus, productive intensification in the LAM cannot do without the fight against deforestation. Empirical studies demonstrate that the recovery of degraded pastures for the implementation of a conventional system intensified with brachiaria is capable of generating negative net emissions between 4 and 5 tC02/ha/year, at costs close to $ 800/ha/year. If each hectare of Amazonian forest emits between 170 and 190 tCO_2 when deforested, it is estimated that one hectare of deforestation nullifies the effort to recover 40 hectares of degraded pastures in terms of carbon, with the investment required for this recovery standing at $ 32 thousand (Assad et al., 2022).

In addition, low-carbon agriculture and livestock production, in general, maintain the chemical-mechanical model, even if adopting bioinputs (biofertilizers, biodefensives and biogas) capable of reducing the intensity of emissions. No-tillage systems, for example, saves on the use of chemical inputs, but because it is adopted mainly in monocultures (grains and grasses)[25], it implies intensive use of fossil fuels in mechanization. Similarly, livestock intensification, although area-saving and based on the recovery of degraded areas, is capital-intensive and highly dependent on chemical and fuel inputs. The exceptions are agroforestry and organic systems.

The low-carbon agriculture that exists today fits into the concepts of biotechnological and bioresources bioeconomy (Costa et al., 2022), but it is not necessarily capable of avoiding the loss of natural assets, nor is it compatible with the preservation and expansion of ecosystem services. Even when guided by productivity gains and the replacement of the chemical component by biotechnologies and bioresources (Vieira Filho, 2017), this type of agriculture maintains a mechanical pattern that sustains the demand for deforested land (stock of previously converted land) and is incompatible with biodiversity.

Except for activity based on agroforestry, regenerative and organic practices (bioecological bioeconomy), modern agriculture is efficient in reducing emissions, but insufficient as a coexistence strategy with the conservation of the Amazon without deforestation.

Thus, the basic conditions for carrying out the transition are the coexistence between productive and competitive agricultural and livestock production based on labor and capital intensification, and the preservation and recovery of the forest and its ecosystem services. This transition should focus on:

1. Strategic land use (landscape approach), including preservation and recovery of natural assets (rivers and forests);

2. Productive intensification, mainstreaming and prioritizing low carbon emission practices[26] in consolidated anthropized areas and degraded areas; and

3. Reducing rural inequality through priority and privileged family farming access to credit, risk mitigation instruments, customized technical and managerial assistance, including for bioeconomy products, in addition to differentiated, institutional markets with denomination of origin.

4.1.1 Strategic land use

Over the past 36 years, the LAM has experienced the greatest change in land use among all biomes and regions in Brazil. Between 1985 and 2021, the region's agricultural area grew by 6.8% per year, with a net expansion of 10.3 Mha in temporary crops, of which 90% represented by soy. The increase in pasture areas was even more noticeable, with annual growth of 3.2% and net increase of 47 Mha in the period. The expansion was accompanied by the drastic elimination of native vegetation. According to data from Mapbiomas (2022b), 59 Mha of vegetation were cleared and replaced by pastures and agricultural crops in the LAM during this period. Seven out of every ten hectares of pasture existing today in the Amazon are the result of deforestation carried out over the past 36 years.

If the extensive use trends persist, a significant increase in the conversion of forest and cerrado areas in the LAM should be expected. According to the Ministry of Agriculture, Livestock and Food Supply, the area planted with grains in the LAM is expected to grow 27% by 2030, concomitant with beef production growth estimated at 1.4% to 2.4% per year. If deforestation-driven growth currently observed is maintained, this would imply an additional area of about 600 thousand to 1 Mha per year (Barreto et al. 2021).

The GEM models presented in Chapter 2 showed that sustaining growth in the BAU scenario, even if based on optimal allocation solutions for land, capital, and labor, will result in the net addition of 51 Mha of pastures and 7 Mha of agricultural land by 2050, doubling the current area destined for temporary agriculture. In this scenario, degraded pasture areas would expand by 29 Mha in net terms, sharply increasing from the current 42 Mha to 71 Mha in 2050, while non-degraded pastures would rise from the current 25 Mha to 47 Mha.

As a result of expansion driven by the current chemical-mechanical model, net deforestation of almost 57 Mha should be expected by 2050, encompassing primary and secondary forest and non-forest formations, an area similar to that which has been replaced by pastures and agricultural crops in the past 36 years. Such deforestation may include the replacement of native vegetation with pastures driven by speculative movements in the land market, but it would be impossible to distinguish this from productive allocation, as this process is currently intrinsic to the increase in land incorporation in the LAM. This limitation, on the other hand, likely underestimates the technical efficiency of livestock production, therefore oversizing the pasture area required for productive allocation, ultimately reproducing the link between the attribution of additional pasture formation and the automatic allocation for the activity (Feltran-Barbieri & Feres, 2021).

It is known that the appropriation of areas in the LAM, including public and non-designated areas, which today add up to almost 52 Mha, is the first step in the transformation of land into a tradable good. Deforestation is the instrument through which more land is added to the system, adding value by clearing forest biomass, replacing biome characteristics by deliberate implantation of pastures or natural invasion of exotic grasses27. In this process, deforestation assumes a pattern, also seen in commodities such as cattle arroba and soy, that responds to two simultaneous stimuli: the variation in amounts of "land" commodity made available to the market by deforestation and the prevailing demand for "land" as a production factor. Their prices and availability do not fully (or simultaneously) reflect the rates of return on agricultural crops and livestock activities, nor opportunity cost expectations.

The opportunity cost[28] of maintaining the standing forest[29], in turn, is seen as an individual and private matter, to be dealt with by the producer, while the benefits (natural assets and ecosystem services) are collective[30], favoring the "free rider" attitude[31]. This is particularly important because, in the quest to minimize costs[32], market prices may not take into account environmental benefits[33]".

In this context, the producer attributes to the standing forest area an opportunity cost equivalent to the agricultural production that he could obtain with deforestation (Costa, 2021; Costa et al., 2021). Such a decision is affected:

1. By the low price of land in the Amazon region, compared to other producing regions in Brazil with limited land supply;

2. By the recurrent practice in Brazil, often unintentional, of disregarding the opportunity cost of land when calculating the total cost of production; and

3. By the capital gain that deforestation and land grabbing generate, that is, the cost of expanding the property area is basically restricted to the cost of transforming forest into pasture or crops, in many cases not even including the cost of acquisition – when land originates from land grabbing.

In the NEA scenario, which assumes economic efficiency without market failures arising from territorial planning, the results indicate that it would be possible to eliminate deforestation and reduce pasture areas in the LAM from the current 67 Mha to 42 Mha in 2050, with reallocation of 13 Mha for bioeconomy-driven forest restoration, 9.7 Mha for agriculture through integrated systems and 650 thousand ha for agroforestry systems.

The reduction in pasture area would be compensated by the intensified use of 8 Mha of highly degraded pastures and 28 Mha of moderately degraded pastures, enabling constant productivity growth of around 1.5% per year.

These results are similar to previous studies that, using different methods, reached similar conclusions (Barreto et al., 2021; Feltran-Barbieri & Féres, 2021)[34].

In the GEM model used in the study, as described in Chapter 2, the required investment is not previously determined, but results from solutions to optimize resource allocation, including differences in productivity according to the portfolios of productive techniques and ecosystem services available in each scenario (especially water availability and nutrients such as nitrogen and phosphorus).

The results indicate that shifting direction from the BAU to the NEA scenario requires additional investments of $ 131.7 billion over the next 30 years, focused on strategic allocation of land use leading to production optimization and assignment of value to environmental assets, including ecosystem services.

In the NEA scenario, investments in agriculture would exceed the BAU scenario by $ 30.4 billion, while investments in livestock production would be $ 58 billion higher.

These values are much higher than those indicated by Observatório ABC, a civil society initiative that monitors the implementation of low-carbon agriculture, which estimated the need for $ 21 billion by 2050 in the Amazon biome and $ 22 billion in the Cerrado (Carlos et al., 2022). This difference is explained by the fact that the estimations in the NEA scenario take into account not only pasture recovery costs, but also the entire optimized allocation of land use, as well as its repercussions in the economy.

4.1.2 Productive intensification, mainstreaming and prioritization of low emission practices in degraded areas and consolidated agriculture

The agricultural and livestock production sector depends directly on the water, carbon, and nitrogen cycles to evolve. Over time, technology applied to agriculture has focused on maximizing the efficiency of primary photosynthetic production, with techniques ranging from chemical fertilization to transgenics (IBGE, 2019, Assad et al., 2020). It is important to highlight the existence of this feedback loop between production and the physical and chemical conditions of the environment.

Methane (nitrogen cycle) and carbon (fossil fuel burning and deforestation) emissions, both GHGs from agricultural and livestock production activities, affect the climate on which they depend. Global warming increases the probability of extreme weather events, such as droughts and floods, in addition to causing systemic and irreversible changes in the medium term, such as shifting of seasonality and extension of dry seasons.

Such events reduce production due to the acute effects of droughts, floods, and pests, and reduce productivity due to the chronic impacts of seasonal changes, water stress and structural and chemical soil deterioration. These factors, added to inappropriate practices such as soil management and deforestation - which led to nutrient leaching, with a resulting increase in production costs or productivity loss - expose agriculture and livestock production to growing technical inefficiency. A wealth of examples of productive disturbances caused by climate change and adaptation practices can be found in Assad et al. (2022).

It is possible to mitigate this perverse cycle. In Brazil, the guidelines for mitigation and adaption of agriculture and livestock production to climate change recognize the importance of combining good production practices with conservation of soil and forests and are mainly outlined in the government initiative ABC+ Plan[35]. In ten years, the plan has already allowed for a significant accumulation of technical knowledge in tropical soil and livestock management practices, led by Embrapa and university research centers.

The GHG emission reduction targets for the agricultural sector were updated in the ABC+ Plan, effective as of 2022 and supplemented by new technologies. The new version expands the scope of recovery of degraded pastures, which represents a significant advance. Studies show that annual investments in the recovery of degraded pastures in Brazil are 6 to 30 times less than the amounts needed to eliminate systemic pasture degradation and promote an increase in technical efficiency of livestock production (Feltran-Barbieri & Féres, 2021).

Table 24 presents a list of low-carbon technologies and practices for different activities and segments of agribusiness. The environmental benefits derived from the implementation of such practices and technologies are also outlined, as well as the economic and financial impacts. In addition to the solutions already provided for in the ABC+ Plan, the table also brings emergent technologies and practices, not yet contemplated in the public policy, as well as actions such as the Science Based Target initiative (SBTi) and success stories.

Table 24 | Low carbon technologies and practices

		Agricultural and Livestock Production		Agribusiness Sector	Environmental Impact	Economic-Financial Impact
Production Practices and echnologies	Agricultural and Livestock Production					
	1	Rainwater harvesting, water reuse and consumption		Inputs	Reduces consumption and increases water quality	Reduces the cost and risk of lack of production factor
	2	Crop, Livestock and Forestry Integration (CLFI)		Inside the Gate	Synergistic effects between the components of the agroecosystem; Improved Animal Welfare	Income increase and diversification
	3	Agroforestry Systems (AFS)		Inside the Gate	Synergistic effects between the components of the agroecosystem	Diversification of income sources
	4	Recovery of Degraded Pastures (RDP)		Inside the Gate	Reduces deforestation pressure; favors infiltration and water quality, reduces erosion and sequesters CO_2	Increase in stocking rate (@/hectare)
	5	No-Tillage System (NT)		Inside the Gate	Favors infiltration and water quality, reduces erosion and sequesters CO_2	Savings on diesel and 30% to 40% on soil preparation work
	6	Biological Nitrogen Fixation (BNF)		Inside the Gate	reduces GHG emissions, in addition to increasing organic matter content (carbon sequestration) and improving soil fertility	Reduces production costs
	7	Integrated Landscape Approach (ILA)		Inside the Gate and Agriservices	"Environmental regularization, landscape appreciation, recovery and conservation of soil, water and biodiversity quality, and appreciation of local specificities and regional cultures"	"Promotes the economic valuation of ecosystem services generated during food production"
	8	Composting		Inside the Gate	Reduces GHG emissions and risks associated with the use of chemical inputs	"Reduces production costs by avoiding consumption of energy and chemical inputs"
	9	Genetic enhancement		Agroindustry	Reduces the production cycle by reducing GHG emissions	Increases productivity
	10	Biorefineries, Biodigesters and Biogenerators		Agroindustry	Reduce GHG emissions	Income increase and diversification
	11	Certifications and Traceability		Agriservices	Prevents leakage	Value adding and access to new markets
	Agricultural Production					
	1	Biofertilizers and Biodefensives		Inputs	Reduces GHG emissions including with the transport of chemical inputs	Reduces input costs and exchange rate exposure
	2	Planted Forests		Inside the Gate	Carbon Mitigation	Long-term (thinning) and short-term (carbon market) source of income
	3	Forest Restoration		Inside the Gate	Carbon Mitigation and Biodiversity Enhancement	Carbon credit and PES
	Livestock Production					
	1	Additives that improve the fermentation of bulky foods Inputs Reduces methane emissions Allows value adding to meat (carbon neutral or low emission)				
	2	Food preservation methods that favor the reduction of emissions		Inputs	Reduces methane emissions	Allows value added to meat (carbon neutral or low emission)
	3	Nutritional strategies to reduce methane emissions in the digestive tract of animals		Inputs	Reduces methane emissions	Allows value added to meat (carbon neutral or low emission)
	4	Other Technologies with potential to mitigate GHG emissions: organic acids, probiotics, nitrates and active immunization		Inputs	Reduces GHG emissions	Allows value added to meat (carbon neutral or low emission)
	5	Intensive Termination		Inside the Gate	Reduces the production cycle by reducing methane emissions	Reduces production cost
	6	Animal Waste Treatment (AWT)		Inside the Gate	Reduces methane emissions	"Increase and diversification of income (organic compost, biofertilizer and/or biogas generation)"
	7	Biogas		Inside the Gate	Reduces GHG emissions	Reduces energy costs and generates an alternative source of income
Iniciativas	1	Soy Moratorium		Agroindustry	Reduces deforestation pressure (conversion of new areas)	Value added and access to new markets for traced soy
	2	Carbon Neutral Meat		Inside the Gate	Reduces methane emissions	Value adding and access to new markets
	3	Low Carbon Meat		Inside the Gate	Reduces methane emissions	Value adding and access to new markets
	4	Liga do Araguaya		Inside the Gate	Reduces methane emissions and reduces the production cycle	Increase in stocking rate (@/hectare), allows value added to meat and enables carbon credits
	5	Soja Plus Program		Inside the Gate	Reduces GHG emissions	Value added and access to new markets
	6	Sustainable Livestock Working Group		Inputs, Inside the Gate, Agroindustry and Agriservices	Reduces methane emissions and reduces the production cycle	Increase in stocking rate (@/hectare), allows value added to meat and enables carbon credits
	7	Bonsucro Certification		Inputs, Inside the Gate, Agroindustry and Agriservices	Reduces deforestation pressure (conversion of new areas) by ensuring traceability of the production chain	Value added and access to markets
	8	ILPF Protocol (Certification carried out by Rede ILPF)		Inputs, Inside the Gate, Agroindustry and Agriservices	Synergistic effects between the components of agroecosystem; Improved Animal Welfare	Increase and diversification of income as well as enabling access to the carbon market
	9	GHG Protocol (WRI)		Inside the Gate	Quantifies emissions allowing the choice of a production system with lower GHG emissions	"Promotes the economic valuation of natural assets and their ecosystem services, and consequently the access to carbon markets"
	10	GHG Protocol (FGV)		Agroindustry	Quantifies emissions allowing the choice of agroprocessing technologies with lower GHG emissions	Product differentiation and access to markets
	11	Science Based Targets (SBTis)		Inputs, Inside the Gate, Agroindustry and Agriservices	Stimulates the productive transition through the use of lower emission technologies and traceability of the value chain	Value added and access to markets

Source: Authors.

Despite large investments in research and development, total loans granted under the ABC+ Program, which is BNDES' agriculture financing arm within the ABC+ Plan, are still at very low levels. It is true that many practices have been widely adopted even before the launch of the plan, such as no-tillage systems, but demand for credit objectively reflects rural producers' propensity to internalize the new paradigm of low-carbon farming.

Between 2013 and 2022, total loans granted throughout Brazil via the ABC+ Program corresponded to only 1.5% of the approximately $ 423 billion granted under the Safra Plan. In that same period, the LAM concentrated 19% of total loans granted under the plan, with $ 80.4 billion in loans, but only $ 1.8 billion under ABC+ (Brazilian Central Bank, 2022).

The National Program for Family Farming Strengthening (Programa Nacional de Fortalecimento da Agricultura; PRONAF, from its initials in Portuguese) represented 19% of total credit granted in Brazil, only 11% of which was granted in the LAM, around $ 8.8 billion. Specific lines for family farming, such as Pronaf Eco, Pronaf Floresta and Pronaf Agroecologia accounted for less than 0.5% of total credit granted under the ABC Program throughout Brazil, with a slightly higher share in the LAM, of 0.9% or $ 82 million. Even so, adding all the programs earmarked to low-carbon agriculture, only $ 1.9 billion were loans granted in the LAM in 10 years, 2.3% of total loans granted in the region under the Safra Plan (Brazilian Central Bank, 2022).

There are many bottlenecks that have prevented the advancement of low-carbon agriculture and its financing (Lima, Harfuch and Palauro, 2020). Among the most important, the five obstacles below create a vicious cycle that prevents the progress of the ABC+ Plan:

1. Lack of territorial organization and inspection limit access to credit, and at the same time discourage capital and labor intensification in already deforested and degraded areas, placing low-carbon agriculture at a clear competitive disadvantage against extensive land incorporation practices, including illegal incorporation;

2. Limited ability to break cultural inertia and promote technical innovation among producers, extensionists and financing agents;

3. Incipient MRV processes that can objectively establish the causal relationship between the adoption of low-carbon practices and their economic and environmental benefits that justify their promotion;

4. Low availability of credit for low-carbon modalities compared to the total funds available under the Safra Plan, and interest rates and requirements incompatible with the urgent need to disseminate low-carbon practices on a large scale, particularly for family farmers and medium-sized agricultural and livestock production establishments;

5. Low supply of technical (Assistência Técnica e Extensão Rural; ATER, from its initials in Portuguese) and management (Assistência Técnica e Gerencial; ATEG, from its initials in Portuguese) rural assistence, which help producers to choose and implement technological packages (including low-carbon options) that are best suited to the reality of each establishment, for example the specificities required by family farming.

Street market in Juruti, state of Pará. Photo: Preta Terra.

4.1.3 Fight against rural inequality

The competitiveness of Brazilian agriculture and livestock production is the result of increased productivity based on technology, especially since the creation of Embrapa in the 1970s. The sector's rising income, however, has gravitated towards a reduced number of establishments, largely excluding small-scale producers from benefits (Vieira Filho J., 2020). As expressed in Box 17 and already demonstrated in Chapter 1, despite the large availability of the land factor, the high levels of inequality in terms of land tenure in the LAM over the past three decades have not only remained unchanged but also reproduced the structure of inequality observed in the rest of the country.

This box helps to understand why Brazil has worse income and wealth inequality indicators than its commercial competitors, despite the fact that Brazilian production of soft-commodities for export (soy, corn, sugarcane and meat) and domestic consumption (rice, beans, cassava and meat) has tripled in the past 50 years. According to the Food and Agriculture Organization of the United Nations (FAO), the country started at a very low level and reached lower growth in Total Factor Productivity[36] (TFP) when compared with neighbors such as Argentina, Uruguay, and Chile (FAO, 2017).

The 2017 Agricultural Census revealed that only 20% of Brazilian rural establishments received Ater assistance, a lower percentage than that recorded in the previous census, in 2006, when the indicator stood at 22%. The smaller the area of the rural establishment, the less access to Ater, reveal the data. Among properties of up to five hectares, only 10% received assistance. The indicator rises to 21% in establishments of five to ten hectares, to 26.8% for those with 10 to 20 hectares, to 64% for those with 2,500 to 10,000 hectares and finally to 72% for establishment of over 10,000 hectares, which demonstrates the systemic problems of technology diffusion and the perverse impacts to family farming (Alves, 2012).

Box 17 | Land tenure inequality is one of the hallmarks of Brazil's North Region

An increase in food production is not enough for Brazil to contribute to global food and nutritional security. The inequalities and inefficiencies that are part of the problem need to be faced. Such inequalities are especially visible in the Amazon, summarized in the following two points:

1) In the North region of Brazil (that encompasses the entire Legal Amazon – LAM), family farming has a larger share in the agricultural sector than in the rest of the country, in terms of number of establishments, employed persons and employed persons with kinship ties with producers. This demonstrates the regional importance of family farming. However, the region's social indicators associated with agricultural and livestock activities (TFP and food and nutrition security) are the worst in Brazil.

2) In 2020, the proportion of households experiencing severe food insecurity in the North region was three times higher than in the country's South and Southeast regions. It also held the lowest proportion of people experiencing food security (under 40% of the population), and the highest proportion of people experiencing moderate or severe food insecurity (18.1% of the population). The majority of households experiencing moderate or severe food insecurity in the region are in rural areas (Rede Penssan, 2021). In Brazil, food insecurity reached 55% of the population (116.8 million of a total of 211.7 million people) and worsened during the COVID-19 pandemic, especially in the Northeast and North regions.

Solving this problem involves a prioritization of family farming access to existing public policies, particularly the ABC+ Plan, and increased respect throughout the chain for natural assets, biodiversity and the unique ecosystem services existing in the Amazon.

Despite the clear disadvantage, family farming in the LAM, defined as establishments that meet Pronaf requirements, already shows strong dynamism, especially in the indicators that are important to the transition to the NEA, therefore essential for the 2050 scenario. Data from the 2017 agricultural census indicate that family farming holds 22% of the land existing in rural establishments in the LAM – including natural vegetation and forests – and produced in 2017 the equivalent to $ 5.6 billion, or 17% of total GO, despite capturing only 11% of rural credit granted (IBGE, 2019).

More than 2.3 million people are employed in rural family farming establishments, no less than 74% of all people employed in the LAM's agricultural and livestock production sector, a share that rises to 82% of jobs held by women, or 764 thousand jobs. Considering non-destructive extraction products, family farming is responsible for 89% of the $ 196 million GO produced in 2017 and 59% of the $ 383 million in native products produced by permanent agriculture in the LAM. Machado et al. (2018) show evidence of how the integration between family farming and school meals (via the National School Meals Program - Programa Nacional de Alimentação Escolar; PNAE, from its initials in Portuguese) has improved food and nutritional security in Brazilian schools.

Nevertheless, although PNAE has led at least 30% of resources transferred to states and municipalities for the purchase of school meals to be directed to family farming, as established by Brazilian Federal Law No. 11,947/2009, in 2011, at least 50% of municipalities still haven't implemented it. In addition, the states in the Brazilian North Region (that parcially encompasses the LAM) showed the lowest percentages of purchases from family farming in small municipalities: 22% in Amapá, 40% in Roraima and 55% in Amazonas and Pará, while the Brazilian average was 79.4%.

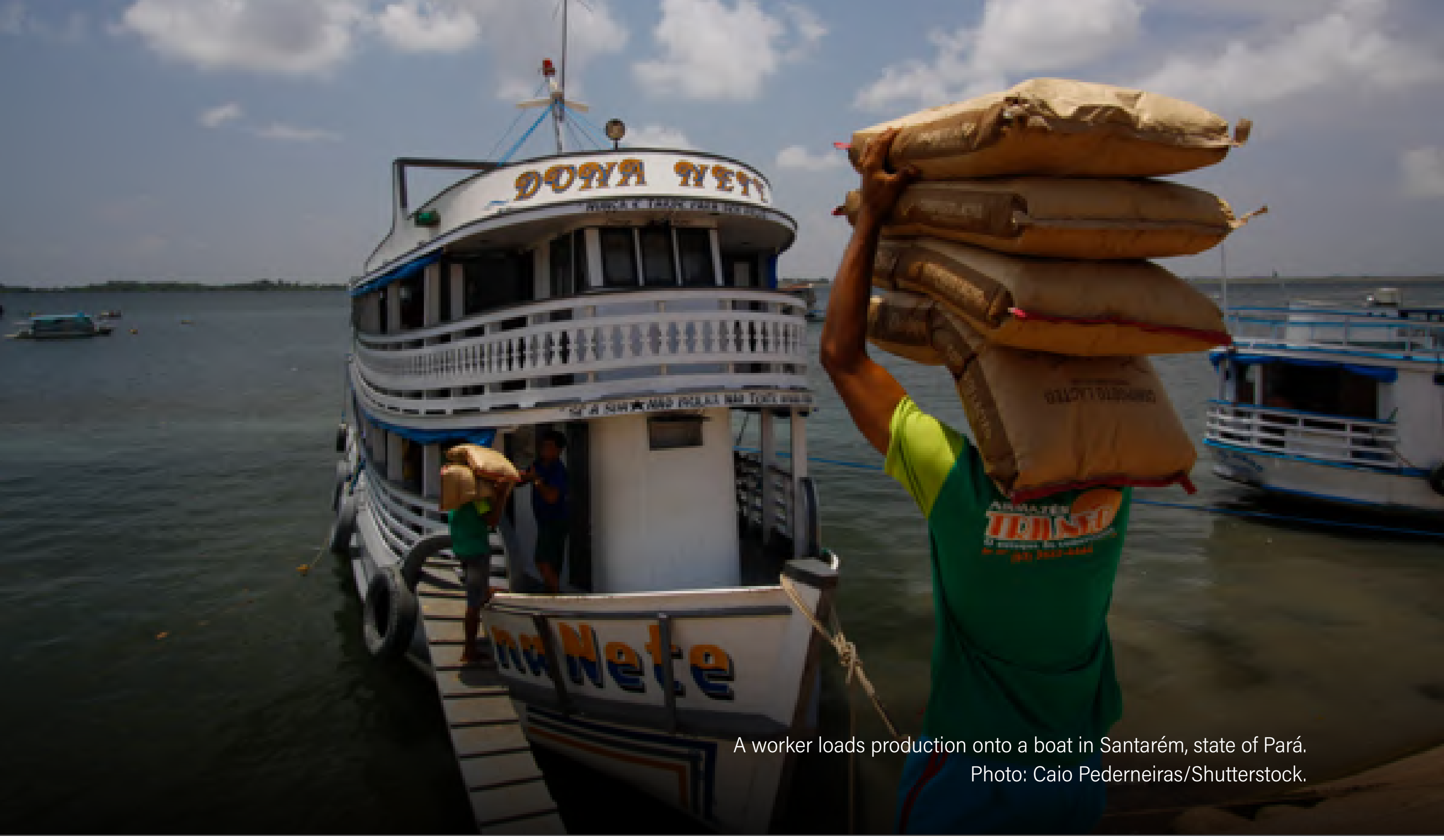
Access to ATER and ATEG and privileged financing are essential to enable the participation of family farming in the necessary transition in rural areas. Particularly dedicated to AFS, regenerative and organic agriculture, among other low-emission production systems, as well as natural regeneration, family farmers stand out for their pioneering spirit and exclusive conduction of rural productive activities that are compatible with biodiversity. Similarly, the bioeconomy developed by family farmers and indigenous and traditional peoples could greatly benefit from customized Ater and Ateg. More support would enable them to add exclusive attributes - increasingly valued by the market - to their products and production processes, leading to increased income.

Agroforestry sistems – along with production from indigenous and traditional peoples – can contribute towards a stable and large-scale supply of bioeconomy products, in addition to reinforcing food security for the producing families. Thus, the recognition of family farming and small-scale bioeconomy activities conducted by local and indigenous communities as essential agents in the transition of agriculture and livestock production in the NEA scenario promotes reduction in land tenure and income inequality, typical of traditional agricultural and livestock commodity production guided by cost minimization via homogenization, monoculture, mechanization, and scale gains.

4.1.4 Why are financial stimuli important for the transition of agriculture and livestock production?

In addition to the technologies and productive practices developed, the first decade of the ABC+ Plan also taught us that "there is no green in red". That is, although rural producers recognize that the adoption of low-emission practices and technologies lead to productivity gains (via more intensive use of natural resources) and, in many cases, lower marginal and operating costs, it still demands significant investment, as it implies the use of new technologies and production practices. Chapter 2 quantifies the investments needed for the transition, with agribusiness and family farming as the main potential recipients of investments related to the "land use" category.

Besides the abovementioned five obstacles to intensifying the transition to low-emission agriculture, there is a critical economic determinant in agricultural and livestock activity that results in a disincentive to investments in low-carbon agricultural



A worker loads production onto a boat in Santarém, state of Pará.
Photo: Caio Pederneiras/Shutterstock.

production. This factor reflects a permanent tension in income distribution among the agents of the four segments of agribusiness: inputs, primary (or "inside the gate"), agroindustry and agroservices.

In general, rural producers operate in markets with adverse conditions, as they buy inputs from a highly oligopolistic industry and sell products in highly competitive markets with few buyers (oligopsony). In highly oligopolistic markets[37] with "low price elasticity of demand"[38], items such as machinery, equipment, tractors, harvesters, seeds, fertilizers, pesticides, and veterinary products are more expensive than in more competitive markets, and many inputs have prices pegged to the dollar, making the cost of production sensitive to exchange rate fluctuations. The exception is labor, the only production factor with ample supply, although this does not apply to skilled workers in agriculture 4.0[39].

Regarding biotechnology and agricultural engineering, levels of market concentration and centralization have increased over the past decade, deepening supply inequality and dependence on commodity exporting countries. Four companies (one Chinese, one North American and two European) hold 53% of the world seed market. They also control two-thirds of the agrochemicals market. Another six companies (two North American, two European, one Japanese and one Indian) own half of the agricultural machinery and equipment market (Shand, 2019).

In terms of fertilizers, the National Fertilizer Plan (Plano Nacional de Fertilizantes; PNF, from its initials in Portuguese)[40], launched in 2021, projects scenarios for the next three decades. The expectation is that by 2050 there will be a 22% to 91% increase in demand compared to the current Brazilian demand of 40.6 million tons[41]. Because the use of pesticides and nitrogenous, potassium and phosphate fertilizers contribute to global warming and can cause damage to human health, water and soil quality and biodiversity, FAO (2021) argues that these products should only be imported as a complement. They should not replace biofertilizers, biodefensives and ecosystem services.

Conserved natural ecosystems, particularly in the Amazon, provide unique inputs for which there are no substitutes that are economically or technically viable on a large scale, such as rainwater irrigation, soil and water conservation, pollinator refuge and climate stability (Assad et al., 2019). In Brazil, only 3% of agricultural production is irrigated. Only 1% use air-conditioned systems (greenhouses and hydroponics) (IBGE, 2019). This reveals that the generation of Gross Output in Brazilian agriculture is highly dependent on ecosystem services.

In terms of value addition through the recognition of the low-emission attribute in the production process, the meat industry has taken the lead in efforts to modernize, securitize and certify the chain, mainly in connection with the foreign market. Still, the levels of informality and illegality, especially in the production and slaughter of cattle in the Amazon, remain very high (Azevedo et al., 2017).

The situation of livestock production focused on supplying the domestic market is worse, because Brazilian consumers are much more sensitive to prices than to production conditions. Value-added and chain traceability initiatives are not incentivized. This is a relevant problem because, unlike the situation in other countries, Brazilian meat production is mainly consumed in the domestic market. As discussed in chapter 1, only 15% of trade value is exported (compared to 69% for soy production, for example). This chain has not yet had any successful experiences along the lines of the Soy Moratorium (Gibbs et al., 2015).

A complicating factor is that certifications imply an additional cost, and the transfer of this cost to consumers is prohibitive for highly competitive markets such as agricultural and livestock commodities. In general, certifications are only available to large and medium-sized rural producers and exporters. Small-scale producers, particularly family farmers, have difficulty accessing them, although a growing number among this group has been seeking certification through cooperatives and associations.

It should be noted that, as most commodity export transactions are not carried out directly by rural producers, but by trading companies or the agroindustry, any market gains obtained with certification end up adding value to the industry, not necessarily to producers. In order to expand the adoption of reliable traceability and emission measurement systems, and consequently contribute to the transition to the NEA, there is a need to address the fact that the maintenance of natural assets that provide ecosystem services often engender public benefits but private costs. Similarly, it is necessary to guarantee access for rural producers of different sizes, especially family farmers, to ATER and ATEG, so that investments in low-emission practices and technologies are economically and financially sustainable, supporting increased productivity and profitability. Finally, the transition calls for improvements in public policy and financing instruments that reduce the cost of credit and financing for investments in agricultural and livestock activities in the LAM, benefiting the region with privileged access to patient capital and green funds already available internationally. These aspects are further detailed in the Chapter 7 of this report, dedicated to financing the NEA scenario.

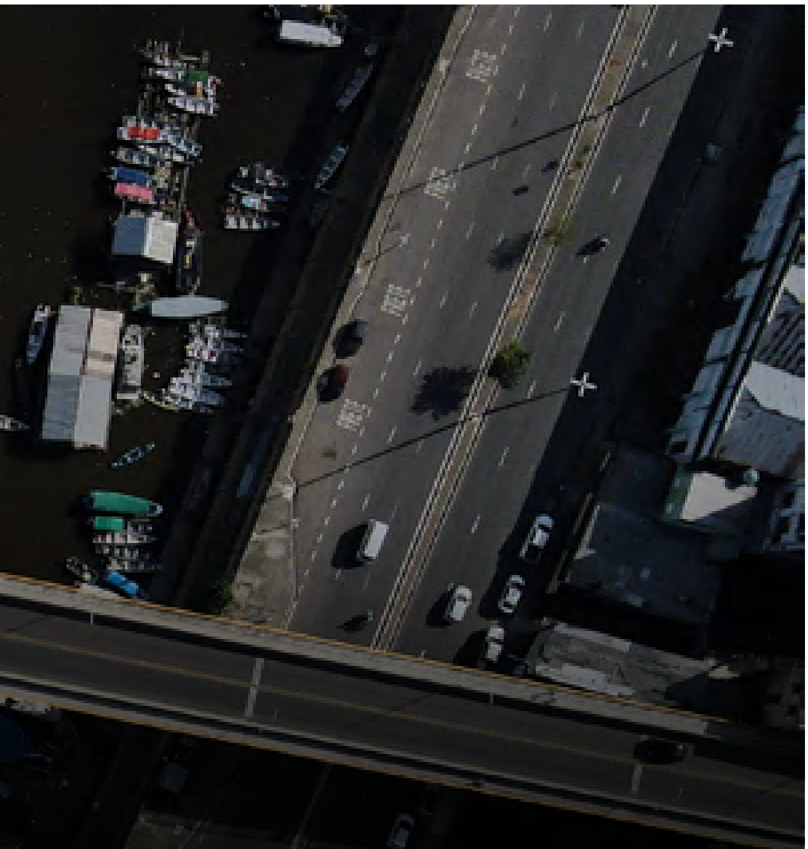
Aerial view of Manaus, state of Amazonas. Photo: Bruno Kelly/WRI Brasil.

4.2 Conclusions

The LAM's agricultural and livestock production sector will play a fundamental role in the transition to the NEA, sustaining GDP and millions of jobs through the progressive replacement of the land factor with capital and labor, and through the decarbonization of productive processes, especially driven by the recovery of degraded pastures and forest restoration via assisted natural regeneration. These efforts, in turn, promote an increase in ecosystem services and rural properties' compliance with the Forest Code.

The three biggest challenges for agriculture in the transition to the NEA are the strategic land use, the productive intensification and mainstreaming of low carbon emission practices and the fight against rural inequality.

The strategic land use, which combines territorial planning and optimization of productive allocation, would bring direct benefits to job creation and efficiency in the use of production factors, with a progressive replacement of land with capital and labor. The elimination of deforestation and expansion of native vegetation would increase the provision of ecosystem services, leading in turn to greater natural land productivity and a reduction in the use of fertilizers, offsetting the traditional expansion process that replaces depleted lands with newly deforested areas.



Thus, the intensification of agriculture and livestock production should occur exclusively in consolidated degraded and anthropized areas, with priority adoption of bioinputs and integrated production systems (Crop-Livestock-Forest Integration and Agroforestry Systems, especially with native forest species).

The conservation of natural assets also calls for the reconciliation of agriculture and bioeconomy. Necessary initiatives include restoring degraded areas, disseminating agroforestry systems based on local knowledge, inputs, and preferences, prioritizing the conservation of water sources and aquifers, and enhancing the recovery of native vegetation and its ecosystem services. It is also necessary to disseminate low-impact agriculture practices, in addition to expanding incentive systems, credit and cross-subsidies for sustainable systems, such as traceability and certification of origin.

Reduction in rural inequality necessarily relies on priority and privileged access of family farming to credit, ATER and ATEG assistance, risk mitigation instruments and differentiated markets. Despite holding only 22% of existing land in rural establishments in the LAM, family farming employs more than 74% of all people working in agriculture and livestock activities in the region, a share that rises to 82% for jobs held by women. Family farming is also responsible for 89% of GO generated by non-destructive plant extractivism and 59% for native permanent agriculture products in the LAM. Similar to the bioeconomy chain, the production arrangements that characterize family farming strengthen social inclusion, circular income flows and the proximity economy, acting as an important driver of development.

The mining industry needs to go beyond ESG practices in the Legal Amazon, investing in the promotion of the bioeconomy and activities that foster the proximity economy. Photo: Nick Elmoor/WRI.

CHAPTER **5**

MINING

Mineral assets are indispensable in the energy transition and in the construction of infrastructure for a low-carbon economy (Ali et al., 2017, Church and Crawford, 2020; Gielen, 2021). To meet this demand, the World Bank points to a growth trend in the supply of several critical minerals[42] for clean technologies such as copper, graphite, and lithium, with their production expected to grow by around 500% by 2050 (World Bank, 2010).

Along the same lines, another study (Taurus and Madzivanyika, 2022) states that the demand for minerals expected to fuel the low-carbon energy transition will be opportune for resource-rich developing nations. These nations will be able to increase revenues while contributing to the fight against climate change.

The Legal Amazon (LAM), responsible for more than half (51%) of the total value generated by Brazilian mining production (ANM, 2020), boasts globally significant reserves, comprising 18% of tantalum, 11% of niobium, 9% of manganese and tin, as well as substantial deposits of aluminum ore, metallurgical bauxite (8%), and iron ore (4%), among other resources. Furthermore, this region currently hosts economic operations involving 6 out of the 25 minerals deemed critical for emerging low-carbon technologies like solar panels, electric batteries, and wind turbines, including bauxite and aluminum, nickel, tin, copper, iron, and manganese (Vakulchuk and Overland, 2021)[43].

These minerals and metals are expected to play a fundamental role in the transition, because of how energy will be generated, transported, stored, and used by society in the coming decades (Enriquez, 2008).

In addition to the currently extracted minerals, there are other significant factors contributing to the expansion of mineral extraction and increased land use within the LAM. This includes the presence of rare earth elements, such as dysprosium, neodymium, and praseodymium, which have not yet been established as proven reserves (Gerard et al., 2003). Additionally, unpredictable and circumstantial pressures may arise, such as the recent geopolitical realignments that disrupted the supply of agricultural inputs, leading to adverse effects on the Brazilian agriculture and livestock sector during the Russia-Ukraine[44] conflict and the COVID-19 pandemic.

In addition to the evolving global dynamics in mineral assets, internal trends within the mining sector are unfolding. These trends encompass the increasing adoption of new technologies and process automation, ushering in an era of Industry 4.0 advancements[45]. Simultaneously, efforts towards decarbonization, waste reuse, and the circular economy are driving the need for more efficient processes and judicious resource utilization.

These demands and trends yield two-fold effects on mining operations in the in the LAM. Automation, for instance, ameliorates environmental impacts by reducing greenhouse gas emissions and curtailing the consumption of water, energy, and materials. However, it also diminishes the demand for labor while amplifying production scale through heightened productivity. This, in turn, curtails the lifespan of mines, leaving less time for mining-dependent regions to diversify their economies for a future beyond mining.

Mining in the LAM holds immense economic significance for Brazil. Nevertheless, future trends foreshadow an increasingly mechanized sector. While this mechanization conserves natural resources, it also distances itself from social concerns, primarily employment generation. Moreover, the LAM is expected to confront mounting pressure to bolster mineral production, both in terms of extracting more minerals from existing mines and opening new ones.

Given these factors, how should the mineral issue in the LAM be best addressed? It is imperative not to underestimate the sector's contribution to the economy. However, the unique circumstances of the Amazon biome, particularly regarding conservation, impose additional responsibilities on the sector. These responsibilities encompass environmental, social, and economic safeguards that must be adhered to as part of the global and Brazilian transition to a low-carbon economy. The critical question at hand is: How can mining actively contribute to the preservation and protection of the Amazon's standing forests, the health of its rivers, the well-being of its inhabitants, socioeconomic development, and the upholding of human rights?

5.1 Analysis of socio-environmental impacts

The historical and contemporary development of mining activity in the Legal Amazon (LAM) is primarily based on two models: small-scale mining, often intertwined with other related activities, and formally established large-scale mining. These models, although occasionally conflated in the media, demand distinct approaches and solutions.

Small-scale mining falls outside the purview of this report. However, its important to address one section of this activity related to illegal mineral extraction. Illegal mining of gold and other precious stones includes a wide array of issues, including environmental, human rights, socioeconomic, public health, and cultural concerns. Although significant, the causes and consequences of illegal mining do not fall within the scope of this report's study objectives and thus cannot be adequately addressed.

Nevertheless, its relevant to note that one of the most pertinent contemporary examples of these consequences is the mining activities within the Yanomami Indigenous Land and their far-reaching effects (Hutukara Associação Yanomami and Associação Wanasseduume Ye'kwana, 2022)[46]. It's important to note that all mining operations on indigenous lands are currently illegal. Despite the provisions in the 1988 Federal Constitution that allow for mining in these territories, subject to specific safeguards, particularly free, prior, and informed consent[47], there is no regulation currently in force permitting mining on indigenous lands[48]. Consequently, all mining activities on indigenous lands are prohibited and classified as illegal.

In contrast, large-scale mining, the second prevailing model in the LAM, originated in the 1950s and has become one of the most significant sources of foreign currency generation, particularly for the federal government. In 2020, mineral exports reached $ 18.5 billion, equivalent to 97% of the total mineral production value. In 2021, the region exported minerals worth $ 27.5 billion, representing a 50% increase from 2020[49] (ComexStat, 2021).

However, despite the impressive economic outcomes, mining is an activity with substantial potential impact, not only in terms of the physical space utilized for mineral extraction but, more importantly, due to its effects on the socioeconomic and environmental dynamics of the regions where it operates. This encompasses the entire logistical infrastructure required for mineral extraction, distribution, and handling of byproducts, as elucidated by Coelho (2015) and Castro and do Carmo (2019).

Moreover, there's a persistent drive to explore and open new mines and mining areas. One illustrative instance is Proposed Federal Law No. 191/2020, which aimed to regulate mining ventures on indigenous lands, primarily driven by the scarcity of essential inputs like nitrogen, phosphorus, and potassium for the production of fertilizers in the agriculture and livestock sector. Notably, the Brazilian Federation of Geologists (FEBRAGEO)[50] and IBRAM opposed this bill (IBRAM, 2020)[51] .

Children play near Juruti, state of Pará.
Photo: Joana Oliveira/WRI Brasil.

The mounting pressures on the LAM, whether associated with low-carbon initiatives or not, may pose threats to traditionally occupied areas, exacerbating pre-existing socio-environmental conflicts in the region. This stems from the competition between mining activities and other forms of land use and occupation, spanning water resources, landscapes, ecosystems, living and non-living resources, all of which significantly impact the ways of life and livelihoods of the local populations.

Hence, without requisite institutional and structural reforms, mining, even in the context of low-carbon technologies, will perpetuate the socio-environmental impacts already witnessed in the region, as detailed below.

Thus, the inclusion of mining in the NEA presupposes the adoption of a series of measures that align the sector with the perspective of a just transition for the region, with bioeconomy growth and development that generates benefits for the local population.

5.1.1 Impacts on local economy

Metallic and non-metallic mining have an important connection with urban agglomerations, whether through product flow or the circulation of goods and services necessary for production. However, studies indicate that the potential benefits are

Table 24 | Socio-environmental impacts of large-scale mining in the Legal Amazon

Type of environmental and social impact	Description
Deforestation	Between 2015 and 2020, mining in the Legal Amazon deforested approximately 41 thousand hectares and added pressure on indigenous lands (1).
Spill from tailings dams and air pollution	Tailings spills from the production of minerals such as alumina and kaolin (2).
Interruption of riverbeds for dam construction	Certain mines depend on a large number of dams, increasing the risk of ruptures, which can cause material damage, loss of human lives, impacts on fauna and flora and disruption of water bodies (4).
Increased violence in mining municipalities	Of the 33 municipalities in Pará with mining activity, 21 registered an increase in homicides per 100 thousand inhabitants between 2009 and 2019, according to the Atlas of Violence (Ipea). Canaã dos Carajás and Oriximiná lead the ranking, with increases of 92% and 388%, respectively (6).
Territorial disorder following the end of the mineral extraction cycle	Cities that economically depend on mining tend to suffer disorganized territorial growth and the formation of poverty pockets associated with accelerated growth, increasing social problems such as poverty, inequality and violence. When the activity is exhausted, people who were involved in mining form poverty pockets, characterized mainly by agricultural subsistence (7).
Negative social externalities caused by mineral transportation structure	Due to the establishment of mineral servitudes, the owner of an area affected by a certain mineral or associated infrastructure cannot choose to have his area excluded from the mining project. In this sense, the infrastructure created for extracting and transporting production has a negative impact on nearby areas - there are reports of people and animals being run over, damage to the foundations of residences due to increased trepidation, grounding of wells, contamination of watercourses and prostitution (8).
Conflicts over land use and increased real estate speculation	Mining stimulates other sectors, such as eucalyptus monoculture aimed at supplying steel blast furnaces, which increases agrarian conflicts and land ownership inequality (8).

Source: (1) APIB and Amazon Watch, 2022; (2) Brazilian Lower House of Representatives, 2018; (3) Gomes, 2021; (4) Andrade, 2018; (5) Wanderley, 2021; (6) Ipea, 2019a; (7) Drummond, 2000; (8) Filho et al., 2020; ANM, 2020; Ipea, 2019b and Prodes, 2019.

contained by losses in revenue. At the LAM, a corporate income tax waiver of 75% is granted to large companies in the region, in addition to a 25% to 32% reduction in freight costs for importing machinery, equipment and inputs.

In terms of tax structure, a possible path could be the application of differentiated tariffs on mining exports, according to processing levels (Coelho, 2015; Sindifisco, 2021). For example, in Australia, royalties range from 2.5% to 7.5%, with lower rates for processed products.

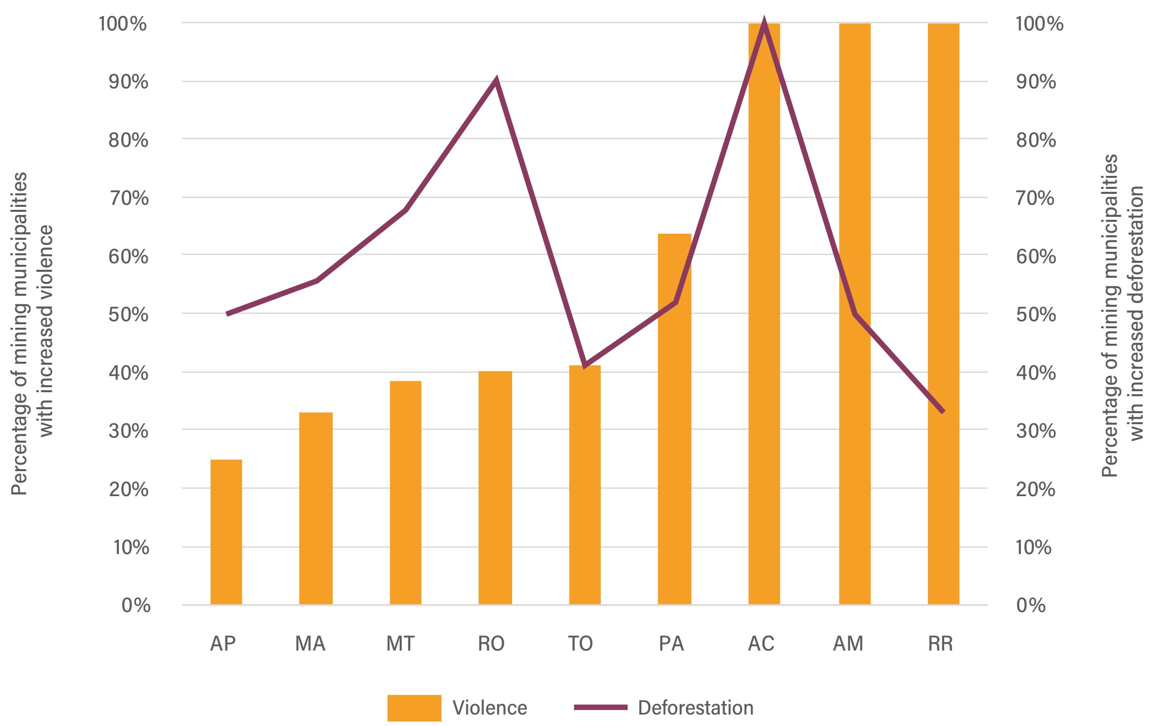
It is also necessary to consider the destination of mining revenues. Canaã dos Carajás was the municipality in the Amazon that received the second highest Financial Compensation for the Exploration of Mineral Resources (Compensação Financeira pela Exploração Mineral; CFEM, from its initials in Portuguese) in 2021 ($ 372 million), while in 2018 about one third of this revenue was allocated by the municipal government to public administration expenses (ANM, 2021c; Siconfi, 2021; Enriquez et al., 2018). Thus, existing resources could be earmarked, at least in part, to development funds supporting the achievement of ESG targets. This would encourage communities to develop more diverse and inclusive economies.

Accordingly, IBRAM (2020) suggests the establishment of long-term municipal funds for the management of mining revenues, with the implementation of transparency and social control mechanisms, focused on creating alternatives to sustain development during and after the closure of mines.

Another possible solution would be to untie mining revenues from the budgets of mining municipalities, allowing communities to develop a diversified and inclusive economy.

These measures would allow the creation of instruments capable of breaking the cycle of dependency on mining activities, providing different options and opportunities for the development of local communities (Martinez-Fernandez et al., 2012; Enriquez et al., 2018).

Chart 19 | Proportion of mining municipalities that posted an increase in violence and deforestation indicators, by state, between 2009 and 2019



Source: ANM (2020), Ipea (2019a) and Prodes (2019).

5.1.2 Connection with forest degradation

The damage caused by mining is most evident in indicators of deforestation and violence. The mining municipalities of the state of Pará, for example, posted a 63% increase in homicides per 100 thousand inhabitants between 2009 and 2019. In over half of these municipalities, deforestation also increased in the period. In the state of Amazonas, all municipalities with mineral production showed an increase in violence and half suffered a reduction in forest areas.

Between 2005 and 2015, 9% of forest loss in the LAM was caused by mining, a number 12 times higher than the deforestation observed within the area licensed to the mining company. Impacts of mining activities were identified within a radius of up to 70 km from the mineral deposits (Sonter et al., 2017).

Such impacts can be direct or indirect. Direct impacts of mining activities are easier to control than indirect and cumulative impacts (Coelho, 2015; Castro and do Carmo, 2019; Machado and Figueiroa, 2020; Enriquez et al. 2018; Martinez-Fernandez et al. 2012).

This situation is compounded by the challenge involving accountability for deforestation activities. Experts argue that more detailed reports and monitoring activities on the direct and indirect impacts of large-scale mining in forested areas such as the Amazon - beyond the limits of areas granted for exploration - would support the creation of better policies and practices.

In order to analyze ways to mitigate deforestation and other negative impacts of mining, in 2019 the World Bank launched the concept of forest-smart mining for mining activities that engage in actions to mitigate impacts on forests and other forms of land use, in addition to social, cultural, ecological and economic impacts (Maddox et al., 2019). The concept builds upon studies on the role of mining companies in climate change mitigation and the global transition to a decarbonized economy, and follows four premises, hierarchically (Bradley, 2020): 1) avoid negative impacts on climate and biodiversity; 2) minimize any impact or loss that may occur; 3) restore or rehabilitate loss of forest cover or biodiversity where impacts are unavoidable; and 4) as a last resort, compensate for damage.

As previously mentioned, in the Amazon, the process of granting mining concessions often involves conflicts with pre-existing forms of use and occupation of the territory. This is an aspect of the larger conflict between the land use for extraction and traditional uses. Regarding this point, companies can mitigate their impacts by commiting to occupy the minimum area needed for extraction. It should be noted that this is not necessarily the usual practice, as illustrated by the case of Canaã dos Carajás (Enriquez et al., 2018).

Research carried out by Chatham House (Bradley, 2020) with the aim of better understanding the application of forest-smart mining found that no company had fully implemented it by 2020. In this sense, mining in the LAM has room for investment in activity optimization in favor of forest-smart mining or other initiatives, including the application of financial mechanisms such as REDD+ to restore degraded areas.

When addressing REDD+ projects or the generation of other carbon credits, whether or not forest-based, the development of nationally recognized MRV systems is imperative. Such systems would help qualify companies and jurisdictions to access carbon markets, as well as create important databases on the management of social, economic, and ecological resources in the region.

The use of a robust MRV system helps mining companies to incorporate elements that are currently excluded from their decarbonization plans. This is because companies tend to prepare plans focused on scope 1 (emissions associated with the use of fuels) and scope 2 (emissions associated with the use of energy). However, in areas such as the Amazon, it is critical to also include scope 3 (emissions indirectly propagated along the company's value chain) with a specific focus on deforestation. The Coalition on Materials Emissions Transparency (Comet) develops methods to help calculate scope 3 emissions, based on the GHG Protocol tool and the Science Based Target initiative (SBTi). Both tools offer important standards for meeting ESG criteria.

Within the scope of public policies, Brazil's NDC could include targets for the decarbonization of the mining sector that encompass activities from scopes 1, 2 and 3 (Bradley, 2020), so that activities causing impacts are properly and comprehensively mitigated. Moreover, subnational and national governments could create regulations in order to guarantee greater rights and safeguards for affected vulnerable populations.

5.2 Mining and just transition

In addition to the legal obligations imposed on the sector, mining activities performed in the LAM involve specific issues that require special attention. First, because they take place in a unique biome with rich and abundant forest, biodiversity, and ecosystem services. Also, because mineral deposits generate substantial mining revenues. And finally, because of the precarious level of socioeconomic development in the region, despite its exceptional wealth in natural resources.

The risk that the world's energy transition results in irreparable damage to the environment and communities close to mineral deposits has been a major concern for governments, companies and investors working to promote just energy transitions. In this sense, there appears to be demand for the production of well-substantiated reports on actions and measures to be taken in the vicinity of mines in order to mitigate risks, in addition to progress monitoring instruments (Benioff, 2018).

Therefore, in addition to complying with legal obligations, some of the large mining companies operating in the LAM have been voluntarily adopting recommendations from representative entities, such as the International Council on Mining and Metals (ICMM), the Sustainability Accounting Standards Board (SASB) and the Task Force on Climate-Related Financial Disclosure (TCFD). Currently, a series of transformations have been appearing with the incorporation of new global trends, such as automation (Machado and Figueiroa, 2020), insertion of ESG practices, reuse of waste[52], circular economy[53] and decarbonization[54].

In terms of the application of ESG criteria, the environmental aspect is addressed first. In this area, new trends have dichotomous effects on the relationship between mining and development in the LAM. On the one hand, automation leads to important reductions in companies' production costs and contributes to reducing environmental impacts (lower CO_2 emissions, water and resource consumption, etc.), but it also reduces the demand for labor, consequently the wage bill and the benefits for the regional economy.

Machado and Figueiroa (2020) mention an increase of 15% to 20% in companies' productivity, but recognize that many conventional jobs will be eliminated, especially in areas where machines advance; the authors cite a study by the International

Planting seedlings contributes to carbon neutrality programs. Photo: IDESAM.

Institute for Sustainable Development (IISD), which foresees that "the efficiency gains from automation will reduce the amount that mines contribute to government revenues in low- and middle-income countries by up to $ 284 million" (Cosbey et al., 2016).

Secondly, the ESG concept as it relates to governance innovates by considering the interests of local stakeholders in companies' activities, impact, or products. Stakeholders' interests become part of the companies' purposes, thus expanding the scope of governance when compared to governance that only considers shareholders.

In practice, this means that companies must offer real opportunities and ensure that local technical professionals hold decision-making positions. Companies also need to participate more actively in councils and forums focused on local development, assuming the role of relevant agents in the construction of development strategies.

Despite there being relative consensus on the environmental and governance criteria, the social dimension of the acronym ESG still lacks common understanding, especially when discussing the benefits that mining as an activity, and the mining company as an operator, should provide for society, the mining company's responsibility and how to articulate with public policies to promote synergies.

In this sense, the RMI Report 2022 (Responsible Mining Foundation, 2022) shows that most mining companies on a global level are still lacking in basic engagement with communities and workers on issues involving basic risks linked to mining activities, such as environmental impacts and safety. Around 97% of more than 250 mines analyzed in 53 countries performed below 25% in assessments of their ability to report or engage with communities and employees on basic risks or topics of public interest, such as water resources management and emergency plans.

One of the possible measures, especially in light of the fact that companies are currently responsible for large tracts of land, mainly in protected areas, is to provide favorable conditions for the local population to organize itself into cooperatives or other entities and carry out responsible management in these areas, in order to promote socio-biodiversity.

It is important that mining companies present in the LAM lead the transition to the NEA, with the inclusion of local communities in mining activities, transparency and monitoring, and do so without separating social aspects from the environmental or governance aspects. The RMI Report 2022 calls attention to the fact that mining companies consistently pick one of the three aspects to concentrate on over the rest.

As underlined in Chapter 3, an economic activity developed inside a forest with high social and biological diversity must value the three aspects – environmental, social and governance – and incorporate local knowledge into its processes, including management. Table 25 indicates some of the possible paths towards a sustainable and responsible future for the mining sector in the LAM.

5.3 Conclusions

Mining in the LAM is a controversial subject and involves a set of productive systems classified between industrial mining and small-scale mining, the latter including legal and illegal operations. This report does not cover small-scale mining in the Amazon. However, the study adopts as a fundamental assumption the continuous prohibition of mining in Indigenous Lands.

In this context, the analysis focused on large-scale industrial mining, particularly involving essential commodities for the global transition to a low-carbon economy. The study points to the need for revision of current production standards and improved monitoring and measurement of socio-environmental impacts, especially important for a just transition.

Governments also need to implement a broad agenda to ensure sustainability and regional development. One possible measure could be the

Table 25 | Requirements for large-scale mining in the Legal Amazon

Enterprise stages	Requirements for companies	Requirements for the government
Granting of mining concession	Expand dialogue between affected communities and companies to resolve conflicts with other uses and forms of occupation of the territory (small farmers, traditional population and small miners, among others), using ESG criteria.	Define clear norms on the ownership of previously used areas, with the revision of mineral servitudes.
Environmental licensing and mining operation	Expand opportunities for local technical professionals to hold decision-making positions. Expand the company's participation in forums aimed at local development. Promote and provide opportunities for the local population, organized into cooperatives, to sustainably manage the protected areas under the company's control. Allocate a percentage of profit to R&D expenditures, in partnership with universities and research institutes in the states and regions where it is installed. Disclose to society the actual numbers for jobs created and taxes collected.	Stop rewarding exports of minerals in natura with tax exemptions and subsidies. Create a system of incentives for companies that add value and generate innovation in the territories where they are installed. Create norms so that mining promotes inclusion and productive diversification in the territory.
Mine closure	Involve the local population in the definition of post-mining use.	Create rules on financial guarantees for mine closure.

Source: Authors based on ANM, (2023), ICMM (2023), GRI (2023), SASB (2023).

review of the policy that grants tax exemptions and subsidies to exports of minerals in natura, replacing it with a system that encourages mining and processing companies to add value to their products and boost innovation in the territory.

In addition, a share of revenues should be applied to investments in research and development focused on overcoming the technological and social bottlenecks inherent to operations in the Amazon. Investments could be made through partnerships with universities and research institutes in the region, which accumulate knowledge on these areas.

Regarding companies, they can ensure, for example, that the area burdened by mining is the minimum necessary[55]. This measure could prevent conflicts with pre-existing forms of use and occupation of the territory in the concession granting phase.

The application of ESG criteria combined with the implementation of MRV systems that cover the direct and indirect impacts of mining activities, including scopes 1, 2 and 3 for GHG mitigation, will provide to the public and private sectors greater access to new markets (such as carbon) and better qualification to apply for climate financing.

To ensure the feasibility of the NEA scenario, the distribution of mining revenues needs to be redefined, including changes in tax structure and the creation of voluntary and regulated funds. Local communities also need to be empowered to become agents of their own development, through training and professional qualification. Finally, the local development process needs to be based on science, technology, and innovation, so that it advances towards a society that generates knowledge, not just minerals.

Water transport on the Amazon River, near Belém, state of Pará.
Photo: ESB Profissional/Shutterstock.

CHAPTER **6**

INFRASTRUCTURE

The transition to the NEA requires the development of new infrastructure[56], compatible with the different socioeconomic realities and biodiversity of the LAM. There is great challenge in the development of new infrastructure that is compatible with the standing forest, takes advantage of regional vocations (such as river systems), minimizes dependence on non-renewable sources and fosters the development of local sources (Junior, 2012; Pereira, 2017). This infrastructure also needs to be competitive and promote the circular and proximity economy (Laurance, 2019; Gatto, 2022). The current trajectory needs to undergo a sharp shift to meet these conditions (IDB, 2018; Barros et al., 2020; Bandura, McKeown and Silveira, 2020; Abramovay, 2022).

As discussed in Chapter 2, NEA adopts the approach of infrastructure induced by changes in the energy mix (Ribas, Lucena and Schaeffer, 2017; 2019). Adapted to the capabilities and limitations of the DOM and GEM models used, the energy solutions result from optimal combinations of technological packages with sources that simultaneously meet GHG emission constraints, the Levelized Cost of Energy and local potentialities and limits, such as solar irradiation, wind speed, temperature, availability of biomass, labor, essential minerals, logistics, among others.

In more detail, the energy infrastructure projections for the BAU and NEA scenarios were carried out by a sectorial downscale of BLUES-REGIA, following the methodology of SEMAS (2022). The changes in the energy mix affect other sectors in the economy and create the need for new infrastructure. Such infrastructure includes electricity transmission networks, biorefineries, non-ferrous metallic mining industries, floating photovoltaic systems, port structures, chargers for electric mobilty and final energy consumption (domestic, industrial, services, rural and transport).

Existing logistics in the electricity generation, transmission, and distribution networks as well as transport routes are coupled to the models to allow the expansion and operability of energy, physical, informational, and financial flows. Structural bottlenecks call for additional investments focused on the expansion of the industrial and logistical base. Such investments must follow previously selected criteria such as the impossibility of duplicating roads or building new land routes, which, in this case, would force investment projects to shift focus to existing river or sea routes with idle capacity.

Electricity and transport solutions are detailed, but the remaining solutions are not spatially explicit (for example, regarding logistics solutions, no new routes are drawn). Rather, such solutions are simply expressed in terms of additional investments. This arises from the peculiarities of specific infrastructure and associated financing sources (as described in the models' databases). This also explains why results indicating investment needs are aggregated and indistinguishable.

GDP, population, and income results from the BAU and NEA scenarios allowed the models to determine the immediate relationship between economic growth and energy consumption (Correia-Silva, Simões and Oliveira, 2017), as well as demand for transport (Marazzo, Scherre and Fernandes, 2021). The increase in efficiency (Bouman et al., 2017; Kozuba & Mateusz, 2019; Serra and Fancello, 2020) and the modal shift (Almeida, 2008; Costa, Caixeta-Filho Arima, 2019) were also considered for determining energy demand for transport. Subsequently, as the scenarios consider electrification of the transportation sector (Baptista, 2020), this demand for electricity was added to the total electricity demand for the other sectors.

It is already known that the approach to infrastructure as induced by changes in the energy mix is insufficient to meet specificities at the local level, for which detailed planning is necessary. On the other hand, it allows the creation of large-scale solutions that are compatible with the LAM's reality, serving as a framework to guide and inform local planning. Many of the solutions arising from the optimization and convergence of emission constraints, levelized cost of energy and local peculiarities (especially river capacity and bioeconomy residues) will require a sharp rupture of the business-as-usual trajectory. Decarbonizing the economy, therefore, implies an enormous challenge.

6.1 The limitations of the current energy mix in the LAM

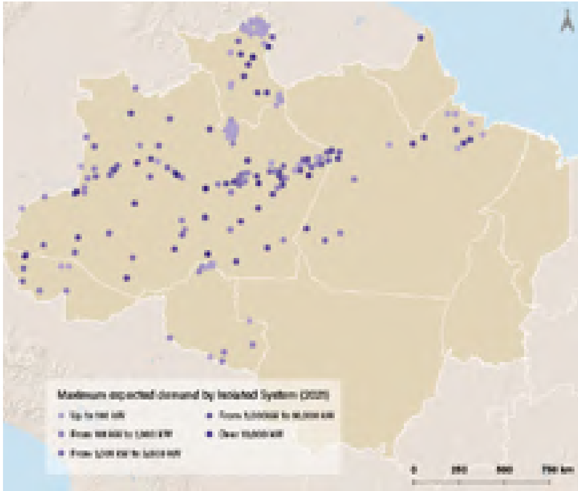
6.1.1 Electricity

The LAM generated 160 TWh (25.7% of the total electricity generated in the country) in 2020, with the water source responding for 83% of this volume (EPE, 2021b). Most LAM states exported electricity – Acre being the only exception. At this volume, the installed capacity in the LAM would be able to guarantee the expansion of its economy beyond 2050 if all generation were retained in the region (EPE, 2020b).

However, almost 60% of the LAM's electricity generation is transmitted to the rest of the country, and many Amazon regions are not integrated to the main national grid - the National Interconnected System (SIN), with several areas in the region lacking access to the public electricity service. Isolated Systems are present in some regions, but long distances and physical and environmental barriers make their connections to the SIN economically unfeasible. Figure 9 illustrates the SIN and the 258 Isolated Systems[57] currently existing in the country.

The current model of the isolated systems is not able to meet the demand for certain services, such as water and sewage treatment and digital inclusion, restricting the expansion of sanitation and connectivity infrastructure (IEMA, 2018; Matiello, 2018; EPE, 2021). Furthermore, more than 90% of the isolated systems' electricity mix depends on

Figure 9 | Location of the National Interconnected System and Isolated Systems



Note: Besides the LAM states, Isolated Systems are only present in Pernambuco.
Sources: ONS (2022) and EPE (2021a).

diesel oil, with a significant impact on the final cost of electricity and GHG emissions[58] (EPE, 2021a). Power generation is subsidized through a sector charge, the Fuel Consumption Bill, paid by SIN consumers through the Energy Development Bill (Conta de Desenvolvimento Energético; CDE, from its initials in Portuguese) (EPE, 2021a).

The use of diesel in isolated systems has other disadvantages besides elevated costs, emissions, and transfer rates. Fuel supply depends on complex logistics based mainly on river transport, which is difficult during the dry season due to lower river levels, exposing the population to frequent interruptions in the supply of energy. Fuels used in isolated systems can be stored for several weeks in warehouses (IEMA, 2018), creating risk of accidents and explosions, which results in additional storage costs (EPE, 2021a; ONS, 2022). The replacement of diesel generation with renewable energy sources (biomass or solar energy) could reduce polluting gas emissions and isolated systems' costs while at the same time stimulating the proximity economy.

There are also remote regions in the LAM that are not connected to the SIN or benefited by national isolated systems[59]. In some cases, energy is supplied independently, by private and collective initiatives involving the acquisition of diesel or gasoline generators. This is the case of the Vila Nova community in the Marajó archipelago, in Pará, the Wai-Wai indigenous community in Roraima, and the Cavalcante community, in Rondônia. In other cases, municipal and state governments bear the costs of this fuel, as in Amapá, with the "Luz Para Viver Melhor" program, which distributes diesel monthly to 152 communities in the state (Amapá, 2021). However, more than 475 thousand people in 161 municipalities in the LAM remain unassisted, without access to any electricity supply program, and often without knowledge of their real energy needs (IEMA, 2020).

To expand the distribution of electricity, the federal government launched the "Luz para Todos" program in 2003, increasing access to energy (Eletrobras, 2021). Recognizing the existence of more regions in the LAM with no public access to electricity, the government then launched the "Mais Luz para a Amazônia" program in 2020. This program established that energy must be supplied through decentralized systems such as the Isolated Microsystems for Electricity Generation and Distribution (Microssistemas Isolados de Geração e Distribuição de Energia Elétrica; MIGDI, from its initials in Portuguese) and Individual Electricity Generation Systems with Intermittent Source (Sistemas Individuais de Geração de Energia Elétrica com Fonte Intermitente; SIGFI, from its initials in Portuguese).

The program establishes renewable sources - wind, solar, biomass and hydroelectric power (MME, 2021) as priority components of its electricity infrastructure. However, the program is focused on residential demand and certain basic services (such as public health centers, schools, churches, community centers). In addition to being incipient and lacking a performance monitoring system, the program disregards demand from economic activities (Ferreira e Silva, 2021).

In fact, the lack of electricity affects local production. Fishing, acai chains and cassava flour production are negatively affected, as activities such as irrigation, crushing, grinding, husking and refrigeration need electricity to be productive and competitive (Barron-Gafford G. A. et al., 2019). In regions such as southern Amazonas, the Marajó archipelago and Baixo Amazonas, with the worst poverty and HDI indicators in the LAM, economic activities and socio-environmental community development could be greatly improved by access to low-cost electricity (Barra, 2021).

Availability of energy would also enable the supply of basic services to more remote communities, such as public lighting, lighting for night schools, energy for public health centers (refrigeration of medicines, vaccines and solutions), food refrigeration, water pumping and treatment, connectivity and improvement in thermal comfort and well-being (Di Lascio and Barreto, 2009; Pereira et al., 2011).

6.1.2 Energy for transport

In addition to the supply of electricity for households and productive structures, another structural problem incompatible with the NEA is the transport of passengers and cargo in the region. In the LAM, 6 million vehicles circulate for urban passenger mobility, including 38 thousand buses, 4 million cars and 1.9 million motorcycles (ONTL, 2019). Gasoline is the main fuel used for individual passenger transport, meeting 70% of demand, followed by ethanol (20%) and diesel (10%). Diesel is the main fuel used for public passenger transport, with a share of approximately 93%, excluding the percentage share of biodiesel (ANP, 2021b). According to estimates from this study, emissions from this segment amounted to 15 $MtCO_2$ in 2020.

Road cargo transport consisted, in 2019, of 271 thousand light trucks, 72 thousand heavy trucks and 441 thousand light commercial vehicles (Denatran, 2021), with emissions estimated by this study at 13.5 $MtCO_2$. Most of this fleet is found in the so-called deforestation arc - which concentrates 80% of the length of highways -, especially in its portion within the state of Mato Grosso. 31% of the LAM's cargo vehicles are registered in this state (DNIT, 2021). The Brazilian truck fleet mostly uses diesel with 13% of biodiesel in the mixture (ANP, 2021a; ANP, 2021b).

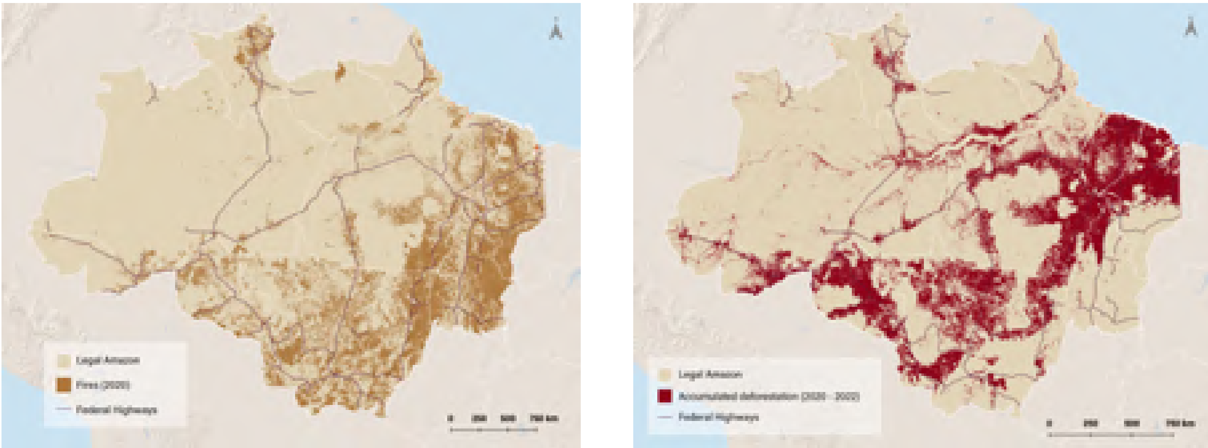
Traffic conditions on the highways are poor due to lack of paving on most of them (CNT, SEST and SENAT, 2022) and their concentration in a few areas. The state of Mato Grosso, for example, concentrates 28% of LAM's highways (DNIT, 2021). Although the expansion and paving of roads in conserved forest regions, such as the Amazon, can provide access to areas for extraction and agricultural activities, as well as inhabited areas, there is vast evidence that such expansion generates deforestation associated with fires (Figure 10). In fact, 94% of deforestation in the Amazon takes place within 5.5 kilometers of existing highways (Barber et al., 2014).

Large distances, low population densities, weather events and climate seasonality make the implementation of land transport infrastructure costly, both financially and for ecosystems. The lack of efficient logistics to promote the transportation of products and people increases the transaction costs of production in the LAM, reducing its competitiveness. The difficulty of transporting production is considered one of the obstacles of the regional bioeconomy (Chelala, Chelala and Almeida Carvalho, 2022).

Excluding professional commercial operations, the technological level – consequently, efficiency – of the Amazon transport park is well below the commercially available technology (CGEE, 2013). Thus, a potential modernization of the regional transport sector would bring positive economic impacts and reduced emissions. In this regard, the wide river network in the region offers an alternative to land transport, and already is the main means used in much of the region. Despite the low speeds achieved, this network is vital for commercial exchanges and distribution of regional production, with the additional advantage of being

Figure 10 | Relationship between (federal) highways, fires and deforestation

Fires — Deforestation (accumulated)



Source: Authors based on Prodes (2022) and RAISG (2022).

a transport mode with low energy intensity per ton transported compared to the road alternative.

Cargo transport in pure cargo vessels (boats and ocean vessels) totaled 80.3 million tons in the region in 2017 and 96.8 million tons in 2020 (Antaq, 2021). Passenger and mixed vessels transported 9.3 million passengers and 3.4 million tons of cargo in 2017 (Antaq and UFPA, 2018), divided between crossing, state, and interstate lines. Nautical vessels use diesel oil, fuel oil or a mix of the two, with fuel oil as the most common. The Brazilian Energy Balance for 2020 reports the use of 29% of diesel oil and 71% of heavy fuel oil by vessels (EPE, 2021b), adding emissions of approximately 2.1 $MtCO_2$ in 2020 as estimated by the models developed in this study.

Air transport is another important component of the regional network. Updated data from ANAC show that the LAM has 105 public civilian airfields (21% of the total in Brazil) and 102 new locations authorized for humanitarian assistance (ANAC, 2022). Additionally, 1,228 private aerodromes are registered (41% of the total in Brazil), 699 of which in Mato Grosso and another 190 in Pará (ANAC, 2021a). Aviation kerosene is currently the main fuel used in commercial aviation, but aviation gasoline is used in small aircraft, such as single-engine aircraft used in agriculture (Petrobrás, 2023a). Emissions from this segment were estimated by the present study at 150 $KtCO_2$. Illegalities involving air transport are frequent in the Amazon. Research from 2022 with satellite images demonstrate the existence of another 1,269 clandestine landing strips in the LAM, especially in Mato Grosso and Pará, in areas where small-scale mining activities were identified (Sousa, 2022; Potter, 2022).

Rail transport, on the other hand, is limited to short extensions, except for the Carajás Railroad, with its 890 km connecting the mining municipalities of Carajás, Marabá and Parauapebas, in Pará, to the Port of Ponta da Madeira in São Luís do Maranhão (ANTF, 2023).

6.2 New Infrastructure for the LAM

6.2.1 Electricity

Based on energy demand, population growth and GDP data estimated in the DOM and GEM models, the total energy demand in the NEA scenario was estimated at 211 TWh, compared to 255 TWh in the BAU scenario and 169 TWh in base year 2020 (all types of energy, including fuels, converted into TWh). Considering only electricity for domestic, industrial, rural, services and transport consumption, 131 TWh would be needed in the NEA scenario, against 74 TWh in the BAU and 52 TWh in 2020.

In addition to the centralized demand for electricity generation connected to the SIN, supported essentially by hydroelectric power plants inside and outside the LAM, local solutions based on renewable sources must compose the electricity mix to feed the SIN, isolated systems, and remote regions.

Usable wind power resources were found to be concentrated in the extreme north of the state of Roraima, within Raposa Serra do Sol Indigenous Land (Badger et al., 2022). The exploitation of this wind power potential, for the benefit of the Indigenous Land population, requires further studies, including the potential impact on avifauna, the available infrastructure for transport and installation of the turbines and potential environmental and social impacts for the region. The project involves social and environmental constraints that require a thorough evaluation that goes well beyond technical and economic feasibility aspects, starting with the indigenous people's protagonism in the decisions. For these reasons, it has not been considered in this study.

Solar energy

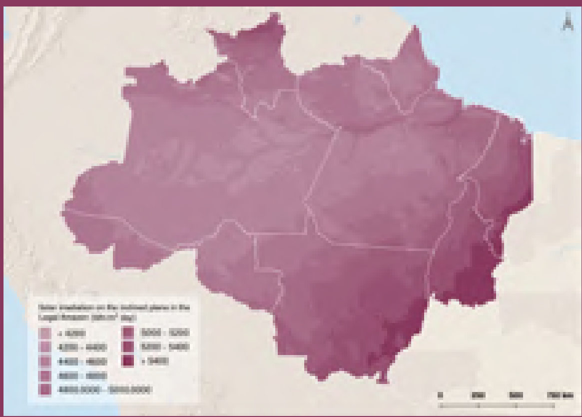
Both the BAU and NEA scenarios show an upward trend in the use of solar energy. A multicriteria methodology considering floating systems on water bodies and ground-mounted systems on degraded pasture areas (Barron-Gafford et al., 2019) was used to measure the supply of solar energy and prioritize deployment areas. The annual average photovoltaic generation potential on the inclined plane, as well as the distances to transmission lines, substations, highways, waterways, and urban centers were considered in the assessments, conducted at municipal levels for the entire LAM (see Box 18). Optimized allocations considered the levelized cost of energy defined by the ratio between total invested capital (Capex) and operating costs (Opex) for energy generated over the 30-year period (see box for more details).

Technician repairs solar panels in Breves, state of Pará.
Photo: Bruno Cesar Spada/Shutterstock.

Box 18 | Potential of photovoltaic generation in the Legal Amazon

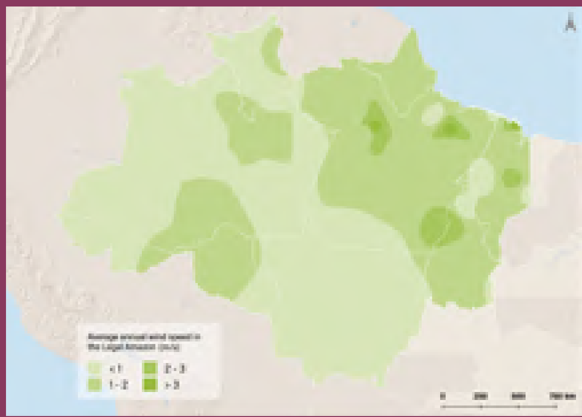
A number of meteorological variables affect the availability of photovoltaic energy, such as solar irradiation, wind speed and temperature (Figures Q18.1, Q18.2 and Q18.3). These climatic variables influence the heat transfer that occurs in photovoltaic modules, affecting the final generation of photovoltaic energy (Santos and Lucena, 2021). Based on studies by Santos and Lucena (2021) and Skoplaki, Boudouvis and Palyvos (2008), the potential for photovoltaic generation on the inclined plane by LAM municipality was estimated (Figure Q18.4).

Figure Q18.1 | Solar irradiation on the inclined plane in the Legal Amazon (Wh/m² day)



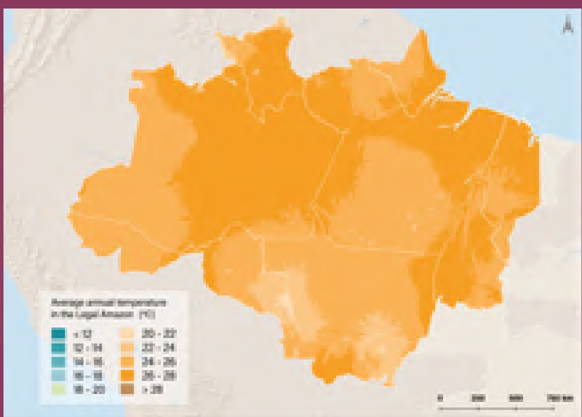
Source: Pereira et al. (2017).

Figure Q18.2 | Average annual wind speed in the Legal Amazon (m/s)



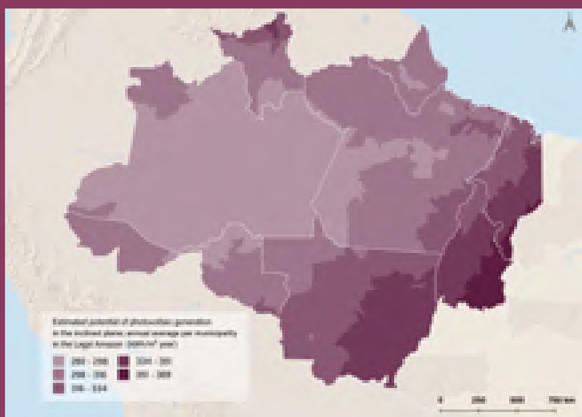
Source: INMET (2022).

Figure Q18.3 | Average annual temperature in the Legal Amazon (ºC)



Source: INPE (2022).

Figure Q18.4 | Estimated potential of photovoltaic generation in the inclined plane; annual average per municipality in the Legal Amazon (kWh/m² year)

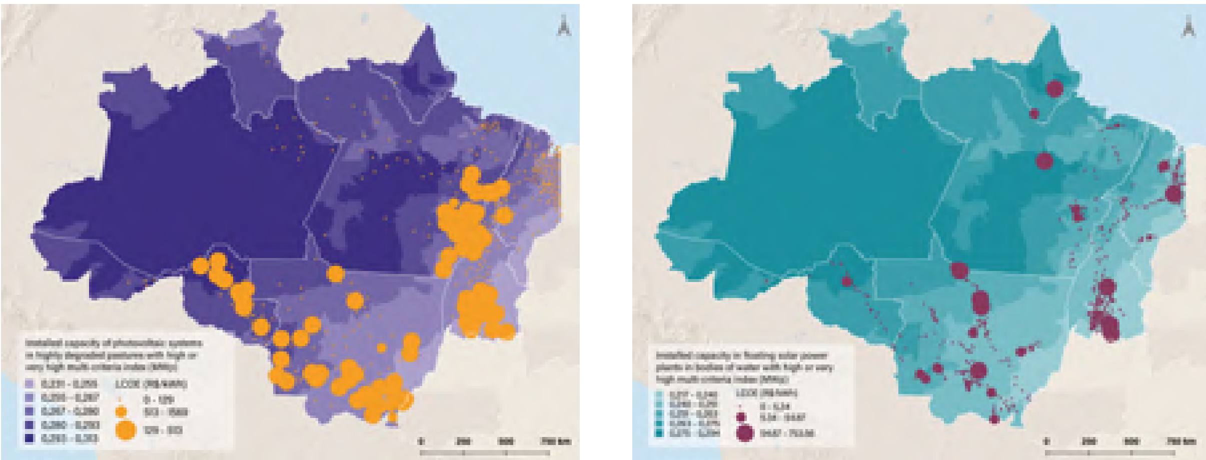


Source: Authors.

The technical potential in floating systems was assessed at 3.1 GWp, with a generation potential of 5.7 TWh per year. This represents about 8% of the energy generated by the Itaipu power plant in 2021 (Itaipu Binacional, 2021). Considering that the consumption of electricity in the LAM, in 2021, totaled 54,399 GWh (EPE, 2022), the technical potential estimated only for floating systems would be equivalent to almost 11% of the current demand in the region.

Approximately 95% of the estimated technical potential for photovoltaic generation is located in dams of existing hydroelectric power plants, enabling interconnection to the SIN, with emphasis on dams in the states of Tocantins (38.8%), Mato Grosso (30.7%), Pará (20.4%) and Amapá (4.0%). For prices below $ 43.4/MWh, no photovoltaic plant on floating systems would be economically viable. As average prices in the LAM region are currently at $ 126.6/MWh (EPE, 2022), more than 95% of floating systems would be economically viable. Figure 11 presents the maps with the locations of the optimal points identified for the installation of the systems.

Figure 11 | Technical potential in water bodies and levelized cost of energy for floating systems and ground-mounted systems on degraded pastures in the LAM



Source: Authors.

Ground-mounted systems exclusively deployed on highly degraded pastures would be installed in a total area of 37.7 thousand hectares, with technical potential of 36.6 GWp and generation potential of 66.7 TWh per year. This potential is equivalent to all the energy generated by the Itaipu power plant in 2021 and approximately 125% greater than the LAM's current total demand. Approximately 35.7% of this potential would be located in Mato Grosso, 26.6% in Tocantins, 22.2% in Pará and 8.5% in Maranhão.

The total installed capacity required to meet the energy demand for livestock production was estimated at 10.3 GWp, implying an area of about 5 thousand hectares of ground-mounted systems, enough to provide shade in rotational systems to a herd of 25.5 million head. Based on energy prices at $ 121.2 MWh, the entire technical potential would be economically viable. As the electricity price for the rural sector in the LAM stands at $ 156.1 MWh (EPE, 2022), the described photovoltaic systems would be viable in almost the entire LAM.

Considering only photovoltaic energy, the technical potential of floating and ground-mounted systems would be able to meet 55% of the 131 TWh demanded by the LAM in 2050 under the NEA scenario.

Table 26 | Installed capacity of photovoltaic systems for LAM designed for 2050

State	Average photovoltaic generation (kWh/m² year)	Potential installed capacity (MWp)	Technical potential (TWh/year)
AC	328	62	0,1
AM	316	22	0
AP	331	1	0
MA	359	3,107	5,6
MT	357	12,856	23,7
PA	338	8,429	14,8
RO	329	2,726	4,6
RR	342	25	0
TO	368	9,346	17,7
LAM	na	36,575	66,7

Note: Results from this study.
Source: Authors.

Waste biomass

Biomass is an additional source of electricity, particularly waste biomass from production chains in the bioeconomy, such as acai and cocoa, and solid urban waste. Waste can also be used to produce biofuels (see box). Waste can be handled through different technologies with different operating costs, complexities, and energy conversion efficiency. Anaerobic digestion, gasification and incineration are among the waste treatment technologies for energy generation that stand out for developing countries (Coelho, 2020).

In the transition to the NEA scenario, treatment of solid waste is a mandatory condition for pollution reduction and energy generation. Currently, around 40% of the waste generated in LAM cities still goes to landfills and another 25% to controlled landfills, with few and isolated treatment initiatives such as capturing methane in landfills to generate electricity (SNIS, 2021). In addition to agricultural waste, acai pods are another important potential source. Close to 1 million tons of acai pods are disposed of per year, despite the potential to generate around 5.23 MWh/year/ton when incinerated.

Catamaran and boat hotel, in Novo Airão, state of Amazonas. Photo: Karoline Barros/WRI Brasil.

Box 19 | Biofuels in the Legal Amazon

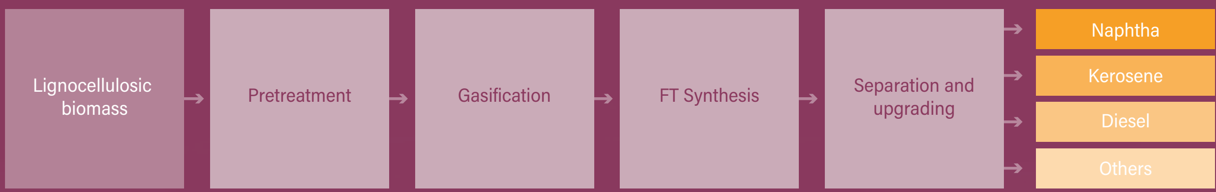
Biofuels can be made from different raw materials, through different production routes. Briefly, raw materials for biofuels range from oilseeds in general, which generate vegetable oils, to lignocellulosic biomass, such as agricultural and forest residues, which generate alcohols or synthesis gas. Each of these by-products undergoes different processes, such as hydrogenation and Fischer-Tropsch synthesis, ultimately generating a range of products that subsequently undergo separation and energy vectors are thus obtained (Szklo et al., 2021).

Results from the assessed scenario show that the biofuels used in the LAM, in both the naval and air sectors, are made through the Fischer-Tropsch Biomass-to-Liquids (FT-BTL) process, with the biomass used as raw material coming mainly from planted forests located in regions outside the Amazon.

However, if 10% of the degraded areas in the region were used for diesel production through the FT-BTL route, it would be possible to meet 23% of the current demand for diesel used in road cargo transport. And this same area would meet 100% of demand by 2050 under the bioeconomy scenario, which foresees the electrification of a large portion of the fleet.

This process does not generate a single final product but a number of heterogeneous products, similar to oil refining, with the composition of the final products determined by the type of catalyst and reactor used, in addition to the operating conditions of the process stages. Figure Q19 illustrates the FT-BTL process.

Figure Q19 | Fuel production process through the FT-BTL technological route



Source: Szklo et al. (2021).

The biomass initially undergoes pre-treatment, followed by gasification, which is carried out through partial oxidation of the raw material. This process creates a synthesis gas that is mostly composed of hydrogen, nitrogen, carbon monoxide, carbon dioxide and methane (Tagomori, 2017). This gas is treated to remove impurities and acids and subsequently undergoes Fischer-Tropsch synthesis, a process in which several adsorption and dissociation reactions of gas substances occur, and simpler compounds are formed. These compounds then combine and form longer chains of hydrocarbons. The products are then separated, and the chains are upgraded with the aim of increasing the quantity of specific final products demanded in each case, as well as adapting the compound to technical specifications - biokerosene and green diesel in the case of the LAM.

Energy recovery from urban solid waste was estimated to generate approximately 10,500 GWh/year by 2050, in addition to another 1,900 GWh/year from agricultural waste and 2,200 GWh/year from acai pods and cocoa biomass.

The potential per source would be heterogeneously distributed across the LAM, with Pará representing 30% of the energy generated from solid waste, followed by Maranhão with 21% and Amazonas with 17%. Mato Grosso would account for 81% of generation from agricultural waste, followed by Pará with another 11%. Pará would account for 91% of the energy generated by acai and cocoa waste, while Amazonas and Rondônia would reach 2% each.

Urban solid waste, agricultural waste and waste from the bioeconomy would generate about 14,290 GWh/year by 2050.

This extra supply of energy, despite corresponding to less than 1% of electricity demand in the LAM under the NEA scenario, would allow, in 2050 alone, the replacement of 358.7 million liters of diesel or 398.9 million liters of gasoline used in generators in remote regions, reducing emissions by almost 1.5 $MtCO_2$. It would also minimize interruptions and boost the circular economy through a reduction in fuel imports and income generation from the purchase of waste.

Microgrids

The energy transition to the NEA considered cost-effective options for both centralized power generation solutions and microgrid solutions. While centralized solutions are only possible for regions connected to the SIN, microgrid solutions are also feasible for locations not served by an electricity network, for isolated systems and for remote regions.

Microgrid generation also has other advantages: (1) it provides stability in the supply of energy generated from intermittent renewable sources (wind, solar and biomass energy, among others); (2) it is consistent with the scenario of transition to the NEA, incorporating waste from the bioeconomy with the purpose of turning it into an energy source; and (3) it allows expansion of energy supply in locations and sectors whose repressed demand may have been underestimated in forecasts (Ustun, 2016).

Microgrids with local renewable resources were thus considered, with decentralized energy generation solutions for isolated systems and remote regions replacing the use of diesel, which, as previously discussed, is inefficient, expensive, and polluting. Assessments focused on the availability of the resource and the configurations capable of promoting energy security. They also focused on the most adequate mechanisms to address the intermittent availability of energy sources. Homer microgrid software was used for this purpose. It is a simulation model that configures several systems in a single run and subsequently classifies the systems according to their cost-effectiveness (BrasilSofts, 2023).

Homer simulations allowed the investigation of complementarities among electricity generation sources for LAM microgrids, with results inserted into the GEM model to produce the respective impacts on demand fulfillment and investment. In addition to the mentioned renewable resources, the following storage technologies were considered: lithium-ion batteries, sodium-sulfur batteries (NaS), flywheels and hydrogen (only for regions close to rivers).

In addition to cost optimization, the simulated microgrids were chosen because they contemplate the maximum number of resources and different electricity demand profiles (see appendix for more details). Table 27 outlines different architectures to meet the microgrid demand in the LAM and shows the variation in costs. It is possible to note that the configurations with lower costs in the NEA scenario are cheaper than the BAU scenario configuration, with diesel generators.

Tabele 27 | Simulated microgrids

Microgrid	Possible architectures	Diesel generators	Wind (275 kW units)	Solar PV (kW)	Generator with MSW (kW)	Generator with agricultural and sociobiodiversity waste (kW)	Li-ion (100 kWh units)	NaS (1450 kWh units)	Flywheel (100 kW units)	H2	Cost at present value (BRL million)	Levelized cost of energy (BRL)
Urucumacuã Bioeconomy	16	-	-	2225	-	400	-	4	-	-	22.9	0.611
		-	-	2173	100	400		4	1	-	23.8	0.635
		-	-	4012	-	-	218	-	-	-	47.2	1.26
		-	No possible architecture was found to meet demand without solar power									
Urucumacuã diesel	1	700									51.2	1.37
Com. Ind. Santa Creuza Bioeconomy	40	-	-	16.3	50	50	1	-	-	-	0.64	0.886
		-	1	-	50	-	1	-	-	-	2.1	2.9
		-	1	8.91	50	50	-	-	1	-	3.32	4.57
		-	-	-	50	50	-	5	-	-	13.3	18.29
Com. Ind. Santa Creuza diesel	1	50									1.61	2.21
Com. Ind. do Canavial Bioeconomy	44	-	-	90.3	50	50	3	-	-	-	1.23	0.804
		-	1	-	50	50	1	-	-	-	2.25	1.47
		-	-	-	50	50	-	31	-	-	79.1	51.5
Com. Ind. do Canavial diesel	1	100									3.09	2.01
Codajás Bioeconomy	4	-	-	6434	3000	5000	101	-	-	-	160	0,332
		-	-	5951	3000	5000	-	18	-	-	183	0.381
		-	-	7479	3000	7000	-	-	-	-	232	0.484
		-	-	8203	3000	7000	-	-	30	-	256	0.534
Codajás diesel	1	7000									614	1.28

Note 1: The hydrokinetic source was excluded from the simulations due to the lack of data for electricity generation calculations.
Note 2: In neither case did Homer choose hydrogen as energy storage.
Note 3: The table shows only some of the architectures found to meet demand.
Note 4: The simulations were performed for 2019 diesel prices.
Note 5: Results of this study.
Source: Authors.

Access to reliable electricity is critical to community socio-economic development. Microgrids are an alternative solution for this issue, and reduce GHG emissions and costs compared to the use of diesel in the proposed configurations. In the simulations, waste proved to be a great ally of variable renewable energies by reducing the need for batteries and thus reducing microgrid costs.

For a successful planning process regarding the implementation and operation of solutions, it is important to improve supply-related measurements such as the speed of rivers in the LAM. Likewise, on the demand side, aspects such as the number of people without access to energy and possible electricity deficits in existing systems need to be assessed. Additionally, it is important that communities are involved in the entire process related to the solutions, especially regarding maintenance and decommissioning, with proper disposal of remaining parts and equipment. This implies the availability of training and capacity building opportunities for the communities. Finally, microgrids require a real-time monitoring and control strategy because of the variability of renewable energy sources. In this sense, access to quality internet connectivity is an important condition for the implementation of microgrids.

Total investments in the electricity sector, only regarding generation, to finance the transition to the NEA were estimated at $ 78.9 billion, of which 72% refer to the use of locally produced biomass.

Investments needed for transmission and distribution, as well as other induced infrastructure, are presented in aggregates that are not distinguishable from other infrastructure. This is due to limitations of the models used. Table 28 shows investments in electricity generation in the BAU and NEA scenarios.

Table 28 | **Expected investments in electricity generation in the LAM, under the BAU and NEA scenarios ($ billion)**

		BAU	NEA
Electricity		188,6	267,5
National Interconnected System	Wind power	39,1	39,8
	Solar power	14,8	15,0
	Biomass	15,4	72,0
	Other sources	86,6	86,6
Local systems	Solar power	32,6	53,8
	Waste	0,0	0,3

Note: Results of this study.
Source: Authors.

Energy from rivers

Hydroelectricity, which is still included in government programs such as the "Mais Luz Para a Amazônia" program, must prioritize lower impact options such as hydrokinetic power plants. Technology that harnesses the kinetic energy of river currents is a technological solution capable of providing electricity to remote rural areas (Davila-Vilchis and Mishra, 2014; Guner and Zenk, 2020; Salleh, Kamaruddin, and Mohamed-Kassim, 2019).

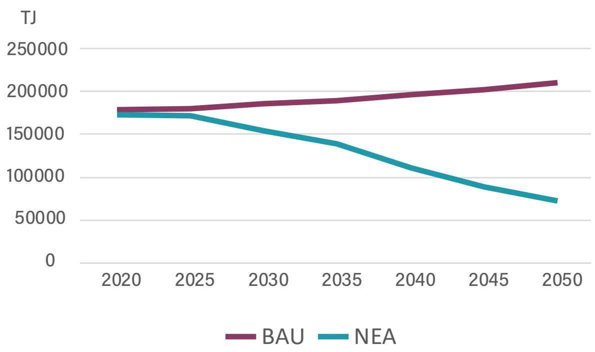
However, there is a significant scarcity of data referring to the speed of rivers in the Amazon, essential for identifying and estimating regions with potential for hydrokinetic energy generation, which makes it impossible to calculate electricity generation from this source. The NEA scenario does not foresee the expansion of conventional hydroelectric power plants.

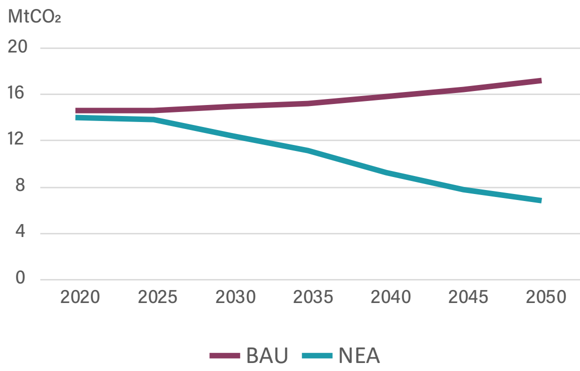
6.2.2 Energy for transport

The mobility infrastructure must meet the strategic needs of the transition, prioritizing alternatives for transport of goods and people that produce less emissions and socio-environmental impacts, added by the inexorable replacement of non-renewable fuels with electrification and, to a lesser extent, second and third generation biofuels.

In road passenger transport, the results of the models pointed to the need for electrification of 75% of the light vehicle fleet, 95% of motorcycles and 94% of the public transport fleet by 2050, with a concomitant 30% increase in the use of collective transport modes. Such changes would result in increased urban mobility and a significant reduction in the time spent in transit, leading to a productivity gain of 37 billion passenger-km (pkm) by the end of 2050. Total demand for energy, as well as emissions of GHG and local pollutants, would fall over the 30-year period by 2.3 M TJ and 177 $MtCO_2$, respectively, when compared to the BAU scenario. Chart 20 compares energy demand and estimated emissions for road passenger transport in the LAM under the BAU and NEA scenarios.

Chart 20 | Comparison of energy demand and estimated emissions for road passenger transport in the LAM under the BAU and NEA scenarios





Note 1: Energy demand in Tera Joules (TJ) in the chart on the left and emissions in millions of tons of CO_2 ($MtCO_2$) on the right.
Note 2: Results of this study.
Source: Authors.

Although these changes seem very ambitious, they are consistent with previous experiences in Brazil, and do not deviate from the expectations of the automotive industry itself, at least in the case of light vehicles. A study by Anfavea (Boston Consulting Group, 2021), for example, forecasts that, as early as 2031, electrified vehicles will reach parity in cost of ownership with flex-fuel vehicles for cars priced up to $ 36 thousand and, in 2035, for cars priced up to $ 20 thousand, while price parity for shared light vehicles has been anticipated to 2028 (Boston Consulting Group, 2021).

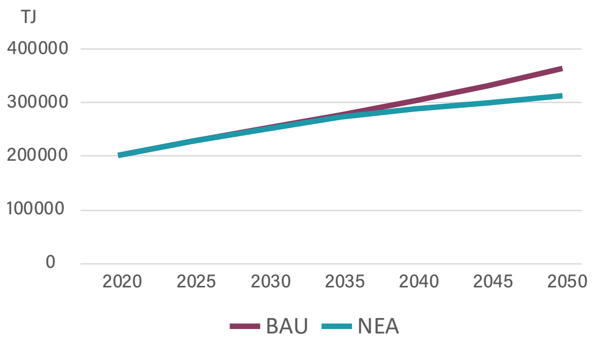
According to Anfavea (Anfavea, 2022), the licensing of electrified vehicles in the country grew at a rate of 56% per year over the past decade, lower than the growth rate observed for ethanol vehicles in the first ten years of the Proálcool program launched in 1979, but double the growth rate for flex-fuel vehicles in the first ten years since their launch in 2003. Even if the calculation basis for electrified vehicles' growth rates is much smaller than in other experiences, the Anfavea study (2021) forecasts that, as early as 2035, electrified vehicles will likely represent 32% of new licenses in a conservative scenario, and 62% if regulations in favor of low carbon emissions come into force. Consequently, electrified vehicles will likely represent between 10% and 18% of the current fleet of light vehicles in the country by 2035.

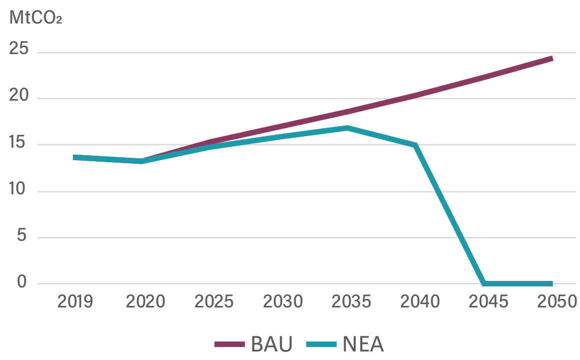
Parallel to the expected changes in passenger transport, road cargo transport needs to be redefined towards more rational arrangements given its characteristics. This transport mode could play an important role in short-distance journeys, for example urban cargo transport, or as an extender or connector of the waterway network, due to its high operational flexibility. Additionally, as the NEA scenario embodies an integrated approach to solutions, the importance of energy-technical alternatives is highlighted, as well as efficiency strategies and logistical optimization for GHG reduction.

The transition scenario foresees road cargo transport requiring 197,000 TJ from biofuels and 119,000 TJ from electricity, while the BAU scenario requires 366,000 TJ from fossil fuels (Pfaff, 2007), with avoided emissions of around 214 $MtCO_2$ in the NEA scenario compared to the BAU.

Chart 21 compares the energy demand and estimated emissions for road cargo transport in the LAM under the BAU and NEA scenarios.

Chart 21 | Comparison of energy demand and estimated emissions for road cargo transport in the LAM under the BAU and NEA scenarios





Note 1: Energy demand in the chart on the left and emissions on the right.
Note 2: Results of this study.
Source: Authors.

The transition to the NEA proposes, for long-distance road transport, that the fraction of biofuels (biodiesel and HVO) in diesel rises from the current 10% to 100% in 2050, which represents annual growth rates 5% above the rates observed since 2004, when the National Biodiesel Production Program was launched (Brazil, 2020). Concomitantly, short-distance road transport would progressively shift to an electric fleet, at a pace at which electrified trucks would represent 100% of new licenses by 2050. The Anfavea study forecasts that in 2035 these trucks would be responsible for 15% of sales in the national market (Boston Consulting Group, 2021). The adoption of these measures would reduce energy consumption and emissions of GHG and local pollutants by, respectively, 1.3 M TJ and 29 $MtCO_2$ over the 30-year period.

Additional measures for road cargo transport include: reduction of empty running conditions; awareness-raising campaigns and training opportunities for drivers; eco-driving (Xu, 2017); standardization of cargo packaging (Mahmoudi, 2020); reduced idling time (Kamakate and Schipper, 2009); promotion of proper vehicle maintenance (Bartholomeu, Péra Caixeta-Filho, 2016); cargo and route optimization (Fleury, 2012); adoption of virtual optimization and monitoring tools (Arruda & et al., 2018); horizontal and vertical cooperation between stakeholders in the logistics sector (Marcucci, 2017); establishment of urban consolidation centers (Schor, 2016); establishment of loading and unloading points in strategic locations (Meidute-Kavaliauskiene, 2022); diversification of vehicle size in last mile stretches (for example, bicycles and tricycles) (Oliveira, 2017); and urban planning (De Oliveira, 2014).

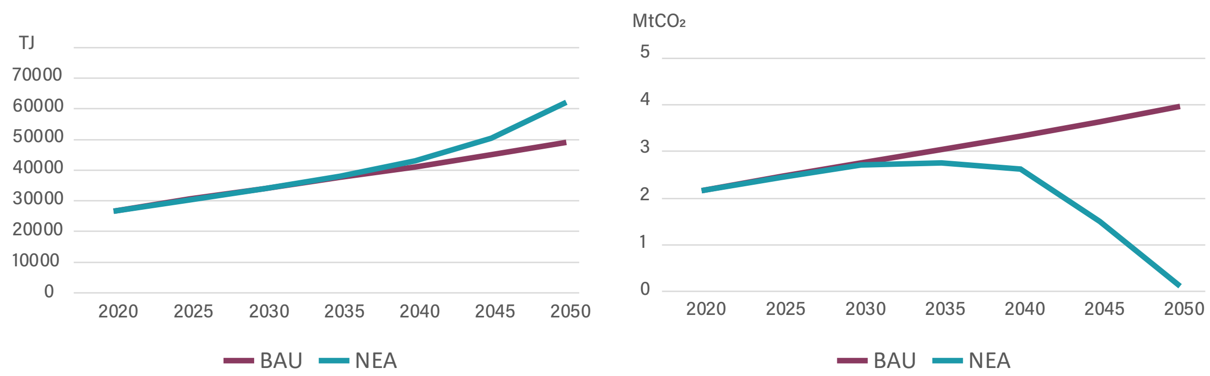
Water transport, already favored by the extensive river network and because it is the modal with the highest efficiency per ton transported (Trancossi, 2016), would be expanded and more intensively used, absorbing 20% of current road cargo transport. In fact, river cargo transport can replace fossil sources with the electrification of routes where the use of batteries is available and economically viable, in addition to the use of biofuels from local waste (Mauler et al., 2021; Kim et al., 2020).

The new infrastructure could benefit from an increased use of waterways to the detriment of road transport, which is less efficient and generates more emissions and deforestation (Pfaff, 2007).

While the BAU scenario foresees a demand of 49 thousand TJ for hybrid water transport (passengers and cargo), with 7.5% corresponding to biofuels and the rest fossil fuels, the NEA scenario would increase demand by 26% (62 thousand TJ), with 70% of this volume met by biofuels and 30% by electrification. Accordingly, the BAU scenario would accumulate, in the 2020-2050 period, additional emissions of 6.92 $MtCO_2$ compared to the NEA scenario.

Chart 22 compares energy demand and estimated emissions for hybrid water transport in the LAM under the BAU and NEA scenarios.

Chart 22 | Comparison of energy demand and estimated emissions for hybrid water transport in the LAM under the BAU and NEA scenarios



Note 1: Energy demand in the chart on the left and emissions on the right.
Note 2: Results of this study.
Source: Authors.

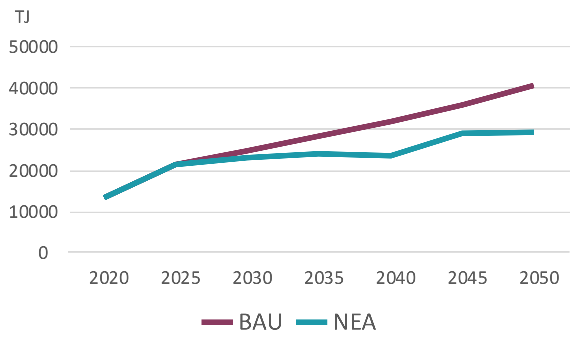
The optimization of routes and vessels is another fundamental component for the sector. The maximization of vessels' capacity factor, speed control and the use of more efficient technologies tend to have a beneficial effect on the modal's energy consumption, reducing energy demand per ton-kilometer. Enabling water transport through the waterway that connects the Juruena and Teles Pires rivers would be an important advance, alleviating the use of highways between the states of Mato Grosso and Pará - important routes for grain transportation originating from Mato Grosso (Amorim and Lopes, 2017).

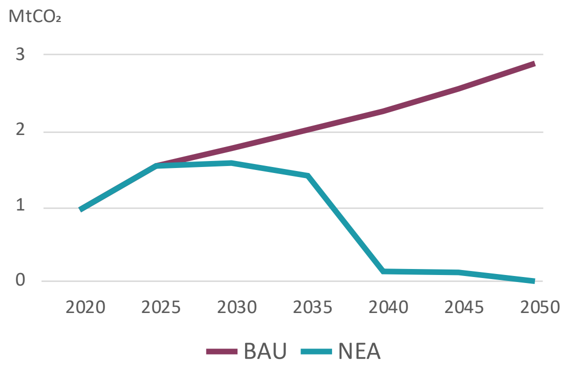
Long-distance river transport for passengers could also benefit from the electrification of air transport (Bauen, 2020; Rendón, 2021). The use of hydroplane-type electric aircraft, replacing regular river transport routes, has the potential to bring financial gains without the need for massive investment in airport infrastructure due to the possibility of using existing infrastructure for river transport (Lanaro, 2021). In addition, the air transport sector enables direct connection within the Amazon region and between the region and the rest of the world for the transport of people and high value-added cargo (Azevedo, 2022).

The evolution of battery technology will lead to gains in efficiency, promoting the adoption of electrically powered air transport, initially on regional and lower-volume routes. This adoption would potentially lead to an advance of this modal. The Amazon region represents the type of market that will benefit the most from this type of aircraft at initial stages.

Electrification brings an economic opportunity to the local economy due to the synergies with several industries present in the region (automotive, naval, electronics), turning the region into a potential hub for this new industry (Azevedo, 2022). The use of drones for on-demand transport of high value-added goods could become a leverage factor for the local economy, with advantages for several applications. However, the operations of autonomous and remotely piloted aircraft beyond ANAC's visual range need to be approved for this to become a reality (ANAC, 2021). Considering the initiatives above for air transport electrification, the BAU scenario outlines accumulated emissions (for the 2025-2050 period) of 13.05 $MtCO_2$, while the NEA scenario accumulates 4.79 $MtCO_2$, a 63% reduction in emissions from this transport mode. Chart 23 compares energy demand and estimated emissions for hybrid water transport in the LAM under the BAU and NEA scenarios.

Chart 23 | Comparison of energy demand and estimated emissions for hybrid water transport in the LAM under the BAU and NEA scenarios





Note 1: Energy demand in the chart on the left and emissions on the right.
Note 2: Results of this study.
Source: Authors.

The main proposed alternatives, therefore, consist of the adoption of more efficient and less carbon intensive propulsion alternatives, as well as the promotion of less energy-intensive modes for cargo transport. These solutions support the local economy by promoting existing industries in the region, such as moped and electronic equipment manufacturers. Moreover, there is the opportunity to create industries focused on the production of electric aircraft and boats, with significant economic potential. The solutions described, in addition to mitigating GHG emissions, have the potential to contribute to other aspects such as improved air quality, job creation and reuse of organic waste (De Oliveira, 2017). However, the adoption of the proposed alternatives faces different challenges, such as those related to logistics and production costs for ship and aircraft manufacturing, as well as technology acquisition costs and investments in charging infrastructure for electric vehicles (Bouman et al., 2017; Zhang and Fujimori, 2020). Table 29 shows the energy balance, in TWh, in base year 2020 and in the BAU and NEA scenarios by 2050.

Table 29 | **Estimated energy balance in base year 2020 and in the BAU and NEA scenarios by 2050**

TWh		Base-year 2020	BAU 2050	NEA 2050
TOTAL ENERGY DEMAND		169.2	255.1	211.3
Electric energy		52.0	74.0	131.2
Fuels		117.2	181.1	80.1
TOTAL USE OF ELECTRIC ENERGY		52.0	74.0	131.2
Residential, industrial, rural, services and others		52.0	69.5	78.0
Transport		0.0	4.5	53.1
ELECTRIC ENERGY SOURCES				
National Interconnected System (except solar power in floating systems and degraded pastures)		49.1	69.0	77.0
Solar power on floating systems and degraded pastures (of the total 72.4 TWh economically viable)		0.0	0.0	44.8
Isolated systems (fossil fuels)		2.9	5.0	0.0
Isolated systems (urban, agricultural and bioeconomy solid waste of a total of 14.6 TWh economically viable)		0.0	0.0	9.4
ENERGY FOR TRANSPORT				
Energy for road passenger transport	Fossil fuels	46.1	49.5	6.9
	Biofuels	4.2	8.0	2.8
	Electricity	0.0	1.7	10.4
Energy for road cargo transport	Fossil fuels	49.8	79.5	0.3
	Biofuels	6.5	19.9	54.6
	Electricity	0.0	2.3	33.0
Energy for water cargo transport	Fossil fuels	6.9	12.2	0.1
	Biofuels	0.1	1.0	11.8
	Electricity	0.0	0.3	5.3
Energy for air-fluvial transport	Fossil fuels	3.7	10.6	0.5
	Biofuels	0.0	0.4	3.1
	Electricity	0.0	0.2	4.5

Note: Results of this study.
Source: Authors.

The investments needed to finance the transition of the transport sector are based on two distinct assessments. The first refers to the demand for transport electrification, embedded in the generation of electricity, as mentioned earlier. The second assessment concerns the investments needed to expand the biofuels production capacity to meet demand from the transport sectors. These two investment needs were estimated ex post, by converting the energy demand for ethanol and biodiesel (TJ) in the models for both scenarios and apportioned according to the investments calculated by the Energy Research Office (EPE, 2022). The results are shown in Table 30.

Table 30 | Investments in biofuels by mode of transport, in the BAU and NEA scenarios ($ billion)

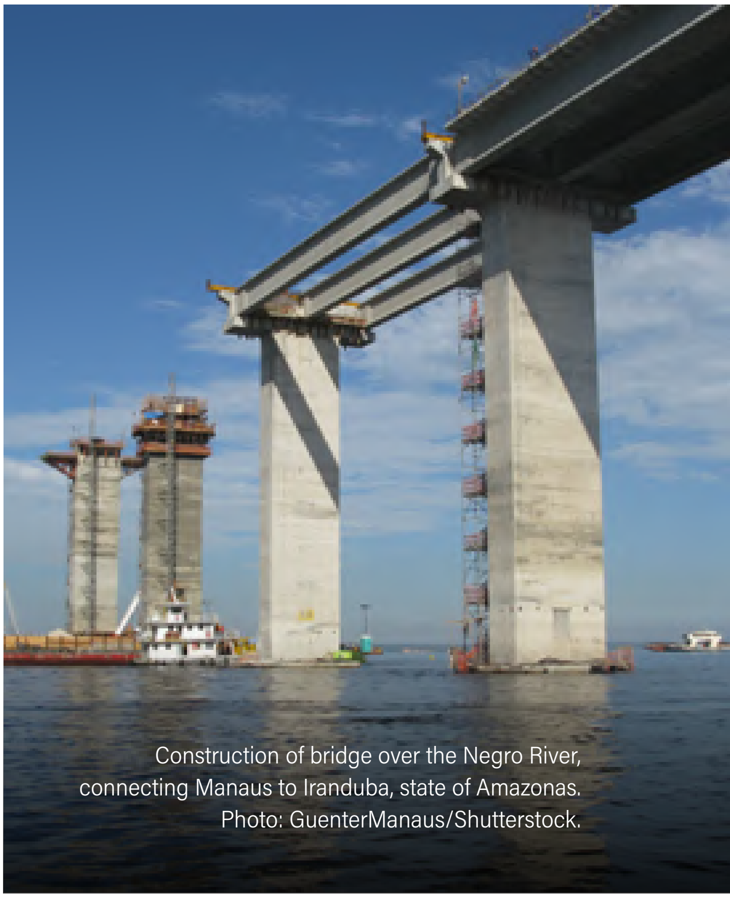
	BAU	NEA
Biofuels	2.8	7.0
Road passenger transport	0.8	2.3
Road cargo transport	1.4	3.1
Hybrid water transport	0.3	0.8
Air-fluvial transport	0.3	0.8

Note: Results from this study.
Source: Authors.

The models used assume a balance between energy supply and demand, although there is an emphasis on the production side – insofar as the models seek optimized solutions for generation. It must be admitted, however, that the resulting energy supply depends on structured demand to materialize. The methods used do not allow a more detailed analysis of demand composition, but it is worth highlighting the roles that cities will likely play in this process.

Mobility policies are among the main changes that will vitally depend on cities, especially medium and large ones, and include (1) public transport concession aimed at fleet electrification; (2) incentives via concession conditions to increase the number and frequency of minibuses, aimed at discouraging the use of individual transport, (3) implementation of exclusive circulation lanes for public transport, (4) implementation of systems on rails in large urban centers, (5) modal transfer policies, aiming at replacing individual transport with micro-mobility, (6) adoption of information technology tools for optimization, security and logistical monitoring, (7) integrated coordination between road-waterway logistics providers, with synchronicity, (9) reduction in docking fees for vessels with batteries.

Investments should include, among other items, (1) adaptation of the waterway infrastructure and intermodal terminals with provision of charging and battery exchange services at gas stations, ports and airports; (2) implementation of input recovery networks for the manufacture of biofuels (agricultural, industrial and urban waste); (3) adaptation of the electrical network to support demand, with the Manaus Free Trade Zone potentially playing a vital role in the production and distribution of inputs and outputs needed for these changes.



Construction of bridge over the Negro River, connecting Manaus to Iranduba, state of Amazonas. Photo: GuenterManaus/Shutterstock.

6.2.3 Considerations on connectivity

Connectivity is an important element for regional development, digital inclusion and regional integration. Access to quality internet connectivity can favor the transition to a low-carbon economy by offering GHG mitigation solutions, such as lower emission electricity generation alternatives, and the adaptation of human activities in the face of risks associated with natural disasters.

The process of "dematerialization" or "virtualization" of face-to-face activities, such as replacing meetings and providing services via remote connection, favors the reduction of GHG emissions. Also, connectivity allows real-time dissemination of information, such as weather forecasts and natural disaster risk alerts, contributing to the adaptation of human activities and risk prevention (Broadband Commission, 2012). There is evidence that the use of mobile phones with Internet access reduces information asymmetry in rural activities, contributing to price setting among grain traders (Aker, 2010) and reducing the spread of disease in poultry among poultry farmers (FAO, 2017), for example.

Internet connectivity can also contribute to the improvement of various social, economic and political aspects, reducing the "digital apartheid" (Brown and Czerniewicz, 2010). The internet facilitates access to information, educational resources, health services, job opportunities and social engagement. It also creates conditions for greater transparency in public policies (UNDP, 2022) and for monitoring of environmental crimes, including deforestation and land grabbing (Amaral, 2006; Souza, 2018). From an economic perspective, internet access by companies can promote digital business opportunities and innovation in service delivery, in addition to reducing commercial transaction costs (Melhem, 2016).

E-commerce can contribute to the diversification of income sources and the creation of new jobs (ITU, 2021). For example, in the Marajó archipelago, in the state of Pará, internet access has facilitated the sale of rural communities' forest and agricultural products, and provided access to social programs such as "Auxílio Brasil". However, the expansion of these activities is limited by

Aerial view of Manaus, state of Amazonas.
Photo: Bruno Kelly/WRI Brasil.

costs and the quality of the available connection infrastructure (Euler and Ramos, 2021).

Nevertheless, internet access inequality remains an impediment to social development and economic growth. In 2022, it is estimated that approximately 5.3 billion people (66% of the world's population) would have access to the Internet, whether mobile or fixed, representing an increase of 1.1 billion people with access since 2019 (ITU, 2023). Despite the growing share of global population with access to the Internet, the distribution of access infrastructure is uneven across countries and locations.

In Brazil, the mobile internet infrastructure is the main access route, followed by computer access (ITU, 2023). Although mobile internet is present in 100% of the country's municipalities, covering 92.3% of the population, there is a significant gap in access to mobile internet infrastructure between rural and urban areas. In rural areas, only 53% of residents have access to mobile internet, while in urban areas the percentage reaches 99% of residents. In the LAM states, the gap in access between rural and urban areas is even greater. 79% of the population in urban areas have access to internet services, compared to only 30% of those residing in rural areas (ANATEL, 2022).

The transition to the NEA therefore depends on overcoming this context of unequal access to connectivity. Solutions that reconcile coverage with connection quality assume that end systems access the internet from homes, community centers, schools, universities, or companies through access networks, also called last mile networks. Access networks connect to networks with greater data transmission capacity, through intermediate networks called backhaul, which, in turn, are connected to backbone networks, the main access route used by a communication network to transmit aggregated data, enabling the connection of remote end users.

Viable solutions in the Amazon context for backbone networks include optical cables installed in already established energy transmission lines, as is the case in Tucuruí, or underwater fiber optic cables, creating the so-called "digital roads" (Horewicz, 2019). For intermediary networks, satellite links are the most promising alternative in terms of lower installation and maintenance costs and better connection quality. This solution is already adopted by the Electronic Government Program – Citizen Assistance Service (Programa Governo Eletrônico – Serviço de Atendimento ao Cidadão; GESAC, from its initials in Portuguese), which offers broadband internet connection through geostationary satellites (Nascimento et al., 2022; Lara, 2021).

For final access networks based on antennas installed in high towers, solutions range from those with broader coverage, such as individual range Wi-Fi, to passive optical networks. Wi-Fi is the collective solution with the lowest implementation cost and is already used for access in community centers and schools (Leão et al., 2019; Neves, 2019). Additional solutions with lower costs and individual reach include access via 4G and 5G, the latter still at an early expansion stage in Brazil.

The evolution of new infrastructure solutions, such as satellite links and fiber optic cables, and connectivity technologies, such as 5G and 6G, has the potential to promote digital inclusion with quality and reduced environmental impact in the LAM. The inclusion of populations residing in rural areas, small and medium-sized businesses, combined with greater capacity to inspect environmental crimes and monitor extreme weather events, can be boosted by more consolidated connectivity, promoting a scenario conducive to the transition to a new regional economy in the LAM.

6.3 Conclusion

The lack of electricity and efficient transport logistics represent bottlenecks in the transition to the NEA. The region needs high-quality sustainable infrastructure designed for the region's socioeconomic and environmental diversity. The main strategies for the infrastructure transition involve the diversification of electricity generation structures and cargo and passenger transport modes. They also involve the replacement of resources used in electricity generation and fuels used in transport modes. In the transition, non-renewable resources are gradually replaced with local renewable resources and the use of batteries. These changes would contribute to the reduction in GHG emissions, and the maintenance of the standing forest and the ecosystem services

"Pontão" river fuel station on the outskirts of Tefé, state of Amazonas.
Photo: Karoline Barros/WRI Brasil.

generated in the Amazon biome, improving the quality of life of the region's population.

This chapter identified solutions that would contribute to this scenario. In the electric power sector, the solutions point to a wide expansion of solar energy and decentralized electricity generation using waste. The proposed microgrids with energy generation from local resources proved to be cheaper than the use of diesel generators in the BAU. The solutions presented are more cost-effective, as they consider the region's social and geographic characteristics.

In the transport sector, there is great potential for diversifying passenger and cargo transport modes, favored by the region's environmental conditions, such as the availability of waterways. Diversification efforts should focus on reducing dependence on road transport and expanding passenger and cargo transport by water and air. The optimization of routes and complementarity of modes is, therefore, a key issue in this transition. Additionally, the region should see a gradual electrification of river and air fleets on routes where the use of batteries is economically viable.

Finally, the solutions proposed include the gradual replacement of non-renewable energy sources, used as fuel for the various transport modes, with local renewable alternatives, including biofuels at advanced stages of development. As a complementary measure, optimizing the use of vessels' cargo capacity would improve the energy efficiency of passenger and cargo transport, resulting in lower emissions. The main proposed alternatives, therefore, consist of the adoption of more efficient and less carbon intensive propulsion alternatives, and the promotion of less energy intensive modes in cargo transport.

Boats moored at the Port of Manaus, state of Amazonas.
Photo: Bruno Kelly/WRI Brasil.

CHAPTER **7**

Considerations on **FINANCING**

FINANCING

The need to decarbonize the economy and achieve net zero GHG emissions by 2050 has led to an enormous global and multisectoral effort to measure the necessary investments that would enable the economic transition over the next 30 years. The 2006 Stern Report indicated the need for investments of around 1% of global GDP, at the time $ 725 billion per year (2006 values at 2022 prices) (Stern, 2006). In 2015, Nicholas Stern himself (Stern, 2015) revised his projections suggesting investments of 2% of global GDP, or $ 1.8 trillion per year (2015 values at 2022 prices).

The results of this study are in line with this literature, pointing to investment needs around 1.8% per year of national GDP. The investments needed for the transition would not apply exclusively to the LAM, given the intricate financial, informational, inputs and products flows between the region and the rest of Brazil.

Concerns around this theme have grown beyond the agendas of governmental and multilateral organizations, with notable interest from sectoral groups. McKinsey & Company, for example, focusing on the energy, transport and land use sectors (similar to this report), estimated that emission neutrality in the global economy by 2050 would require investments of approximately $ 3.5 trillion per year (McKinsey Sustainability, 2022). On the other hand, the Swiss Re Institute (Guo, Kubli and Saner, 2021) calculated that the cost of not curbing global warming below 2°C would range between 4% and 18% of global GDP by 2048. These costs, not incorporated in this study, therefore not applied to the BAU scenario, include premature depreciation of existing infrastructure that is incompaltible with the NEA; remediation of chronic and wide-ranging climate problems such as rising input prices and falling factor productivity; and acute problems requiring reinvestments and material and immaterial damage repair.

Despite the robust knowledge that has been produced to estimate required investments, little progress has been made in the mobilization of these resources. The Swiss Re Institute clarifies that the gap is associated with the lack of solutions that foster the creation of innovative financing mechanisms within a conservative environment, paradoxically advancing at an inertial pace while recognizing the increase in climate risks. In this context, investors have to face a dilemma between provisioning resources for remediation or advancing with investments in mitigation and adaptation, which makes it even more difficult to identify innovative mechanisms (Guo, Kubli and Saner, 2021). The distortion caused by fossil fuel subsidies and their economy-wide multiplier effects reduce the competitiveness of alternative financing instruments (Naran et al., 2022).

In fact, although liquidity in global markets currently amounts to $ 200 trillion, enough to achieve decarbonization targets, the volume of financing committed to decarbonizing the economy stood below $ 940 billion in 2021, with an average of $ 480 billion per year over the past decade. The gap forces a shift in the investment supply curve, given the steep 590% increase needed by 2030 in order to reach the minimum level of investments required for the next 30 years (Naran et al., 2022). Fossil fuel subsidies amounted to $ 6.8 trillion over 10 years, 40% above the total volume of decarbonization funding over the same period.

In Brazil, subsidies to fossil fuels over the past decade were estimated at $ 222 billion (Inesc, 2022), while total investments in electricity from non-fossil sources through public tenders held by the Brazilian Electricity Regulatory Agency (Agência Nacional de Energia Elétrica; ANEEL, from its initials in Portuguese) and the Chamber of Electric Energy Commercialization (Câmara de Comercialização de Energia Elétrica; CCEE, from its initials in Portuguese) reached $ 57 billion in the same period (ANEEL, 2022).

Brazil, however, faces a peculiar condition. Although its exposure to climate risks is greater than the global average (Swiss Re Institute risk index), weakened especially by the population's poverty level and the agricultural and livestock production sector's exposure to chronic drought events and acute dry spells, the investment needs associated with the country's decarbonization are lower than the global average. This is because, unlike developed and oil-intensive economies, Brazil already has a cleaner energy mix and its emissions are mainly associated with land use change, which correspond to relatively lower transition costs.

If, from a global perspective, the country emerges as a territory of great opportunities, structural problems pose significant domestic challenges. Over the past three decades, Brazil has shown a systematic decline in the stock of infrastructure in relation to GDP. Although investment rates have been above depreciation, they are below the necessary levels to sustain demand derived from economic growth, which indicates structural constraints in the medium term (Frischtak, Mourão, 2017).

Among the sectors with lower investments and more relevance to the LAM, those where investments fall short of depreciation stand out, such as sanitation (0.19% of GDP), ports (0.09% of GDP) and waterways (0.01% of GDP). Achieving the target stock of infrastructure at 60% of GDP (according to Ipea, in 2020 this indicator reached 41.2% in Brazil), a level that would allow the country to grow while minimizing risks of structural constraints, would require an investment of 4.5%

of GDP per year from 2020 onwards, reaching the target between 2041 and 2050, depending on overpricing levels in the economy (Frischtak, Mourão, 2017). This would imply total investments between $ 1.72 and $ 2.71 trillion (2022 values).

As estimated by this report, the transition to the NEA requires investments of approximately $ 513 billion over the next 30 years. These investments are not necessarily additional to those required for the formation of a stock of infrastructure - which could potentially be dimensioned and induced by the clean energy mix - but the competitive environment to access funds in order to meet so many needs, including basic sanitation, adds to the challenge.

Add to this the fact that the estimates are produced under optimization assumptions, without considering market failures and transaction costs. In practice, however, as the estimates refer to investments that still lack specific and innovative applications, institutional arrangements need to play an effective role in order to make them viable. Such arrangements could, for example, provide for reduced transaction costs, which are not computed in the estimates of investments needed for the transition. This would alleviate potential conflicts caused by disputes reflecting the preference for investments with higher returns compared to those related to alternative uses of capital.

On the other hand, the cost of not making the transition to the NEA could be much higher than the BAU scenario suggests. In the GEM models used in this study, economic growth in the LAM as shown in the BAU does not include opportunity costs of the technologies employed in the NEA scenario, nor does it include do-nothing costs, which reduce GDP in the business-as-usual trajectory due to chronic and acute disturbances caused by climate change.

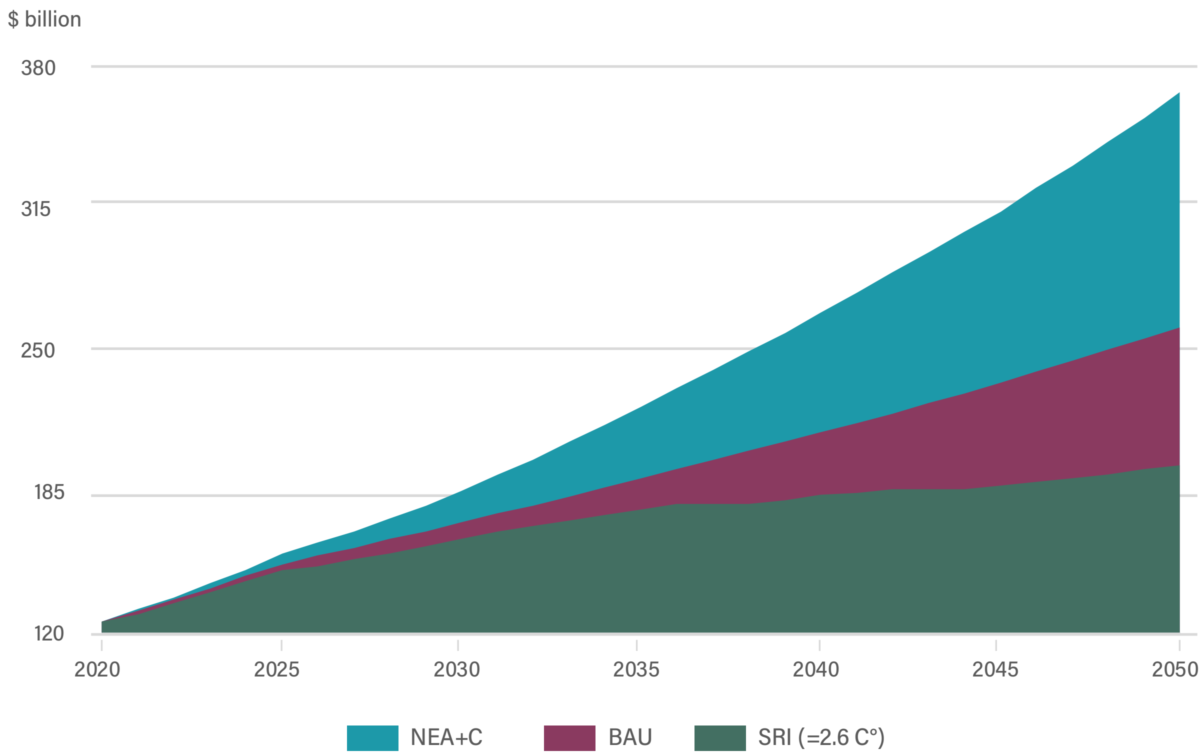
By way of comparison, if do-nothing costs suggested for Brazilian GDP by the Swiss Re Institute are applied vis-à-vis the evolution of national GDP estimated in the NEA scenario, Brazilian GDP in the transition would be, between 2020 and 2050, $ 1.3 trillion above GDP under a low do-nothing penalty scenario (warming below 2°C), $ 4.4 trillion above GDP under an intermediate penalty scenario (2°C warming) and $ 8 trillion above GDP under a high penalty scenario (warming up to 2.60°C). Applying the same reasoning to the LAM, assuming high do-nothing penalties, the region's GDP in 2050 would only amount to $ 232.4 billion.

Man working in honey production in the community of Arraiol, in the Bailique archipelago, state of Amapá. Photo: Diego Baravelli/Greenpeace.

The difference between the scenarios is even greater if one considers the pricing of environmental assets, specifically carbon stocks. As already highlighted in other sections of this report, the NEA scenario would end 2050 with a forest carbon stock 19% higher than the BAU, resulting from almost 81 Mha of additional forests, 59 Mha of which associated with avoided deforestation and 22 Mha with additional restoration compared to the BAU.

Considering that the restoration is implemented in the first 10 years, at a rate of 1/10 per year starting in 2020, and that the capacity to store carbon in the restored areas behaves as a logarithmic curve with sequestration peak in the 40th year after planting (Poorter et al., 2016), the carbon stock in the NEA scenario arising only from restoration would reach, by the end of 2050, 6.68 $GtCO_2$ against 0.65 $GtCO_2$ in the BAU. Considering carbon prices of $ 15 per ton (half the social cost of carbon estimated by Stern, 2006), and assuming that carbon revenues are invested in the economy with an impact of 2.05 (income elasticity of the investments estimated in this report), LAM GDP in 2050 under the NEA scenario with carbon priced in would reach $ 368.2 billion, against $ 260.2 billion under the BAU and $ 232.4 billion under high do-nothing costs.

Chart 24 | Evolution of LAM GDP in scenarios with carbon reinvestment and penalty rates for do-nothing costs, between 2020 and 2050



Note: The NEA scenario with carbon priced in comprises the result of the GEM models, with the impact of carbon revenues on GDP estimated ex post, assuming reinvestment in the economy. The SRI Scenario (>2.0), also estimated ex post, represents GDP under the BAU scenario penalized by conditions in which carbon concentrations lead to global warming above 2°C and deteriorate production, according to scenarios developed by the Swiss Re Institute for Brazil (Guo, Kubli and Saner, 2021).
Source: Authors.

Although the exercises to include avoided costs (opportunity and do-nothing costs) and carbon pricing impacts offer new layers of comparability, showing a much greater gap between the NEA and BAU scenarios, the efforts to finance the transition should focus on the $ 513 billion estimated and detailed in Chapter 2.

Financing considerations are discussed in the following sections, with emphasis on strategic land use, which accounts for 20% of transition investments but 60% of avoided emissions.

7.1 Sources of financing

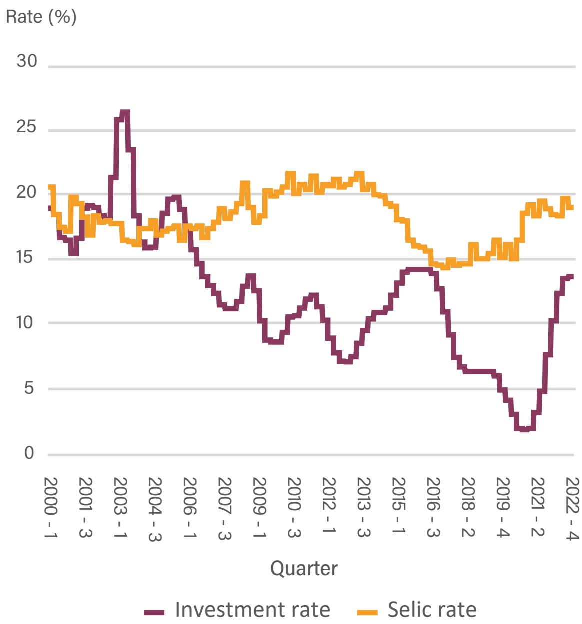
The large gap between investment needs and current financing to decarbonize the economy has generated a prolific discussion on the necessary instruments. These range from classic solutions, including taxation and cross-subsidies, to more controversial alternatives, such as the differentiation of reserve requirements to expand the creation of credit earmarked to low-carbon sectors, as suggested by Campiglio (2015).

Regardless of the weight assigned to each option, a consensus has been formed around two fundamental points: the relevance of the public sector and the need for multiple sources, instruments and mechanisms. The first reflects the recognition of the condition of existence of the State as a promoter of well-being, which includes, in contemporary society, policy-making for climate mitigation and adaptation, through which the State exercises its allocative and distributive role in the economy. The second point of consensus is the realization that an expansion in financing supply, or at least the availability of investments, will not be achieved without a combination of converging strategies.

In fact, experience has reinforced the consensus. The share of public financing vis-à-vis private financing in the global economy has remained relatively constant at a parity of 1:1, with growth in total financing for decarbonization around 7% per year. The induction effect has led to an upward and positive spiral, parallel to the fact that sources have been diversifying (Naran et al., 2022).

Brazil, on the other hand, faces historical obstacles not only associated with investment financing, but also with financing of production costs. In macroeconomic terms, the obstacles include insufficient volumes of loanable resources and high opportunity costs associated with the decision to invest in productive activities compared to the option of income generation via financial investments (opportunity cost of money). This is expressed in Chart 25, based on Ipea data, which shows that while in the first half of the 2010s investment represented, on average, 20.8% of GDP, this indicator receded to 15.3% in the years between 2016 and 2020, reflecting a long period (2013 to 2016) marked by high monetary rates in the economy.

Chart 25 | **Evolution of the Selic rate and investment share in Brazil's GDP, between 2010 and 2021**



Source: Authors based on IPEA (2023) and Brazilian Central Bank (2022).

In microeconomic terms, one important characteristic of the LAM is the low productivity of production factors observed in the region. In general, this inefficiency is explained by the distance between consumer centers and input-output suppliers, which consequently gave rise to special policies introducing direct and indirect subsidies, introduced by the Amazon Appreciation Plan and maintained by Sudam and SUFRAMA (FiBraS, LAB and FEBRABAN, 2020; FiBraS, 2021).

If Brazil lacks investments (Trace & Considera, 2021), the North region faces a worse situation, with marginal access to credit. Pamplona, Salarini and Kadri (2021), IBGE (2021d) and BNDES (2021) demonstrate that while Brazil has access, on average, to credit equivalent to 6% of GDP, this figure is only 3% for the LAM region. The North region receives only 5% of total BNDES disbursements, although this number has doubled between April 2012 and April 2021, reaching $ 36 billion. When including the state of Mato Grosso and certain municipalities of Maranhão, credit granted in the LAM rises to 6.8% of Brazil's total volume, still below the region's participation in national GDP, at 8% (BNDES B. N., 2023).

The Amazon bioeconomy is characterized by a wide range of products and relatively small and seasonal production. Products come from distant regions, with limited transport, storage, and distribution capacity. It is also characterized by the existence of many small-scale producers, most of them informal, lacking conditions, such as sufficient collateral, to access loans. In general, such characteristics increase the transaction costs and risks of credit operations aimed at financing the bioeconomy. Pamplona, Salarini and Kadri (2021), IBGE (2021d) and BNDES (2021) show that, between 2017 and June 2021, BNDES posted an average monthly disbursement of only $ 85 thousand related to products potentially originating from the North region's bioeconomy.

This demonstrates that the direct and indirect subsidies that have lasted for decades in the Amazon, especially tax expenditures in the Manaus Free Trade Zone (ZFM), have not had a positive impact on the productivity of labor, capital, and land beyond what is observed in areas outside the influence of the ZFM. Added to this, the evidence of increased deforestation in the LAM region discussed in Part 1 of this report shows that such economic incentives have also failed to reduce deforestation, which indicates that the current distribution of such benefits does not contribute much to the NEA.

The transformation of the LAM from an immense forest territory into the largest depository of pastures in Brazil was made possible in part by such heavy subsidies (Sudam, 2016). Addressing this issue, therefore, must be part of the efforts towards a new direction for the region's economy, with the advantage that the world economy now recognizes the need to drastically reduce carbon intensity, a stance that has been guiding private investment from abroad and the population's selective consumption habits.

From a regional to a sectoral perspective, it is also important to consider that subsidies to carbon-intensive sectors or inputs that are still in force in Brazil have perverse effects on the feasibility of decarbonization.

For example, subsidies to fossil fuels in the past decade, as previously mentioned, estimated at $ 222 billion (Inesc, 2022), represent almost 60% of the necessary investments for the transition of the energy mix in the NEA scenario. In agriculture, if the entire Safra Plan were earmarked to investment projects under the ABC+ Plan, the annual average values of rural loans granted in the LAM would be enough to cover (if replicated over the 30-year period) almost 40% of the investment needs in the NEA scenario, and 30% higher than the transition

The financial resources to enable the NEA transition are essentially of three types:

1. National public resources:

- **a.** Tax incentives from the federal government or state and local governments.
- **b.** Traditional credit mechanisms, such as earmarked resources with interest rate and price equalization, originating from public funds, constitutional funds and bank savings.
- **c.** Budgetary expenditures for the maintenance of the standing forest, such as those related to climate management and command and control policies.

2. National private resources:

- **a.** Private resources from rural producers, business owners, trading companies and cooperatives, including credit.
- **b.** Various financial arrangements and capital markets instruments.
- **c.** Impact and non-refundable funds, etc.; and
- **d.** Carbon market and payments for environmental services

3. International sources:

- **a.** Public, private and multilateral funds.

b. Resources from capital markets, pension funds, impact, and non-refundable funds; and

c. Carbon market and payments for environmental services

Figure 12 presents the funding sources mentioned above, associating them with the agents and financial instruments currently available to finance the transition to the NEA. From left to right, the six financing sources expressed in the figure show a progressive change in the breakdown of funds, with decreasing participation of the State and public resources, accompanied by growing participation of the productive private sector, particularly the financial sector.

Despite the low volume of public funds historically allocated to public policies focused on the maintenance of the standing forest and biodiversity, and bioeconomy development, Brazil accumulates significant experience in the development of portfolios compatible with such practices. This is partly due to the expertise developed by BNDES in the management of the Amazon Fund, largely financed by Norway, and the Climate Fund, which has budgetary resources available but has shown low execution in recent years.

Figure 12 | Financing sources, agents, and financial instruments for the economic transition in the Legal Amazon

	1. International - Multilateral - Impact Funds	**2. Public spending, public funds and subsidies** (OGU, states and municipalities)	**3. Individual and corporate private resources**	**4. Resources of the commercial banking system** (rural savings, reserve requirements and financial agents' resources)	**5. Capital market** (CRA, LCA, funds and carbon market)	**6. Voluntary carbon markets, ecosystem services markets, etc**
Agents	· Development banks including BNDES · Public and private institutions	· Public and private commercial banks · Public and private organizations, companies, OSCIPs, Sistema S, insurance companies, etc. · Municipal, state and federal governments · Development banks including BNDES	· Rural and livestock producers · Agroindustry · Trading companies · Cooperatives · Input suppliers	· Public and private commercial banks · Financial cooperatives · Fintech companies	· Brokers and securities distributors able to negotiate with B3 · Transactions structuring firms · Second opinion agents · Insurers and reinsurers · Commercial, investment and development banks	· All agents
Private financial and public policy instruments	· Green Climate Fund (GCF) · Amazon Fund and REDD+ · PCI MT	· Equalized resources of the Safra Plan (includes ABC Plan, Pronaf, Pronamp, PSR) · FNO and FCO · Minimum price policy · Kandir Law	· Rural Producer's Certificate (CPR), green CPR and CPR in US dollars · Barter · Agribusiness Credit Rights Certificates (CDCAs)	· Safra Plan funding (includes ABC Plan, Pronaf, Pronamp, PSR, etc.)	· Agribusiness Receivables Certificates - Green CRA (Rizoma/Ecoagro, Klabin, Tereos, Suzano, FS Bioenergia) · Green bonds, Sustainability and Social bonds (BRF, Suzano, IBS and Marfrig) · Credit Rights Investment Funds (FIDCs) · Agribusiness Credit Bill (LCA) · Investment Funds in Agroindustrial Production Chains (Fiagro)"	· Decarbonization credits (CBIOs) · Payment for environmental services (PES) · Carbon market

Source: Authors.

Although commercial (government-owned and private) and development banks play a prominent role in the financing strategy, the significant volume of resources estimated for the transition ($ 513 billion) points to the national and international capital market as its major enabling agent. It is expected that the financial sector contributes towards a reduction in transaction costs and risks involved in financing operations for the new economy, as well as making business models compatible, economically, and financially, with climate ambitions and socio-biodiversity.

By structuring financial operations that incorporate the attributes of low carbon emissions, biodiversity and social impacts on local populations, banks and credit unions can become agents of transformation of the Amazon reality towards the NEA (FiBraS, LAB and FEBRABAN, 2020).

This work must be carried out not only via public funds invested directly, but also through partnerships with the national and global capital markets, via green bond issuances and blended finance mechanisms, in which the financial sector acts to reduce risks, offering guarantees and supporting the consolidation of business models compatible with the conservation and development of the Amazon (BNDES, 2023). Development banks can also provide special financing mechanisms for green projects, such as BNDES Finame Energia Renovável, the Amazon Fund and the Climate Fund Program (BNDES, 2022).

It is known that the development of the Amazon bioeconomy soon will depend on a larger availability of non-reimbursable resources. In this sense, the BNDES has been pursuing and encouraging important strategies, such as the structuring of value chains, connecting cooperatives and associations of small producers and extractivists. The institution has already been working with blended finance mechanisms, made up of investors who are interested in contributing to sustainable development and accept lower financial returns and longer terms compared to operations without a sustainable attribute.

These new financial mechanisms – blended finance and green bonds – have the potential to enable investments and productive activities in the transition to the NEA, as they better address the elevated costs associated with new technologies involved in the transition, the uncertainties related to the demand for goods promoted, and long payback periods. An example is the financing line for the bioeconomy made available by Banco do Estado do Pará, Banpará Bio (see previous box). The line, launched in 2021, is supported by the creation of a specific financial mechanism in which the bank acts as a guarantee fund for investments in the bioeconomy.

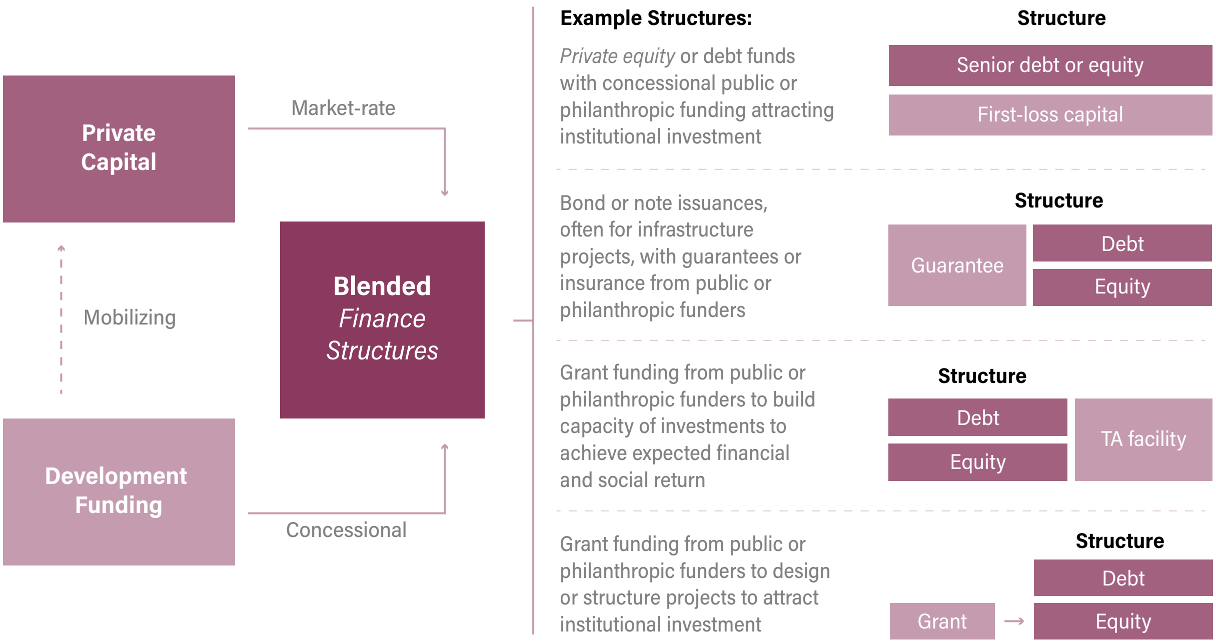
Box 20 | Guarantee fund already promotes the bioeconomy in Pará

In 2021, the state of Pará created the Guarantee Fund for Small Rural Producers and the Bioeconomy Industry (Law No. 9.312/2021) based on the finding that part of the demand for rural credit to finance activities linked to the bioeconomy was held back by producers' lack of sufficient collateral. Unlike credit for traditional production systems, such as extensive livestock production or monoculture, activities linked to the bioeconomy, especially in the restoration chain, lacked adequate products in the financial market. This led the state to go beyond the Guarantee Fund and structure a line of credit specifically designed to foster the bioeconomy, Banpará Bio, through state-owned Banco do Estado do Pará.

In 2022, more than $ 3 million have already been granted, mainly for restoration with agroforestry systems.

The recent increase in access to significant resources in the capital markets, via green bonds, credit bills and receivables certificates also demonstrates the enormous potential of these alternative sources of exclusively private financing for the LAM. Green bonds are debt securities issued to raise funds for investments in sustainability and climate change mitigation projects. They can be issued by governments, banks, or companies. Green versions of instruments already common in the Brazilian and international markets can be used for these operations, such as debentures, infrastructure debentures, agribusiness receivables certificates (CRA), real estate receivables certificates (CRI), agribusiness credit bills (LCA), real estate credit bills (LCI), credit rights investment funds (FIDC).

Figure 13 | **Typical blended finance structures and mechanisms**



Source: Convergence (2021)

In June 2020, the German Agency for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit, GIZ) published a report on the emerging green finance market in Brazil, showing a still incipient demand for green financial products, but with an upward trend. According to the analysis, green bonds in Brazil held a small share of the total volume raised in fixed income in 2020. Nevertheless, Brazil is the second largest market in Latin America, having issued around $ 1.6 billion in 28 green bonds and one social bond between 2015 and 2020. According to another survey carried out by the Brazilian Federation of Banks (Febraban) in partnership with Fundação Getúlio Vargas (FGV) in 2018, banks allocated at least $ 68.2 billion (21% of the total portfolio) to credit operations with companies related to the green economy.

7.1.1 National public resources

Tax and financial incentives

The contribution of public funds towards interest rate equalization on financing operations has an impact on the federal government's primary fiscal result. Tax incentives, on the other hand, represent a waiver of revenue by governments, which impairs tax collection, and can reduce the ability to finance public policies, such as interest rate equalization. Both are considered subsidies. Chart 26 shows that total tax and financial subsidies in Brazil reached 4.6% of GDP in 2018, of which 4.3% were tax subsidies.

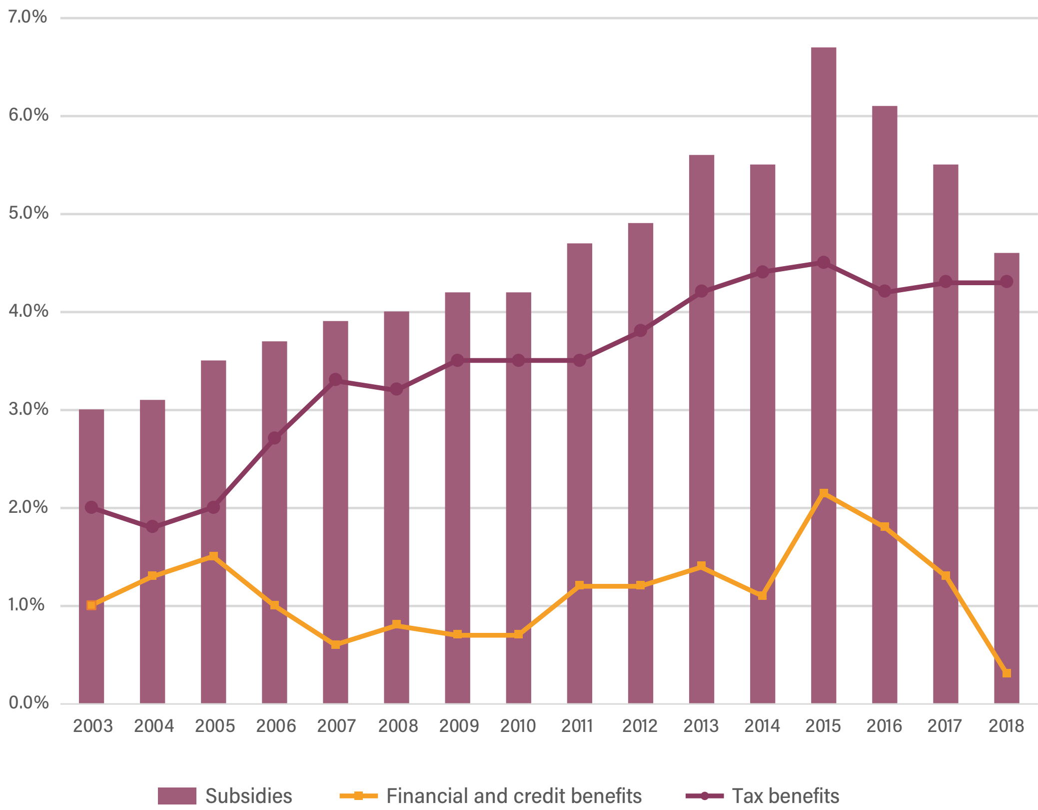
The fiscal crisis aggravated by the COVID-19 pandemic imposes limits on the expansion of public spending. Compliance with the fiscal rules in force in the country, such as Constitutional Amendment 109/2021, has demanded a reduction in tax, financial and credit benefits from 4.6% of GDP in 2018 to 2% by 2028. Thus, the effort to prioritize the LAM in the granting of subsidies aligned with the NEA scenario tends to evolve in a context of sharp competition for this type of tax benefit.

Although most subsidies benefit the commercial and services sector (largely due to the "Simples Nacional" program), it is important to mention that the agricultural and livestock production sector accessed $ 5,5 billion in tax subsidies (9.7% of this incentive's total volume), $ 2 billion in financial subsidies (35% of this incentive's total volume) and $ 1 billion in credit benefits (55.9% of this incentive's total volume). The agricultural and livestock production sector benefits from subsidies in a much greater proportion (more than triple, totaling $ 8.7 billion or 13.9% of GDP) than its contribution to wealth generation in Brazil, which stood at 4.42% of GDP in 2018.

Of the $ 5.7 billion in tax benefits granted to Brazilian agriculture, for example, $ 340 million referred to PIS ($ 60 million) and Cofins ($ 280 million) exemptions on purchases of agricultural pesticides. Another $ 640 million corresponded to exemptions on the Rural Worker Assistance Fund (Funrural) and $ 1.5 billion on rural exports.

Little information is available by region regarding subsidies. Nevertheless, Table 31 reveals that economic incentives are heavily concentrated in the country's Southeast region. The North region, even considering the Manaus Free Trade Zone, is still among the Brazilian regions that least benefit from such public policy instruments. There is, therefore, much room for a redistribution of resources towards the development of the bioeconomy in the region and the transition to a low-carbon economy.

Chart 26 | Evolution of the Brazilian federal government's subsidies, from 2003 to 2018 (% GDP)



Source: Secap (2020).

Table 31 | Distribution of economic incentives in Brazil, in 2017 and 2018, by region ($ billion)

Region / year	Financial and credit benefits		Tax benefits	
	2017	2018	2017	2018
North	1.42	0.74	6.10	7.02
Northeast	4.18	1.68	6.94	7.62
Center-West	1.94	0.58	4.32	5.74
Southwest	5.76	0.88	29.96	29.70
South	3.56	0.38	8.44	8.50
Brazil	16.86	4.26	55.76	58.58

Source: Data from Secap and the Ministry of Economy (2019).

There are virtually no tax incentives strictly aimed at low carbon rural production or production of goods and services compatible with the maintenance of the standing forest and restoration. Two rare exceptions are the Ecological ICMS experiences implemented by the states of Amazonas and Goiás.

Traditional credit mechanisms

In addition to tax incentives, the public sector can stimulate the LAM's economic transition through traditional financing instruments, such as Pronaf, the Safra Plan, the Investment Support Program, among others.

Brazil has a long-standing set of public policies and rural financing instruments in place (see appendix), responsible for a leap in food production. The financing of Brazilian crops has migrated, however, to private resources, particularly from the capital markets.

Three main elements explain this change in profile: the limited fiscal space on the part of the federal government, the growing need for resources to finance ever-increasing crops and the wide supply of global resources in the capital markets, including, more recently, green bonds and other green financial instruments.

From the beginning of this century until around 2015, Brazilian crops were financed, on average, in three equal tranches. A third part with resources from the Safra Plan, another third with resources from trading companies, cooperatives, and the capital market, and another third part with producers' own resources. With harvests approaching $ 204 billion in the following years and $ 240 billion in 2021/2022, the Safra Plan's resources, although essential, financed only a fifth of the Brazilian agricultural and livestock production. Progressively, the capital market has been expanding its participation in the sector's financing via commercial banks and, more recently, also via development banks.

The National Rural Credit System (Sistema Nacional de Crédito Rural; SNCR, from its initials in Portuguese), created in 1965, operates the National Agricultural Financing Policy, which is based on three pillars: earmarked bank credit, interest rates below market rates, and incentives for family farmers and small and medium-sized producers, through specific credit lines and programs. The Safra Plan provides financing for production, investment, commercialization, and agro-industrialization, in addition to risk mitigation instruments.

For sustainable agriculture, the lowest interest rates are those offered by Pronaf's environmental credit lines, followed by those offered by the ABC Program, and finally the North Region's Constitutional Fund (Fundo Constitucional do Norte; FNO, from its initials in Portuguese) in the case of the Amazon biome, and the Central-West Region's Constitutional Fund (Fundo Constitucional Centro-Oeste; FCD, from its initials in Portuguese), in the case of Mato Grosso. The level of credit utilization for these lines is relatively low, as shown in Table 30, in the contracted/scheduled line.

Considering both public and private resources earmarked to the Safra Plan, the historical participation of ABC Plan has corresponded to 2% of the total. Even with the steep increase to $ 200 million available in the 2021/2022 Safra Plan, equivalent to 7% of the total $ 14.7 billion earmarked to investments that year, the total loans granted under the ABC Plan did not reach $ 600 million. The number of loan contracts fell by 16.5% compared to the previous year, as shown in Table 32.

Table 32 | **ABC and ABC+ Plans: evolution of resources and loan contracts signed**

	$ Million 2020	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Brasil	Total Loans Granted	40,606	45,045	38,147	27,070	37,774	39,426	37,320	41,229	53,315	61,058
	Loans Granted for Investments	10,659	11,196	7,613	4,606	6,403	7,540	7,057	8,704	11,988	11,608
	ABC e ABC+	703	929	552	200	323	454	431	460	477	739
LAM	Total Loans Granted	5,652	6,868	5,539	3,764	6,115	6,976	6,885	8,073	11,416	12,946
	Loans Granted for Investments	2,673	3,264	2,317	1,375	2,114	2,470	2,518	3,193	4,485	4,947
	ABC e ABC+	146	207	135	59	112	160	152	164	165	258
LAM/ Brazil	Total Loans Granted (%)	14	15	15	14	16	18	18	20	21	21
	Loans Granted for Investments (%)	25	29	30	30	33	33	36	37	37	43
	ABC e ABC+ (%)	21	22	24	29	35	35	35	36	35	35

Note: Contracted in the 2021/22 harvest. Survey carried out on June 27, 2022.
Source: Authors based on Rural Credit Data Matrix (Brazilian Central Bank, 2023).

An assessment carried out in 2020/21 by MAPA and Agroícone (Lima, Harfuch and Palauro, 2020) on the ten years of operation of the ABC Plan, and which guided the planning of the current ABC+ Plan, concluded that the GHG reduction targets were achieved and exceeded, and also that most of the resources (more than 50%) were allocated to soil correction, formation or recovery of pastures, followed by afforestation and restoration, acquisition of cattle and sugarcane. Breaking down the credit borrowers, 70% are medium-sized rural producers. It was also found that most of the resources were allocated to the country's Southeast and Central-West regions, and shortfalls in monitoring of the ABC Plan were identified (Mbow et al., 2019).

This report argues that the commitment of Brazilian sectors such as mining and agribusiness to the conservation of natural assets, biodiversity and ecosystem services in the Amazon would represent a unique opportunity to access resources, in unprecedented amounts and with privileged conditions to meet the growing demand for minerals, food, fibers and energy.

Budgetary expenditures on bioeconomy, climate management and command and control policies

This report also analyzed the direct expenditures of the federal and state governments with environmental protection, bioeconomy, and forest conservation. The nine LAM states spent, on average, only 0.41% of their budget between 2016 and the first two months of 2022 on environmental management. Table 33 shows that Amapá posted the lowest relative share (0.08%) for this budget function among the LAM states, while Acre posted the highest (0.92%). In the federal government, expenditures on environmental management were equivalent to only 0.31% of total expenditures, net of public debt financing.

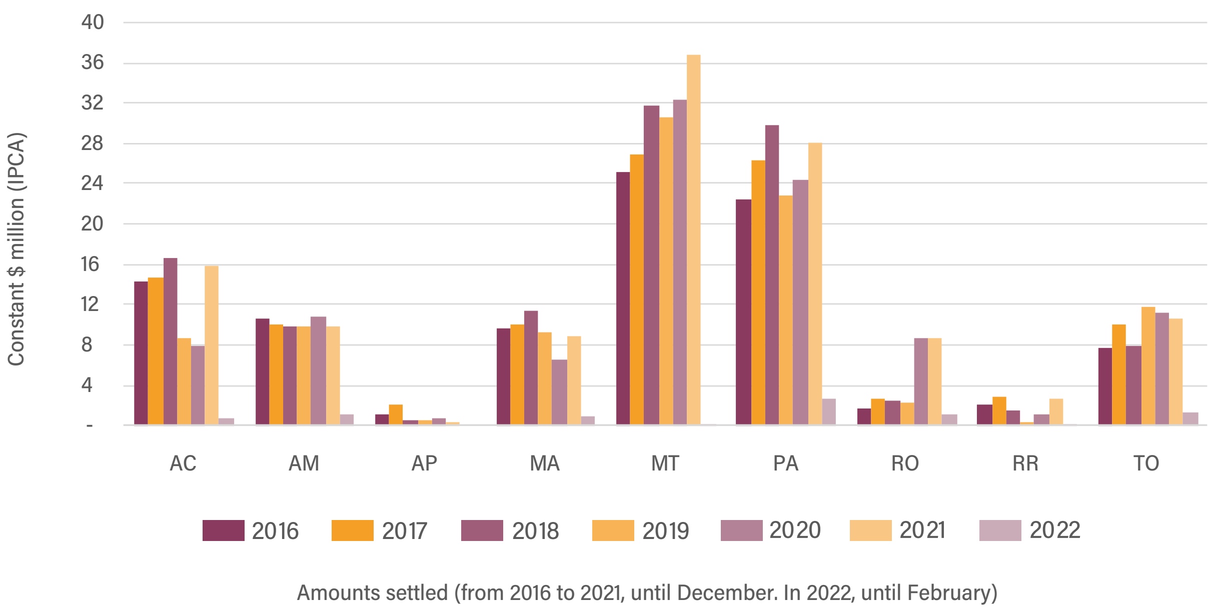
Chart 27 shows, for the same period, the annual evolution of spent amounts (expenses contracted in previous years and accounted for) by LAM state.

Table 33 | Expenditures on environmental management, by Legal Amazon state (from 2016 to February 2022)

UF	2016 to 1Q of 2022		
	$ million		Environmetal management expenditures/total (%)
	Environmetal management expenditures	Total expenditures *	
AC	79	8,576	0.92%
AM	62	25,077	0.25%
AP	5	6,457	0.08%
MA	56	25,408	0.22%
MT	184	24,576	0.75%
PA	157	37,046	0.42%
RO	27	10,063	0.27%
RR	10	5,250	0.20%
TO	61	12,527	0.48%
Expenditure of LAM States on environmental management vs. total expenditures by states in the country	641	154,981	0.41%
Expenditure of all Brazilian states on environmental management vs. total expenditures by states in the country	6,410	1,194,360	0.54%
Federal expenditures on environmental management	6,684	2,136,697	0.31%

Source: Authors based on State Budgets of SIAFI.

Chart 27 | Annual expenditures on environmental management, by Legal Amazon state (2016 to February 2022)



Source: Authors based on State Budgets of SIAFI.

Among the expenditures in the federal government's general budget, the number of resources applied to the maintenance of the standing forest is very low[61]. A pillar of the NEA, such expenses have a marginal participation (less than 0.05%) in the federal government's budget, including expenses connected with deforestation control, protected areas, biodiversity conservation, bioeconomy, and territorial planning.

Table 34 shows a leap in the volume of expenditures with budgetary actions connected with the fight against deforestation, especially in 2020, when it surpassed the $ 200 million mark. That year, the expenditures authorized by the Ministry of Defense for Verde Brasil 2 operation more than doubled the funds allocated to environmental agencies to fight deforestation, including expenses with satellite monitoring by the National Institute for Space Research (INPE). The increase in military spending followed the dismantling of environmental agencies.

Table 34 | Annual expenditures in the federal government's general budget compatible with the NEA (from 2016 to February 2022) (in $ million)

YEAR*	$ million					
	Combating deforestation	Biodiversity conservation	Conservation lands	Indegenous land	Land tenure regularization	Bioeconomy
2016	42.9	33.0	35.8	6.5	5.1	-
2017	33.3	26.6	35.0	4.5	2.9	0.3
2018	37.2	13.4	37.6	8.7	3.0	0.4
2019	40.3	8.3	41.8	10.7	1.4	0.2
2020	133.9	12.1	26.4	9.7	50.7	0.2
2021	81.5	10.4	22.8	8.7	6.2	0.9
2022	11.4	1.3	2.4	0.8	0.4	0.0
TOTAL	380.4	105.1	201.9	49.5	69.8	1.9

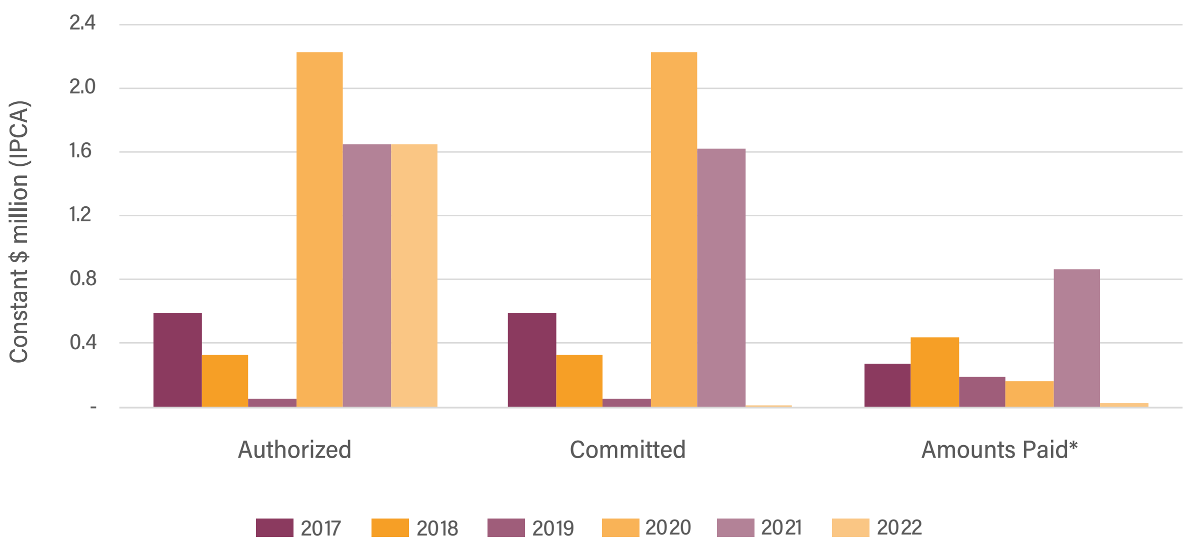
* From 2016 to 2021, until December. In 2022, until March.
** Amounts paid with the annual budgets, plus the remaining amounts paid.
Source: Contas Abertas Association based on SIAFI/Siga Brasil.

Over the analyzed period, authorized expenses allowing INPE to monitor deforestation and fires through satellites reduced by half (from $ 1.42 million in 2016 to $ 714 thousand in 2022). Authorized expenses associated with the creation, implementation and management of Conservation Units fell by more than half, from $ 58 million to $ 23 million between 2017 and 2022, in values adjusted for inflation. Expenses associated with demarcation and inspection of indigenous lands, which together with Conservation Units help to curb deforestation in the Amazon, fell by 27%, from $ 12 million in 2018 to $ 9 million in 2022.

Between 2017 and March 2022, only $ 1.94 million was disbursed for research and promotion of the bioeconomy, which has the potential to boost the region's sustainable development. Of this total, $ 563 thousand were spent on the budgetary action entitled "Sustainable Development of the Bioeconomy", aimed at increasing the participation of family farmers, settlers, traditional peoples, and communities in activities involving extractivism, agro-extractivism, sociobiodiversity, bioinputs, traditional agricultural systems, renewable energies, medicinal plants, as well as structuring chains and productive arrangements.

The best years of the analyzed period for bioeconomy-related expenditures were 2020 for authorized expenditures ($ 2.22 million) and 2021 for disbursements ($ 860 thousand). The main budgetary action linked to the theme was launched in

Chart 28 | Annual executions of funds linked to the bioeconomy function in the federal government's general budget, authorized and committed (from 2016 to February 2022)



Note: From 2017 to 2021, until December. In 2022, authorized allocation for the year and amounts committed and amounts paid* until March.
Source: Authors based on SIAFI data.

2020 by the Ministry of Agriculture, Livestock and Food Supply, although since 2017 the Ministry of Science and Technology has been promoting research in the area, albeit with low values (less than $ 600 thousand per year). These are not expressive values.

In the analyzed period, several budgetary actions disappeared. "Bolsa Verde", a program associated with the fight against extreme poverty in the country, was suspended in 2017. After that year, budgetary resources for Payments for Environmental Services (PES) became unavailable.

7.1.2 National private resources

There are several initiatives underway from the private sector with focus on the LAM, particularly in the bioeconomy sector. In 2020, the three largest private banks in the country (Bradesco, Santander and Itaú) launched "Plano Amazônia", a project aimed at fostering sustainable development, zero deforestation in the meat production chain and conservation of the largest tropical forest on the planet. And progress has been seen, such as the launch of Amaz, an impact accelerator for around 30 startups, now considered the best startup acceleration program in northern Brazil. In addition, banks have been increasing the offer of financing lines that support the construction of sustainable chains for businesses and agricultural crops in the region, such as cocoa, acai, cupuacu and coffee.

Companies in the bioeconomy sector are also flourishing in the Amazon thanks to investments from other large corporations operating in the region. As an example of a successful experience, Coex Carajás sells its production of ucuuba, andiroba, murumuru and acai to Natura. The cosmetics company has been present in the region for some years now, purchasing 26 raw materials from 34 communities. Currently, 16.5% of inputs for the company's products come from the Amazon region, with an expected expansion to up to 55 bioactive compounds.

Beraca, a company formerly headquartered in the state of Pará that has sustainably used Brazilian flora for over 20 years, was acquired in 2022 by Clariant, a Swiss company. Beraca has been posting annual growth between 25% and 30% and supplies companies such as O Boticário, L'Oreal, P&G, Unilever, L'Occitane Brasil, Simple Organic, Aveda and Feito no Brasil. The company produces vegetable oils, mineral ingredients and other active compounds from fruits, herbs, shrubs, and seeds supplied by 1,600 families in the LAM states.

The number of bioeconomy companies in the pharmaceutical sector has grown. This is the case of Grupo Centroflora, which uses jaborandi to produce pilocarpine, a substance used to treat glaucoma, xerostomia, and presbyopia. The group supplies two thirds of the pilocarpine consumed in the world. Production consumes 500 to 600 tons of jaborandi leaves per year, supplied by a network of 1,100 direct sellers who represent 30 thousand pickers in Pará, Maranhão and Piauí. Production is almost entirely exported to companies such as Aurobindo, Bausch&Lomb, Advanz, AbbVie, Amneal and Tubilux. In the domestic market, the company supplies Aché, Myralis, EMS, Sanofi, Hypera, Arese, Kley Hertz and Takeda for the manufacture of phytomedicines.

In addition to public and private sources, Payments for Environmental Services (PES) and the Carbon Market[62] are sources of funds with potential to finance the transition to the NEA, as these mechanisms significantly favor conservation and forest restoration in degraded areas.

Studies conducted by WRI Brasil (Batista et al., 2021) show that, in terms of green financing sources, forest restoration is the cheapest and most efficient way to capture carbonxxxvi. Despite the potential, ongoing initiatives in Brazil are still modest. The definition of a legal framework for the carbon market in Brazil has faced resistance, aggravated by the high complexity of the national tax system.

The REDD+ mechanism is another relevant option that should be closely followed. The Amazon states have been working to improve (Acre and Mato Grosso) and create (other Amazon states) their REDD+ systems, enabling compliance with carbon certification standards for the voluntary and regulated markets. Once regulated, these systems will support the trade of millions of tons of carbon over the next five years and contribute to the achievement of Brazil's climate commitments.

In 2022, the Ministry of Economy estimated that Brazil has the potential to generate more than $ 100 billion through its carbon market by 2030, in addition to creating 8 million jobs, a considerable opportunity to promote actual social and environmental development in the country[38].

The financial sector has also developed initiatives focused on eliminating deforestation in the Amazon and contributing to forest restoration in more vulnerable areas. A company headquartered in Rio de Janeiro received an initial investment of $ 78 million with the goal of restoring 1 Mha of Atlantic and Amazon forest. Funds were provided by traditional asset managers in the Brazilian market such as Lanx Capital, BW, Dynamo and Gávea Investimentos, which expect to obtain returns through sustainable private equity investments. The company's main plan is to buy land in original forest areas that have been converted into pastures, and restore, sell and transform this land into Conservation Units. To raise funds, the company launched the Amazon Restoration Fund. The project will be monetized through the sale of premium carbon credits.

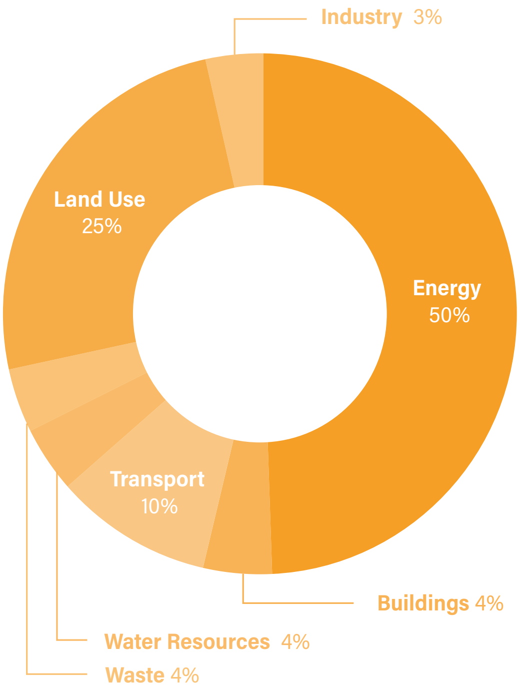
7.1.3 International sources

According to the Climate Bonds Initiative (CBI, 2021) Brazil is the largest market for green bonds in Latin America and the Caribbean, and the second largest for Green, Social and Sustainability (GSS) bonds. Between 2013 and 2020, the total volume of these bonds increased by $ 18 billion in Brazil, with 59 issuances covering different sectors of economic activity: water infrastructure, cargo transport and low-carbon agriculture, urban mobility and waste management. Resources raised through bond issuance in Brazil have been invested in energy (50%), land use (25%), transport (10%), buildings (4%), water resources (4%), waste (4%) and industrial sector (3%) projects, as shown in Figure 14.

In 2020, financial companies carried out their first green bond issuances in Brazil, although non-financial companies remain the main issuers in the country. Social bonds make up the smallest fraction of GSS issuances in Brazil and are generally intended to expand credit to micro and small enterprises and generate employment. Issuance of sustainability-linked bonds has grown significantly in Brazil, and already constitutes the second largest segment of green bonds, second only to social bonds.

Figure 14 | Issuance of green, social and sustainability bonds in Brazil

Brazil Green Points Table



Brazil Green Points Table

ALC Ranking	1
Total issuances	$ 10.3 billion
Number of entities	44
Recurring issuers	
Number of transactions	78
Average value	$ 123 million
Largest issuer	Suzano Papel e Celulose ($ 1.7 billion)

Brazil Sustainability Points Table

ALC Ranking	3
Total issuances	$ 1.4 billion
Number of entities	6
Recurring issuers	
Number of transactions	8
Average value	$ 174 million
Largest issuer	Amaggi Luxembourg International Sart ($ 750 million)

Brazil Social Points Table

ALC Ranking	110
Total issuances	$ 34.2 million
Number of entities	i9
Recurring issuers	
Number of transactions	12
Average value	$ 9 million
Largest issuer	Banco ABC ($ 24.9 million)

Source: CBI (2021)

Regarding sustainable agriculture, from 2015 to February 2021, Brazil issued $ 9 billion in bonds aimed at financing projects, assets, and activities. Of this total, $ 4.4 billion corresponded to green bonds and $ 700 million to sustainable bonds, both issued by the agricultural sector. Companies linked to the agricultural, forest and bioenergy sectors were responsible for $ 4 billion in issuances. According to the same study, the investment potential for agriculture in Brazil totals $ 163 billion (BRL 815 billion) until 2030.

As for investments made by international organizations, an initiative launched by the Inter-American Development Bank (IDB) in March 2021 stands out, aimed at designing sustainable development models over the next five years based on the Amazon region's human capital, natural wealth, and cultural heritage. With a $ 20 million contribution from IDB, the initiative is being carried out jointly with the Amazon countries and the Amazon Cooperation Treaty Organization (ACTO), in addition to partners from the private sector, civil society and funds, such as the Green Climate Fund and the Global Environment Facility. The initiative is focused on the bioeconomy, sustainable management of agriculture, livestock and forests, human capital, and sustainable infrastructure.

The "Innovative Finance for the Amazon, Cerrado and Chaco" (IFACC), created by The Nature Conservancy (TNC), the World Economic Forum and the United Nations Environment Programme (UNEP) represents another international initiative, announced during the 26th United Nations Climate Conference (COP26) in 2021 to support increased private sector investment in forests and nature-based solutions (NBS). That year, the initiative announced a commitment to provide $ 3 billion to accelerate the production of deforestation-free cattle and soy. One of the promises is the implementation of the first "Responsible Commodities Facility" (RCF) program in South America. In partnership with actors involved in the soy supply chain, the RCF program plans to provide funding for the production and commercialization of deforestation and conversion-free soy from the Brazilian Cerrado region. UK soy buyers from major retailers such as


Sustainable wood harvesting in the Mamirauá Sustainable Development Reserve, in Tefé, state of Amazonas. Photo: Ricardo Oliveira.

Tesco, Sainsbury's and Waitrose are taking part in the project, which foresees funding through green CRAs issued by companies Gaia Impacto and Traive.

The Amazon Fund, created by BNDES in 2008, is responsible for fundraising, contracting and monitoring projects financed by the fund for the LAM region. By 2021, the fund had received approximately $ 680 million in donations, with 93.8% coming from the Norwegian government, 5.7% from the German government through KfW Entwicklungsbank, and 0.5% from Petrobras. Also, by 2021, $ 360 million were allocated (with a disbursement of 79.5%) to 102 projects, 47 of which already concluded. After the suspension of new projects in 2019, the Amazon Fund was reactivated in January 2023, following the inauguration of President Luiz Inácio Lula da Silva and Minister of the Environment and Climate Change Marina Silva. In the same period, Germany allocated an additional $ 38 million to the fund and the US announced a collaboration with an initial contribution of $ 50 million.

Regarding international private sector investment, in 2021 big tech company Amazon announced that it would launch, together with TNC, an Agroforestry and Restoration Accelerator in the Brazilian Amazon Forest, through the "Right Now Climate" fund. The initiative focuses on restoration and agroforestry regeneration initiatives in the region, added by income generation initiatives in the state of Pará, benefiting 3,000 local farmers.

There is still a long way to go, and this chapter highlights two main challenges related to green finance for the Amazon transition:

Challenge 1: Increase transparency in resources earmarked to the ABC+ Plan and the bioeconomy

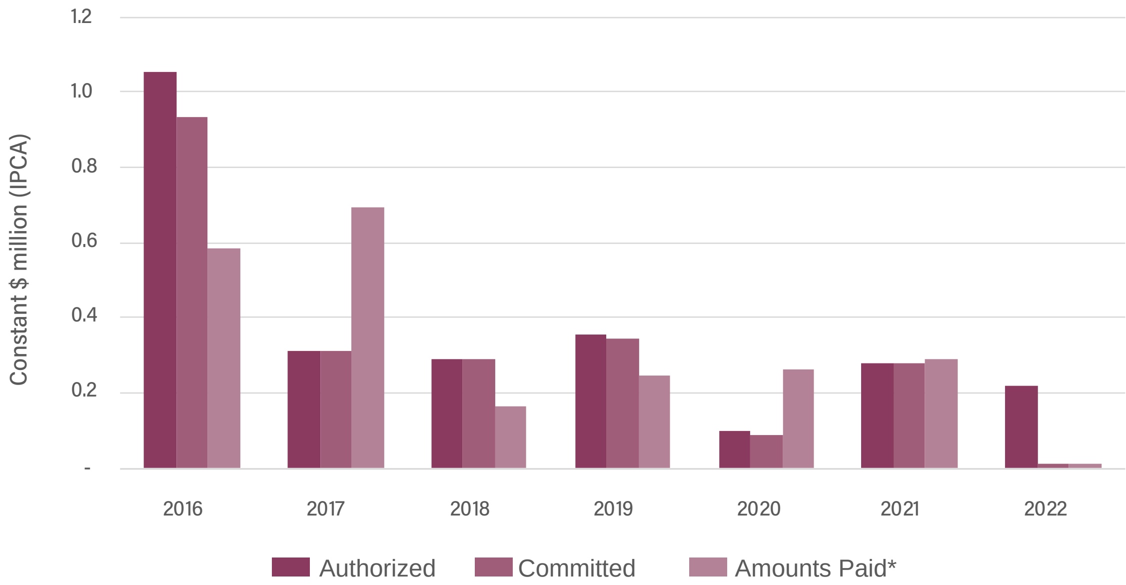
The objective of the ABC+ Plan is to scale up the adoption of consolidated and prominent practices and technologies, but it does not outline specific targets per biome. There is a lack of clear socio-environmental criteria and metrics in the plan's decision-making and monitoring processes regarding loans, and family farmers have difficulty accessing these loans. ABC+ Plan resources, in turn, correspond to only 2% of the total credit foreseen for the 2021/2022 harvest (July to June) as part of Safra Plan's total resources. Additionally, there is no transparency about the share of Safra Plan's financial, tax and credit subsidies that would be allocated to the ABC Plan.

The federal government's budget identifies as expenditures on low-carbon agriculture only a fragment of a budgetary action entitled "Support for the Development of Sustainable Agricultural and Livestock Production". This entire action corresponded to disbursements between 2016 and March 2022 of only $ 2.3 million. It is necessary to include the socio-biodiversity bioeconomy in the federal government's budget, based on the standardization and internalization, by public officers, of its concept, scope, objectives and expected impacts.

The most relevant portion of public spending on low-carbon agriculture stems from the equalization of interest on credits granted to rural producers. But the expenses with these subsidies are accounted for by the National Treasury with no distinction between low carbon agriculture and conventional agriculture and no association with the bioeconomy, which imposes critical obstacles to the monitoring and assessment of the effectiveness and efficiency of this public policy. There is also no breakdown of expenditures on these subsidies by region of the country. Therefore, it is not possible to know how much of the $ 5.12 billion disbursed between 2016 and March 2022 as subsidies to agribusiness financed the reduction of emissions (Ministry of Economy, 2019).

In addition to the financial constraints, there are also technical barriers to the mainstreaming of rural producer access to financing lines for low-carbon agriculture in Brazil, encompassing agroforestry systems and regenerative agriculture. The main barrier refers to producers' resistance in migrating from traditional to sustainable production systems. In general, producers do not recognize the associated social benefits and those that affect the agricultural and livestock activity itself, in terms of reduction of risks associated with extreme events. The dissemination of good practices and rural producers' guaranteed access to technical assistance and new markets, and increased value-added to their products, are essential to overcome this resistance.

Chart 29 | **Authorized and committed annual public resources earmarked to rural credit equalization (from 2016 to March 2022)**



From 2016 to 2021, until December. In 2022, authorized allocation for the year and amounts committed and amounts paid* until March.

Source: Authors based on SIAFI.

* Amounts paid with the annual budgets; plus remaining amounts paid. There is no distinction between subsidies for intensive and low-emission agriculture. During the analyzed period, some budgetary actions disappeared, such as the one that addressed the recovery of vegetation cover in degraded areas, and the "Bolsa Verde" program.

Challenge 2: Establish a framework that guides NEA-compliant green investments

The effort to reduce risks, typical of investment decisions, takes on a particular meaning in undertakings that, directly or indirectly, may affect the Amazon's biodiversity. This basic principle encounters challenges in the region, given the lack of taxonomy, criteria and baseline indicators on impacts derived from productive and infrastructure undertakings. Even low-carbon agriculture and livestock production can drive deforestation through the unique regional dynamics of the land market, analyzed in Part 1 of this study. That is, in the LAM's context, even if low-emission agriculture intensifies the replacement of the "chemical" component with biotechnologies and bioresources, the "mechanical" standard by itself tends to maintain pressure on the land asset, as it is based on monoculture activities that fundamentally challenge the conservation of biodiversity.

Therefore, there is a lack of minimum guarantees for investors and the agribusiness, industry, mining, energy, and other infrastructure sectors on what actually constitutes a green investment compatible with socio-biodiversity in the Amazon. The establishment of a taxonomy that adheres to the Amazon reality has the potential to unlock financial flows, particularly from international sources, in all their potential.

Mapará fishing in the city of Cametá, state of Pará.
Photo: Raimundo Pacco.

7.2 Conclusions

Estimated at $ 513 billion, investments for the NEA illustrate the magnitude of the challenges and efforts needed to achieve decarbonization in the LAM while fostering the region's original socio-biodiversity.

Guided by the strategic land use, the NEA focuses on available and promising sources of funds and financial instruments that pave the way for the large volume of investments required to change the regional economic matrix by 2050. That is, required to meet investment needs associated with sustainable infrastructure and low carbon agriculture, livestock production and mining, bioeconomy development, guaranteed forest restoration and supply of ecosystem services, and zero deforestation. Political command and control guidelines allied to the reallocation and provision of economic incentives are vital and urgent. While public policies essentially depend on the federal government's budget, financing the transition will depend on both public and private, national, and international resources.

Financing the transition as proposed by the NEA should be guided by a combination of traditional credit mechanisms – with interest rate equalization based on budgetary resources and government funds –, tax incentives from the federal and/or state and municipal governments, impact, constitutional and international funds, and alternative financing sources via capital markets. The banking sector will be responsible, above all, for bringing about a reduction in transaction costs and risks involved in financing operations.

The NEA sees the national and international capital markets and non-reimbursable funds, such as the Amazon Fund, as key financing agents for the transition. Their contribution will take place through various financial instruments and arrangements – with a highlight to green bonds and blended finance mechanisms –, structured and operated mainly by commercial, investment and development banks.

While the volume of loanable funds required to meet the growing investment needs are only found in the capital markets, non-reimbursable funds are the most promising source, and often the only one available, of financing for small-scale initiatives with high risks and fixed and operating costs, market tests - including carbon -, and social impact initiatives in general, where public interests are still neglected in favor of private benefits - particularly in cases involving the conservation of natural assets and the provision of ecosystem services.

How to make the New Economy for the Brazilian Amazon

PART **3**

HAPPEN




The New Economy for the Brazilian Amazon report presents propositional axes for economic growth with conservation and expansion of environmental assets in the form of a new economic trajectory compatible with the targets of the Paris Agreement to contain global warming to 1.5°C.

The path to 2050 needs to be broadly debated, but also urgently paved and trodden. Therefore, the report concludes by proposing actions to be prioritized over the next five years to better guide a just transition to the NEA.

The transition to this new economic model that is sustainable, socially inclusive, and consistent with the conservation of the Amazon would need at least 30 years to unfold. During this period, consolidated activities in the region, such as agriculture, livestock production and mining, would undergo a series of adjustments, and the bioeconomy would gain scale.

The final part of this report organizes the main conclusions and provides recommendations that should contribute to the planning of actions consistent with the NEA. The transition must be driven by plans and programs of the highest technical level and strong political prioritization – starting with budgetary planning at the federal and state government levels. The recommendations proposed in the following chapter acknowledge these limits and view them as guidelines that can support different public and private agents in their decision-making processes.

Boy in canoe in the Mamirauá Sustainable Development Reserve, in the Médio Solimões region, state of Amazonas. Photo: Ricardo Oliveira.

CHAPTER **8**

Conclusions and **RECOMMENDATIONS**

The economy of the LAM is characterized by the regional specialization of production, especially low value-added agricultural and mineral commodities that are intensive in carbon emissions and deforestation. It was estimated, through the development of the IIOM-LAM, that in 2015 only 12% of value-added by the LAM in the cotton and grains, livestock and mining chains is associated with demand from inside the LAM, against 41% associated with demand from the rest of Brazil and 47% with international demand. Of the approximately 1.5 Mha deforested in the LAM in 2015, 919 thousand hectares (58%) were associated with demand from the rest of Brazil, 362 thousand hectares (25%) with international demand and only 245 thousand hectares (17%) with local demand.

Other important characteristics of the LAM's economy include the high share of public administration services in GDP formation, a deficit in commercial transactions with the rest of the country, high informality in the labor market and professional qualification and wages below national averages. On the other hand, the LAM stands above the national average in the share of total jobs held by black, brown and indigenous people (80% compared to 74%), especially in extractive activities (92%).

In the IIOM-LAM, the distinction between destructive (timber, firewood and charcoal) and non-destructive (non-timber products) plant extractivism made it possible to assess that the GO and VA of the non-destructive sector, at \$ 298 million and \$ 187 million, respectively, have already reached levels very close to those posted by the destructive sector (\$ 394 million and \$ 202 million), while the sector produces a local production multiplier with a proportionally higher net impact (32% against 31% for destructive extractivism). The expansion of the non-destructive plant extractivism economy would greatly contribute to job creation and income generation for racial and ethnic minorities in the LAM.

Urban agglomerations' productive structures are very integrated with their adjacent regions, which makes these areas important consumption and innovation hubs for regional products, and the main drivers of the circular and proximity bioeconomy. Urban centers play logistical roles, integrating biodiversity products into social life. They act as platforms upon which social relations are deepened and direct economic relations are formed around these products, stimulating the economy in an intra and intersectoral way. On the other hand, they have little integration with the rest of the LAM. The agglomerations concentrate the technology and value-added sectors without spreading their benefits to the region, while contributing little to the demand for products from the rest of the LAM, characterized by the concentration in low-value-added commodities with demand mainly coming from the rest of Brazil and foreign trade.

The bioeconomy (extractive primary and agricultural, secondary and tertiary sectors), as assessed through the IOM-Alpha and comprising 13 products and 14 sectoral segments, currently generates in LAM a GO of \$ 3 billion and VA of \$ 1.9 billion in the LAM, with a wage bill of \$ 378 million, values much higher than those estimated in the IIOM-LAM for non-destructive extractivism (extractive primary sector). Economic projections for 2050 indicate that the bioeconomy has the potential to reach a GDP of approximately \$ 7.7 billion with 947 thousand jobs in 2050. However, the bioeconomy should be much larger when considering the hundreds of biodiversity products already used by local populations.

Using DOM and GEM models coupled to Computable Land Use Change Modules, four different scenarios were produced for the LAM economy in 2050, combining two constraints: restriction on total emissions to comply with the Paris Agreement (estimated at 7.7 $GtCO_2$ for Brazil and 1.4 $GtCO_2$ for the LAM) and restriction on deforestation (zero), focusing on land use and the energy mix (which currently account for 98% of LAM emissions). In the BAU scenario, no restriction was previously established; in the Technological Support scenario (STE), restrictions on emissions were imposed to comply with the Paris Agreement, but deforestation was not controlled. In the Forest Support scenario (SFL), the opposite was done, with no restriction on total emissions, but zero deforestation from 2025 onwards. Finally, the transition for the New Economy for the Amazon (NEA) scenario met both restrictions, combining optimization of land use and the energy mix to reach the target of 7.7 $GtCO_2$ with zero deforestation.

Brazil will not be able to achieve the targets established by the Paris Agreement if deforestation persists. The Technological Support scenario (STE) failed to produce a solution and reach mathematical convergence, which reflects the impossibility of achieving the Paris Agreement's targets without imposing restrictions on deforestation. Merely eliminating deforestation would also be insufficient to meet the targets. Without combining the decarbonization of agriculture and livestock production and the energy mix, the SFL scenario indicates that accumulated emissions would reach 21.1 $GtCO_2$ by the end of 2050, a value almost three times above the target. In the NEA scenario, emissions would be restricted to the target of 7.7 $GtCO_2$, deforestation would be eliminated, forest restoration would reach 24 Mha and more than 95% of the fossil-based energy mix in the LAM would be replaced mostly by electricity, and biofuels. The BAU scenario shows that maintaining current practices by 2050 means deforesting 59 Mha, with net forest losses of 57 Mha, similar to what was deforested over the past 36 years, and total net emissions would reach 43.6 $GtCO_2$, five times above the 1.5°C target.

The analysis of GDP results produced in the scenarios shows that it is possible to maintain economic growth with a standing forest, even with underestimated values for the bioeconomy. National GDP in 2050 in the BAU scenario was estimated at $ 2.88 trillion, while in the NEA it reached $ 2.93 trillion. Considering only LAM's GDP, $ 260 billion would be reached in the BAU scenario compared to $ 268 billion in the NEA scenario, a difference of $ 8 billion, 312 thousand jobs would be created in addition to the number of total jobs in the BAU, totaling 23.1 million jobs, with 365 thousand additional jobs created in the bioeconomy sector, replacing jobs in carbon-intensive chains.

Although the two scenarios produce very similar GDPs, the qualified GDP in the NEA reaches the end of 2050 with less than a fifth of total emissions observed under the BAU scenario and an additional 81 Mha of native vegetation, comprising 59 Mha of already existing vegetation in 2020 (avoided deforestation) and another 24 Mha of restored areas, 22 Mha more than the BAU. The carbon stock would be 19% higher, water loss through surface runoff would be 13% lower (more water absorption in the soil) and nitrogen and phosphorus losses 16% and 18% lower, respectively, leading to lower fertilizer replacement costs.

Investments over the 30-year period were estimated at $ 671 billion in the BAU scenario (1.03% of national GDP per year) and $ 1,184 billion in the NEA scenario) (1.81% of national GDP per year) until 2050. Of the additional $ 513 billion in the NEA scenario, $ 131.7 billion would be applied to strategic land use – through technical changes to intensify agricultural and livestock production, the bioeconomy and restoration –, $ 82 billion to changes in the energy mix, and another $ 297.9 billion to induced infrastructure. Investments would not be restricted to the LAM, given the intricate input-output relationship between the region and the rest of the country, implying a harmonization of standards, products, and processes. The Amazon would be the great catalyst for the decarbonization of the Brazilian economy.

Traditional acai fair in Belém, state of Pará.
Photo: Paralaxis/Shutterstock.

Recommendations

Methodological Innovation

Adoption of Input-Output Matrices capable of segmenting activities typical of the Amazon economy and its different regions. Social and economic development of the LAM cannot occur without instruments capable of identifying regional and sectoral heterogeneities in the Amazon. Instruments such as the IIOM-LAM, with the proposed segmentation, offer a technically robust alternative that is sensitive to this heterogeneity and should be adopted by the states and planning and financing institutions in the LAM, allowing a more accurate assessment of the sectors considered fundamental for the current and future economy of the LAM and its different regions. There is a particular need to segment the forest sector into destructive (timber, firewood, and charcoal) and non-destructive extractivism (non-timber products from the standing forest).

Adoption of accounting techniques for monetary flows capable of revealing intersectoral relationships that are underestimated by conventional methods, despite sustaining the local economy, especially with respect to the bioeconomy. As revealed by IOM-Alpha, the bioeconomy consists of chains that are strongly connected with the economic and social life of a significant part of the Amazonian population, generating value and jobs far above the levels shown by the current instrumentation. The pervasive under-dimensioning of these activities reinforces their informal character and prevents their relevance from being recognized and, therefore, included as part of the solution through the circular and proximity economy.

Inclusion of environmental dimensions that can measure economic growth in terms of parameters that converge with climate commitments. The qualification of GDP formation is essential to the development of economic activities guided by the pursuit of goals that transcend conventional ones, as shown in this report, including GHG emissions, carbon stock, water availability, protection of biodiversity and loss of soil fertility. Adjusting the course of decarbonization of the economy is only possible with the use of a Monitoring, Reporting and Verification (MRV) system applied to GDP qualifiers.

Innovation in sanitary, fiscal, and environmental traceability of LAM inputs and outputs, with special attention to regional and national markets As evidenced in this study, the regional and national markets are the main destinations for some of LAM's inputs and outputs. Although traceability methods and equipment can be universally used regardless of origin and destination, the integration of sanitary, fiscal and environmental control systems needs to be implemented concomitantly with the organization of physical and informational checkpoints. Brazil already has a fiscal control system with a high level of transparency for exported and imported inputs and outputs (Secex, 2022), but not for the domestic market, which largely lacks integration and sanitary and environmental control. Although the current structure enables the verification of commodities in the cotton and grains and mining supply chains, mainly destined to the international market, there are situations such as for example the beef chain, which generates more than $ 20 billion and accounts for more than 90% of deforestation and emissions in the LAM, and primarily serves regional and national markets, with presumably significant control evasions.

Bioeconomy

Bioeconomy plans or programs must establish clear milestones in the conceptualization of these terms and be compatible with products, processes and productive structures that guarantee the maintenance and expansion of the standing forest. The bioeconomy is not to be confused with low-carbon agriculture and livestock production, although they are complementary in the transition to the NEA. The structuring of promotion, innovation, research, and product development systems must be based on the precepts of the bioecological bioeconomy, while safeguarding all those who hold traditional knowledge, whether indigenous or from other communities.

Municipal planning must contain economic development strategies that guarantee the permanence and expansion of local markets for bioeconomy products. Cities, far beyond concentrating consumers of sociobiodiversity products, promote urban mediation – articulation, intensification, expansion and creation of innovation trends and economic diversification – boosting the circular and proximity economy. The mapping of the technical and institutional mechanisms, available in the region's urban centers and which have been able to guarantee, for centuries, the connection between the urban economy and products of the Amazon's biodiversity, need to be brought to the forefront. Improving, revitalizing and promoting popular markets for biodiversity products are crucial steps in strengthening the bioeconomy.

Ensuring the effective participation of indigenous leaders in all instances of debate, planning, decision-making and execution on the Amazon economy, not restricted to their territories or to the bioeconomy. It is imperative that the development of initiatives and decision-making always rely on the opinions, knowledge, and concerns of the indigenous populations. Specifically concerning the bioeconomy in their territories, processes and products related to their identities, the indigenous people consulted in this study made recommendations regarding technical, financial and managerial support for the development of the productive chains identified, by themselves, as relevant for their participation in markets, in the exchange of experiences between different indigenous and non-indigenous ethnic groups, thus guaranteeing representation and professional inclusion.

The bioeconomy lacks adaptation of the agricultural credit, research and development system. Credit for scientific research in the Amazon must privilege the development of technologies that are compatible, and not just compete, with family production structures, going far beyond primary sector production, guaranteeing value-added with remuneration for holders of traditional knowledge. Part of the earnings from carbon credits should be earmarked to the implementation of agroforestry and restoration systems, contributing to income generation for traditional and vulnerable populations.

Agriculture and livestock production

Redirect the availability of rural credit, gradually transforming the Safra Plan into a Low Carbon Agricultural and Livestock Production Plan (ABC+). Currently, only 3% of all credit for investment in agriculture and livestock production in the LAM coming from the Safra Plan is earmarked to low-carbon practices. As demonstrated in this study, if the current volume of loans granted in the LAM were annually applied only to low-carbon agriculture and livestock production, it would be enough to finance 40% of the investments necessary for the transition to the NEA in the agricultural and livestock sector. This study endorses the recommendations of the Brazilian Coalition on Climate, Forests and Agriculture (2022), in particular its recommendation to increase funds that authorize the payment of interest rate equalization on rural financing granted under the Safra Plan for low-carbon agriculture, in addition to including private investment funds that finance credit lines aligned with the ABC+ and Pronaf ABC+ programs.

Mainstreaming of low-carbon practices and intensification of agricultural and livestock production exclusively in consolidated degraded and anthropized areas, with a focus on the adoption of bio-inputs and integrated production systems (Integrated Crop-Livestock-Forest and Agroforestry Systems, especially with native forest species). Expand the ABC+ Plan through an ample supply of technical and rural extension assistance (ATER) and management assistance (ATEG) customized to producers and livestock farmers, particularly those in family farming, helping them to adopt low-carbon technologies and production practices, regenerative agriculture and livestock farming and agroforestry systems. Enforce the implementation of the Forest Code, with the recovery of forest liabilities and increased efficiency of the Rural Environmental Registry (CAR), in addition to structuring and operationalizing the market for environmental services (supply and demand), in accordance with Law No. 14,119, which institutes the National Policy for Payments for Environmental Services.

Urucum seeds produce natural dye in Juruti, state of Pará. Photo: Joana Oliveira/WRI Brasil.

Energy mix and induced infrastructure

Eliminate subsidies or promote cross-subsidies from fossil fuels to energy from renewable sources, with an emphasis on solar generation and second-generation biofuels. As shown in this study, the volume of subsidies to fossil fuels in Brazil, in the past decade alone, amounted to half of what is needed to structure the energy mix under the NEA scenario, or 75% higher than investments for the transition (additional to the BAU scenario). Differentiated taxation favoring electric vehicles, public transport concession policies that incentivize fleet electrification, regulation that leads to a progressive increase in the volumetric content of biodiesel in diesel oil and reduction of docking fees for vessels carrying batteries and biofuels are other points to be addressed by fiscal policies in order to promote the decarbonization of transport in the region.

Mobility planning in large cities needs to anticipate changes in transport modes to offer services compatible with the transition to the NEA. The infrastructure induced by changes in the energy mix will require additional investments of $ 297.9 billion by 2050. The resulting energy supply depends on the demand to be met, such as that resulting from the implementation of priority routes for the circulation of electrified public transport, new waterway infrastructure and modal and intermodal terminals equipped for battery charging and exchange. Changes also involve the implementation of input recovery networks to produce biofuels (agricultural, industrial and urban waste) and adaptation of the electrical network to support energy demand.

Mining

In the transition to the New Economy for the Amazon, revenues from industrial and large-scale mining activities must be tapped to finance sectors linked to the socio-biodiversity economy. Illegal mining and other illegal activities must be suppressed, and alternatives to these degrading practices must be promoted to more vulnerable populations. Current compensatory mechanisms, such as the Financial Compensation for

Mining (CFEM), are far from fulfilling their goal of mitigating the socio-environmental impacts of large-scale mining. Furthermore, the current tax framework does not favor mineral value adding in the territory; an example of such a policy would be regressive taxation, according to the degree of processing, with lower tax rates for products with greater value-added.

Institutional

Formation of Inter-Ministry Technical Groups, subnational executive secretariats and civil society mobilized to plan and execute actions that support the transition to the NEA. Thematic technical groups formed by Ministries, their state equivalents, research centers and institutes and civil society to develop transition plans for the NEA. Among the main thematic groups, Fiscal Policies for "Prioritization of LAM Incentives for Activities with Low Environmental Impact" and "Subsidies to Fossil Fuels and Competitiveness of Alternative Energies"; Sectorial Policies, such as "Pre-Competitive Strategies in Energy", "Methodological and Taxonomic framework for the financial and capital markets towards the development of green investments"; "Task Forces to Combat Deforestation", "Promotion of Restoration and Bioeconomy", "Expansion of Conservation Units and Indigenous Lands"; in Agriculture and Livestock Production, the "Renegotiation and Expansion of the Soy Moratorium for the entire LAM", "Livestock Production Moratory and Intensification of Prodution in the LAM", "Safra Plan and ABC+ Plan"; in the cities, "Master Plans for the Transition to the New Economy".

Federative Pact to balance responsibilities and achieve an equivalent budget allocation, with greater autonomy to conduct subnational and municipal policies in the transition to the NEA. The decentralization of decision-making for full compliance with the constitutional responsibilities of the government entities requires not only the equivalent redistribution of resources, but also the expansion of the direct fiscal base, mainly to guarantee higher budgetary savings and autonomy in the application of resources. This study endorses the recommendations of the Institute for Social Development (Ribeiro, Checco & Couto, 2022), especially with regard to the adoption of the Sustainable Development Goals as a structuring basis for medium and long-term planning, formulation and implementation of a national sustainable economic recovery strategy, strengthening the role of states as promoters of sustainable regional development policies, expansion and improvement of the use of socio-environmental indicators as criteria for part of the mandatory transfers to municipalities.

Restoration of the federal government's role in territorial management and governance

Reinforce the Action Plan for the Prevention and Control of Deforestation in the Amazon and support for the updating of State Plans for the Prevention and Control of Deforestation. Both are necessary tools to guarantee the integrity of the Amazon biome. Deforestation control depends on the restructuring of the inter-institutional arrangement and governance, in addition to the establishment of objectives, strategies, actions and appropriate targets equivalent to budget increases, institutional responsibilities and the definition of priority areas and actions.

Reestablishment of destination of public forests for conservation, Indigenous Lands, and sustainable forest management. Non-destined public forests in the LAM total almost 56 Mha and recently make up the land category with the highest increase in deforestation, accounting for almost a third of the total area deforested between 2019 and 2021 (Azevedo-Ramos, et al., 2020). Since the 1988 Federal Constitution, an average of seven protected areas (including Conservation Units and Indigenous Lands) were destined per year, a cycle broken in 2019, when not a single protected area was ratified. The cancellation of CAR registrations overlapping these areas is another sign that they will not be regularized for purposes other than conservation and sustainable forest management.

Restoration of territorial security in protected areas (Indigenous Lands and Conservation Units) and support for forest-based economies. Guarantee territorial security in Indigenous Lands and in already recognized Conservation Units, as well as for traditional peoples and communities, with the removal of invaders and training of indigenous and community agents to monitor and manage the territories. The structuring of value chains with sociobiodiversity products that benefit community businesses represents another important action to strengthen these territories in order to guarantee sources of income and improve the quality of life of these populations.

Support governance and guarantee the investments of the Amazon Fund. The Amazon Fund, in addition to providing support for command-and-control actions, indigenous communities and CAR implementation and analysis, must play a vital role in the development of the bioeconomy. Fund resources can both initiate the structuring of new chains and generate scale gains for existing chains and businesses, including large-scale projects involving restoration of deforested and degraded public areas. The possible actions include priority investments on enterprise management, technical and management assistance, access to markets, working capital, logistics, technology and provision of specialized services.

Promotion of large-scale restoration

Implementation of the National Plan for the Recovery of Native Vegetation (PLANAVEG) and state programs for the restoration of landscapes and native vegetation, with economic incentives for the conservation of private forest assets. Strengthen the implementation of the Forest Code through economic incentives for producers with legal environmental status, encouraging them to maintain the standing forest, and providing facilitated access to differentiated markets and credit lines for good practices. Another important point is the promotion of other economic instruments such as payments for environmental services, which may contribute to the reduction of deforestation in private rural properties.

Structuring of jurisdictional systems for Reducing Emissions from Deforestation and Degradation (REDD+) in the Amazon states. Considering that a good portion of deforested areas in the Amazon is located within public lands (Moutinho e Azevedo-Ramos, 2016; Azevedo-Ramos, et al., 2020), it is important to structure the REDD+ jurisdictional systems of the Amazon states in order to strengthen their legal and institutional structures, which in turn will support the implementation of their State Plans for the Prevention and Control of Deforestation. This structuring process is necessary to mobilize national and international public and private resources, for the execution of actions to reduce deforestation and to encourage activities aimed at scientific research, adoption of technologies, innovation, entrepreneurship, and businesses linked to or derived from environmental assets.

Support the development of a sustainable economy in Indigenous Territories with the participation of indigenous peoples. The main needs include strategies for product transportation and distribution in remote regions, with greater assignment of value and profit retention along indigenous links in the supply chain, support associated with certifications, financial education and best technological practices aimed at adding value to forest products. These actions must be implemented in a participatory manner, valuing traditional knowledge and involving Indigenous Peoples' political representations. Indigenous professionals should lead the planning and operation of production chains, from production to commercialization.

Creation of a methodological framework and taxonomies that guide the financial and capital markets on the requirements for green investments in the Amazon that promote reduction in emissions and biodiversity preservation. A legal framework for the carbon market in Brazil is thus necessary, based on a broad discussion with society about the rerouting of subsidies, leading to their progressive shift from carbon-intensive activities to the development of new technologies and the implementation of low emission productive practices throughout the economy. There are many potential sources of funds, both domestic and international. These sources must be accessed and give rise to a new mainstream financing model.

Community of Combu Island in Belém, state of Pará. Photo: Nayara Jinknss/WRI Brasil.

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End notes

Chapter 1

1 Non-destructive plant extraction is an activity that produces are goods that require deforestation od forestland (timber extraction, some form of rubber, etc.).

Non-destructive plant extraction is an activity that produces goods or products in forest areas that do not entail in deforestation (examples are seeds, some for of oils, fruits, etc.).

2 The 2015 national Input-Output Matrix is the most recent version made available at the time of conclusion of this report.

3 To divide the LAM into 27 regions, the following steps were taken:

- **Determination of microregions according to their technological trajectories.** The 109 microregions that comprise the LAM were classified according to the technological trajectory of land use and occupation. Technological trajectories were defined by the combination of agrarian structure, typology (family and non-family), intensity in the use of factors of production (capital, land and labor), categories and diversity of products and types of income obtained by producers (income from production and other incomes), based on the persistence of these indicators between the agricultural and livestock production censuses of 1996, 2006 and 2017 (Costa, 2016; 2021).

- **Inclusion of urban agglomerations.** The six main urban agglomerations of the LAM (Belém, Manaus, Rio Branco, Porto Velho, São Luís and Cuiabá) were detached from their respective microregions due to the observation that such agglomerations constitute their own distinct regions, which are not represented by the classification of technological trajectories (Simmons, Perz and Pedlowski, 2002; Guedes, Costa Brondizio, 2009; Santos, 2022). It was considered that urban agglomerations are formed by the conurbation of two or more municipalities in a given metropolitan region.

- **Clustering and homogenization.** In order to make computational resources compatible with the generation of input-output matrices and to optimize interregional interpretations, the mosaic of the 115 resulting regions was grouped by the Two Step Cluster Model for non-hierarchical variables (Kent, Jensen and Kongsted, 2014), considering the seven trajectories, the six agglomerations and the two dominant biomes (Amazon and Cerrado areas). Isolated or bordering microregions were absorbed by the dominant surrounding cluster, determined by the ArcGIs nearest-neighbor chain tool, having as points of contact the perimeters of the regions in question.

4 The segmentation of forest management products used the following criteria:

- **Forestry products.** Obtained from plantations of exotic tree species, aimed at supplying roundwood, pulpwood, firewood, charcoal and resins (IBGE, 2022), used as inputs for the pulp and paper, furniture manufacturing, civil construction, pig iron manufacturing and pharmaceutical sectors. They were allocated in the IIOM-LAM according to GO weighting and product and sector specification (IBGE, 2018).

- **Destructive plant extraction products.** Obtained from native species in natural forests, such as roundwood, firewood, charcoal, tannin, wax, bark and heart of palm, whose extraction involves felling of or irreversible damage to the parent plant (IBGE, 2022). These products are inputs for the wood processing, furniture manufacturing, construction, pig iron, non-metallic materials, food and pharmacochemicals production sectors, allocated according to GO weighting and product and sector specification (IBGE, 2018).

- **Non-destructive plant extraction or standing forest products.** Derived from native species in natural forests, whose production requires the maintenance of the plant and, on a large scale, of the forest itself, from which fruits, leaves, straw, fiber, seeds, oils, gums, resins and latex are obtained (IBGE, 2019). Such products are also inputs for the food, beverage, cosmetics, pharmacochemicals, rubber and furniture manufacturing sectors, allocated according to GO weighting and product and sector specification (IBGE, 2018).

5 The deforestation cycle begins with the extraction of wood from the forest, after the removal of the most profitable species. Fire is used so that the area can be used for livestock production first and then agriculture (Barlow and Peres, 2006; Souza Jr. et al., 2013).

6 The successive enactment of laws on land tenure management in the Amazon has led to a federalization of land management, whereby, under the argument of national interest, states lose control over significant portions of their territory. Consequently, there is confusion about which federative entity is responsible for granting land ownership titles in a given territory.

7 Conflicts over land tenure have been identified as strong factors influencing deforestation in protected areas in the Amazon (Nolte, Agrawal and Barreto, 2013), leading to an increase in land inequality (Lapola et al., 2014). Analysis of data from the Rural Environmental Registry (CAR) reveals that out of 330 Indigenous Lands in the Amazon, 275 have registration indicating private ownership. Also, between 2016 and 2020, there was a 55% increase (from 2.3 Mha to 3.57 Mha) in areas improperly declared as private within Indigenous Lands in the Amazon. The number of registrations in the CAR increased by 75% (from 3,517 to 6,170 registrations) during the same period. Most of these registrations (75%) relate to establishments of up to 100 hectares, but which occupy only 2.24% of the irregularly registered area. Large establishments (more than 1,000 hectares) accounted for 7.11% of registrations, but represented 88% of the area overlapping Indigenous Lands (Fellows et al., 2021). These data reinforce the existence of a process of land tenure inequality based on the illegal grabbing of public lands intended for conservation.

8 Further information in Abreu (2021).

9 Project for Litigation over Irregular Areas (MPF, 2022), available at http://amazoniaprotege.mpf.mp.br/

10 CAR is an instrument created by the Forest Code (Law No. 12,651/2012), aimed at addressing the issue of territorial planning. However, as it is self-declaratory, the CAR faces problems such as the overlapping of lands already registered as Indigenous Lands, Conservation Units and other public lands. This practice is carried out by land grabbers and informal settlers, whose bad faith cannot be presumed (Agência Senado, 2022).

11 The estimation of jobs and occupations by race is done by coupling the IIOM-LAM with job qualification vectors, following the methods described in the Box 8.

12 Although the data in this study mostly refers to large companies, they clarify the systematics of deforestation resulting from mining activities.

13 Mining is illegal within demarcated Indigenous Lands and Conservation Units.

Chapter 3

14 The Soy Moratorium is the name given to the environmental pact established between the entities representing soybean producers in Brazil and environmental NGOs, later joined by the government, with the aim of adopting measures against deforestation in the Amazon. It had an initial duration of two years starting in July 24, 2006. In practice, the moratorium prohibits the purchase of soybeans from newly deforested areas in the Amazon. In May 2016, the moratorium was renewed indefinitely (Abiove, 2022).

15 Costa et al. (2022) identified the concepts of bioeconomy adopted by several national and international institutions, consolidating them in a table that indicates disputes over the term.

16 Since the mid-1960s, the proportion of malnourished people has fallen from one-third to one-sixth of the world's population. This reduction was made possible by the expansion of the food supply, supported by productivity gains in agriculture, derived from the Green Revolution (Wik, 2008).

Among other factors, the increase in productivity was the result of public and private investments in the genetic improvement of agricultural cultivars, particularly high-yield varieties of wheat, rice, corn and sorghum. Public policies to control food prices, encourage research and disseminate technologies aimed at improving productivity were also important.

17 Among the main characteristics and objectives of the chemical-mechanical standard in agriculture is the need to regulate the physical-chemical and biological reactions generated by the decrease in natural diversity and its effects on the soil-plant complex, which directly interfere with the ecological conditions of land productivity. In this case, it is necessary to incorporate exogenous sources of energy and nutrients as an agronomic control strategy (Romeiro, 1998).

18 This paradigm is characterized by the following factors: coexistence with the original ecosystem, technologies applied to manage (and not control) botanical diversity and ecological systems, productive operations adjusted to the rhythms and cycles of nature, attempts to imitate natural processes, conjugation and succession of species in the same production system, autonomy relative to external sources of inputs, energy and nutrients.

19 Sometimes invisible in the official the urban economy data, the beaters form a peculiar supply chain for acai pulp, especially in the urban areas of Baixo Tocantins, Marajó and the estuary of the Amazon River. Federal Revenue data show that, as of 2010, the number of beaters in the formal economy increased, a change possibly linked to the growth of sanitary control in the acai whitening process and changes in legislation, requiring formalization through the MEI and Simples programs (Ferreira et al., 2006; Oliveira, 2011). In the LAM, according to data from the acai chain, individual entrepreneurs represent 62.2% of all registrations, entering into activity mainly between 2010 and 2019.

20 Brondízio (2004) spoke of the need to discuss categories such as forest farm; forest farmers.

21 According to IBGE (2022).

22 The family standart is global. According to estimates, between 5.5 million and 6 million family farmers sustain the supply of cocoa beans in the international cocoa market (FOUNTAIN; HÜTZ-ADAMS, 2015, p. 37; DUGUMA et al., 2001).

Chapter 4

23 See CNA (2022).

24 In addition to mitigating risk to rural producers, the recent expansion of PSR coverage reduces potential public liabilities resulting from recurrent debt renegotiations with the sector and allows for a gradual reduction of subsidies to agriculture. For an analysis of the importance of the PSR, see Souza (2020).

25 The ABC+ Plan foresees, for 2022, in an unprecedented way, a No-Tillage System for vegetables.

26 For a review of the main agricultural concepts related to sustainability, see Annex I.

27 Another product derived from the land commodity is forested land, constituting a collection of private productive or speculative capital (Costa F. A., 2010; Costa F., 2011). For more details see annex.

28 The opportunity cost of the standing forest corresponds to the production that the rural producer is prevented from undertaking due to the decision not to deforest.

29 According to Law No. 12,651/2012, the minimum percentage of a rural property's Legal Reserve Area (LRA) depends on its location. In the Amazon biome, it is 80%. PPA can be considered as LRA, and there are conditions provided by law for the economic exploitation of these areas.

30 Even for rural producers, the benefits are for the entire sector, not just for those who conserve.

31 The "free rider" behavior refers to the advantage of individuals who enjoy the benefits of a good paid for by third parties (Mankiw, 2020). In the Brazilian case, it can refer to private agents that benefit from ecosystem services provided by forests conserved

with private resources or by the Brazilian State. Thus, the costs of offering this good (the natural asset) or service (the ecosystem services) are transferred to the State and to rural producers, generating a cost for them and discouraging the maintenance of supply.

32 In highly competitive markets, with atomized price-taking producers, profit maximization basically takes place via production cost minimization.

33 See Rodrik (2014) and Jaffe (2005).

34 Strassburg (2019) is even more optimistic and suggests a potential to quadruple livestock productivity.

35 The ABC+ Plan, successor to the ABC Plan, updated the targets for the agricultural sector and the technologies for mitigating GHGs. Technologies become one of the nine strategic axes of the Sustainable Systems, Practices, Products and Production Processes (SPSABC). The No-Tillage System for Vegetables (SPDH), Irrigated (SI) and Intensive Termination (TI) systems were added to the set of technologies. Some technologies from the previous plan were expanded in scope. The Recovery of Degraded Pastures (RPD) was renamed Practices for the Recovery of Degraded Pastures (PRPD), also focusing on the recovery of pastures with some degree of degradation. Animal Waste Treatment (TDA) was renamed Animal Production Waste Management (MRPA) and incorporated other animal waste. Biological Nitrogen Fixation (BNF), now Bioinputs (BI), now includes Plant Growth Promoting Microorganisms (MPCP) and multifunctionals. The Integrated Crop-Livestock-Forest system became National Integration Systems (SIN) encompassing Agroforestry Systems, with treatment independent of ICLF systems (Brazil, 2021; MAPA, 2021).

36 TFP is measured by the quotient between total production and total input indicators. It corresponds to the increase in production attributed to efficiency gains, and not to the marginal increase in inputs. For a methodological description of the indicator see (Gasques, 1997; Jorgenson, 1966; Christensen, 1975; Alves E. R., 1979; Gasques, Bastos, & Bacchi, 2009; Alves E., 2010) .

37 International Panel of Experts on Sustainable Food Systems (2017) (Development, 2018).

38 Inelastic products or products with low price elasticity of demand have demand that is not very sensitive to price variations. Faced with a market with few suppliers, an increase in the price of an input does not imply a significant reduction in the quantity demanded by the rural producer. The net margin of the agricultural activity tends to reduce, as the sale prices of commodities are given.

Chapter 5

39 Brazil is highly dependent on imported fertilizers. More than 80% of consumption comes from abroad. In addition to adding pressure to production costs “inside the gate”, this significantly increases the carbon footprint of food and fiber production. Currently, the country is responsible for 8% of global fertilizer consumption, behind only China, India and the United States. In 2018, out of 24.96 million tons of fertilizers, 42% were potassium chloride (94% imported and 6% domestic), 35% nitrogen fertilizers (76% imported and 26% domestic) and 23% phosphate fertilizers (55% imported and 45% national) (SEAE, 2020). In 2021, the country broke the fertilizer import record, with 41.6 million tons (Special Secretariat for Strategic Affairs, 2020).

40 See Brazil (2021).

41 Fertilizer import data available at SECEX/ Ministry of Economy (ComexStat, 2021), at http://comexstat.mdic.gov.br/pt/geral/57571

42 Bauxite, copper, iron, manganese, nickel and tin.

43 In September 2020, at a UN symposium, a new standard for power nuclear reactors was proposed, which are now referred to as 4th generation nuclear reactors. They would meet the requirements of inherent security and make the proliferation of nuclear weapons impossible, while being economically competitive and ecologically acceptable. The proposal was endorsed by the International Atomic Energy Agency of the United Nations (Bastos, 2002). Available at: https://www.ipen.br/biblioteca/cd/inac/2002/ENFIR/R14/R14_104.PDF.

44 In this sense, Bill No. 191/2020 regulates the exploitation of mineral, water and organic resources in indigenous reserves

45 In the LAM, the disruptive technologies at Vale's S11D mine are examples of this trend.

46 The Statute of Indigenous Peoples, Federal Law No. 6,001/1973, provides two hypotheses for subsoil exploitation in indigenous lands. The first, art. 20, provides that the federal government may, exceptionally, enact federal intervention for exploitation. The second, art. 45, determines that the wealth of the subsoil of indigenous lands can only be exploited under the terms of Decree No. 88,985/1983, which establishes exclusivity of exploitation of the wealth and utilities of the soil to the indigenous peoples (art. 2). However, it establishes the possibility that companies come to be authorized by the federal government for exploitation (art. 4). However, these permissions were suspended with the advent of the 1988 Constitution, which conditioned exploitation to a series of requirements listed in art. 231, paragraph 3, which must be complied with according to a law that has not yet been enacted. In the absence of regulations on how such requirements may be met, mineral, water and energy resource exploitation on indigenous lands remains impossible.

47 According to Convention 169 of the International Labor Organization (ILO).

48 Despite initiatives to regulate article 231, paragraph 3 of CF/88, which would allow mineral exploitation on indigenous lands, such as Bill No. 191/20, the article remains unregulated, which categorically prevents any mining activity from taking place on indigenous lands.

49 Including semi-manufactured mineral products and oil and gas oils

50 "The desire to exploit a strategic mineral would be legitimate if it weren't for the immense problems that, to this day, have not allowed the country to carry out its intention to exploit. Among the challenges that need to be overcome, four stand out as the most emblematic: (1) the deposits are located at about 900 meters deep in an extremely sensitive area of the Amazon Forest (in the state of Amazonas) and close to the estuary of the Madeira river; (2) mineral exploitation and processing still needs to overcome significant technological challenges due to its characteristics (high solubility); (3) there is no infrastructure, especially for energy supply, in the required scale, to make a project of this nature viable, which would require the implementation of an energy branch from Tucuruí or Belo Monte. This in turn would require environmental licenses and considerable investments associated with mitigation mechanisms related to the construction of a high voltage network inside the forest; and (4) most of the reserves are found underground in regions that make up a mosaic of indigenous lands where, according to current legislation (art. 231 of the Federal Constitution, still unregulated), this type of undertaking is not permitted, because these are areas belonging to the native peoples (although the resource is almost a kilometer deep)." (Technical Note on Bill No. 191/2020).

51 The institute stood in favor of the regularization of mining in indigenous lands, being opposed to small-scale and illegal mining in these areas. However, with regard to Bill No. 191/2020, IBRAM understands that the way in which the proposal was being conducted is not adequate – on an urgent basis in Congress and without broader debates. According to the institute, there would be risk to Brazil's international reputation in case of approval (Amaral, 2022).

52 Aiming at transforming waste into new products. In the LAM, there are promising examples, such as that of Canadian company Canada Rare Earth Corporation (CREC) which, according to the magazine, intends to implement a project to process 70 million metric tons of waste accumulated in the Bom Futuro mine, in Rondônia, containing rare earth elements, cassiterite, zirconium and ilmenite. Investments are estimated at $ 303 billion and the undertaking should generate 300 direct jobs and 4.5 thousand indirect jobs (Brasil Mineral, 2022).

53 There are advanced studies, including in Brazil, on capturing and storing carbon in geological environments that are conducive to this practice (CPRM). Kinnunen and Kaksonen (2019) point out that the economic use of mining waste requires technology and development in terms of integrating value chains, which represent important challenges for the application of circular economy principles in mining activity.

54 In global terms, mining accounts for 1% of all global scope 1 and 2 carbon emissions (or 4% to

7% when fugitive methane emissions from coal mining are included) and holds a 28% share of all emissions when scope 3 is taken into consideration. As the largest mining company present in the LAM, Vale announced at the Glasgow Conference that it intends to invest between $ 4 billion and $ 6 billion to reduce its direct and indirect emissions by 33% and the emissions of its value chain by 15% by 2050. Available at: https://valor.globo.com/patrocinado/vale/transformando-o-amanha-juntos/noticia/2021/11/08/cop26-tera-apresentacao-de-plano-de-descarbonizacao.ghtml.

55 As the case of Canaã dos Carajás (Enriquez et al., 2018) well illustrates, in which an area corresponding to one third of the municipality's area was acquired.

Chapter 6

56 Infrastructure, according to the Global Commission on the Economy and Climate, is defined as: structures and facilities that support energy, transport, telecommunications, water and waste management systems. It includes investments in systems that improve resource efficiency and demand-side management, such as energy and water efficiency measures. And it encompasses both traditional infrastructure (including power for public transport, buildings, water supply and sanitation) and natural infrastructure (considering forest landscapes, wetlands and watershed protection) (New Climate Economy, 2016).

57 Decree No. 7,246/2010 defines Isolated Systems as "electricity systems for public distribution of electricity that, in their normal configuration, are not electrically connected to the National Interconnected System (SIN), for technical or economic reasons".

58 As users of these systems are not financially able to sustain these costs, energy generation is subsidized through a sectoral charge, the Fuel Consumption Bill (CCC), paid by SIN consumers through the Energy Development Bill (CDE) (EPE, 2021).

59 According to Decree No. 7,246/2010, remote regions are considered as "small groups of consumers located at an Isolated System, far from municipal governments, and characterized by the absence of economies of scale or density". Remote regions differ from each other. In some cases, energy is supplied independently, by private and collective initiatives involving the acquisition of diesel or gasoline generators, as seen in the Vila Nova community in the Marajó Archipelago, in Pará, in the Wai-Wai Indigenous Community in Roraima and in the Cavalcante Community, in Rondônia. In other cases, municipal and state governments bear the costs of this fuel, as in Amapá, with the "Luz Para Viver Melhor" Program, which distributes diesel monthly to 152 communities in the state (Amapá, 2021).

Chapter 7

60 In the states, expenditures settled and total expenditures were considered. In the federal government, the total amount paid and primary expenditures (excluding interest payments) were considered.

61 In the absence of a specific delimitation for such budgetary actions in the federal government's general budget and based on the detailed descriptions of each one of them, this section of the NEA report captured the budgetary actions in the ministries of the Environment, Agriculture and Livestock Production, Science, Technology and Innovation, Justice and Defense for this purpose. Only "final expenses" were surveyed, that is, payroll expenses in the respective actions were already excluded. The register of budgetary actions is available at

61 The international carbon market emerged in 1997 through the Kyoto protocol. In 2015, with the Paris Agreement, a new international treaty was created, replacing the Kyoto Protocol from 2020 onwards, and expanding it to 195 countries. There are two types of carbon markets: the regulated market (which concerns mandatory reductions defined in international agreements) and the voluntary market (in which companies have the initiative to offset emissions generated by their industrial and business operations). Currently, the largest market is the European Union (EU-ETS) (European Union Emissions Trading System), created in 2005. Others are also very advanced, such as those of California (USA) and Quebec (Canada).

About the New Economy for the Brazilian Amazon

The New Economy for the Brazilian Amazon (NEA-BR) is an initiative led by WRI Brasil and The New Climate Economy, in partnership with more than 75 researchers from various Brazilian regions, and organizations, including the Federal University of Pará (UFPA), University of São Paulo (USP), Federal University of Rio de Janeiro (UFRJ), Federal University of Minas Gerais (UFMG), Institute for Environmental Research in the Amazon (IPAM), Instituto de Conservação e Desenvolvimento Sustentável do Amazonas (IDESAM), Center for Climate Crime Analysis (CCCA), Concertation for the Amazon and Associação Contas Abertas.

The initiative has the financial support of Instituto Clima e Sociedade (iCS), the Danish Ministry of Foreign Affairs, the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection of Germany, Instituto Arapyaú, Good Energies Foundation, and the Climate and Land Use Alliance (CLUA).

Cocoa fruit produced in Combu Island, Belém, state of Pará.
Photo: Dado Photos/Shutterstock.

About WRI Brasil

WRI Brasil is a research institute that transforms great ideas into actions to promote environmental protection, economic opportunity and human well-being. It works in the development of studies and implementation of sustainable solutions in climate, forests and cities. It combines technical excellence with political articulation and works in partnership with governments, companies, academia and civil society.

WRI Brasil is part of the World Resources Institute (WRI), a global research institution operating in more than 60 countries. WRI relies on the expertise of approximately 1,400 professionals in offices in Brazil, China, the United States, Europe, Mexico, India, Indonesia and Africa.

About The New Climate Economy

The Global Commission on Economics and Climate and its flagship project The New Climate Economy were created to help governments, businesses and society make more informed decisions about how to achieve prosperity and economic development while addressing climate change.

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https://doi.org/10.46830/wrirpt.22.00034en