SynCER: Synthesising post-disturbance Carbon Emissions and Removals across Brazil's forest biomes

Day 3: Towards integrating synthesized regrowth rates and methods into policy (GFOI-led)

São José dos Campos, 31 Oct 2025

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Session 3.1: Accounting for carbon removals/fluxes in secondary forests for MRV process - Advances, needs, and challenges

SynCER: Synthesising post-disturbance Carbon Emissions and Removals across Brazil's forest biomes

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MRV of forest degradation and regrowth: country cases

Carla Ramirez

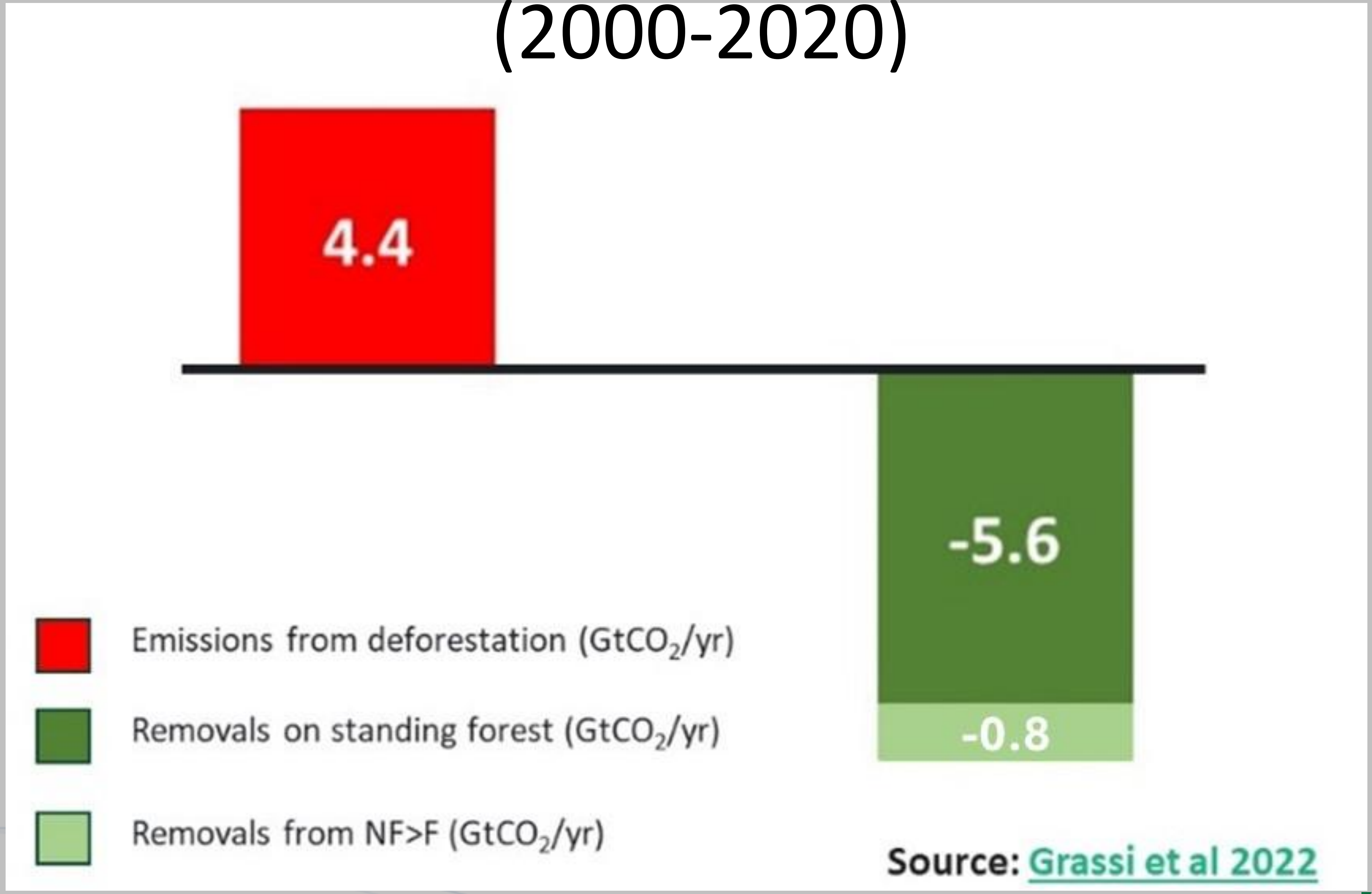
Session 3.1: Accounting for carbon removals/fluxes in secondary forests for MRV process

São José dos Campos, 31, Oct 2025

Overview

- ✓ Global anthropogenic CO_2 fluxes from forests
- ✓ Removals in carbon standards
- ✓ MRV of removals– forest degradation in Latina American & Caribbean countries
- ✓ Country cases
- ✓ Good practices for data improvement

Global anthropogenic CO2 fluxes from forests



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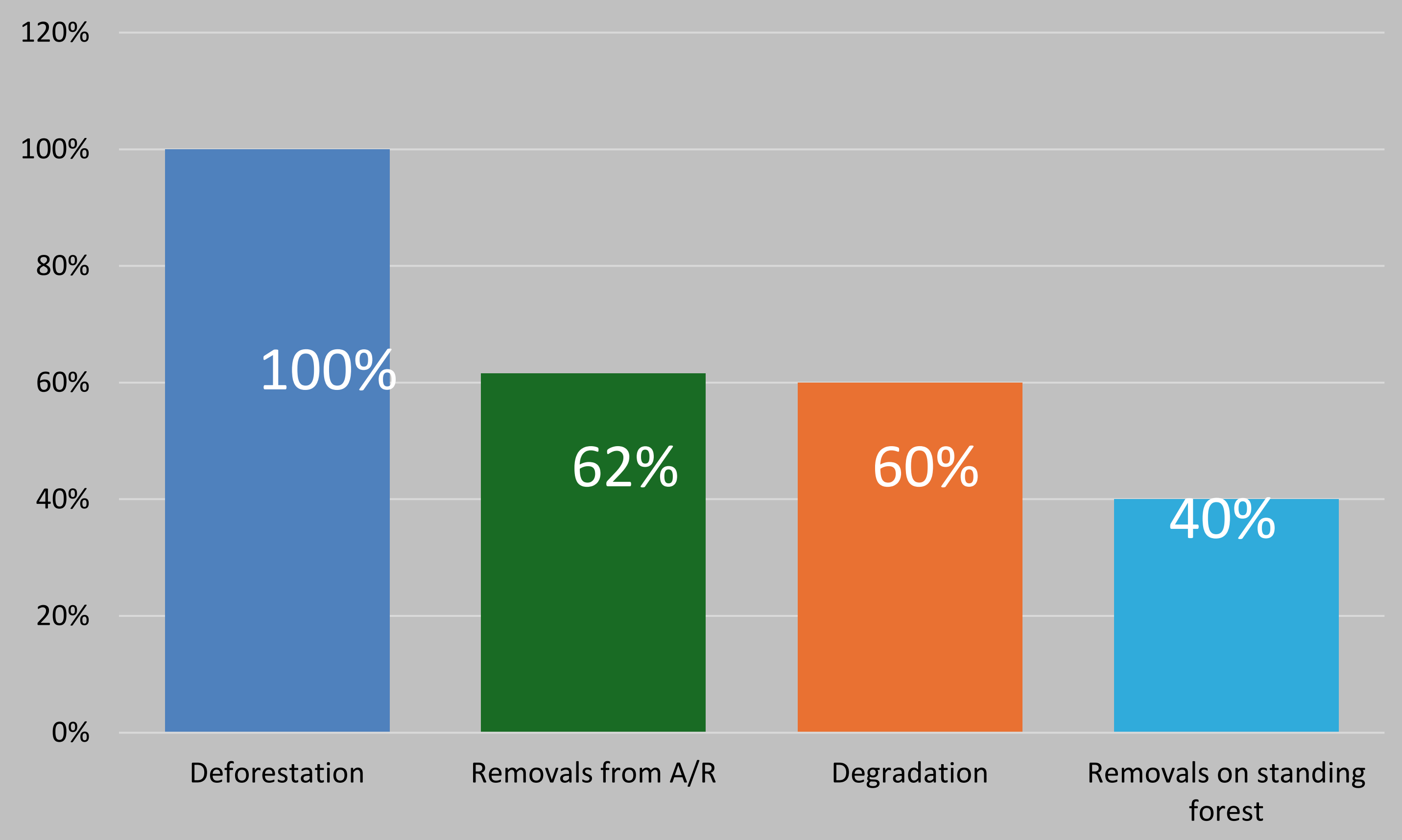
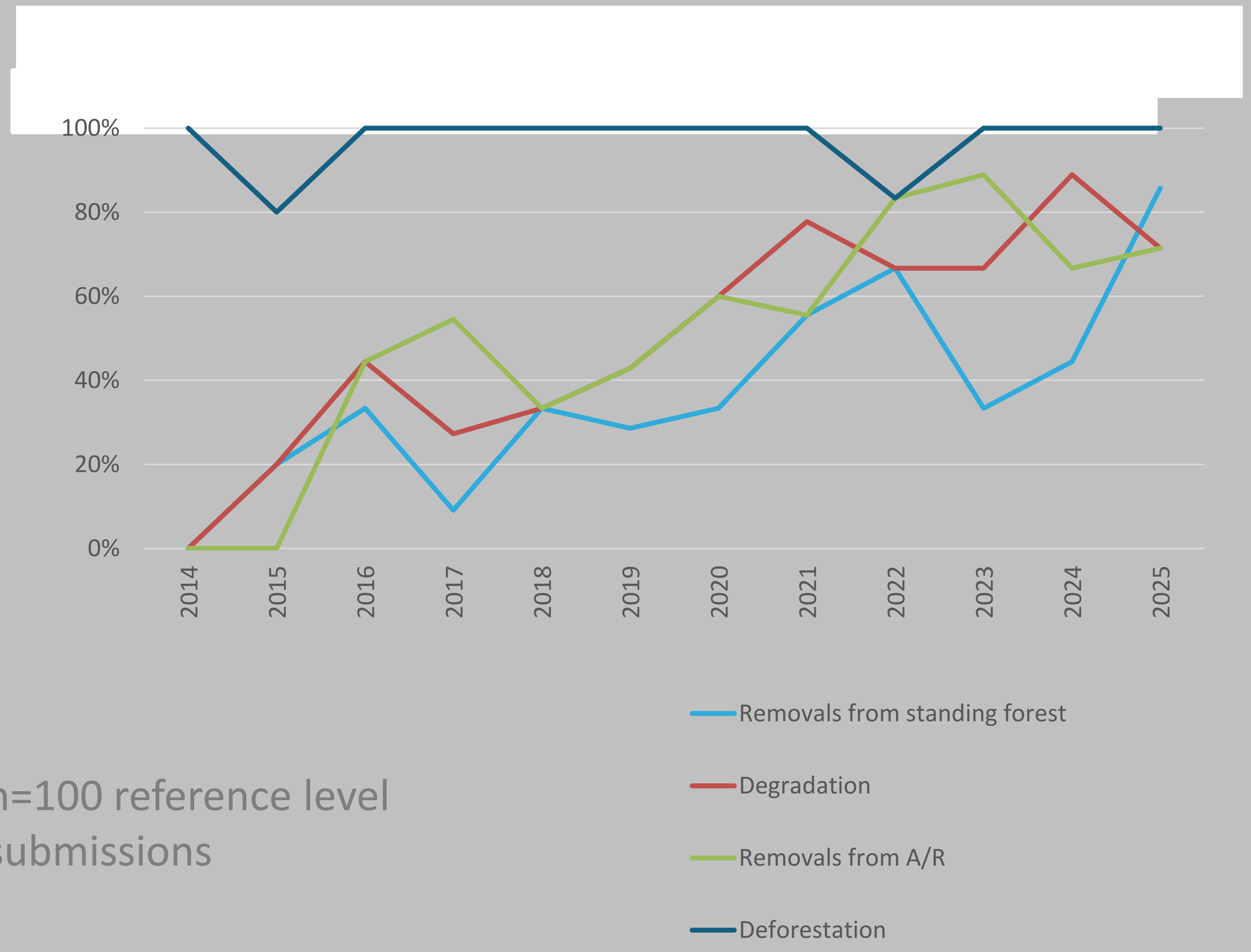
Standing forests carbon flux reporting

Removals from standing forests is the least reported REDD+ carbon flux…



n=65 countries with reference levels

…but looking at the % fluxes included in submissions over time, it is catching up!



n=100 reference level submissions

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REDD+ reporting converging with GHG reporting?

Forest land emission and removals from REDD+ and GHGI aligning to some extent…

	REDD+	GHGI
Forest land net removals	-647 mln tCO_2e	-805 mln tCO_2e

…but at country level differences can be large (for multiple reasons)

Per ha fluxes REDD+ reporting range from -11 to +1.5 tCO_2/ha

GHGI courtesy of Melo & Grassi (does not yet include BTRs without CRT

Belize and Honduras excluded since data did not allow to disaggregate forest flux without deforestation
Cuba excluded because subnational

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Emission reductions reported to the UNFCCC

Removals only small share of overall ER reporting…

	ERs in '000 tCO2e	Share of total
F > NF	13,189,829	91.2%
Emissions F>F	-79,459	-0.5%
Removals NF>F & F>F	490,246	3.4%
Mixed	857,390	5.9%
Total	**14,458,005**	**100%**

n = 24 countries

…but large share when only including countries with removals in scope

	ERs in '000 tCO2e	Share of total
F > NF	243,148	27%
Emissions F>F	-189,833	-21%
Removals NF>F & F>F	490,246	54%
Mixed	369,793	40%
Total	**913,355**	**100%**

n = 8 countries

Removals in carbon standards

	FCPF-MF	GCF scorecard	ART-TREES	VCS-JNR
Removals from A/R				
Removals from standing forest				

Approximately 9% of emission reductions reported are removal increases A/R

Approximately 21% of reported emission reductions are removal increases

Carbon standards exclude removals from standing forest due to high uncertainties

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Age to consider a secondary forest

IPCC, 2006

*“It is clear that most forest ecosystems will take longer than 100 years to return to the level of biomass, soil and litter pools in undisturbed state; however human-induced activities can enhance the rate of return to stable state of carbon stocks. With this in mind and as a practical matter, **the default 20-year time interval is suggested**"*

Art – Trees Standard

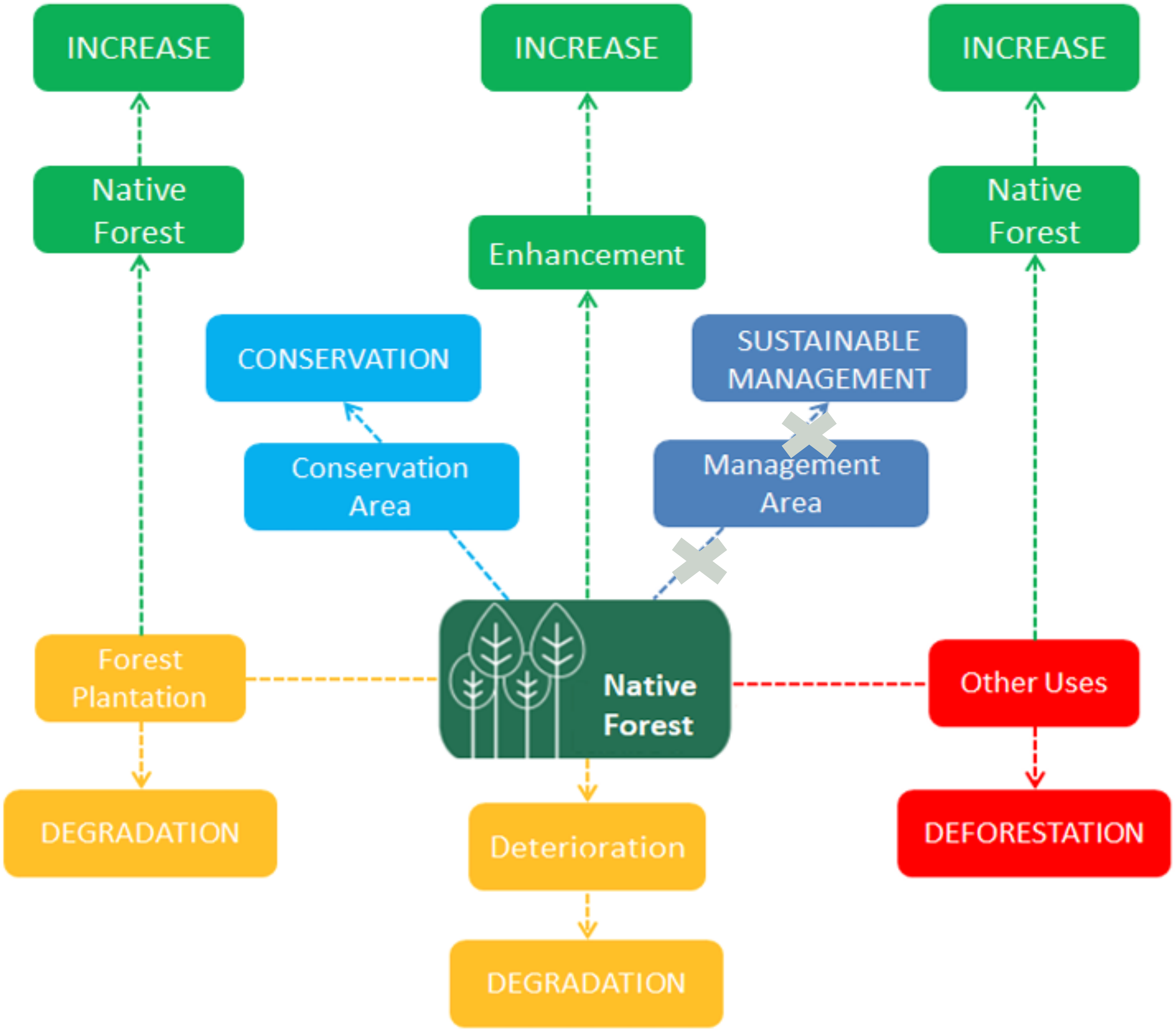
- *Need to **demonstrate** the ARR area as **non-forest 5 years prior to planting or start restoration activities***
- *More credits to natural forest restoration than commercial forest**, it is recommended to separate them***
- *Eligible removals from commercial forest: those that **exceeds the average from the reference period (5-years)***
- *Eligible removals from natural restored forest: **growth in areas restored up to 10 years before the crediting period***

LAC cases according to the latest FREL reporting

Country	Removals NF - F	Removals F - F	Data period	Difference SF / DF	Annual AD collection	Age SF recognition	Removals T CO^2e / yr
Belize	Y	Y	2001 - 2020	Y	Y	< 20 > 20 < 50	only net balance
Brazil	Y– Amazon / Cerrado	Y – Amazon / Cerrado	2016 .2021	Y	N	ND	- 59,395,580 / - 9,379,957
Chile	Y	Y	2001 - 2013	Y	N	ND	-20,166,878
Costa Rica	Y	Y	2010 -2019	Y	N	4 -- 8	-5,660,563
Cuba	N	Y	2014 -2019	N	N	> 20	-32,638,725
Dominican Republic	Y	Y	2000-2015	Y	Y	20?	-10,845,741
El Salvador	Y	Y	2006 - 2015	Y	N	ND	-3,117,260
Guatemala	Y	Y (from deg)	2006 - 2016	N	N	ND	-2,873,725
Honduras	Y	Y	2016 - 2020	Y	Y	6 -- 8	-37,695,733
Nicaragua	Y	N	2005 - 2015	Y	N	ND	-2,350,000
Panama	Y	Y	2016 .2020	Y	y	ND	-38,051

Country case: Chile

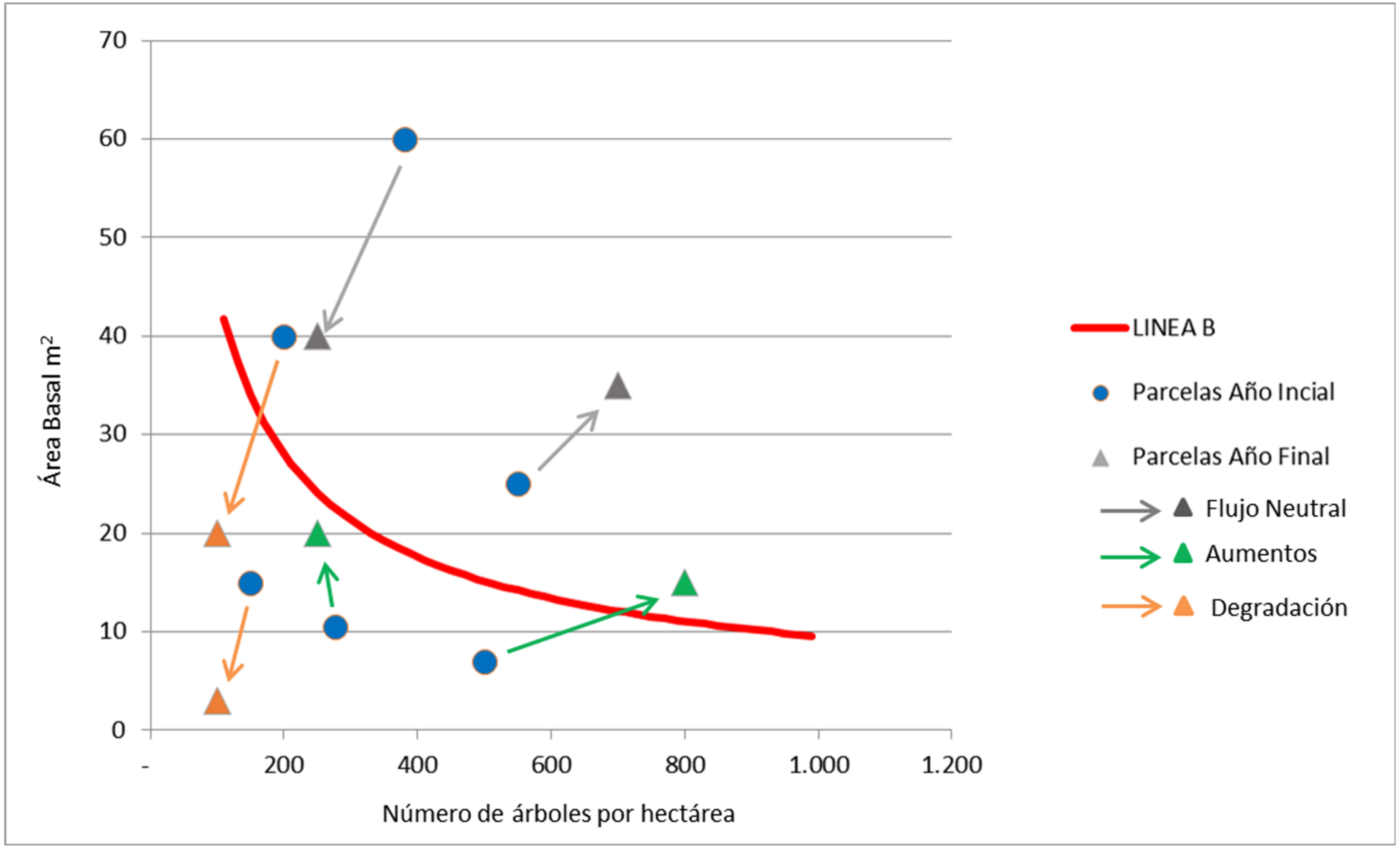
Carbon fluxes



Chile, 2023. Nivel de referencia de emisiones forestales / Nivel de referencia forestal

Estimation strategy

Country case: Chile



- AD: Combination NFI – RS data
- Data: Nº Trees/ha – AGB/ha
- Non-parametric K-nearest neighbor extrapolation
- EF: NFI

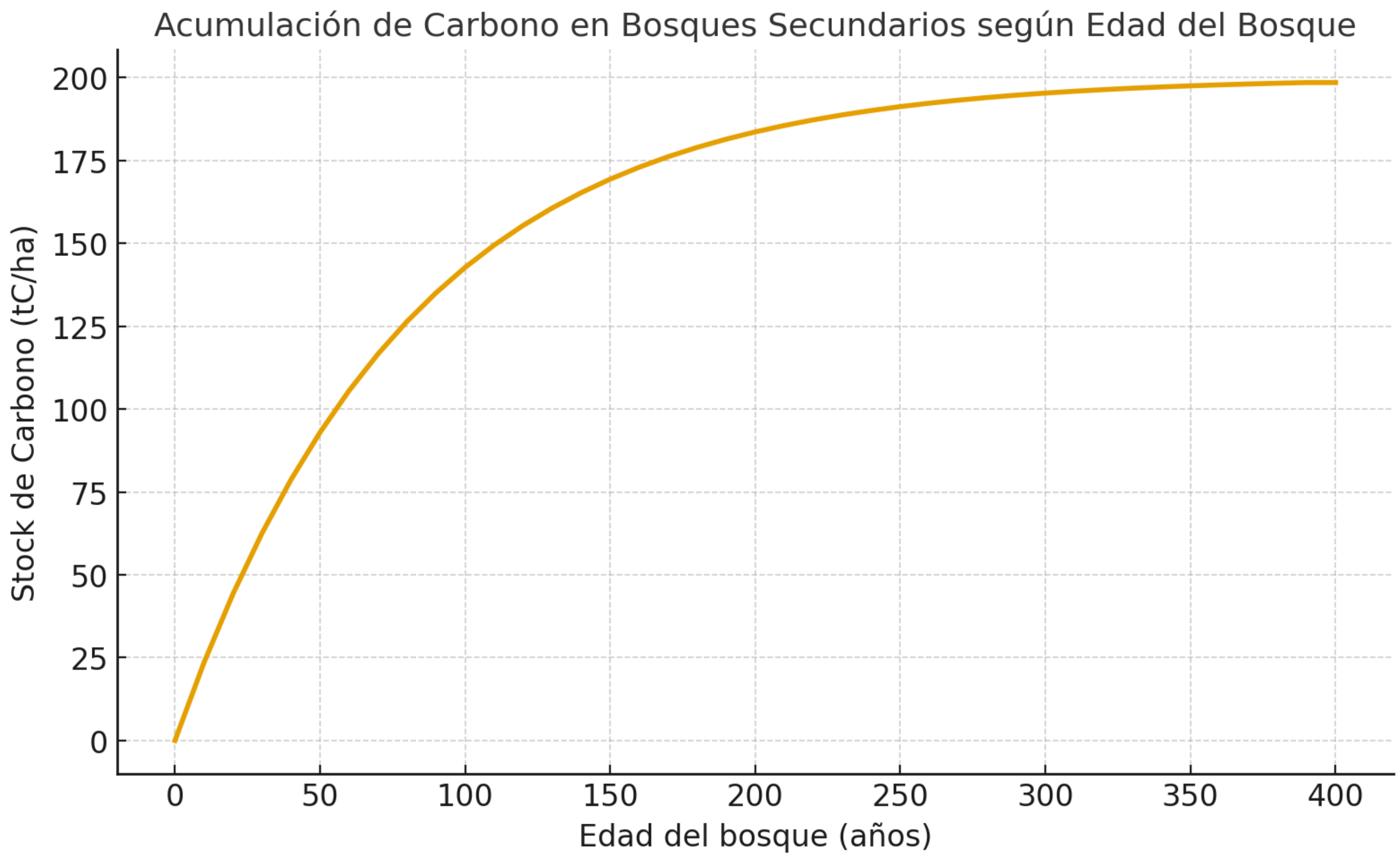
✓ FREL – GHGI

SOP

Chile, 2023. Nivel de referencia de emisiones forestales / Nivel de referencia forestal

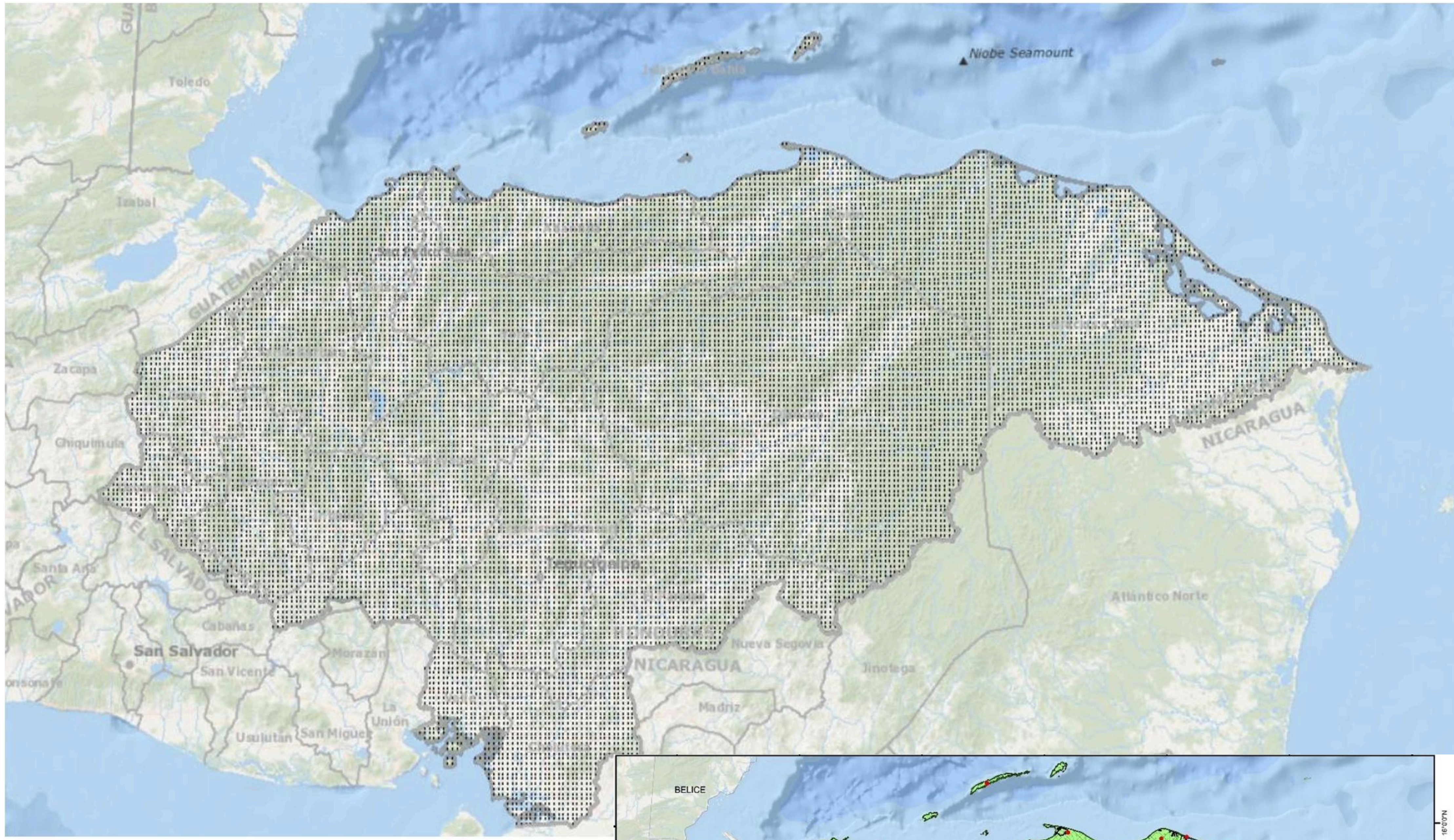
Country case: Costa Rica

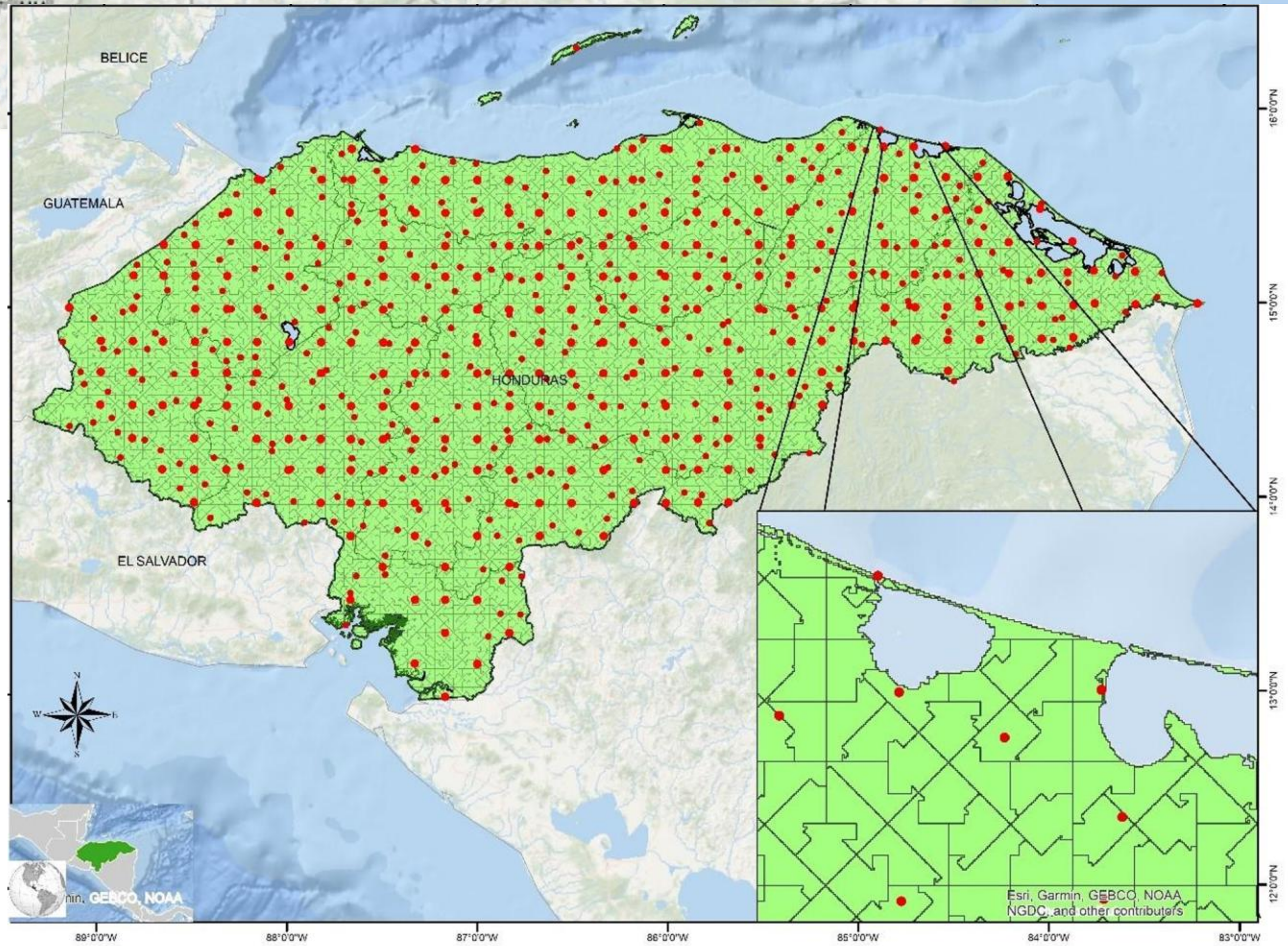
- AD: mapping-based SF / sampling-based DF
- TAR: to separate SF – DF
- EF: model different ages
- SF recognition ages: 4 yr humid forest / 8 yr dry forest



Country case: Honduras

- AD: sampling-based
- EF: NFI – secondary forest / growth rate / yr
- SF recognition ages: not defined
- Applied growth rate to all standing forest (mature/secondary)



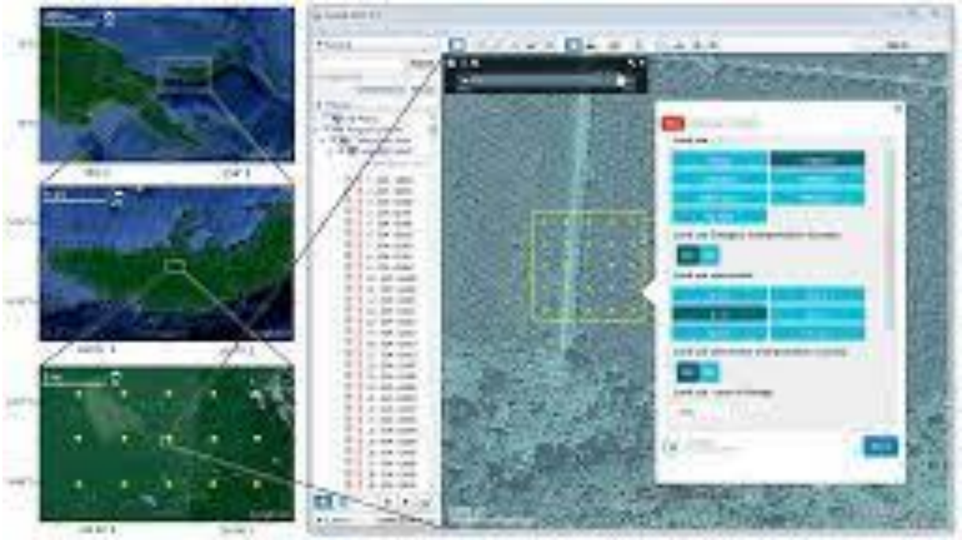


-37,695,733 Ton CO^2 e / ha

Role of new technologies

Improved imagery

New satellites providing imagery of higher temporal and spatial resolution



Global tree cover products and algorithms

Dense time-series analysis algorithms and global tree cover (change) products: Global Forest Change product, Tropical Moist Forest product etc.

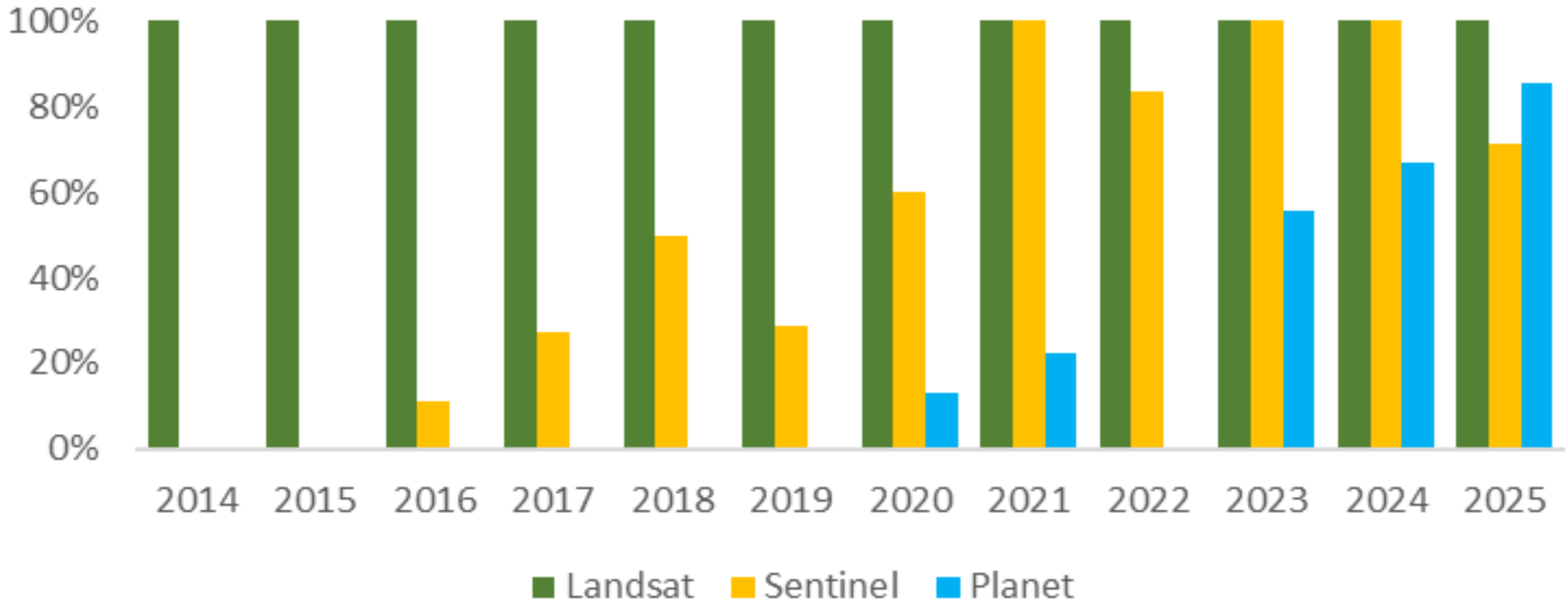
Improved methodologies

The science around area estimation has improved

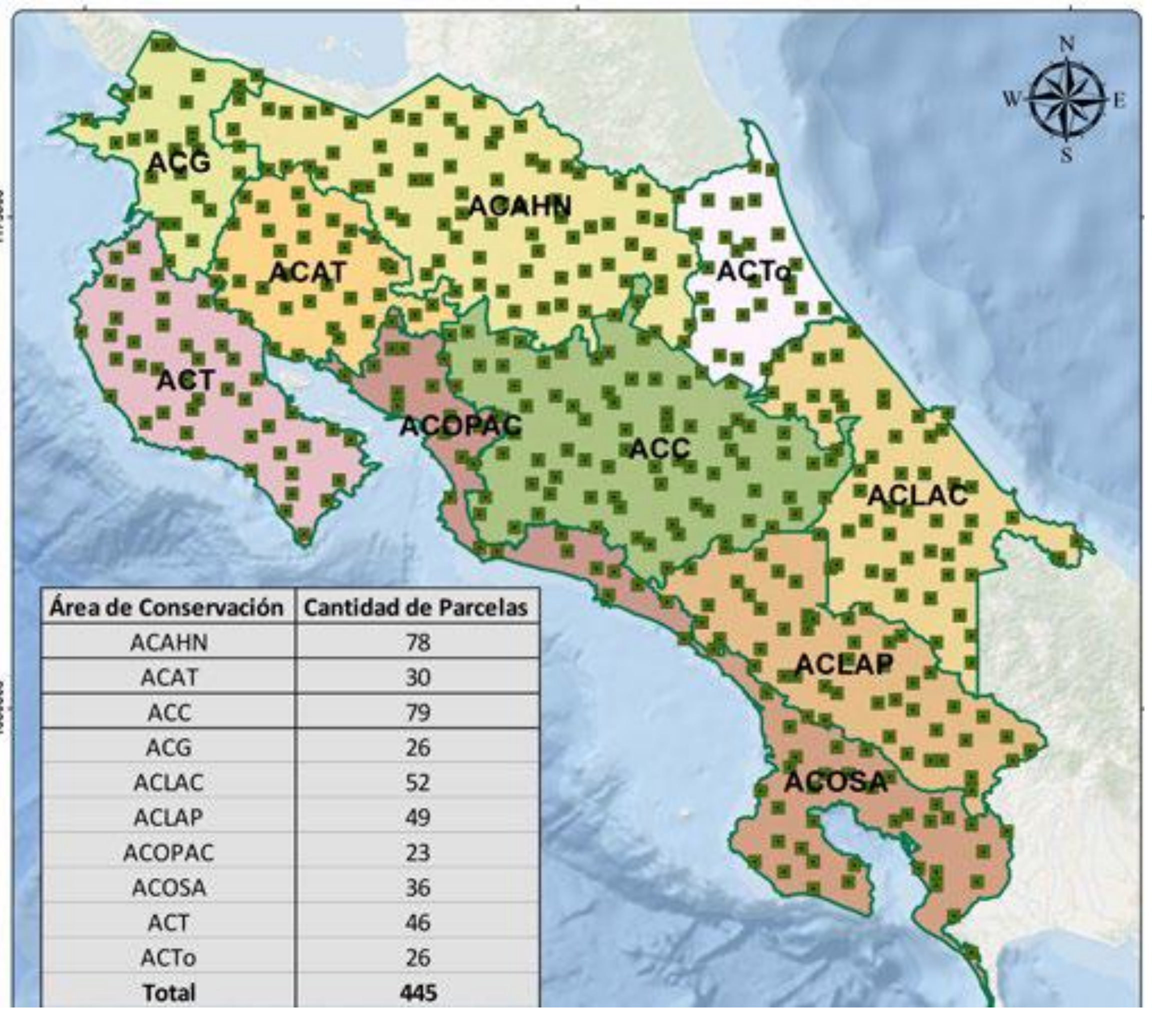
Open-source solutions

Platforms to access and analyse spatial data, such as Open Foris

Imagery used in UNFCCC reference level submissions

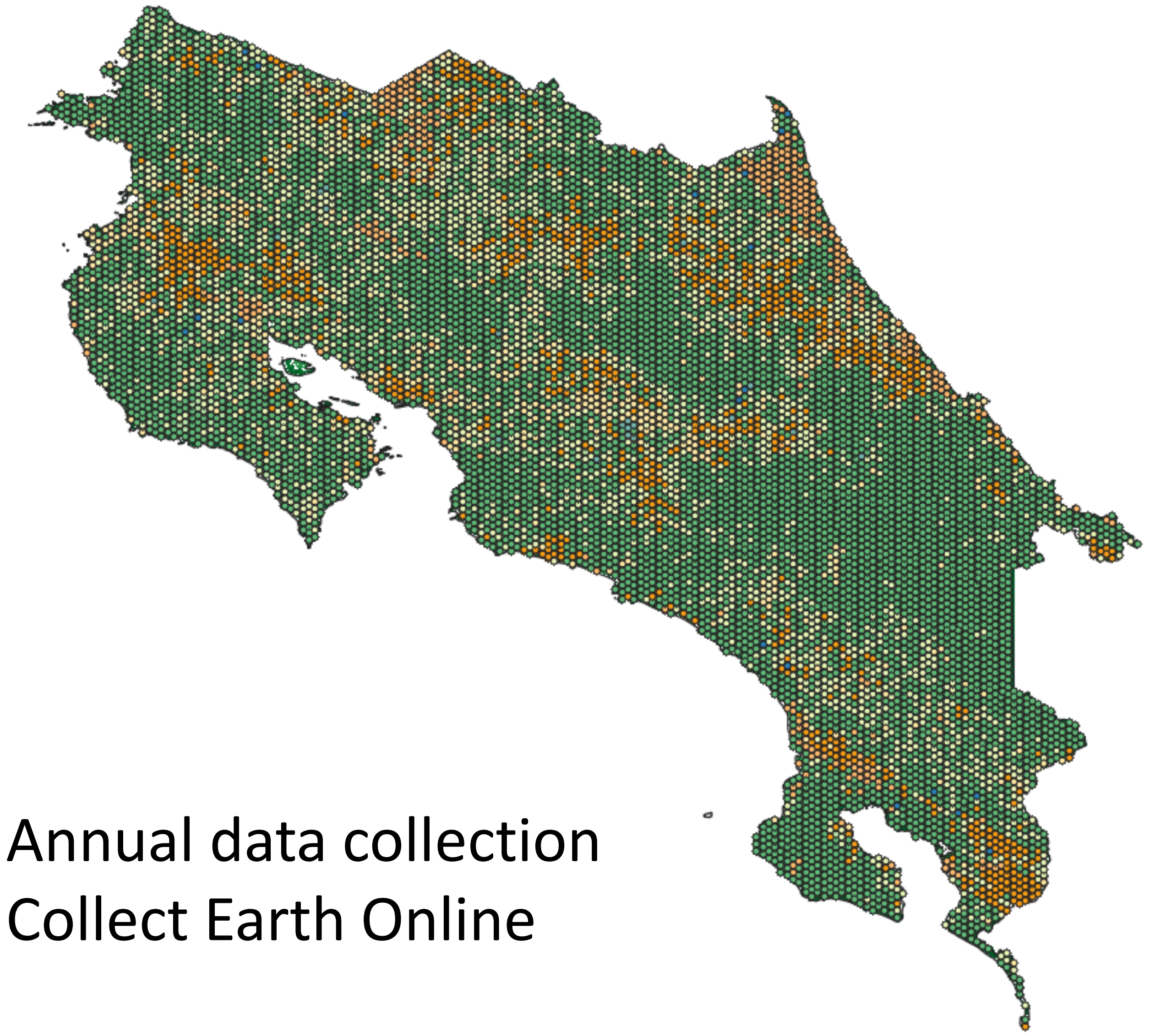


Source: FAO 2025 https://www.fao.org/forest-monitoring/dashboard/en

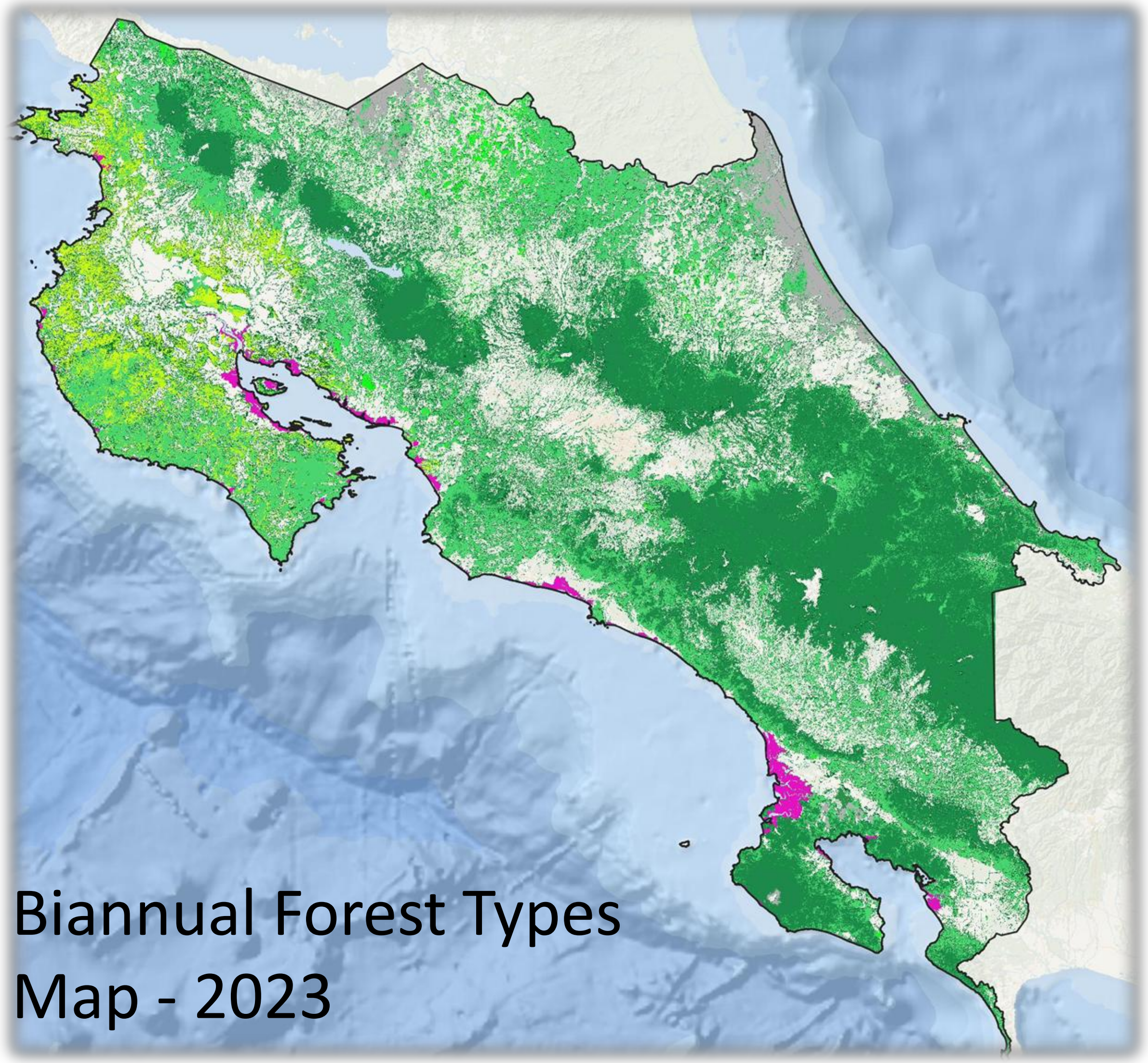


Área de Conservación	Cantidad de Parcelas
ACAHN	78
ACAT	30
ACC	79
ACG	26
ACLAC	52
ACLAP	49
ACOPAC	23
ACOSA	36
ACT	46
ACTo	26
Total	**445**

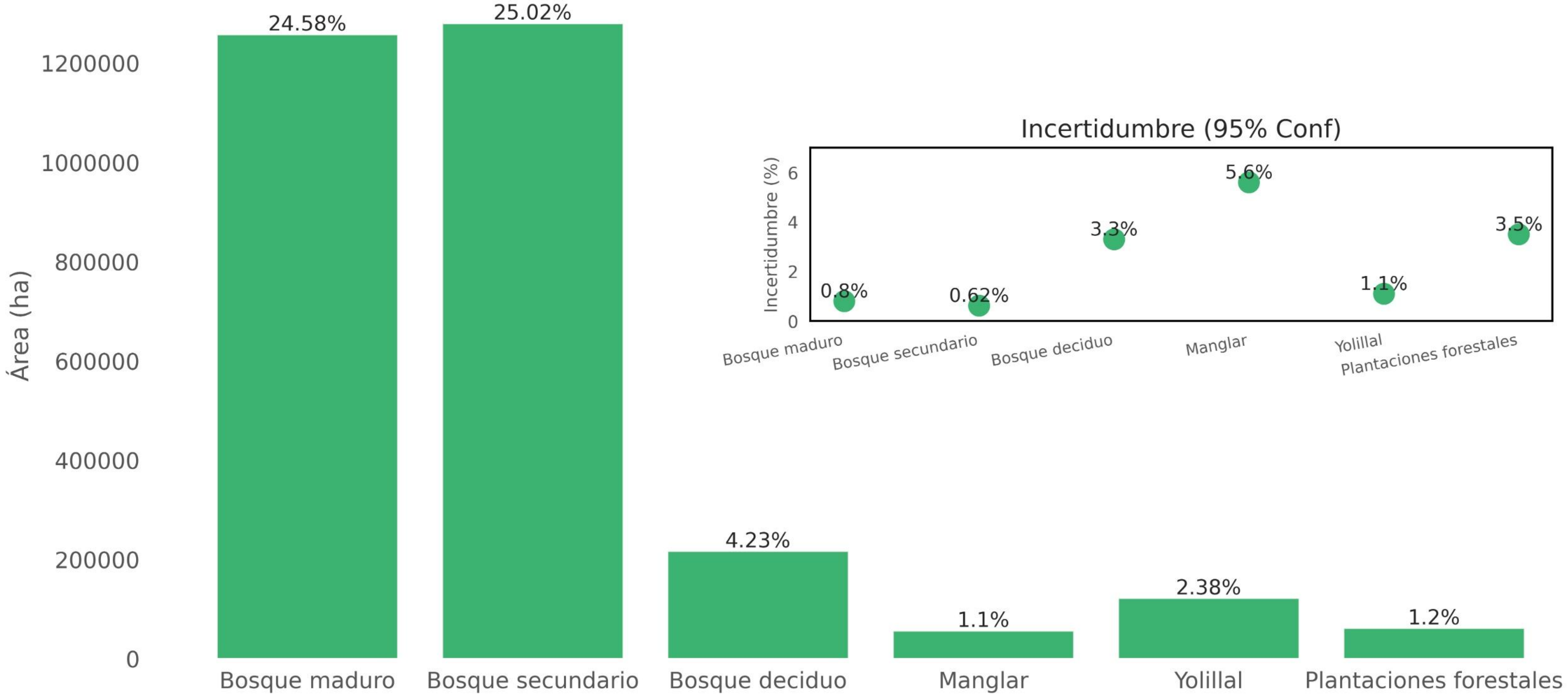
NFI sample plots



Annual data collection
Collect Earth Online



Biannual Forest Types
Map - 2023



Example Good practice

SINAC, 2023. Mapa de tipos de bosque

Thank you

For more information:

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Integrating Scientific Advances on Post-Disturbance Carbon Emissions and Removals into Brazil's National MRV Systems

Celso Silva Junior

Session 3.1: Accounting for carbon fluxes in secondary forests for MRV process

São José dos Campos, 31 Oct 2025

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Integrating Scientific Advances on Post-Disturbance Carbon Emissions and Removals into Brazil's MRV Systems

Integrando os Avanços Científicos sobre Emissões e Remoções de Carbono Pós-perturbações nos Sistemas de MRV do Brasil

Celso H. L. Silva-Junior

Researcher at IPAM Amazônia

UK PACT
GREEN RECOVERY CHALLENGE FUND

What is MRV? (O que é o MRV?)

What is MRV? (O que é o MRV?)

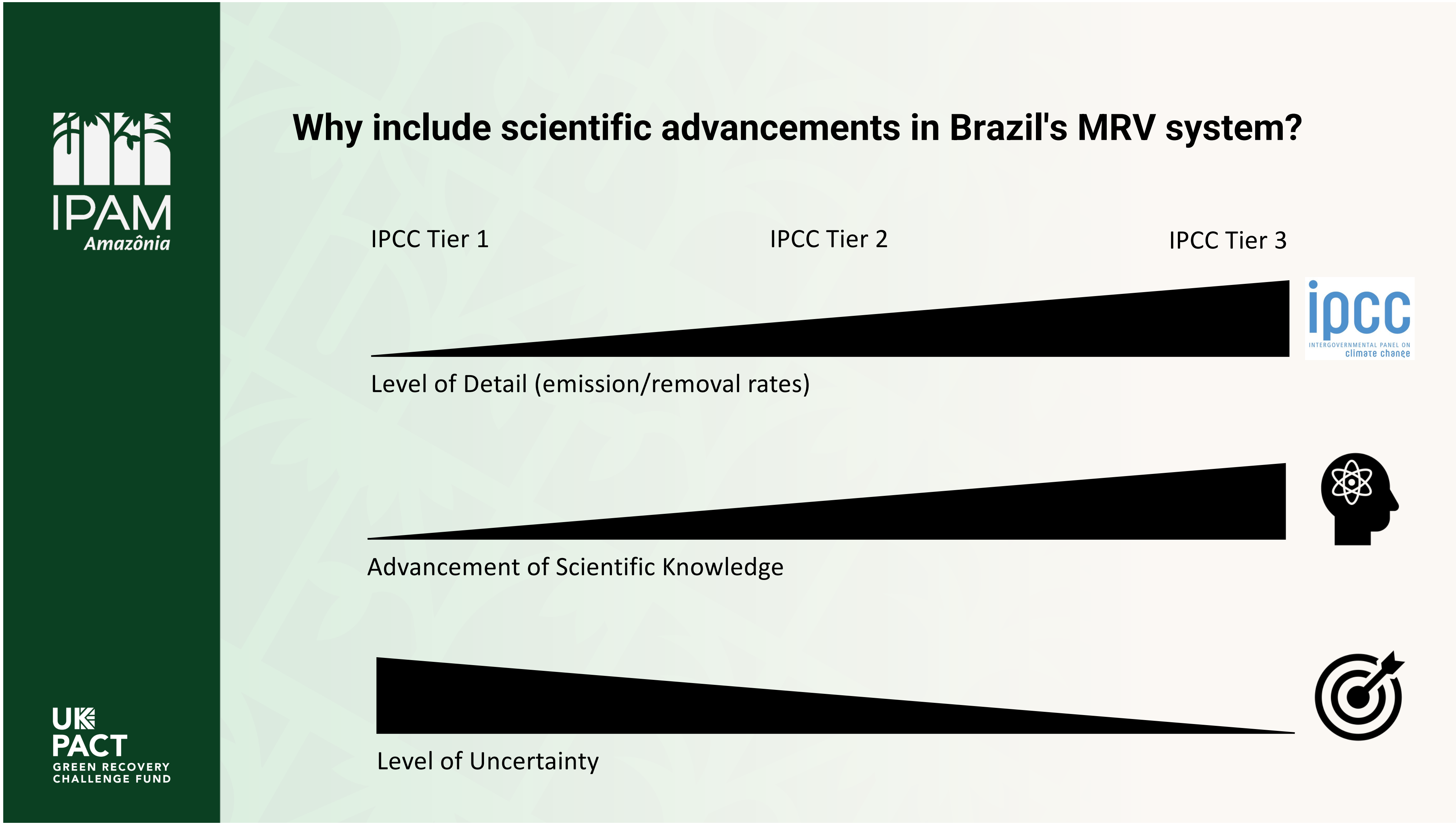
MRV (**M**onitoring, **R**eporting and **V**erification) is the set of technical processes aimed at ensuring the transparency, consistency, and credibility of information on greenhouse gas (GHG) emissions and removals.

O **MRV** (**M**onitoramento, **R**elato e **V**erificação) é o conjunto de processos técnicos voltados para garantir a transparência, a consistência e a credibilidade das informações sobre as emissões e remoções de gases de efeito estufa (GEE).

What is MRV? (O que é o MRV?)

In the Brazilian context, the MRV system is structured across different scales and instruments — including the National GHG Inventory, the Forest Reference Emission Level (FREL/UNFCCC), and jurisdictional REDD+ programs.

No contexto brasileiro, o sistema de **MRV** é estruturado em diferentes escalas e instrumentos — incluindo o Inventário Nacional de GEE, o Nível de Referência de Emissões Florestais (**FREL/UNFCCC**) e os programas **jurisdicionais** de **REDD+**.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Why include scientific advancements in Brazil's MRV system?
IPCC Tier 1
IPCC Tier 2
IPCC Tier 3
ipcc
INTERGOVERNMENTAL PANEL ON
climate change
Level of Detail (emission/removal rates)
Advancement of Scientific Knowledge
Level of Uncertainty
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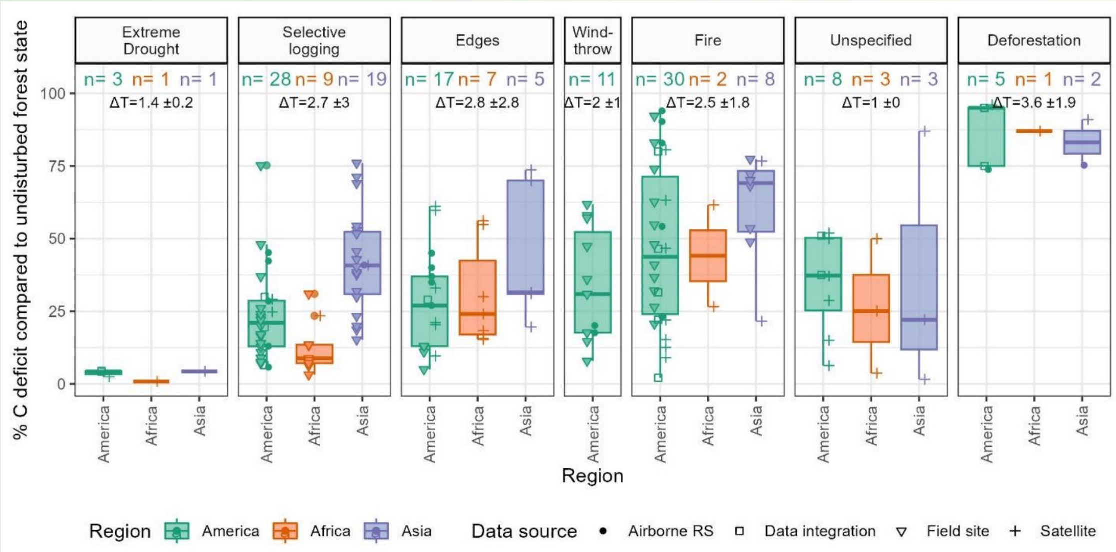
GREEN RECOVERY
CHALLENGE FUND

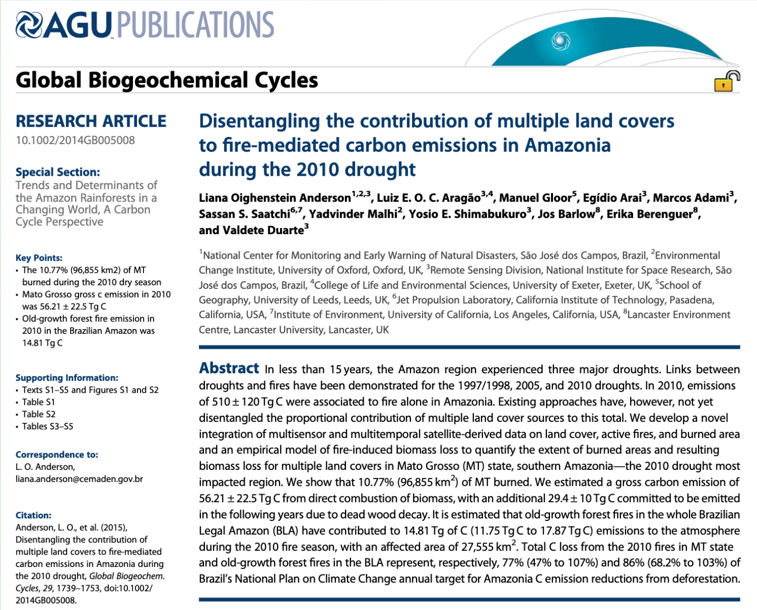
Why include scientific advancements in Brazil's MRV system?

In Heinrich et al. (2025), **115 studies** were identified that quantified above-ground carbon losses and gains in tropical forests after disturbances.



Heinrich et al. 2025. A multi-data synthesis of carbon losses and gains from tropical moist forest degradation and regeneration. In Review.

Advances in accounting for emissions from forest fires



AGU PUBLICATIONS

Global Biogeochemical Cycles

RESEARCH ARTICLE

10.1002/2014GB005008

Special Section:
Trends and Determinants of the Amazon Rainforests in a Changing World, A Carbon Cycle Perspective

Key Points:
- The 10.77% (96,855 km2) of MT burned during the 2010 dry season
- Mato Grosso gross c emission in 2010 was 56.21 ± 22.5 Tg C
- Old-growth forest fire emission in 2010 in the Brazilian Amazon was 14.81 Tg C

Supporting Information:
- Texts S1–S5 and Figures S1 and S2
- Table S1
- Table S2
- Tables S3–S5

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Citation:
Anderson, L. O., et al. (2015), Disentangling the contribution of multiple land covers to fire-mediated carbon emissions in Amazonia during the 2010 drought, *Global Biogeochem. Cycles*, *29*, 1739–1753, doi:10.1002/2014GB005008.

Disentangling the contribution of multiple land covers to fire-mediated carbon emissions in Amazonia during the 2010 drought

Liana Oighenstein Anderson[1,2,3], Luiz E. O. C. Aragão[3,4], Manuel Gloor[5], Egídio Arai[3], Marcos Adami[3], Sassan S. Saatchi[6,7], Yadvinder Malhi[2], Yosio E. Shimabukuro[3], Jos Barlow[8], Erika Berenguer[8], and Valdete Duarte[3]

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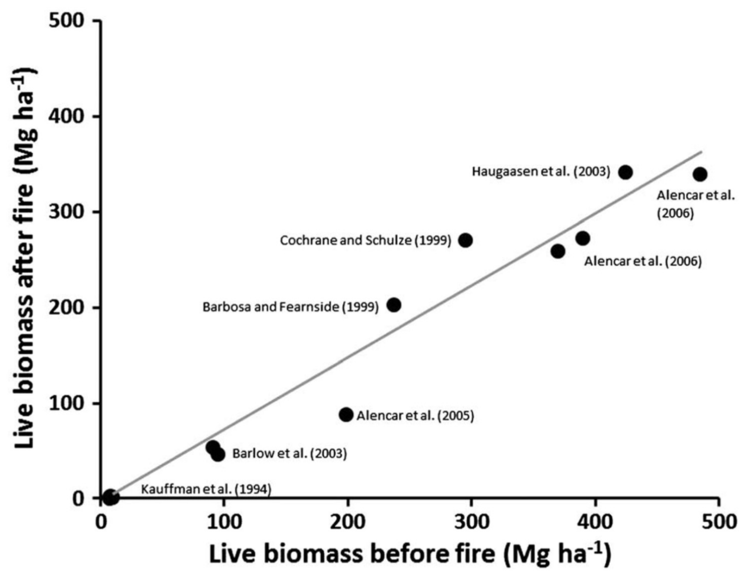
Abstract In less than 15 years, the Amazon region experienced three major droughts. Links between droughts and fires have been demonstrated for the 1997/1998, 2005, and 2010 droughts. In 2010, emissions of 510 ± 120 Tg C were associated to fire alone in Amazonia. Existing approaches have, however, not yet disentangled the proportional contribution of multiple land cover sources to this total. We develop a novel integration of multisensor and multitemporal satellite-derived data on land cover, active fires, and burned area and an empirical model of fire-induced biomass loss to quantify the extent of burned areas and resulting biomass loss for multiple land covers in Mato Grosso (MT) state, southern Amazonia—the 2010 drought most impacted region. We show that 10.77% (96,855 km^2) of MT burned. We estimated a gross carbon emission of 56.21 ± 22.5 Tg C from direct combustion of biomass, with an additional 29.4 ± 10 Tg C committed to be emitted in the following years due to dead wood decay. It is estimated that old-growth forest fires in the whole Brazilian Legal Amazon (BLA) have contributed to 14.81 Tg of C (11.75 Tg C to 17.87 Tg C) emissions to the atmosphere during the 2010 fire season, with an affected area of 27,555 km^2. Total C loss from the 2010 fires in MT state and old-growth forest fires in the BLA represent, respectively, 77% (47% to 107%) and 86% (68.2% to 103%) of Brazil's National Plan on Climate Change annual target for Amazonia C emission reductions from deforestation.



Advances in accounting for emissions from forest fires

remote sensing

MDPI

Article

Intercomparison of Burned Area Products and Its Implication for Carbon Emission Estimations in the Amazon

Ana Carolina M. Pessôa [1,*], Liana O. Anderson [2], Nathália S. Carvalho [1], Wesley A. Campanharo [1], Celso H. L. Silva Junior [1], Thais M. Rosan [3], João B. C. Reis [2], Francisca R. S. Pereira [1], Mauro Assis [4], Aline D. Jacon [5], Jean P. Ometto [5], Yosio E. Shimabukuro [1], Camila V. J. Silva [6], Aline Pontes-Lopes [1], Thiago F. Morello [7] and Luiz E. O. C. Aragão [1,3]

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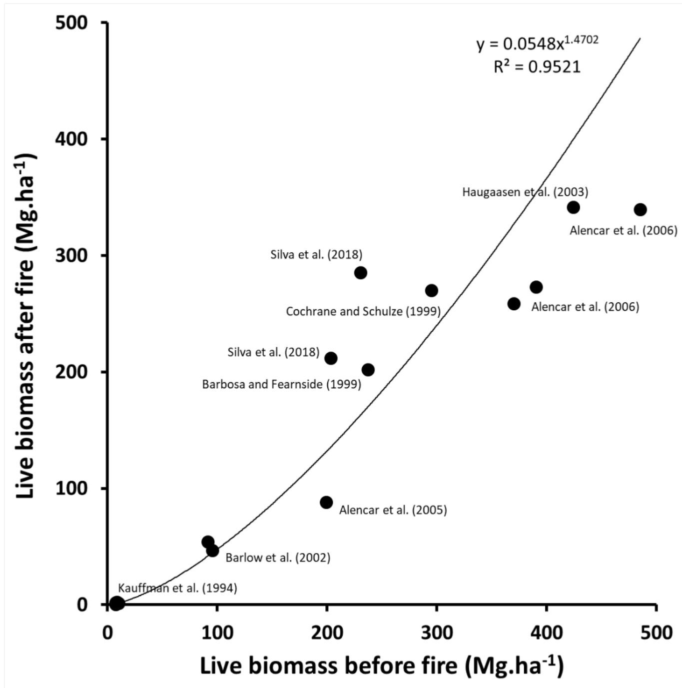
Received: 23 October 2020; Accepted: 20 November 2020; Published: 25 November 2020

check for updates

Abstract: Carbon (C) emissions from forest fires in the Amazon during extreme droughts may correspond to more than half of the global emissions resulting from land cover changes. Despite their



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Advances in accounting for emissions from forest fires


Research Square

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Article

Unveiling the Hidden Green House Gases Footprint of Amazonian Forest Fires

Aline Pontes-Lopes, Camila Silva, Jos Barlow, Ane Alencar, Wallace Da Silva, and 12 more

This is a preprint; it has not been peer reviewed by a journal.

https://doi.org/10.21203/rs.3.rs-6580384/v1

Status: Under Review

nature portfolio

Version 1
posted 08 May, 2025

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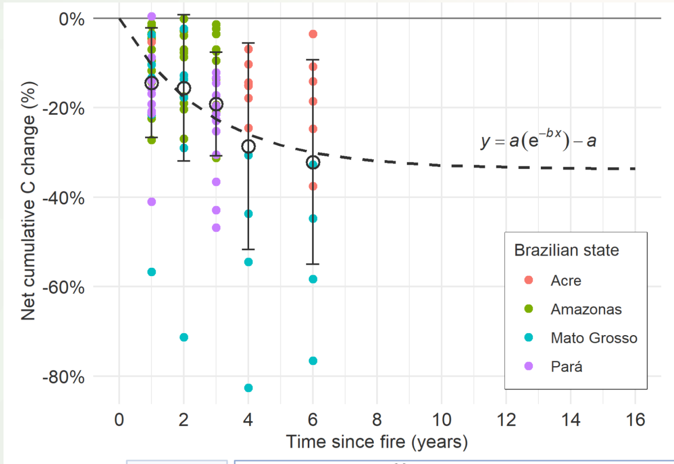
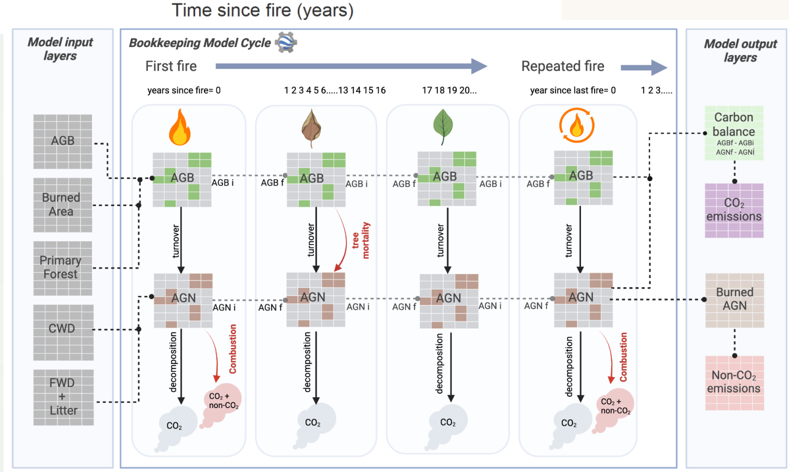
Abstract

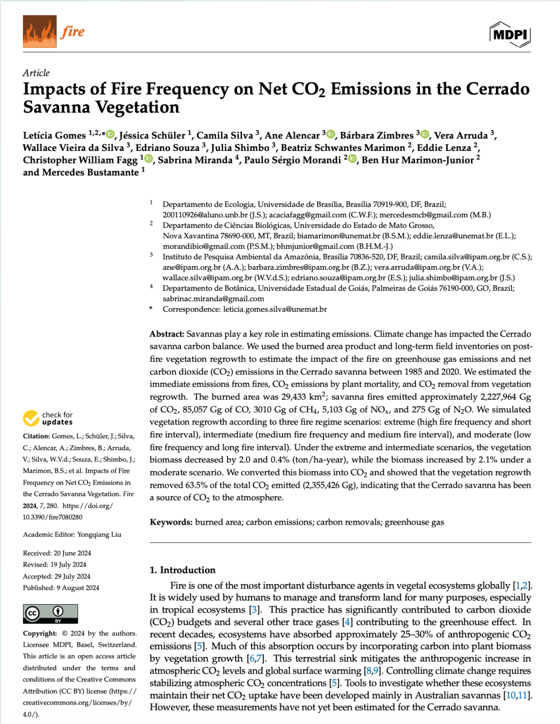
Frequent and extensive fires, which do not occur naturally in Amazonia, are a neglected net source of anthropogenic emissions in national and global carbon budgets. More fires are expected in Amazonian humid forests with the increase of severe droughts combined with land cover change. However, it is challenging to integrate them into estimates of emissions from Land Use, Land-use Change and Forestry (LULUCF). Amazonian forest fires are still not accurately represented in the global carbon budgets. A key reason for that is the absence of long-term carbon fluxes (post-fire decomposition emissions and uptake from regrowth) in the models. Here, we combine spatial datasets with a large-scale in-situ assessment of carbon stocks to quantify the unaccounted emissions from burned standing forests. We developed





UK PACT GREEN RECOVERY CHALLENGE FUND

Advances in accounting for <u>emissions from forest fires</u>



fire MDPI

Article

Impacts of Fire Frequency on Net CO_2 Emissions in the Cerrado Savanna Vegetation

Letícia Gomes [1,2,*], Jéssica Schüler [1], Camila Silva [3], Ane Alencar [3], Bárbara Zimbres [3], Vera Arruda [3], Wallace Vieira da Silva [3], Edriano Souza [3], Julia Shimbo [3], Beatriz Schwantes Marimon [2], Eddie Lenza [2], Christopher William Fagg [1], Sabrina Miranda [4], Paulo Sérgio Morandi [2], Ben Hur Marimon-Junior [2] and Mercedes Bustamante [1]

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Abstract: Savannas play a key role in estimating emissions. Climate change has impacted the Cerrado savanna carbon balance. We used the burned area product and long-term field inventories on post-fire vegetation regrowth to estimate the impact of the fire on greenhouse gas emissions and net carbon dioxide (CO_2) emissions in the Cerrado savanna between 1985 and 2020. We estimated the immediate emissions from fires, CO_2 emissions by plant mortality, and CO_2 removal from vegetation regrowth. The burned area was 29,433 km^2; savanna fires emitted approximately 2,227,964 Gg of CO_2, 85,057 Gg of CO, 3010 Gg of CH_4, 5,103 Gg of NO_x, and 275 Gg of N_2O. We simulated vegetation regrowth according to three fire regime scenarios: extreme (high fire frequency and short fire interval), intermediate (medium fire frequency and medium fire interval), and moderate (low fire frequency and long fire interval). Under the extreme and intermediate scenarios, the vegetation biomass decreased by 2.0 and 0.4% (ton/ha-year), while the biomass increased by 2.1% under a moderate scenario. We converted this biomass into CO_2 and showed that the vegetation regrowth removed 63.5% of the total CO_2 emitted (2,355,426 Gg), indicating that the Cerrado savanna has been a source of CO_2 to the atmosphere.

Keywords: burned area; carbon emissions; carbon removals; greenhouse gas

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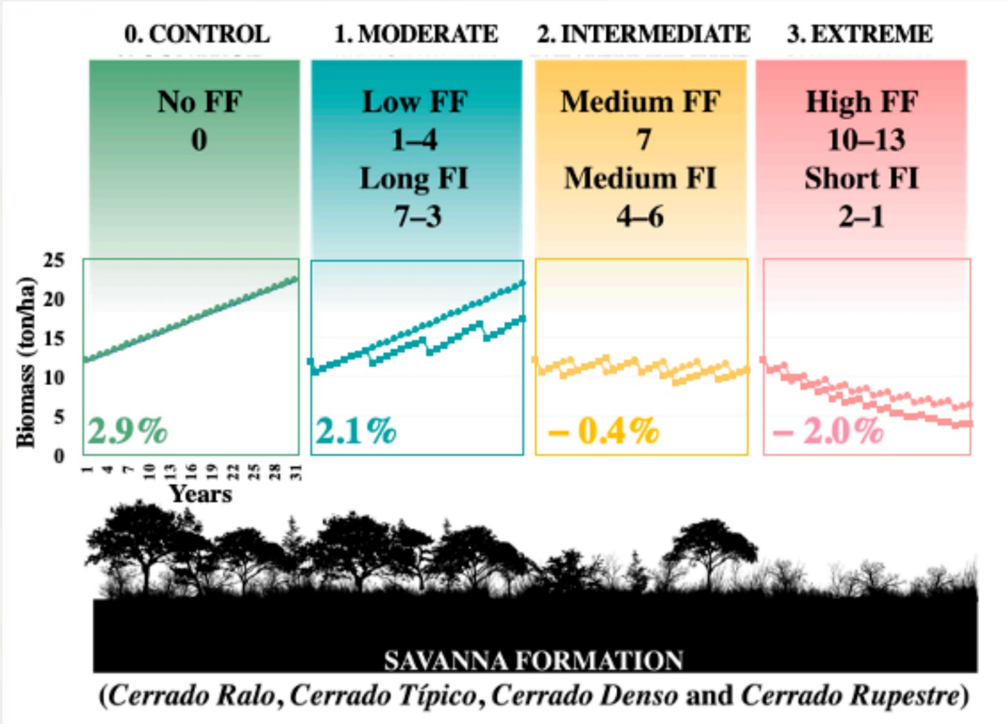
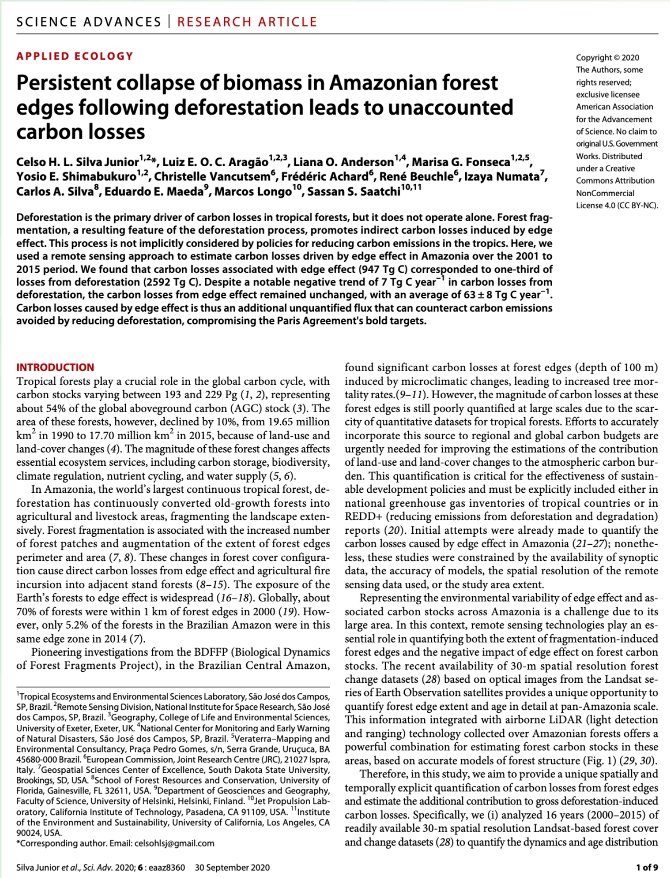
1. Introduction

Fire is one of the most important disturbance agents in vegetal ecosystems globally [1,2]. It is widely used by humans to manage and transform land for many purposes, especially in tropical ecosystems [3]. This practice has significantly contributed to carbon dioxide (CO_2) budgets and several other trace gases [4] contributing to the greenhouse effect. In recent decades, ecosystems have absorbed approximately 25–30% of anthropogenic CO_2 emissions [5]. Much of this absorption occurs by incorporating carbon into plant biomass by vegetation growth [6,7]. This terrestrial sink mitigates the anthropogenic increase in atmospheric CO_2 levels and global surface warming [8,9]. Controlling climate change requires stabilizing atmospheric CO_2 concentrations [5]. Tools to investigate whether these ecosystems maintain their net CO_2 uptake have been developed mainly in Australian savannas [10,11]. However, these measurements have not yet been estimated for the Cerrado savanna.



Advances in accounting for emissions from edge effects



SCIENCE ADVANCES | RESEARCH ARTICLE

APPLIED ECOLOGY

Persistent collapse of biomass in Amazonian forest edges following deforestation leads to unaccounted carbon losses

Celso H. L. Silva Junior[1,2]*, Luiz E. O. C. Aragão[1,2,3], Liana O. Anderson[1,4], Marisa G. Fonseca[1,2,5], Yosio E. Shimabukuro[1,2], Christelle Vancutsem[6], Frédéric Achard[6], René Beuchle[6], Izaya Numata[7], Carlos A. Silva[8], Eduardo E. Maeda[9], Marcos Longo[10], Sassan S. Saatchi[10,11]

Deforestation is the primary driver of carbon losses in tropical forests, but it does not operate alone. Forest fragmentation, a resulting feature of the deforestation process, promotes indirect carbon losses induced by edge effect. This process is not implicitly considered by policies for reducing carbon emissions in the tropics. Here, we used a remote sensing approach to estimate carbon losses driven by edge effect in Amazonia over the 2001 to 2015 period. We found that carbon losses associated with edge effect (947 Tg C) corresponded to one-third of losses from deforestation (2592 Tg C). Despite a notable negative trend of 7 Tg C year^{-1} in carbon losses from deforestation, the carbon losses from edge effect remained unchanged, with an average of 63 ± 8 Tg C year^{-1}. Carbon losses caused by edge effect is thus an additional unquantified flux that can counteract carbon emissions avoided by reducing deforestation, compromising the Paris Agreement's bold targets.

INTRODUCTION

Tropical forests play a crucial role in the global carbon cycle, with carbon stocks varying between 193 and 229 Pg (*1*, *2*), representing about 54% of the global aboveground carbon (AGC) stock (*3*). The area of these forests, however, declined by 10%, from 19.65 million km^2 in 1990 to 17.70 million km^2 in 2015, because of land-use and land-cover changes (*4*). The magnitude of these forest changes affects essential ecosystem services, including carbon storage, biodiversity, climate regulation, nutrient cycling, and water supply (*5*, *6*).

In Amazonia, the world's largest continuous tropical forest, deforestation has continuously converted old-growth forests into agricultural and livestock areas, fragmenting the landscape extensively. Forest fragmentation is associated with the increased number of forest patches and augmentation of the extent of forest edges perimeter and area (*7*, *8*). These changes in forest cover configuration cause direct carbon losses from edge effect and agricultural fire incursion into adjacent stand forests (*8–15*). The exposure of the Earth's forests to edge effect is widespread (*16–18*). Globally, about 70% of forests were within 1 km of forest edges in 2000 (*19*). However, only 5.2% of the forests in the Brazilian Amazon were in this same edge zone in 2014 (*7*).

Pioneering investigations from the BDFFP (Biological Dynamics of Forest Fragments Project), in the Brazilian Central Amazon, found significant carbon losses at forest edges (depth of 100 m) induced by microclimatic changes, leading to increased tree mortality rates.(*9–11*). However, the magnitude of carbon losses at these forest edges is still poorly quantified at large scales due to the scarcity of quantitative datasets for tropical forests. Efforts to accurately incorporate this source to regional and global carbon budgets are urgently needed for improving the estimations of the contribution of land-use and land-cover changes to the atmospheric carbon burden. This quantification is critical for the effectiveness of sustainable development policies and must be explicitly included either in national greenhouse gas inventories of tropical countries or in REDD+ (reducing emissions from deforestation and degradation) reports (*20*). Initial attempts were already made to quantify the carbon losses caused by edge effect in Amazonia (*21–27*); nonetheless, these studies were constrained by the availability of synoptic data, the accuracy of models, the spatial resolution of the remote sensing data used, or the study area extent.

Representing the environmental variability of edge effect and associated carbon stocks across Amazonia is a challenge due to its large area. In this context, remote sensing technologies play an essential role in quantifying both the extent of fragmentation-induced forest edges and the negative impact of edge effect on forest carbon stocks. The recent availability of 30-m spatial resolution forest change datasets (*28*) based on optical images from the Landsat series of Earth Observation satellites provides a unique opportunity to quantify forest edge extent and age in detail at pan-Amazonia scale. This information integrated with airborne LiDAR (light detection and ranging) technology collected over Amazonian forests offers a powerful combination for estimating forest carbon stocks in these areas, based on accurate models of forest structure (Fig. 1) (*29*, *30*).

Therefore, in this study, we aim to provide a unique spatially and temporally explicit quantification of carbon losses from forest edges and estimate the additional contribution to gross deforestation-induced carbon losses. Specifically, we (i) analyzed 16 years (2000–2015) of readily available 30-m spatial resolution Landsat-based forest cover and change datasets (*28*) to quantify the dynamics and age distribution

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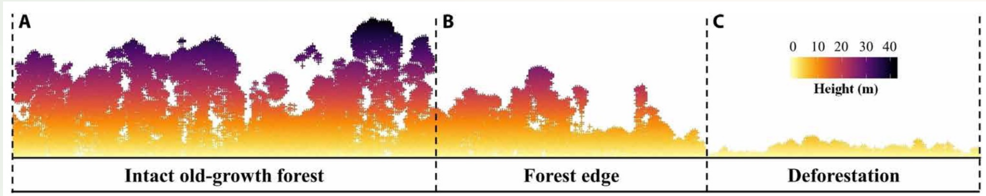

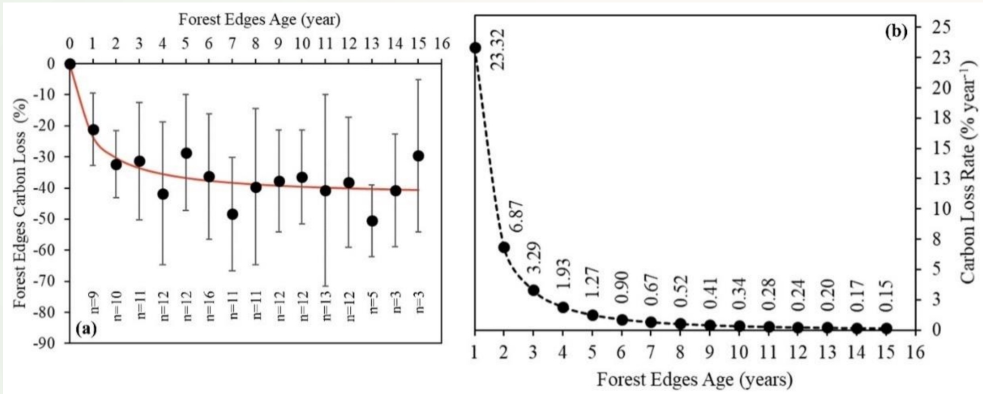

Advances in accounting for removals from secondary forests

nature COMMUNICATIONS

ARTICLE

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Large carbon sink potential of secondary forests in the Brazilian Amazon to mitigate climate change

Viola H. A. Heinrich[1✉], Ricardo Dalagnol[2], Henrique L. G. Cassol[2], Thais M. Rosan[3], Catherine Torres de Almeida[2], Celso H. L. Silva Junior[2], Wesley A. Campanharo[2], Joanna I. House[1,4], Stephen Sitch[3], Tristram C. Hales[5], Marcos Adami[6], Liana O. Anderson[7] & Luiz E. O. C. Aragão[2,3]

Tropical secondary forests sequester carbon up to 20 times faster than old-growth forests. This rate does not capture spatial regrowth patterns due to environmental and disturbance drivers. Here we quantify the influence of such drivers on the rate and spatial patterns of regrowth in the Brazilian Amazon using satellite data. Carbon sequestration rates of young secondary forests (<20 years) in the west are ~60% higher (3.0 ± 1.0 Mg C ha^{-1} yr^{-1}) compared to those in the east (1.3 ± 0.3 Mg C ha^{-1} yr^{-1}). Disturbances reduce regrowth rates by 8–55%. The 2017 secondary forest carbon stock, of 294 Tg C, could be 8% higher by avoiding fires and repeated deforestation. Maintaining the 2017 secondary forest area has the potential to accumulate ~19.0 Tg C yr^{-1} until 2030, contributing ~5.5% to Brazil's 2030 net emissions reduction target. Implementing legal mechanisms to protect and expand secondary forests whilst supporting old-growth conservation is, therefore, key to realising their potential as a nature-based climate solution.

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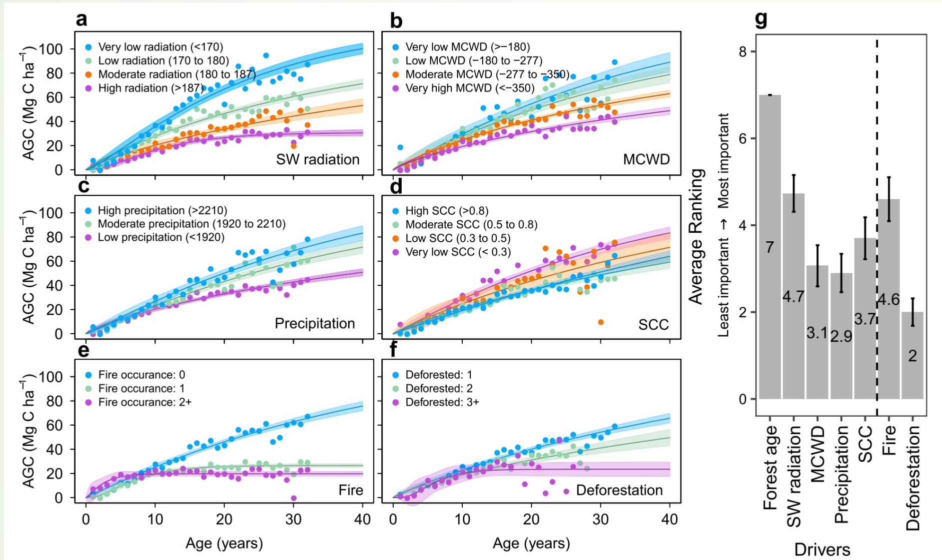

Advances in accounting for removals from secondary forests

Article

The carbon sink of secondary and degraded humid tropical forests

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The globally important carbon sink of intact, old-growth tropical humid forests is declining because of climate change, deforestation and degradation from fire and logging[1–3]. Recovering tropical secondary and degraded forests now cover about 10% of the tropical forest area[4], but how much carbon they accumulate remains uncertain. Here we quantify the aboveground carbon (AGC) sink of recovering forests across three main continuous tropical humid regions: the Amazon, Borneo and Central Africa[5,6]. On the basis of satellite data products[4,7], our analysis encompasses the heterogeneous spatial and temporal patterns of growth in degraded and secondary forests, influenced by key environmental and anthropogenic drivers. In the first 20 years of recovery, regrowth rates in Borneo were up to 45% and 58% higher than in Central Africa and the Amazon, respectively. This is due to variables such as temperature, water deficit and disturbance regimes. We find that regrowing degraded and secondary forests accumulated 107 Tg C $year^{-1}$ (90–130 Tg C $year^{-1}$) between 1984 and 2018, counterbalancing 26% (21–34%) of carbon emissions from humid tropical forest loss during the same period. Protecting old-growth forests is therefore a priority. Furthermore, we estimate that conserving recovering degraded and secondary forests can have a feasible future carbon sink potential of 53 Tg C $year^{-1}$ (44–62 Tg C $year^{-1}$) across the main tropical regions studied.

The Forest and Land use Declaration negotiated at the 26th Climate Change Conference of the Parties (COP26)[8] confirmed that tropical moist forests (TMFs) are a vital nature-based solution to addressing the climate and ecological emergencies[9]. However, across the world's three largest continuous TMF regions—the Amazon, Borneo and Central Africa—disturbances owing to different anthropogenic drivers result in continuing forest cover losses[10] (Supplementary Table 1). Between 2001 and 2019, emissions from forest loss in the Amazon (370 ± 170 Tg C $year^{-1}$), Borneo (150 ± 70 Tg C $year^{-1}$) and Central Africa (110 ± 50 Tg C $year^{-1}$) collectively made up 29% of global gross forest emissions[11]. The result is a patchwork of forest types at different stages of recovery from disturbance, with limited understanding at present of their contribution to forest carbon dynamics.

Here we consider two forest types that we term 'recovering forests': (1) secondary forests, which grow on deforested, now abandoned, land and (2) degraded forests, which are forested lands that have suffered partial loss of their tree canopy, structure and function owing to selective logging, fire or climate extremes[4]. Forests recovering from (human-induced) disturbances are important for results-based payments frameworks such as Reducing Emissions from Deforestation and Forest Degradation (REDD+). The Global Stocktake[12], which evaluates the collective progress to reaching the Paris Agreement goals, requires credible monitoring, reporting and verification of all carbon sources and sinks. This should include accurately quantifying the carbon accumulation rates in all recovering forests, which are expanding across the tropics[4].

Such quantitative information is only available at present for secondary forests, based on field-plot data scaled up to large ecozones[6,13,14] or spatially explicit satellite-based data available only for specific regions[15]. Small-scale studies of carbon recovery in degraded forests have been conducted in some regions with sufficient in situ data[16,17]. However, field data alone cannot capture the complex forest dynamics across these vast areas. Critically, there has been no large-scale, pan-tropical assessment of the AGC sink in both secondary and degraded forests, resulting in uncertainties in their role in carbon removal. The increasing availability of satellite-derived products offers a viable solution, providing pan-tropical, continuous spatial and temporal coverage, to monitor forest dynamics.

The primary aim of this study was to capture the regrowth variability of all recovering forests in the Amazon, Borneo and Central

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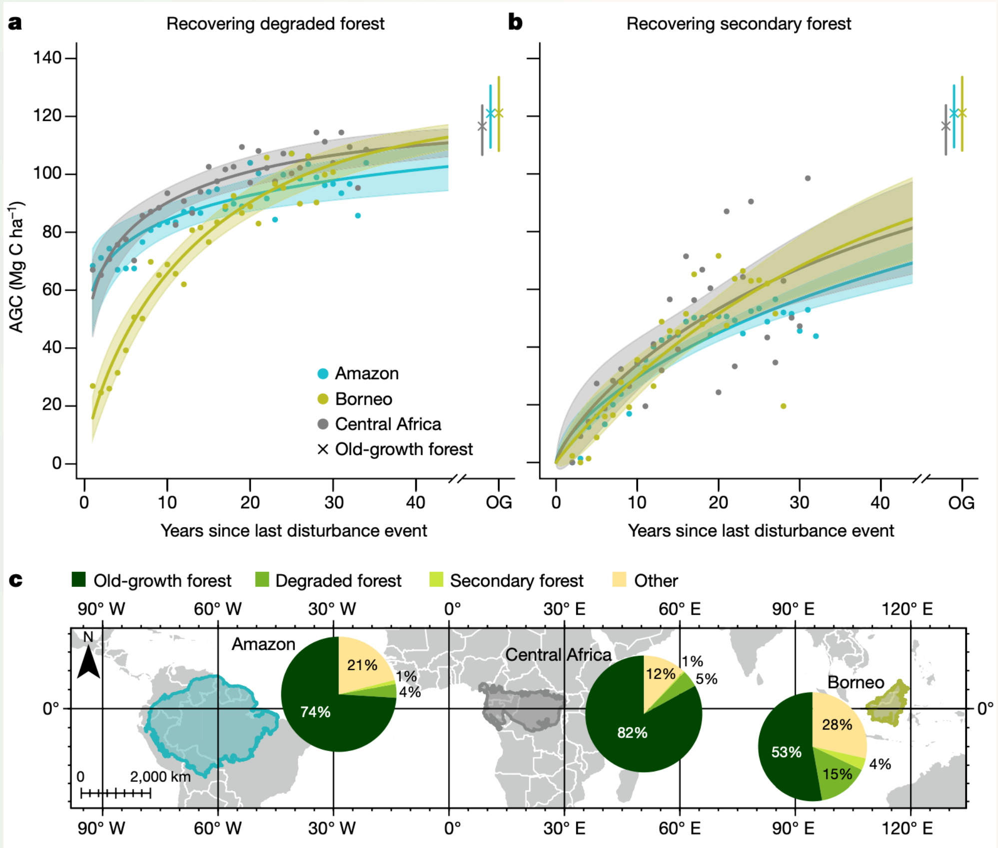

Advances in accounting for removals from secondary forests

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Revealing the spatial variation in biomass uptake rates of Brazil's secondary forests

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ARTICLE INFO

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ABSTRACT

Monitoring forest aboveground biomass (AGB) is essential for quantifying the carbon cycle and mitigating climate change. Tropical secondary forests are significant carbon sinks that sequester large amounts of carbon dioxide. While recent studies have attempted to estimate the AGB recovery rates in tropical forests, considerable uncertainty remains in the estimation of AGB recovery of secondary forests and the spatial variability of the effects that different environmental conditions and degrees of human use may have on AGB recovery. These knowledge gaps hinder further understanding of climate change mitigation potential of secondary forests. Remote sensing products provide spatially and temporally explicit information for understanding and monitoring secondary forest dynamics. To explore the local effects of different factors on AGB of secondary forests in Brazil, we used geographically weighted regression (GWR) models that account for spatial heterogeneity in geospatial data to estimate the AGB of secondary forests in Brazil. Secondary forest areas (29142 polygons) were extracted from Brazil's forest age maps between 1984 and 2019. The AGB of these areas was derived from the Climate Change Initiative Biomass maps. The effects of selected predictors such as forest age, climatic water deficit, the cation exchange capacity of soil and surrounding tree cover were analyzed. The two most influential factors, forest age and surrounding tree cover were utilized to estimate the AGB and the recovery rates per year. Our results show the high spatial variation of different predictors' effects on the AGB of secondary forests. Also, the GWR model (with an adjusted R^2 of 0.74) showed considerable improvements regarding "goodness of fit" of models compared with the Ordinary Least Squares (with an adjusted R^2 of 0.53). Our estimated average AGB recovery rate across all Brazil's biomes is 7.5 Mg ha^{-1} yr^{-1} (using forest age) for the first 20 years. We presented the map of the spatial variation of AGB recovery rates in Brazil. The estimated AGB recovery rates range using forest age is 28.9 Mg ha^{-1} yr^{-1}. Our estimated mean AGB recovery rates of different biomes are 17.7 % on average higher than IPCC default rates. Our results provide baseline information for reducing uncertainties related to carbon sink estimation of secondary forests in Brazil, hence assisting in developing sustainable forest management and ecosystem restoration strategies.

1. Introduction

Secondary forests are playing increasingly important roles in the global carbon cycle. Secondary forests are forests that regrow in regions that have experienced complete forest removal (Chokkalingam & De Jong, 2001). The secondary forests increased rapidly in their extent and covered more than 60 % of the global forest at the end of the 20th century (Orihuela-Belmonte et al., 2013; Mackey et al., 2015; Pain et al., 2021). A previous study estimated the aboveground biomass (AGB) recovery rate of young secondary forests in the Neotropics and found that the carbon uptake rate is eleven times of that in old-growth forests (Poorter et al., 2016). Research carried out in the secondary forests of the Amazon biome revealed that the mean gross carbon sequestration increased substantially from 1986 (10.38 ± 9.7 million Mg) to 2017

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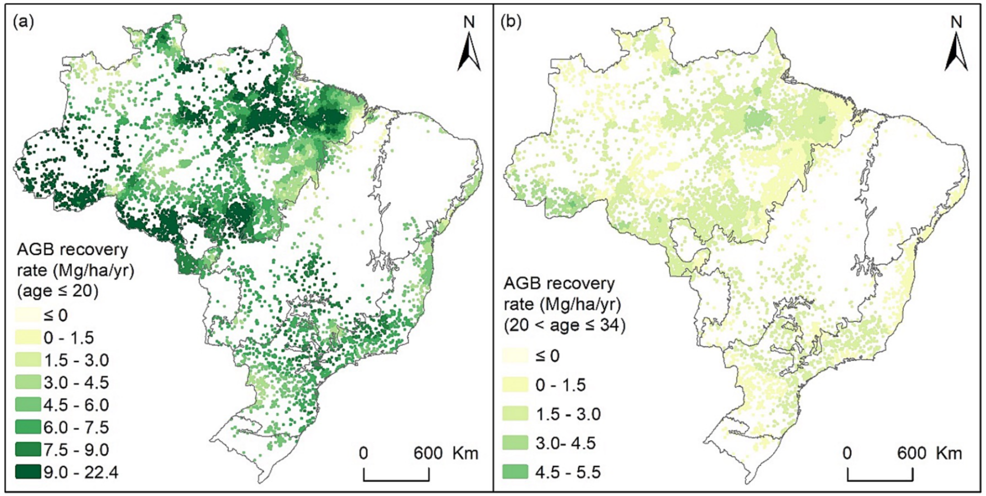

Fig. 5. AGB recovery rates of younger and older secondary forests based on GWR using only forest age.

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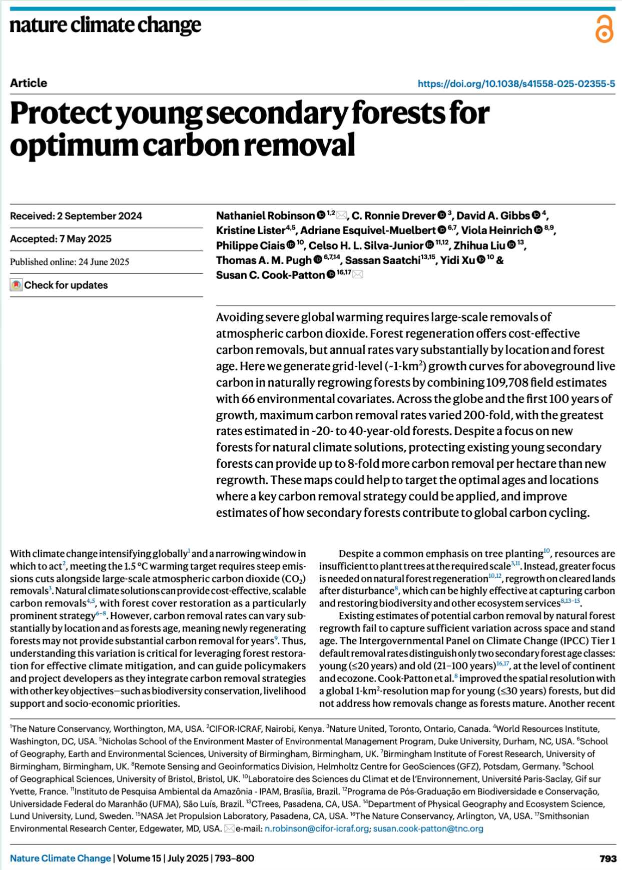

nature climate change

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Protect young secondary forests for optimum carbon removal

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Avoiding severe global warming requires large-scale removals of atmospheric carbon dioxide. Forest regeneration offers cost-effective carbon removals, but annual rates vary substantially by location and forest age. Here we generate grid-level (~1-km^2) growth curves for aboveground live carbon in naturally regrowing forests by combining 109,708 field estimates with 66 environmental covariates. Across the globe and the first 100 years of growth, maximum carbon removal rates varied 200-fold, with the greatest rates estimated in ~20- to 40-year-old forests. Despite a focus on new forests for natural climate solutions, protecting existing young secondary forests can provide up to 8-fold more carbon removal per hectare than new regrowth. These maps could help to target the optimal ages and locations where a key carbon removal strategy could be applied, and improve estimates of how secondary forests contribute to global carbon cycling.

With climate change intensifying globally[1] and a narrowing window in which to act[2], meeting the 1.5 °C warming target requires steep emissions cuts alongside large-scale atmospheric carbon dioxide (CO_2) removals[3]. Natural climate solutions can provide cost-effective, scalable carbon removals[4,5], with forest cover restoration as a particularly prominent strategy[6–8]. However, carbon removal rates can vary substantially by location and as forests age, meaning newly regenerating forests may not provide substantial carbon removal for years[9]. Thus, understanding this variation is critical for leveraging forest restoration for effective climate mitigation, and can guide policymakers and project developers as they integrate carbon removal strategies with other key objectives—such as biodiversity conservation, livelihood support and socio-economic priorities.

Despite a common emphasis on tree planting[10], resources are insufficient to plant trees at the required scale[3,11]. Instead, greater focus is needed on natural forest regeneration[10,12], regrowth on cleared lands after disturbance[8], which can be highly effective at capturing carbon and restoring biodiversity and other ecosystem services[8,13–15].

Existing estimates of potential carbon removal by natural forest regrowth fail to capture sufficient variation across space and stand age. The Intergovernmental Panel on Climate Change (IPCC) Tier 1 default removal rates distinguish only two secondary forest age classes: young (≤20 years) and old (21–100 years)[16,17], at the level of continent and ecozone. Cook-Patton et al.[8] improved the spatial resolution with a global 1-km^2-resolution map for young (≤30 years) forests, but did not address how removals change as forests mature. Another recent

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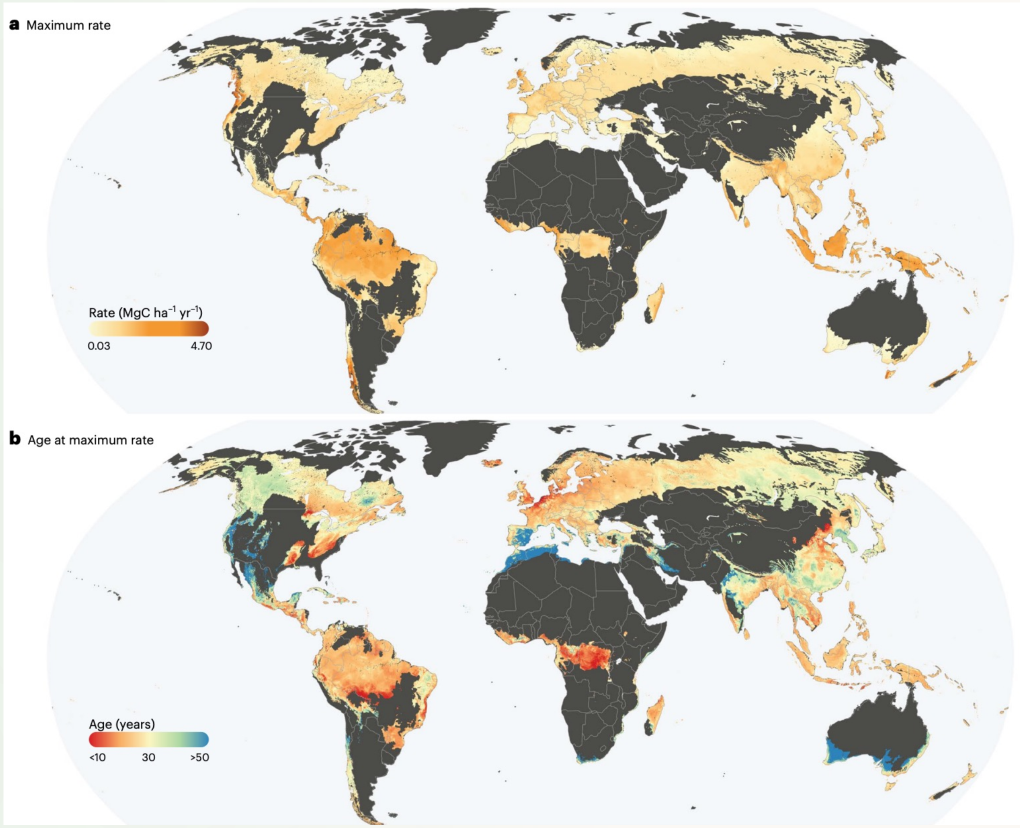

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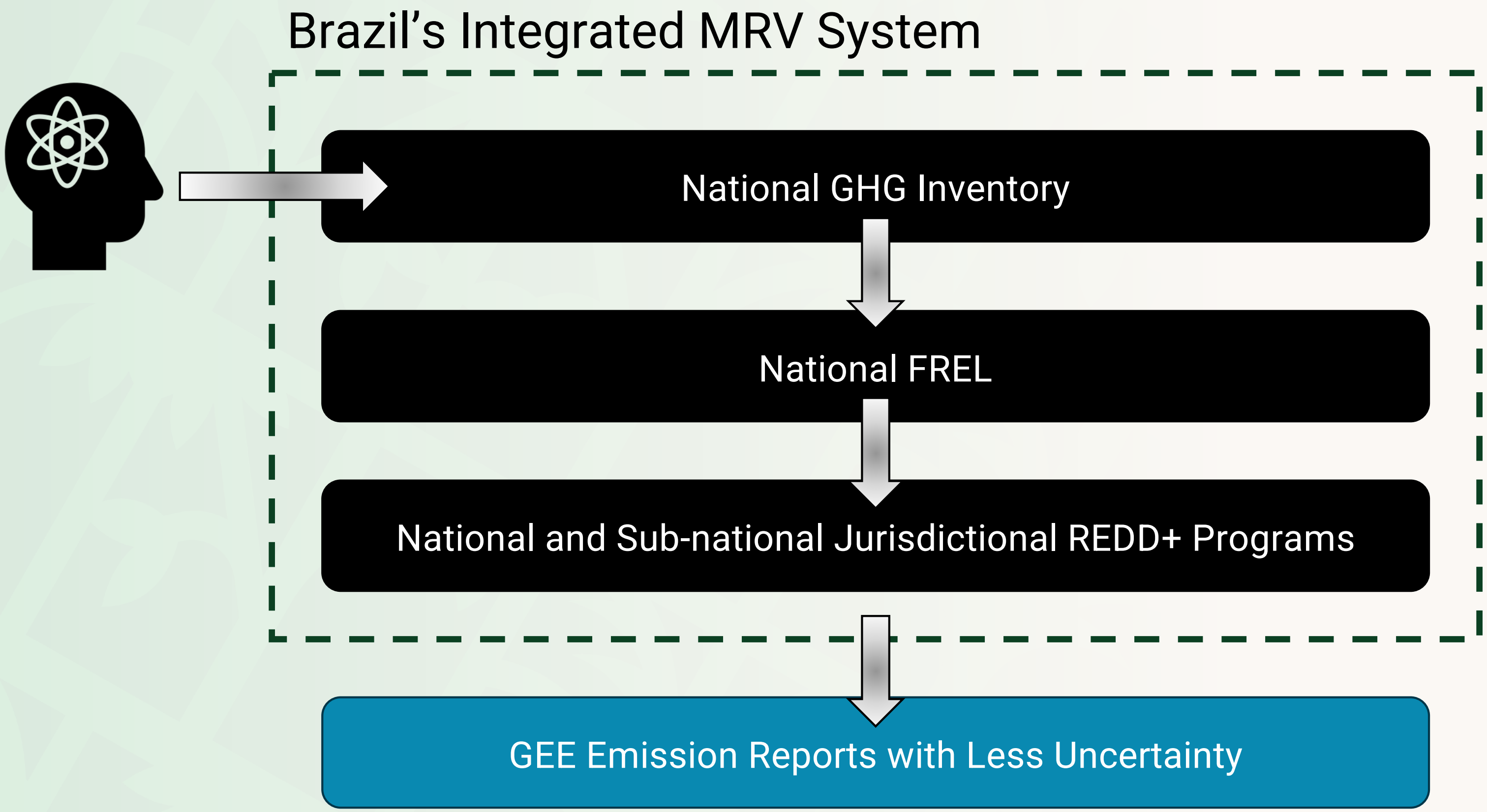
Towards an integrated MRV for Brazil



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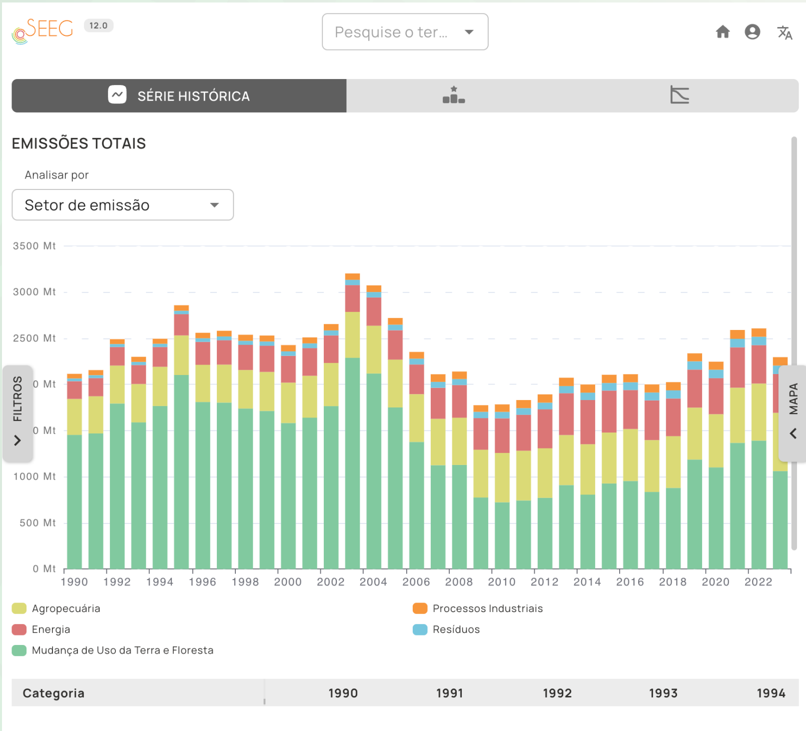
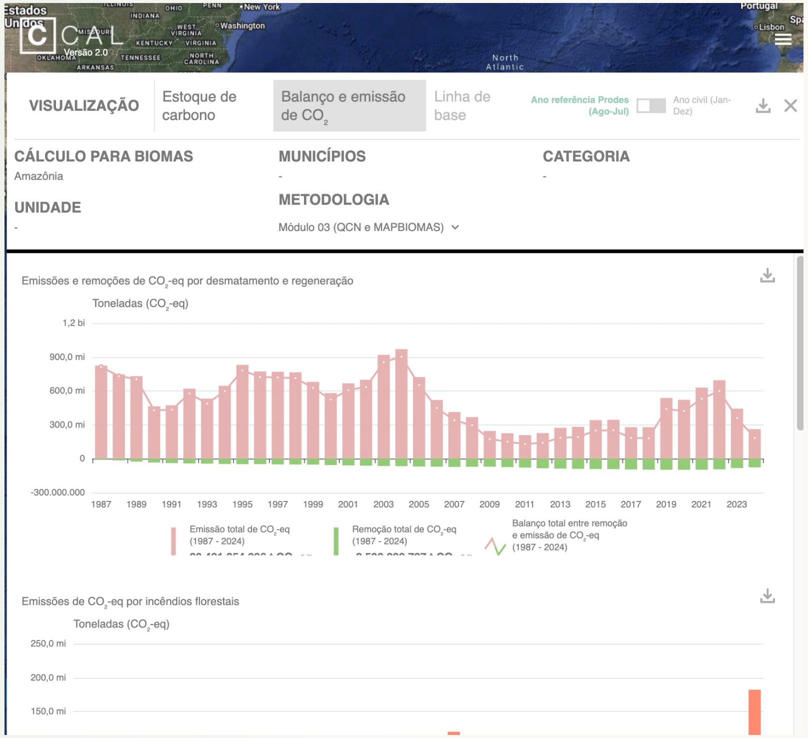
Is it possible to integrate scientific advances into MRV systems?





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Final Considerations

- An integrated MRV system for Brazil is urgently needed;
- Recent scientific advances on secondary forest removal and emissions from forest degradation need to be included in the national GHG inventory;
- Guarantee of annual monitoring of deforestation, forest degradation, and secondary forests at the national level.

UK PACT GREEN RECOVERY CHALLENGE FUND

Obrigado!

Celso H. L. Silva-Junior
E-mail: celso.junior@ipam.org.br

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UK PACT
GREEN RECOVERY CHALLENGE FUND

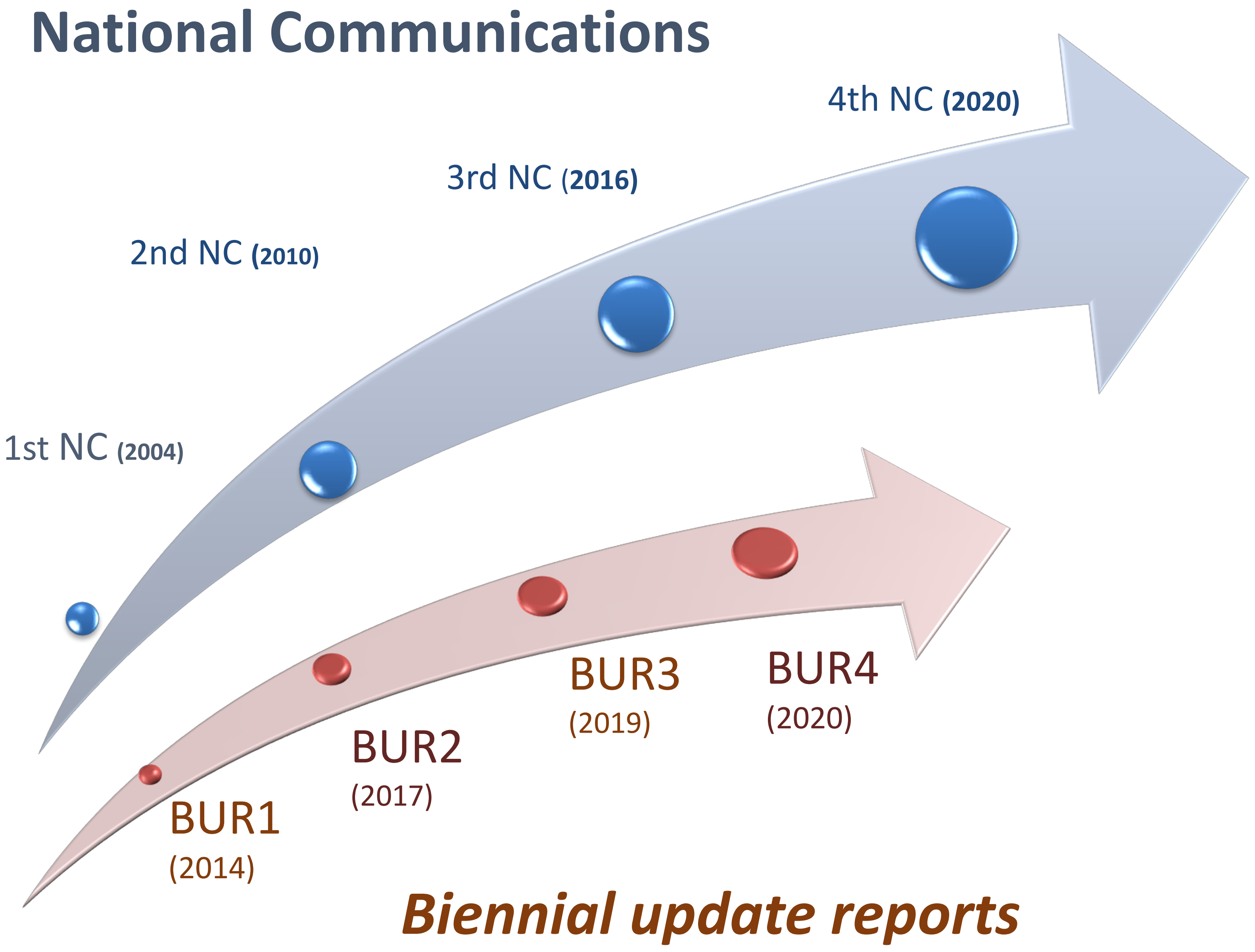
Secondary Forests in Brazil's National Greenhouse Gas Inventory (GHGI) – current status

Iris Roitman and Juliana Davis (MCTI-CGCL/UNDP)

Session 3.1: Talks: Accounting for carbon removals/fluxes in secondary forests for MRV process – advances, needs and challenges

São José dos Campos, 31 Oct, 2025.

Submissions to the UNFCCC



2024 (1990-2022)

BTR1

NIR

BUR5

CIÊNCIA&CLIMA

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO

GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

Project BRA/23/G31

2024 | 2025 | 2026 | 2027 | 2028 | 2029

BTR1
(nov 24)
Inventory (1990-2022)

BTR2 and 5NC
(nov 26)
Inventory (1990-2024)

BTR3
(nov 28)
Inventory (1990-2026)

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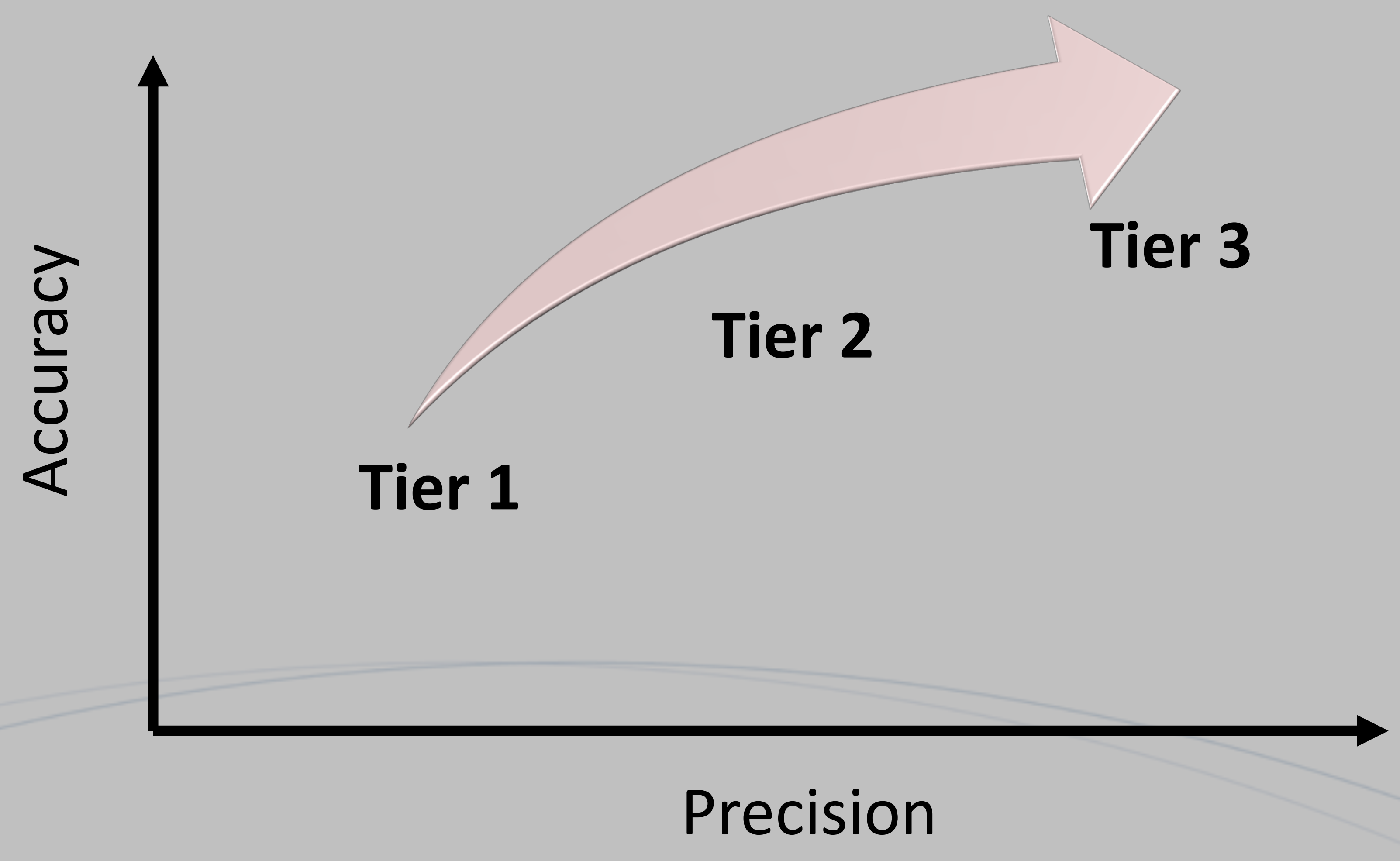
LULUCF Methodology (IPCC 2006)

- Principles: transparency, accuracy, completeness, consistency and comparability

Methodological levels



Tiers

- Methods and calculations;
- Sources of activity data;
- Emission factors and other parameters.

- All tiers are designed to produce unbiased estimates.

- This flexibility allows countries to use different methods and focus their efforts on the most significant categories.

The LULUCF sector modulates emissions in Brazil.

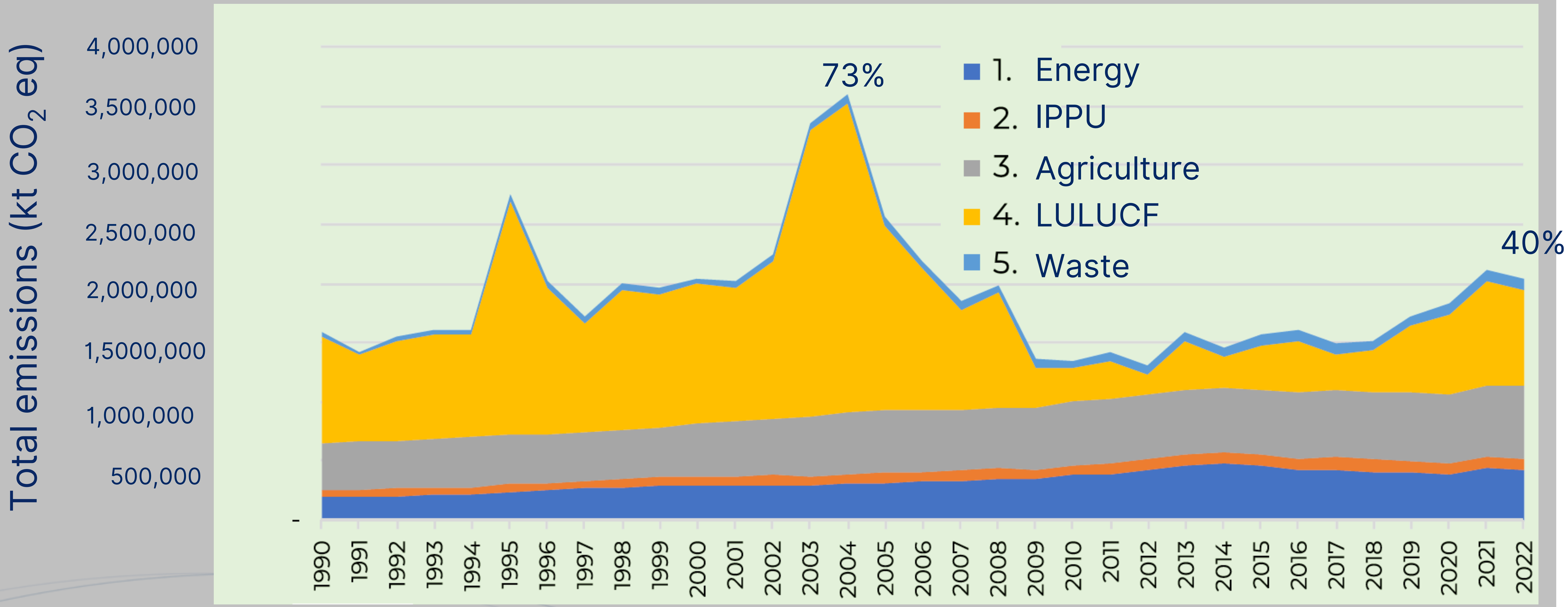


Figure 1. Total emissions in Brazil for the 1990-2022 period.

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What do we report?

Land use and land-use change

CO_2
- Emissions due to deforestation and degradation (selective logging in the Amazon);
- Removals in secondary vegetation (for conversions between mapping years);
- Removals in protected areas (primary vegetation) (Conservation Units and Indigenous Territories).

Non-CO_2 gases
- Emissions due to slash-and-burn processes (conversions of natural vegetation) (CH_4, N_20, CO e NO_X).

Harvested wood products (HWP)

CO_2
- Emission/removals due to prodcution, imports and exports of HWP and their respective residues.

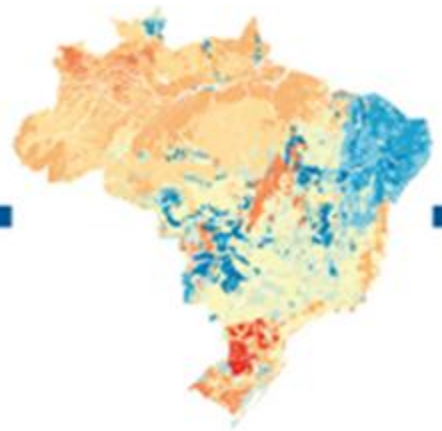
Land-use change maps and other information layers

Visual interpretation (Landsat) (1:250,000) : 1990, 1994, 2002, 2005 (Amazonia), 2010, 2016

Land-use change maps

Geographic limits (states/municipalities)

Biome limits (IBGE 2004)



Soil organic carbon map

Protected areas

Past vegetation map (past carbon)

Transition matrices

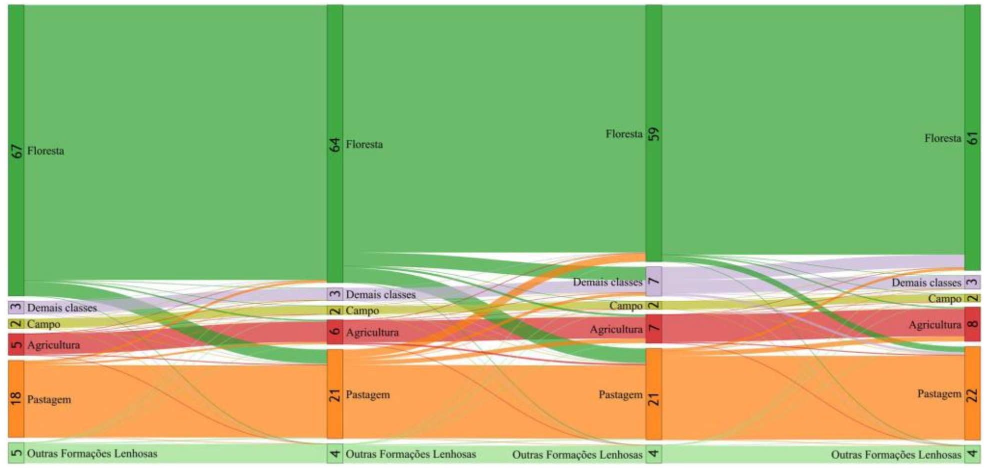


Table 1 - Percentage of carbon stocks of secondary forests compared to primary forest forests in the 3rd National GHG Inventory.

Mean (%)	Age (y)	Biome/State	Reference
36,75 (4,53 – 71,50)	2 – 18	Amazon/AM	Alves et al., 1997
64,41 (27,34 - 87,84)	5 – 80	Amazon/PA	Fearnside & Guimarães, 1996
29,09 (0,67 – 63,17)	1 – 28	Atlantic Forest/SP	Melo & Durigan, 2006
45,23 (8,02 - 62,55)	64- 124	Pantanal/MT	Schongart et al., 2011
Mean = 44%			

4th National GHG Inventory (2020) and 1st Biennial Transparency Report (2024)

44% (same value)

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Secondary-forest CO_2 removal rates

Table 2 – Secondary-forest CO_2 removal rates in the 3rd National Inventory (2016).

History	Biome					
	Amazon	Cerrado	Atlantic Forest	Pampa	Pantanal	Caatinga
	(t C ha^{-1} y^{-1})					
Forest	4.96	1.72	5.35	1.76	2.77	0.6
Pasture	2.85					
Cropland	4.73					
Other history	0.59					

Table 3 – Secondary-forest CO_2 removal rates in the 4th National Inventory (2020) and BTR1 (2024).

History	Amazon	Cerrado	Atlantic Forest	Pampa	Pantanal	Caatinga
	(t C ha^{-1} y^{-1})					
Forest	4.97	1.72	1.66	1.76	2.77	1.03
Pasture	3.03	2.85	1.66	2.85	2.85	0.64
Cropland	5.22	4.73	1.66	4.73	4.73	0.66
Other history	0.62	0.59	1.66	0.59	0.59	0.59

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Secondary forests' area per biome in Brazil (1994-2016)

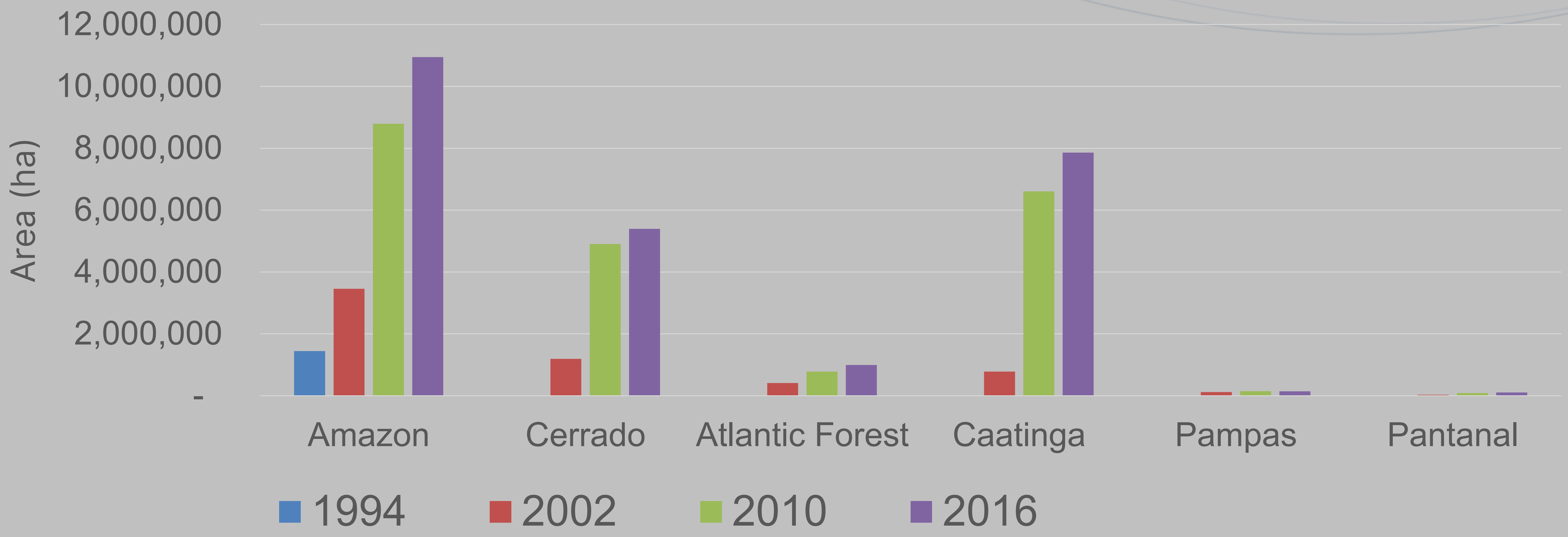

Figure 1 - Area of secondary forests per biome in the years 1994, 2002, 2010, and 2016 in Brazil.

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Secondary forests CO_2 emissions per mapping period in Brazil

Table 4 – Secondary forests area and CO_2 emissions per mapping period in Brazil in the 4th National Inventory (2020) and BTR1 (2024).

Period	Area		Gross emissions		Net soil emissions		Gross removals		Net emissions	
	hectares	(%)	Gg CO_2	Gg (%)	Gg CO_2	Gg (%)	Gg CO_2	Gg (%)	Gg CO_2	Gg (%)
1994-2002	6,069,553	0.7	632,481	4.9	6,356	-83.4	220,628	**7**	418,209	4.3
2002-2010	21,318,566	2.4	489,245	3.3	7,626	17.6	380,153	**7.8**	116,719	1.2
2010-2016	25,447,659	2.9	256,401	5	3,859	7.6	142,674	**4.6**	117,586	5.9

In the 2010-2016 period, secondary forests contributed to 5.9% of Brazil's net CO_2 emissions.

Main challenges

- Monitoring forest regrowth and degradation (temporal consistency).
- Emission factors → net removal rates (age, vegetation type, climate).

Improvement opportunities

- Land-cover activity data → INPE Restore+ (TerraClass).
- Literature review update → carbon stocks and removal rates.

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Brazilian FREL: advances and challenges to include secondary vegetation

Roberta Z. Cantinho (MMA)

Alexandre Avelino

Luan Motta

Session 3.1: Accounting for carbon removals/fluxes in secondary forests for MRV process - advances, needs and challenges

São José dos Campos, 31 Oct 2025

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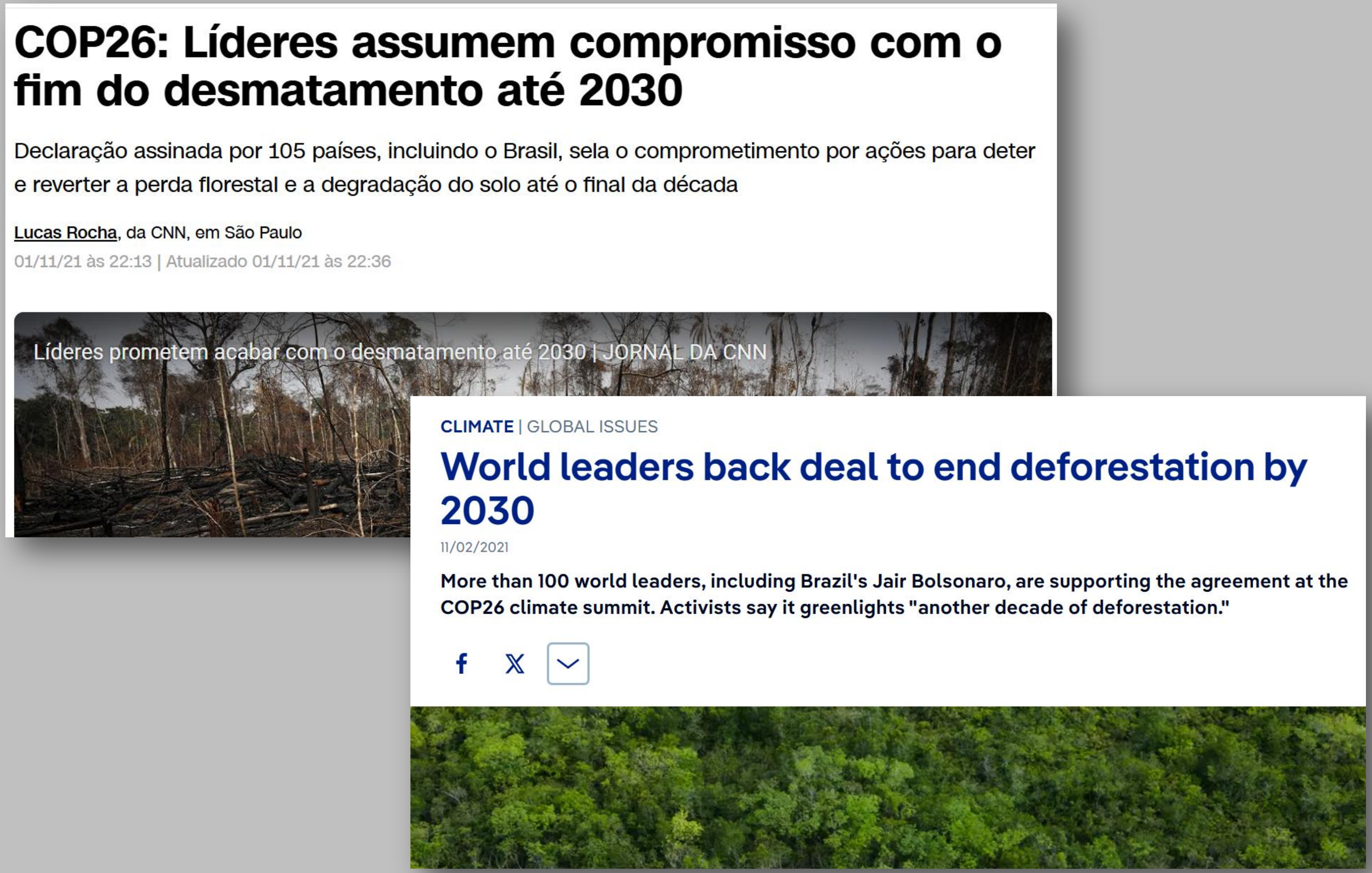
Zero deforestation by 2030

What is it?


COP26: Líderes assumem compromisso com o fim do desmatamento até 2030

Declaração assinada por 105 países, incluindo o Brasil, sela o comprometimento por ações para deter e reverter a perda florestal e a degradação do solo até o final da década

Lucas Rocha, da CNN, em São Paulo

01/11/21 às 22:13 | Atualizado 01/11/21 às 22:36

Líderes prometem acabar com o desmatamento até 2030 | JORNAL DA CNN

CLIMATE | GLOBAL ISSUES

World leaders back deal to end deforestation by 2030

11/02/2021

More than 100 world leaders, including Brazil's Jair Bolsonaro, are supporting the agreement at the COP26 climate summit. Activists say it greenlights "another decade of deforestation."

GLASGOW LEADERS' DECLARATION ON FORESTS AND LAND USE

"We therefore commit to working collectively to halt and reverse forest loss and land degradation by 2030 while delivering sustainable development and promoting an inclusive rural transformation."

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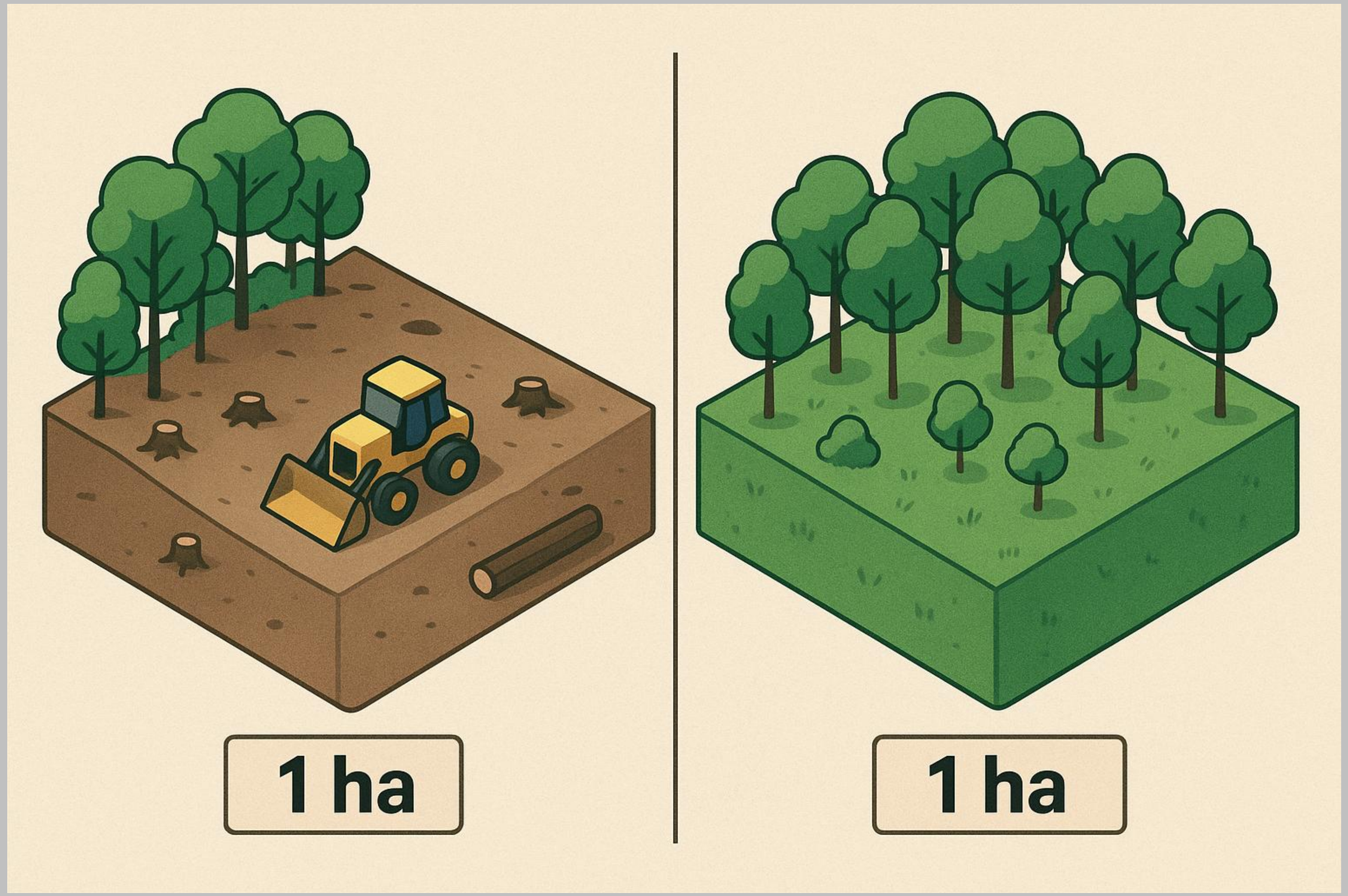
Zero deforestation by 2030

What is it for Brazil?

- Elimination of illegal deforestation by 2030
- Reduction of legal deforestation throw application of the environmental law and financial instruments (50% by 2030 or 7.692 km^2 and 75% by 2035 or 4.425 km^2)
- After 2030, 1ha deforested = 1ha recovered (Planaveg 12M ha)



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Zero deforestation by 2030

What is it for Brazilian NDC?

https://www.gov.br/mma/pt-br/composicao/smc/plano-clima/apresentacao-plano-clima-atualizada-mai24-lgc-1.pdf

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Zero deforestation by 2030

What Brazil is doing to achieve it?

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REDD+ evolution

Mercado Voluntário

Primeiro projeto voluntário de REDD na Bolívia

Criação de padrões privados para projetos de carbono: VCS/Verra, Gold Standard...

VERRA

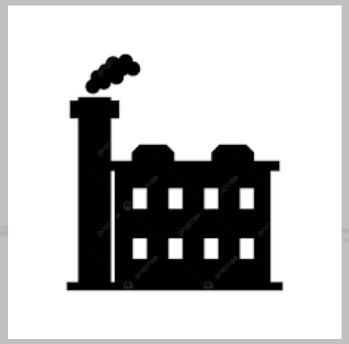
ART Architecture for REDD+ Transactions

LEAF Coalition Coordinated by Emergent

1992 — Convenção-Quadro das Nações Unidas sobre Mudança do Clima (UNFCCC)

UNFCCC

1997 — Protocolo de Quioto: Mecanismo de Desenvolvimento Limpo (MDL)



2005 — Introdução do REDD nas negociações da UNFCCC (COP 11, Montreal)

2007 — Adição do "+" ao conceito de REDD (COP 13, Bali)

2013 — Primeira "regulamentação" do REDD+: Marco de Varsóvia (COP, 19)

COP19/CMP9 UNITED NATIONS CLIMATE CHANGE CONFERENCE WARSAW 2013

2015 — Acordo de Paris: REDD+ no Art. 5

COP21 · CMP11 PARIS 2015 UN CLIMATE CHANGE CONFERENCE

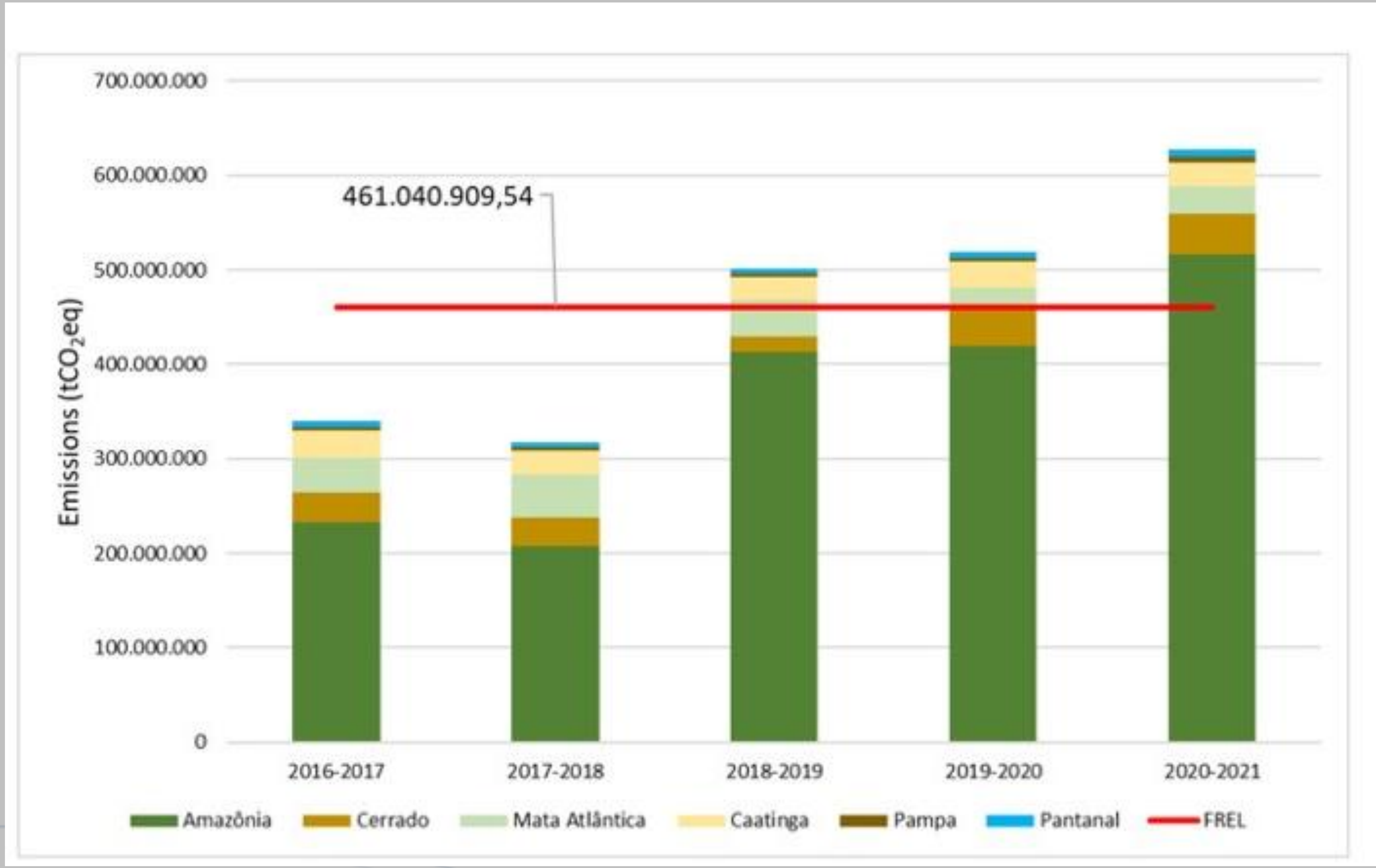
2020 — CORSIA aceita créditos de REDD+ jurisdicional para compensar emissões da aviação internacional

CORSIA

2021

REDD+ in Brazil

FRELs



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REDD+ in Brazil

FRELs evolution

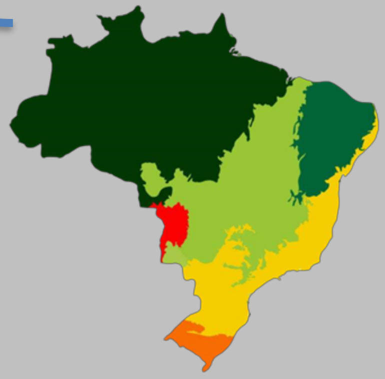
Increase in forest carbon stocks (Amz/Cerrado) + Degradation (Amazônia)

Degradation by fire and selective logging

1º FREL (2014)
Abrangência: bioma Amazônia
Atividade: Redução de Emissões por Desmatamento
A: 2006 a 2010 (Média 1996 a 2005)
B: 2011 a 2015 (Média 1996 a 2010)

2º FREL (2017)
Abrangência: bioma Cerrado
Atividade: Redução de Emissões por Desmatamento
2011 a 2020 (Média 2000 a 2010)

3º FREL (2018/2019)
Abrangência: bioma Amazônia
Atividade: Redução de Emissões por Desmatamento
2016 a 2020 (Média 1996 a 2015)



4º FREL (2023)
Abrangência: Nacional (média 5 anos)
Atividades: Desmatamento (líquidas Amazônia e Cerrado)
Degradação Florestal (Amazônia)
Incremento dos Estoques de Carbono Florestal (Amazônia/Cerrado)
2022 a 2026 (Média 2017 a 2021)

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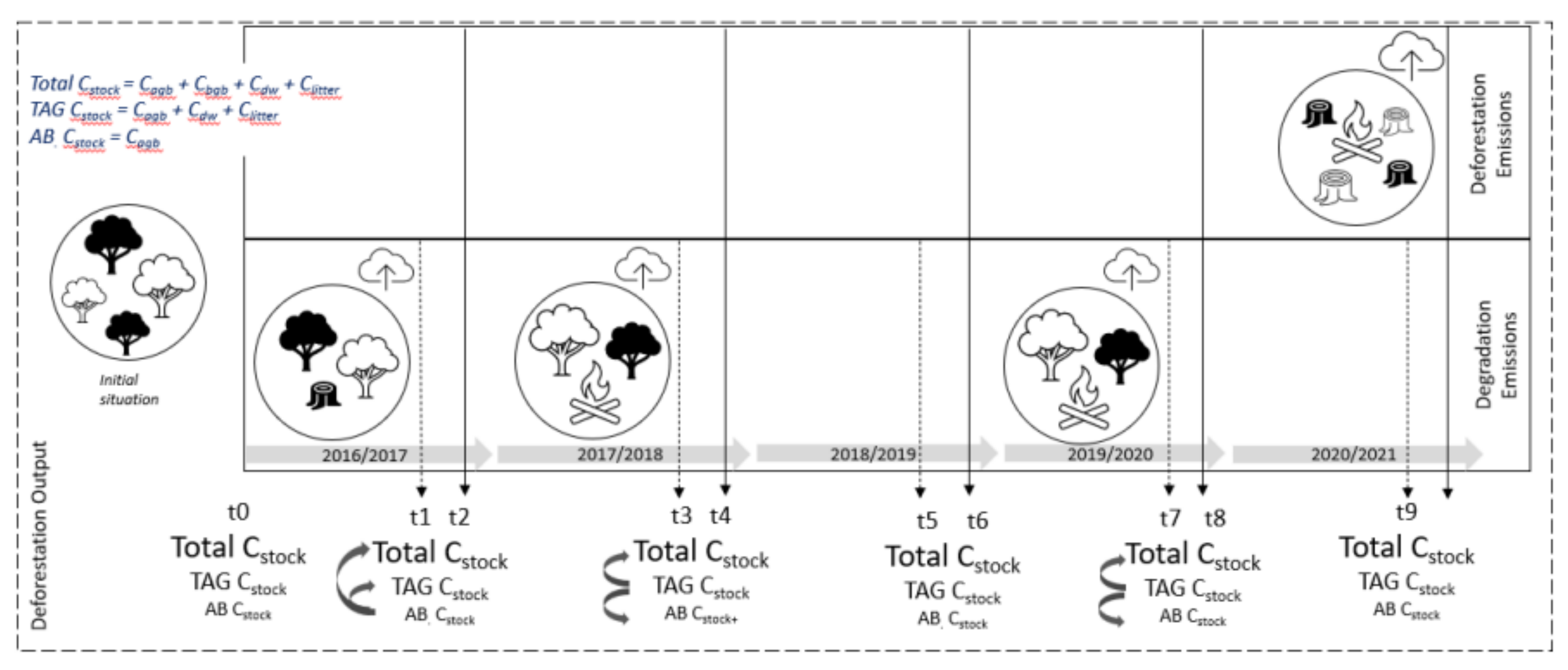
REDD+ in Brazil

Forest degradation

Emission factor	Value	Unit	Source
Combustion factor (C_f)	0.368	Dimensionless	Table 49 (Brazil, 2020) – value for the Amazon biome
Emission factor (G_{ef}) CH_4	6.8	g/kg dry matter (d.m.)	Table 2.5 (IPCC, 2006) – values for Tropical Forest
Emission factor (G_{ef}) N_2O	0.2	g/kg dry matter (d.m.)	
Carbon content	0.47	tonne C/tonne d.m.	IPCC, 2006
AGB "loss factor" CS1	- 29	%	Table 30 (Brazil, 2020) - these values are relative to the remaining biomass and represent the most updated peer-reviewed estimates currently available in Brazil
AGB "loss factor" CS2	- 27	%	
AGB "loss factor" CS3	- 26	%	
AGB "loss factor" CS4	- 22	%	

- **Drivers:**
  - fires in managed forests (UCs and TIs)
  - disordered selective logging
- **Source:** DETER/Inpe
- Only Amazônia



REDD+ in Brazil

Vegetation regrowth

- Source: TerraClass/Inpe
- Only Amazônia and Cerrado

Carbon removal from secondary vegetation growth	3.03	tonne C/ha year

Carbon removal from secondary vegetation growth	2.85	tonne C/ha year

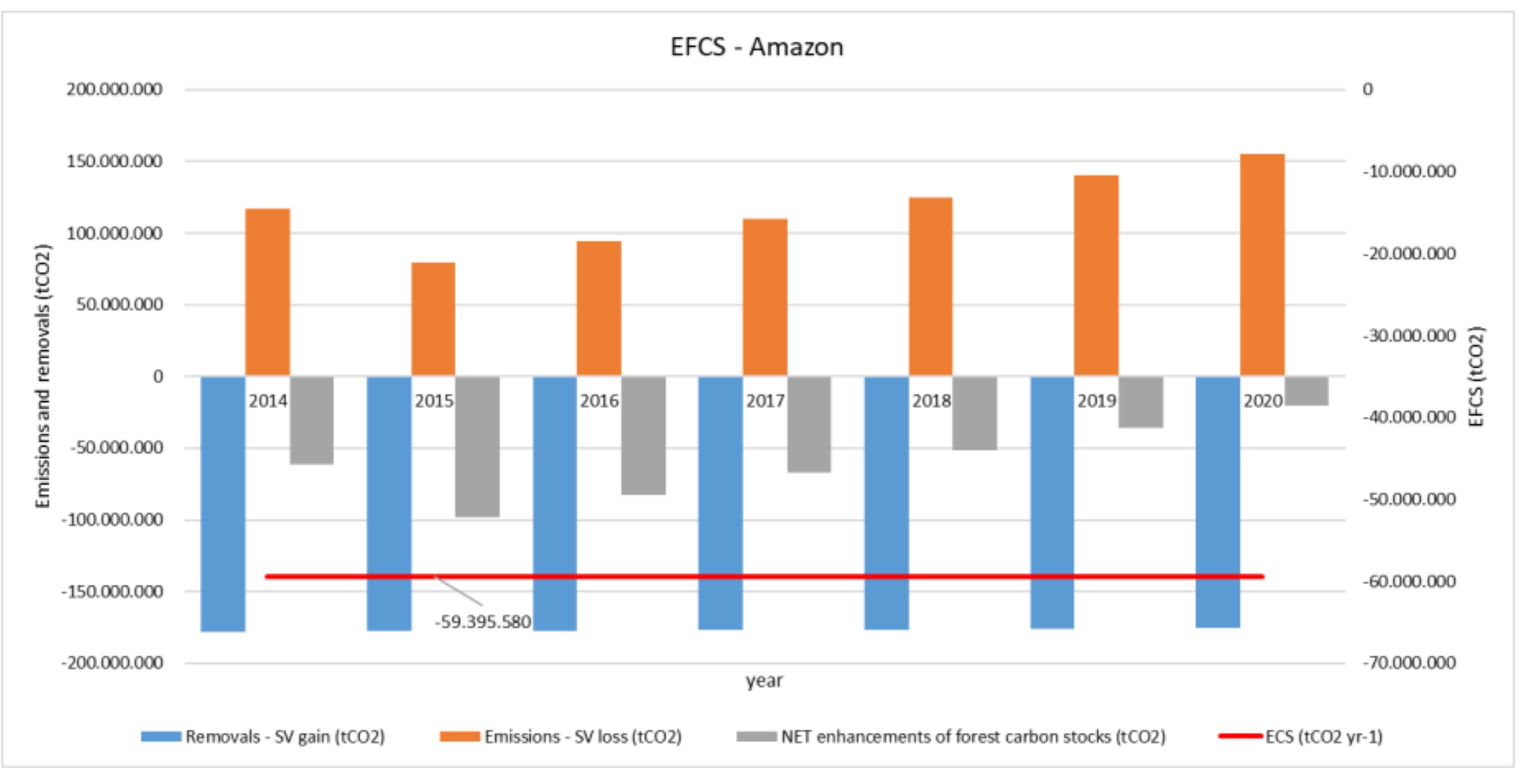


Figure 31: Net emissions from EFCS in the Amazon, reference period from 2014 to 2020

Amazon biome[11]	Cerrado biome[12]
2004, 2008, 2010, 2012, 2014 and 2020	2018 and 2020
	
	In English should read as follows:
VEGETAÇÃO NATURAL FLORESTAL PRIMÁRIA	Natural primary forest vegetation
NÃO FLORESTA	Non-forest zone
CULTURA AGRÍCOLA PERENE	Perennial agriculture crop
CULTURA AGRÍCOLA SEMIPERENE	Semi-perennial agriculture crop
CULTURA AGRÍCOLA TEMPORÁRIA	Temporary agricultural crop
CORPOS D'ÁGUA	Water bodies
DESFLORESTAMENTO NO ANO	Deforestation in current year
MINERAÇÃO	Mining
NÃO OBSERVADO	Not observed
OUTROS	Others
PASTAGEM CULTIVADA ARBUSTIVA	Shrub pasture land
PASTAGEM CULTIVADA HERBÁCEA	Herbaceous pasture land
SILVICULTURA	Silviculture
ÁREA URBANIZADA	Urban area
VEGETAÇÃO NATURAL FLORESTAL SECUNDÁRIA	Natural forest secondary vegetation

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REDD+ in Brazil

Net emissions

- Source: TerraClass/Inpe
- Only Amazônia and Cerrado

Emission factor	Value	Unit	Source
Carbon stocks in pastures	10	tonne C/ha	Table 29 (Brazil, 2020)
Carbon removal in perennial agriculture	0,91	tonne C/ha year	Table 29 (Brazil, 2020)
Carbon removal in semi perennial and temporary agriculture	0	tonne C/ha year	Table 29 (Brazil, 2020)

Emission factor	Value	Unit	Source
Carbon removal from secondary vegetation growth	2.85	tonne C/ha year	Table 29 (Brazil, 2020) – annual removal factor per unit area for secondary forest in pasture land[15]
Carbon stocks in pastures	7.57	tonne C/ha	Table 29 (Brazil, 2020)
Carbon removal in perennial agriculture	2.6	tonne C/ha year	Table 29 (Brazil, 2020)
Carbon removal in semi perennial and temporary agriculture	0	tonne C/ha year	Table 29 (Brazil, 2020)

Amazon biome[11]	Cerrado biome[12]
2004, 2008, 2010, 2012, 2014 and 2020	2018 and 2020

	In English should read as follows:
VEGETAÇÃO NATURAL FLORESTAL PRIMÁRIA	Natural primary forest vegetation
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DESFLORESTAMENTO NO ANO	Deforestation in current year
MINERAÇÃO	Mining
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PASTAGEM CULTIVADA ARBUSTIVA	Shrub pasture land
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ÁREA URBANIZADA	Urban area
VEGETAÇÃO NATURAL FLORESTAL SECUNDÁRIA	Natural forest secondary vegetation

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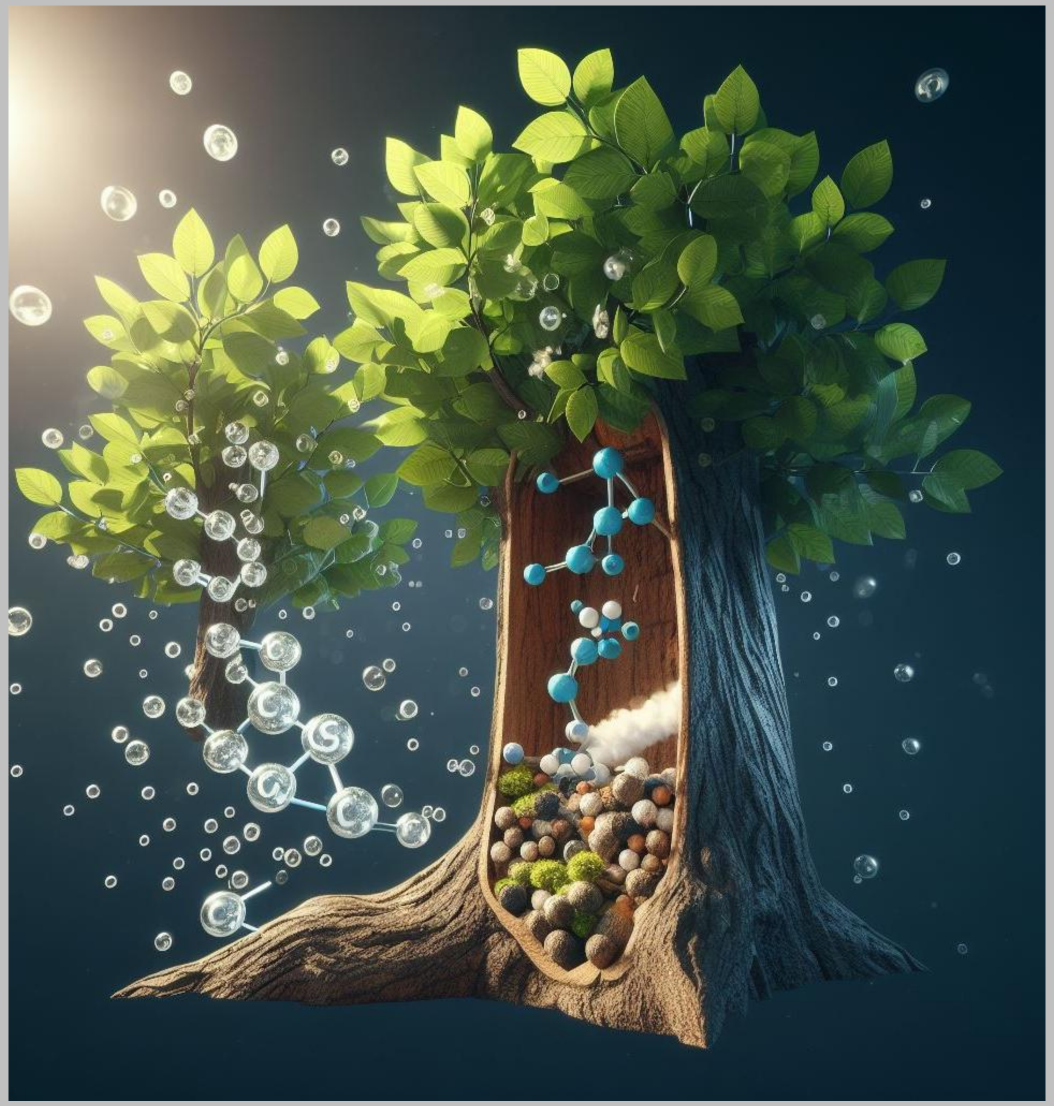
Main conclusions

What/Why do we need?



- Monitoring forest regrowth = NDC monitoring
- REDD → REDD+ (Amazon Fund)

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Obrigada!

Departamento de Políticas de Controle do Desmatamento e Incêndios
Secretaria Extraordinária de Controle do Desmatamento e Ordenamento Ambiental Territorial

reddbrasil@mma.gov.br

Aproxime a câmera do seu celular e acesse a página do REDD+ Brasil

MINISTÉRIO DO **MEIO AMBIENTE E MUDANÇA DO CLIMA**

GOVERNO FEDERAL
BRASIL
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Secondary Forest Carbon Removals in Practice: MRV perspectives from JREDD and ARR

Henrique Cassol & Graciela Tejada

Session 3.1: Accounting for carbon removals/fluxes in secondary forests for MRV process - advances, needs and challenges

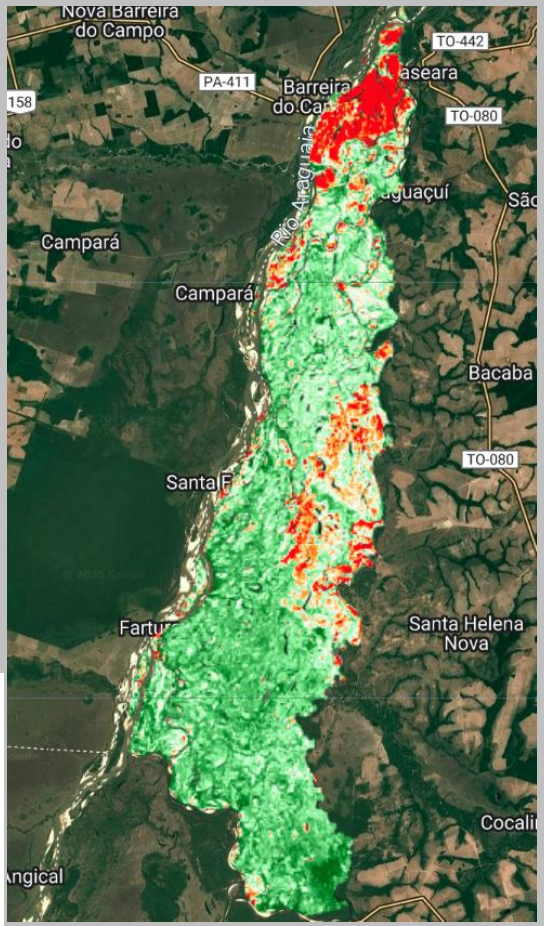
São José dos Campos, 31 Oct 2025

Cantão State Park

Afforestation, Revegetation, and Revegetation Project

- ‘Amazonian Pantanal inside Cerrado’
- Alluvial deciduous forest
- Partially flooded
  - *Circa* 15k ha project area

NDFI 2024
-1: Alta degradação / solo exposto
-0.5
0: Transição
0.5
1: Vegetação densa



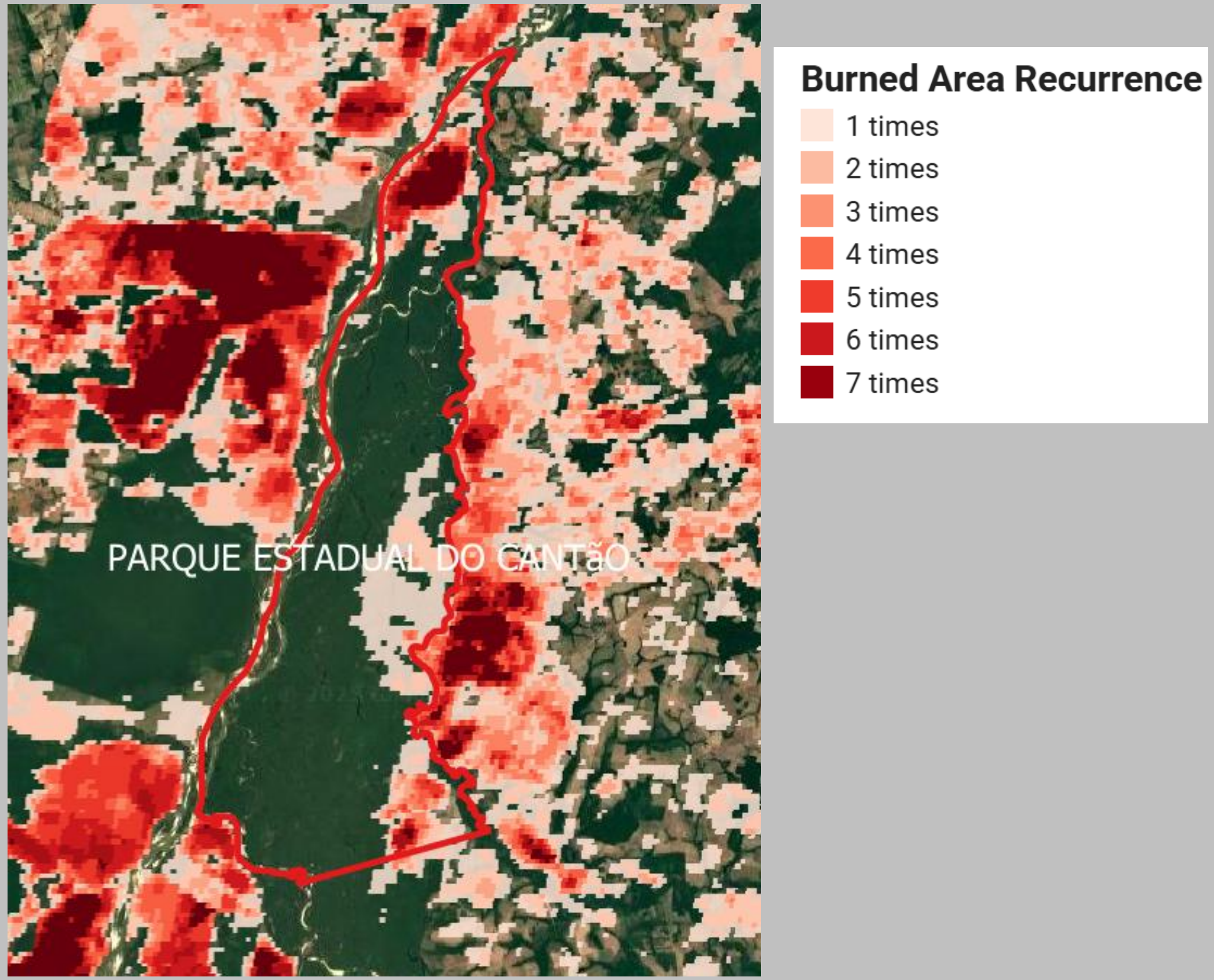


Fig. 1. Location of Cantão State Park and previous degradation

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Cantão State Park

Afforestation, Revegetation, and Revegetation Project

- Two strata: Open grassland
  Recent burned or degraded

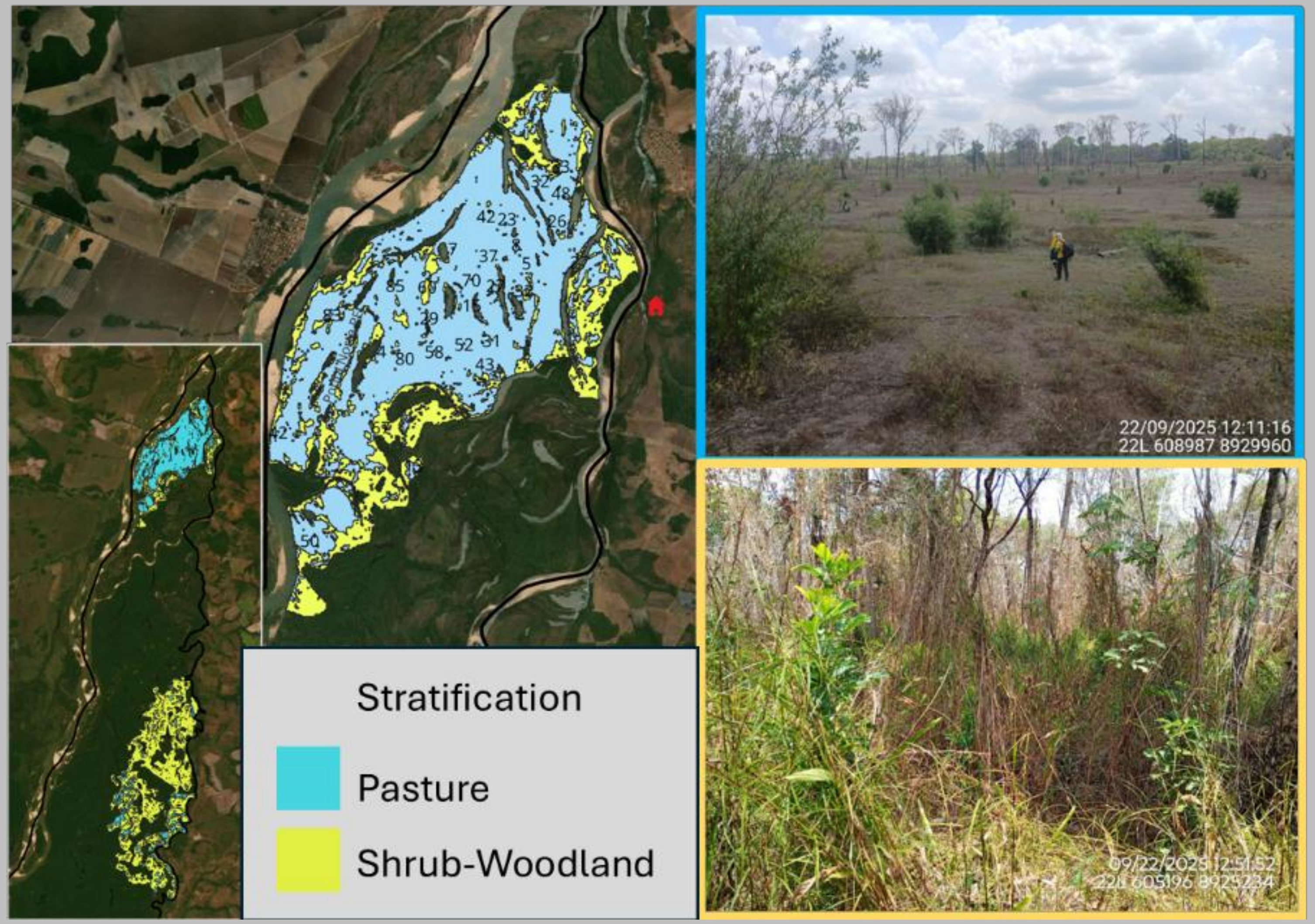

Fig. 2. Stratification of Cantão State Park

Cantão State Park

Afforestation, Revegetation, and Revegetation Project

- Chapman-Richards (asymptote)
- Growth curves by strata
- Spatial and temporal resolution

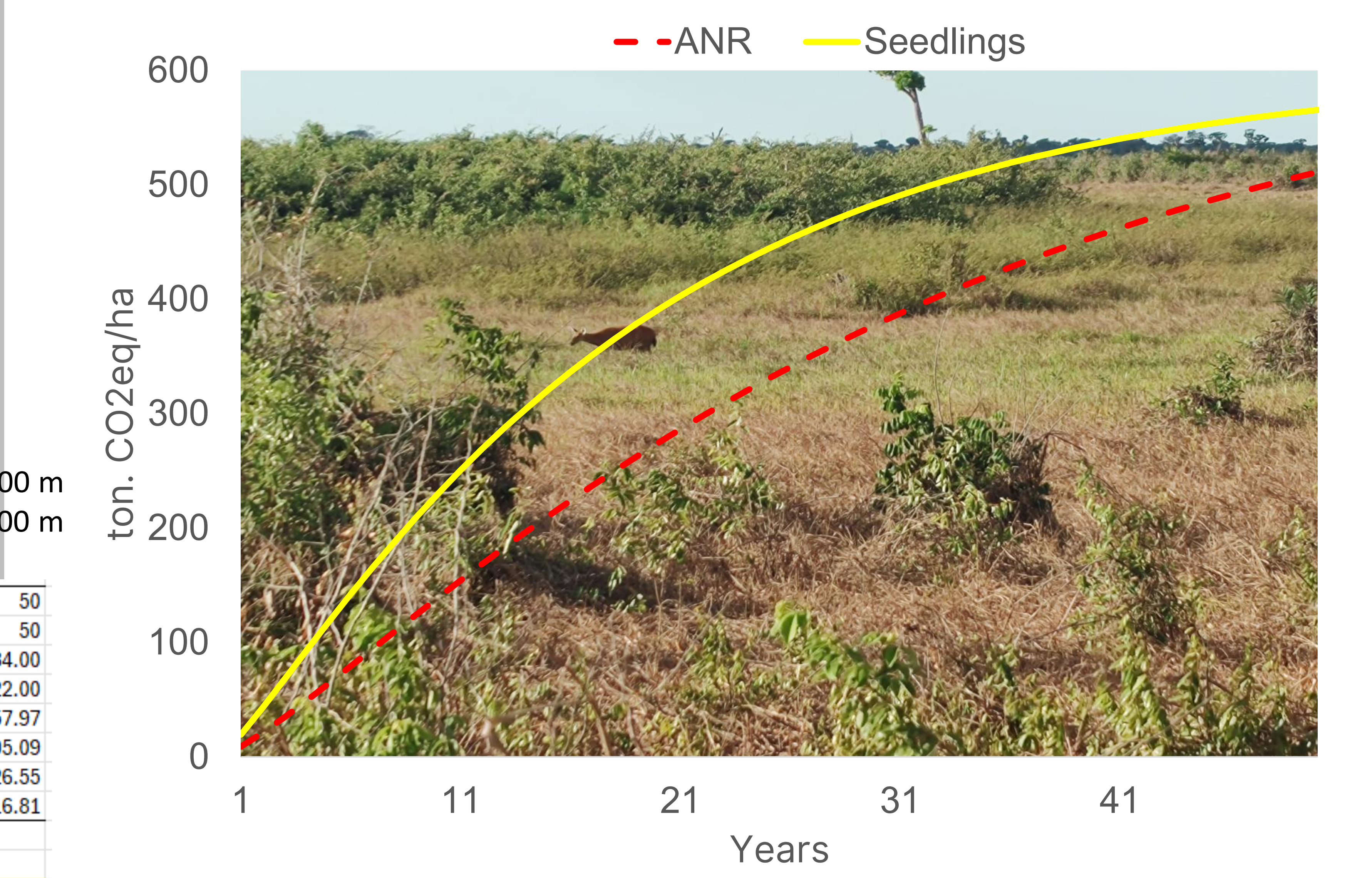

Fig. 3. Growth curves

AGB Soto-Navarro (2010): 100x100 m
Parcelas: 100x100 m

Total		50
Area amostrada		50
Min		13.19
Max		261.73
Média		167.26
Variância		6121.97
Desvio-padrão		78.24
Coeficiente de Variação		46.78
Intensidade Amostral		
n (pop infinita)		88
teste-t (49 G.L.)		2.009
E (%)		10
N		15000
Intensidade Amostral	Recálculo	
n (pop infinita)		84
teste-t		1.96
E (%)		10

AGB Spawn (2010): 100x100 m
Parcelas: 100x100 m

Total		50
Area amostrada		50
Min		5.36
Max		99.65
Média		58.02
Variância		648.77
Desvio-padrão		25.47
Coeficiente de Variaçãc		43.90
Intensidade Amostral		
n (pop infinita)		78
teste-t (49 G.L.)		2.009
E (%)		10
N		15000
Intensidade Amostral	Recálculo	
n (pop infinita)		74
teste-t		1.96
E (%)		10

AGB Baccini (2012): 100x100 m
Parcelas: 100x100 m

Total		50
Area amostrada		50
Min		84.00
Max		222.00
Média		157.97
Variância		705.09
Desvio-padrão		26.55
Coeficiente de Variaçãc		16.81
Intensidade Amostral		
n (pop infinita)		11
teste-t (49 G.L.)		2.009
E (%)		10
N		15000
Intensidade Amostral	Recálculo	
n (pop infinita)		11
teste-t		1.96
E (%)		10

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Cantão State Park

Afforestation, Revegetation, and Revegetation Project

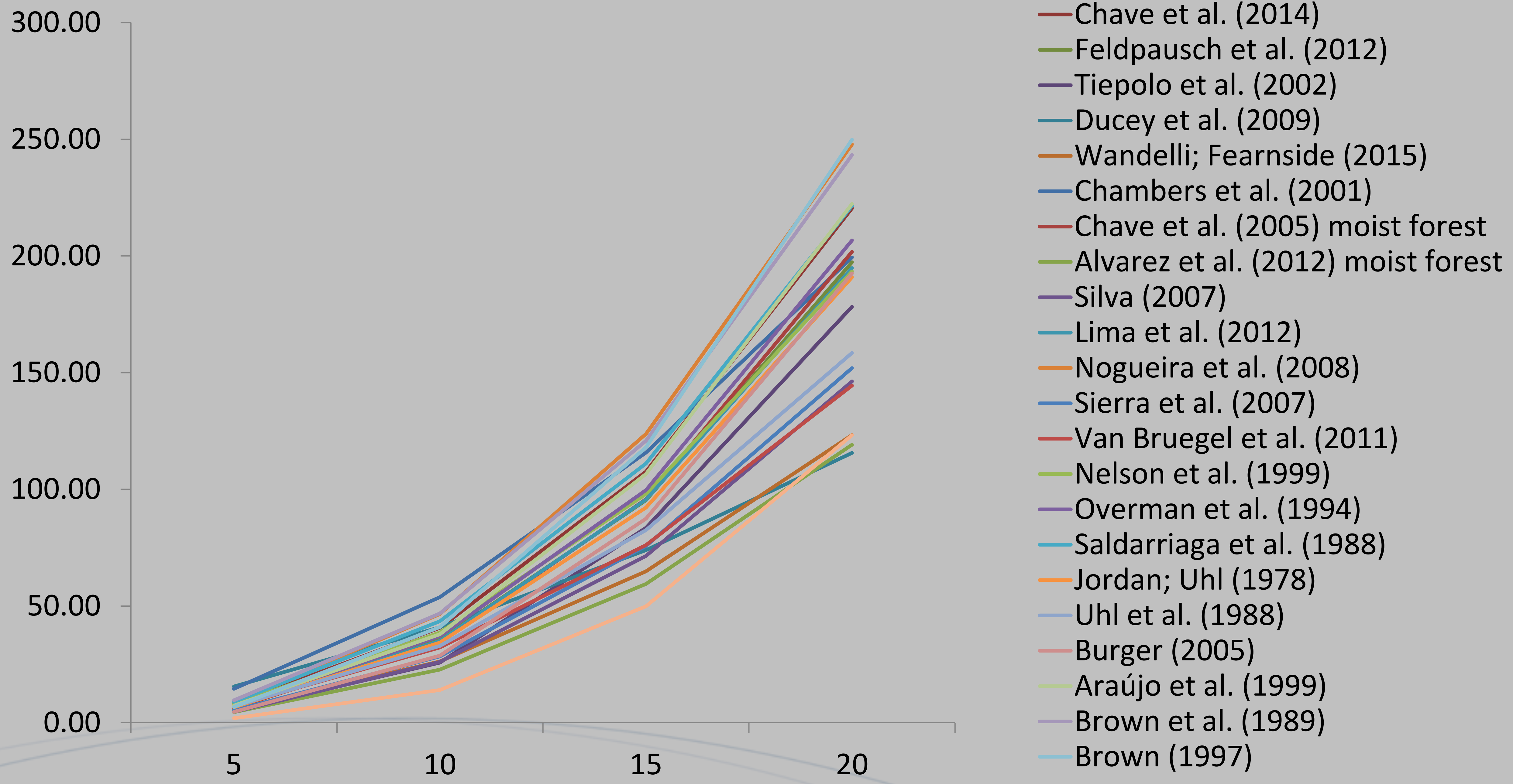
- Challenges:
  - Retrieving suitable Stocking Index (VM0047 1.1, Verra 2025)
  - Plants adapted to flooding
  - No roads and bridges for planting and nursery

Fig. 4. Main access to State Park

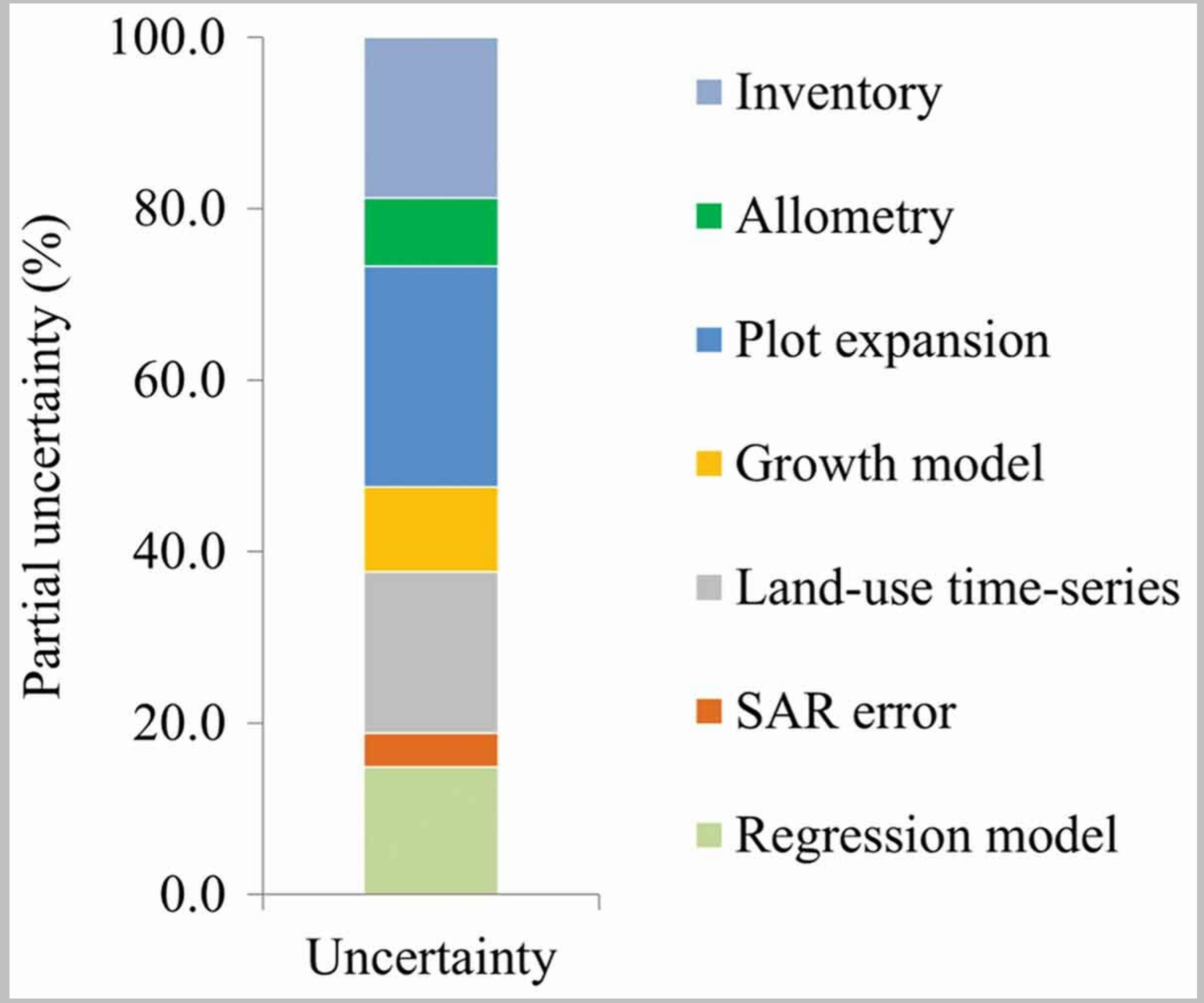
Geonoma

Cantão State Park

Afforestation, Revegetation, and Revegetation Project



Variation CV (%)	40%	26%	23%	24%



Cassol et al. (2021)

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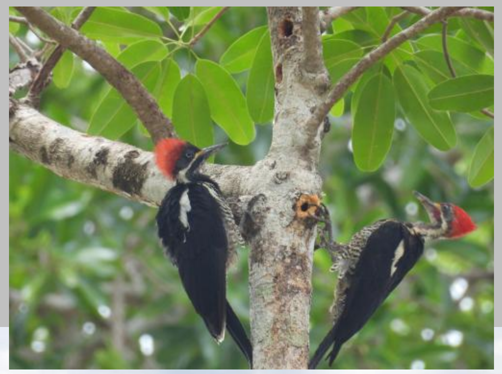
Geonoma

Cantão State Park

Afforestation, Revegetation, and Revegetation Project

- Forest Carbon (baseline) 13/10 – 25/10



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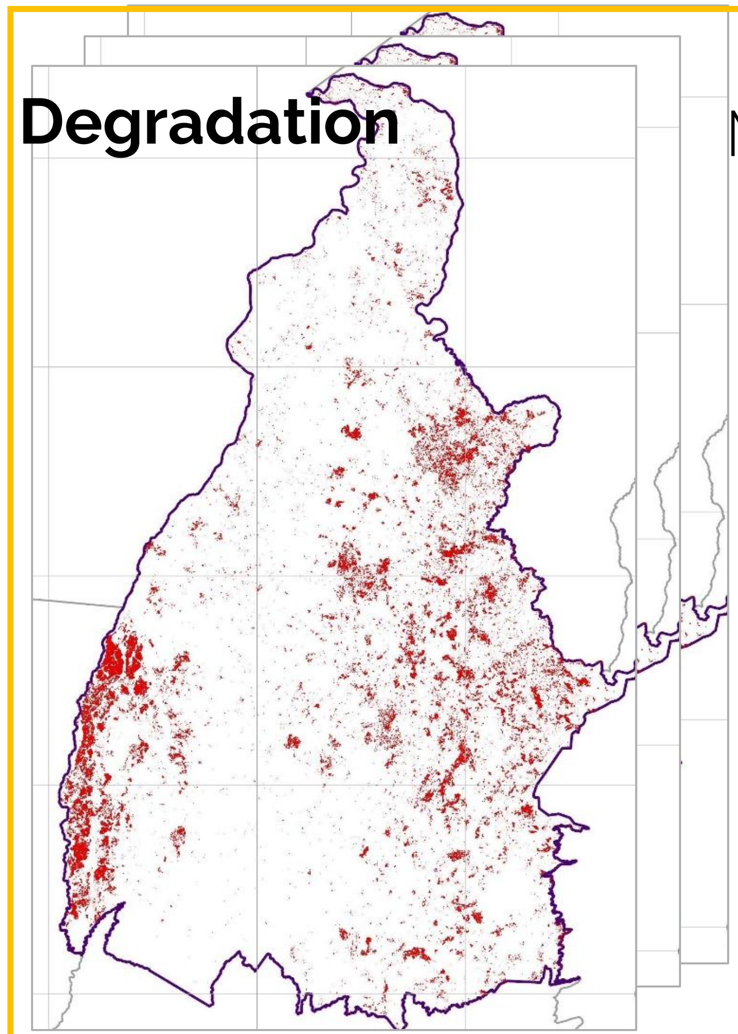
Jurisdictional REDD+ Program of the State of Tocantins (JREDD TO)

Architecture for REDD+ Transactions

- The REDD+ Environmental Excellence Standard (TREES) version 2.0
  - TREES Registration Document (TRD)
  - TREES Monitoring Report (TMR)
- Submitted and accepted by ART
- Under Validation and Verification (VVB)

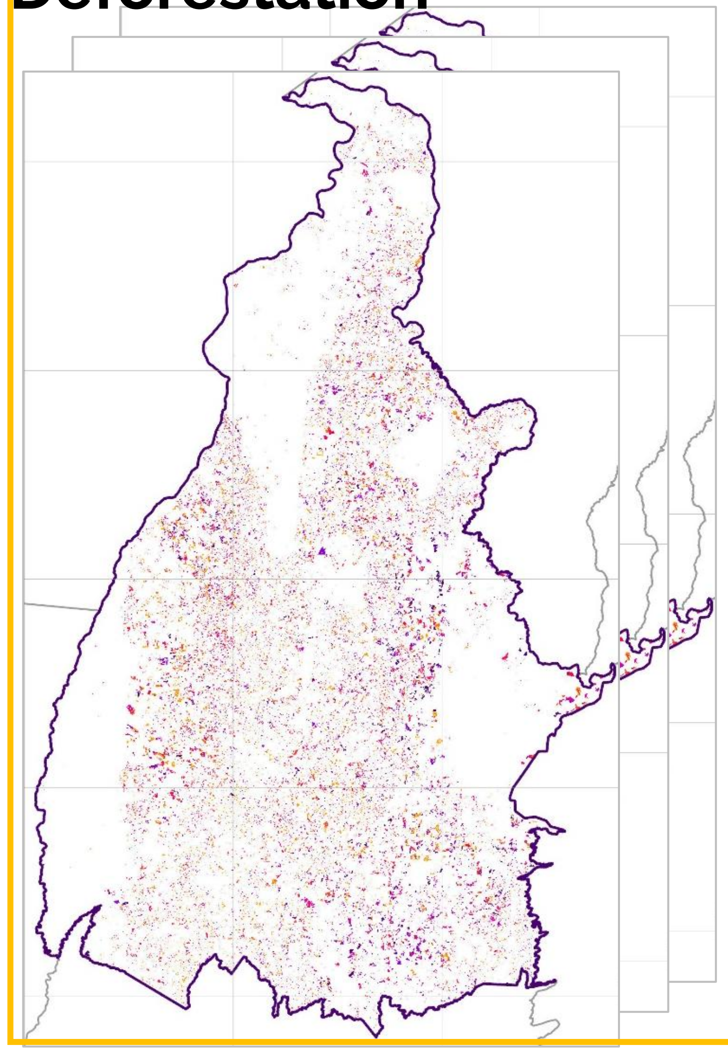
Degradation



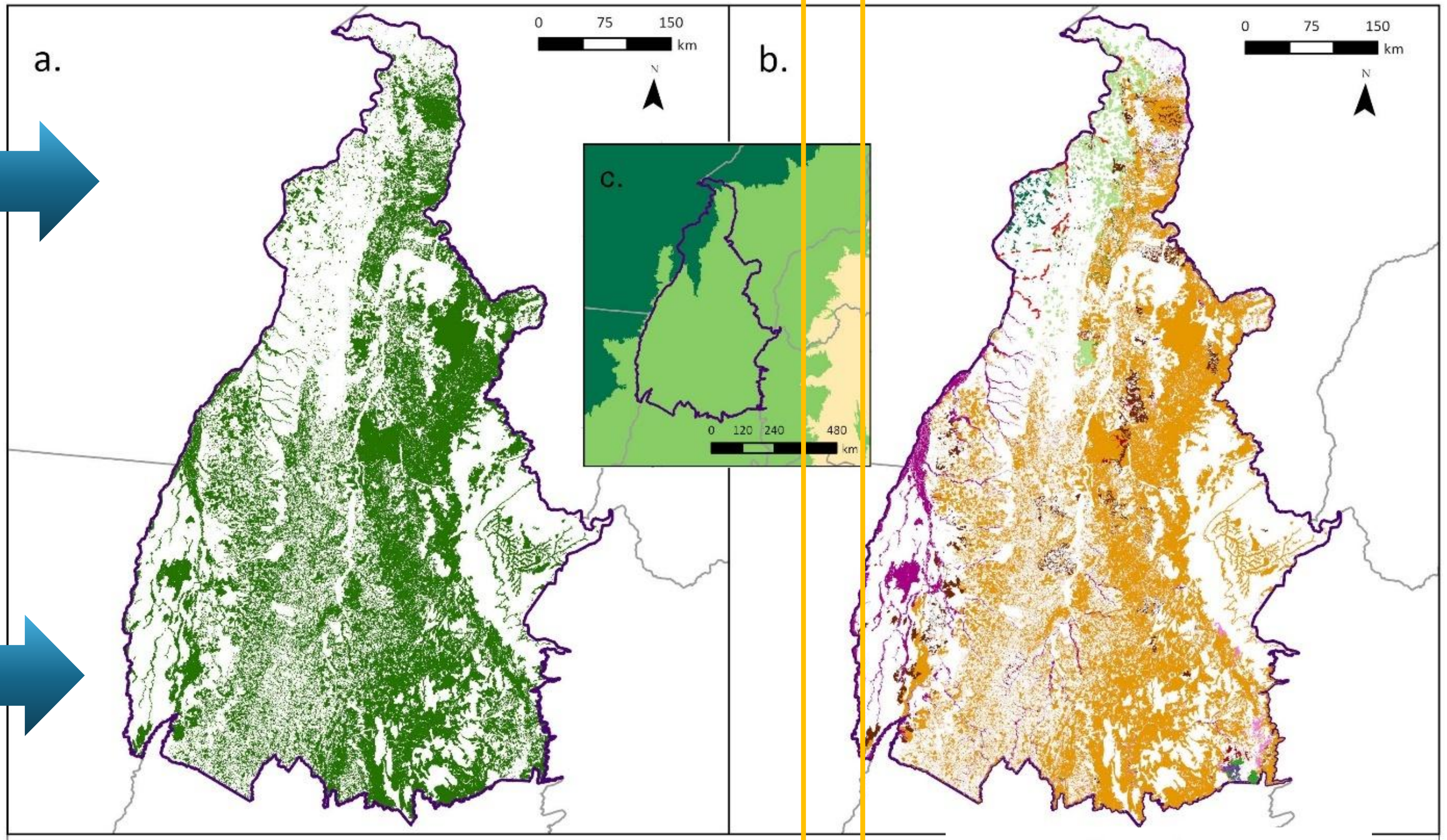
Burned area
MapBiomas Fogo c.3.1

IPAM model (Gomes et al. 2024)

Deforestation



Carbon map
FREL-Brazil 2024



Forest mask

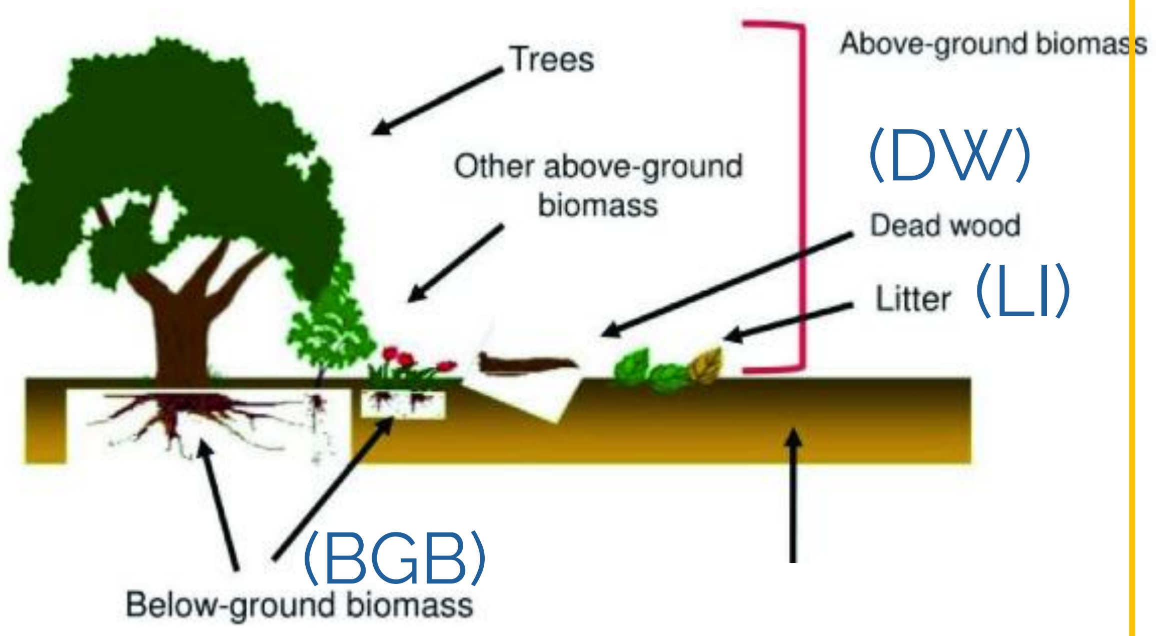
Forest phytophysiognomies of FREL

Model based on FREL

Deforestation
PRODES

AD

Carbon pools

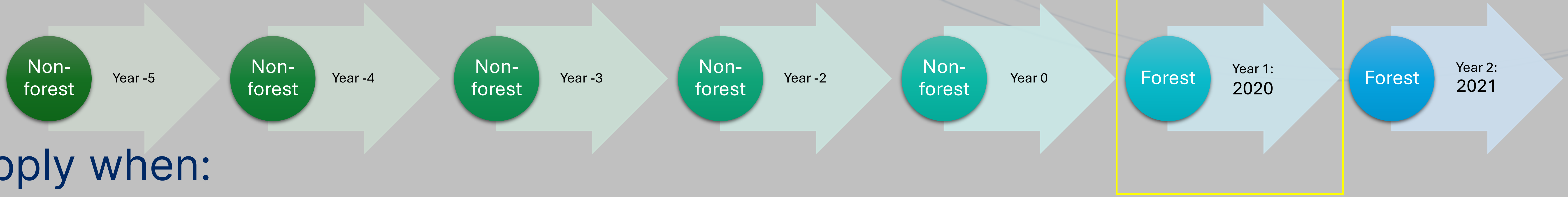


Not yet Removals:

ART-TREES: Conversion of non-forest to forest occurred on lands that have been non-forest for a period of **five years** prior to the start of planting or restoration.

EF

Removals



Apply when:

- Deforestation and degradation emissions below the TREES Crediting Level
- Included removals are connected to the REDD+ activities

Removal areas:

- non-forest for 5 years
- forest prior to being non-forest.
- ‘ongoing removals stratum’ annually
- Differentiate: **Natural Forest Restoration** (tree planting or natural regeneration of native species) and **Commercial Forest** (commercial harvests)

Challenges

- Annual secondary vegetation data
  - TerraClass 2020 and 2022 (Every 2 years)
  - MapBiomas: Deforestation and secondary vegetation module
  - MapBiomas: Recovery Monitor module "Monitor da Recuperação"
- Annual differentiation: **Natural Forest Restoration** and **Commercial Forest**
- Correspondence to Brazil's FREL and National Communications
  - Cerrado biome

* Degradation: Deter Cerrado data

ART-TREES:

- Nesting
- Map accuracy assessment of secondary vegetation data and area adjustment
  - At State level or scale

SynCER: Synthesising post-disturbance Carbon Emissions and Removals across Brazil’s forest biomes

(10:30-11:00) Break

São José dos Campos, 31 Oct 2025

SynCER

GFZ Helmholtz Centre for Geosciences

INPE

IPAM Amazônia

esa

Research priority topics, planning next steps for MRV-related activities in a changing climate

São José dos Campos, 31 Oct 2025

SynCER

GFZ Helmholtz Centre for Geosciences

INPE

IPAM Amazônia

esa

SynCER: Synthesising post-disturbance Carbon Emissions and Removals across Brazil's forest biomes

(12:30-13:30) Lunch

São José dos Campos, 31 Oct 2025

SynCER

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SynCER: Synthesising post-disturbance Carbon Emissions and Removals across Brazil's forest biomes

Workshop and breakout groups

São José dos Campos, 31 Oct 2025

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SynCER: Synthesising post-disturbance Carbon Emissions and Removals across Brazil's forest biomes

Final plenary: next steps and beyond COP30

São José dos Campos, 31 Oct 2025

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