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

Day 1: Mapping Secondary Forest – where are they regrowing according to who/what dataset

São José dos Campos, 29 Oct 2025

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Session 1.1: Welcome, objectives, and keynote

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

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Welcome

Luiz Aragao (INPE) + Lúbia Vinhas (INPE) + Frank Martin Seifert (ESA)

Session 1.1: Welcome, Objectives, and Keynote

São José dos Campos, 29 Oct 2025

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SynCER in context of past workshops + Main Objectsives

Viola Heinrich

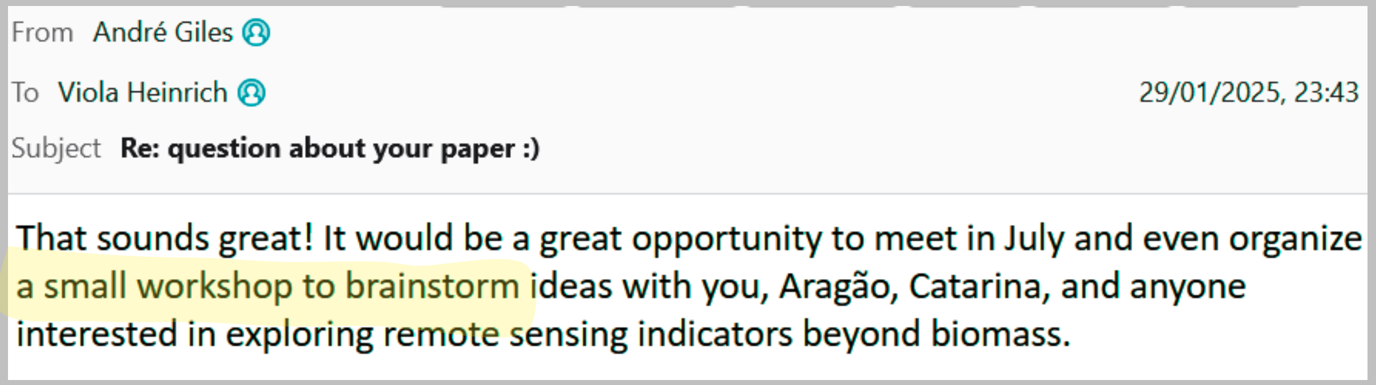
Session 1.1: Welcome & Objectives

São José dos Campos, 29th October 2025

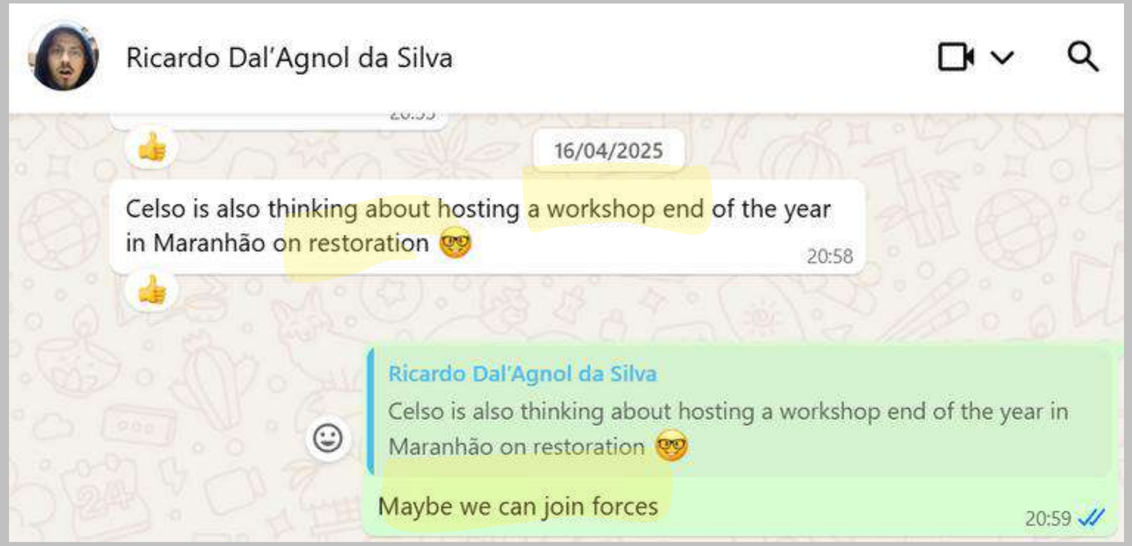
Why SynCER?

SynCER: **Syn**thesising post-disturbance **C**arbon **E**missions and **R**emovals across Brazil's forest biomes

COP30 BRASIL AMAZÔNIA BELÉM 2025


From André Giles
To Viola Heinrich 29/01/2025, 23:43
Subject **Re: question about your paper :)**

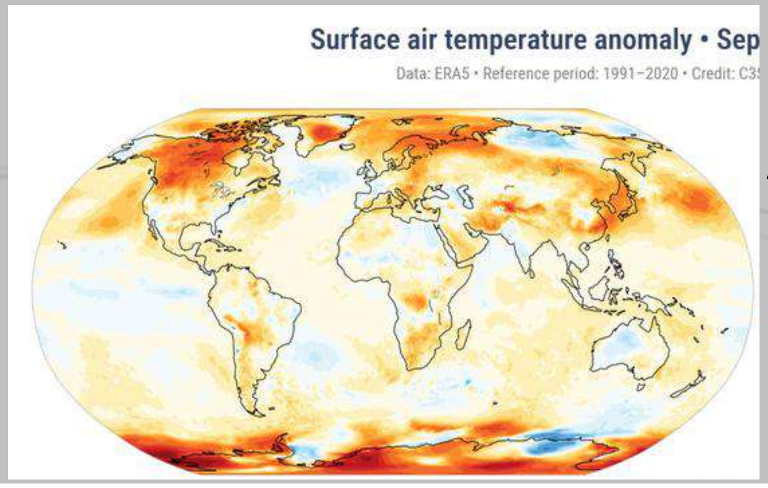
That sounds great! It would be a great opportunity to meet in July and even organize a small workshop to brainstorm ideas with you, Aragão, Catarina, and anyone interested in exploring remote sensing indicators beyond biomass.


Ricardo Dal'Agnol da Silva

16/04/2025

Celso is also thinking about hosting a workshop end of the year in Maranhão on restoration 🤓 20:58

Ricardo Dal'Agnol da Silva
Celso is also thinking about hosting a workshop end of the year in Maranhão on restoration 🤓
Maybe we can join forces 20:59



"Between September 2024 to August 2025 average global temperatures were 1.52°C above pre-industrial levels."

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The Fellowship of the Biomass workshops

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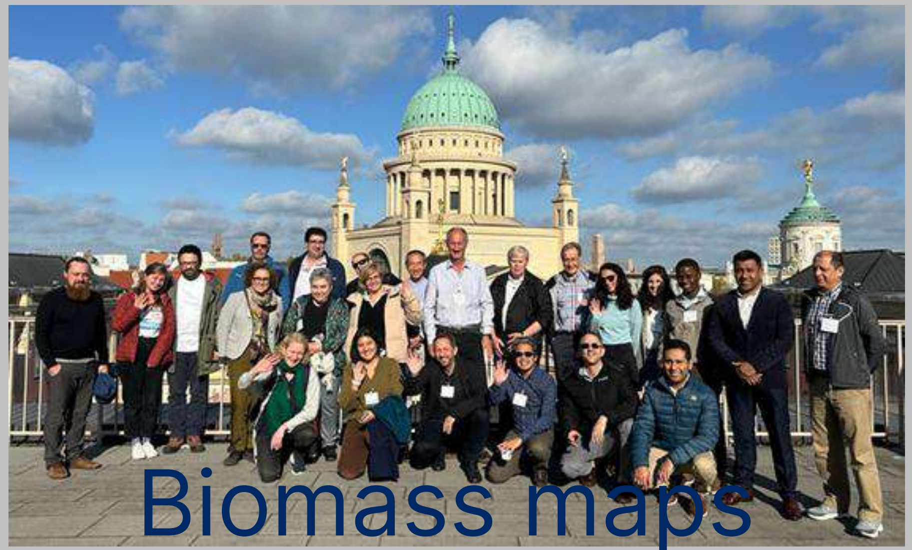
The Fellowship of the Biomass workshops

R2D2, Potsdam, March 2024



Biomass maps
Potsdam, Oct 2024

FAO AI, Rome,
June 2025

IPCC, Ispra,
June 2024

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The Fellowship of the Biomass workshops

R2D2, Potsdam, March 2024

Journal	Article Type	Title	First Author Name	Status	Last Activity Date
Science Advances	Review	A multi-data synthesis of carbon losses and gains from tropical moist forest degradation and regeneration	Heinrich, Viola	To Review	08-Oct-2025

Comment | Published: 15 May 2025

Improving land-use emission estimates under the Paris Agreement

Giacomo Grassi, Glen P. Peters, Josep G. Canadell, Alessandro Cescatti, Sandro Federici, Matthew J. Gidden, Nancy Harris, Martin Herold, Thelma Krug, Michael O'Sullivan, Julia Pongratz, María J. Sanz, Clemens Schwingshackl & Detlef van Vuuren

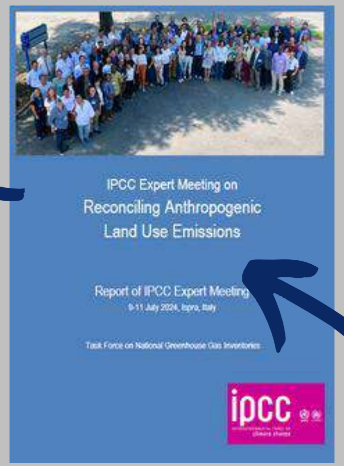
Nature Sustainability **8**, 579–581 (2025) | Cite this article

GFOI Global Forest Observations Initiative

Biomass Maps

Information on the potential and limitations of global or regional biomass datasets in the context of National greenhouse gas inventories

Journal	Article Type	Title	First Author Name	Status	Last Activity Date
Science	Research Article	The hidden demography of the 21st century global forest carbon sink	Liang, Jingjing	Under Evaluation	14-Oct-2025



Biomass maps
Potsdam, Oct 2024

FAO AI, Rome,
June 2025

IPCC, Ispra,
June 2024

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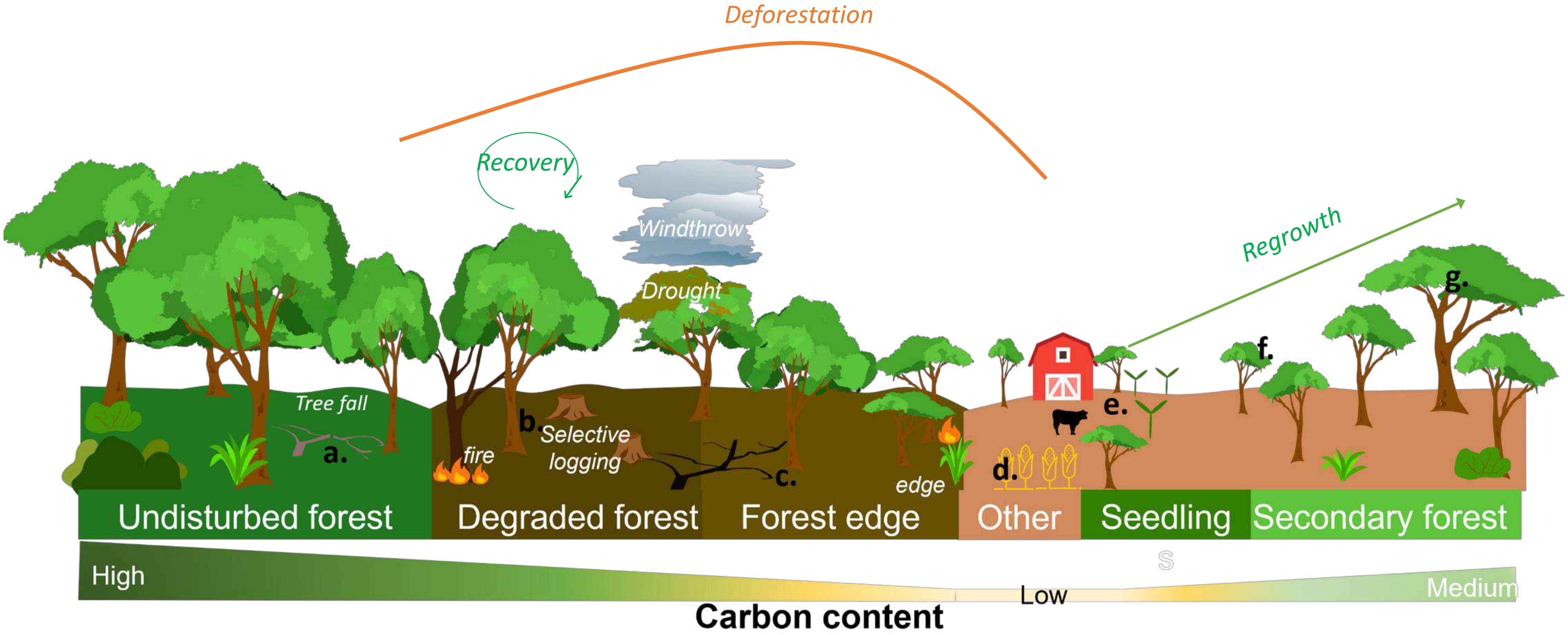
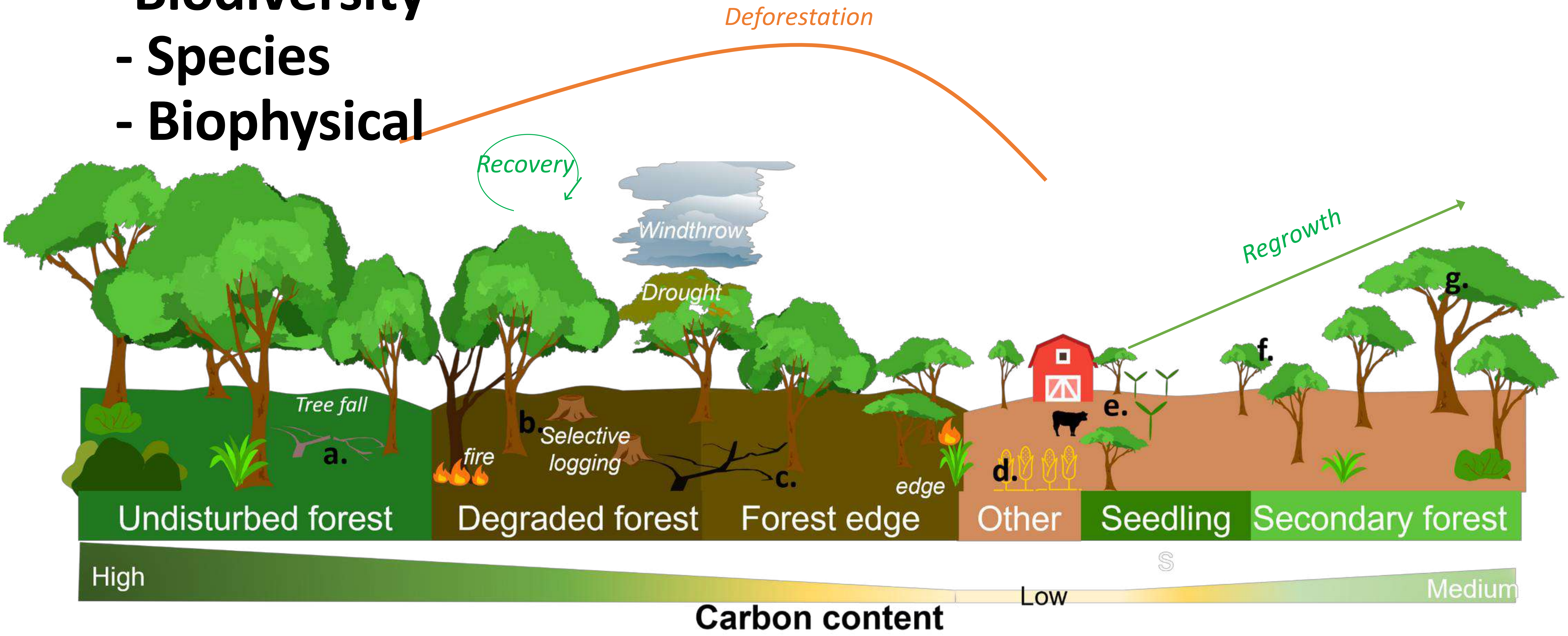
Carbon losses and gains in the tropical moist forest

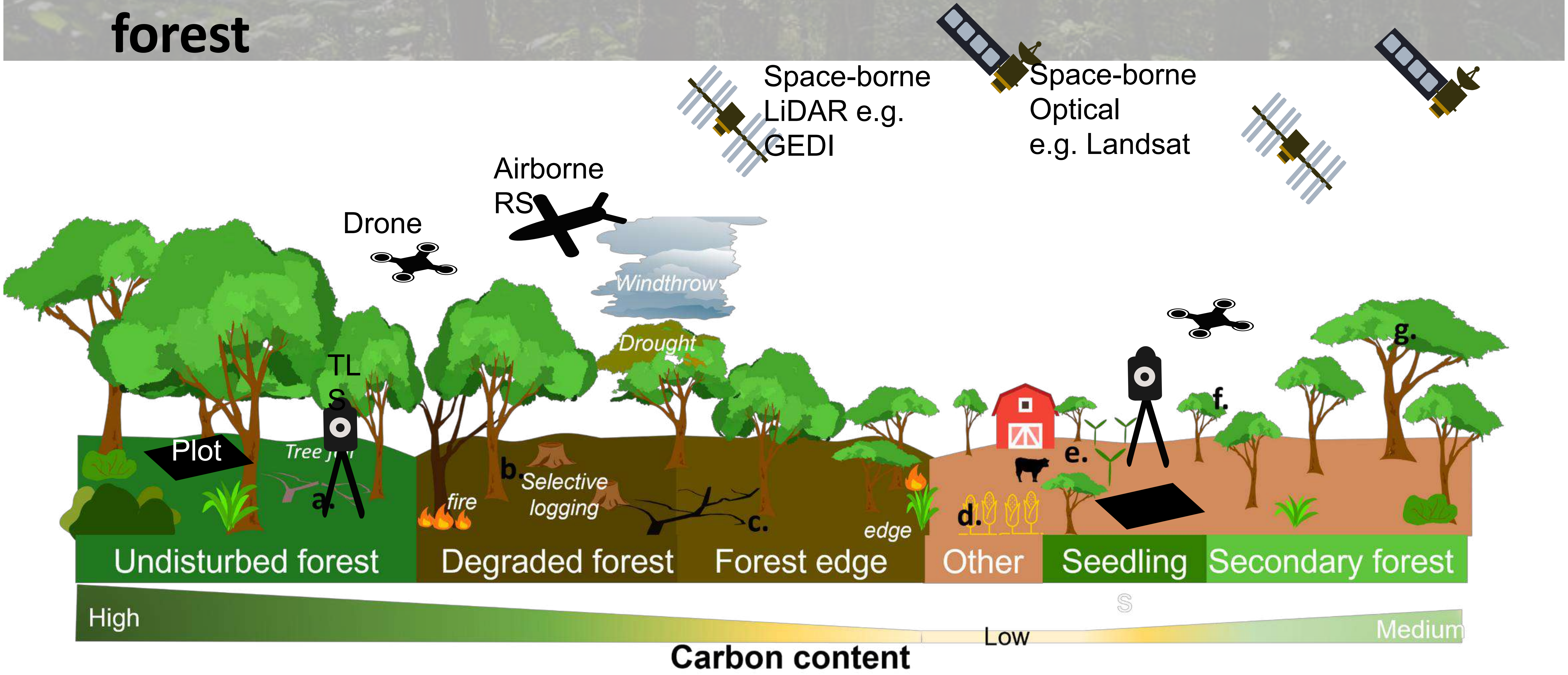


~~Carbon~~ losses and gains in the tropical moist forest

-Biodiversity
- Species
- Biophysical



Measuring carbon losses and gains in tropical moist forest



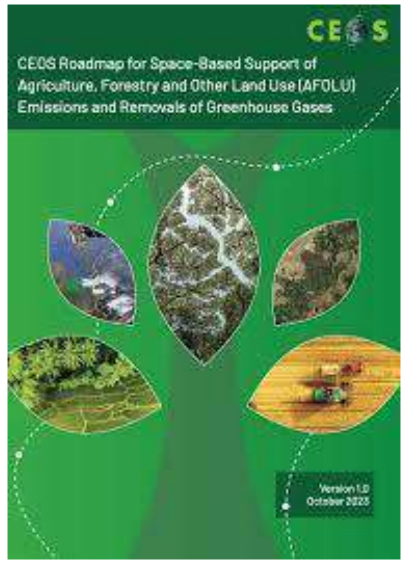
There are many new estimates emerging quantifying carbon losses and gains post-disturbance from so many data sources…

And many more to come…

u et al. (Accepted), Rosan et al (in Review.), Liang et al. (in Review.), Haddad Ruiz (in Prep

...while new estimates drive science forward, they can create confusion for application purposes

Earth Observation Initiatives



CEOS Committee on Earth Observation Satellites

International efforts

2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Volume 4

Agriculture, Forestry and Other Land Use

Edited by Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize S., Osako, A., Pyrozhenko, Y., Shermanau, P. and Federici, S.

Task Force on National Greenhouse Gas Inventories

ipcc INTERGOVERNMENTAL PANEL ON climate change

National Reporting Efforts

TROPICAL FOREST FOREVER FACILITY

GFOI

Project level standards

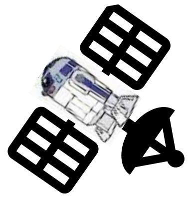
REDD+

ART Architecture for REDD+ Transactions

Aim - To synthesize studies quantifying carbon losses and gains in tropical moist forest to bring clarity on:

- how estimates from disparate data sources **align**
- how estimates/methods can be **integrated** into monitoring and reporting

Work inspired by the collaborative effort from R2D2 workshop:
"Quantifying Regrowth and Recovery from Deforestation and Degradation (R2D2)."
March 2024



Synthesising 115 studies

- **Who?** *Viola, Amelia and Clément*
- **Why?** *To bring clarity on how estimates of post-disturbance aboveground carbon loss/gain from different data sources align*
- **When?** *Peer-reviewed studies published 1980 to 2024*
- **What?** *Key variables extracted from each paper*

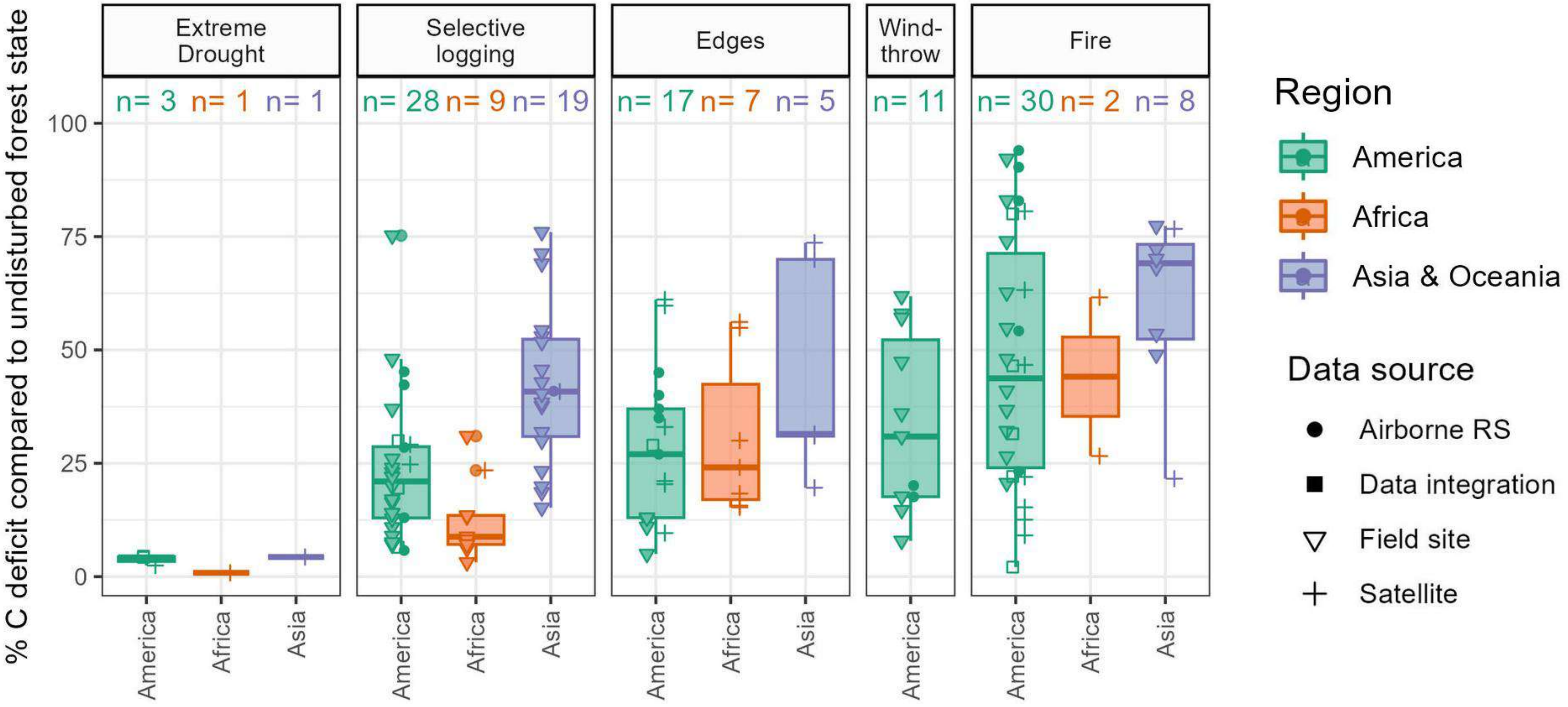
Study Type: *Field data, Data Integration,*
Airborne Remote Sensing, Satellite

Region: *America, Africa, Asia*

- Study ID
- Study Type
- Forest Type
- Degradation Driver
- Cumulative Disturbance?
- Region
- Sub-region
- Age/YSLD
- **Absolute C loss/gain**
- **Percent Loss/gain**
- Error
- Additional comments

~ 60-fold difference in carbon losses across degradation types

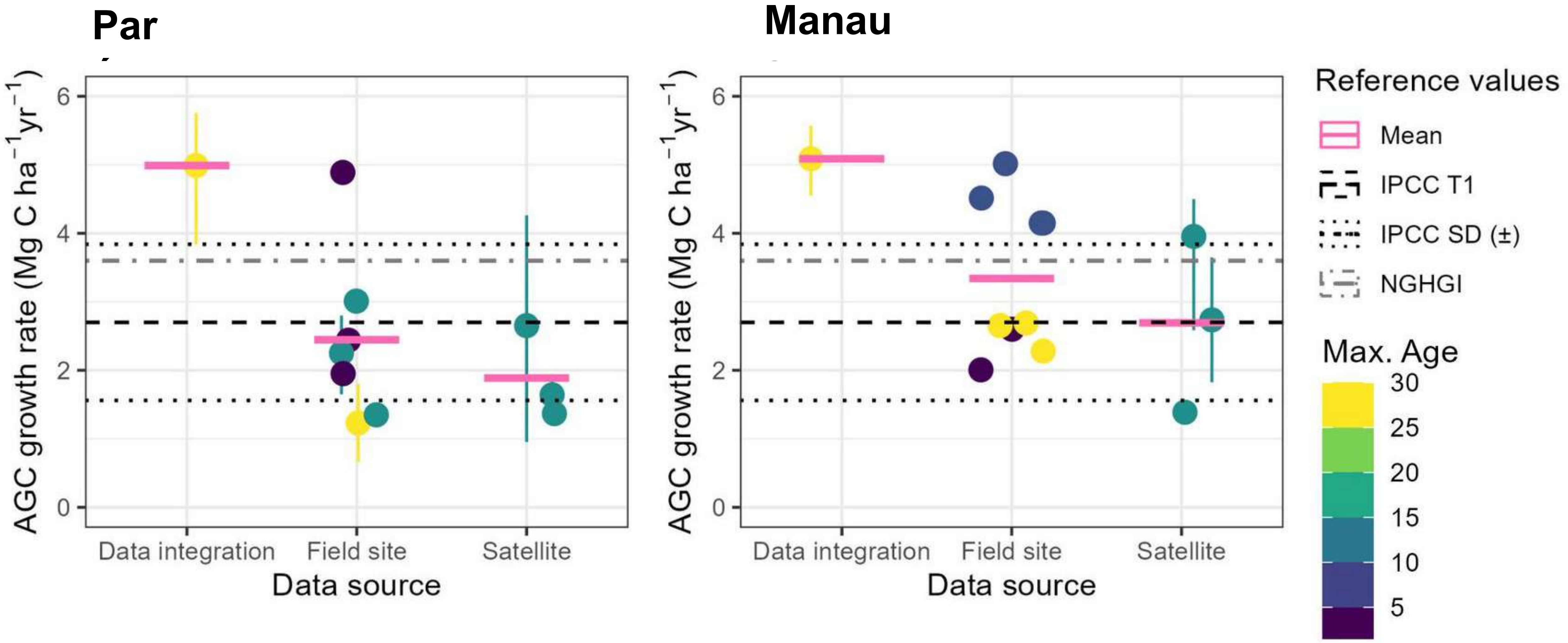
Synthesising 65 papers on carbon losses from different degradation types



(n = number of studies; each point is a study)

Regional regrowth rates across data sources may not align

Aboveground carbon accumulation rates in young Secondary Forest in the Brazilian Amazon



While we hope this paper addresses many issues around carbon emissions & removals...

...Gaps remain

A multi-data synthesis of carbon losses and gains from tropical moist forest degradation and regeneration

Viola Heinrich[1,2*∞], Amelia Holcomb[3*], Simon Besnard[1], Daniela Requena Suarez[1], Susan Cook-Patton[4], Clement Bourgoin[5], Robin Chazdon[6], David Gibbs[7], Flavia Souza Mendes[8], Iain McNicol[9], Charlotte Wheeler[10, 11], Celso Silva Junior[12, 13], Bienvenu Amani[14], Na Chen[15], Philippe Ciais[16], Ricardo Dalagnol[17], Xueyuan Gao[18,19], Bruno Hérault[20], Jo House[2], David Lapola[21], Mengyu Liang[22], Gert-Jan Nabuurs[23], Johannes Reiche[24], Stephen Sitch[25], Ruben Valbuena[26], Anne-Juul Welsink[24], Yidi Xu[16], Luiz Aragão[25,27], Martin Herold[1,28]

What is the area of secondary forest in the Brazilian Amazon biome in 2022?

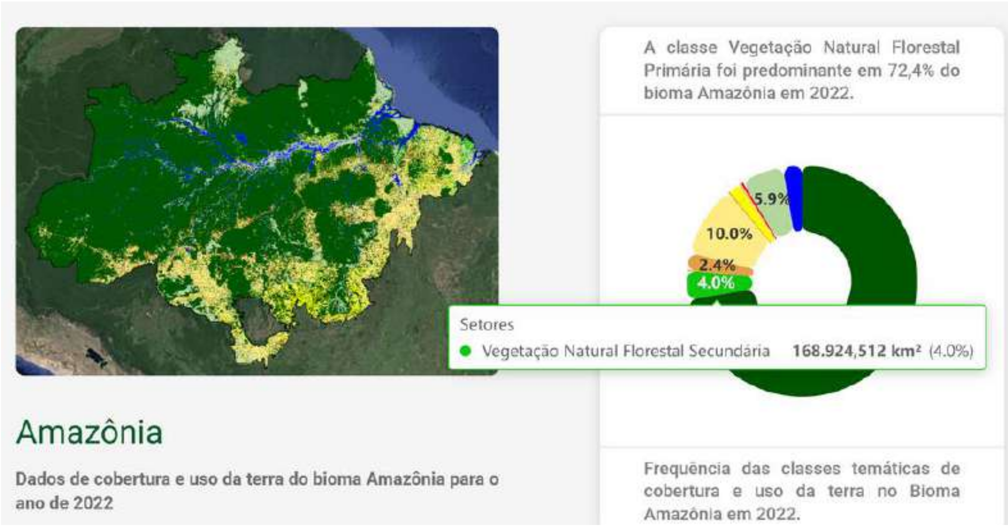
168,924.51km^2

75,709.39 km^2

51,100.00 km^2

What is the area of secondary forest in the Brazilian Amazon biome in 2022/2023?

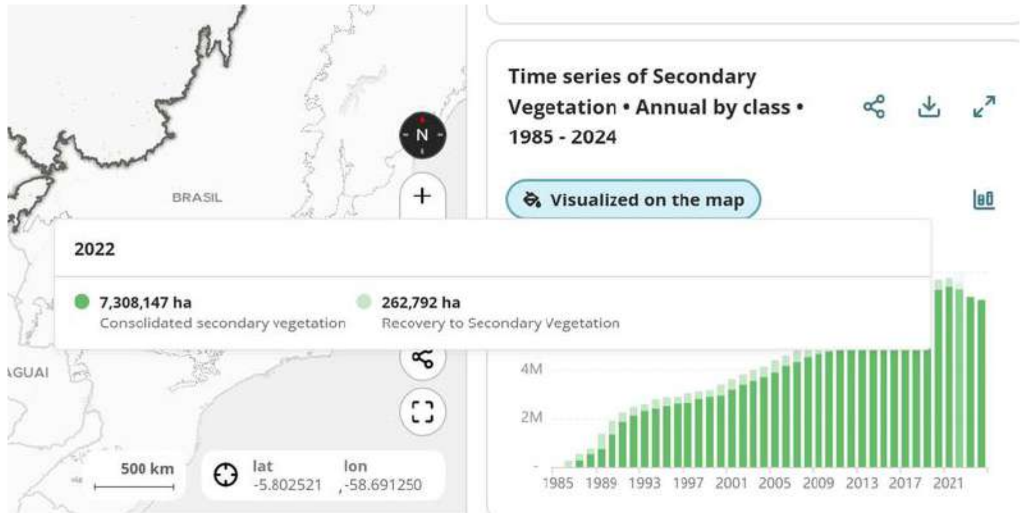
168,924.51km^2



TerraClass

75,709.39 km^2

MAPBIOMAS



51,100.00 km^2

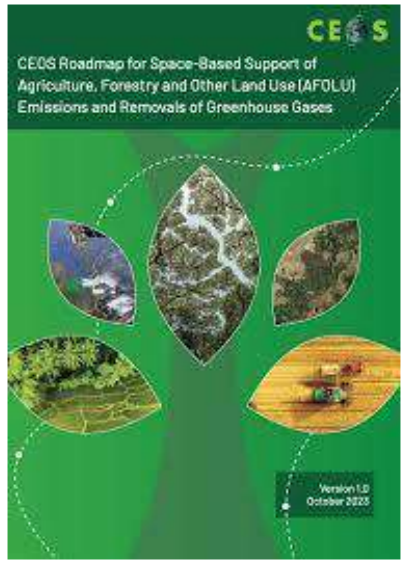
Deforestation and Forest Degradation in the Amazon - Update for year 2023 and assessment of humid forest regrowth

Beuchle, R., Bourgoin, C., Carreiras, J., Heinrich, V., Achard, F.

The MapBiomas dataset described above (section 4.4) was compared with the forest regrowth *sensu lato* obtained from JRC-TMF for the year 2023. Overall, Silva Junior et al. (2020) [83] mapped 56,900 km^2 of secondary forest in the Brazilian Amazon moist forest domain (as defined by the JRC-TMF dataset) while JRC-TMF mapped 51,100 km^2. However, there is a strong spatial mismatch

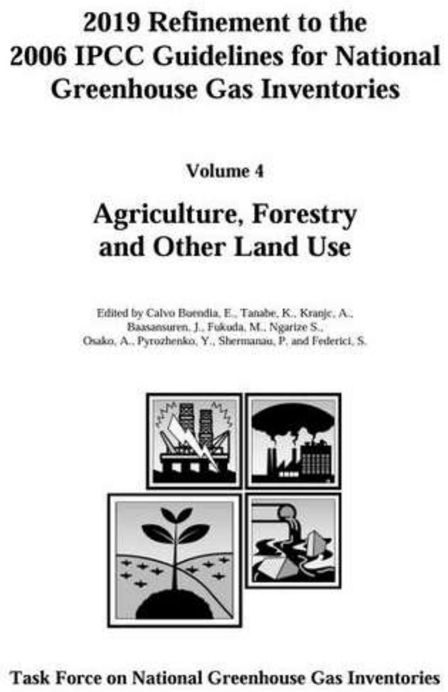
…while new estimates drive science forward, they can create confusion for application purposes

Earth Observation Initiatives



CEOS Committee on Earth Observation Satellites

International efforts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ART Architecture for REDD+ Transactions

Workshop aims

1. Explore the main **advances made and challenges** in mapping disturbance & regenerating forest.
2. Synthesize available estimates of **carbon emissions and removals** following disturbance/regrowth for (sub-)national estimations in Brazil.
3. Explore the **diverse metrics** for measuring regeneration success.
4. Discuss the applications and lessons learned for **MRV**

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Agenda Overview

Daily themes

Day 1

Mapping & Data Integration

Talks:
Session 1.1 - Objectives + previous work
Session 1.2 - Mapping Secondary Forest - where are they regrowing according to what dataset?
Session 1.3 - Linking Field, ALS + satellite data of secondary forest
Session 1.4: Keynote address: Thelma Krug + Frank Martin Seifert

Workshop discussions: “moving towards aligning field data and satellite estimates of secondary forest extent & age”

Sala 2

Sala 6

Auditorium

Agenda Overview

Daily themes

Day 2

Quantifying carbon fluxes & other metrics

Talks:
Session 2.1 - Biomass datasets + missions
Session 2.2 -Estimates of carbon accumulation from various approaches & other metrics

Workshop discussions: “Measuring disturbance & regeneration success: metrics in a changing climate”

Sala 2

Sala 6

Auditorium

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Agenda Overview

Daily themes

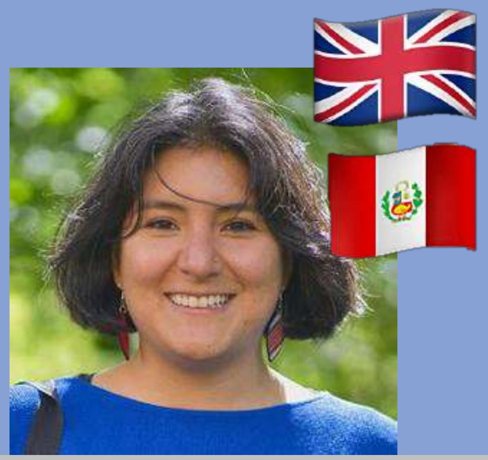
Day 3

Policy Integration

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

Workshop discussions: “Research priority topics, planning next steps for MRV-related activities in a changing climate”

Sala 2



Sala 6

Auditorium

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The Essentials

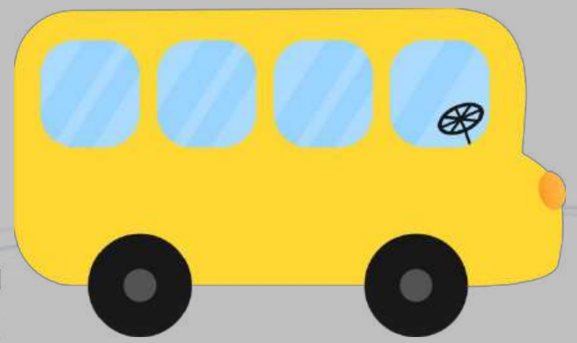
Breaks, Lunch, Wifi + Toilets

Day 1: @ 10.45 - 11.15 & 15.00 - 15.30
Day 2: @ 10.30 - 11.00 & 15.00 - 15.30
Day 3: @ 10.30 - 11.00

@ 12.30 - 13.30 (+ Group Photo)
@ 12.45 - 13.45
@ 12.30 - 13.30

Wifi:
Username: Syncer
Password: syncer2025

Turn left, down the stairs



Day 1: 8.00 --------------------> 17.15
Day 2: 8.30 --------------------> 17.00
Day 3: 8.30---------------------> 15.45

Dinner at Sheriff Tonight @ 19.00
Depart from Hotel at 18.30

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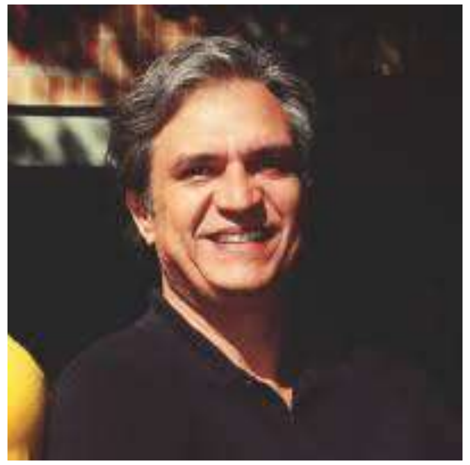
Thank you / Obrigada

Hannah

Isadora

Luiz



Martin

Daniela

Celso

Christin

Lilli

Adriana

Denise

Dana

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Thank you / Obrigada

Funding

Organisation

GFZ Helmholtz Centre for Geosciences

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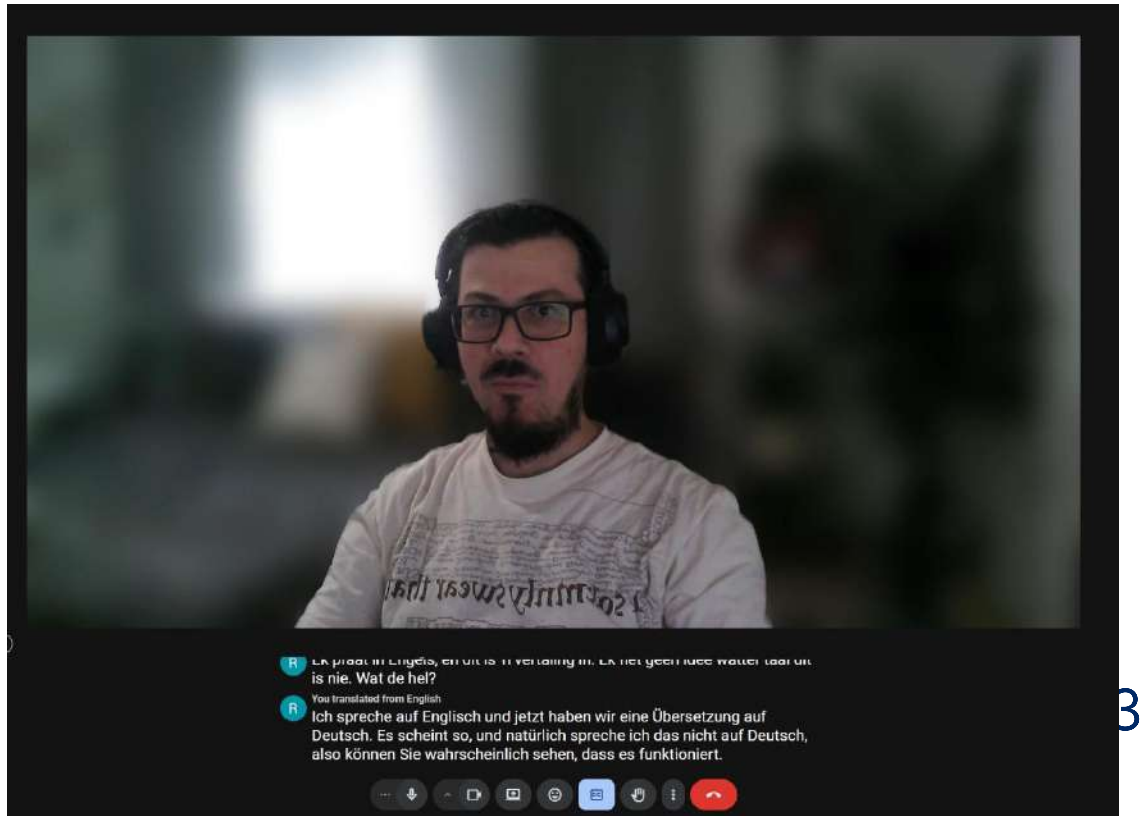
Online translation

CTrees



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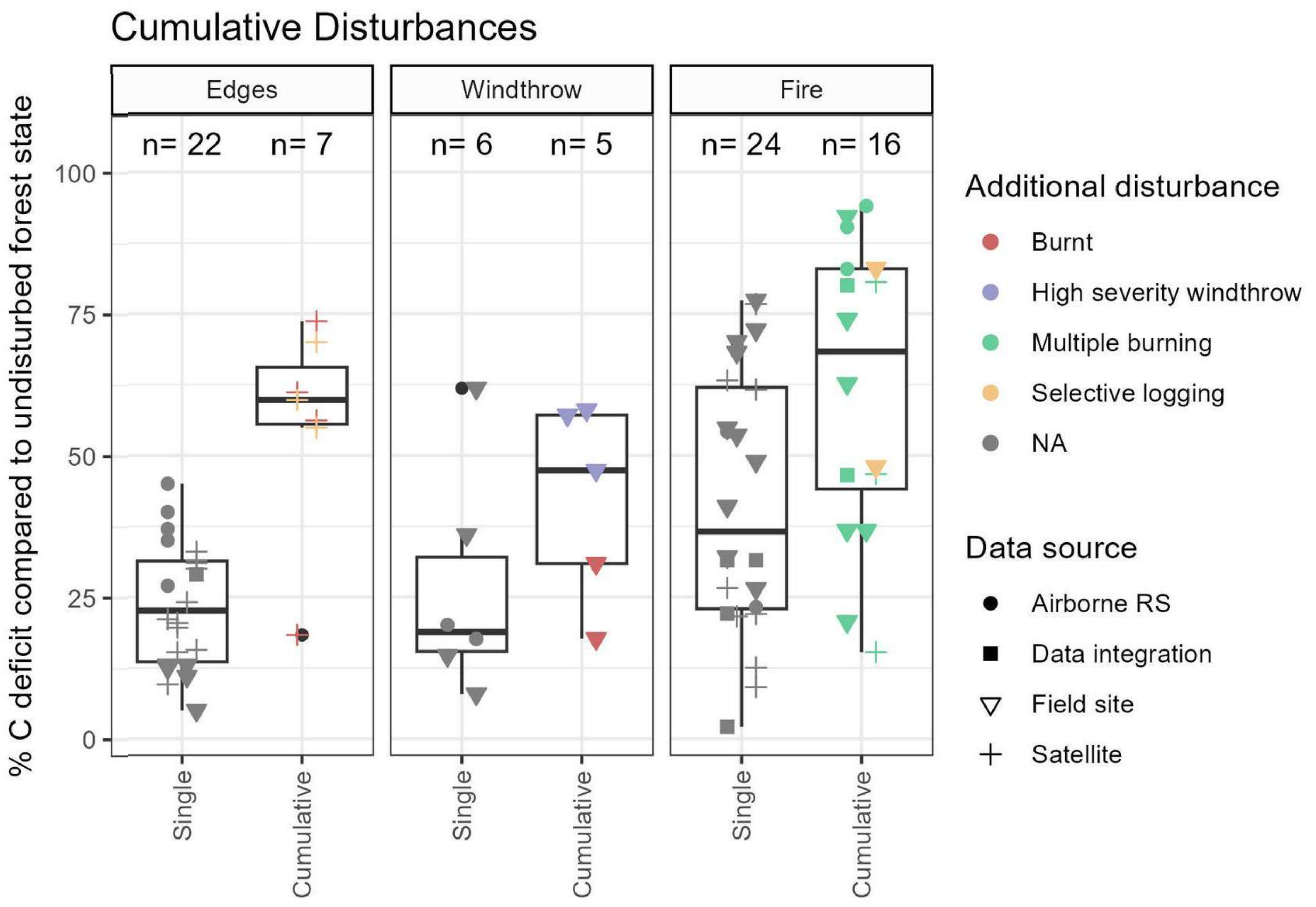
Cumulative disturbances result in greater carbon losses

- It is crucial to consider cumulative disturbances when quantifying C losses
- Satellite remote sensing driving the science on forest dynamics along edges, with generally good agreement

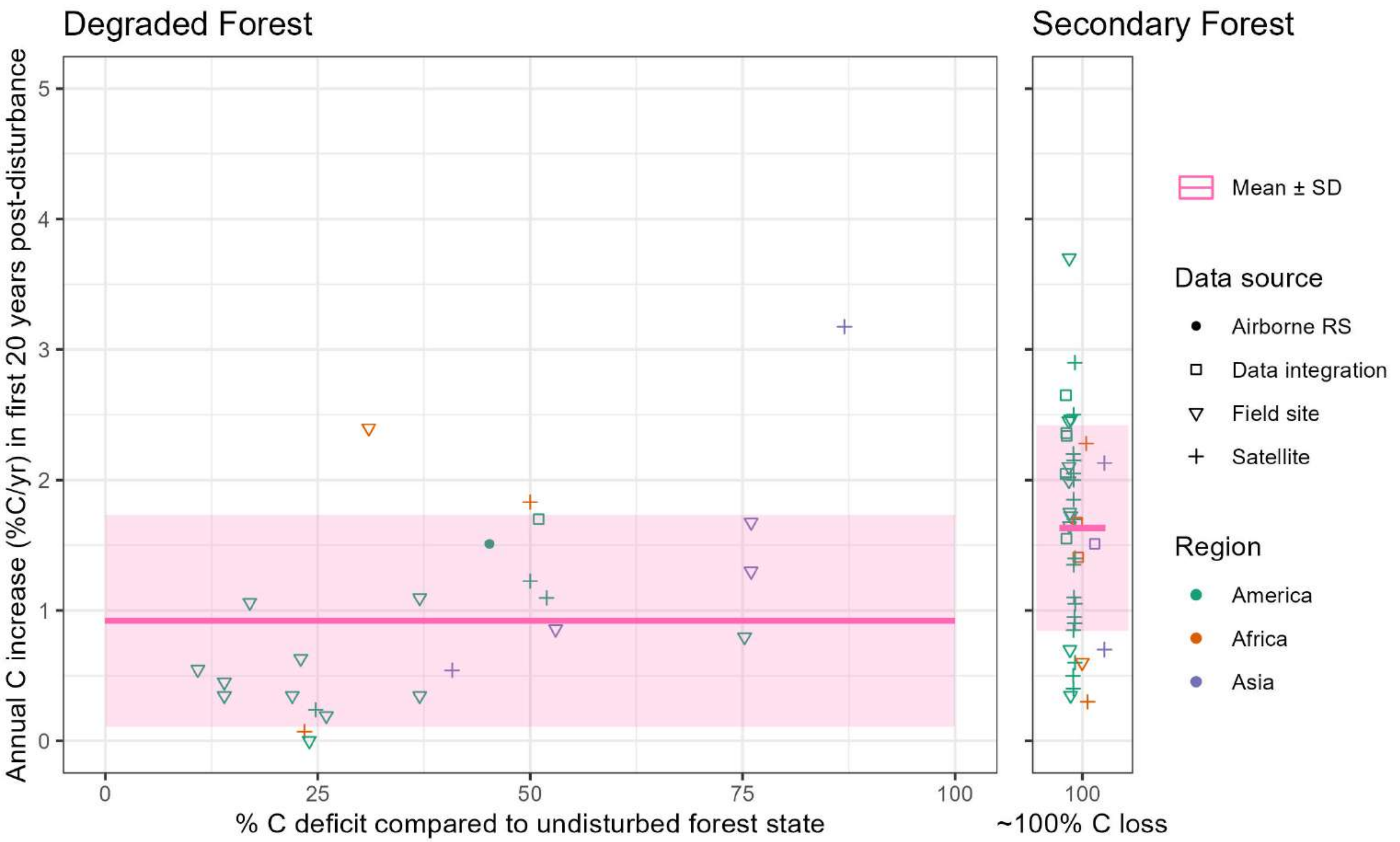


(n = number of studies; each point is a study)

Carbon gains in recovering degraded and secondary forests

Main results after synthesising 67 papers

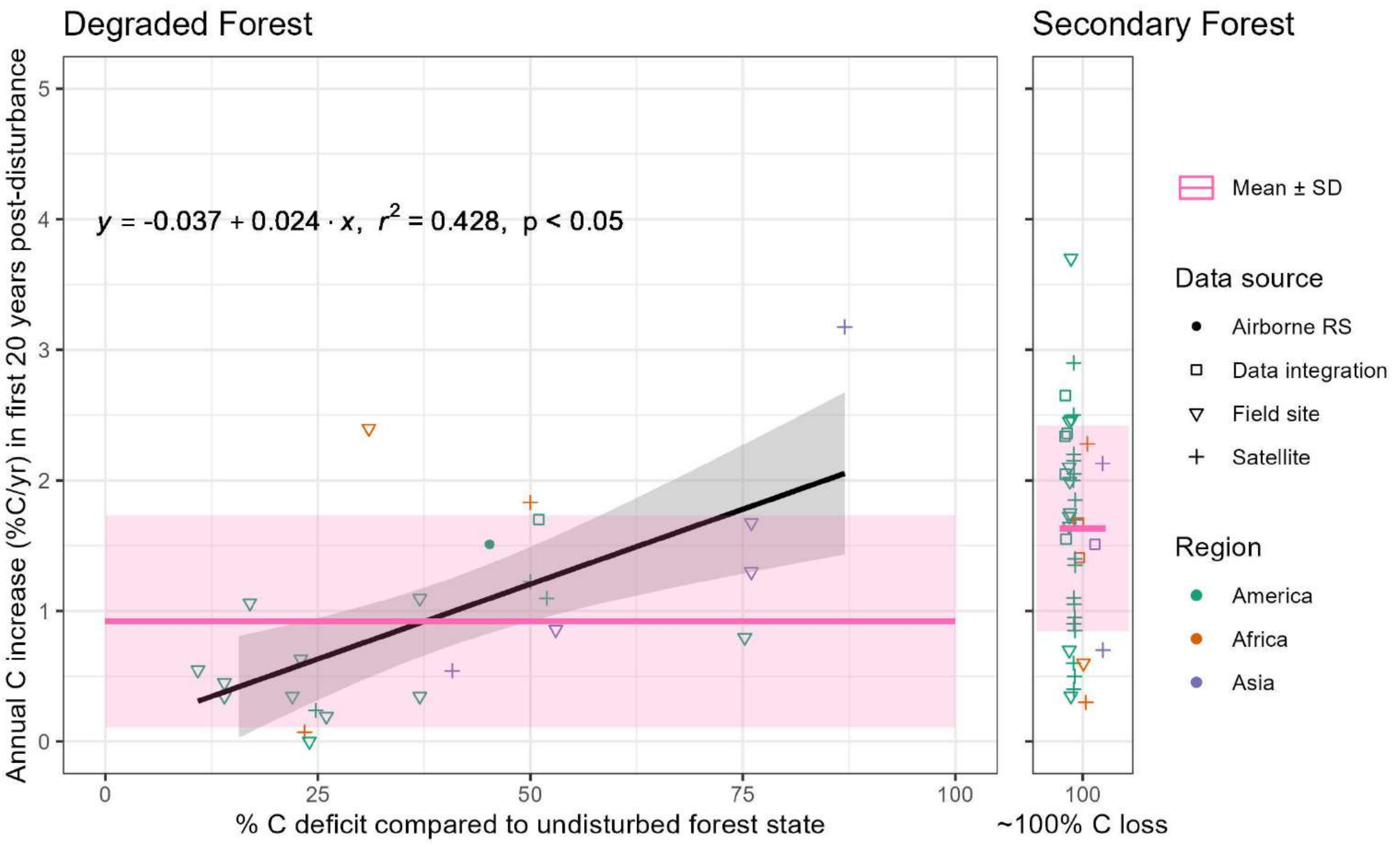
1. Lower regrowth rate in degraded than secondary forest.
   But low confidence



Carbon gains in recovering degraded and secondary forests

Main results after synthesising 67 papers

1. Lower regrowth rate in degraded than secondary forest.
   But low confidence
2. Faster C accumulation rate in degraded forest with greater C deficit?



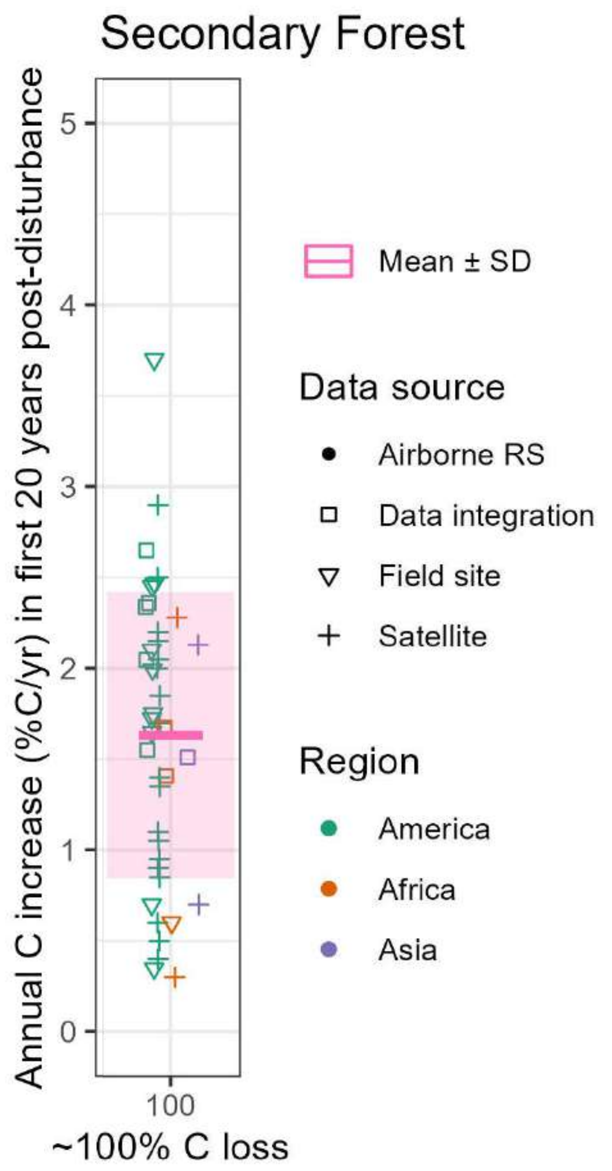
Carbon gains in recovering degraded and secondary forests

Main results after synthesising 67 papers

1. Lower regrowth rate in degraded than secondary forest.
   But low confidence
2. Faster C accumulation rate in degraded forest with greater C deficit?
3. Large variation in C gains in secondary forest reflecting regional regrowth complexity?

A spatial bias towards America, specifically Amazon

54/70 America based data points are from Amazon



Session 1.2: Mapping Secondary Forest – where are they regrowing according to what dataset?

São José dos Campos, 29 Oct 2025

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Official mapping of secondary forest in Brazil

Silvana Amaral

Deputy Coordinator of the Strategic Project Division 1 – DIPE 1
Earth Observation and Geoinformatics Division - DIOTG
National Institute for Space Research - INPE

São José dos Campos, SP - October, 29th, 2025

Official mapping of secondary forest in Brazil

BiomasBR - INPE´s vegetation monitoring by satellite Program

Concepts

Contribution for Carbon losses & gains

Large scale deforestation

Degradation
- **Selective logging**
- **Fragmentation**
- **Edge effects**
- **Drought/windthrow**

BiomasBR - INPE

INPE´s vegetation monitoring program by satellite image

Systematic information on native vegetation, **deforestation** (suppression) and **degradation** activities for all Brazilian biomes

Official Brazilian deforestation data for public policies

Conservation and sustainable development

To Attend different purposes → Different timing and methods

https://data.inpe.br/big/web/biomasbr/

Biomas Br

PRODES

Large scale deforestation

Inventory of
primary vegetation loss

<u>Annual</u> Monitoring of Native Vegetation Suppression

https://data.inpe.br/big/web/biomasbr/prodes-monitoramento-anual-da-supressao-de-vegetacao-nativa/

What is Prodes deforestation/suppression?

Deforestation: removal of ***primary vegetation*** areas by ***anthropogenic*** actions.

Primary vegetation?

Amazon (forest): forest observed at the beginning of monitoring (1988)

Other biomes: “Baselines” – native vegetation at the beginning of monitoring **– 2000**

Deforestation/Suppression:

Forest: loss of >70% forest cover;
Loss of biomass, biodiversity, and ecological functions of forests;

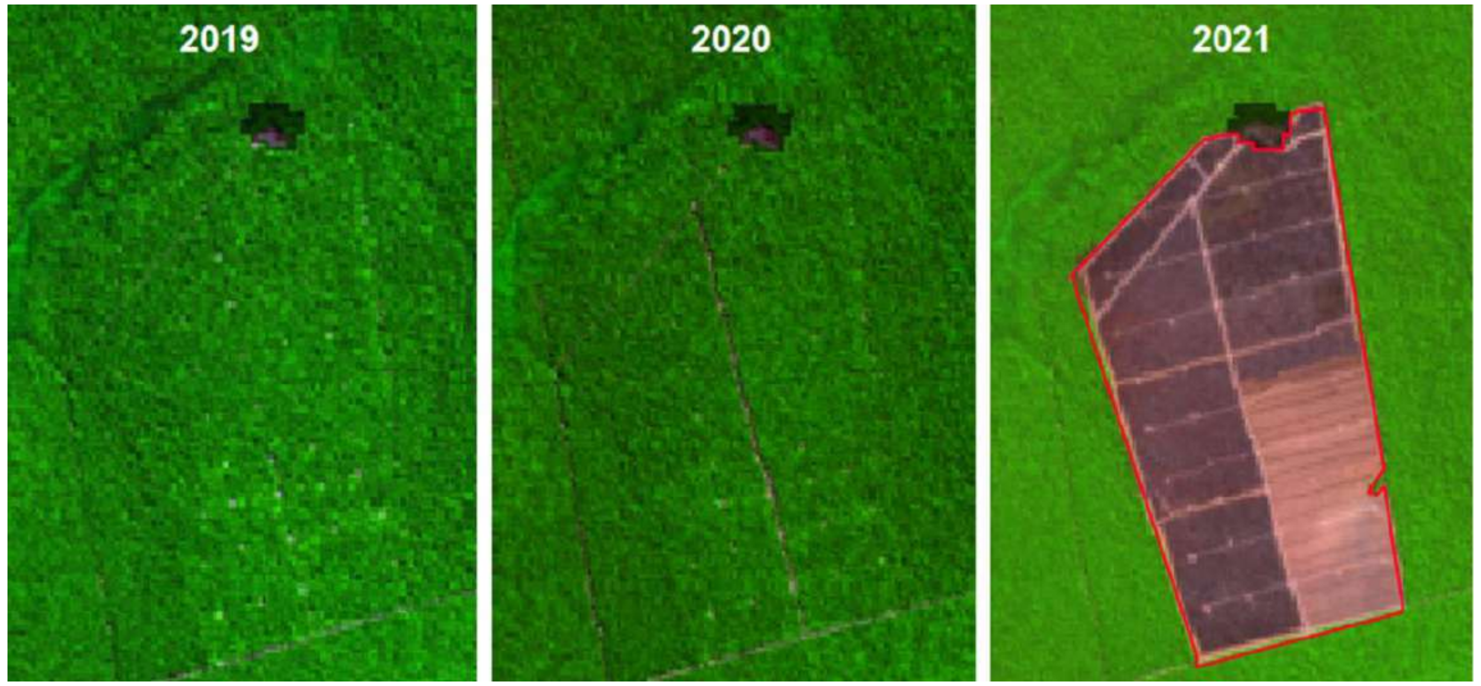
Open non-forest Vegetation: complete removal of native vegetation; exposed soil/other cover

Deforestation/Suppression mapping

Observed by satellite imagery at the current year

AND

Primary vegetation observed in two previous years

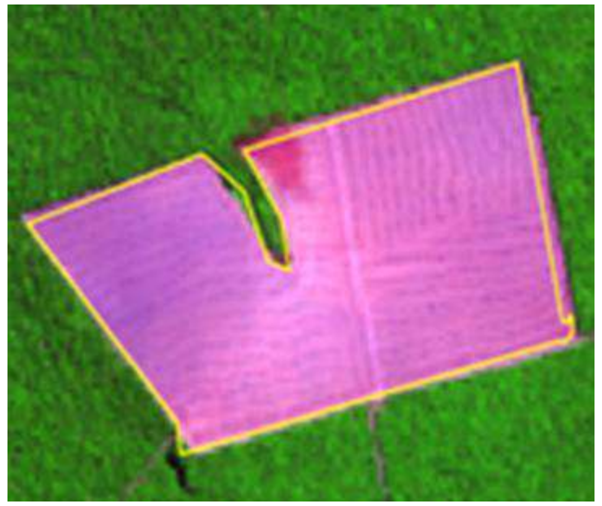


Almeida et al. (2022) Metodologia Prodes e Deter <http://urlib.net/8JMKD3MGP3W34T/47GAF6S>

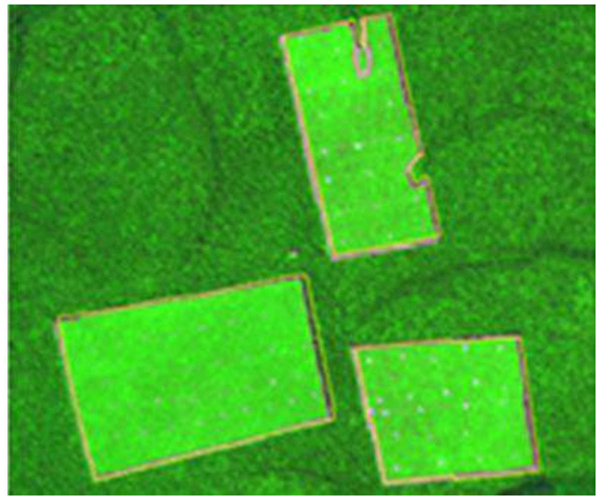
Prodes - Annual Monitoring of Native Vegetation Suppressio

Prodes Amazon – Class

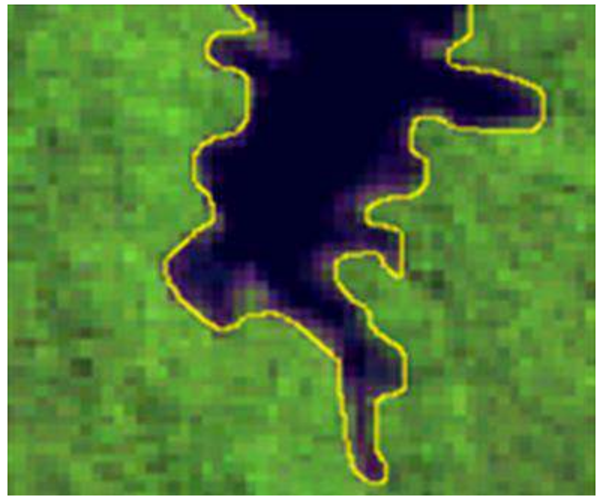
Clear-cut deforestation
bare soil



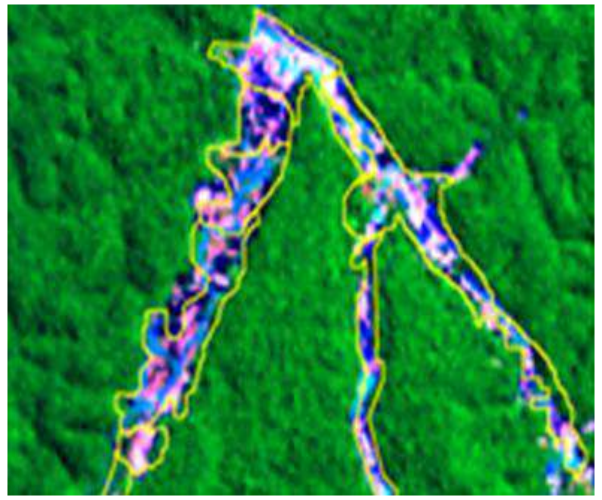
Clear-cut deforestation
herbaceous vegetation



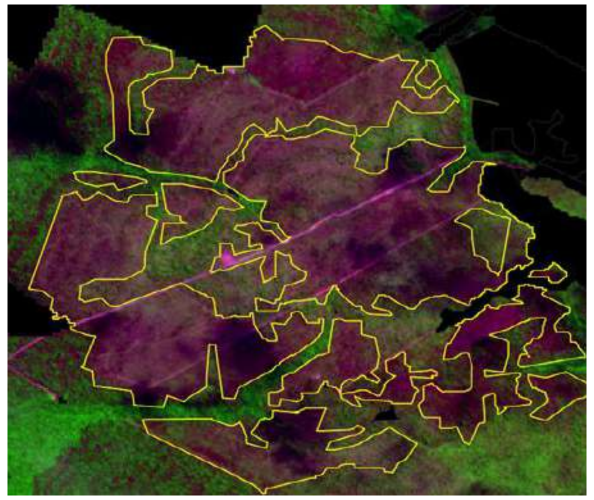
Clear-cut deforestation
flooded forest



Clear-cut deforestation
mining



Deforestation by
progressive degradation



Minimum Mapping Unit **1 ha** (6,25 ha - longest historic series)

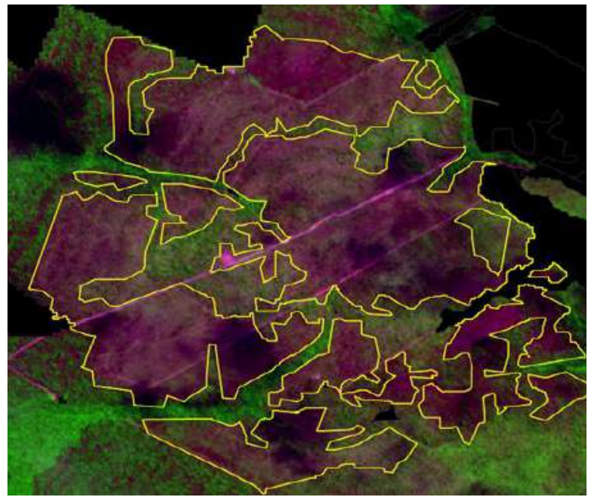
Biomas Br

Prodes - Annual Monitoring of Native Vegetation Suppression

PRODES

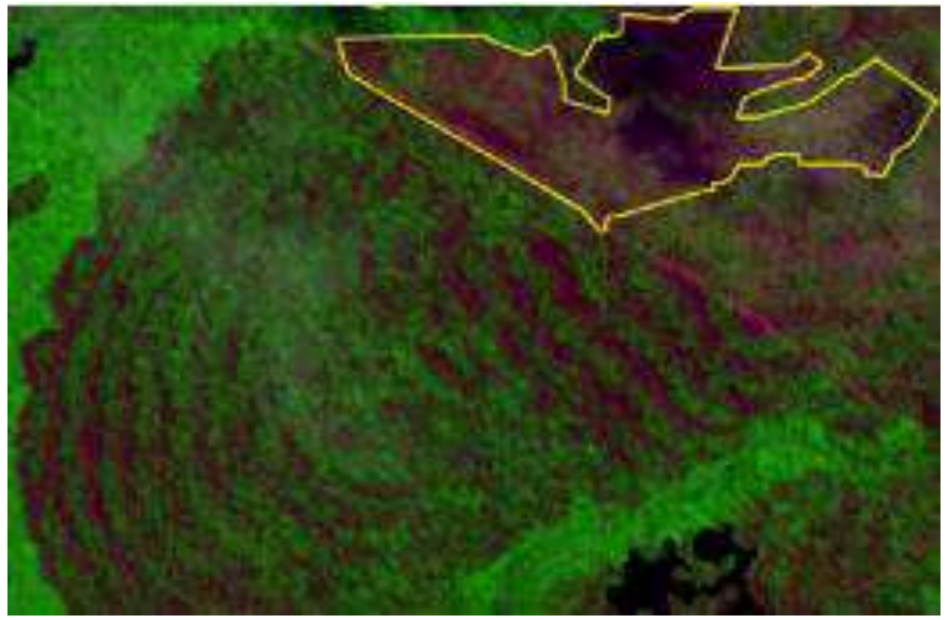
Prodes Amazon – Degradation Classes - from 2022

Deforestation by Progressive degradation



Selective logging

Forest fire recurrence



Prodes - Annual monitoring of native vegetation suppression

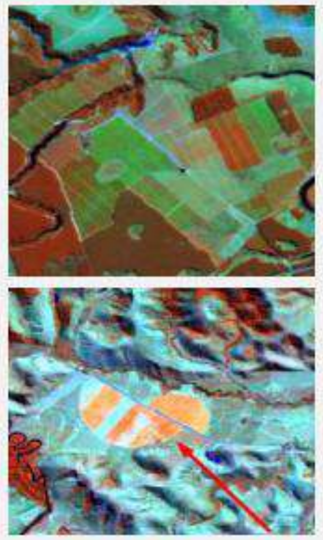
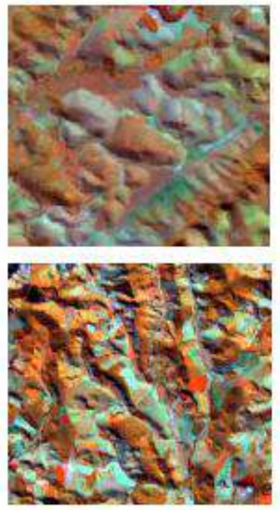
Other biomes
Only

Native Vegetation Suppression
“DEFORESTATION”

Interpretation keys
Interpretive classes:

- Agriculture
- Pasture
- Mining
- Urban
- Forestry
- Water
- etc.

Tabela 3.2 – Chave de interpretação para as classes mapeadas e interpretadas pelo Prodes Mata Atlântica.

Classe	Subclasse interpretativa	Elementos da fotointerpretação	Exemplo composição Sentinel R8G11B4	Exemplo Google Earth
Desmatamento	Área Agrícola	**Cor:** Vermelho, Verde ou Azul **Tonalidade:** Clara (maioria), varia com o vigor da pastagem e tempo de colheita; **Textura:** Lisa (maioria), rugosidade leve a depender do estágio de crescimento da cultura; **Forma:** Regular, retangulares e cilíndricas; **Padrão:** Costuma ser regular a depender da região; **Tamanho:** Grande, porém pode variar de médio a pequeno conforme tipo de propriedade; **Contexto:** São geralmente cercadas por algum elemento físico; a matiz muda a depender do tipo de cultura e fase de desenvolvimento. Pode ser evidenciado periodicamente feições de solo exposto.		
Desmatamento	Área de pastagem	**Cor:** Verde ao Magenta; Tonalidade: Clara, varia com o vigor da pastagem; **Textura:** Lisa, pode variar conforme o manejo; **Forma:** Costuma ser regular a depender da região; **Padrão:** Costuma se regular a depender da região; **Tamanho:** Costuma ser grande a depender da região; **Contexto:** O vigor das herbáceas varia ao longo do ano, conforme a distribuição pluviométrica da região. Ocorre em toda a extensão do bioma; costuma acontecer em regiões de relevo acidentado montanhoso intercalados de fragmentos de florestas.		

METODOLOGIA DO SISTEMA PRODES MATA ATLÂNTICA – Edição 2023, INPE (2025)

Prodes - Annual Monitoring of Native Vegetation Suppressio

Prodes BRASIL

Since 1988- Brazilian Legal Amazon

All Biomes* from 2001 to **2023** (1ha)

Sentinel-2 - Brazil Data Cube, Process automation

Official deforestation data from the Brazilian government

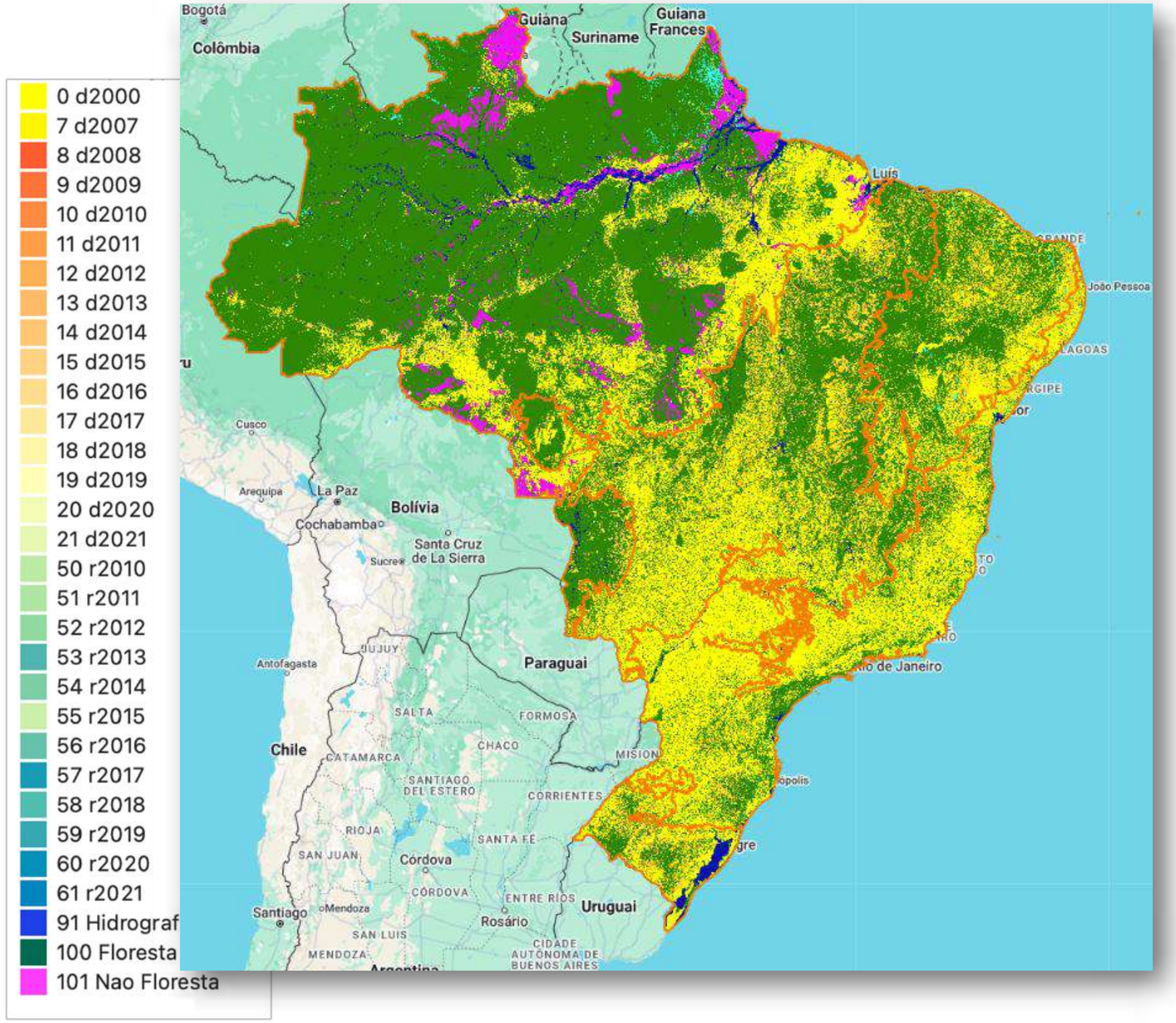
- *Public policies: PPCDAm, Cerrado, 4 biomes, REDD+;*
- *Environmental compliance: Soy Moratorium, Meat TAC, EUDR*
- *Scientific productions.*

Contribution for Carbon losses & gains

Large scale deforestation

Degradation

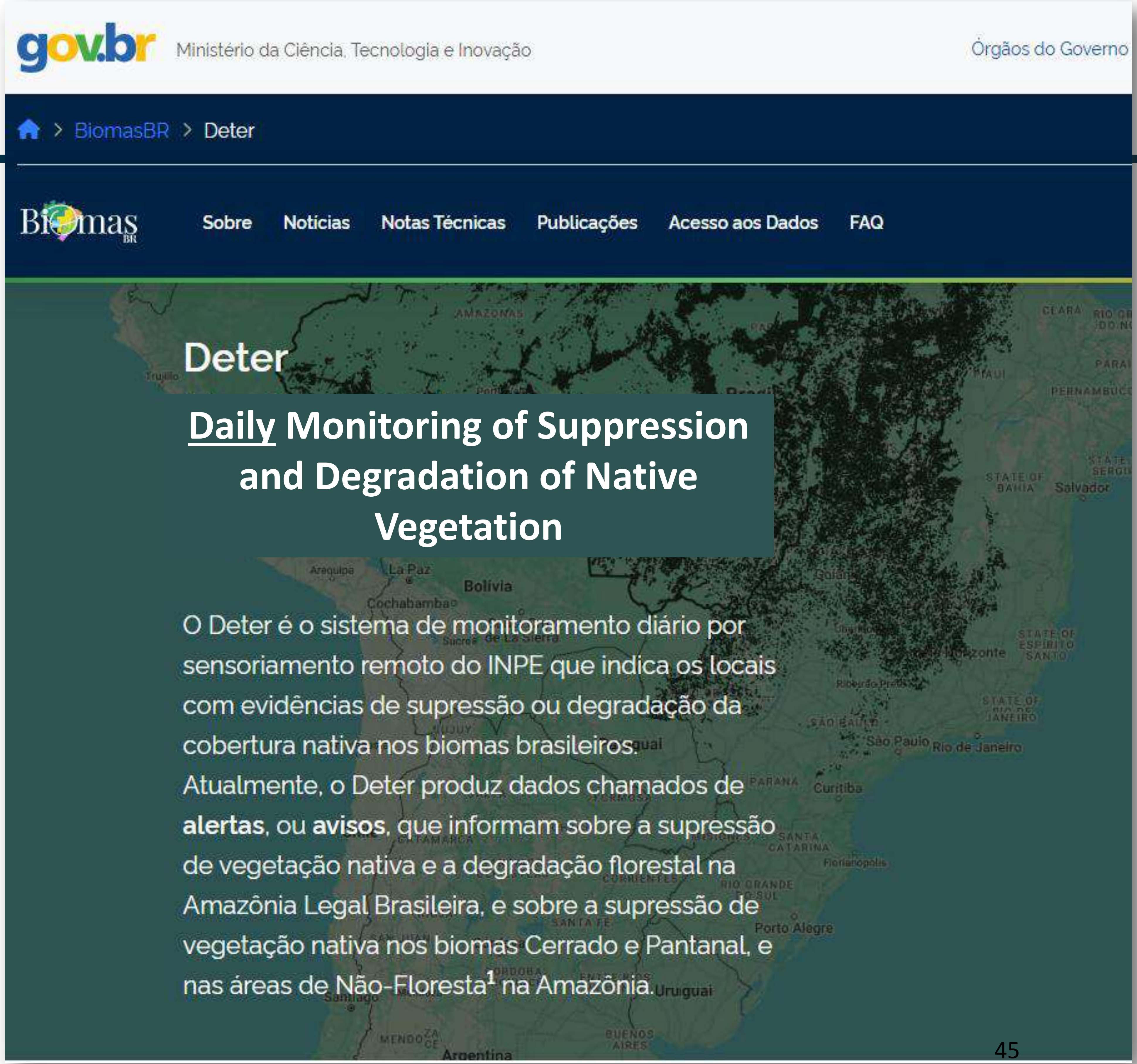
- Selective logging (AMZ)



Biomas Br

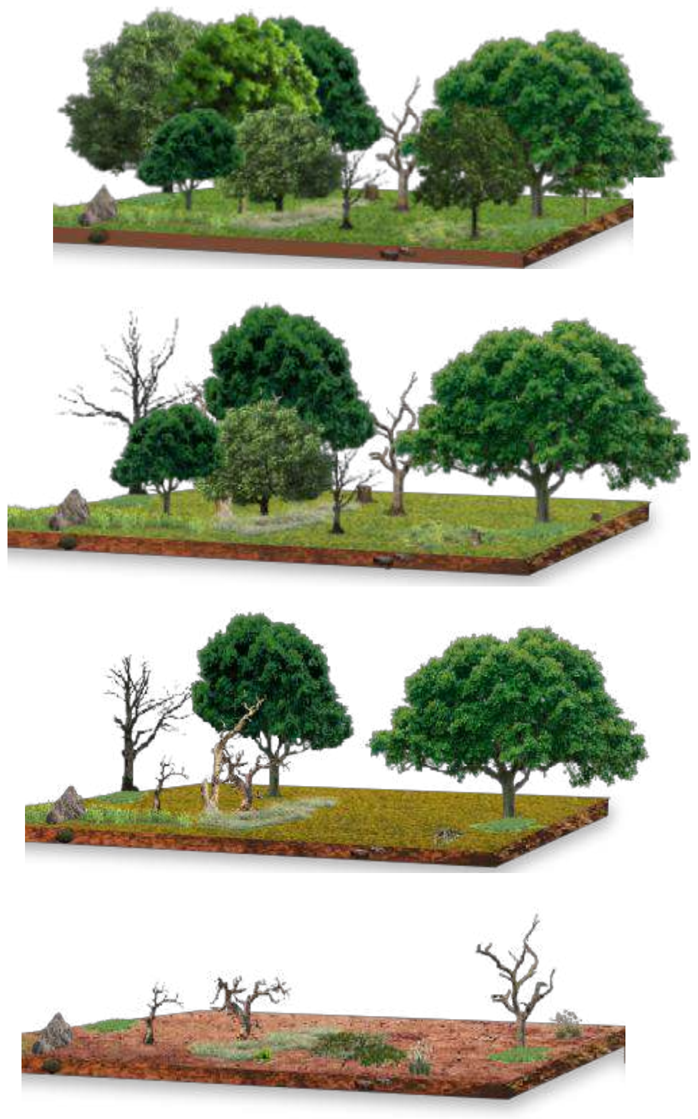
DETER

Daily Monitoring of Suppression and Degradation of Native Vegetation



https://data.inpe.br/big/web/biomasbr/deter-monitoramento-diario-da-supressao-e-degradacao-de-vegetacao-nativa/

Suppression and Degradation Alerts



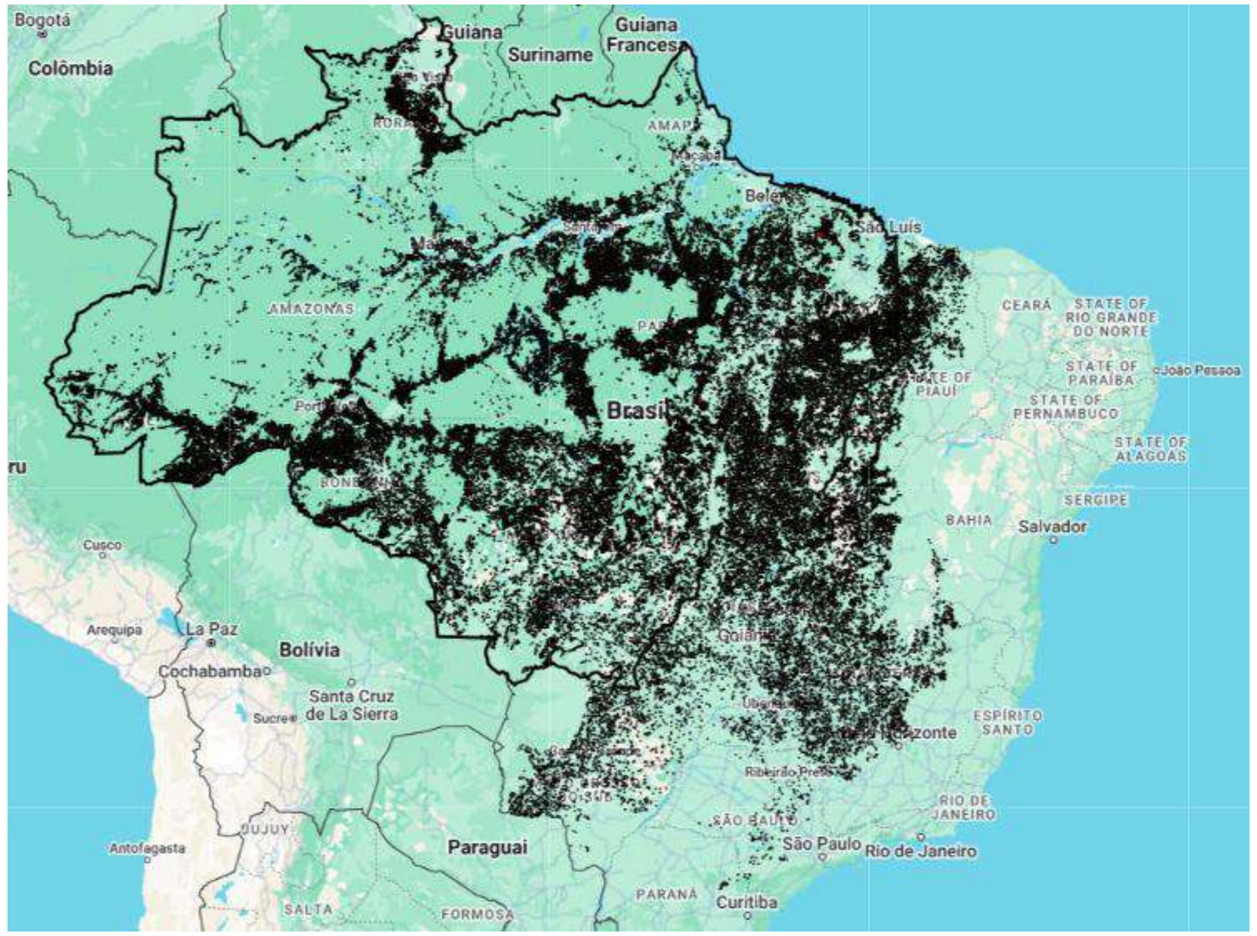
Deter

Amazon, Cerrado,
Pantanal and Non Forest Amz

Daily <u>alerts</u> are produced
Monthly aggregates - also released

Alerts are sent to control institutions
IBAMA, state and municipal environmental secretariats, etc.

Data: polygons, tables, vectors;
Available on the TerraBrasilis platform



Minimum area of **3 hectares**

https://data.inpe.br/big/web/biomasbr/deter-monitoramento-diario-da-supressao-e-degradacao-de-vegetacao-nativa/

Suppression and Degradation Alerts

Biomas Br

DETER

Deter

Daily alerts

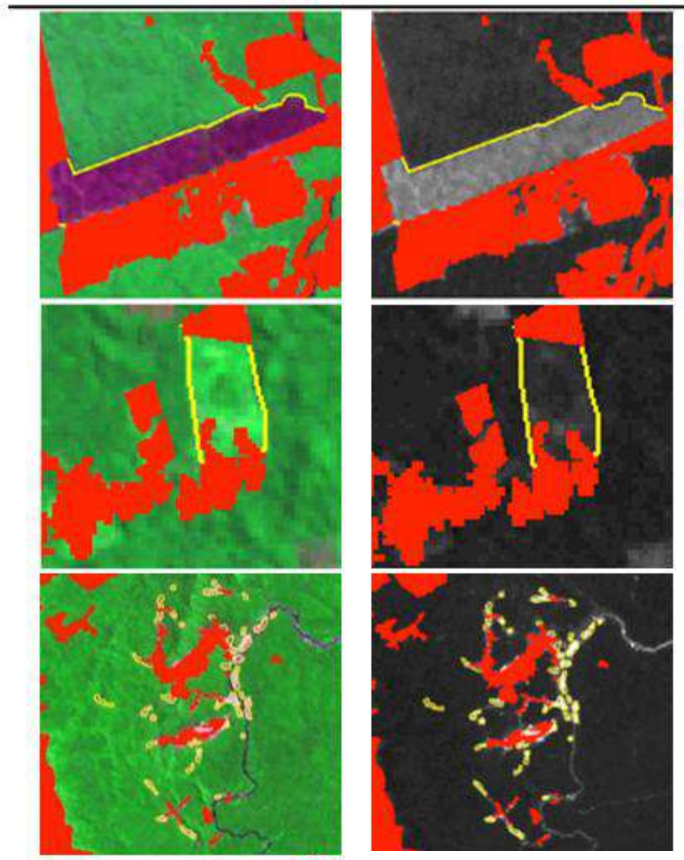
Class:

***Deforestation*/**
Suppression,

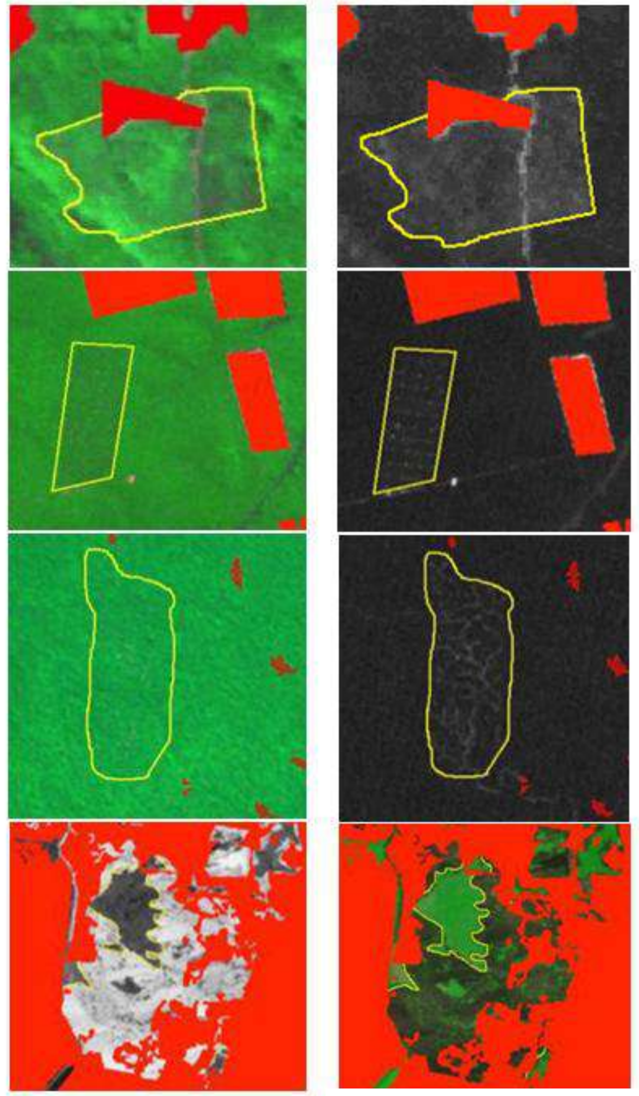
and

Fire scars,
Forest Degradation, and
Selective logging
(Proxies of forest ***degradation*)**

DETER Class - Amazon

WFI / CBERS-4	Soil/shadow	Alert Class
		Clear-cut Deforestation Bare soil Clear-cut Deforestation Vegetation Clear-cut Deforestation Mining

■ Prodes Mask

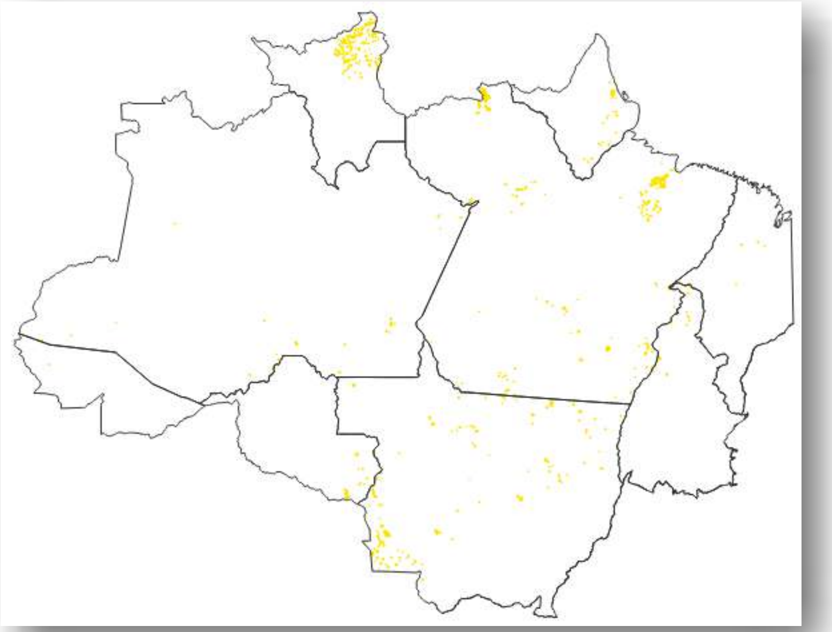
WFI / CBERS-4	Soil/shadow Fraction	Alert Class
		Forest Degradation Selective logging (geometric) Selective logging (irregular) Fire scars

■ Prodes Mask

https://data.inpe.br/big/web/biomasbr/deter-monitoramento-diario-da-supressao-e-degradacao-de-vegetacao-nativa/

Suppression and Degradation Alerts

Non-Forest Amz



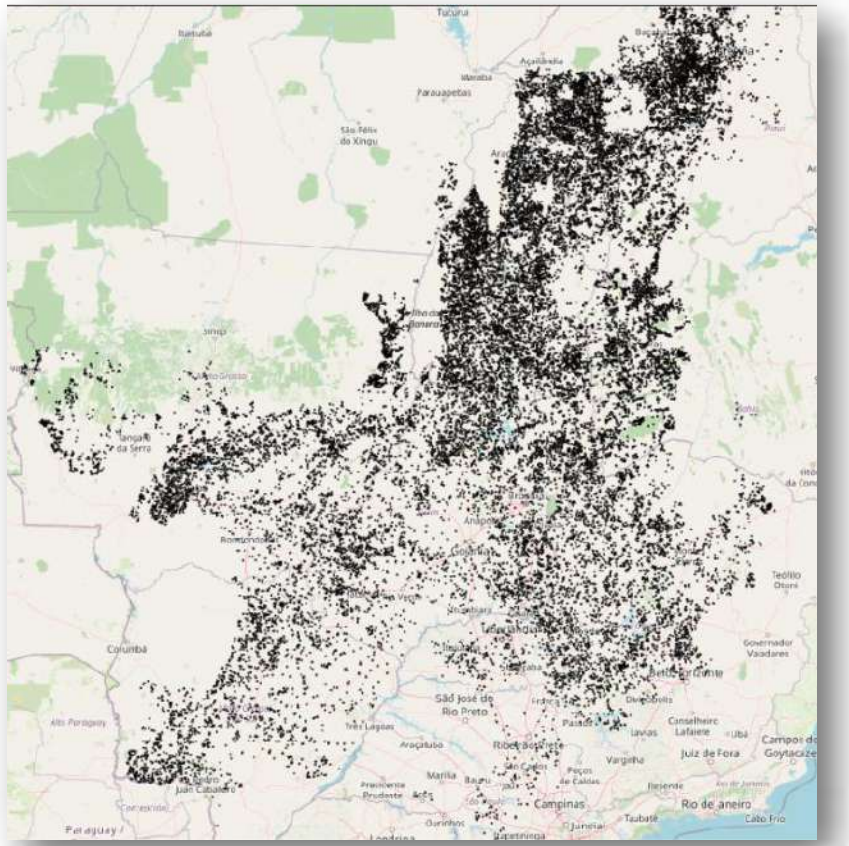
Pantanal

Deter

Daily alerts

Classes

DETER Class - Cerrado



Native Vegetation Suppression:
-With bare soil
-With vegetation

Mining
Fire scars ***(Proxies of forest degradation)***

Native Vegetation Suppression

https://data.inpe.br/big/web/biomasbr/deter-monitoramento-diario-da-supressao-e-degradacao-de-vegetacao-nativa/

Suppression and Degradation Alerts

DETER maps, polygons and statistics available at TerraBrasilis Platform

Data valuable for:

- *planning and monitoring strategies*
- *analyse **deforestation trends** by comparing periods*

Contribution for Carbon losses & gains

Degradation

- **Selective logging**

Regular and Irregular

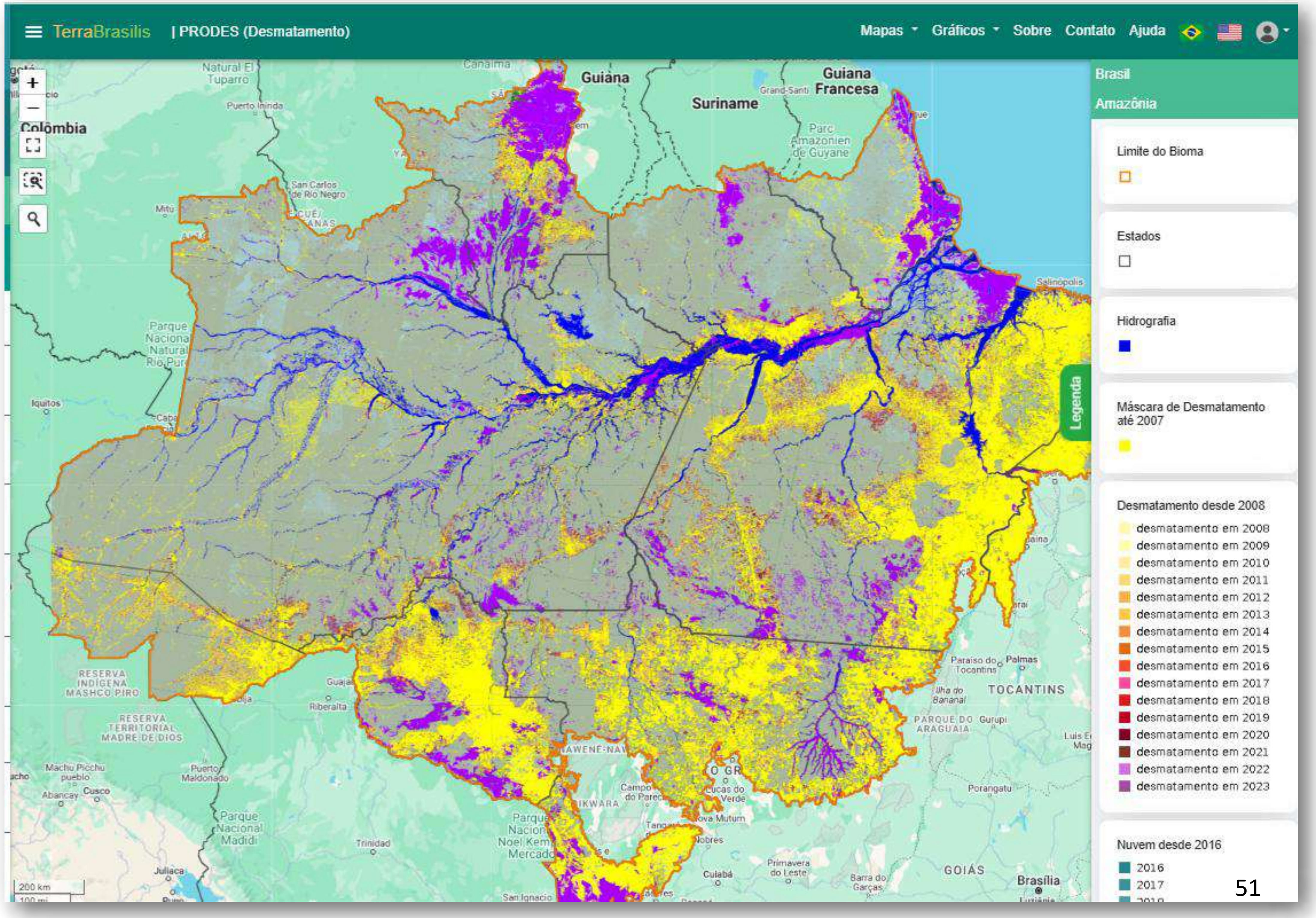
- **Fire scars**

https://terrabrasilis.dpi.inpe.br/app/dashboard/alerts/biomes/amazonia-nb/aggregated/

Systemic Monitoring of land use and land cover

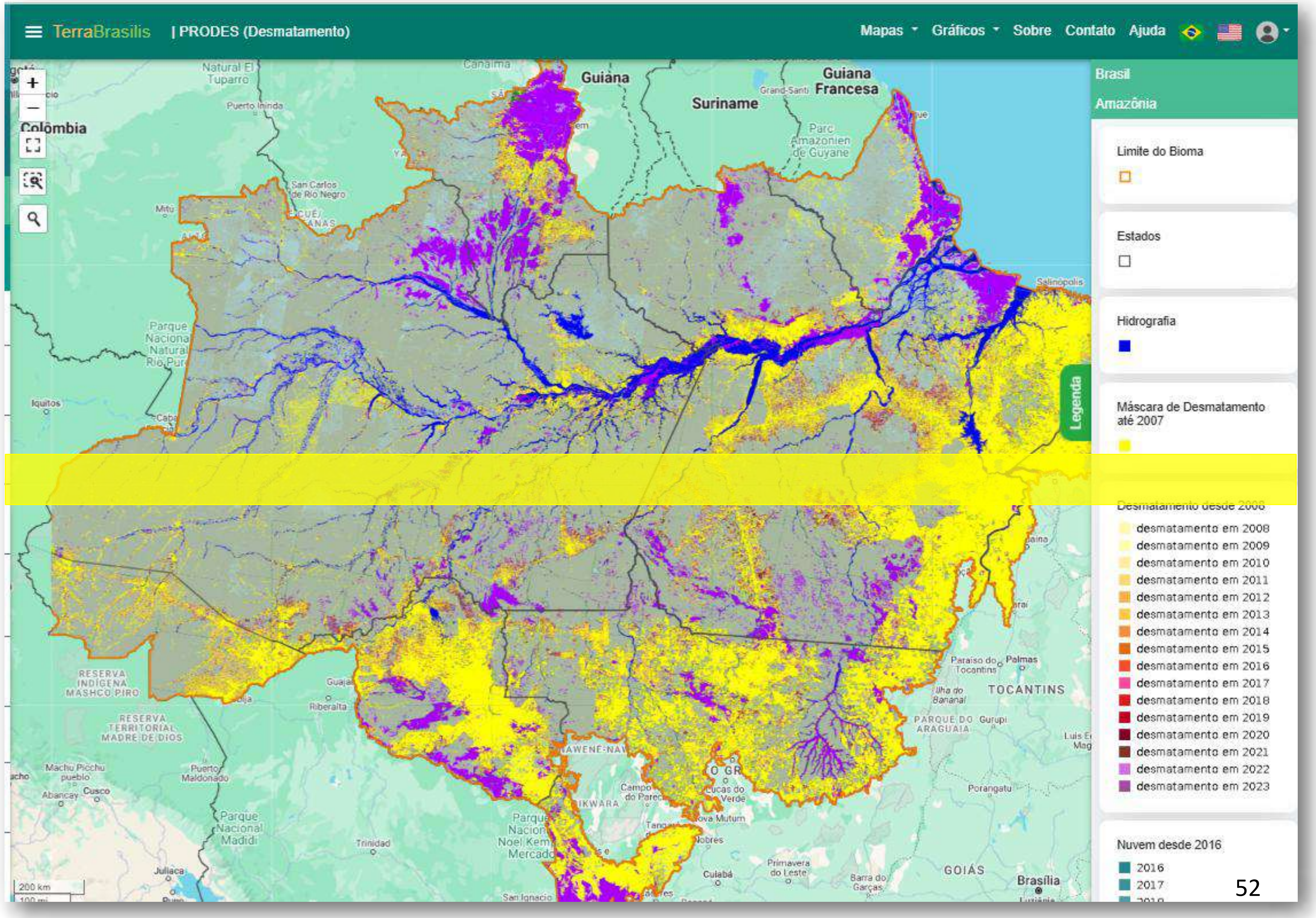
https://data.inpe.br/big/web/biomasbr/terraclass-monitoramento-sistemico-de-uso-e-cobertura-da-terra/

What land use and land cover has replaced native vegetation?



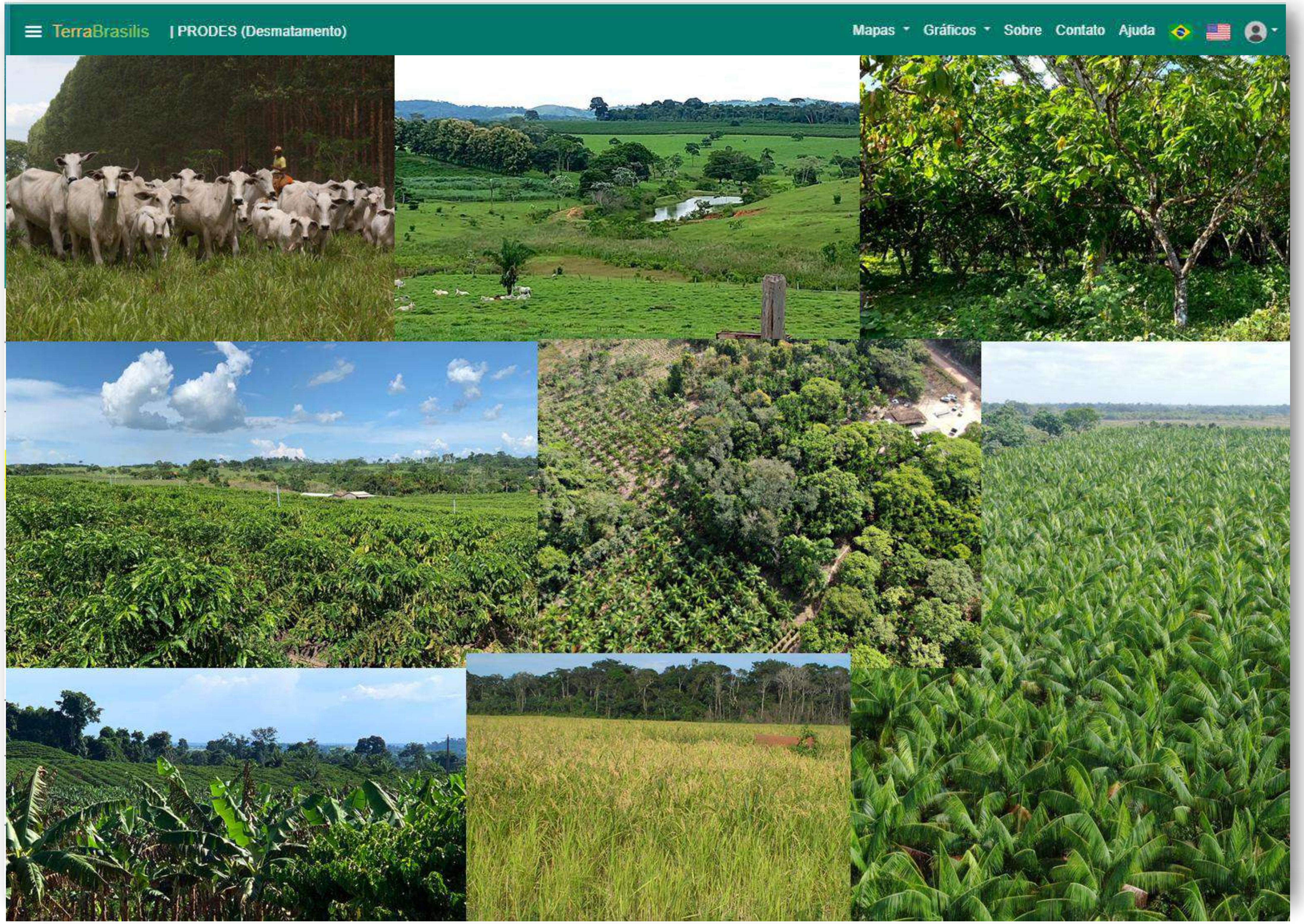
From deforestation (Prodes)

What land use and land cover has replaced native vegetation?



From deforestation (Prodes)

What land use and land cover has replaced native vegetation?



From deforestation (Prodes)
to
Land use and cover TerraClass

Ventirueri (2025)

Biomas Br

TERRACLASS PROJECT

TerraClass

Partnership between INPE and EMBRAPA (since 2011)

Embrapa
MINISTÉRIO DA AGRICULTURA E PECUÁRIA
GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

INPE
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO
GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

Biomas Br

TerraClass – Data Production

TerraClass

Embrapa

- Herbaceous Pasture
- Shrub/Tree Pasture
- Semi-perennial Agricultural Crop
- Temporary Agricultural Crop of 1 Cycle
- Temporary Agricultural Crop More than 1 Cycle
- Silviculture
- Perennial Agricultural Crop

INPE

PRODES

- Primary Natural Forest Vegetation
- Water Body
- Non Forest
- Deforestation

TerraClass

- Secondary Natural Forest Vegetation
- Mining
- Urban
- Aquaculture
- Others

COEAM (2025)

METHODOLOGY

Thematic Classes

Agriculture

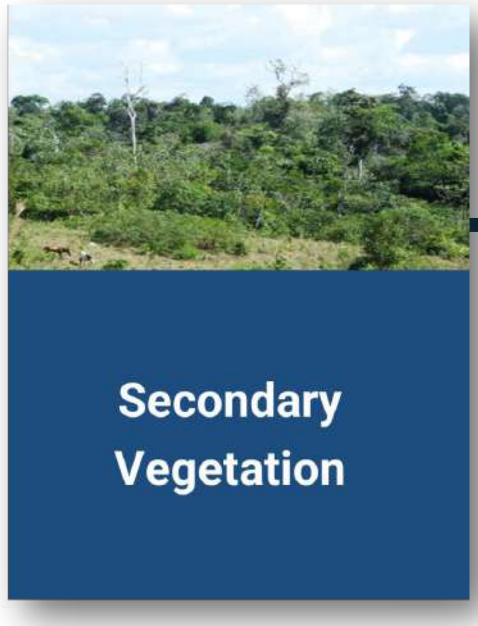
1. Perennial
2. Semi-perennial
3. Temporary 1 cycle
4. Temporary 2 or more cycles

Pasture

1. Herbaceous Predominance
2. Shrub/Tree Predominance

Secondary Vegetation

Secondary Vegetation



After Deforestation – Prodes…

Secondary Vegetation is detected as

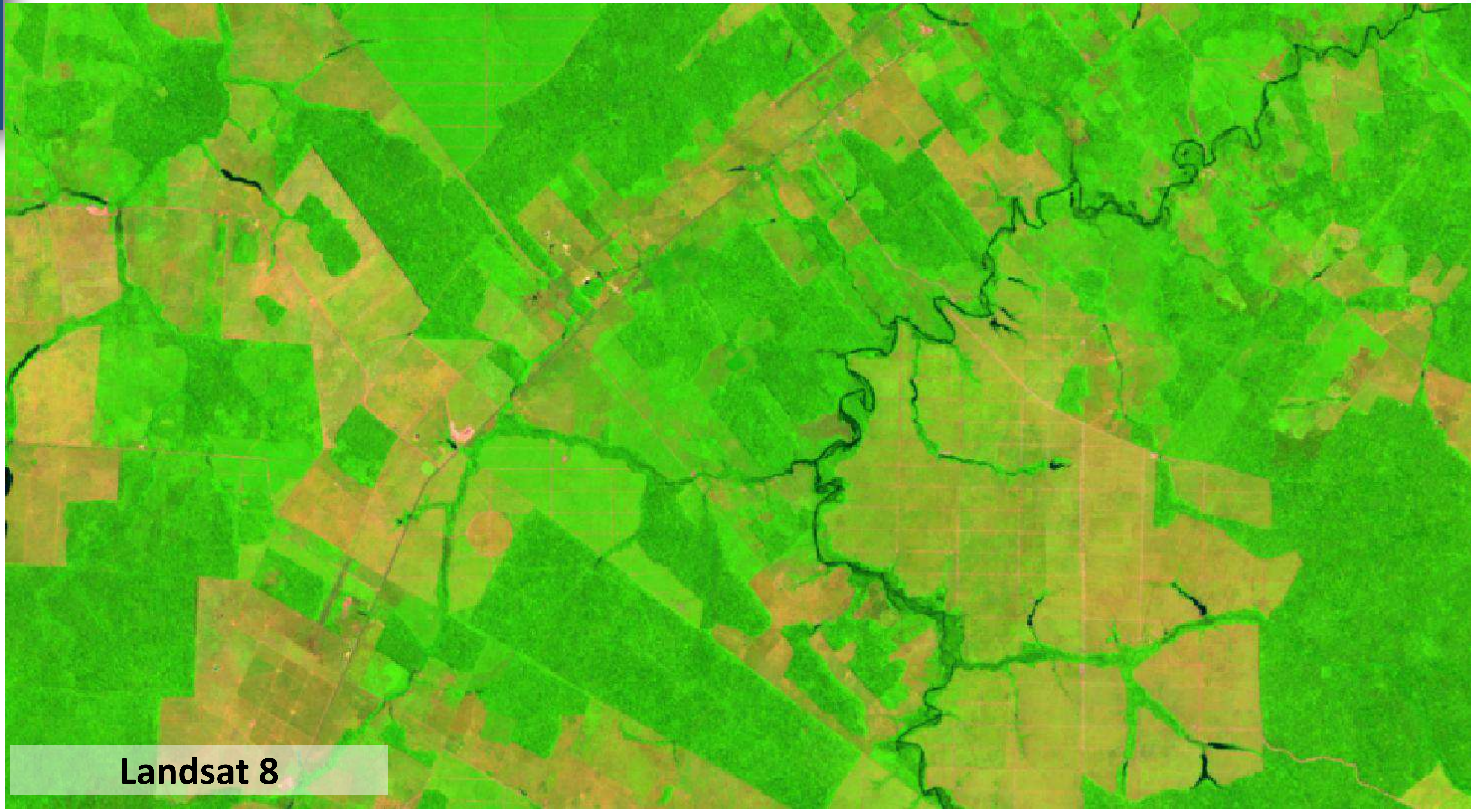
Areas that have been deforested (Prodes/clear-cut) and are in an advanced stage of regeneration, with trees and shrubs present (forest cover regeneration)

Fotos: Alexandre Coutinho

Secondary
Vegetation

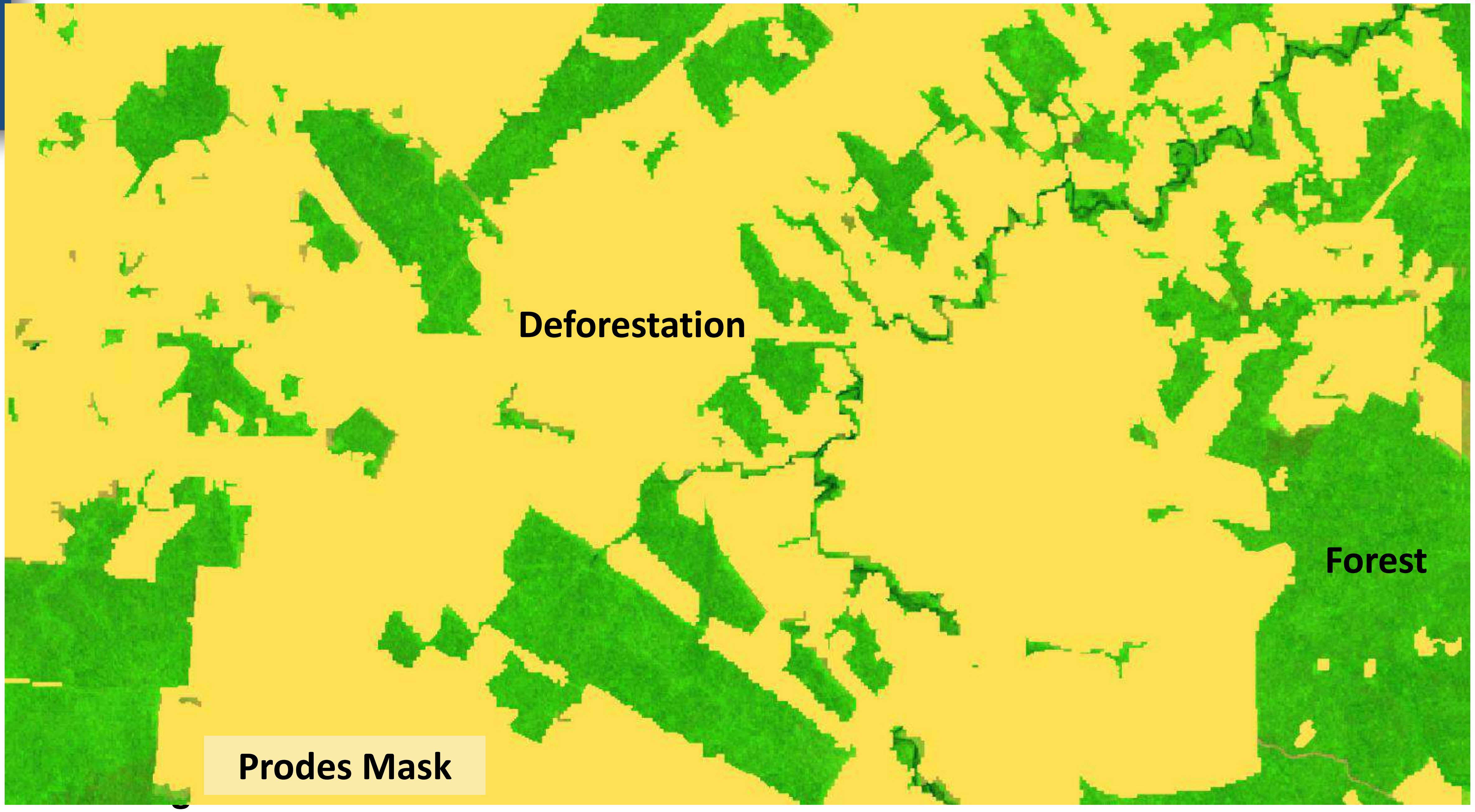
Secondary Vegetation Mapping

TerraClass



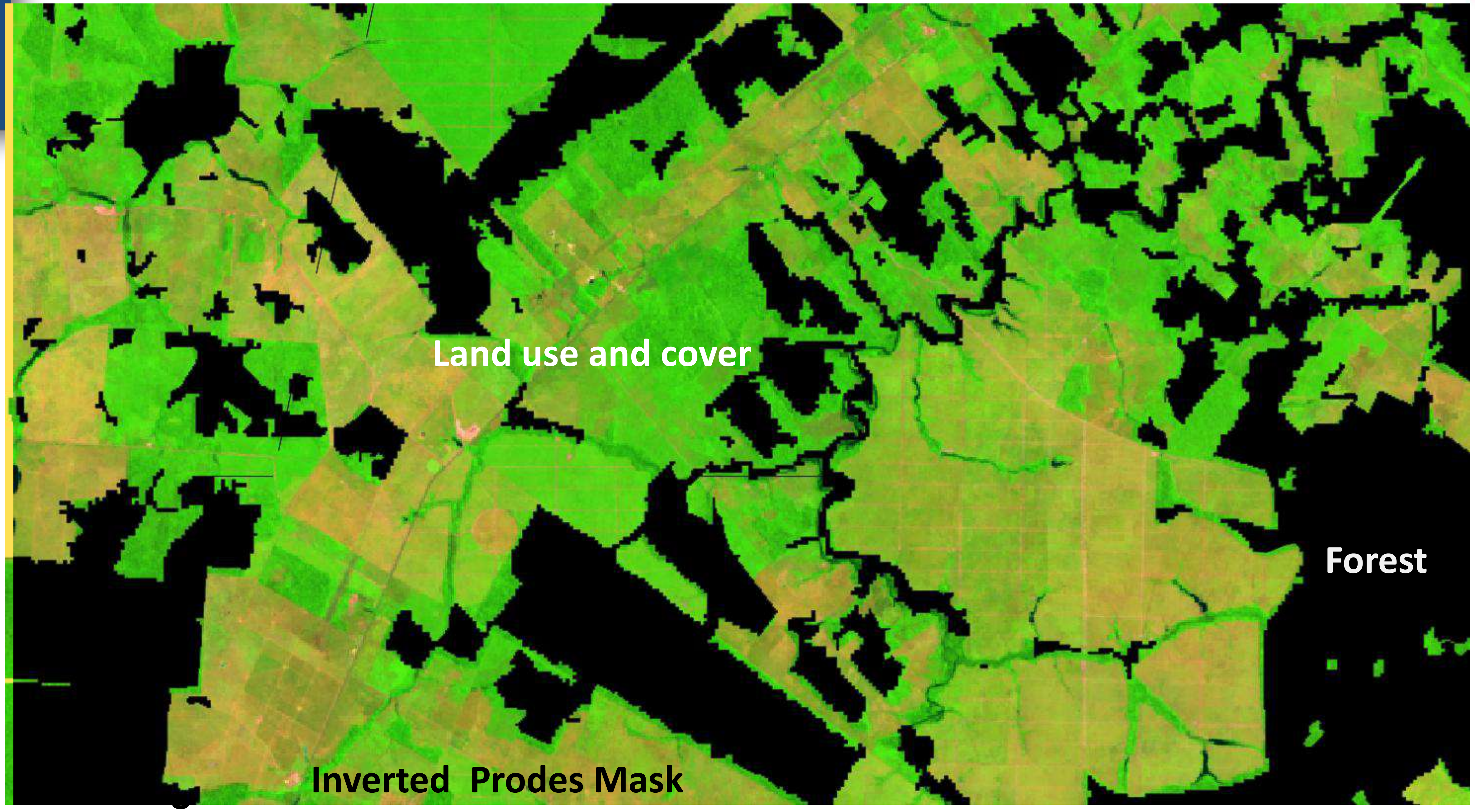
Secondary Vegetation

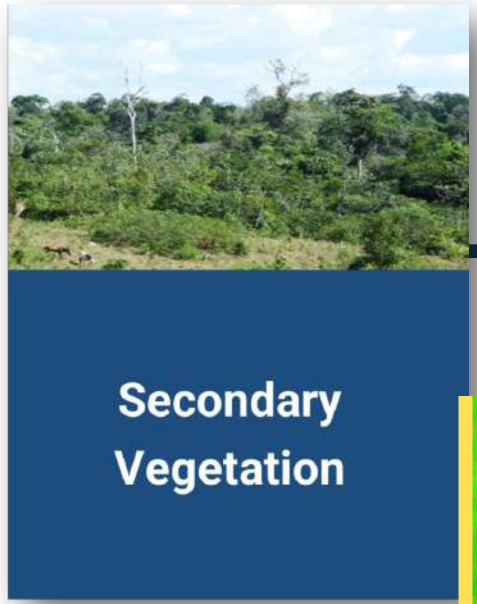
Secondary Vegetation Mapping



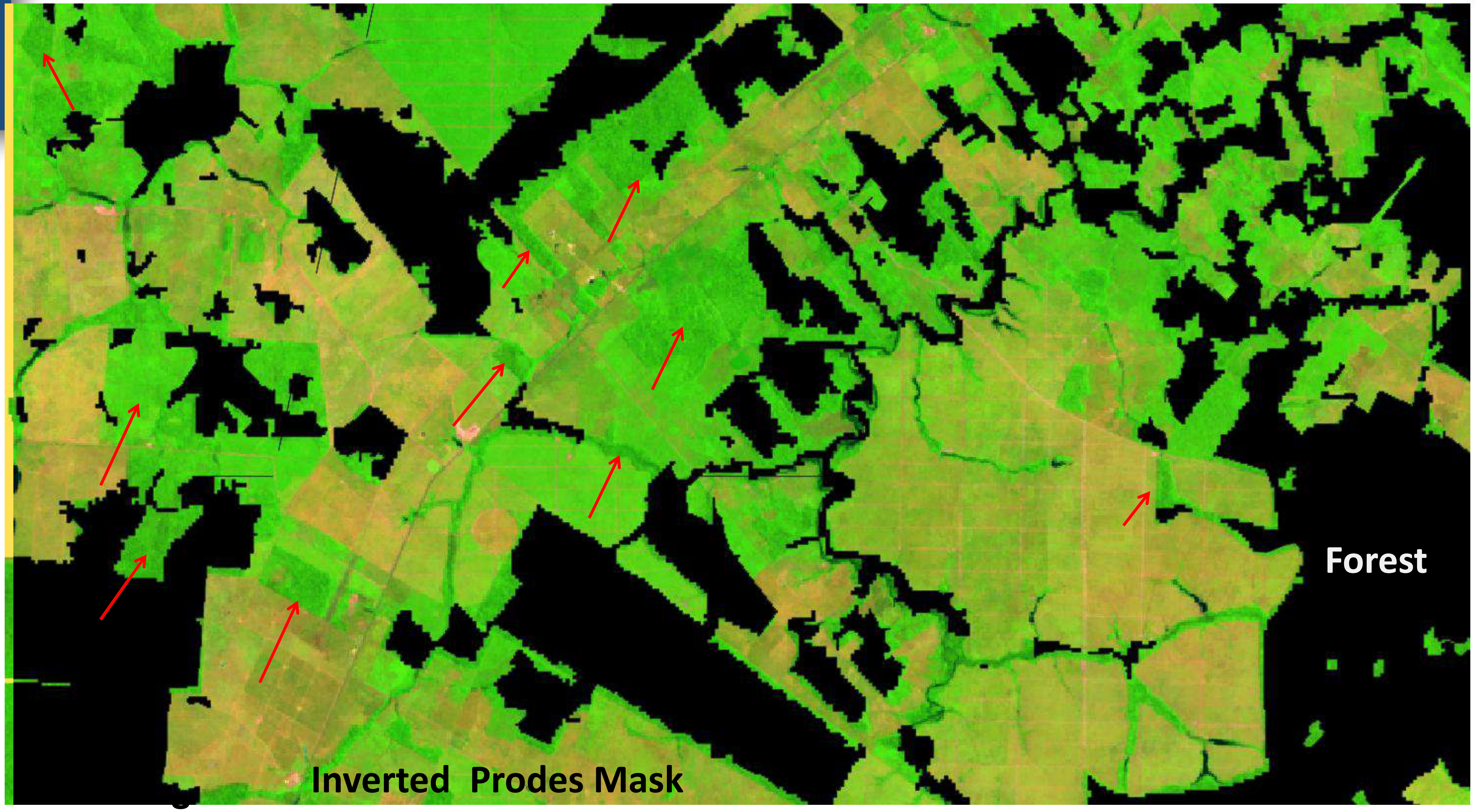
Secondary
Vegetation

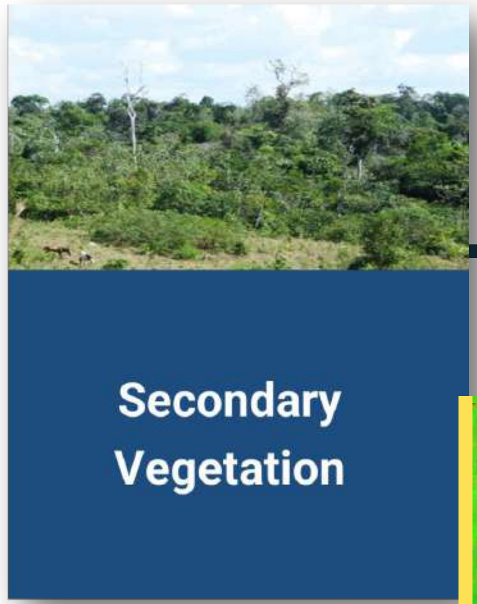
Secondary Vegetation Mapping



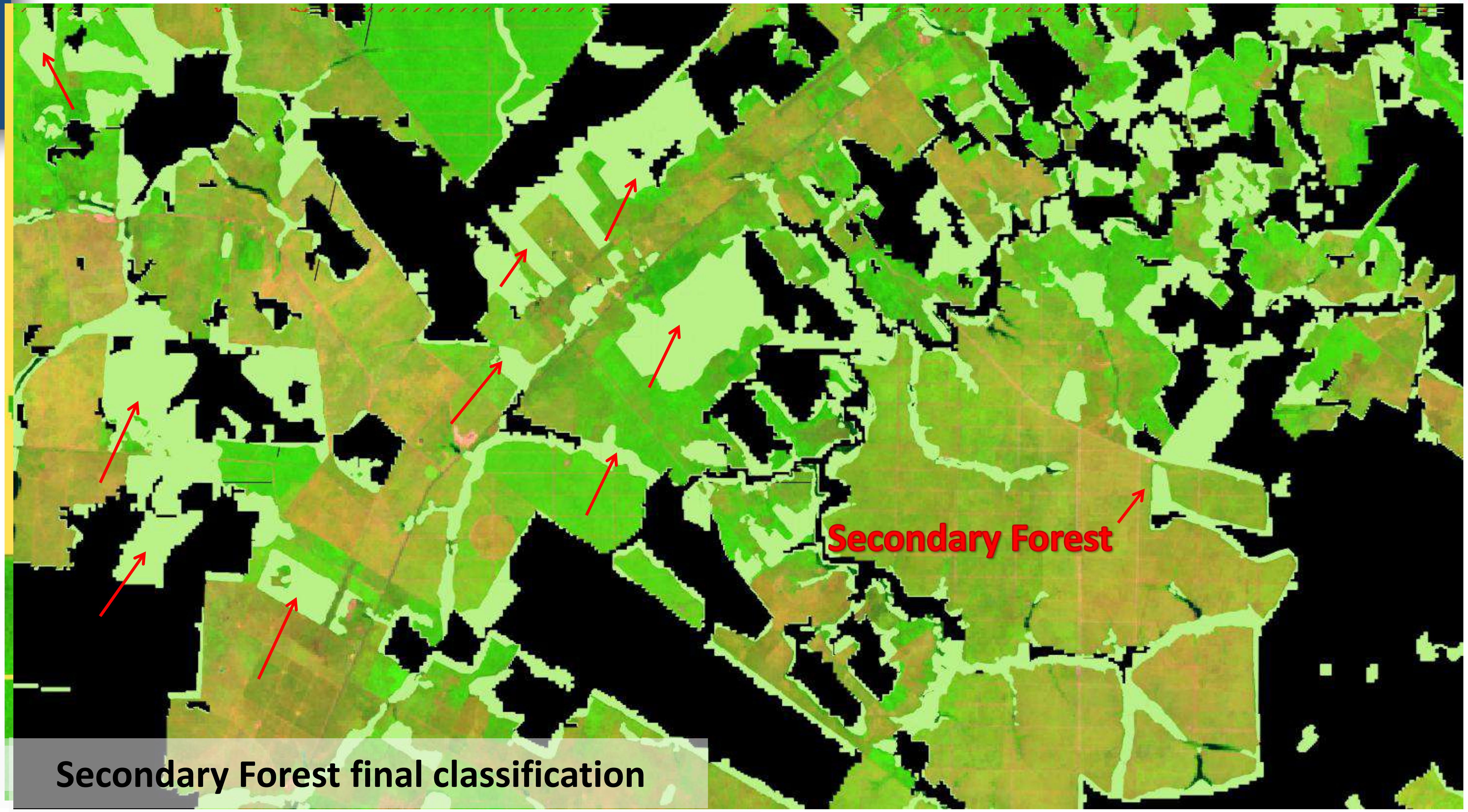


Secondary Vegetation Mapping



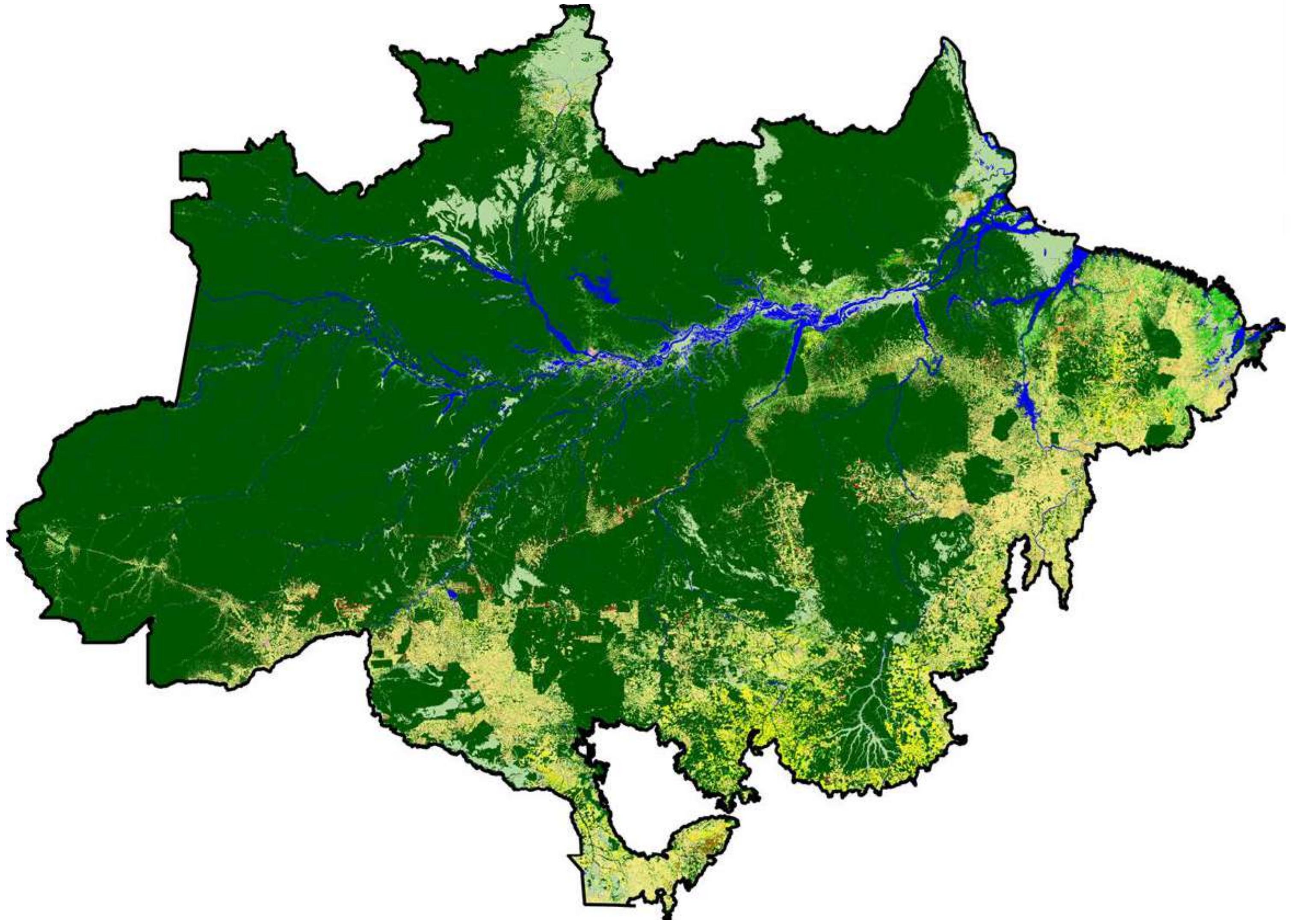


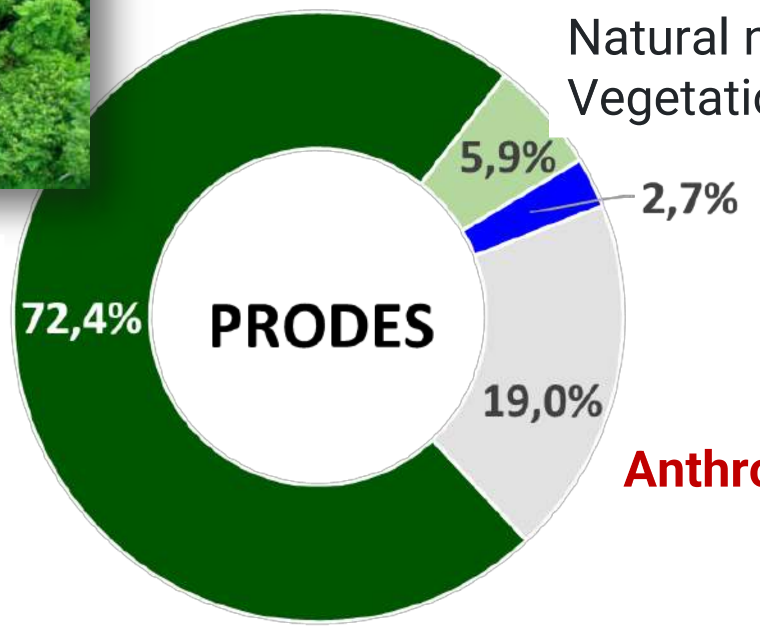
Secondary Vegetation Mapping



RESULTS

TerraClass 2022

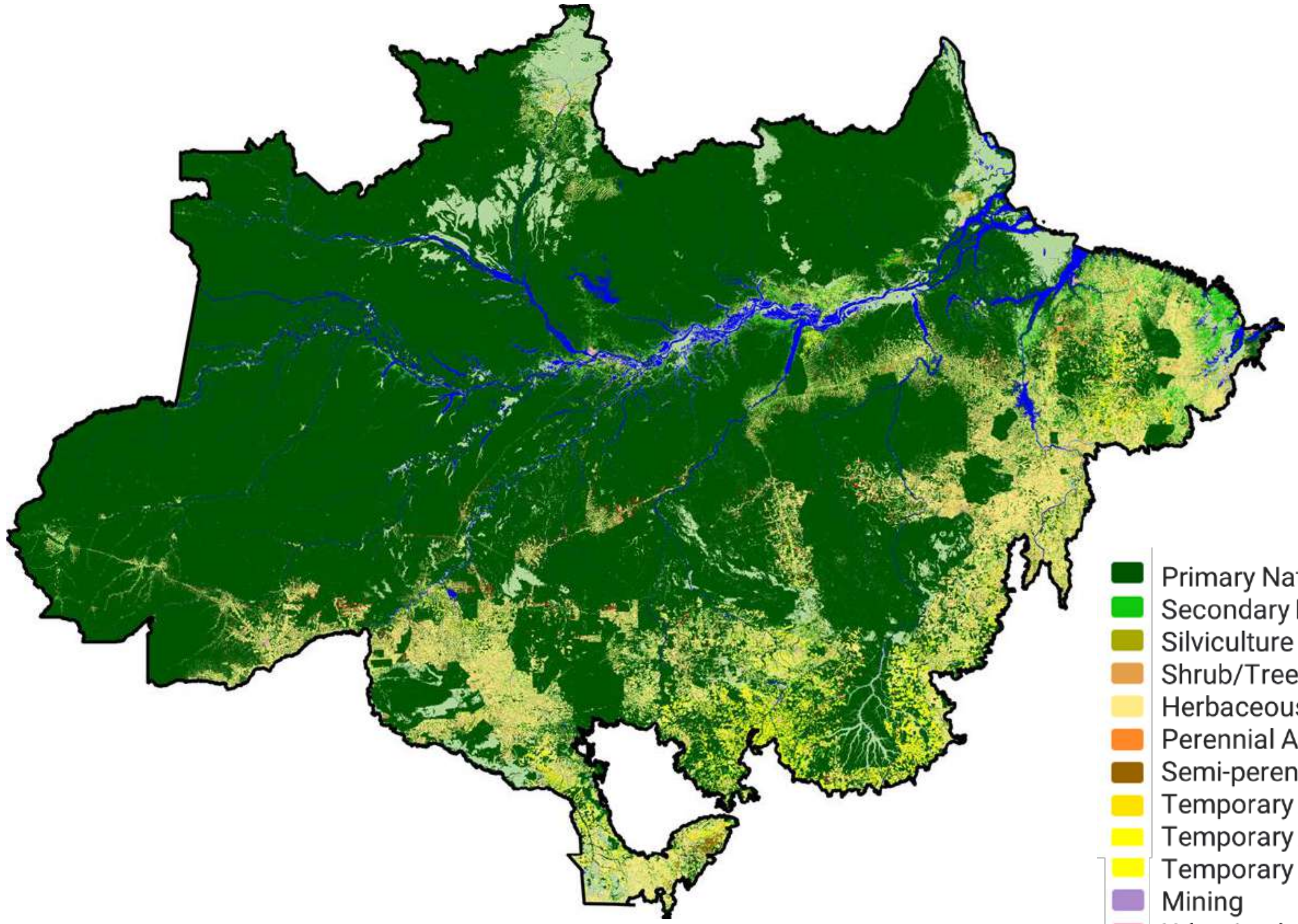


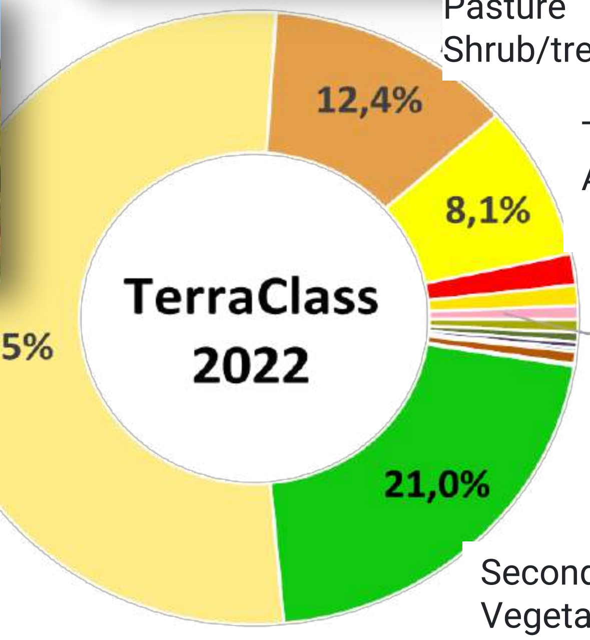


PRODES (2022)

RESULTS

TerraClass 2022

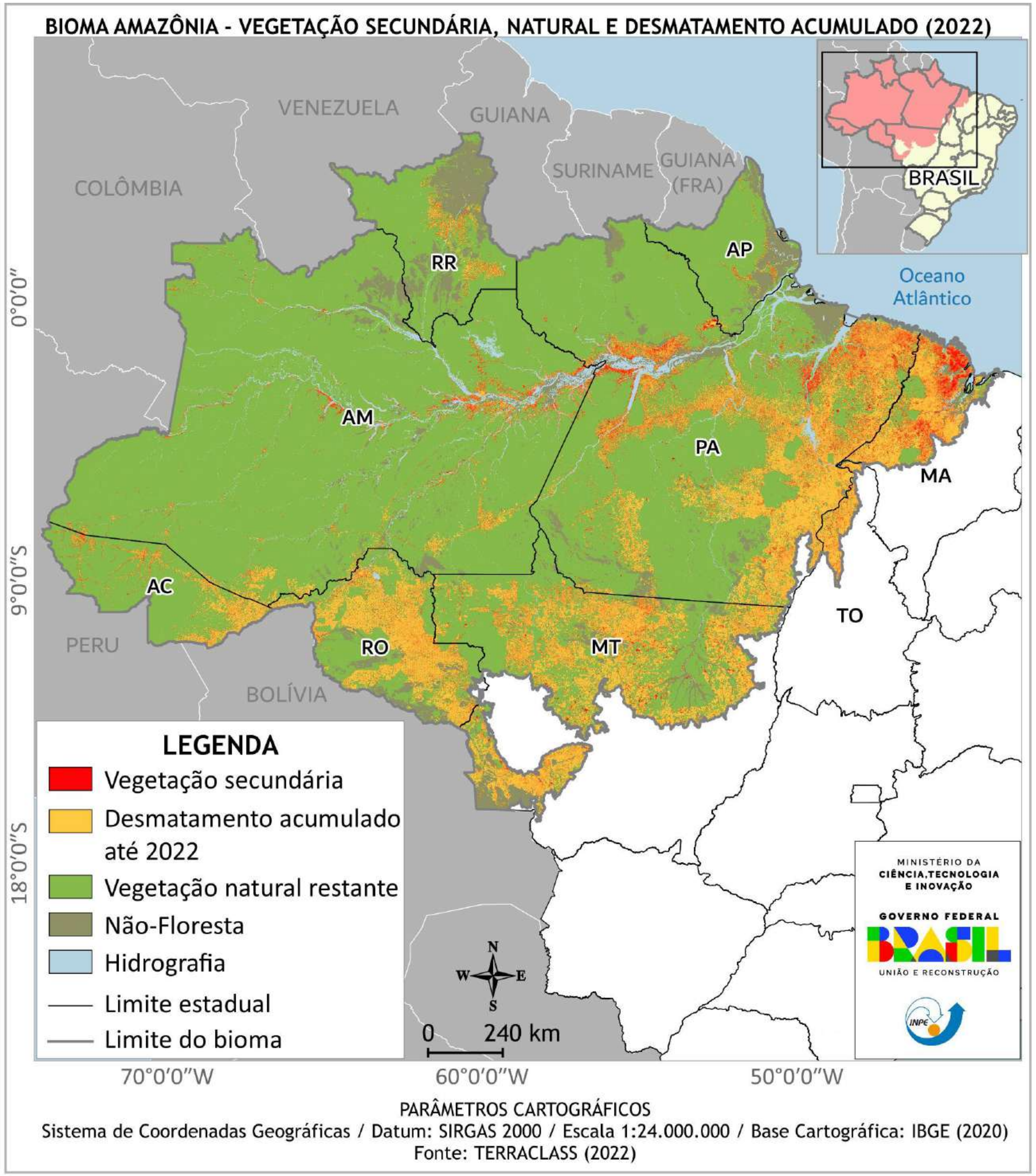




TerraClass (2022)

Amazon

2008
2010
2012
2014
2016
2018
2020
2022
2024 *

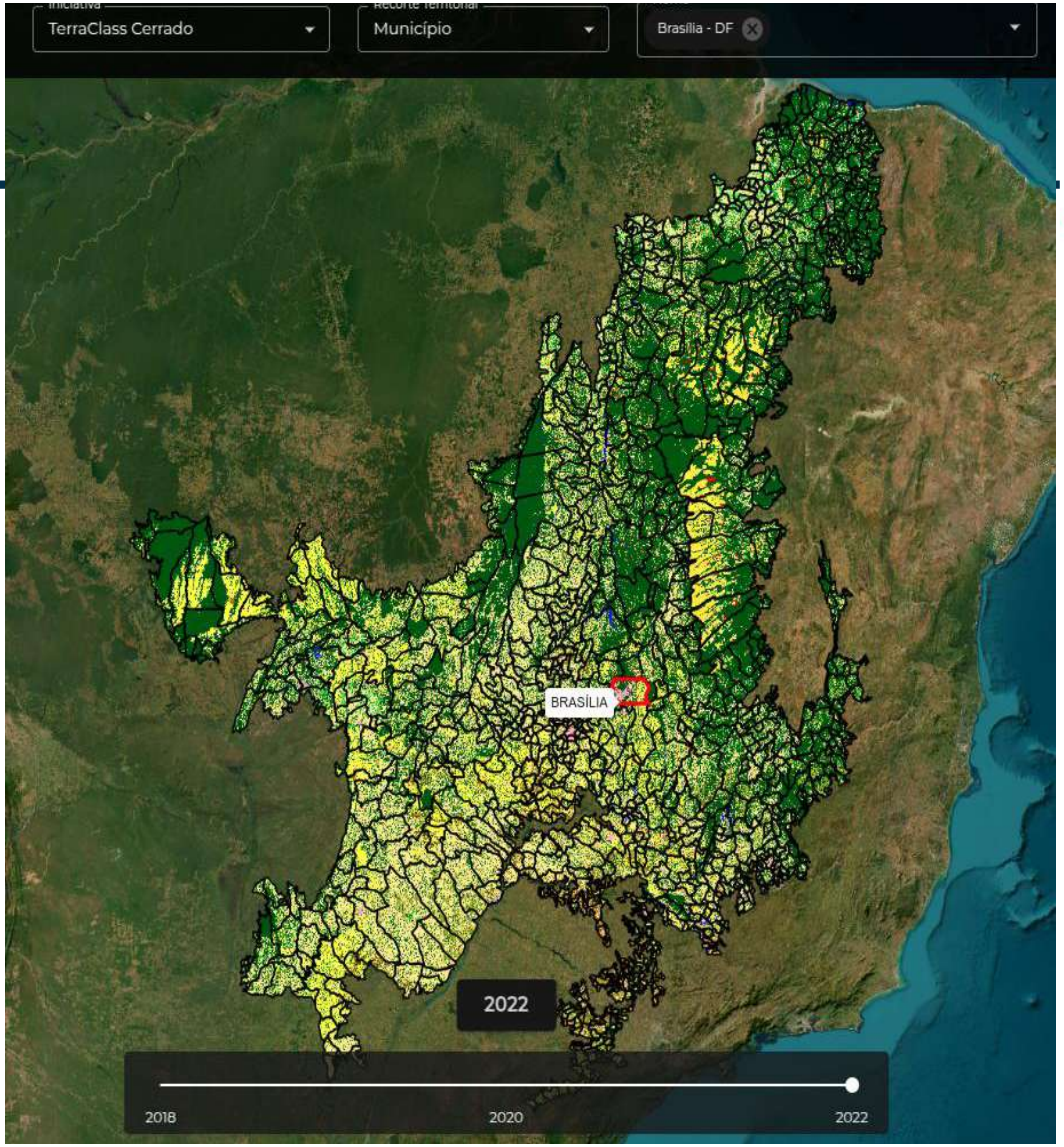


Biomas Br

TerraClass

Cerrado

2018
2020
2022
2024

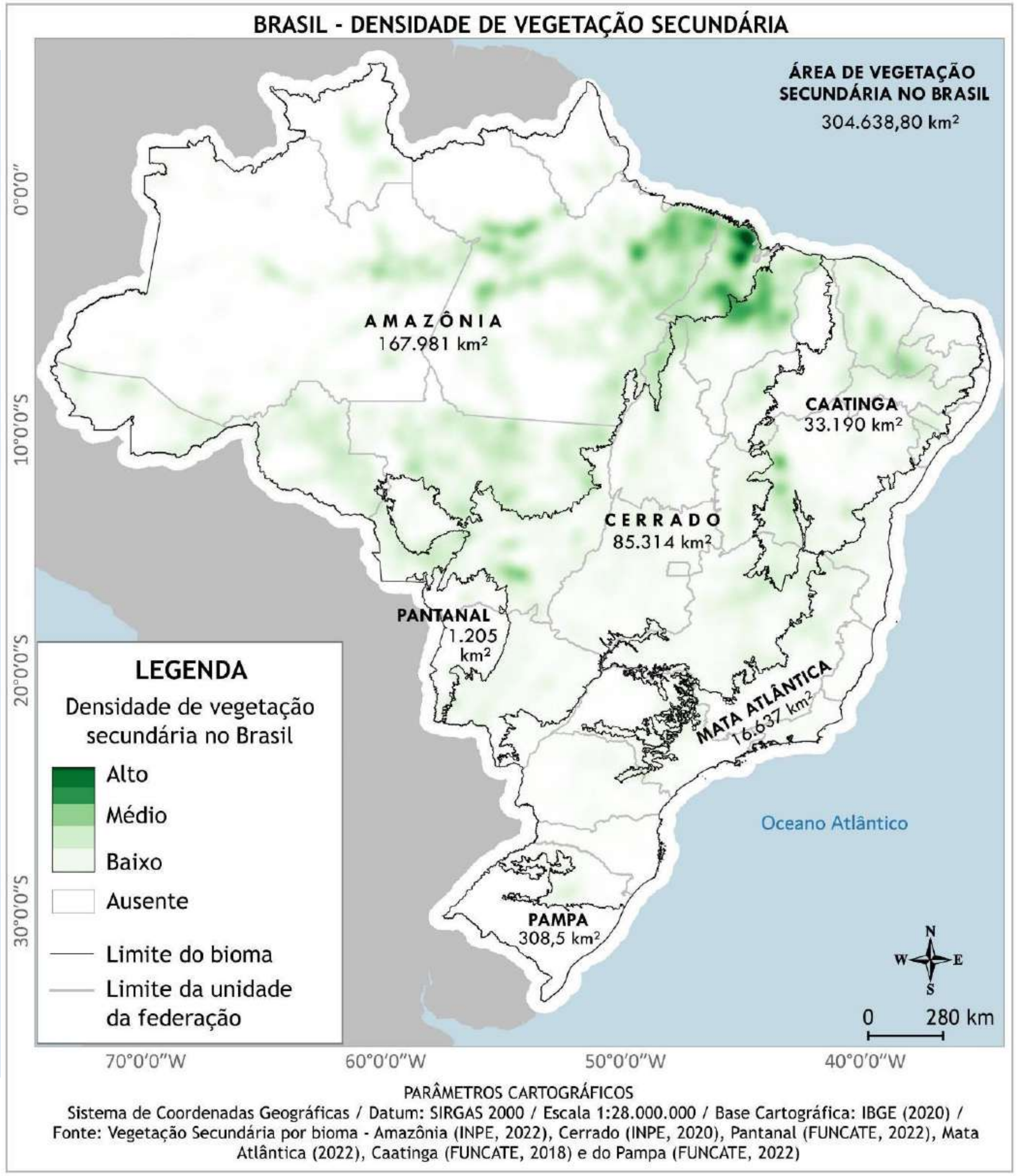


TerraClass

TerraClass - Official mapping of secondary forest in Brazil

Brazil - Secondary Vegetation Mapping

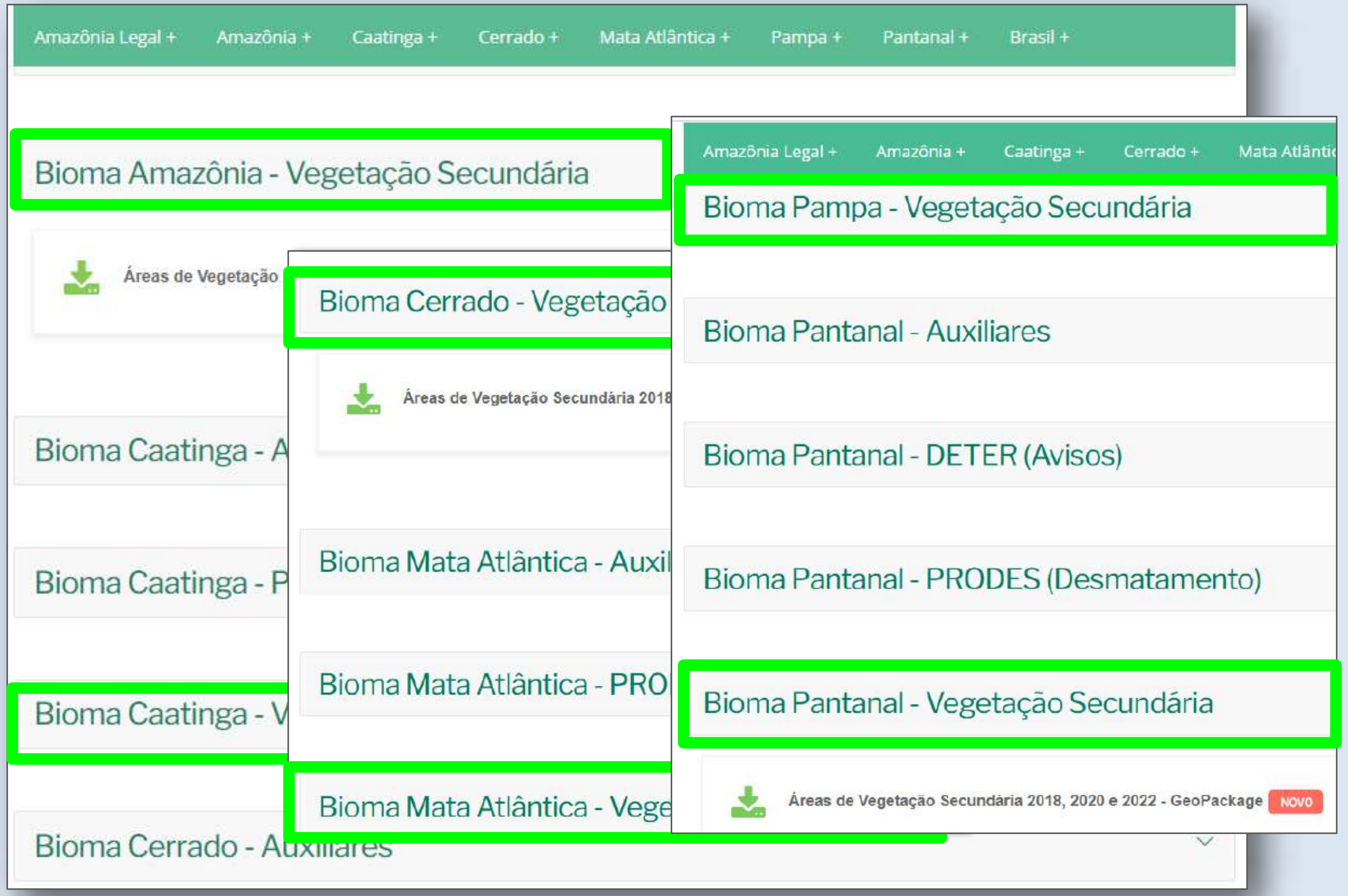
2018
2020
2022
2024*



TerraClass - Official mapping of secondary forest in Brazil

Biomas Br

Secondary Vegetation monitoring: 2018-2020-2022



Contribution for Carbon losses & gains

Regrowth

- Fragmentation
- Edge effects

https://terrabrasilis.dpi.inpe.br/downloads/

TerraClass – Landscape (MMA-INPE)

Biomas Br

Secondary Vegetation (SV) Landscape analysis

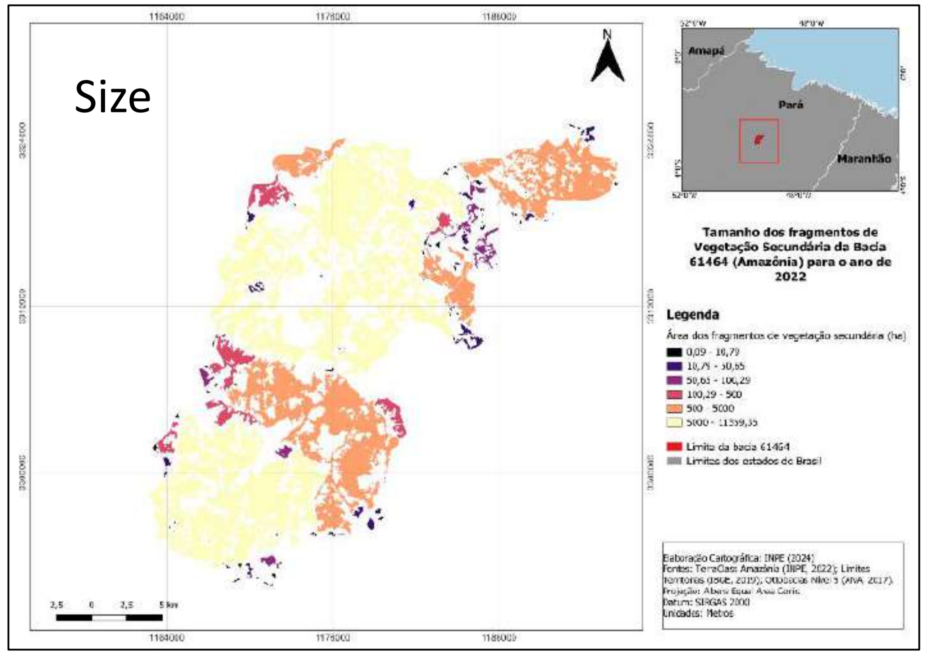
Remnants of secondary forest fragments

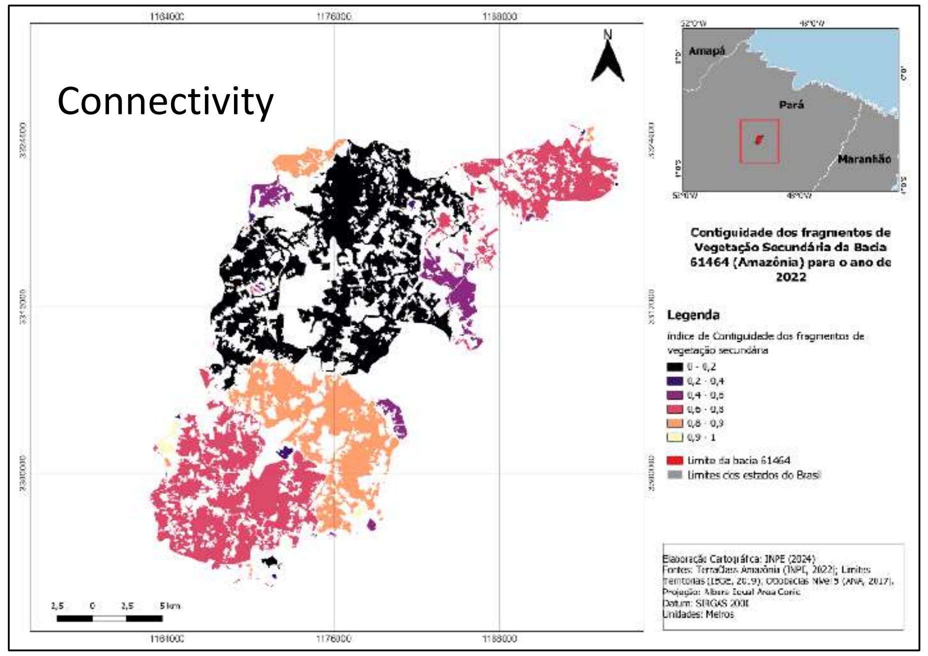
Spatial Distribution

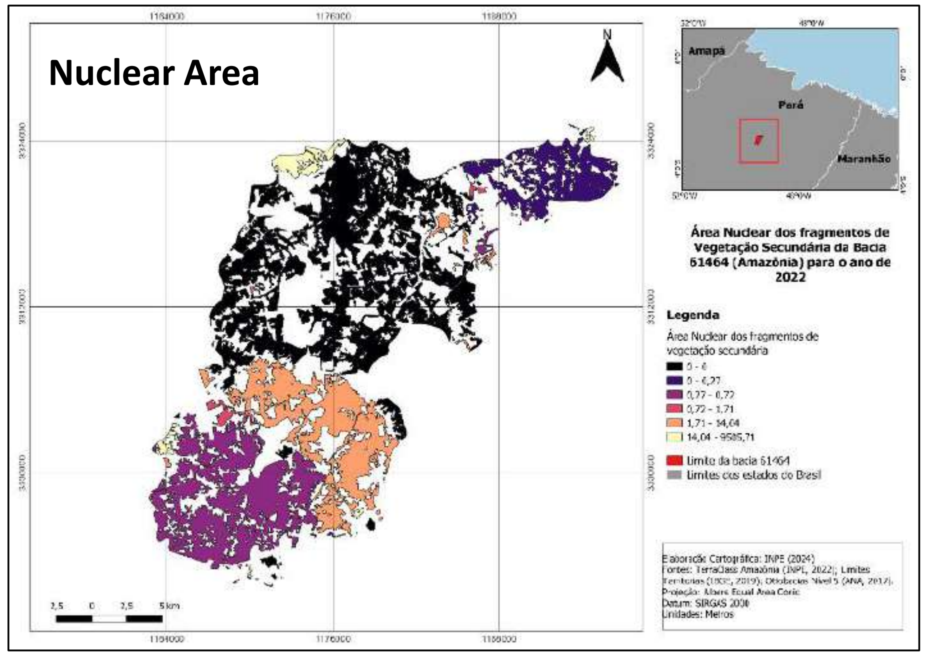
- Distribution
- Land tenure type
- Weighted age of vegetation (years);

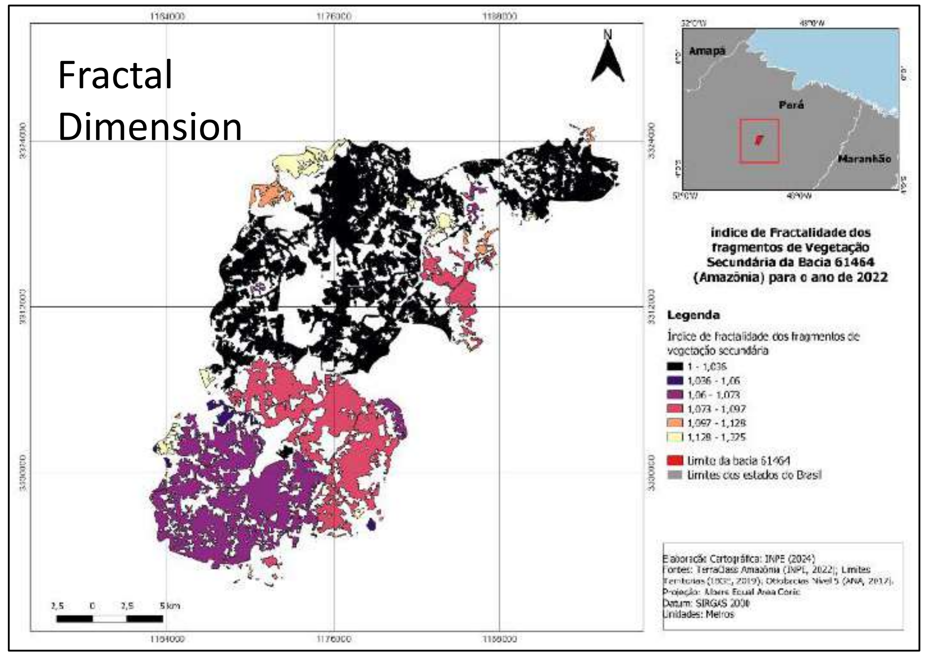
Landscape Metrics:

- Area (ha);
- Core area (ha);
- Fractal dimension index (dimensionless);
- Euclidean distance - nearest neighbor (m).
- Type of nearest neighboring vegetation.

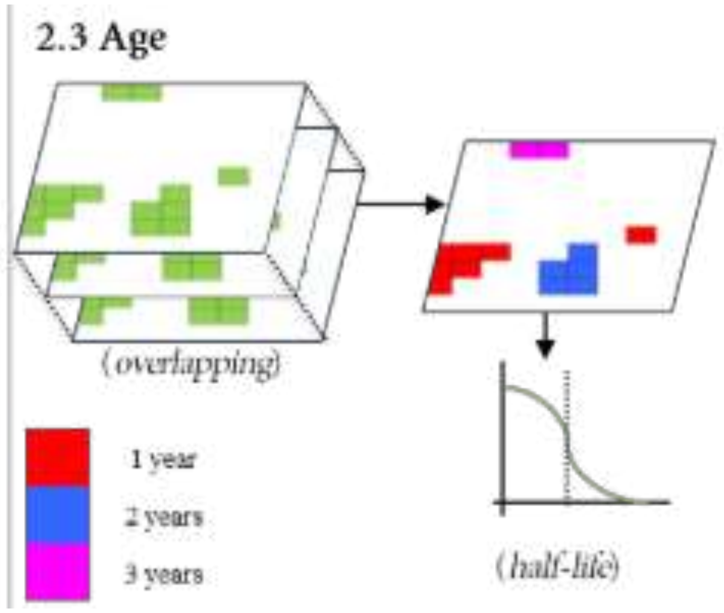








Weighted age of the Fragment

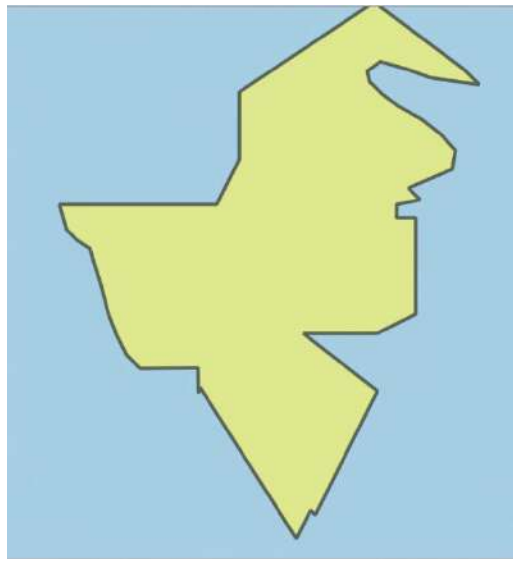


2022 SV polygon AGE

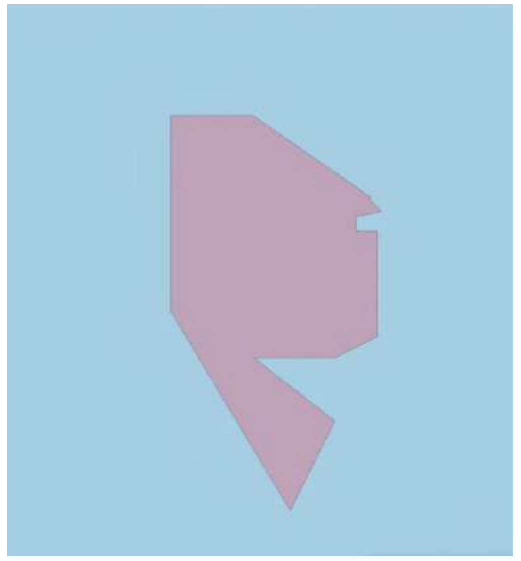
Can be resulted from sub-areas of different ages

Average age weighted by Year_area

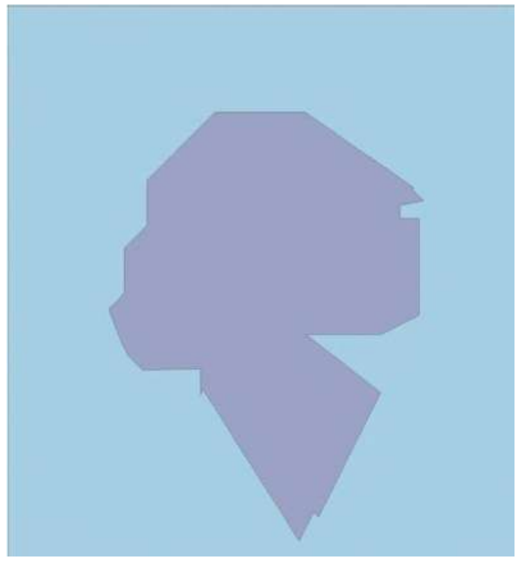
2022 SV Age?



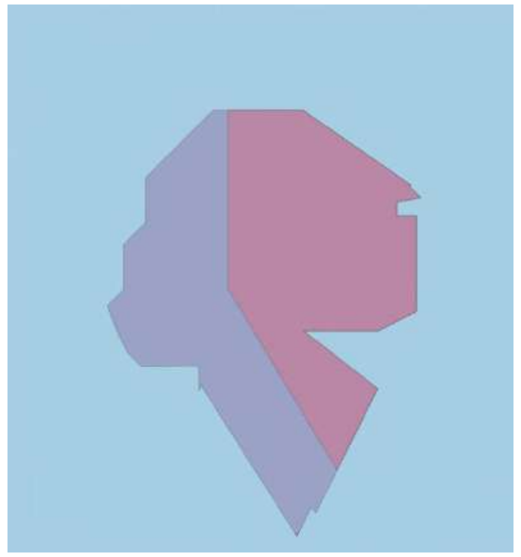
SV2018



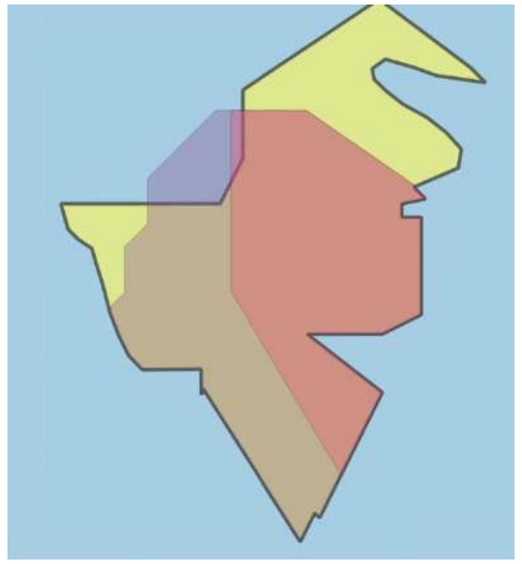
SV2020



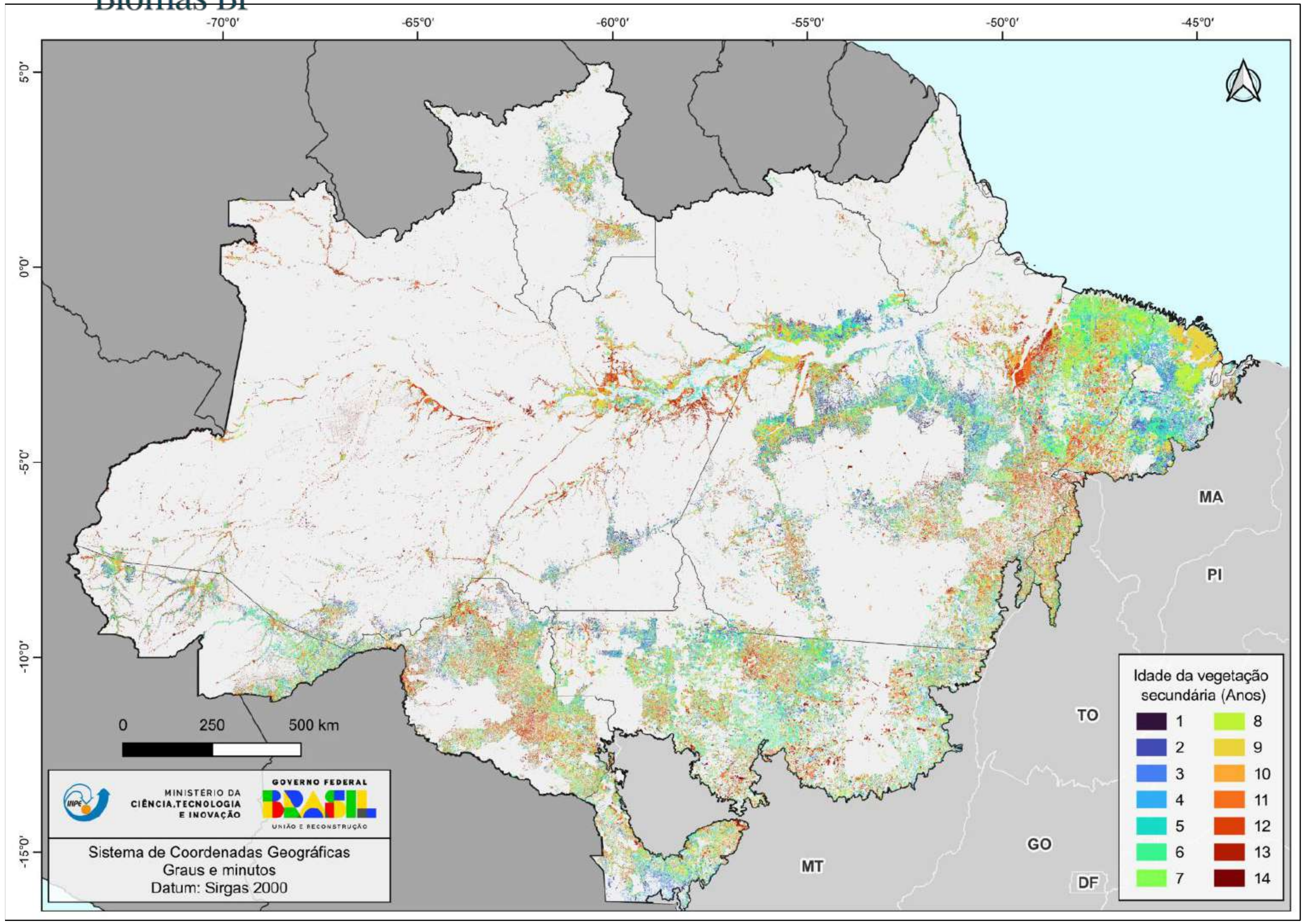
SV2018 and 2020



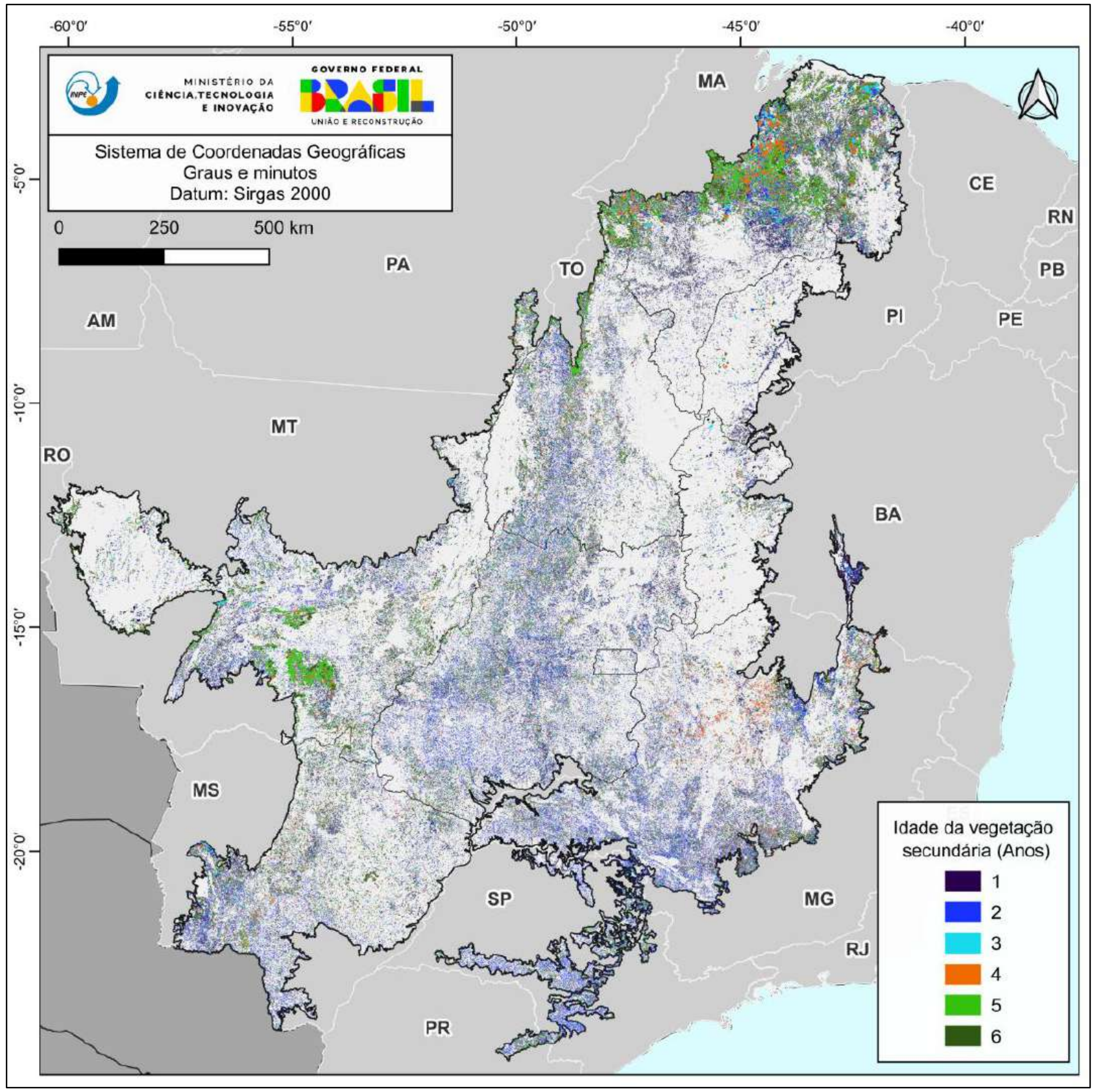
SV2018_2020_2022



Weighted age of Secondary Vegetation fragments

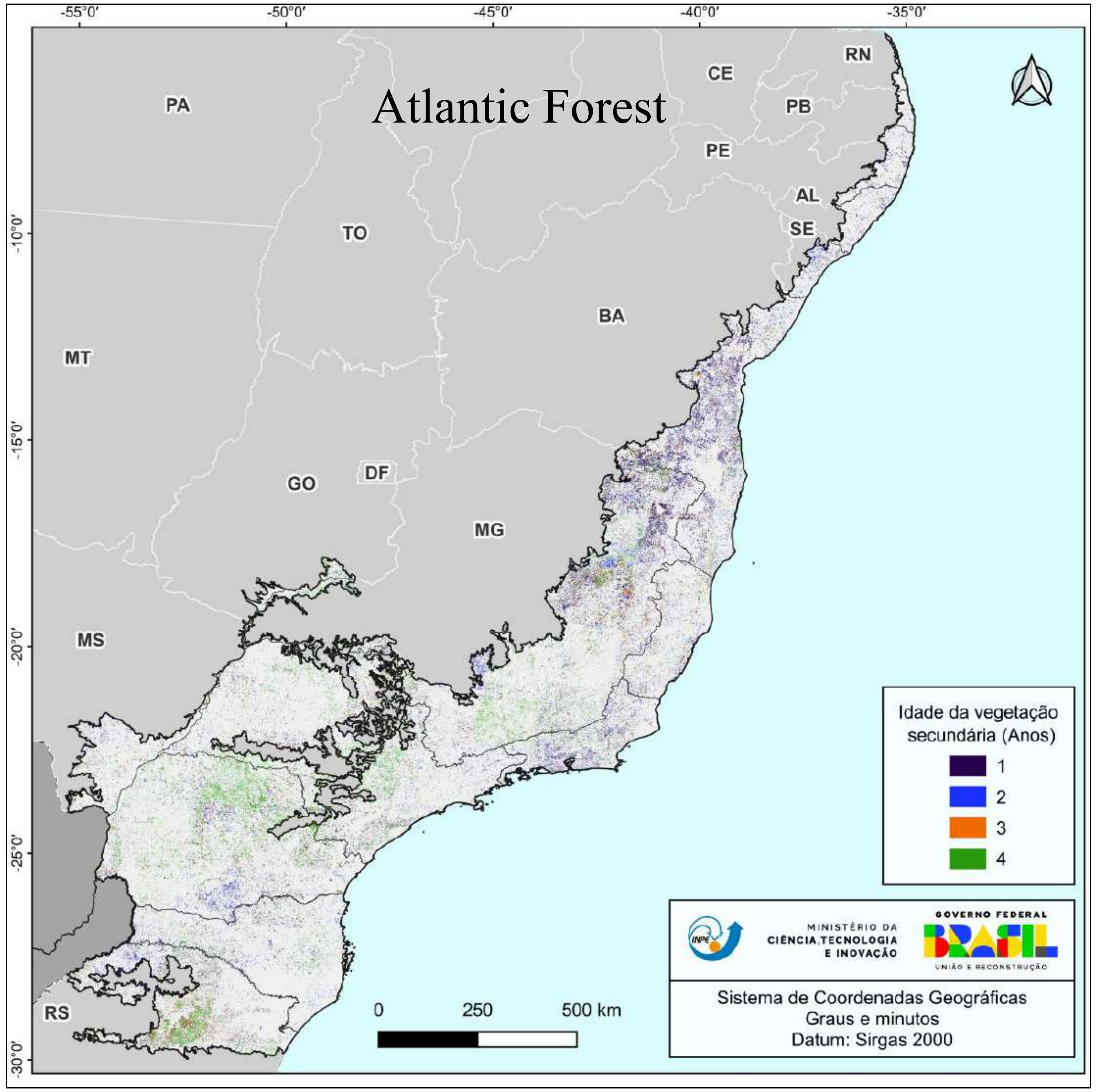


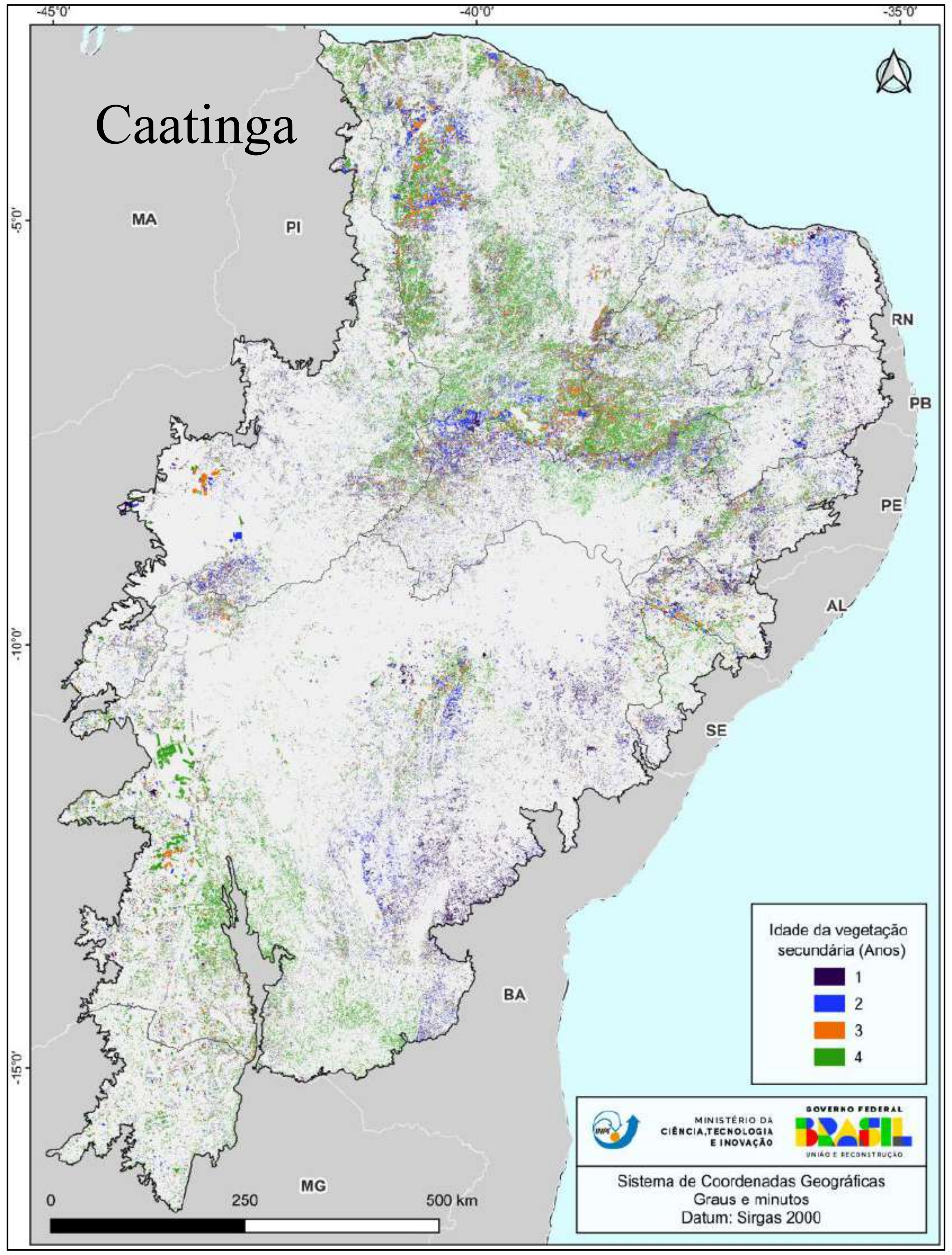
Amazon



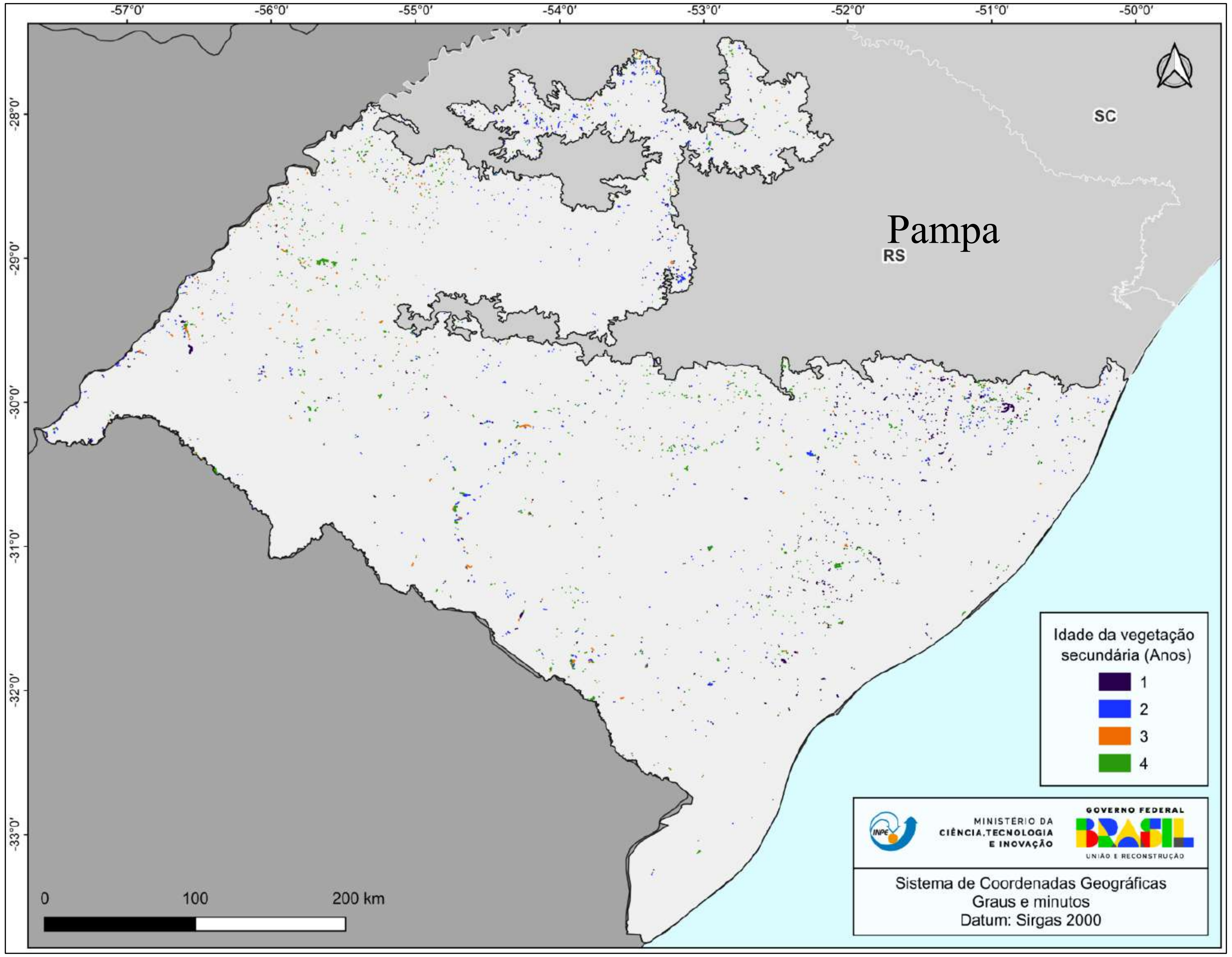
Cerrado

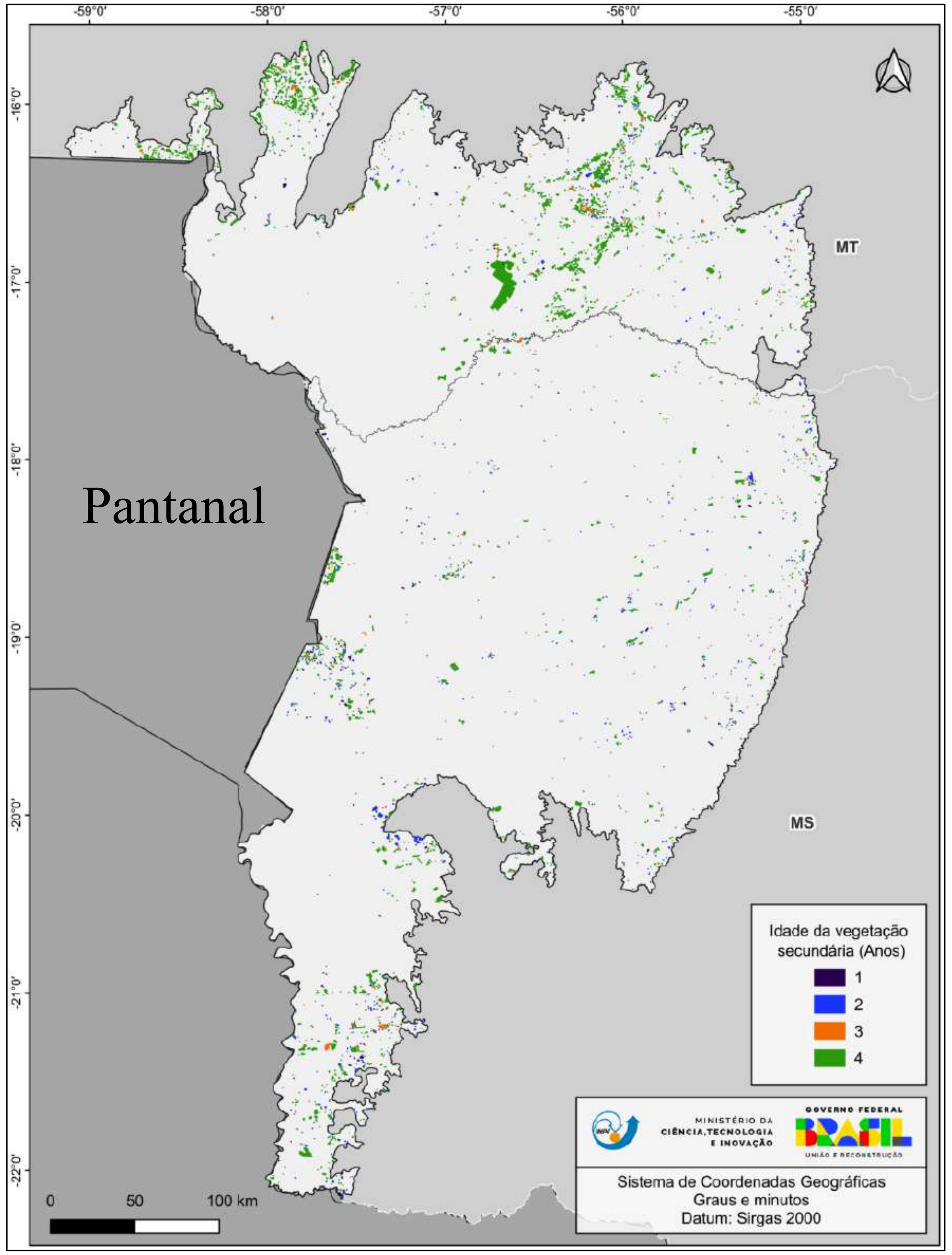
Weighted age of Secondary Vegetation fragments





Weighted age of Secondary Vegetation fragments





Land Tenure x Secondary Vegetation

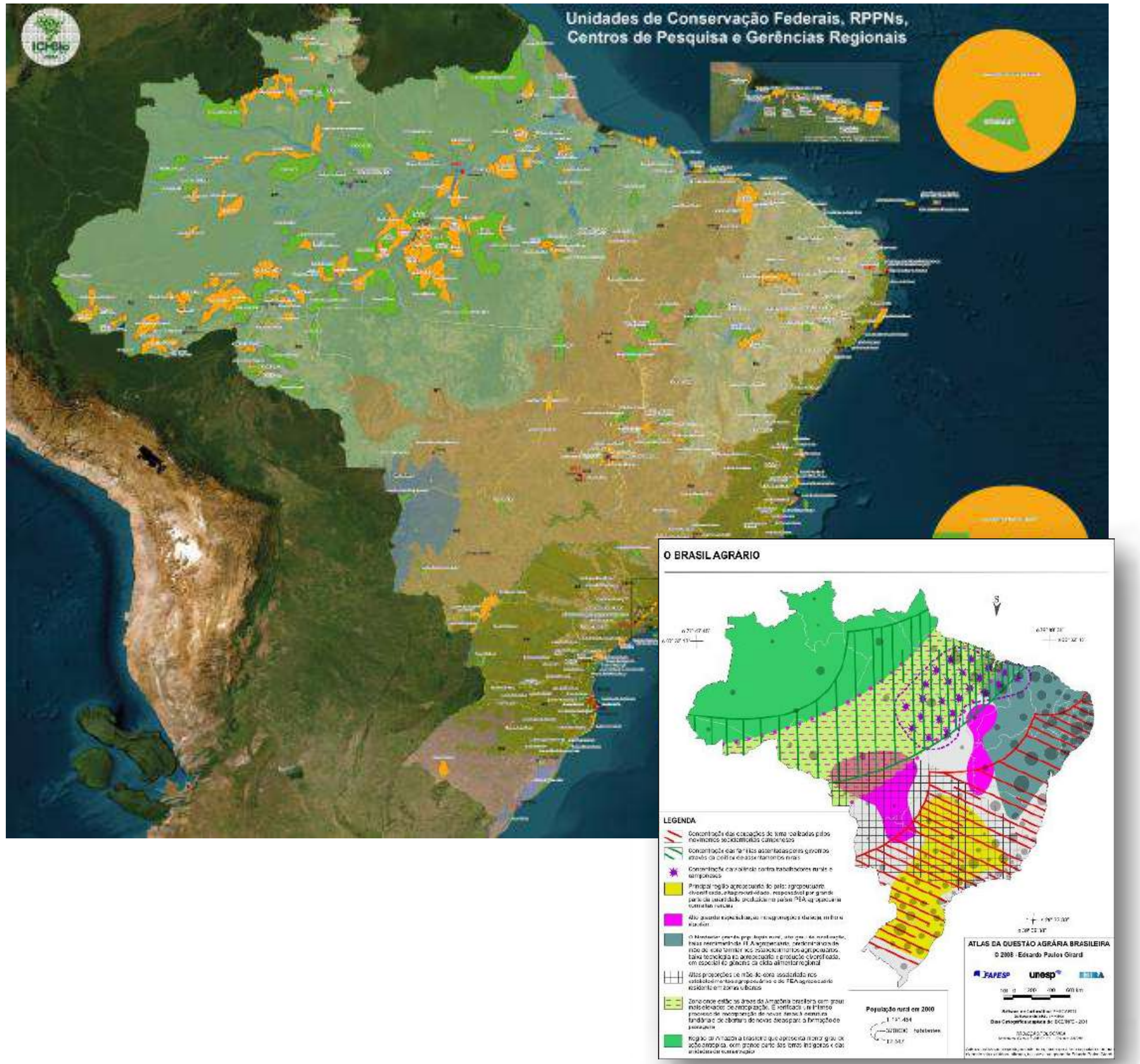
Sala de Situação

DETER | Queimadas

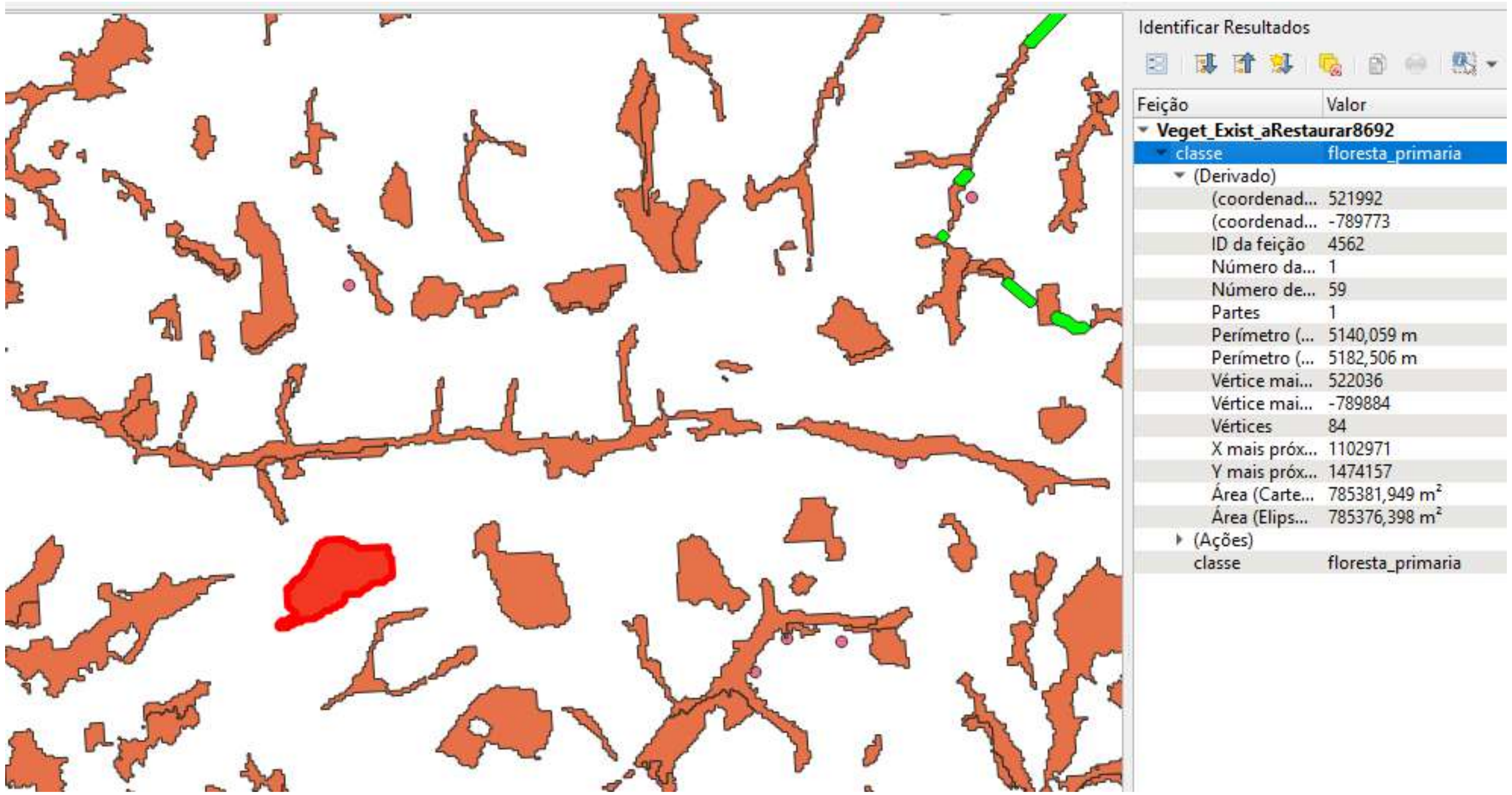
Visualização sinótica de indicadores de áreas críticas de supressão da vegetação nativa e focos de queimadas

Reference priorities
Land condition categories
Combined data from federal and state spheres (available)

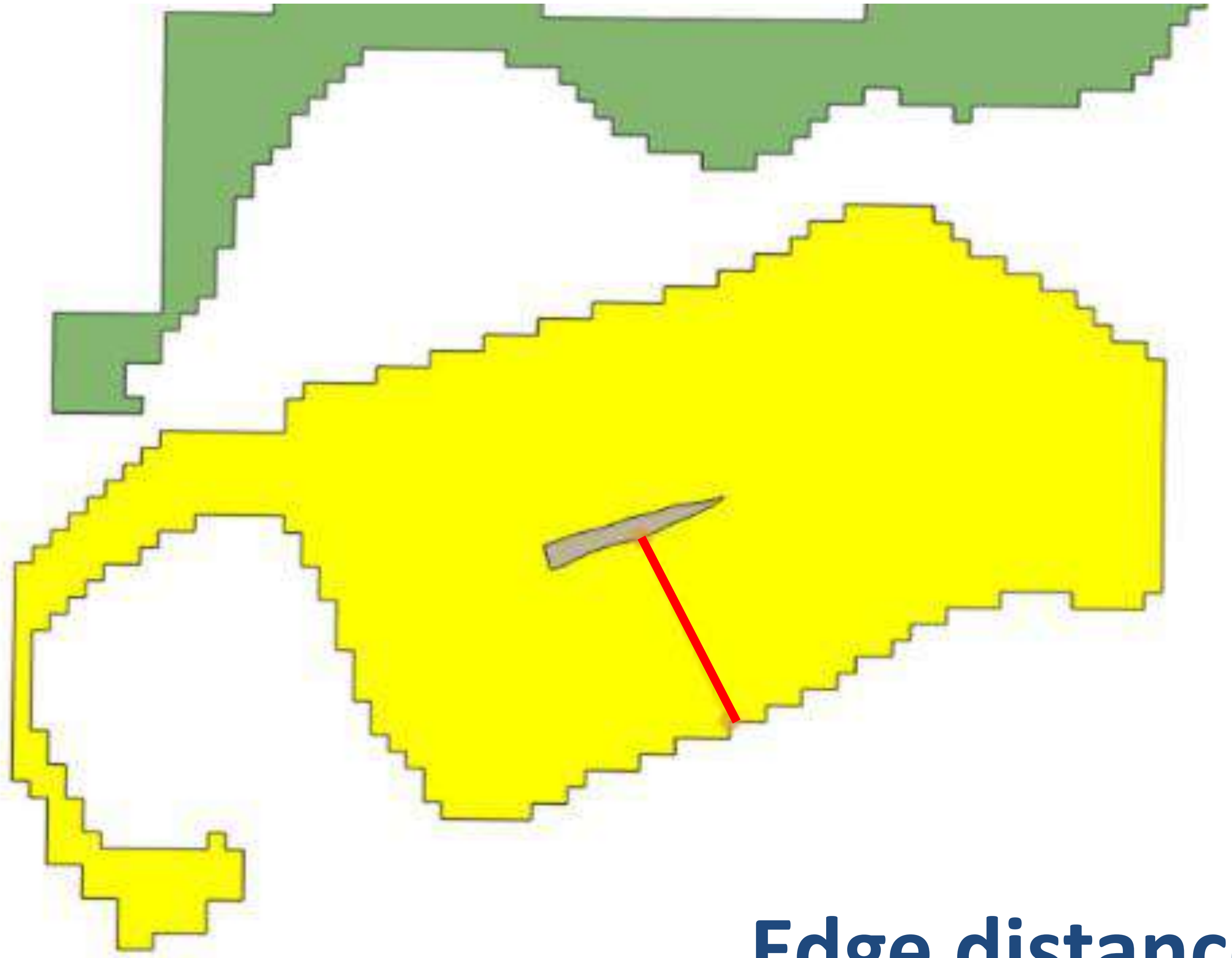
	PRIORITIES:	
1	Indigenous Lands	FUNAI
2	Conservation Units (UCs) – Integral Protection	ICMBio
3	Conservation Units (UCs) – Sustainable Use (Without APA)	ICMBio
4	Quilombola Territories	INCRA
5	Rural Settlements – INCRA Settlement projects- all types	INCRA
6	Environmental Protection Area (APA) - includes private Properties	ICMBio
7	Private Properties - SIGEF	SIGEF/INCRA
8	Undesignated Public Forest (FPND)	SFB
9	Areas without land registration.	



Area of Secondary Vegetation fragments



Core Area of Secondary Vegetation fragments



Patch's size and shape

References

BRASIL, I. D. S. et al. Contributions of Forest Regeneration After Intense Fragmentation in the Amazon through Morphological Spatial Pattern Analysis. **Forest Science**, v. 68, n. 5-6, p. 508-520, 2022.

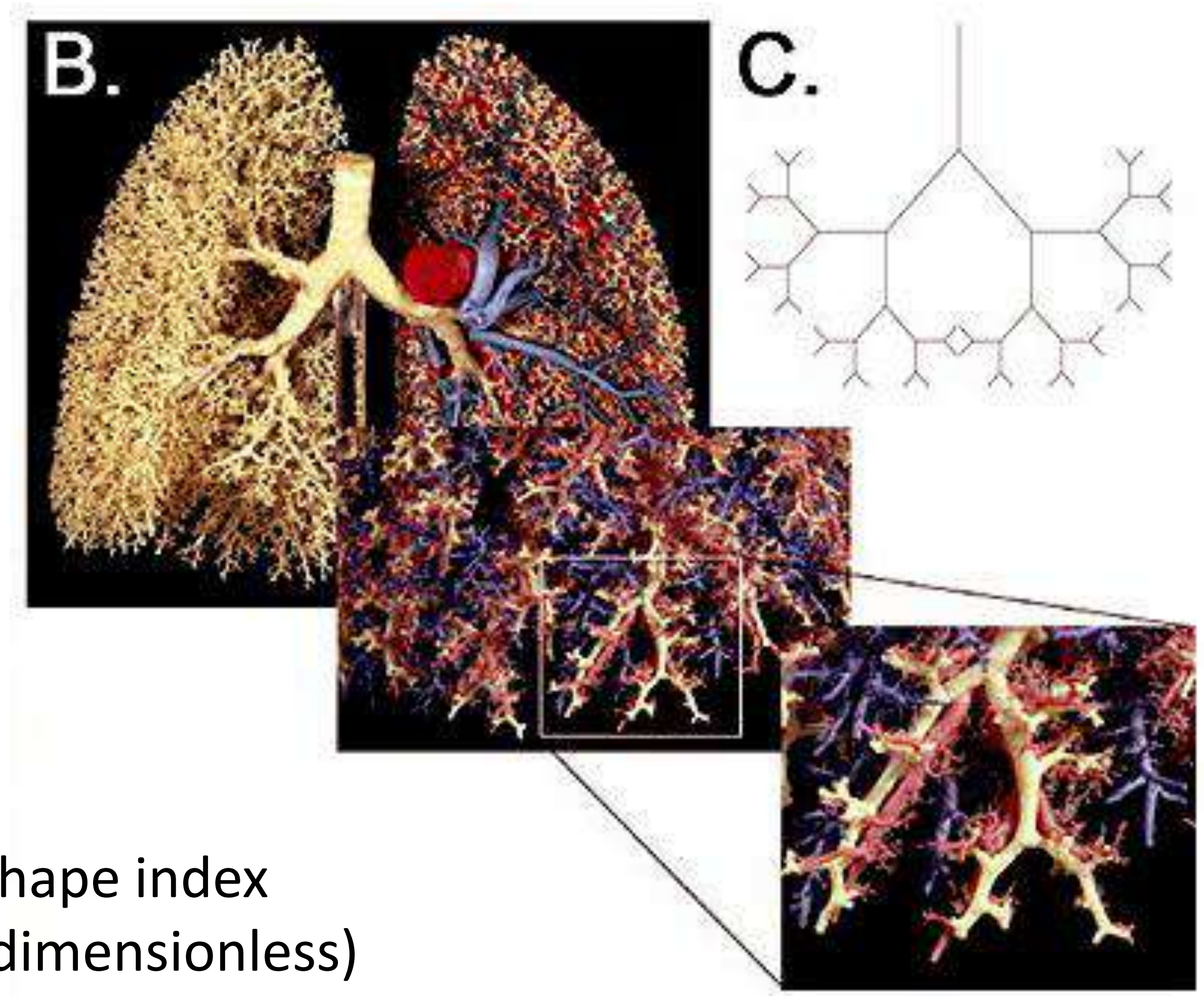
SILVA JUNIOR, C. H. L. et al. Persistent collapse of biomass in Amazonian forest edges following deforestation leads to unaccounted carbon losses. **Science Advances**, v. 6, n. 40, 2020.

Edge distance = 120, 90, 60, 30 **m.**

Biomas Br

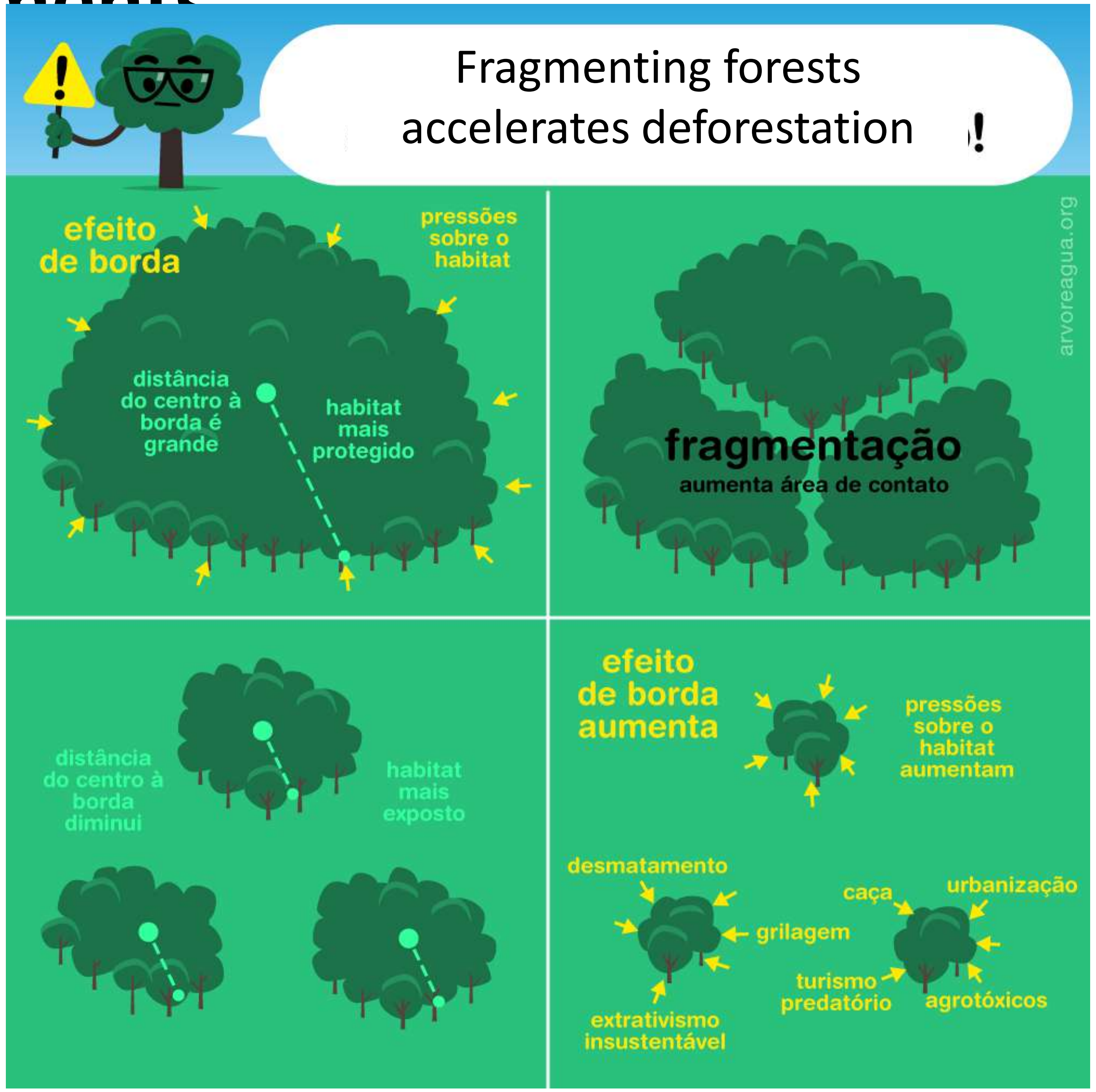
Fractal Dimension of Secondary Vegetation fragments

The larger the fractal dimension,
the greater the contact surface area.



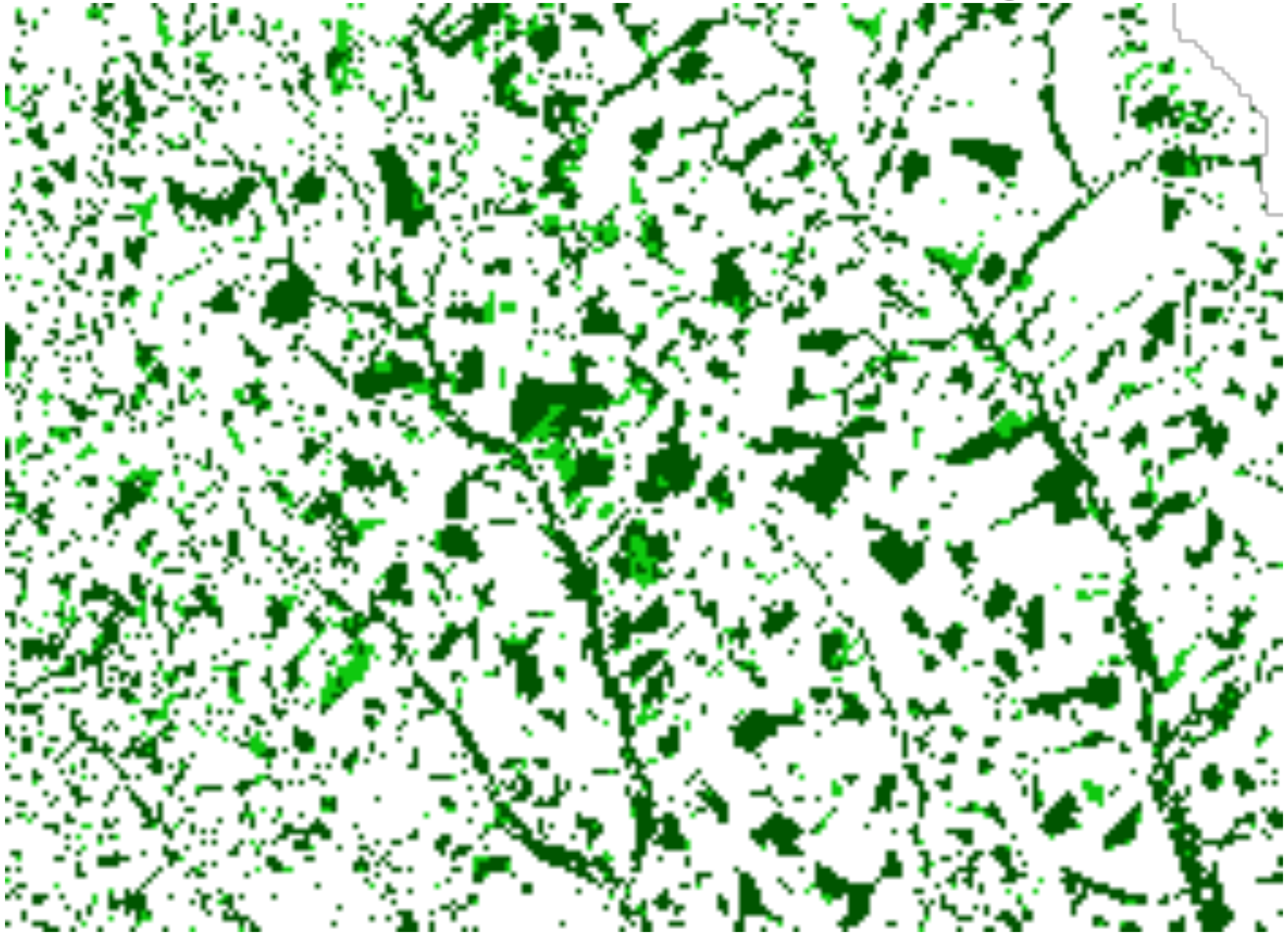
Shape index
(dimensionless)

Fonte: https://cientistasdescobriramque.com/2014/12/03/o-que-tem-o-pulmao-humano-em-comum-com-o-leito-de-um-rio-uma-fortificacao-ou-um-cristal-de-gelo/



Fonte: https://arvoreagua.org/crise-climatica/fragmentacao

Distance and the closest Fragment Type to SV fragments



Euclidean distance to the nearest neighbor (m)

The greater the distance, the more isolated the fragment

Primary Vegetation

Secondary Vegetation

Connectivity

Biomas Br

Secondary Vegetation Analysis

Spatial and Landscape metrics for all biomes

Land Category	Area (%)
Quilombola territories	0.85
Integral Protection UC	1.28
Undesignated Public Forests	1.82
Sustainable Use UC (without APA)	3.11
Indigenous Lands	5.03
Environmental Protection Area (APA)	6.18
Rural settlement	**15.46**
Private properties (SIGEF)	**22.34**
Area without Land Registration	**43.92**

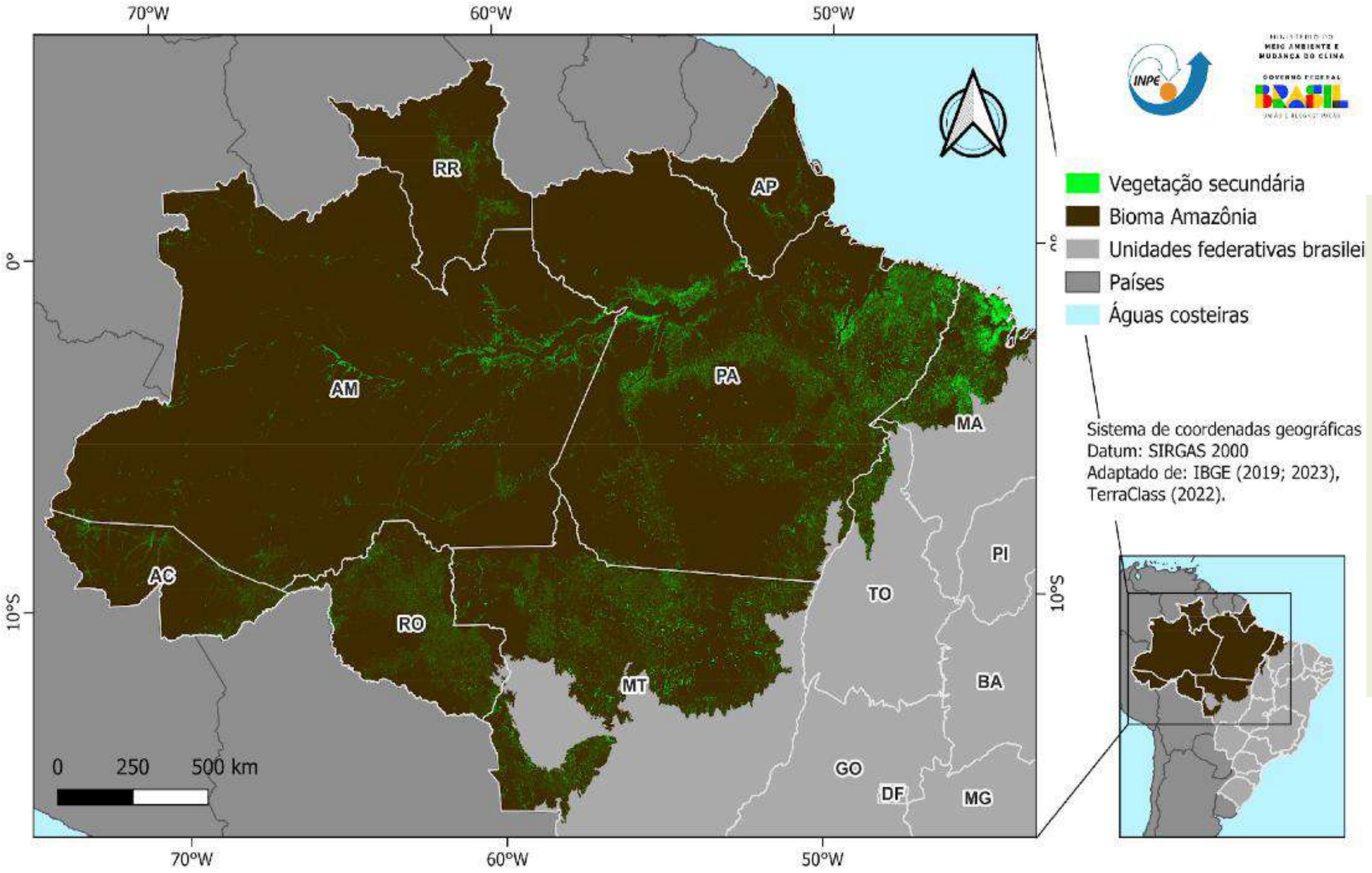
Total area (SV) = 16,247,366.72 ha (689,288 patches)

METRIC	Analysis		
	Area	Polygons	OBS
Weighted age (years)	(34.38%) 7–9 (07.66%) 1–3	(34.69%) 4 - 6 (09.36%) 13 - 14	**young (4 – 9 years)**
Area (ha)	(32.51%) 100 –|1,000 (19.28%) > 1,000	(42.25%) 2 –| 5 (39.40%) 5 –| 20	**Many small, relevant big ones**
Core area	(41.40%) 10 –| 1,000	(87.04%) zero	**relevant edge effect**
Fractal Dimension	(99,33%) 1.25–1.5	(93.76%) 1.25–1.5	**geometric shape - anthropogenic**
Euclidean distance nearest neighbor	84.30% - 0 m	69.80% - 0m	**adjacent to vegetation**
Nearest neighboring vegetation	85.47% - primary vegetation	73.85% - primary vegetation	**primary vegetation**

To be presented by Débora Tomiatti….

Secondary Vegetation Analysis

Spatial and Landscape metrics for all biomes



Amazon Biome Secondary Vegetation

Contribution for Carbon losses & gains

Degradation

- **Fragmentation**
- **Edge effects**

Official mapping of secondary forest in Brazil

BiomasBR - INPE´s vegetation monitoring by satellite Program

Data freely Available

Contribution for Carbon losses & gains

Large scale deforestation

Degradation
- **Selective logging**

SV
- **Fragmentation**
- **Edge effects**

Restore+ BR LandUse (1985 -2025) National Inventory

From secondary vegetation detection to Carbon estimates….

Biomas BR

Thank you!

Silvana Amaral

+55 12 996255480

silvana.amaral@inpe.br

https://data.inpe.br/big/web/biomas/

INPE

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO

GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

Four Decades of Change in Brazil’s Primary and Secondary Vegetation

Barbara Costa

Session 1.2: Mapping Secondary Forest – where are they regrowing according to what dataset?

São José dos Campos, 29 Oct 2025

SynCER

GFZ Helmholtz Centre for Geosciences

INPE

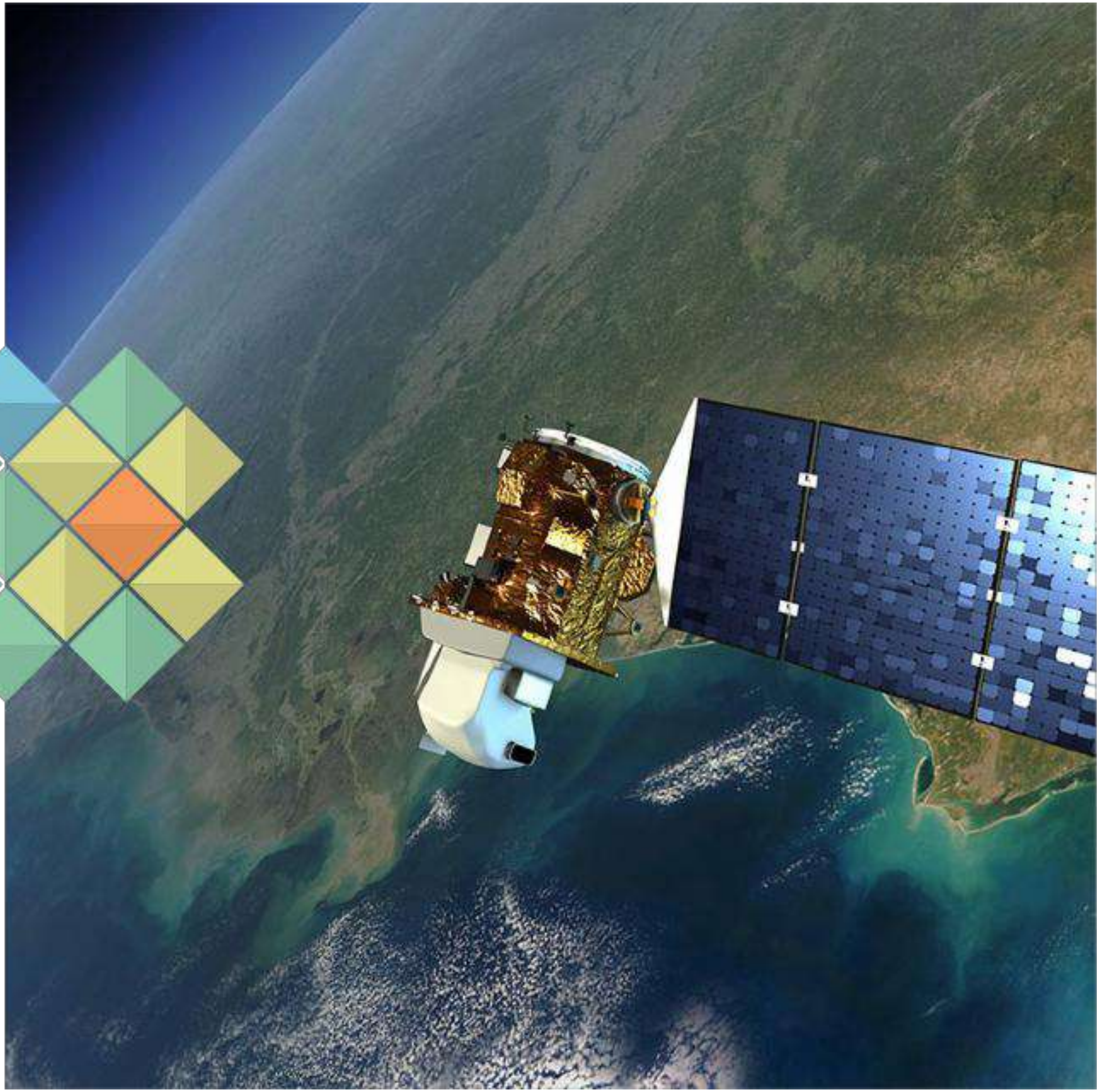
IPAM Amazônia

esa

MAPBIOMAS

Open, collaborative, and applied science for climate change mitigation

10 ANOS
MAPBIOMAS



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- Imazon
- IPAM – Instituto de Pesquisa Ambiental da Amazônia
- SOS Pantanal
- APNE – Associação Plantas do Nordeste
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- EcoStage
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- UFBA – Universidade Federal da Bahia
- ecode
- GeoKarten
- remap

MAPBIOMAS

Since 2015

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- instituto arapyaú
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- AVIV comunicação conteúdo sustentabilidade
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- ICLEI
- brasil.io

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NICFI Norway's International Climate and Forest Initiative

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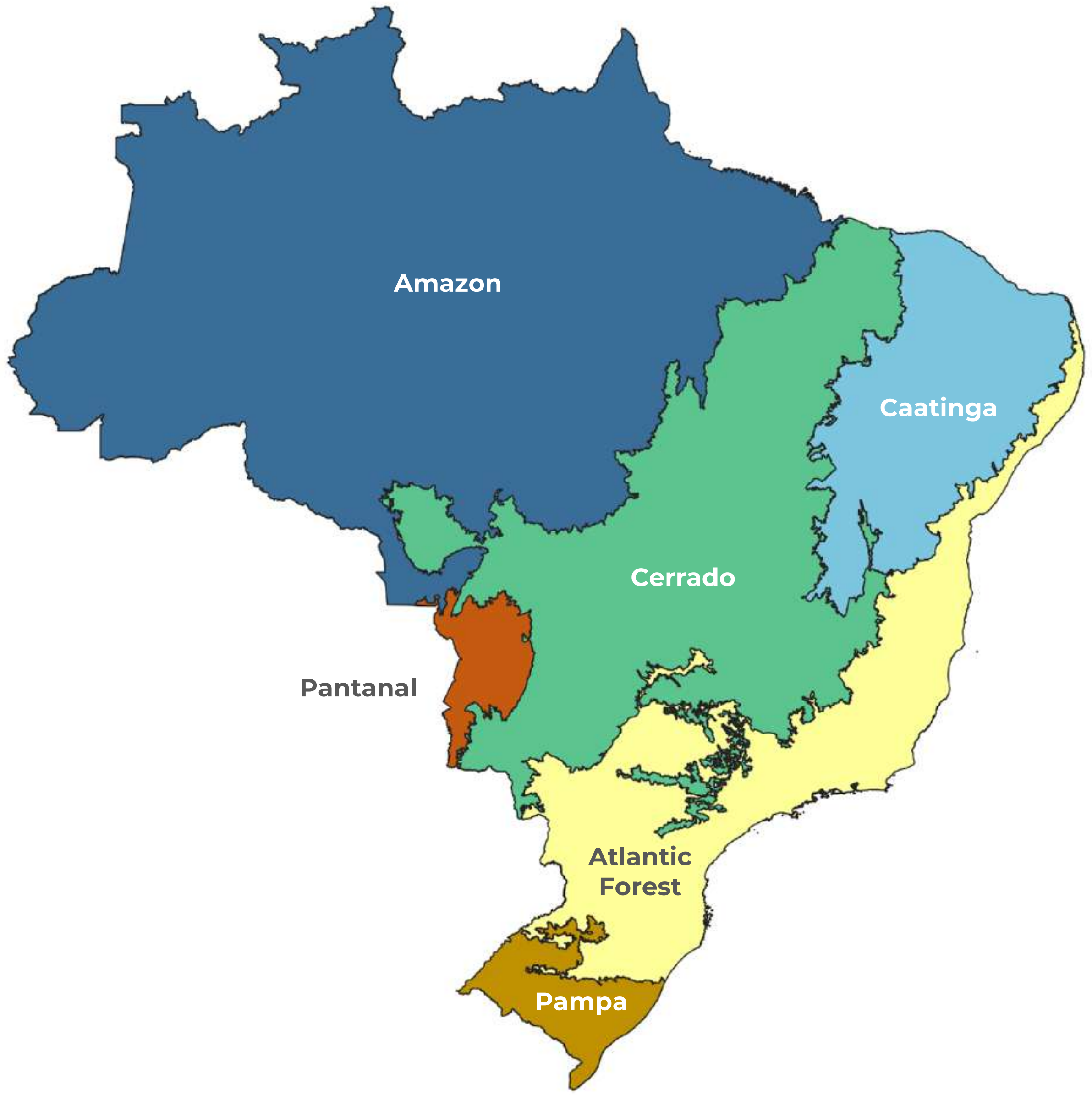
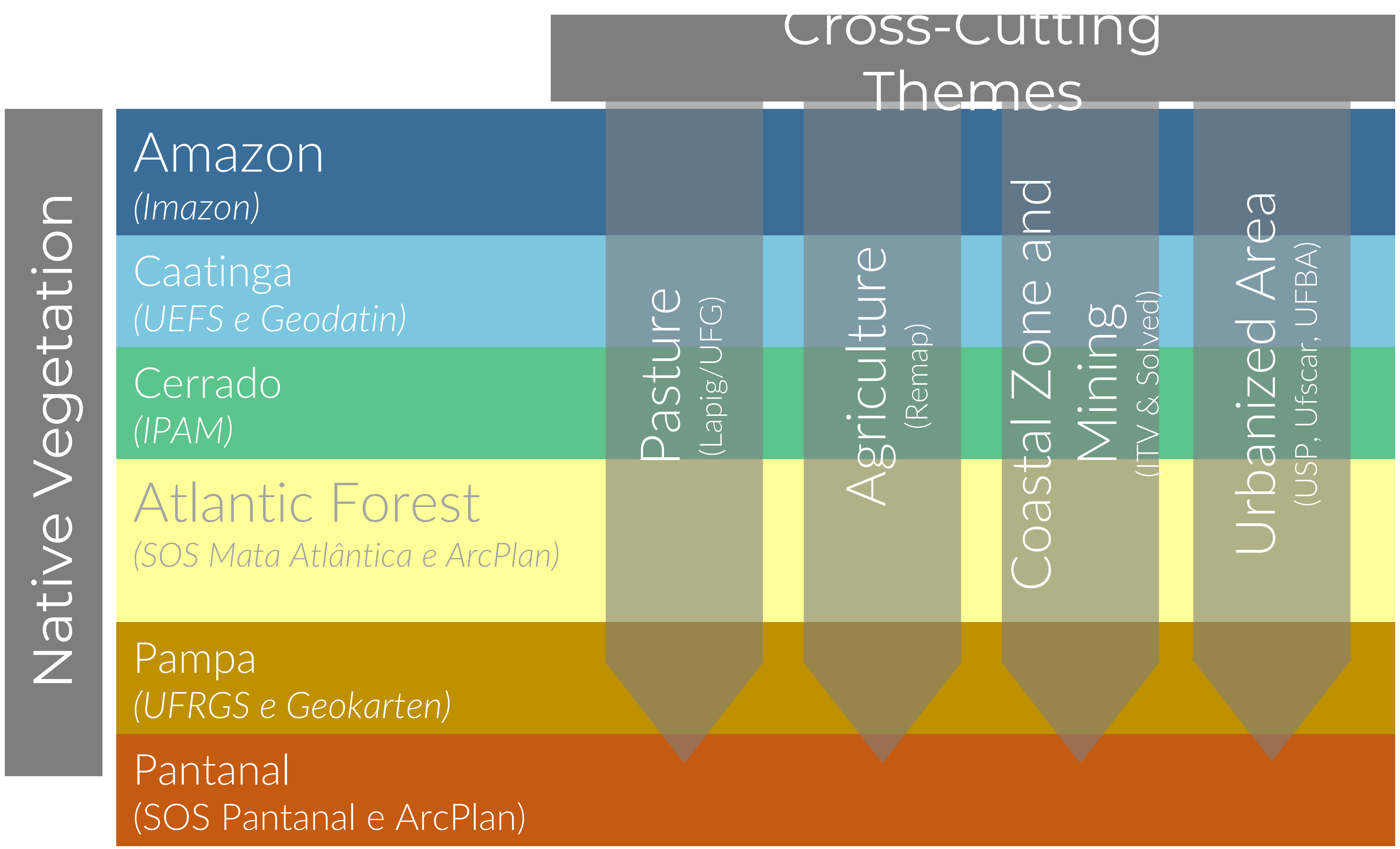
HOW WE ARE ORGANIZED?

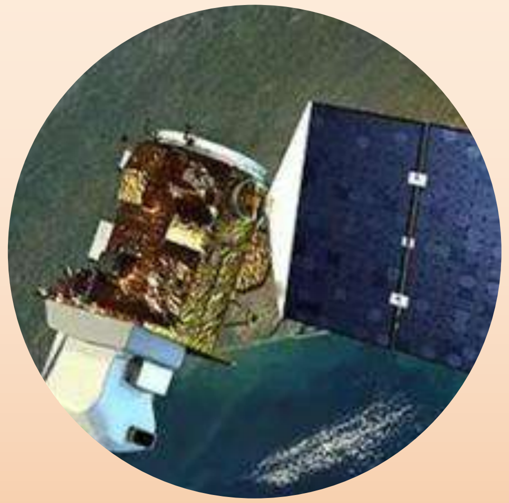
BIOMES AND CROSS-CUTTING THEMES





SUMMARY OF THE DATA GENERATION PROCESS

BIOMES AND CROSS-CUTTING THEMES



Construction of historical series covering the entire territory

Pixel-by-pixel processing

Use of artificial intelligence

(machine learning and deep learning)

Networking and cloud processing with Google Earth Engine

Production of a new data collection each year: **extended mapping period**, **more details with more classes**, and **improved accuracy**

SET OF PRODUCTS AVAILABLE

Products generated by the MapBiomas Brazil

MAPBIOMAS 10 ANOS

MAPBIOMAS v. 10.0

- Land Cover and Use
- Deforestation
- **Secondary Vegetation**
- Agriculture
- Mining
- Infrastructure
- Pasture
- Urban

MAPBIOMAS SOIL

MAPBIOMAS 10 METERS (BETA)

MAPBIOMAS DEGRADATION (BETA)

MAPBIOMAS FIRE

MAPBIOMAS WATER

MAPBIOMAS ALERTA

MONITOR DA FISCALIZAÇÃO

MAPBIOMAS Rural Credit

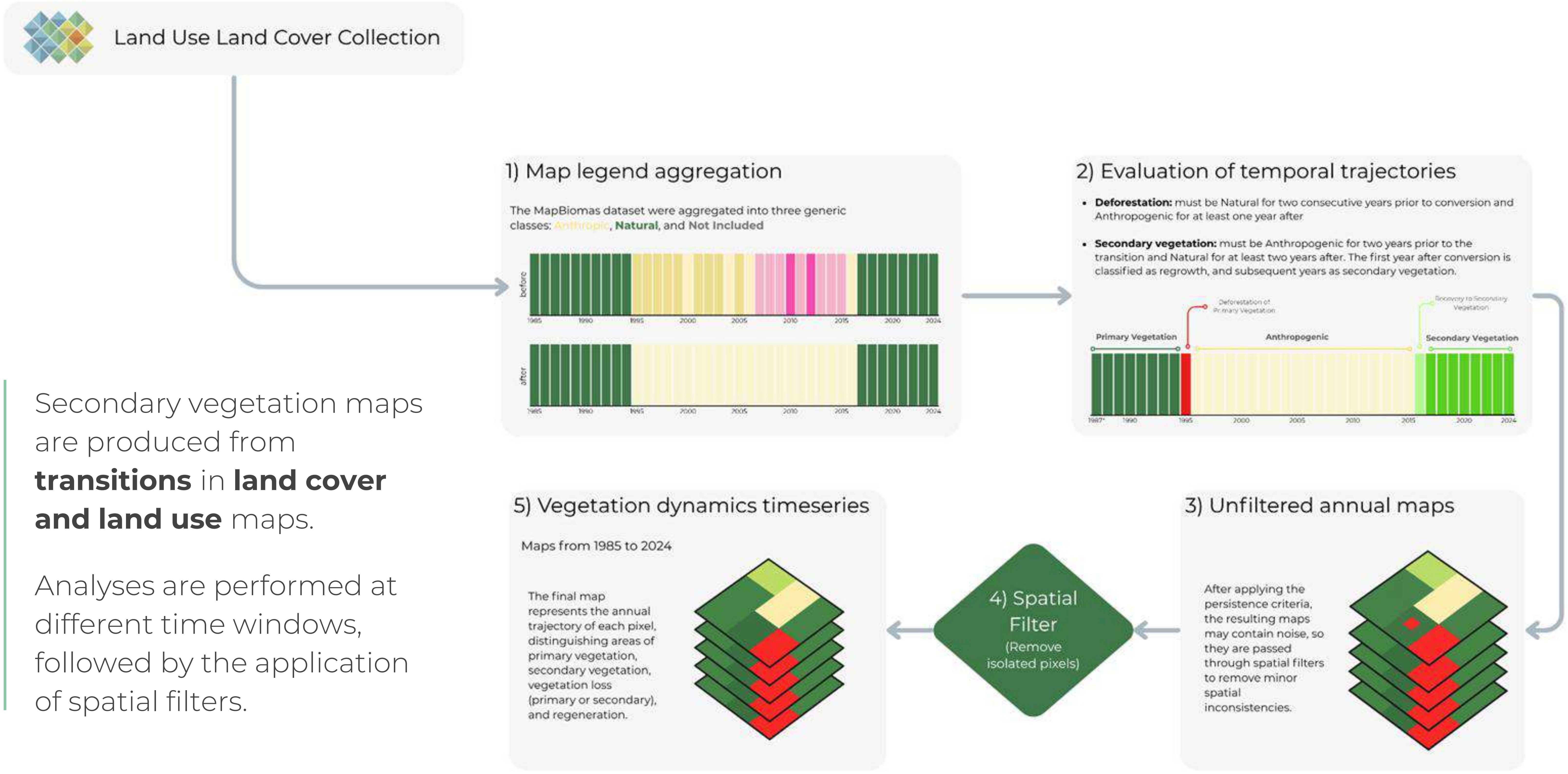
MAPBIOMAS RECUPERAÇÃO

RAD - Annual Deforestation Report

RAF - Annual Fire Report

MAPPING SECONDARY VEGETATION AND DEFORESTATION

Method overview



Secondary vegetation maps are produced from **transitions** in **land cover and land use** maps.

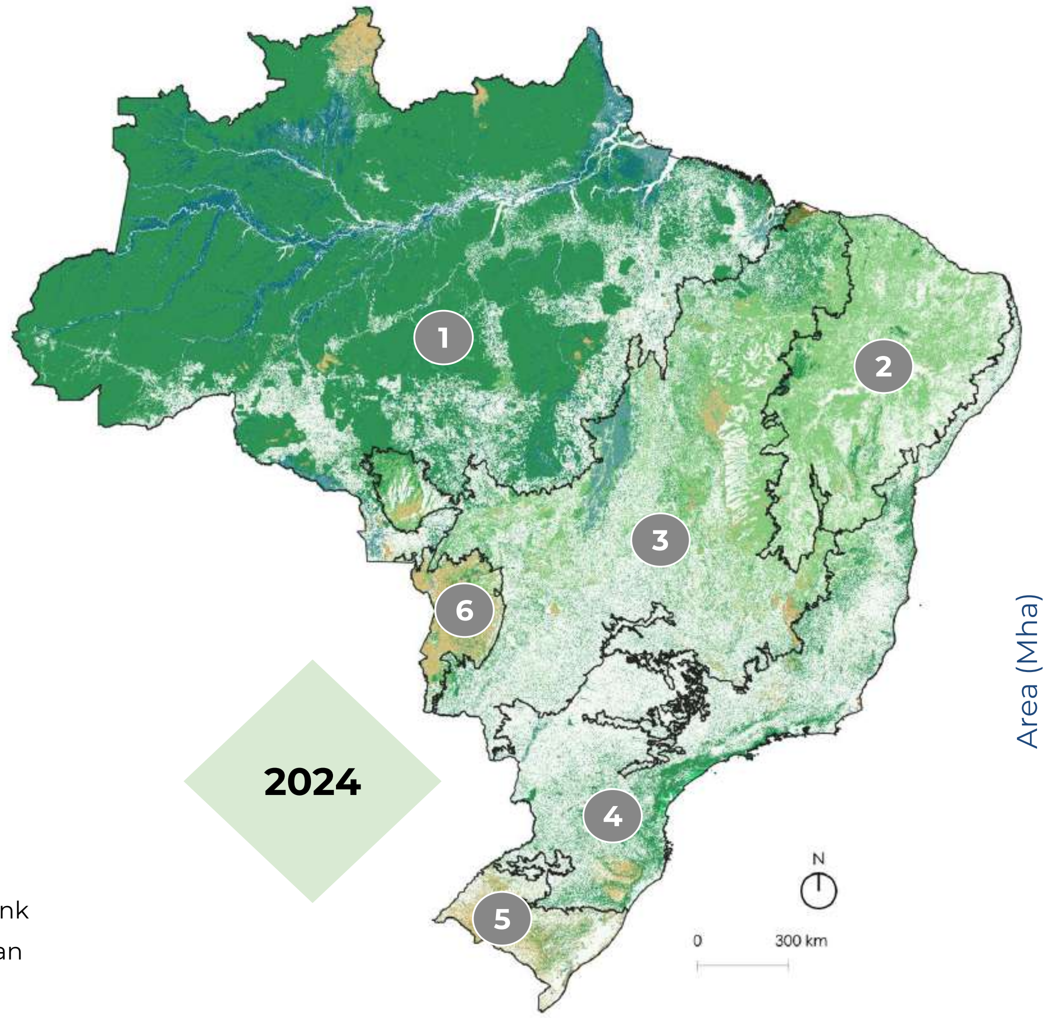
Analyses are performed at different time windows, followed by the application of spatial filters.

A 40-YEAR OVERVIEW OF VEGETATION IN BRAZIL

1985 - 2024

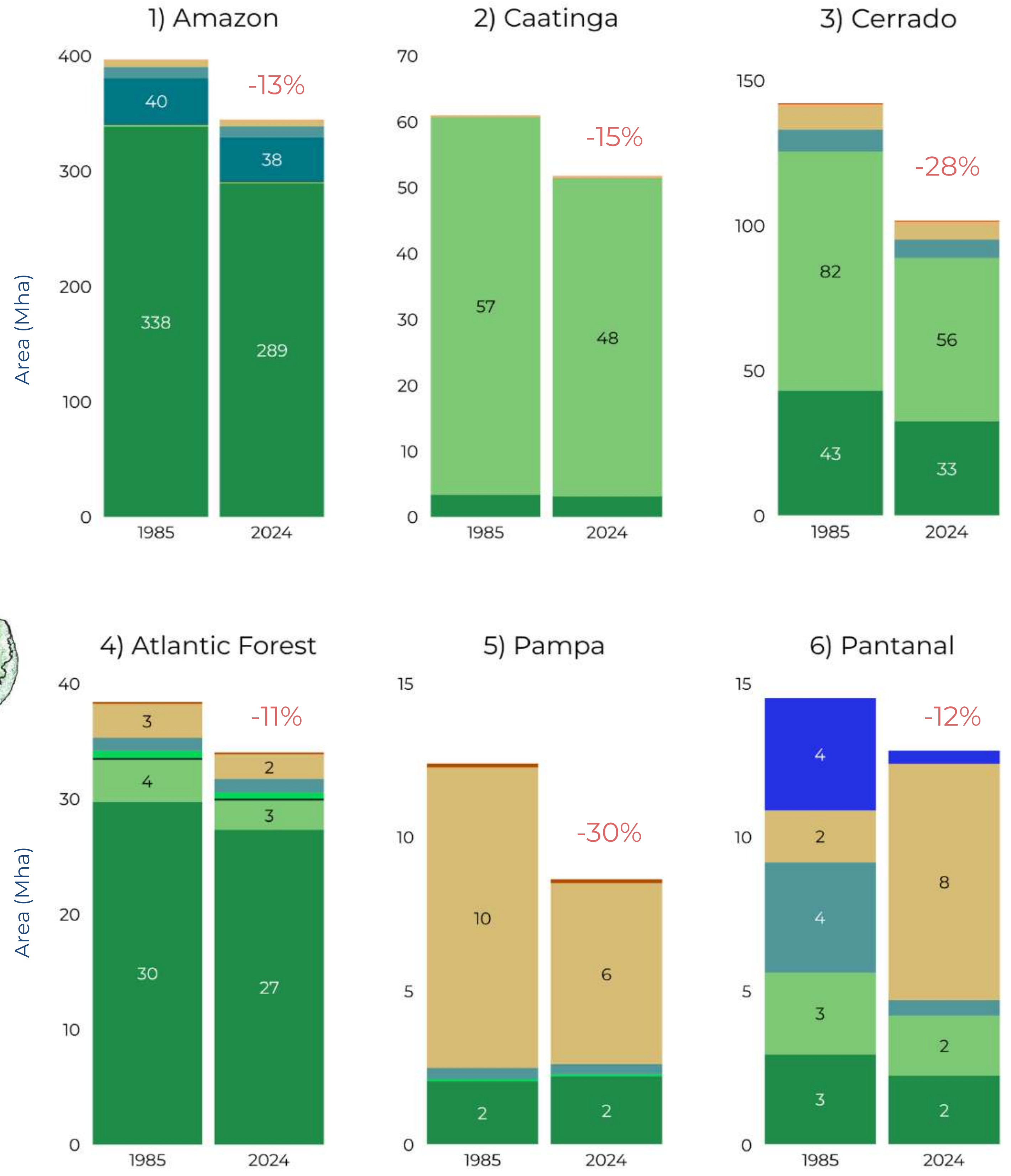
MAPBIOMAS 10 ANOS

Reduction of **108.4** million hectares (16%) of native vegetation in Brazil in 40 years, an average of 2.8 million hectares lost per year



Pampa and **Cerrado** are the biomes that have lost the most native vegetation area proportionally.

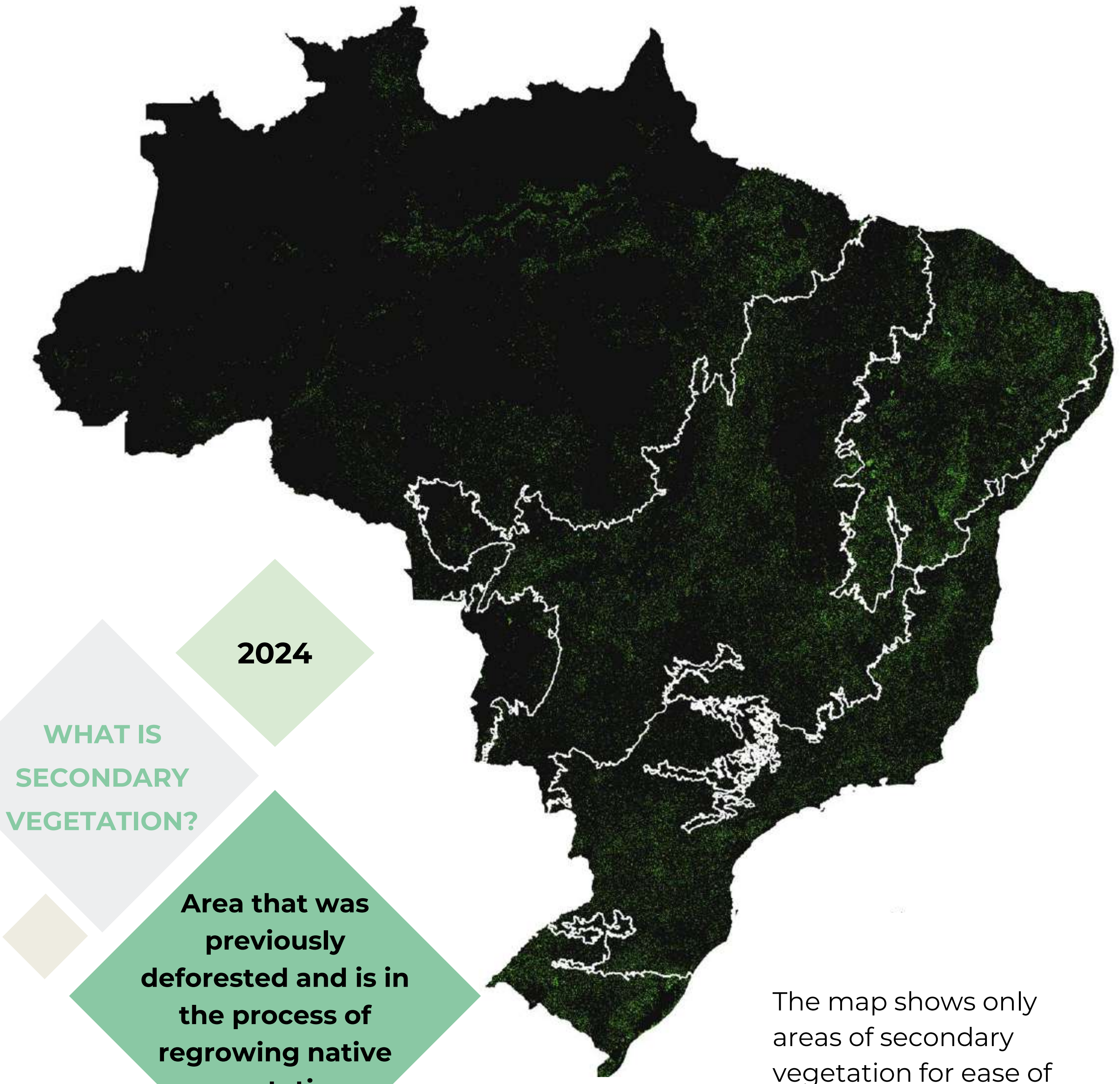
Forest Formation
Savanna Formation
Floodable Forest
Mangrove
Wooded Sandbank
Wetland
Grassland
Hypersaline Tidal Flat
Rocky Outcrop
Herbaceous Sandbank
River, Lake and Ocean



PRIMARY AND SECONDARY VEGETATION IN BRAZIL

1985 - 2024

MAPBIOMAS 10 ANOS



34.7 Mha secondary vegetation in Brazil in 2024

Over the last decade (2015–2024), the area of secondary vegetation in Brazil has grown at an average rate of **34.5 Mha/year.**

of the country's native vegetation is secondary (2024)

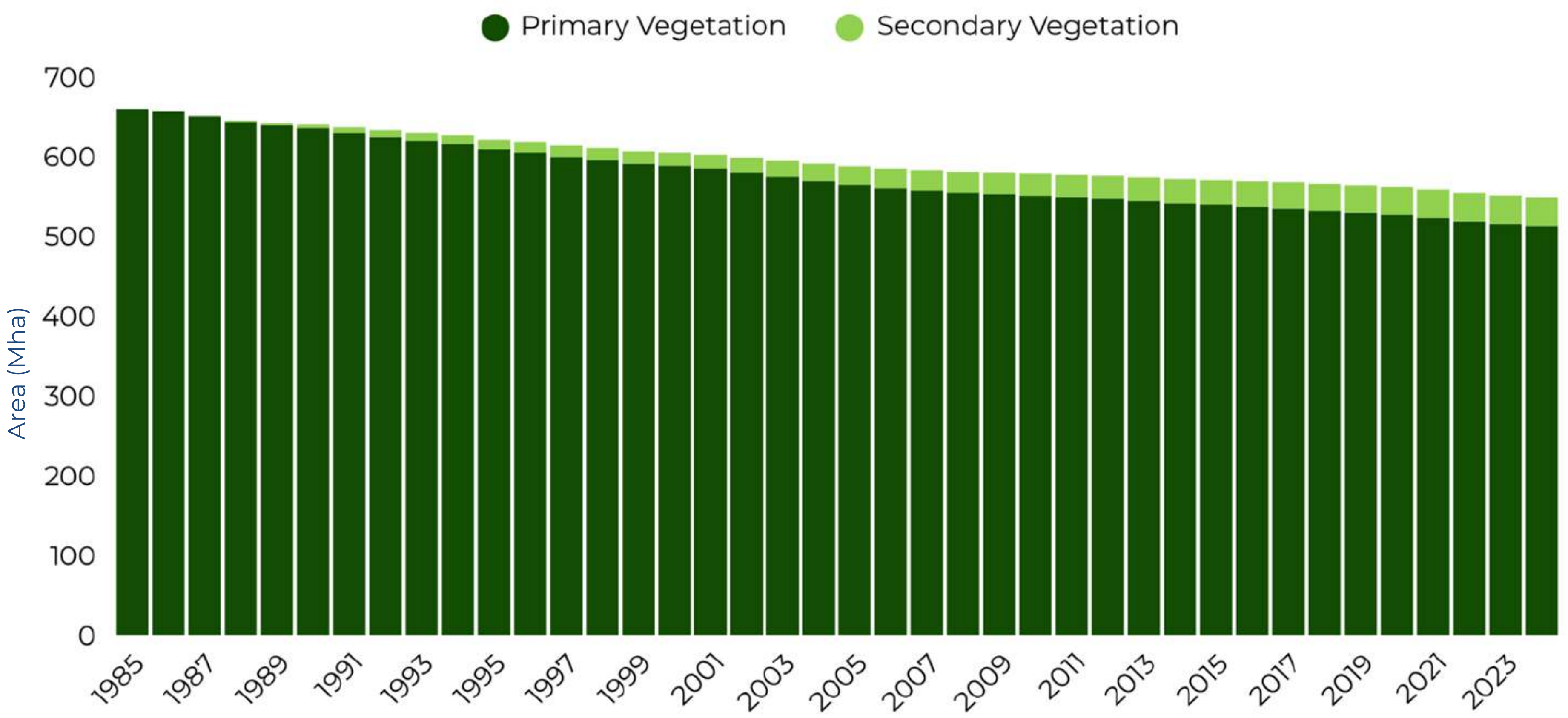
2024

WHAT IS SECONDARY VEGETATION?

Area that was previously deforested and is in the process of regrowing native vegetation

The map shows only areas of secondary vegetation for ease of visualization.

AREA OF PRIMARY AND SECONDARY VEGETATION IN BRAZIL (1985 - 2024)



PRIMARY AND SECONDARY VEGETATION IN BRAZILIAN BIOMES

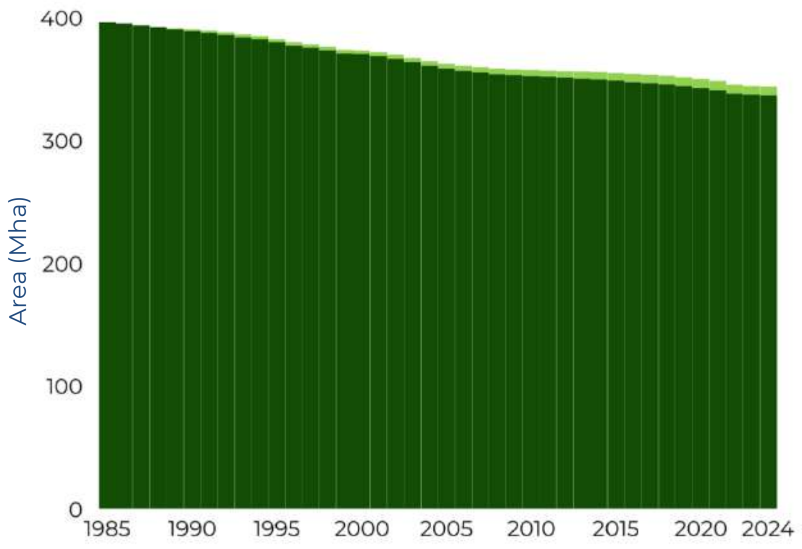
1985 - 2024

Atlantic Forest and Pampa biomes have the **highest proportions** of secondary vegetation, **22.1%** and **22.8%**, respectively. These proportions are higher than the national average

Amazon and **Pantanal** have the **lowest proportions** of secondary vegetation. In absolute terms, the **Caatinga** and **Cerrado** have the **largest areas** of secondary vegetation.

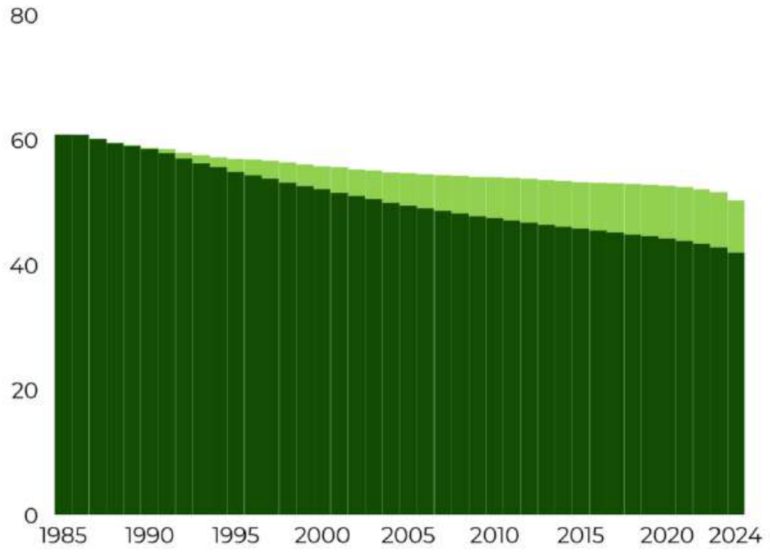
Amazon

2024: **2%** secondary vegetation* (6,9 Mha)



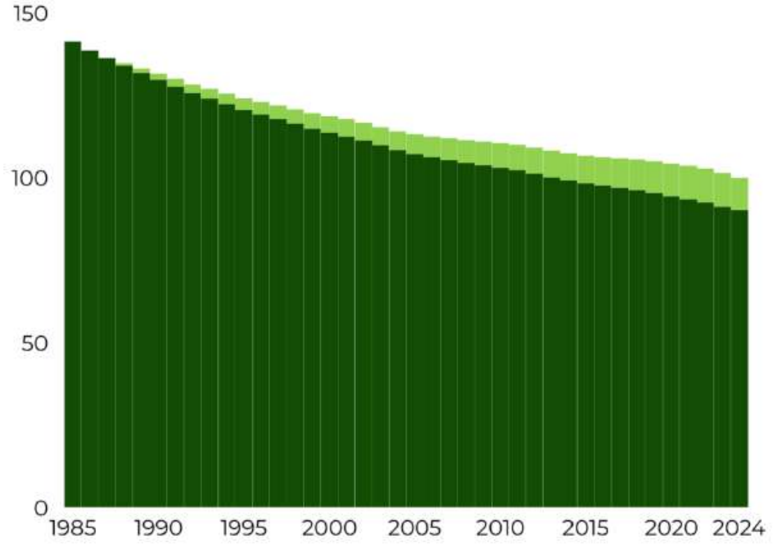
Caatinga

2024: **16,6%** secondary vegetation* (8,3 Mha)



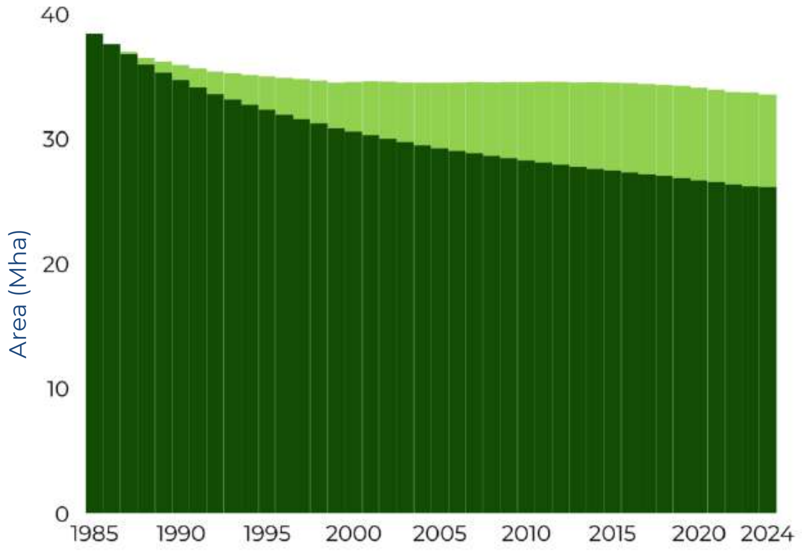
Cerrado

2024: **9,8%** secondary vegetation* (9,8 Mha)



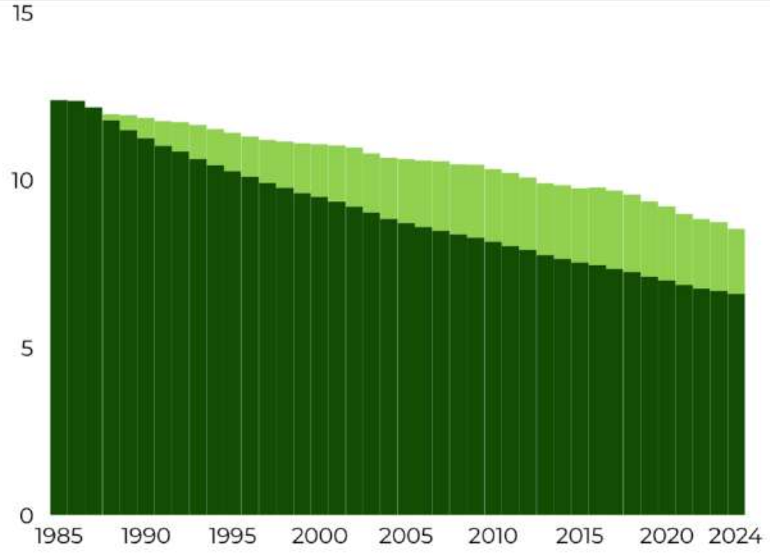
Atlantic Forest

2024: **22,1%** secondary vegetation* (7,4 Mha)



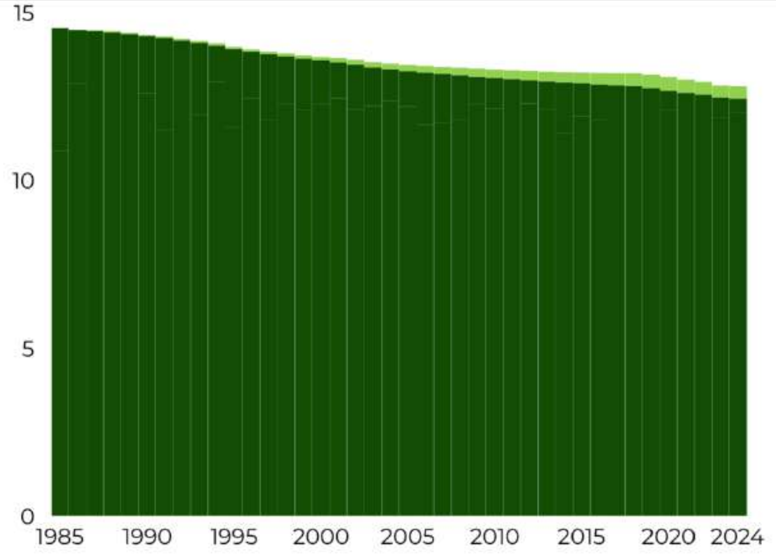
Pampa

2024: **22,8%** secondary vegetation* (1,9 Mha)



Pantanal

2024: **2,8%** secondary vegetation* (0,3 Mha)



Primary Vegetation

Secondary Vegetation

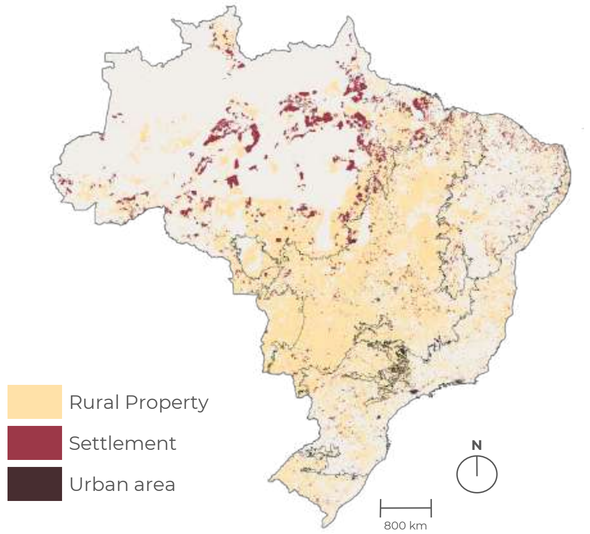
* In relation to the total area of native vegetation

LAND TENURE AND SECONDARY VEGETATION IN BRAZIL

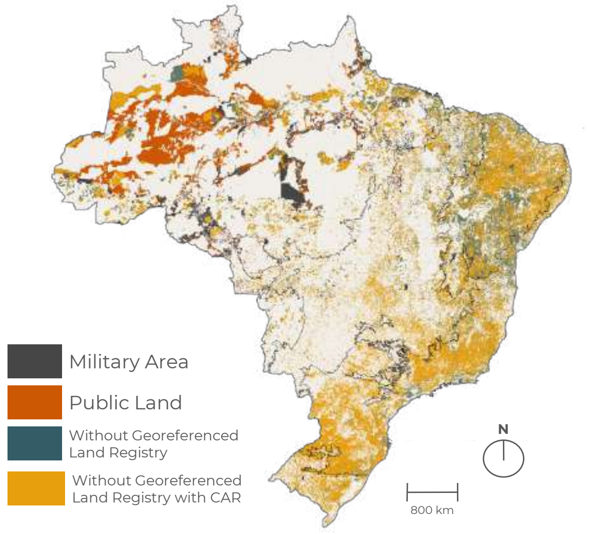
Insights for 2024

MAPBIOMAS 10 ANOS

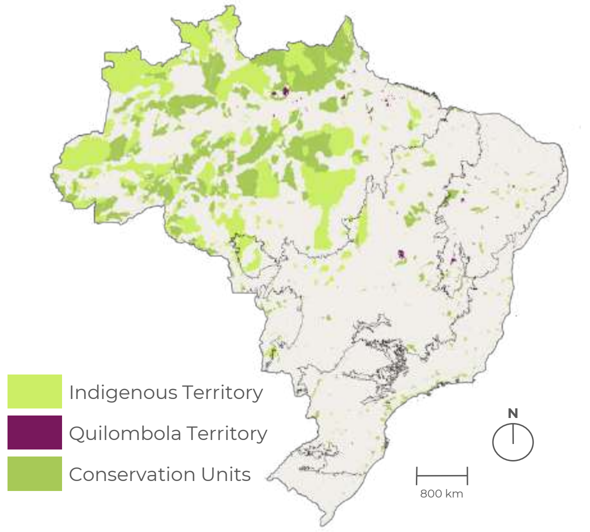
Private Areas
(with georeferenced land registry)



Public Lands or Lands Without Georeferenced Land Registry

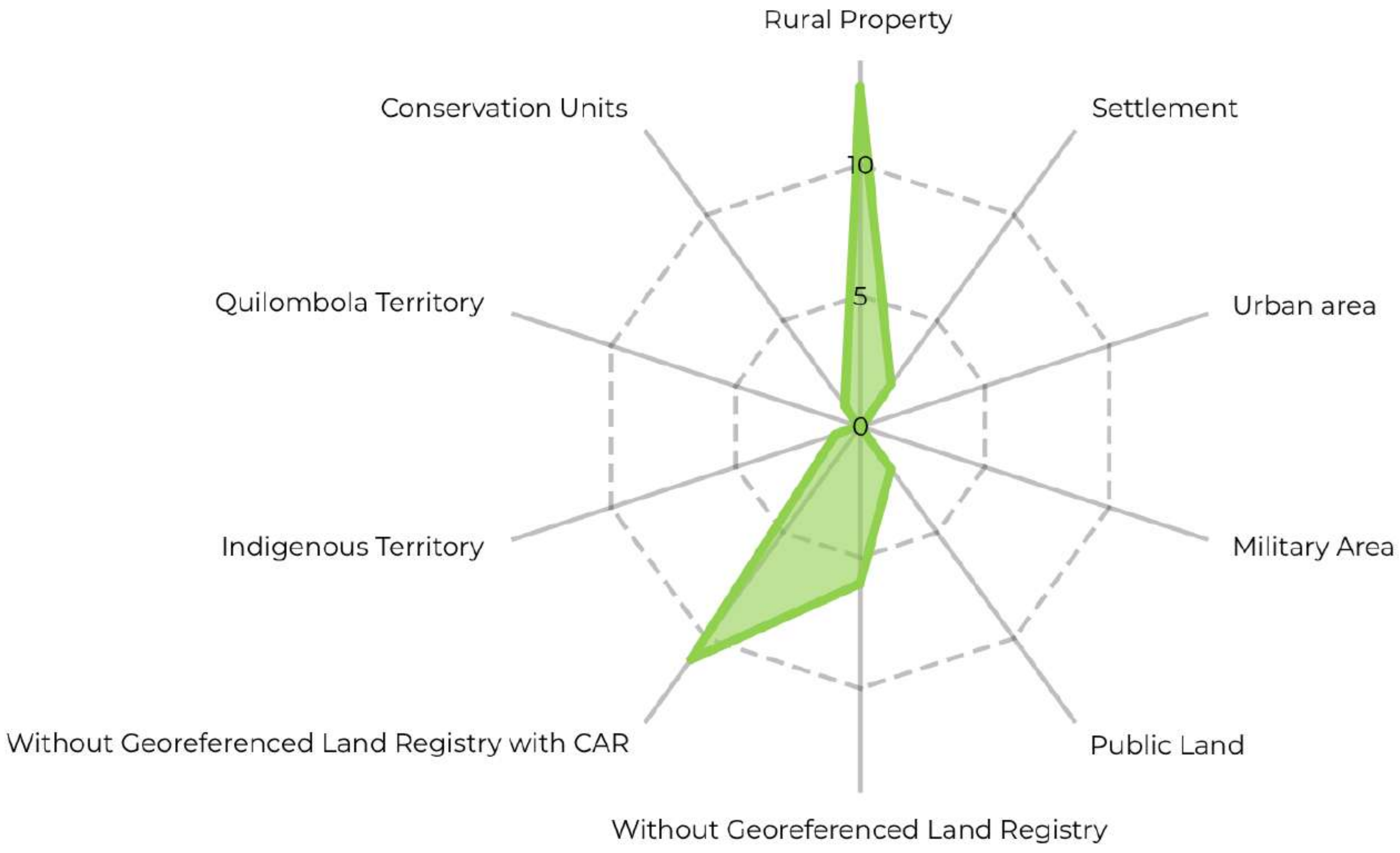


Protected Areas or Areas for Collective Use



From the **34.7 Mha** of secondary vegetation in Brazil in 2024, **13.3 Mha** (38%) are on **rural properties**

TOTAL OF SECONDARY VEGETATION PER LAND TENURE (2024)



More than 85% of secondary vegetation is **outside protected areas**, concentrated on rural properties and land without georeferenced registration.

Protected and community-use areas (conservation units, indigenous lands, and quilombola communities) have a **low proportion** of secondary vegetation.

*Data source: GPP (ESALQ/USP), IMAFLORA, and CITE, 2025. Technical note: Matrix land use grid of Brazil – Piracicaba, SP, Brazil. Access: https://cartasdaterra.com.br/

LAND TENURE AND SECONDARY VEGETATION IN BRAZIL

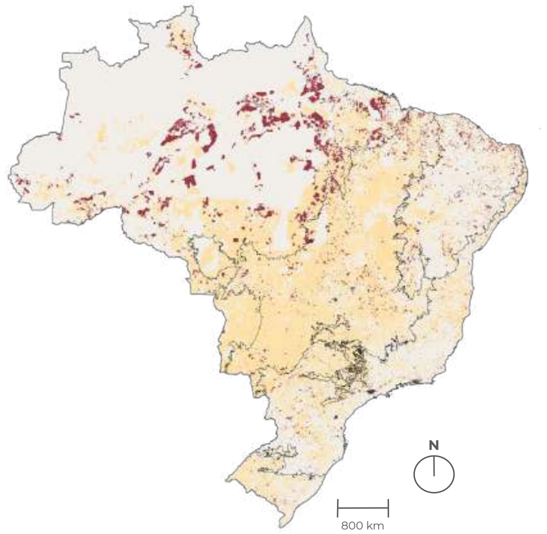
Insights for 2024

MAPBIOMAS 10 ANOS

Primary Vegetation

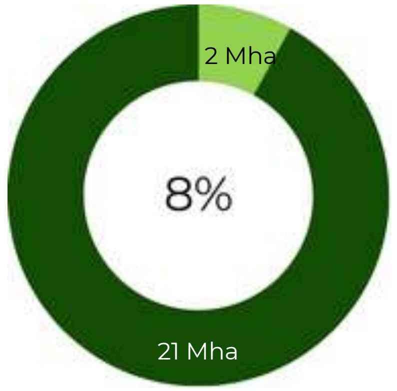
Secondary Vegetation

Private Areas
(with georeferenced land registry)

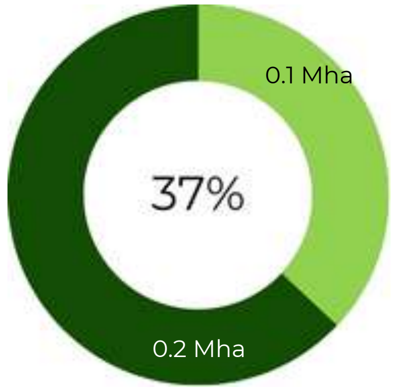


Rural Property
32% of Brazil (268,4 Mha)

Settlement
5% of Brazil (40,2 Mha)

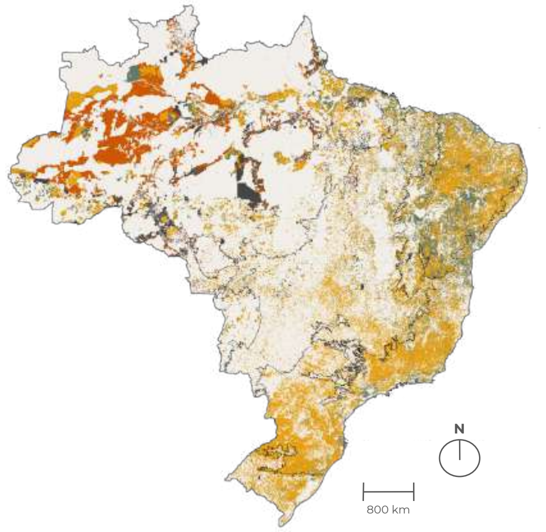


Urban Area
1% of Brazil (4,8 Mha)



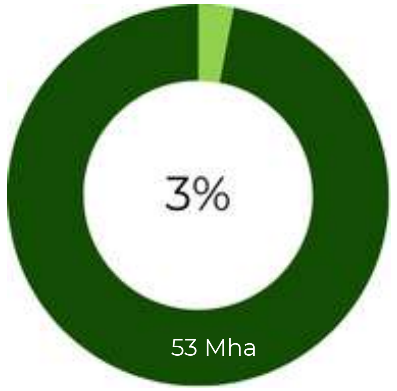
Rural properties account for the **largest total area** of secondary vegetation (13 Mha, or 10% of native vegetation in these areas)

Public Lands or Lands Without Georeferenced Land Registry

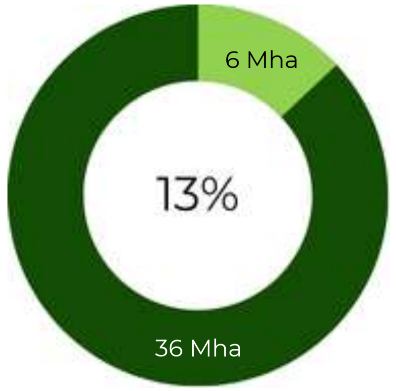


Military Area
0,3% of Brazil (2,8 Mha)

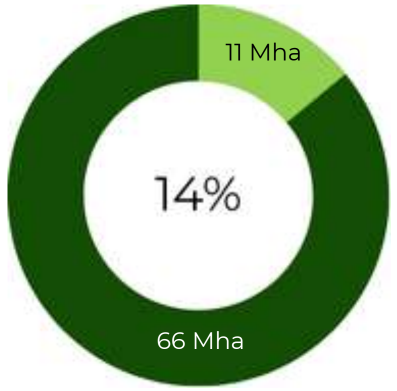
Public Land
8,1% of Brazil (68,7 Mha)



Without Georeferenced Land Registry
8% of Brazil (70,9 Mha)

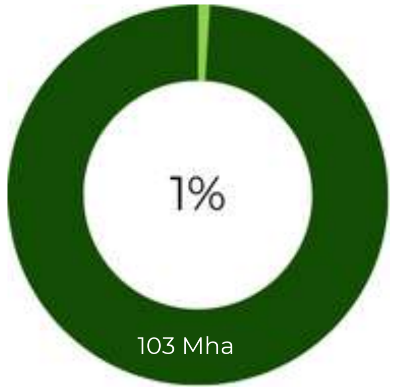


Without Georeferenced Land Registry with CAR
19% of Brazil (159,0 Mha)

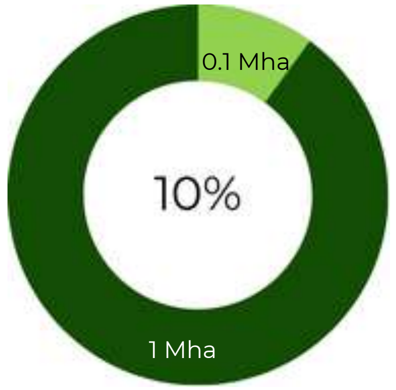


Protected Areas or Areas for Collective Use

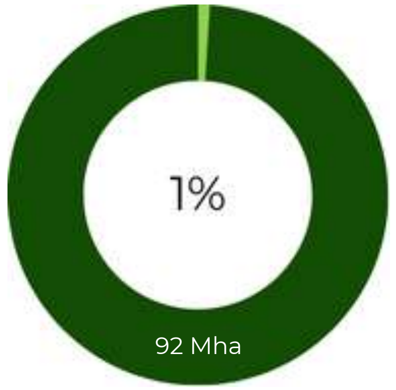
Indigenous Territory
13% of Brazil(111,7 Mha)



Quilombola Territory
0,2% of Brazil (1,6 Mha)



Conservation Units
11% of Brazil (96,3 Mha)



Indigenous territories and **conservation units** have only **1% secondary vegetation**, indicating more stability and preservation of primary vegetation

*Data source: GPP (ESALQ/USP), IMAFLORA, and CITE, 2025. Technical note: Matrix land use grid of Brazil – Piracicaba, SP, Brazil. Access: https://cartasdaterra.com.br/

SECONDARY VEGETATION AREA BY AGE IN BRAZIL

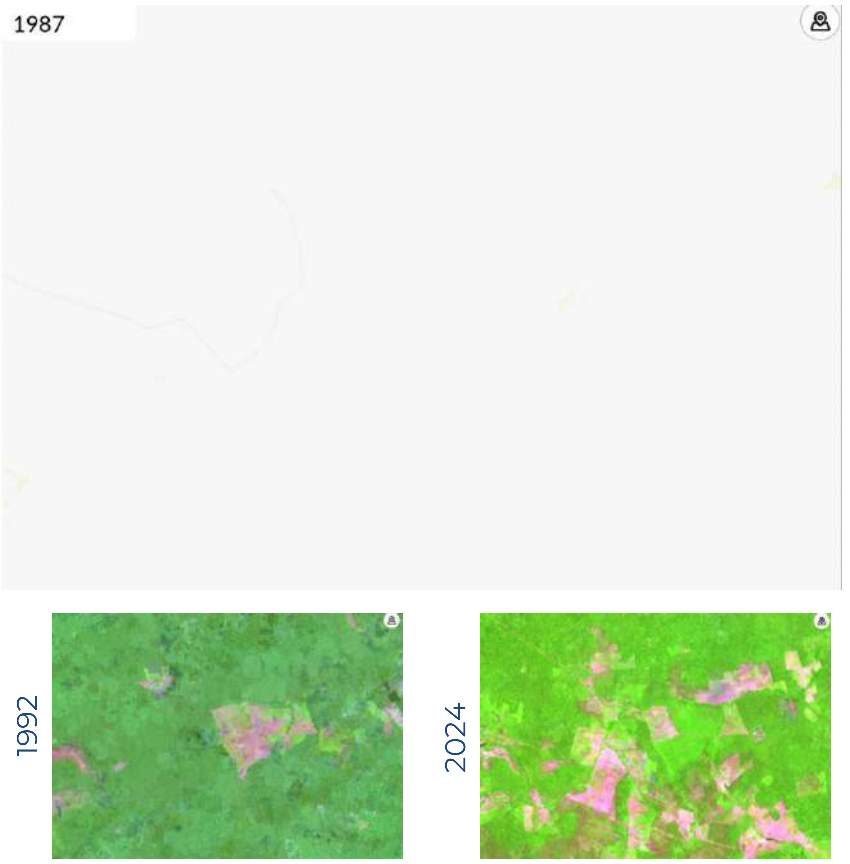
1985 - 2024

Young secondary vegetation predominates.

Most of it is up to 10 years old, with ages between 3 and 7 years being the most common. Secondary vegetation over 30 years old represents a small fraction of the total.

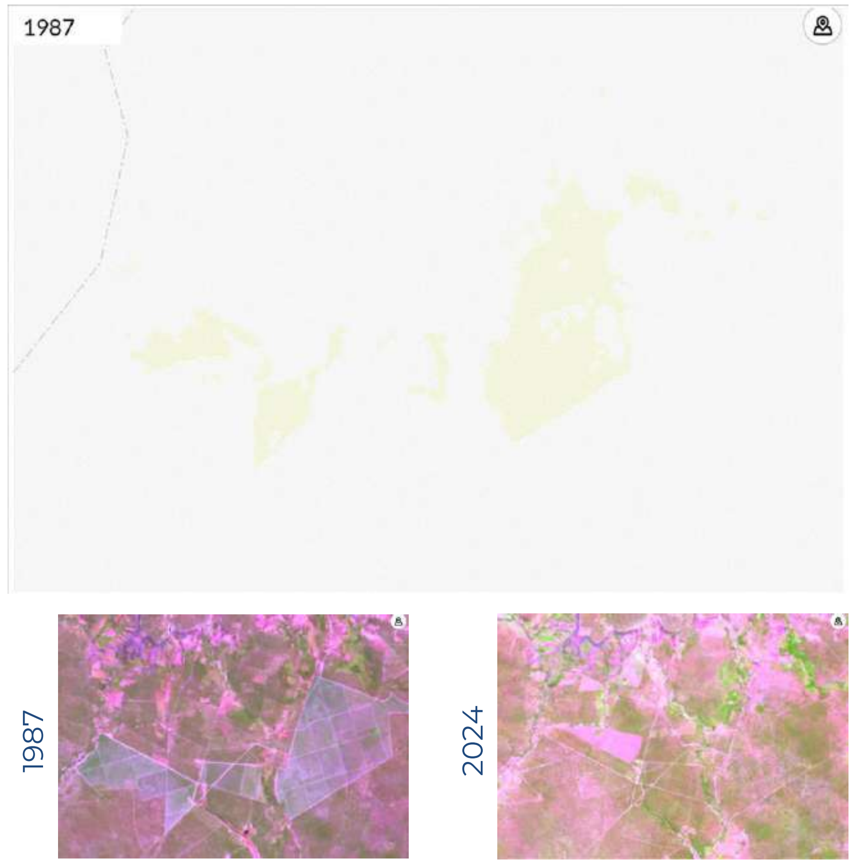
Amazon

Municipality: Prainha (PA)



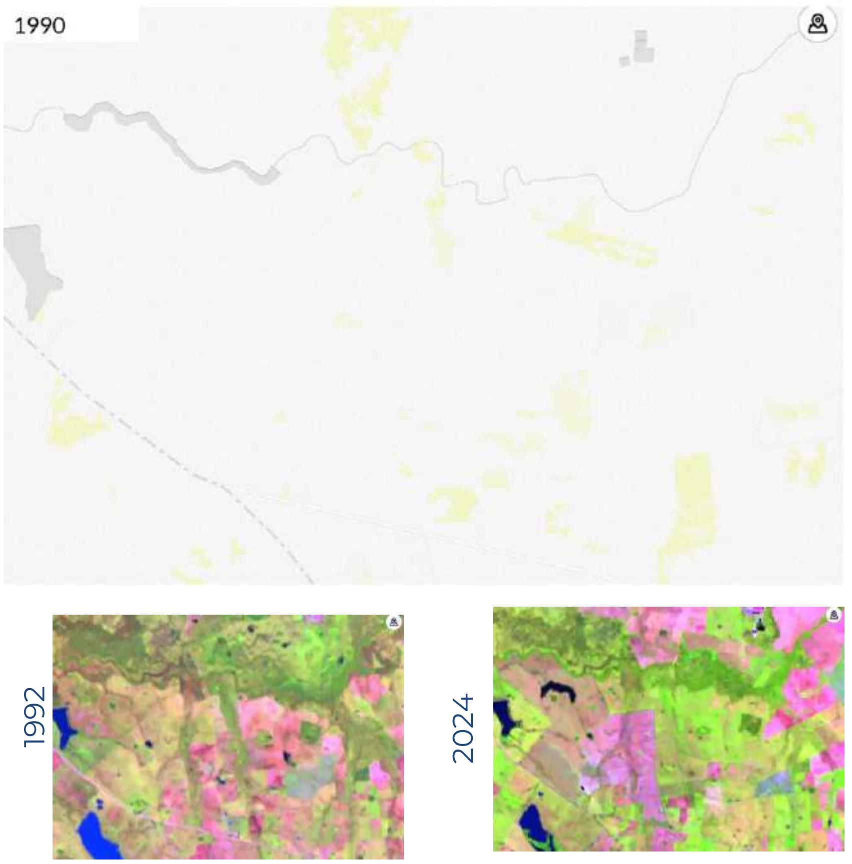
Cerrado

Municipality: Januária (MG)

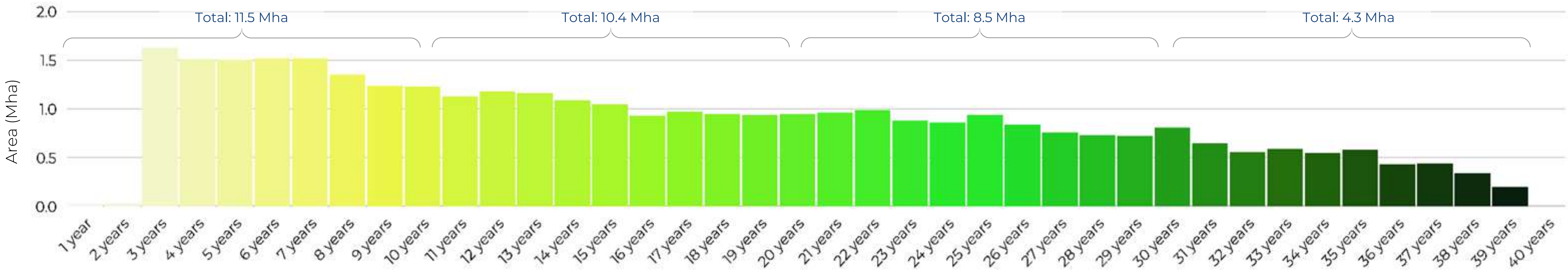


Pampa

Municipality: Bagé (RS)

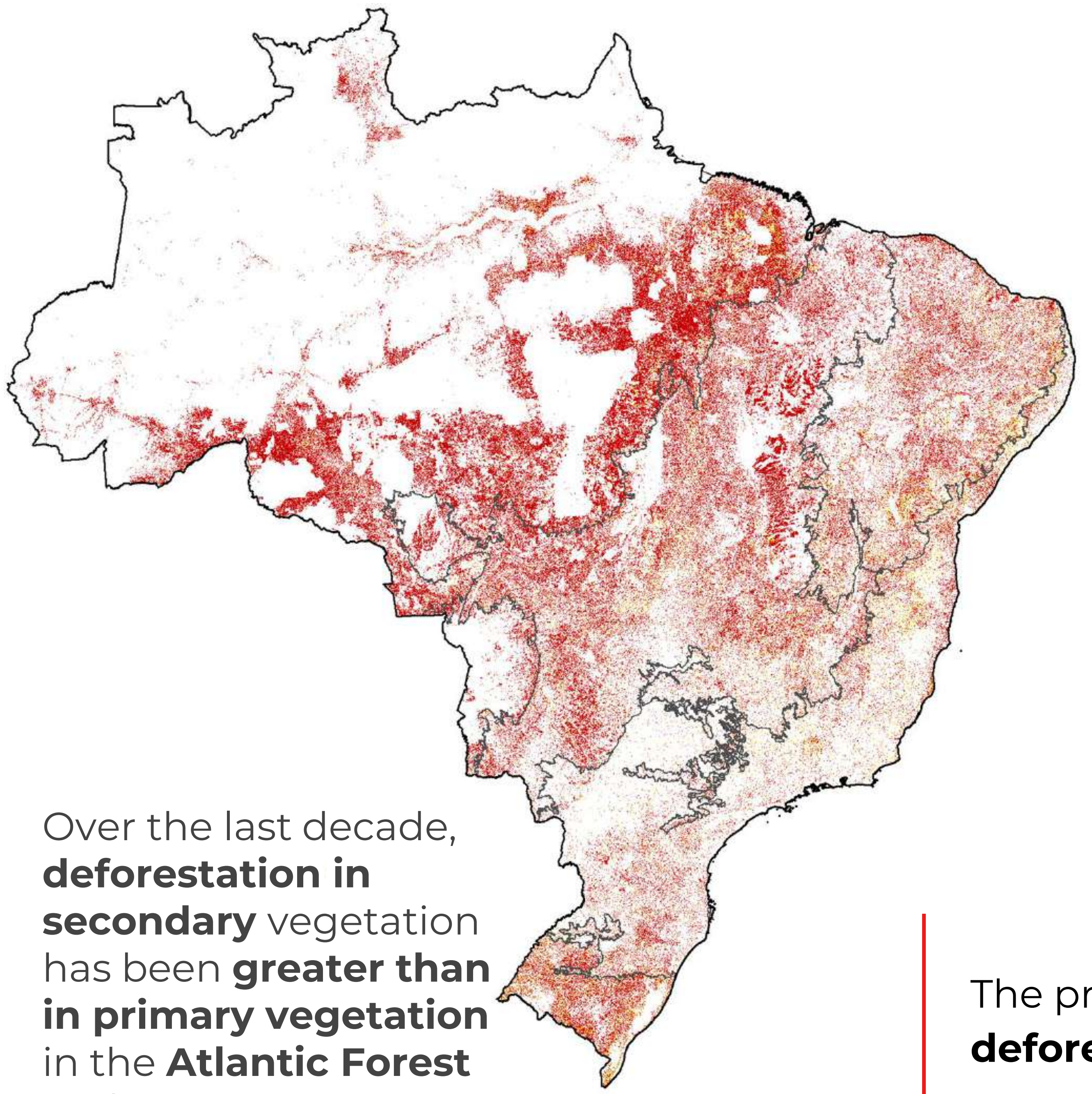


Secondary Vegetation • Age by class •



DEFORESTATION OF PRIMARY AND SECONDARY VEGETATION

1985 - 2024

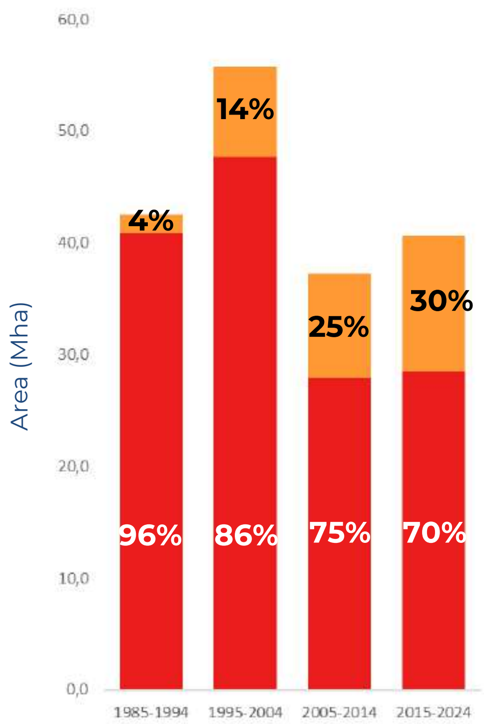


Over the last decade, **deforestation in secondary** vegetation has been **greater than in primary vegetation** in the **Atlantic Forest** and **Pampa**.

Deforestation of primary vegetation

Deforestation of secondary vegetation

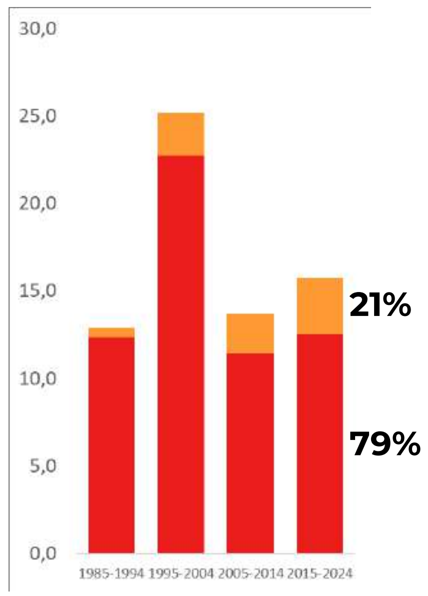
Brazil



The proportion of **deforestation in secondary vegetation** is **higher** from **2015 to 2024** compared to other decades.

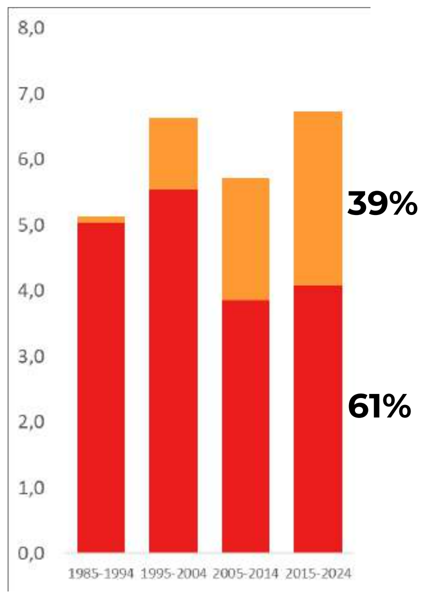
Amazon

In 40 years, 59 Mha (87%) in primary vegetation and 8.5 Mha (13%) in secondary



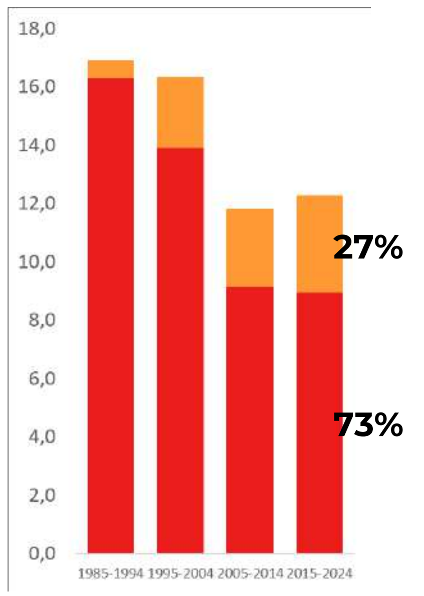
Caatinga

In 40 years, 18.5 Mha (76%) in primary vegetation and 5.7 Mha (24%) in secondary



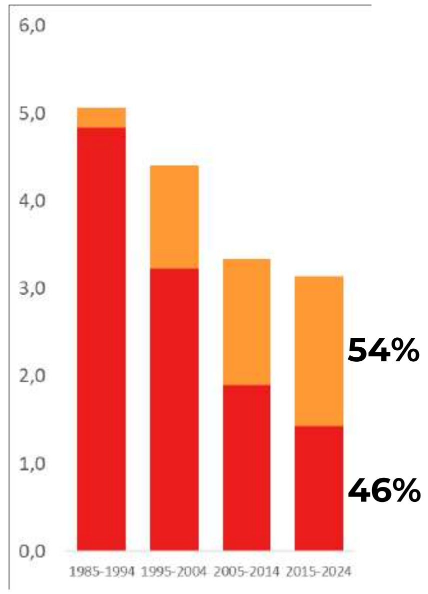
Cerrado

In 40 years, 48.3Mha (84%) in primary vegetation and 9 Mha (16%) in secondary



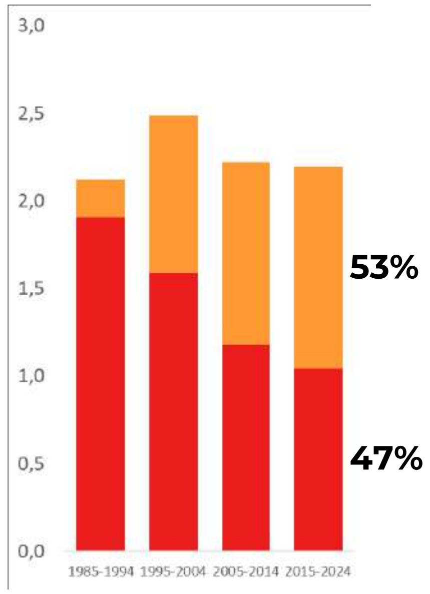
Atlantic Forest

In 40 years, 11.4 Mha (71%) in primary vegetation and 4.5 Mha (29%) in secondary



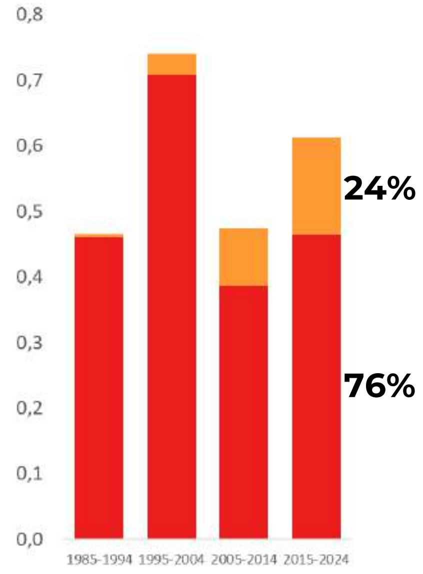
Pampa

In 40 years, 5.7Mha (63%) in primary vegetation and 3.3 Mha (37%) in secondary



Pantanal

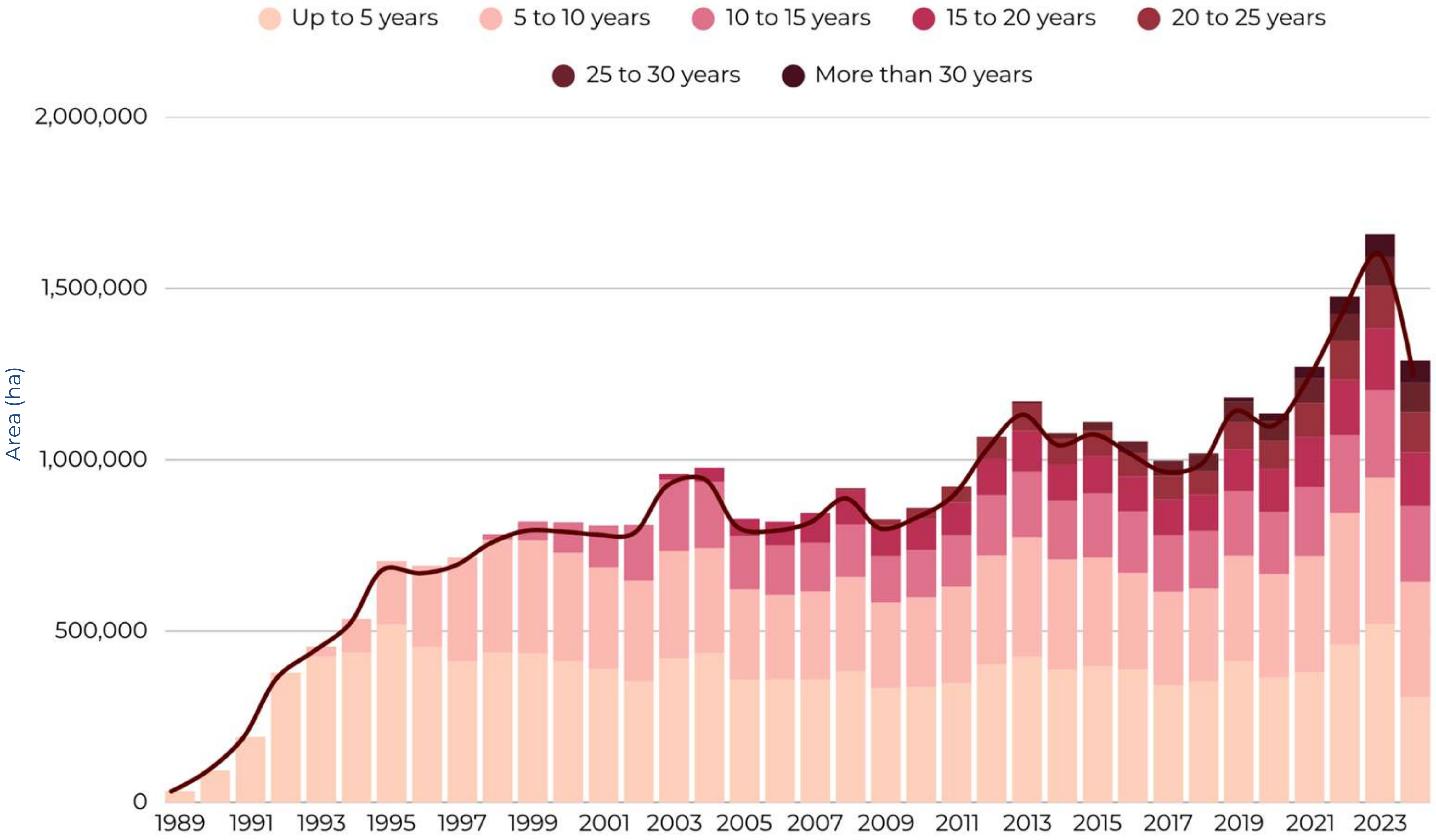
In 40 years, 2Mha (88%) in primary vegetation and 0.3 Mha (12%) in secondary



PATTERNS OF SECONDARY VEGETATION DEFORESTATION BY AGE

1989 - 2024

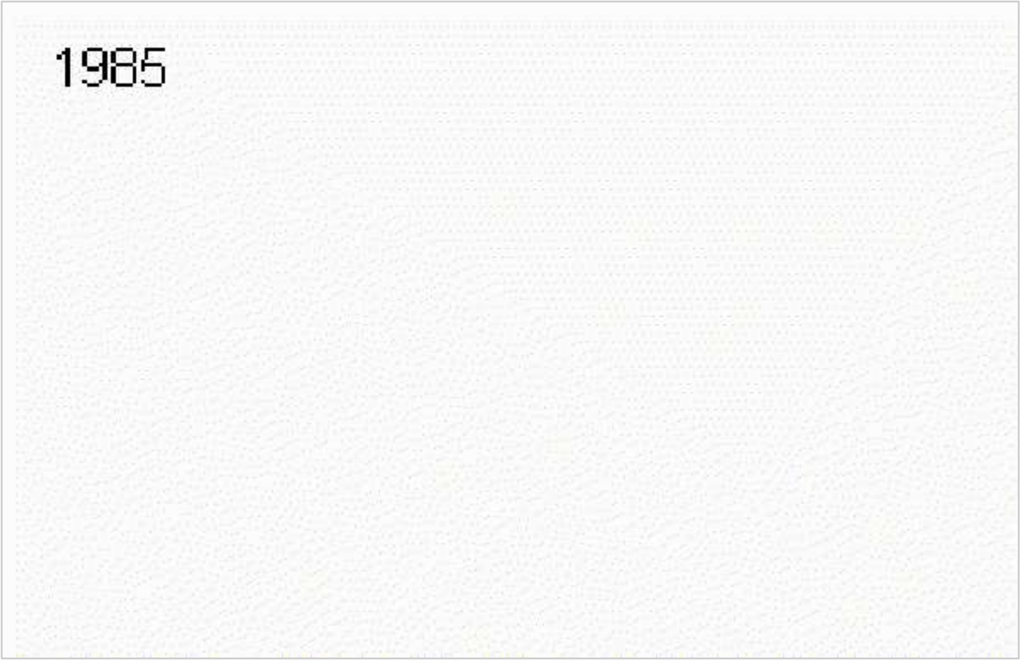
How old is the secondary vegetation when deforestation occurs?



On average, **68%** of s**econdary vegetation deforestation** in the last decade (2015–2024) occurred in areas **older than 5 years**.

Secondary vegetation over **20 years** old accounted for **14%** of deforestation.

Municipality: Correntina (BA)

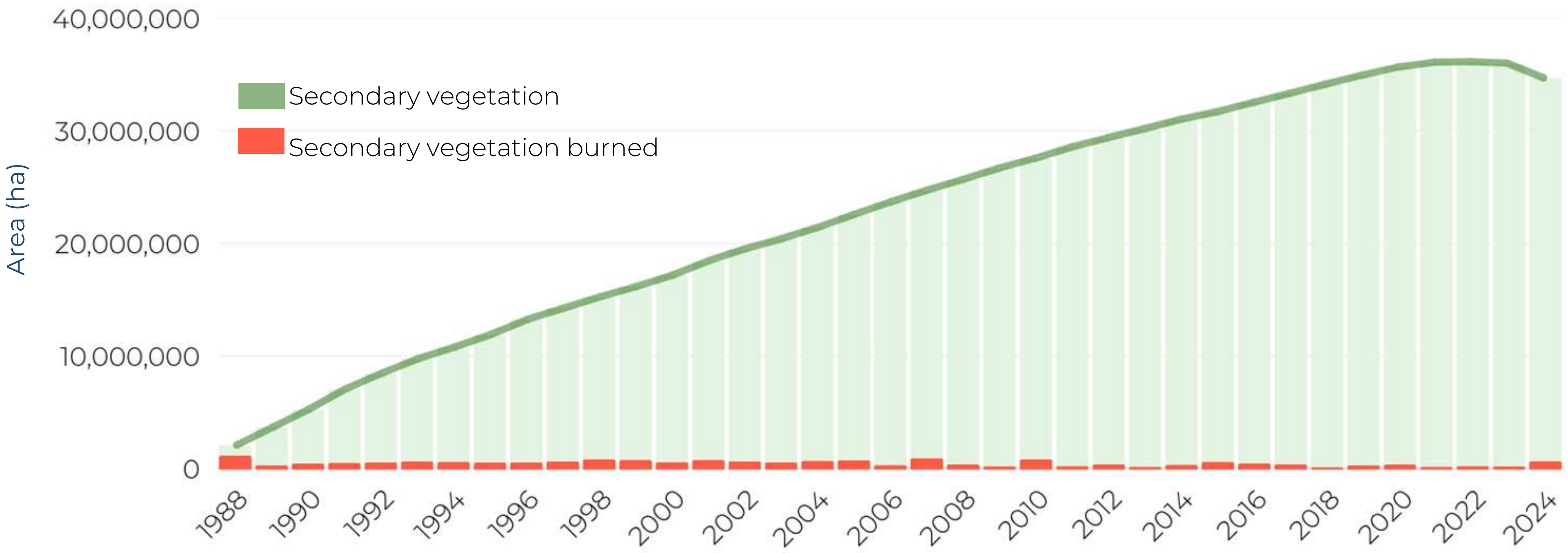


HOW MUCH SECONDARY VEGETATION BURNS EACH YEAR?

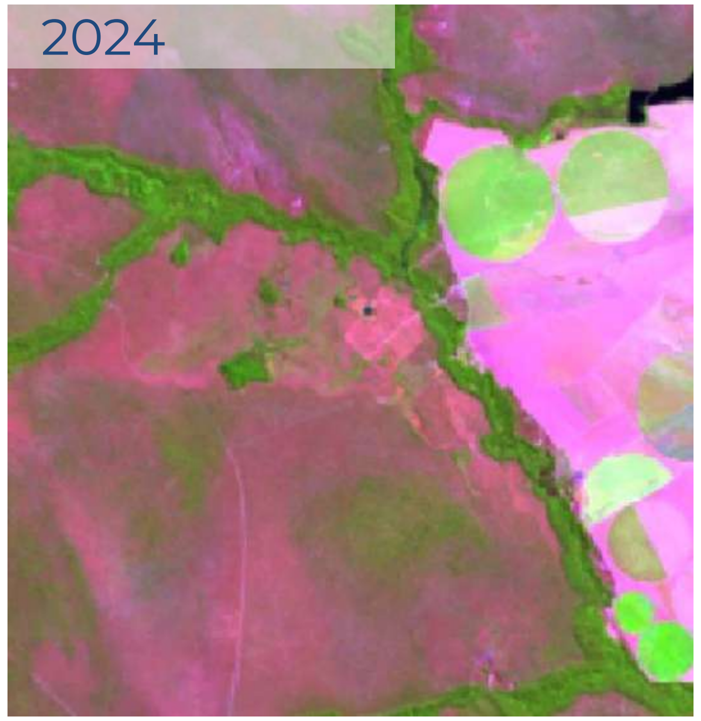
1988 - 2024

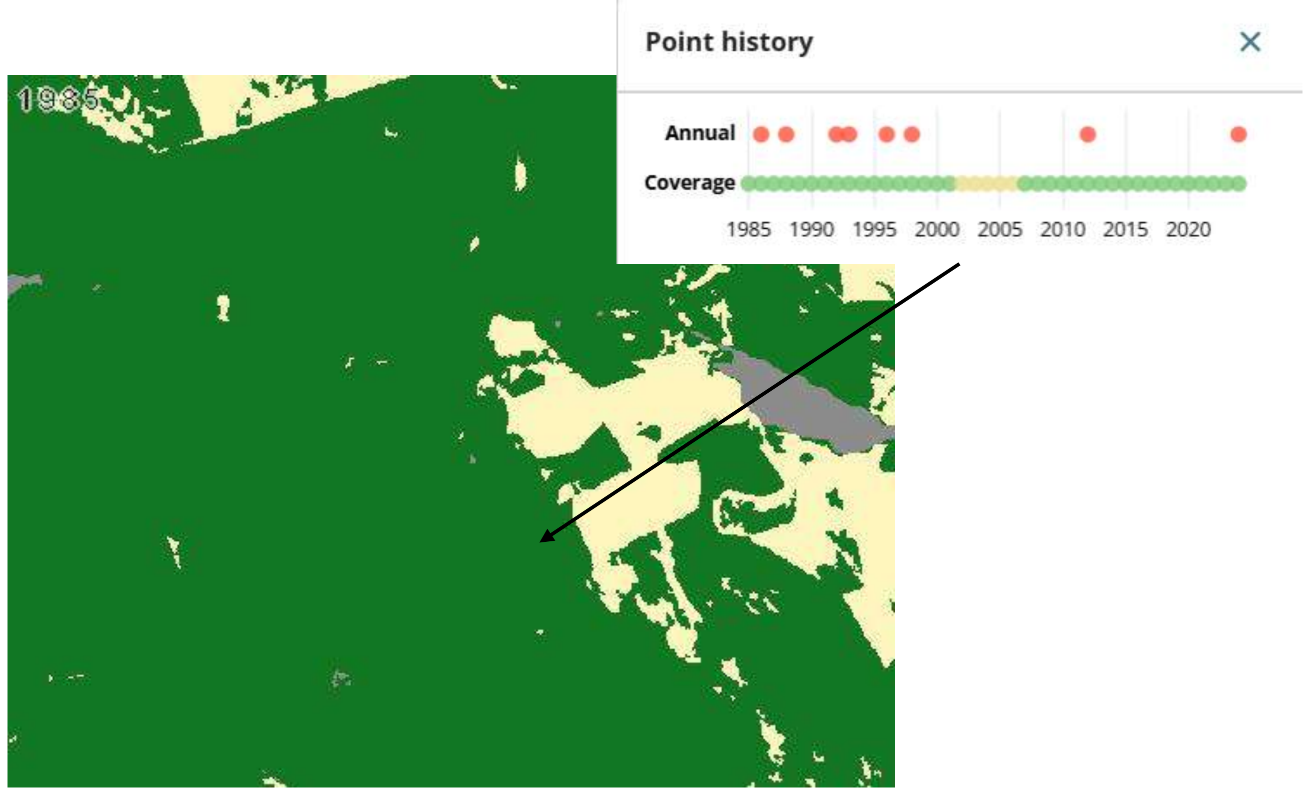
On average, **2 to 4%** of secondary vegetation in Brazil **is burned** each year, with around **50%** of this area **having been burned more than once** in the last 40 years.

The years 1988, 2007, and 2010 are the years with the largest area of secondary vegetation burned.



Example in the region of Fort Santa Bárbara in Formosa (GO)





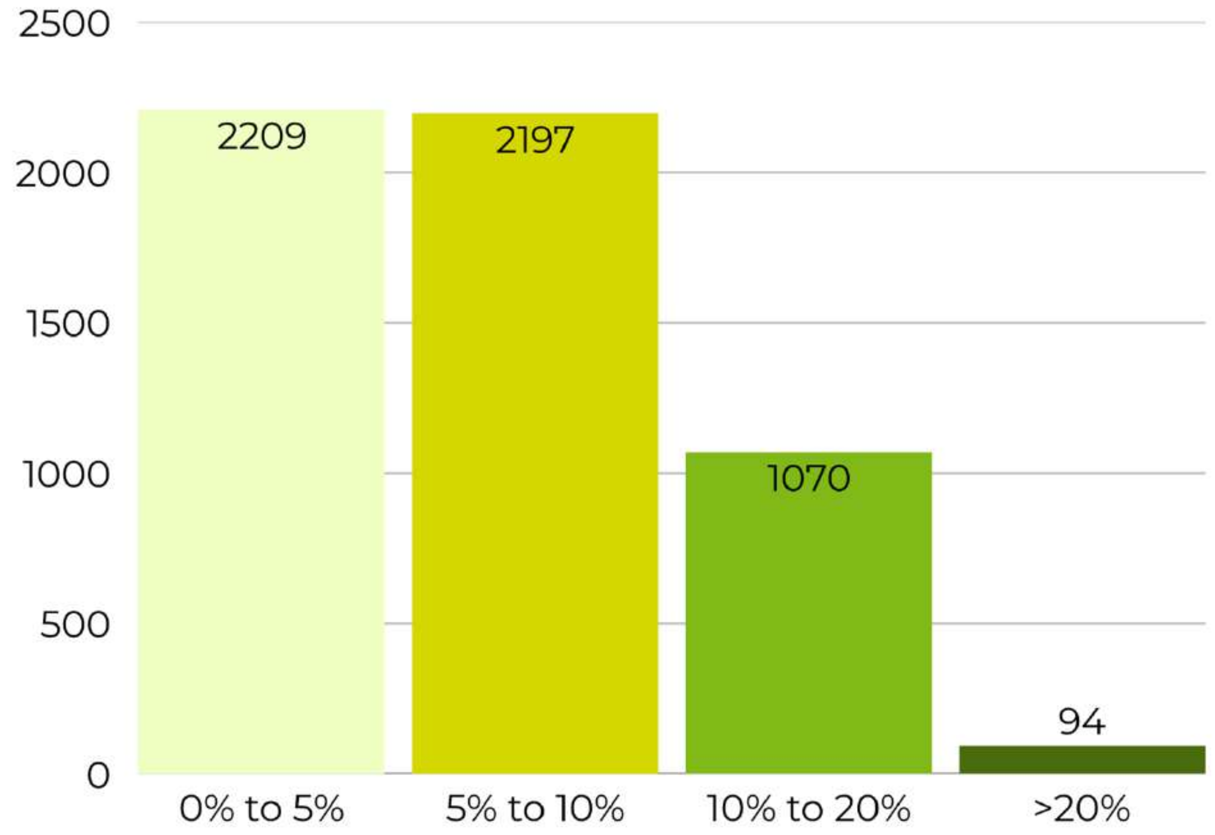
SECONDARY VEGETATION ACROSS BRAZILIAN MUNICIPALITIES

Insights for 2024

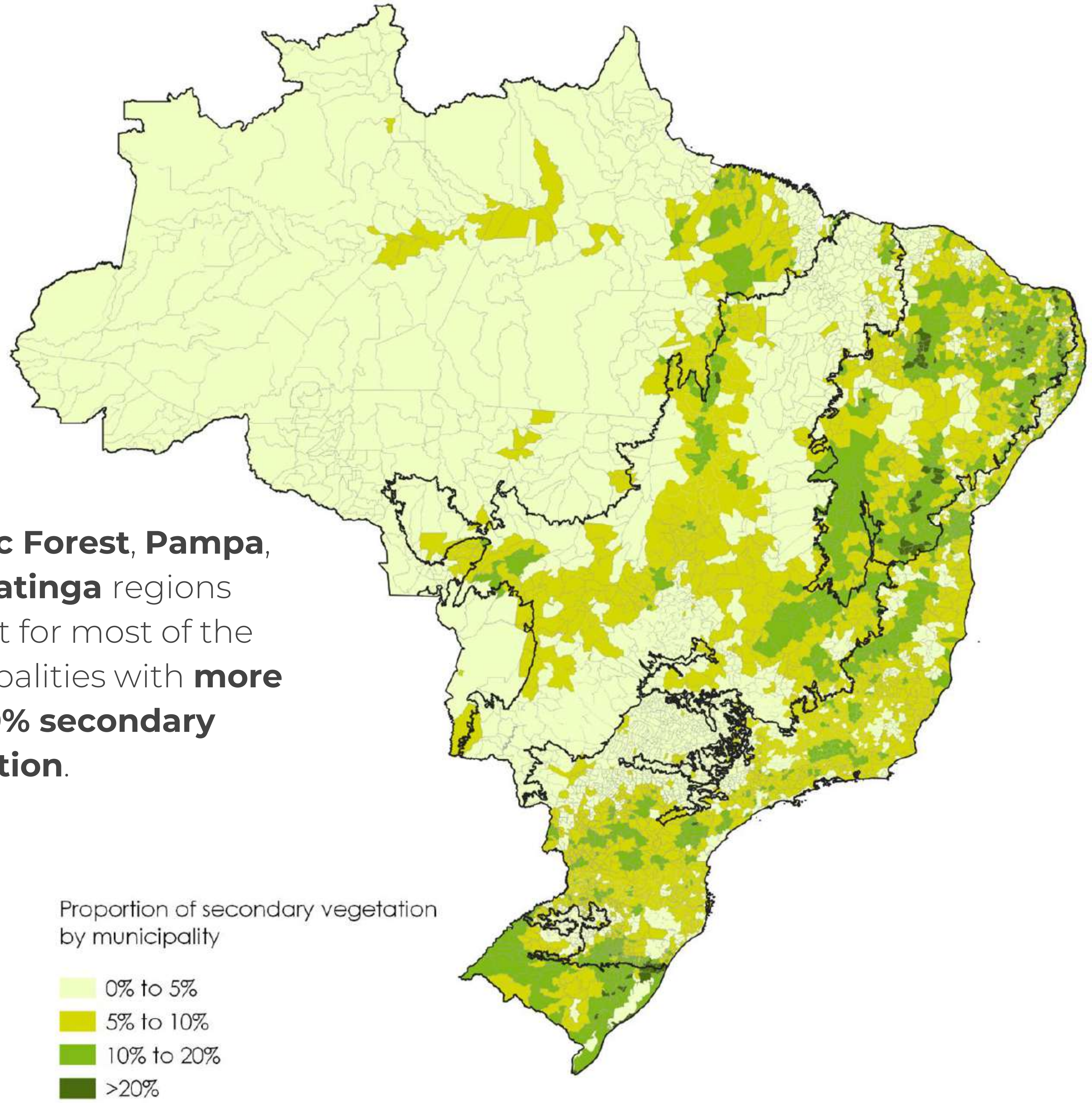
Almost **half of Brazilian municipalities** (44%) have **less than 5%** secondary vegetation.

Only **94 municipalities** have **more than 20%** secondary vegetation, representing less than **2% of the total**.

Number of municipalities by category



Atlantic Forest, **Pampa**, and **Caatinga** regions account for most of the municipalities with **more than 10% secondary vegetation**.



SET OF PRODUCTS AVAILABLE

Products generated by the MapBiomas Brazil

MAPBIOMAS 10 ANOS

MAPBIOMAS v. 10.0

- Land Cover and Use
- Deforestation
- **Secondary Vegetation**
- Agriculture
- Mining
- Infrastructure
- Pasture
- Urban

MAPBIOMAS SOIL

MAPBIOMAS 10 METERS BETA

MAPBIOMAS DEGRADATION BETA

MAPBIOMAS FIRE

MAPBIOMAS WATER

MAPBIOMAS ALERTA

MONITOR DA FISCALIZAÇÃO

MAPBIOMAS Rural Credit

MAPBIOMAS RECUPERAÇÃO

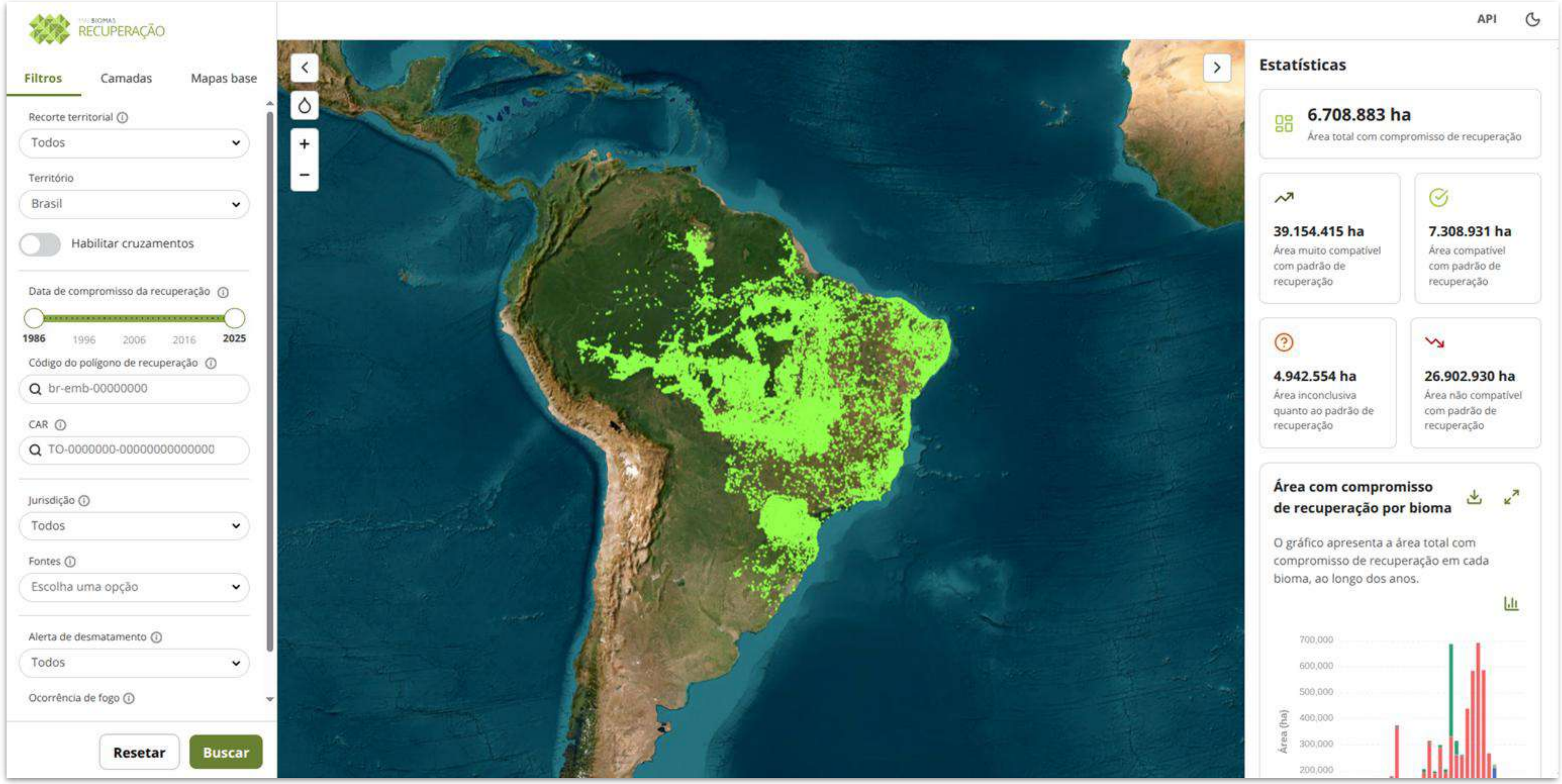
RAD - Annual Deforestation Report

RAF - Annual Fire Report

WHAT IS THE RECOVERY MONITOR?

Acess: plataforma.recuperacao.mapbiomas.org

The Recovery Monitor is a platform for **viewing and monitoring areas with commitments or obligations to restore native vegetation**, including polygons embargoed due to deforestation and polygons from the **Brazilian Restoration Observatory**, as well as other areas with commitments to forest restoration.



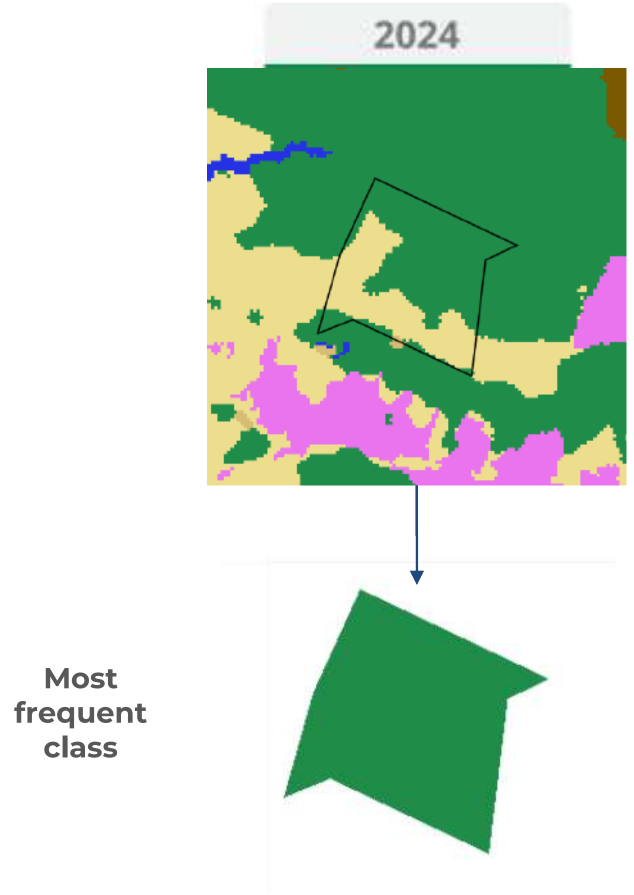
The Monitor also presents an initial approach to **categorizing compatibility with the environmental recovery** process.

CATEGORIZATION OF RECOVERY PATTERN COMPATIBILITY

MAPBIOMAS RECUPERAÇÃO

1. Current land use and land cover class (MapBiomas Col 10 – year 2024)

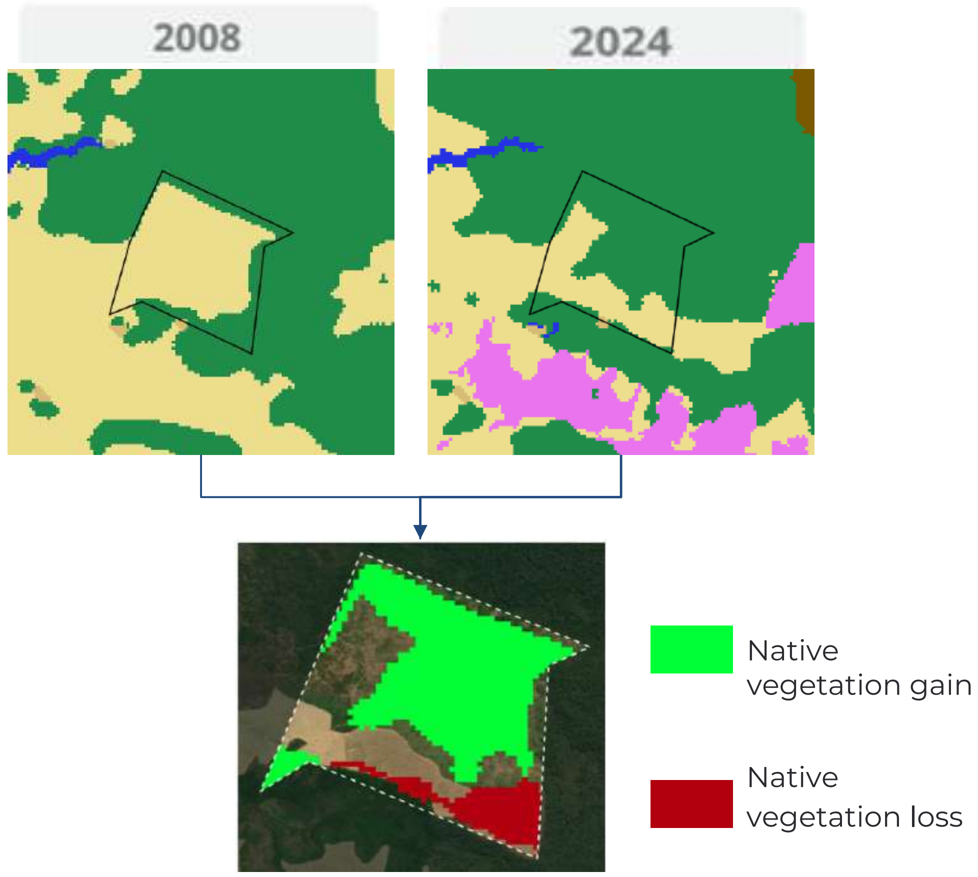
This corresponds to the predominant modal class in the polygon in the most recent year, used to verify the current state of land use and land cover.



2. Land use and land cover transition

(MapBiomas Col 10 – year 2024)

Compares the land use and land cover class between the year of the commitment and the current year (2024), identifying the type of change.



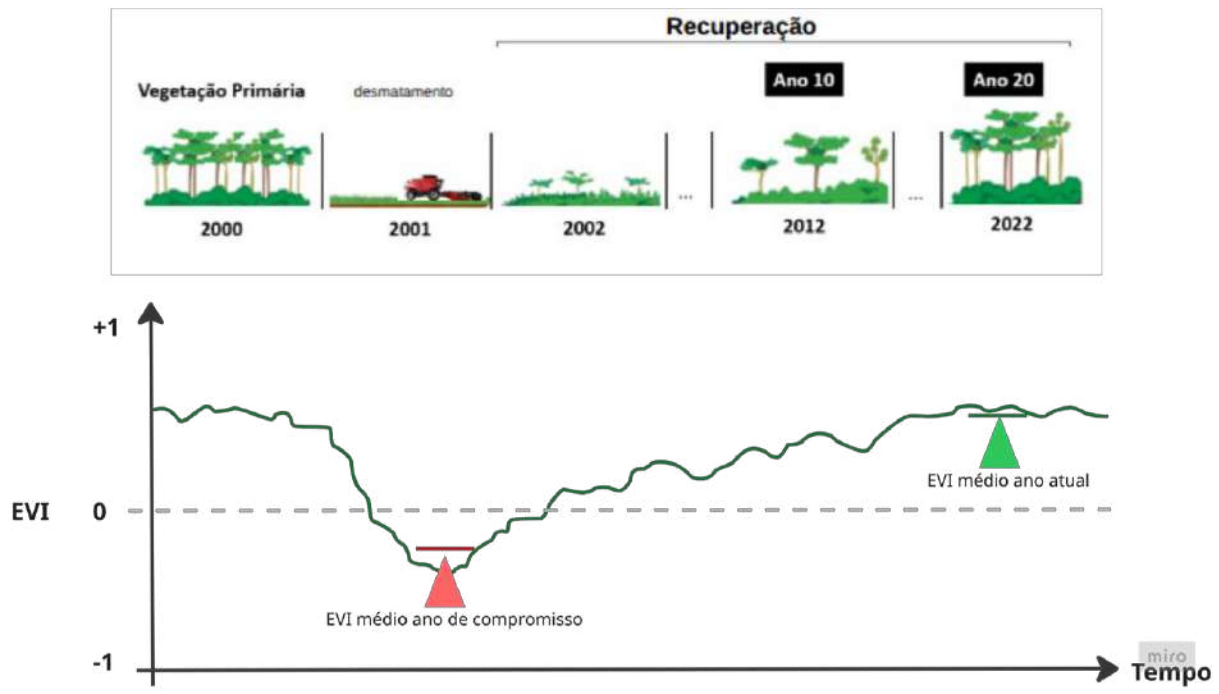
3. Difference in vegetation index (ΔEVI)

ΔEVI = EVI current year - EVI commitment year

ΔEVI < -0.1 → negative difference between the current year and the recovery commitment year

-0.1 ≤ ΔEVI ≤ 0.1 → stable difference between the current year and the recovery commitment year

ΔEVI > 0.1 → positive difference between the current year and the recovery commitment year



HOW TO ACCESS MONITOR DATA?

» Platform available with open, public, and free data!

Acess: **plataforma.recuperacao.mapbiomas.org**

» Document with the main highlights

https://brasil.mapbiomas.org/wp-content/uploads/sites/4/2025/10/Factsheet-Monitor_de_Recuperacao_22.10_v3.pdf

» Launch event on YouTube

https://www.youtube.com/live/vbctGGJROpM?si=VrJC0tVXnVrrzLEz

8th Edition of the MapBiomas Award

Registration until March 22, 2026

https://brasil.mapbiomas.org/premio-mapbiomas/

General Category

1st PLACE — Value of R$ 15,000.00 Fifteen thousand reais

2nd PLACE — Value of R$ 10,000.00 Ten thousand reais

Young Category

1st PLACE — Value of R$ 10,000.00 Ten thousand reais

2nd PLACE — Value of R$ 5,000.00 Five thousand reais

Highlight Applications in Public Policies

Value of **R$ 10,000.00** Ten thousand reais

Highlight Applications in Business

Value of **R$ 10,000.00** Ten thousand reais

Highlight Applications in Schools

Value of **R$ 10,000.00** Ten thousand reais

Actions to Reduce Deforestation

Value of **R$ 10,000.00** Ten thousand reais

Climate Emergencies Category

Value of **R$ 10,000.00** Ten thousand reais

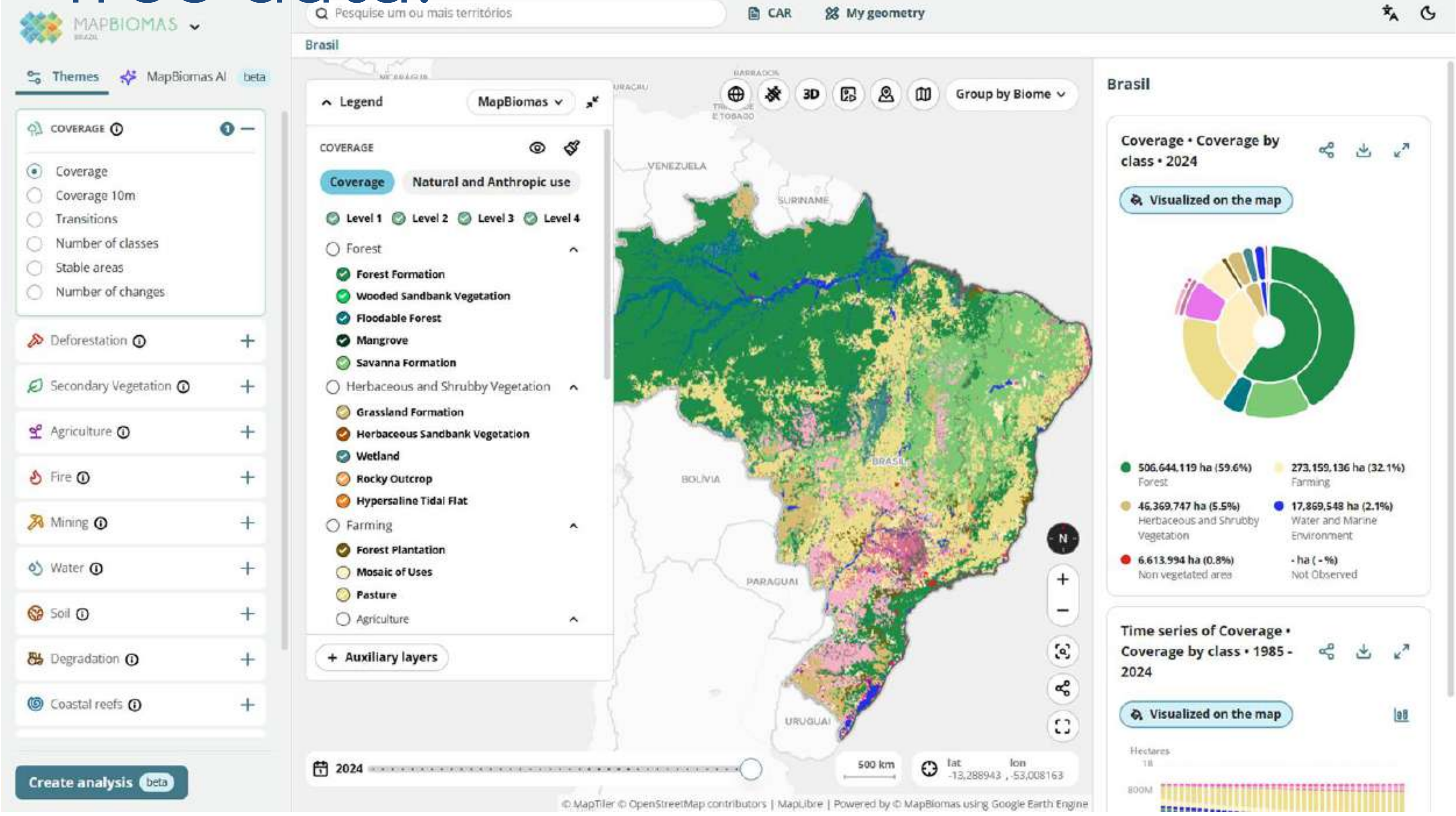
Peoples and Traditional Communities Category

NEW!

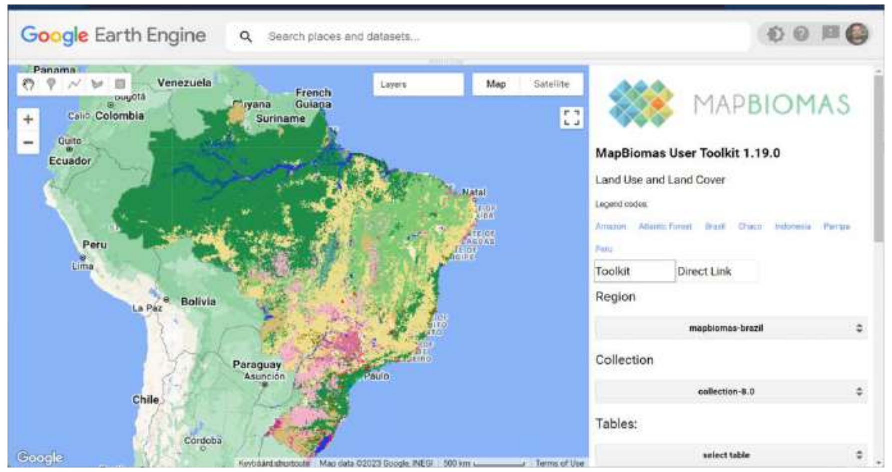
Value of **R$ 10,000.00** Ten thousand reais

HOW TO ACCESS MAPBIOMAS DATA?

» Platform available with open, public, and free data!



Acess: https://plataforma.brasil.mapbiomas.org/

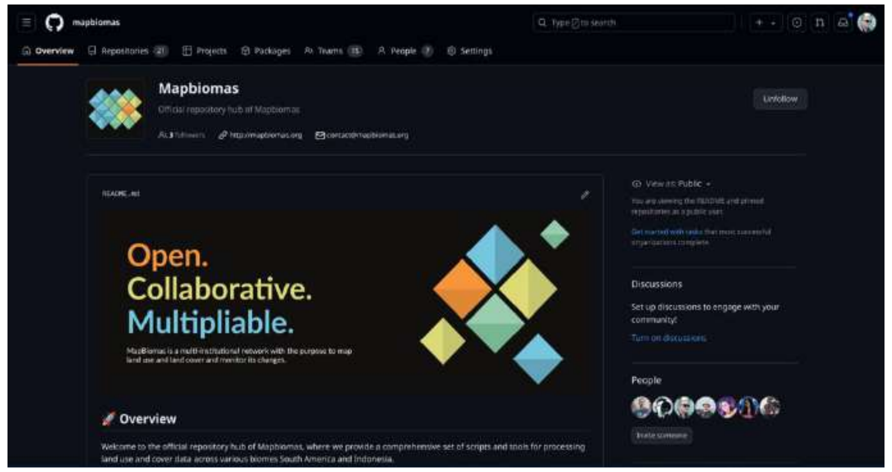


Toolkit to download maps

https://brasil.mapbiomas.org/colecoes-mapbiomas/

FactSheet (highlights document) with key results

https://brasil.mapbiomas.org/destaques/



GitHub with processing codes

https://github.com/mapbiomas

10 ANOS

MAPBIOMAS

Monitoring secondary forests using the JRC Tropical Moist Forest system: design and validation

João Carrieras & Clement Bourgoin

Session 1.2: Mapping Secondary Forest – where are they regrowing according to what dataset?

São José dos Campos, 29 Oct 2025

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European Commission

Monitoring secondary forests using the JRC Tropical Moist Forest system

design and validation

João Carreiras, Clément Bourgoin, René Beuchle, Silvia Carboni, Dario Simonetti

amazonia+ Financiado por Implementado por Global Gateway fiap

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Joint Research Centre

JRC-TMF in a nutshell

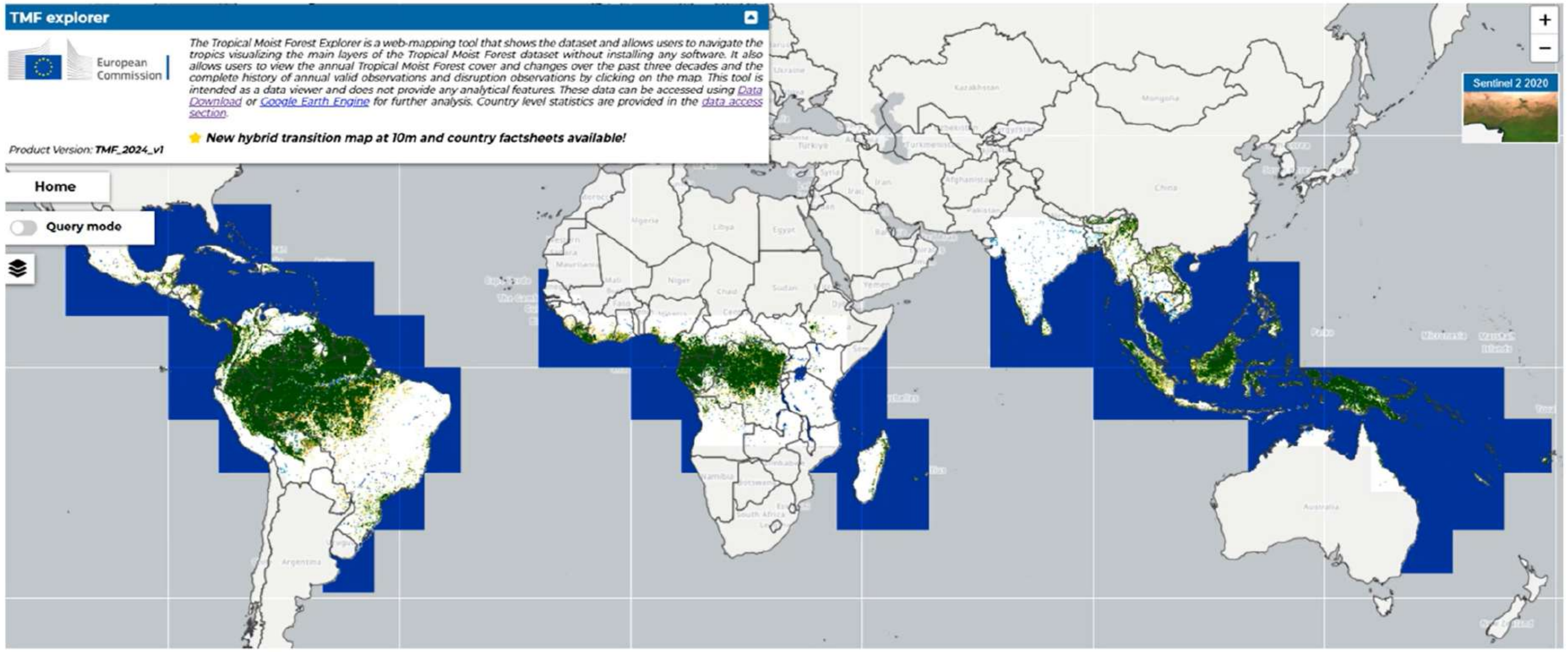
- Wall-to-wall pan-tropical coverage of the extent of moist forests
- Long history (1990-2024) on an annual basis at 30m with sub-annual metrics (duration, intensity and recurrence)
- Consistent data collection and methodology for the entire time-serie
- Changes are characterized based on their trajectories, timing, intensity and recurrence
  - The occurrence and extent of the **forest degradation**
  - The extent and age of **secondary forests** and **afforestation**

SCIENCE ADVANCES | RESEARCH ARTICLE

ENVIRONMENTAL STUDIES

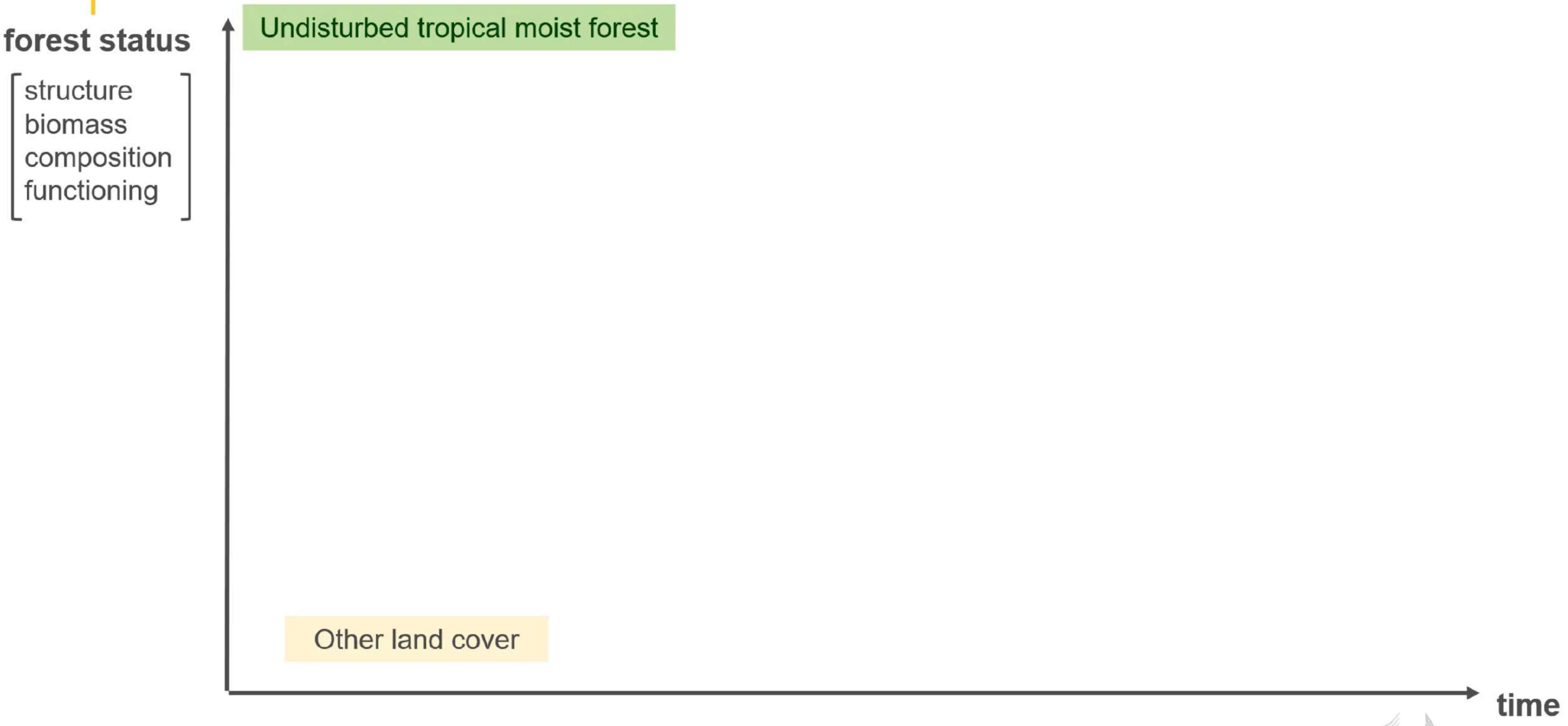
Long-term (1990–2019) monitoring of forest cover changes in the humid tropics

C. Vancutsem[1]*, F. Achard[1], J.-F. Pekel[1], G. Vieilledent[1,2,3,4], S. Carboni[5], D. Simonetti[1], J. Gallego[1], L. E. O. C. Aragão[6], R. Nasi[7]

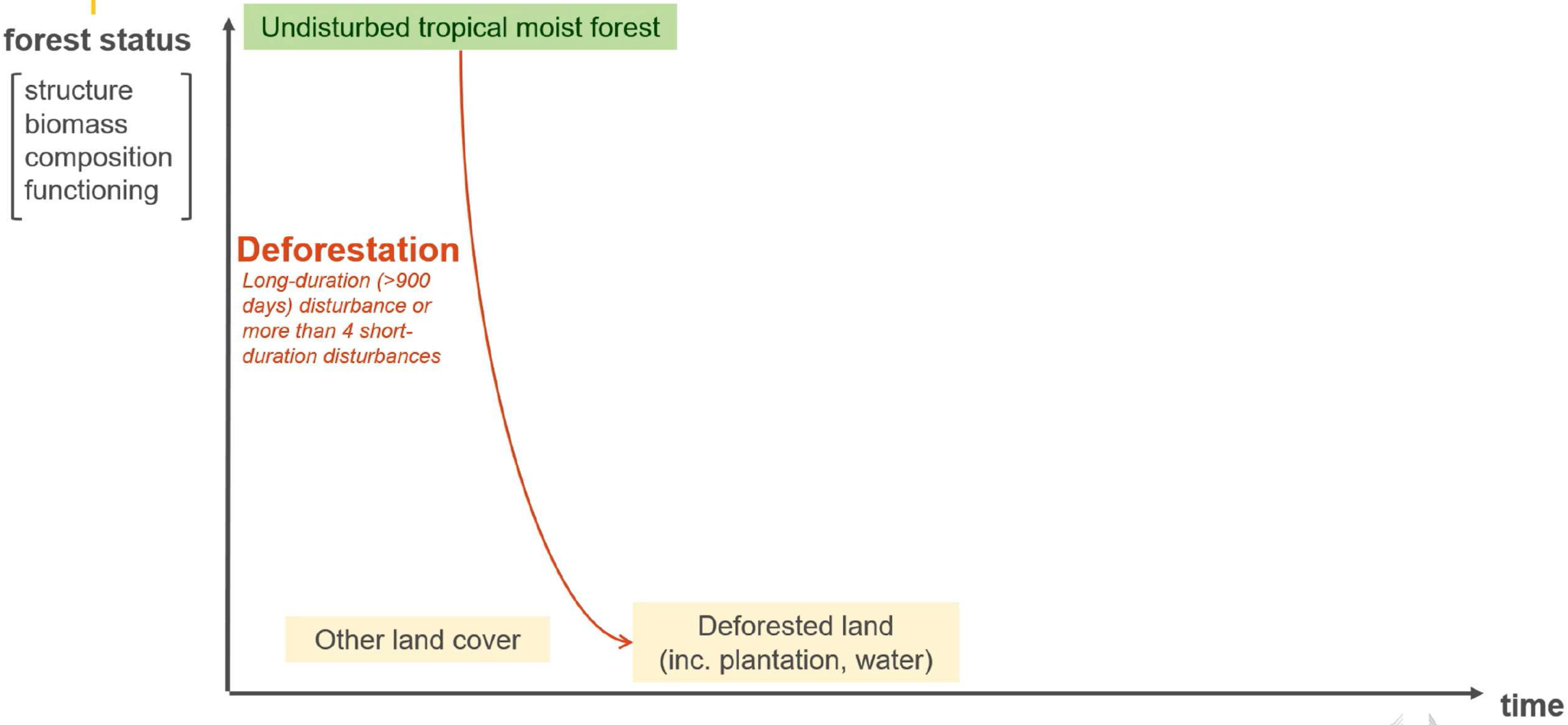


European Commission

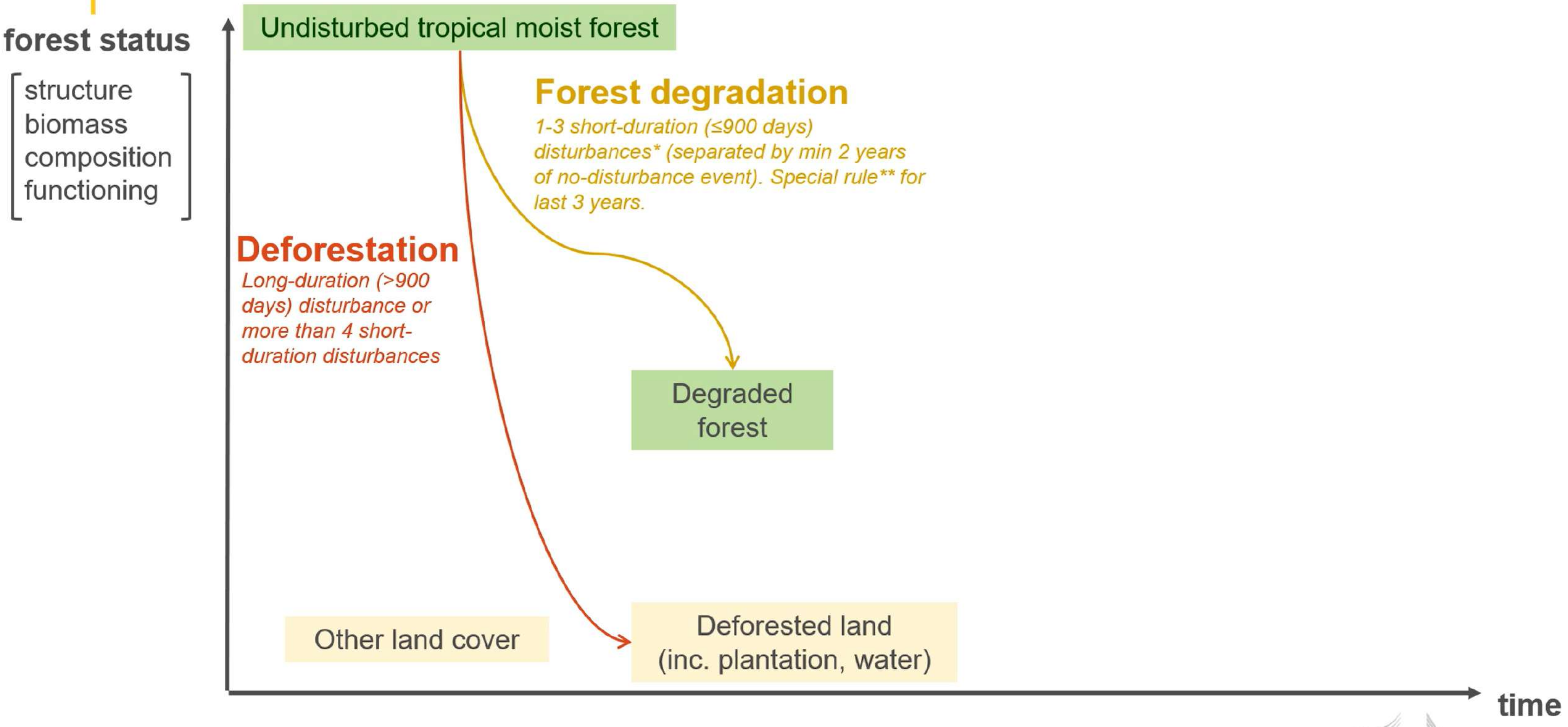
Trajectories and temporal rules



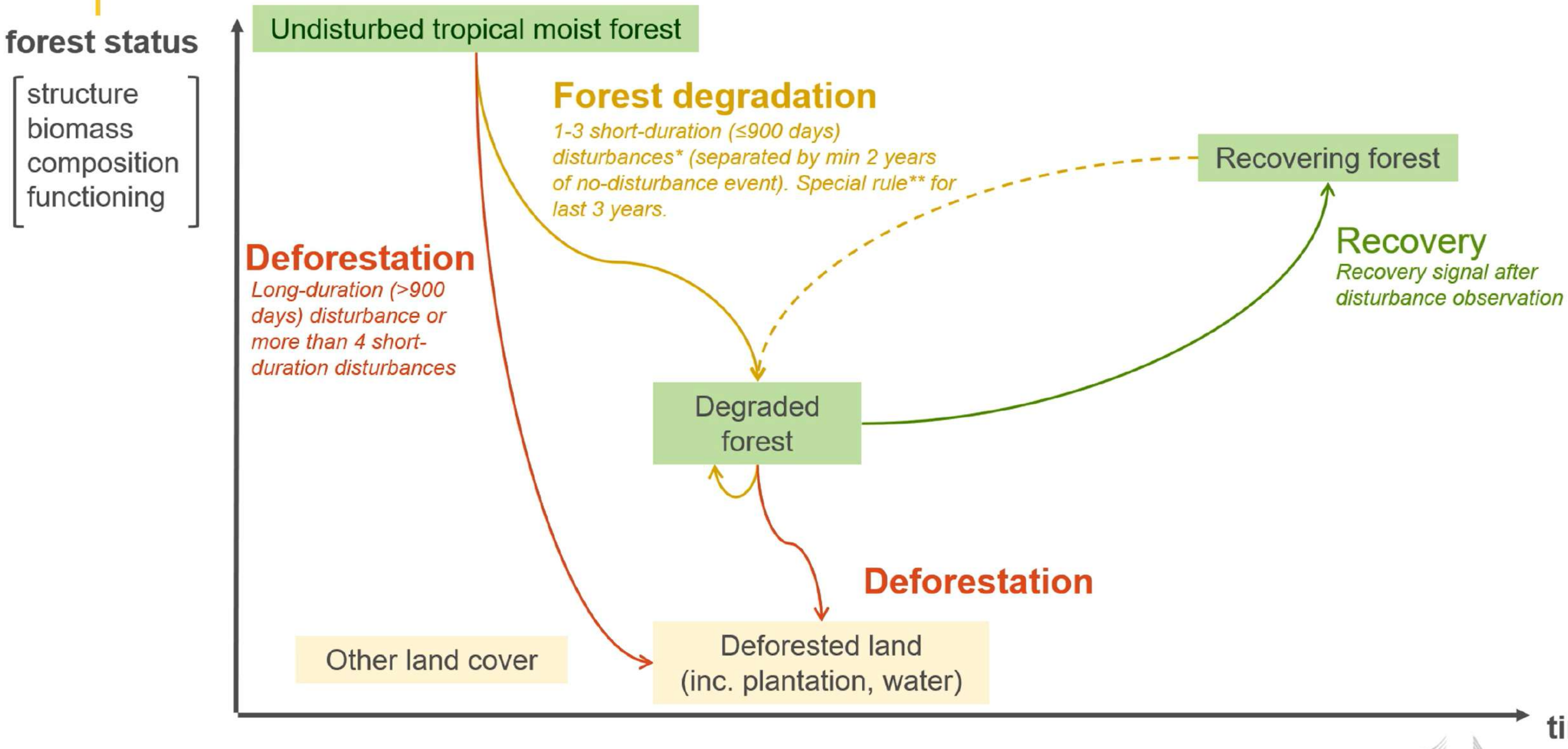
Trajectories and temporal rules



Trajectories and temporal rules

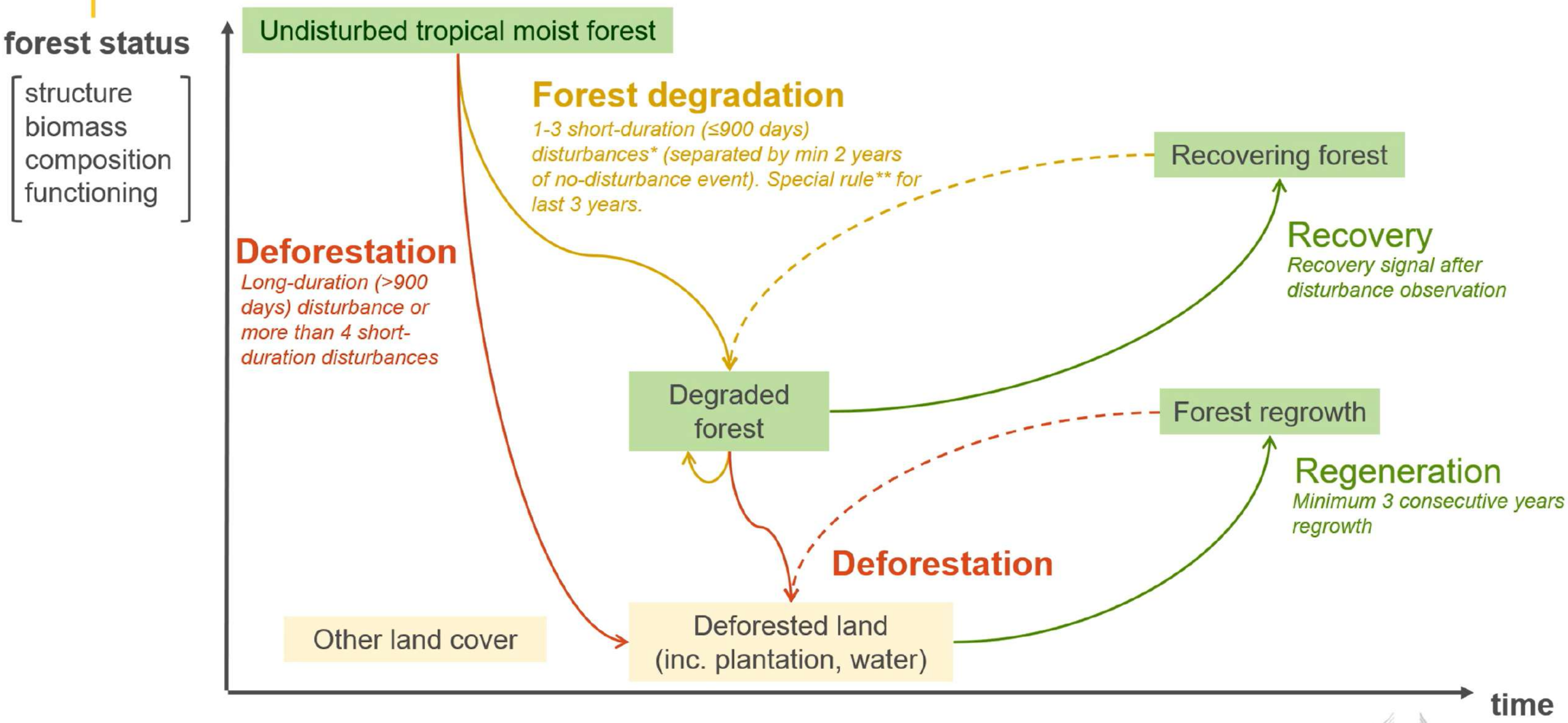


Trajectories and temporal rules

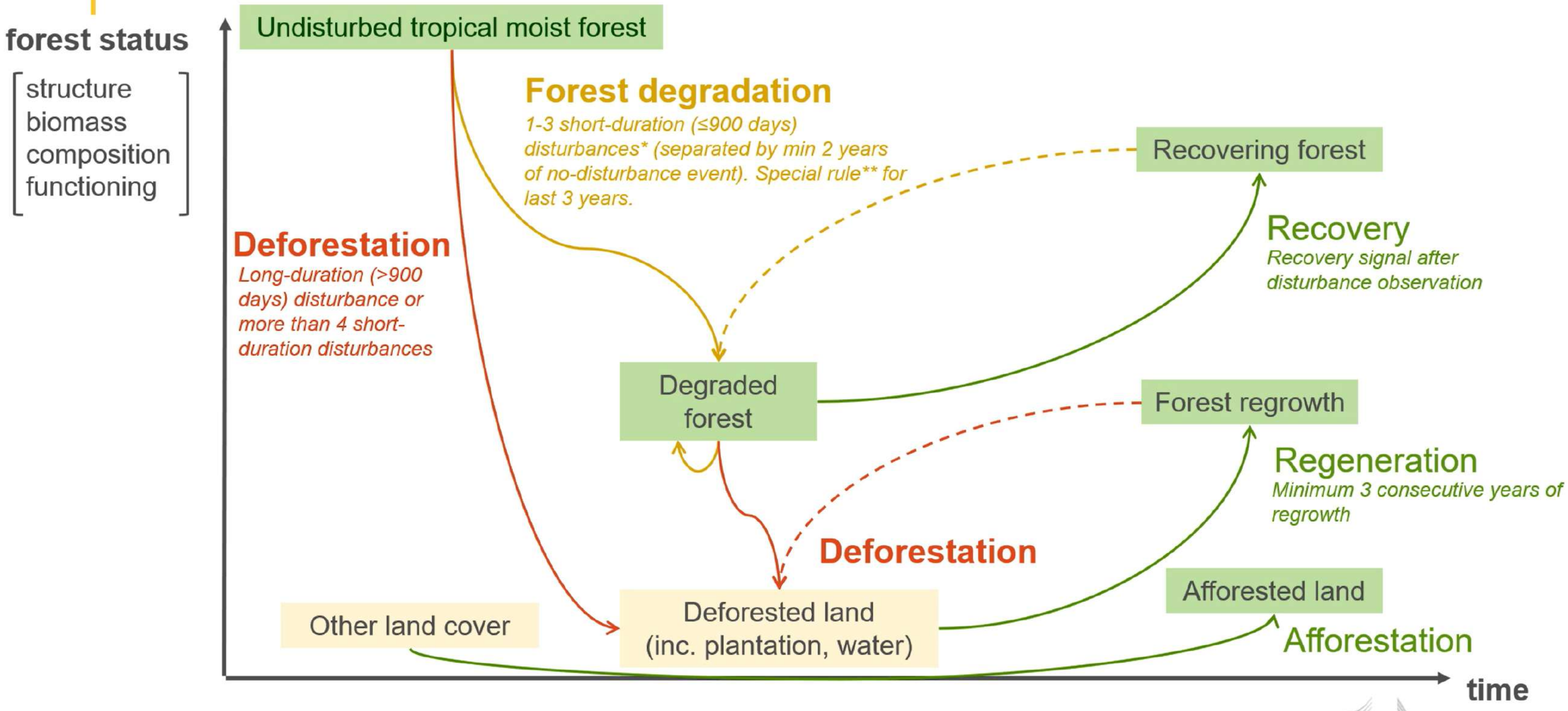


European Commission

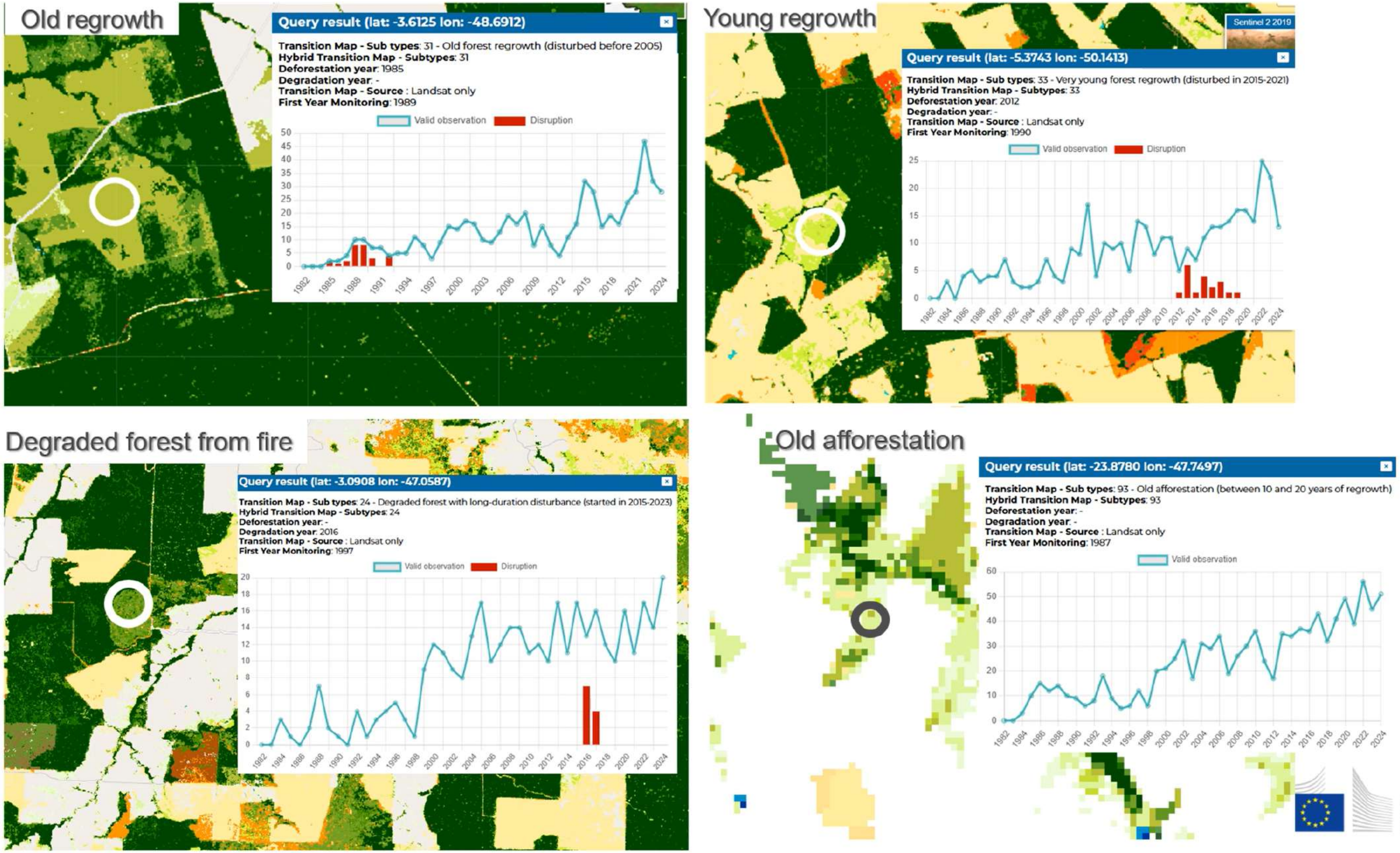
Trajectories and temporal rules



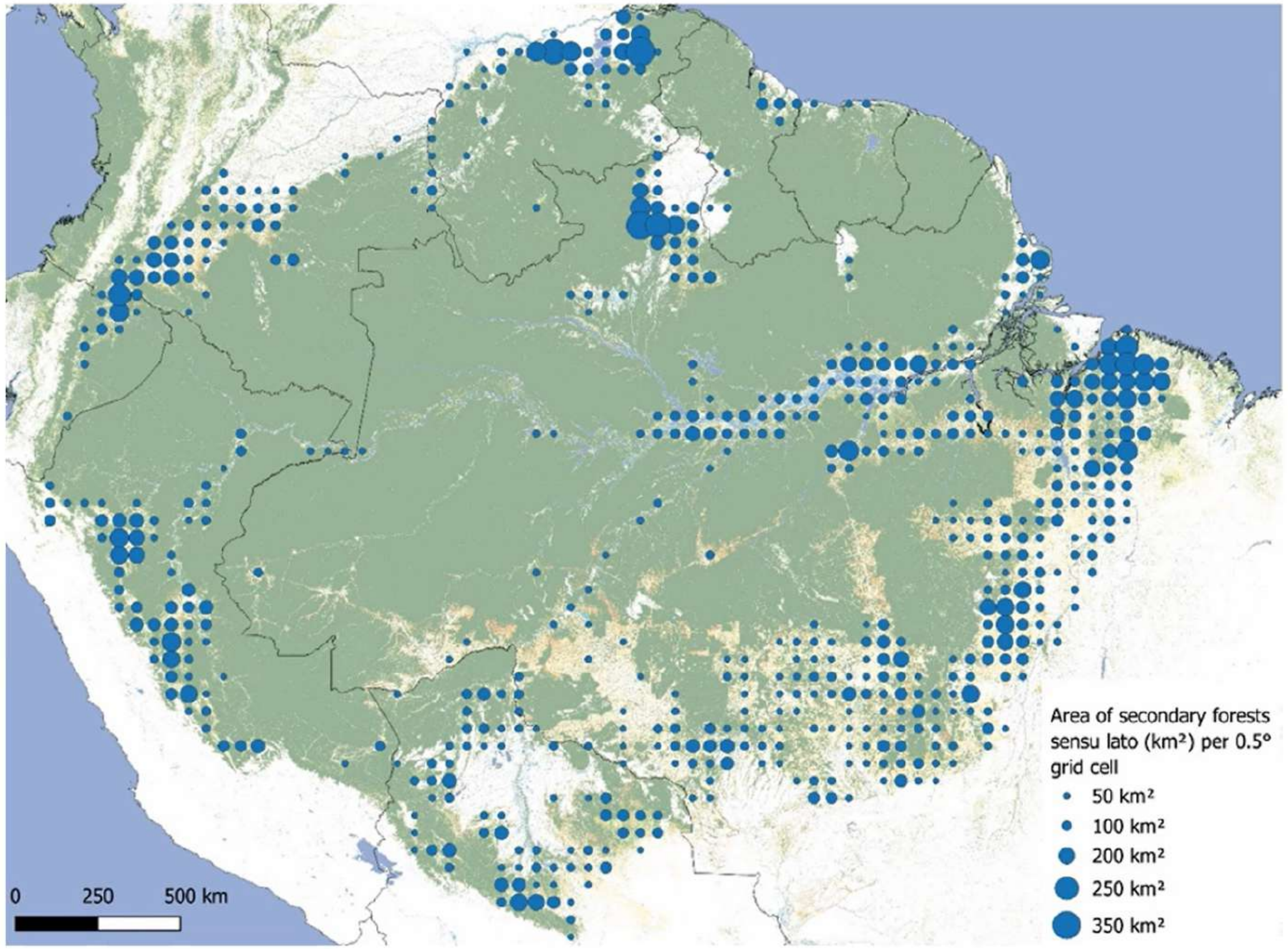
Trajectories and temporal rules

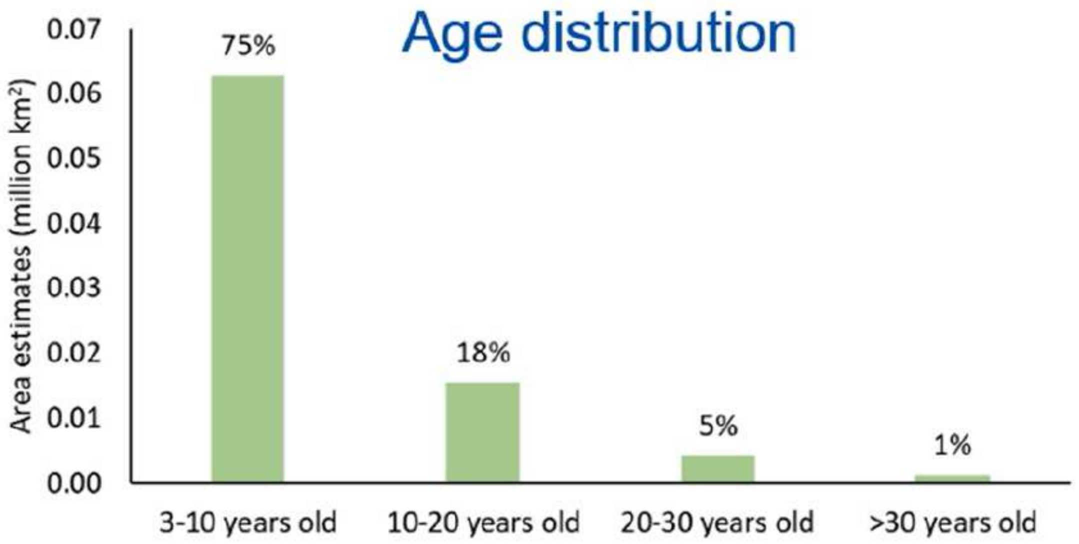


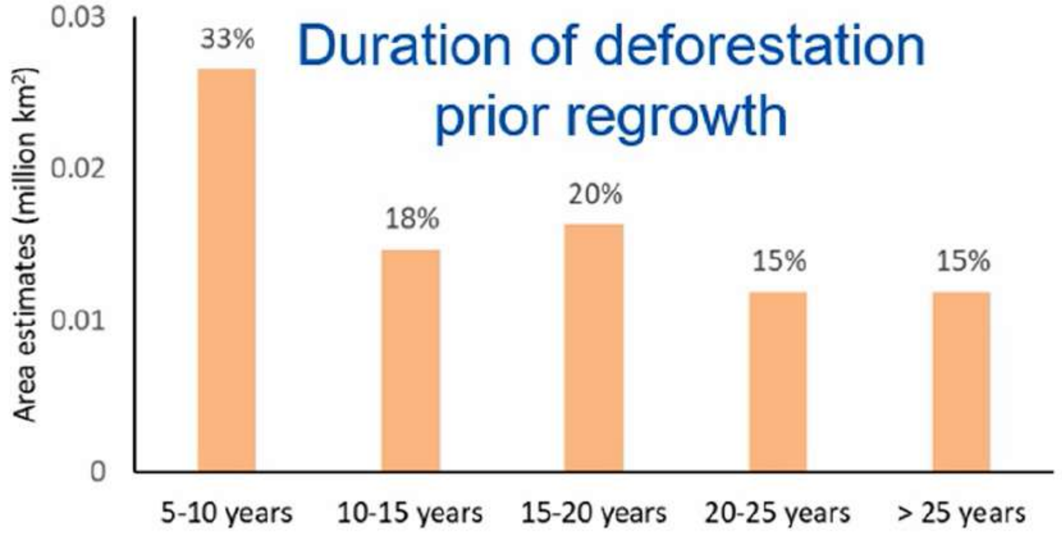
Secondary regrowth within regenerating forests



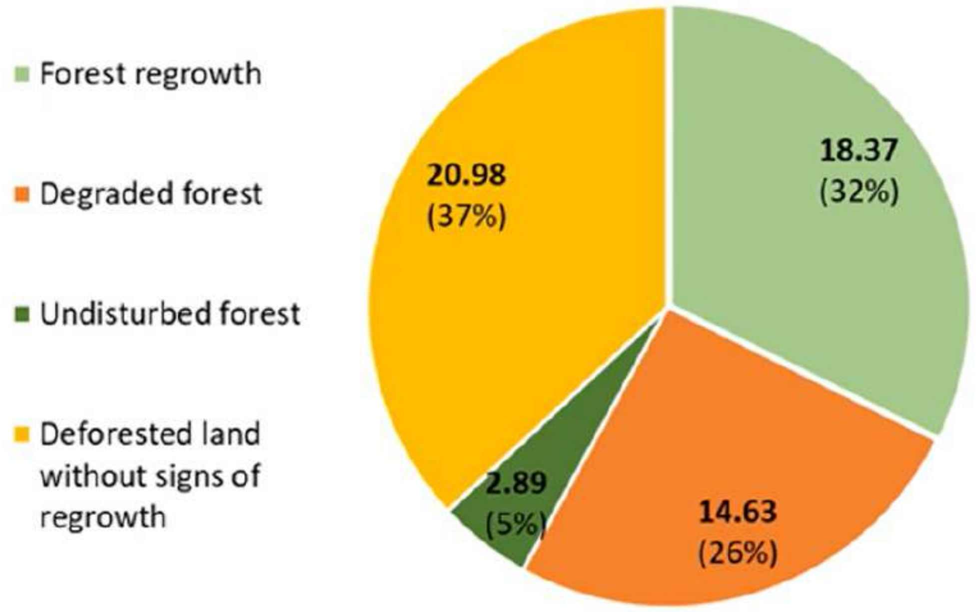
~ 0.08 million km2 of secondary forests in the Amazon region







TMF classes within Mapbiomas' secondary forests



https://data.europa.eu/doi/10.2760/7304684

Validation of JRC's TMF land cover trajectories (1990-2020)

Objectives

To report on the area and accuracy of several land cover trajectories obtained from JRC's Tropical Moist Forest (TMF) dataset in the period 1990-2020

Proposed trajectories:

- Stable forest
- Stable non-forest
- Degraded forest
- Deforested land
- Secondary forest
- Afforested land

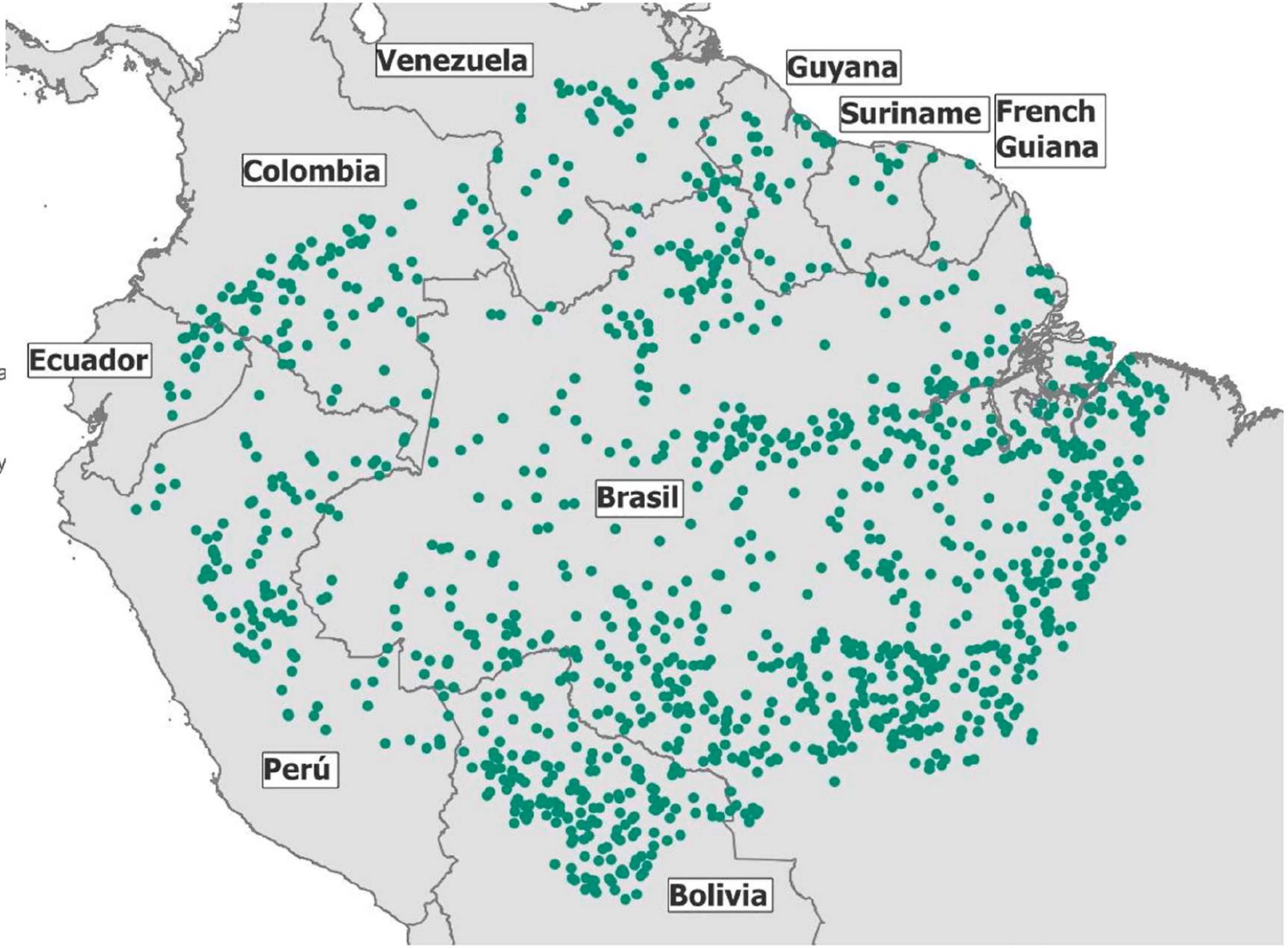
Stratification and sampling approach

Probability-based stratified random sampling

$$n = \left(\frac{\sum_{i=1}^{k} W_i S_i}{S(\hat{O})}\right)^2$$

$S(O)$ - standard error of the estimated overall accura
W_i - mapped proportion of area of trajectory i
S_i - standard deviation of stratum i, estimated as:
$S^2_i = U_i\,(1-U_i)$, with U_i being the user's accuracy

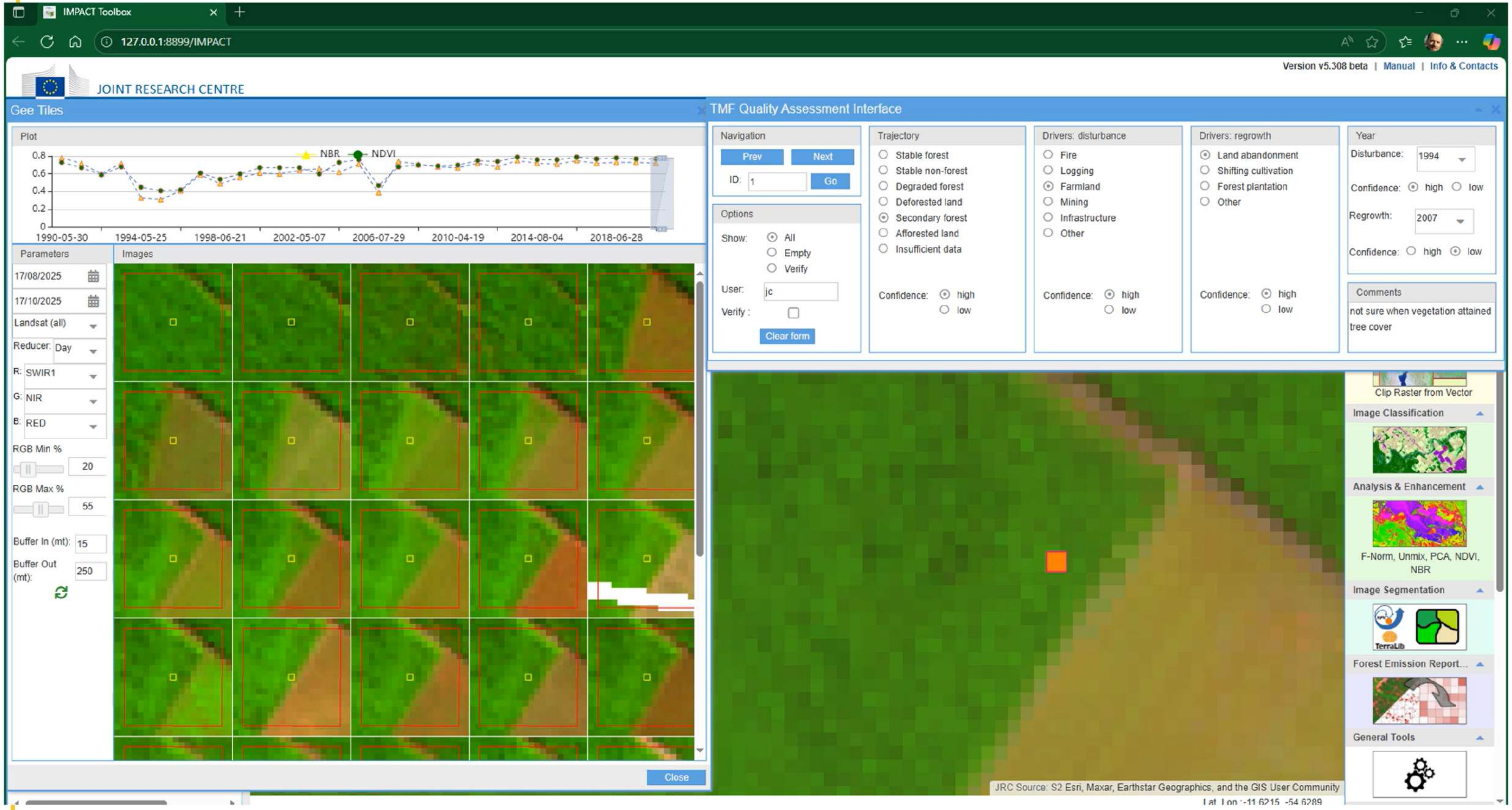
Strata	n
Stable forest	208
Stable non-forest	208
Degradation 1 (<= 2000)	38
Degradation 2 (2001-2010)	72
Degradation 3 (>= 2011)	98
Deforestation 1 (<= 2000)	75
Deforestation 2 (2001-2010)	85
Deforestation 3 (>= 2011)	49
Secondary forest 1 (<= 10 yr)	87
Secondary forest 2 (11-20 yr)	95
Secondary forest 3 (>= 21 yr)	27
Buffer	208
	1250



Response design

- each sample site: 30 m × 30 m
- trajectory
- drivers of disturbance
  - degradation: fire, logging
  - deforestation: farmland, mining, infrastructure
- drivers of regrowth/afforestation
  - land abandonment, shifting cultivation, forest plantation
- year disturbance(s) started
- year regrowth started
- confidence level (high, low)

JRC IMPACT Toolbox



Preliminary results

- accuracy and area estimators when the strata differs from the map classes
  - described in Stehman (2014)
  - **OA = 92% (± 2%)**

Map accuracy and area estimates (Stehman 2014)

Trajectory	Area proportion	Area (Mha)	Omission error (%)	Commission error (%)
Stable forest	0.767 ± 0.008	493.3 ± 4.9	3.5 ± 1.0	0.9 ± 0.5
Stable non-forest	0.105 ± 0.006	67.4 ± 3.7	7.8 ± 3.3	13.8 ± 2.1
Degraded forest	0.027 ± 0.004	17.6 ± 2.7	50.5 ± 7.7	66.3 ± 5.9
Deforested land	0.078 ± 0.003	50.1 ± 1.7	16.6 ± 2.2	28.4 ± 5.4
Secondary forest	0.015 ± 0.002	9.3 ± 1.2	71.3 ± 5.8	45.0 ± 8.4
Afforested land	0.009 ± 0.004	5.7 ± 2.5	88.0 ± 6.2	57.0 ± 10.3

Moving forward…

- consolidate the reference dataset (disagreements)
- assess trajectories on sub-periods (5-year intervals) and possibly at (some) country-level
- include drivers of disturbance/recovery in the analysis
- availability to support ongoing or future validation exercises (regional, global)

Thank you for your attention

- joao.carreiras@ext.ec.europa.eu
- clement.bourgoin@ec.europa.eu

Towards a global reference dataset of forest regrowth

Hannah Graham

Session 1.2: Mapping Secondary Forest – where are they regrowing according to what dataset?

São José dos Campos, 29 Oct 2025

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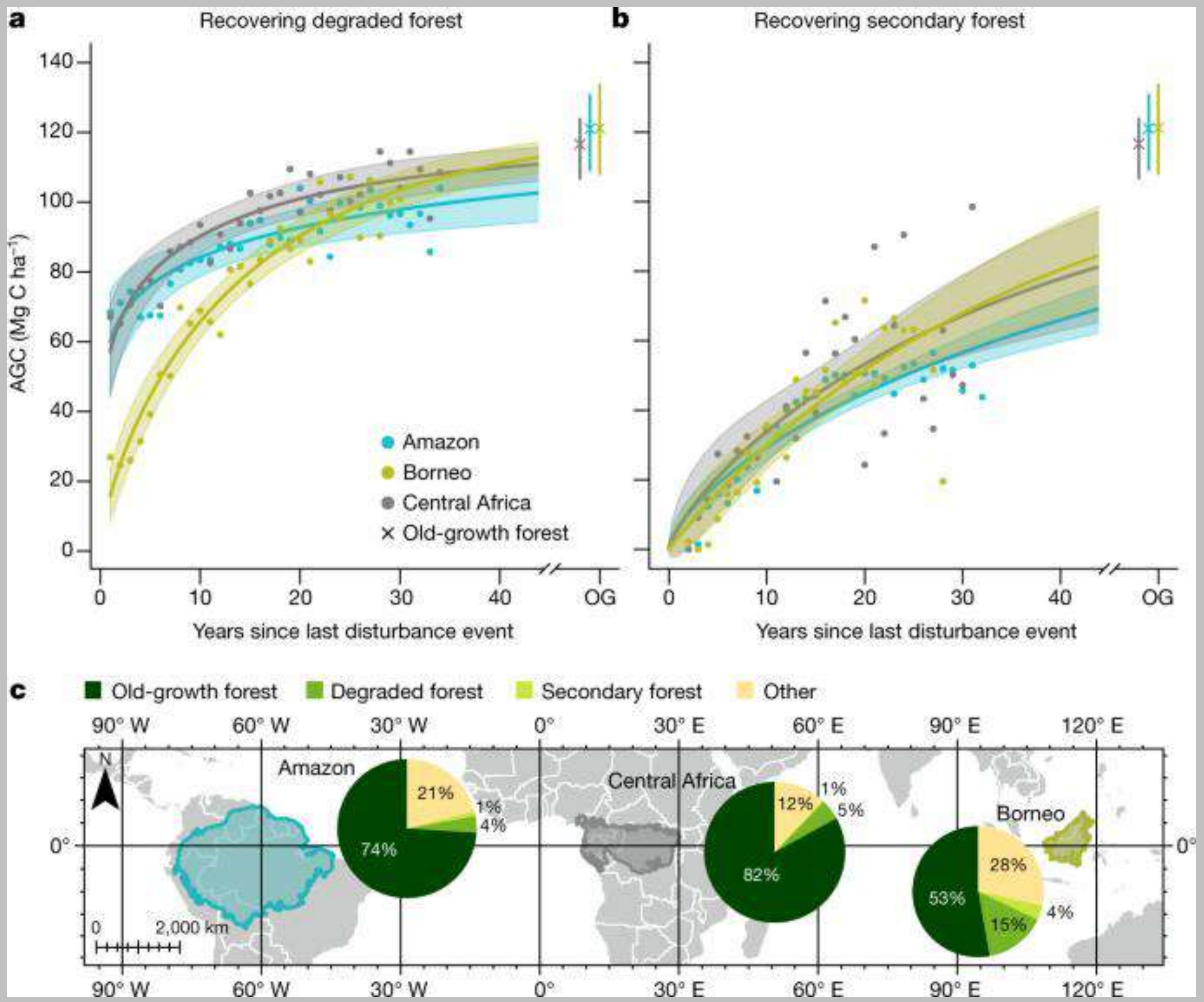
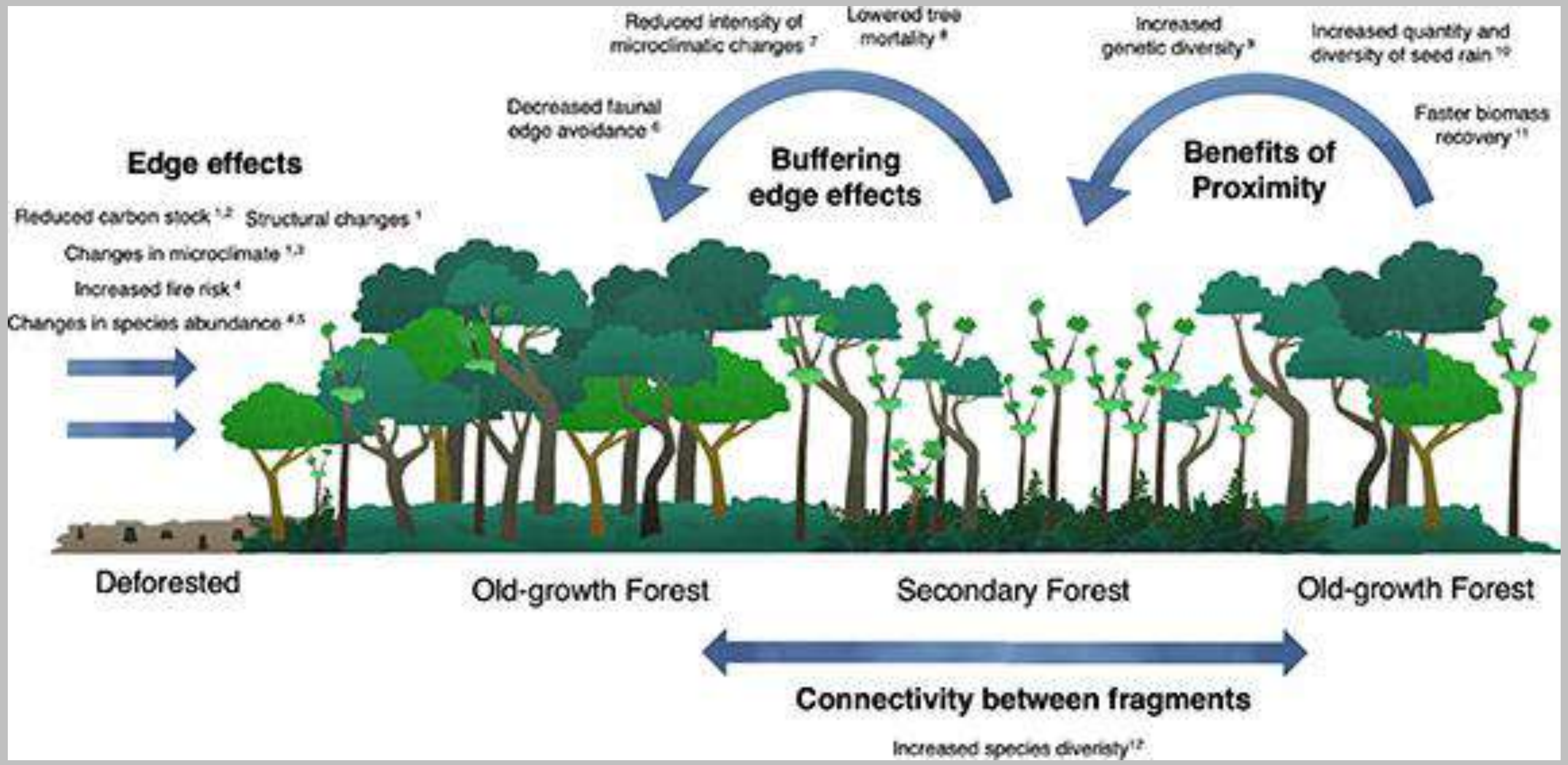
Value of naturally regenerating forests



Heinrich et al. 2023



Smith et al. 2023

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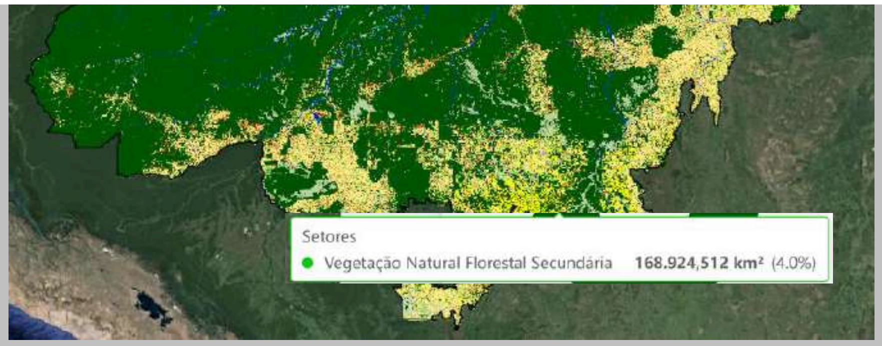
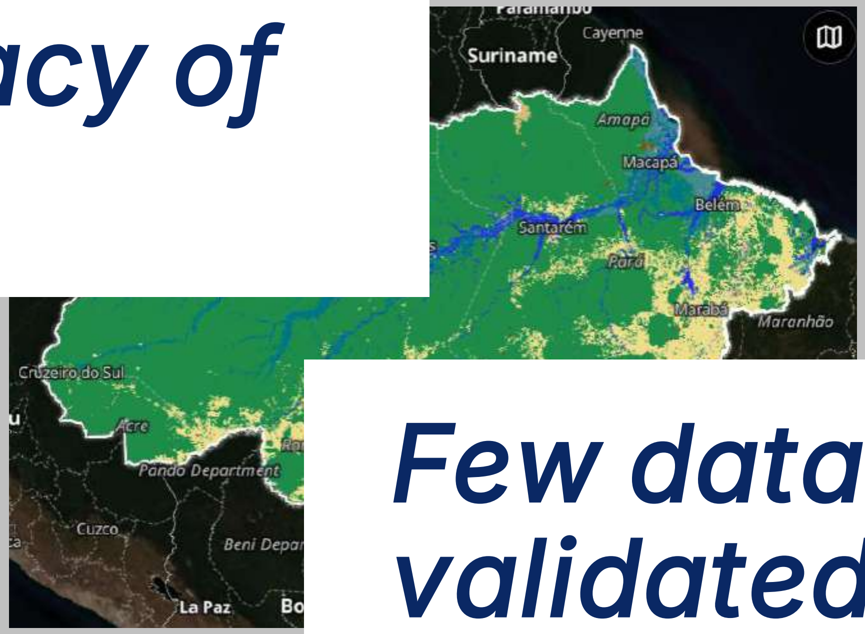
Research Needs for a Reference Dataset

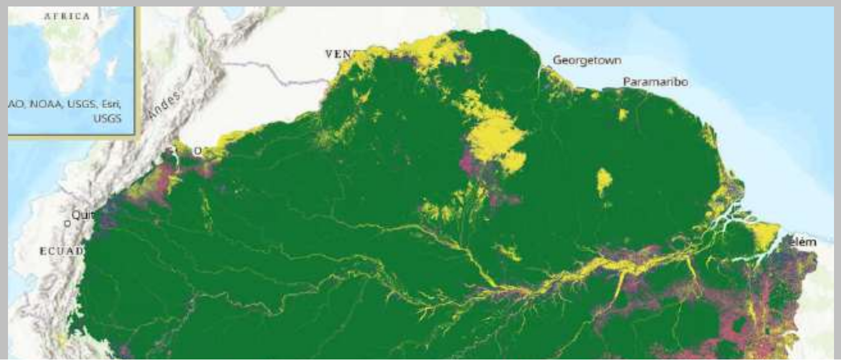
Needs to understand and improve the accuracy of regrowth data



168,924.51 km^2



75,7



Few datasets are specifically validated for forest gains (secondary forest regrowth, recovering degraded forests)

What is a Reference Dataset?

- Created with higher quality information
- Can help us validate + compare regrowth products
- Can be used for area estimation

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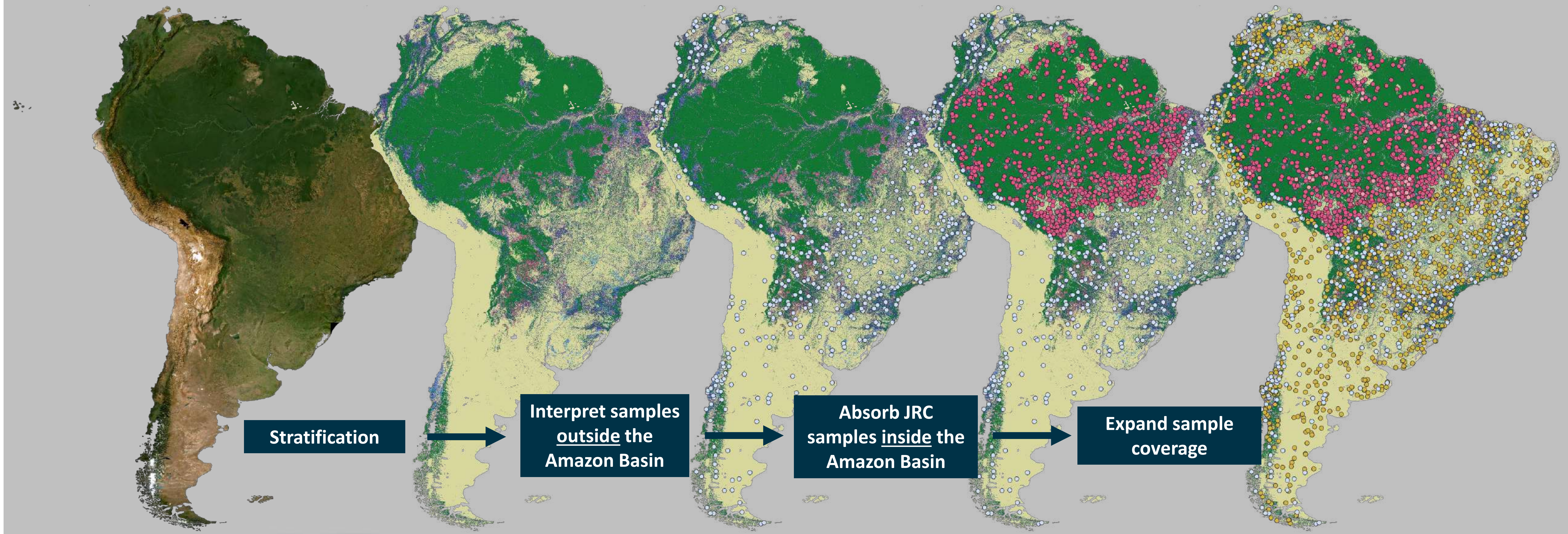
Creating a Reference Dataset



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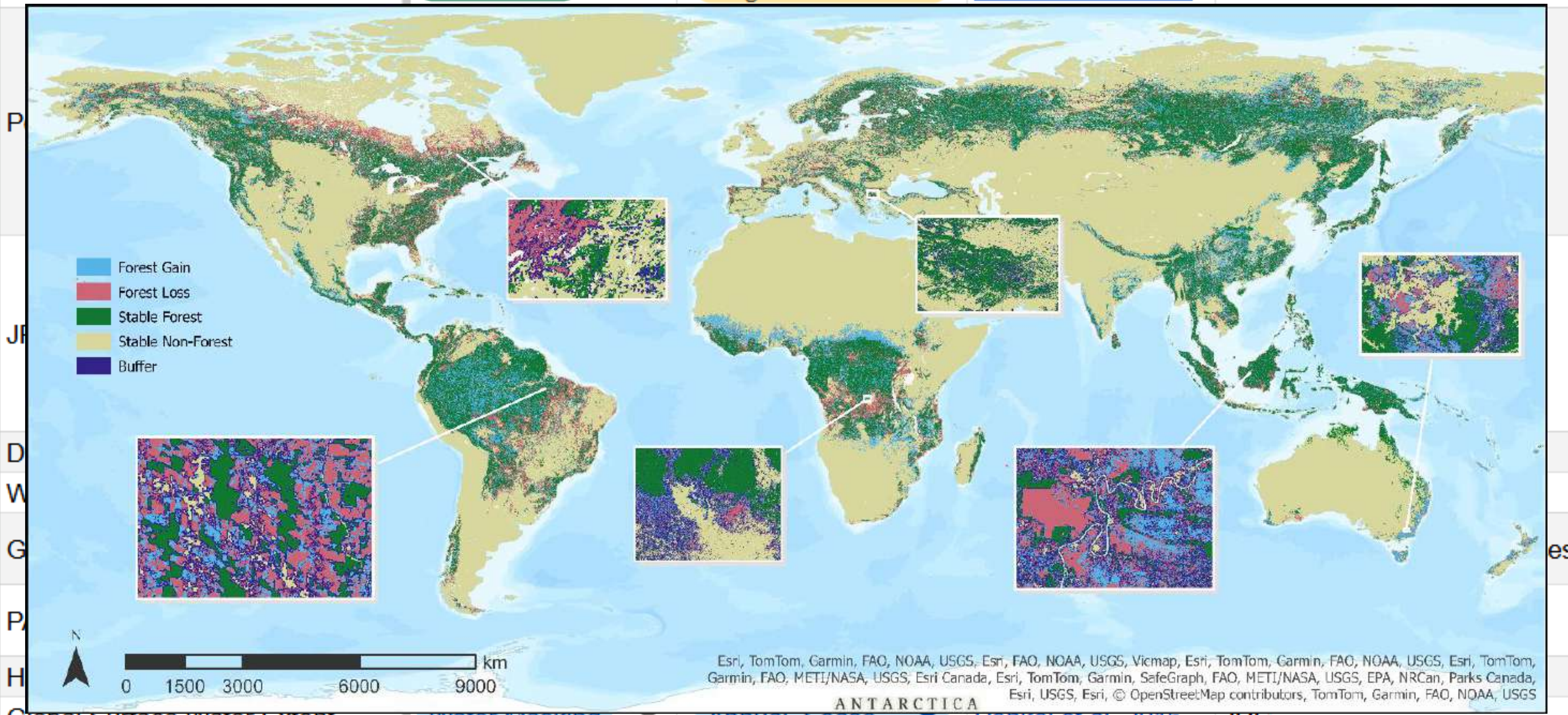
Designing Consistent and Robust Strata

	Name	Relevance	Temporal Resolution	Source	Institute	Derived From	Temporal Coverage	Spatial Resolution	Possible Filters	Forest I
2	Hansen Treecover	Forest 2000	Single	Hansen et al. 2013	UMD	Landsat	2000	30m	Canopy %	5m,
3	P									Forest: ar managed natural tre trees outs unstocked criterion t forests??
4	JF									Using the reach tho unstocked disturban overestim commodi
5	D									
6	W									
7	G					es				Closed fo Open fore
8	P									Forest: tr a canopy
9	H									
0	Global Surface Water Extent	Water Masking	Annual, Seaso…	Pekel et al. 2016	JRC					Currently
1	Global Land Cover Type	Forest 2000	Single	Stibig et al. 2003	JRC	SPOT-VGT	2000	1km		Confusing



Input layer criteria:

- ✓ 10% canopy cover
- ✓ 0.5ha minimum area
- ✓ 5m+ tree height
- ✓ Global coverage
- ✓ Forest land *cover**
- ✓ Validation available
- ✓ 30m* resolution

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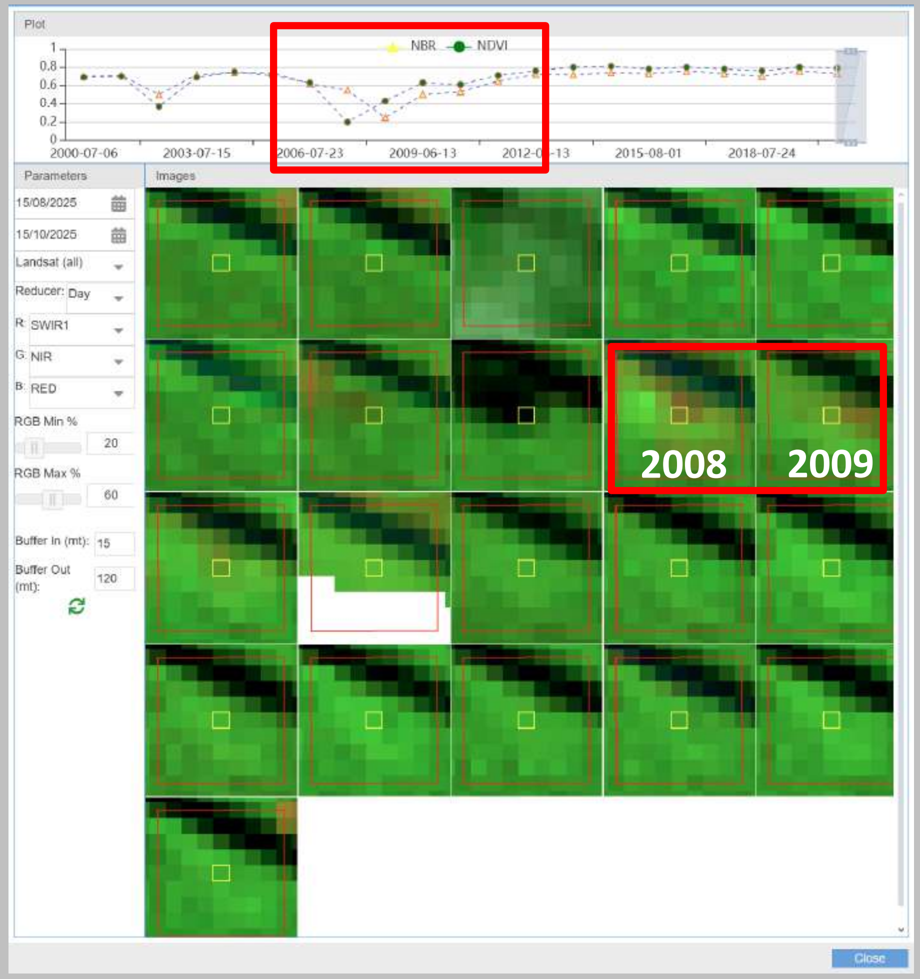
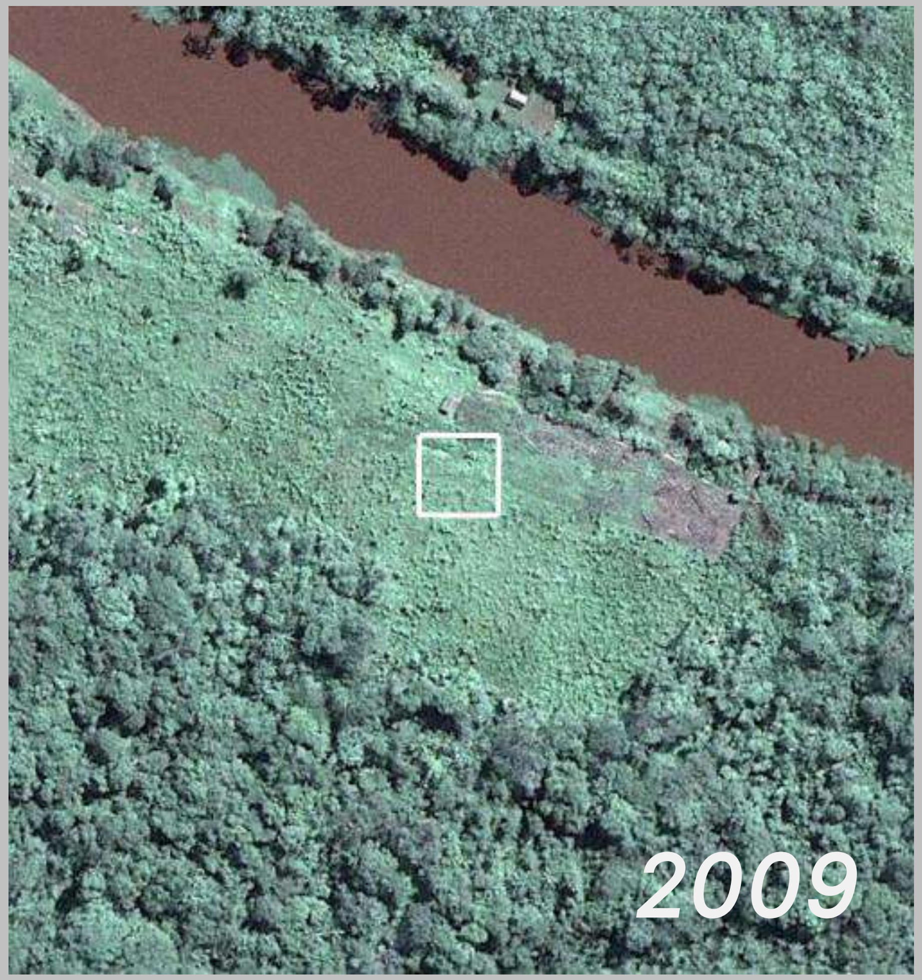
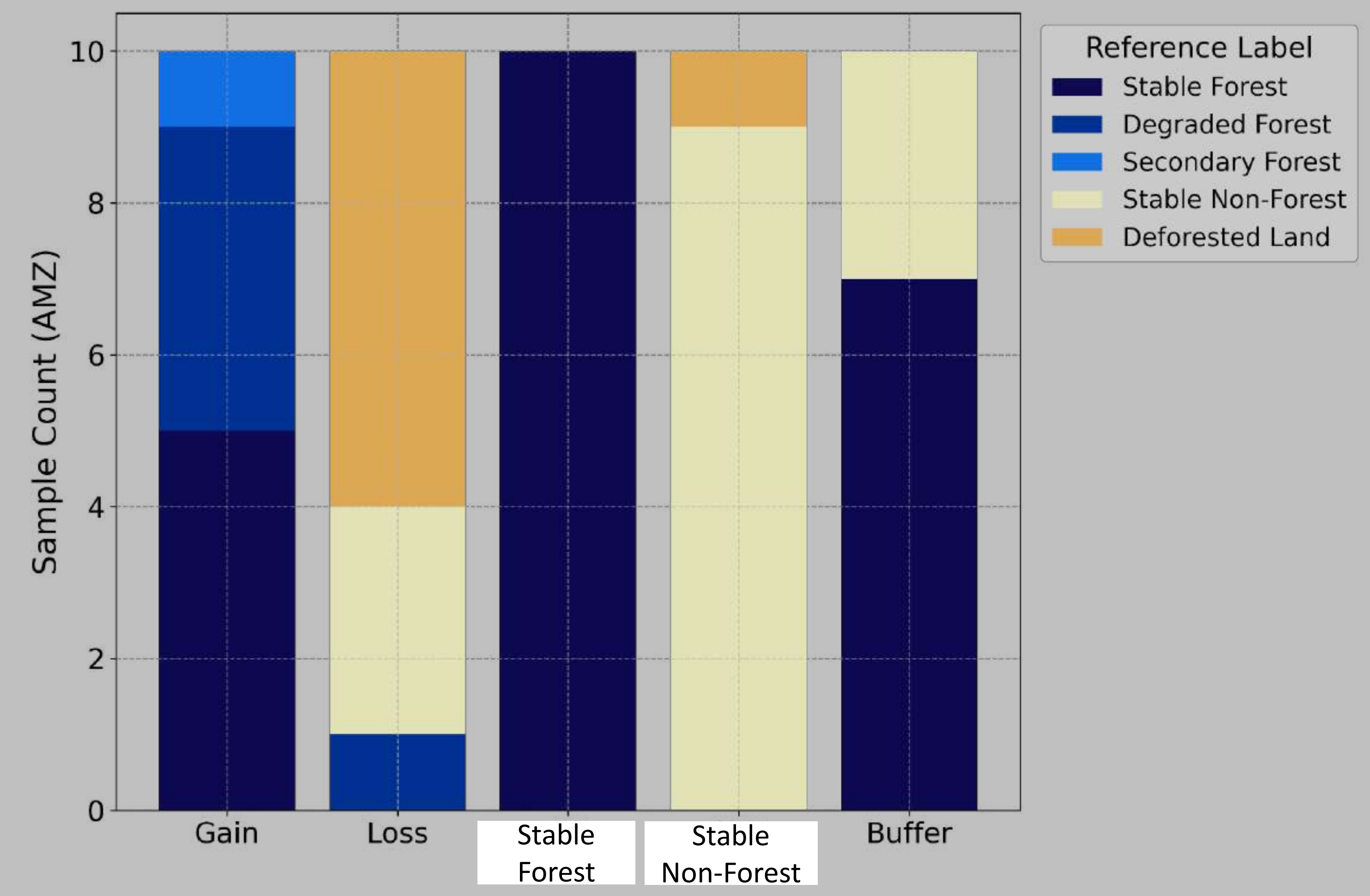
Naturally Regrowing Secondary Forests



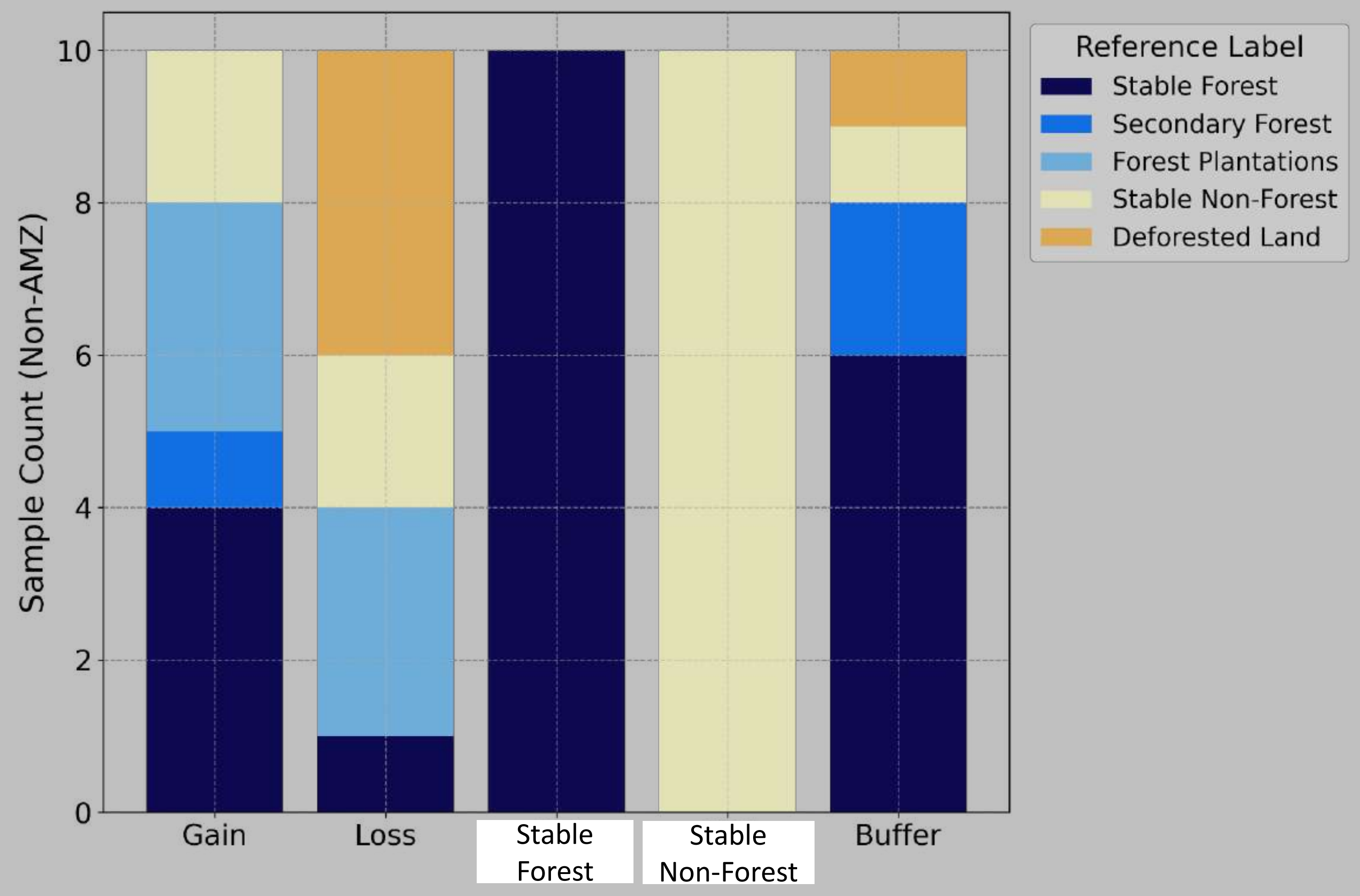


A sample allocated to the Forest Gain stratum and interpreted as ***secondary forest***

Interpretation Results



Interpretation of forest trajectories inside the Amazon Basin



Interpretations of forest trajectories outside the Amazon Basin

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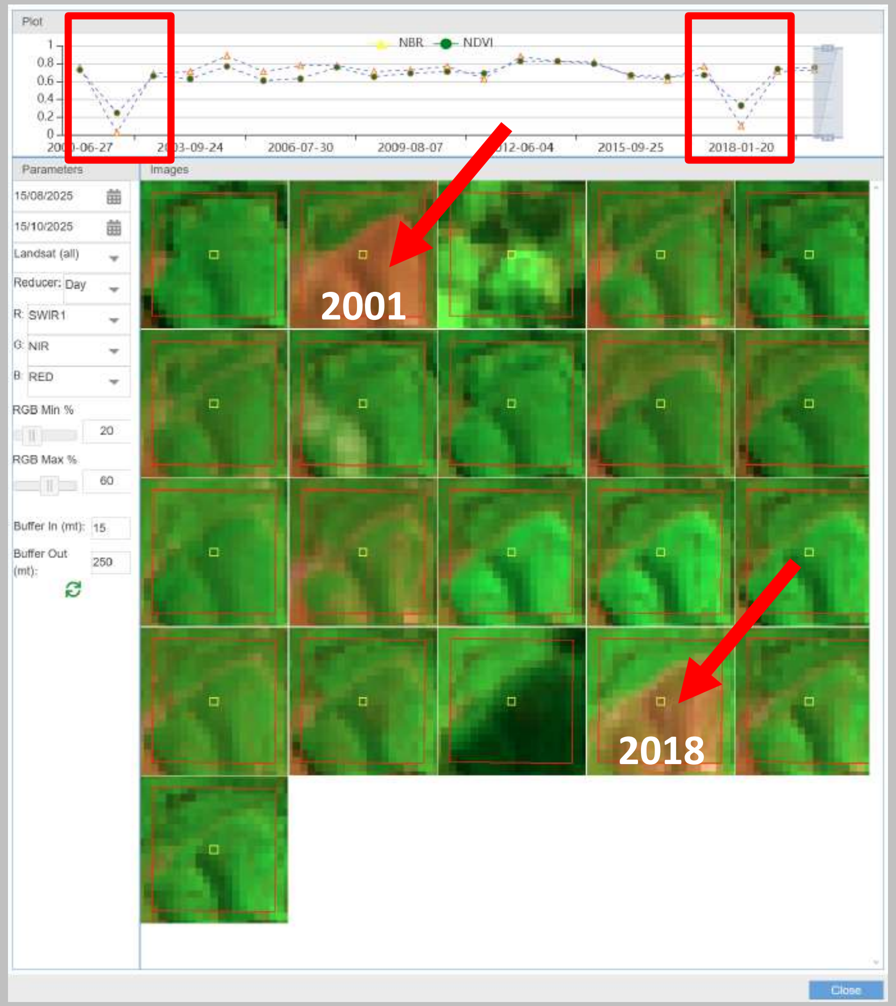
Commission Errors: Forest Plantations



A sample allocated to the Forest Gain stratum but interpreted as a ***forest plantation***

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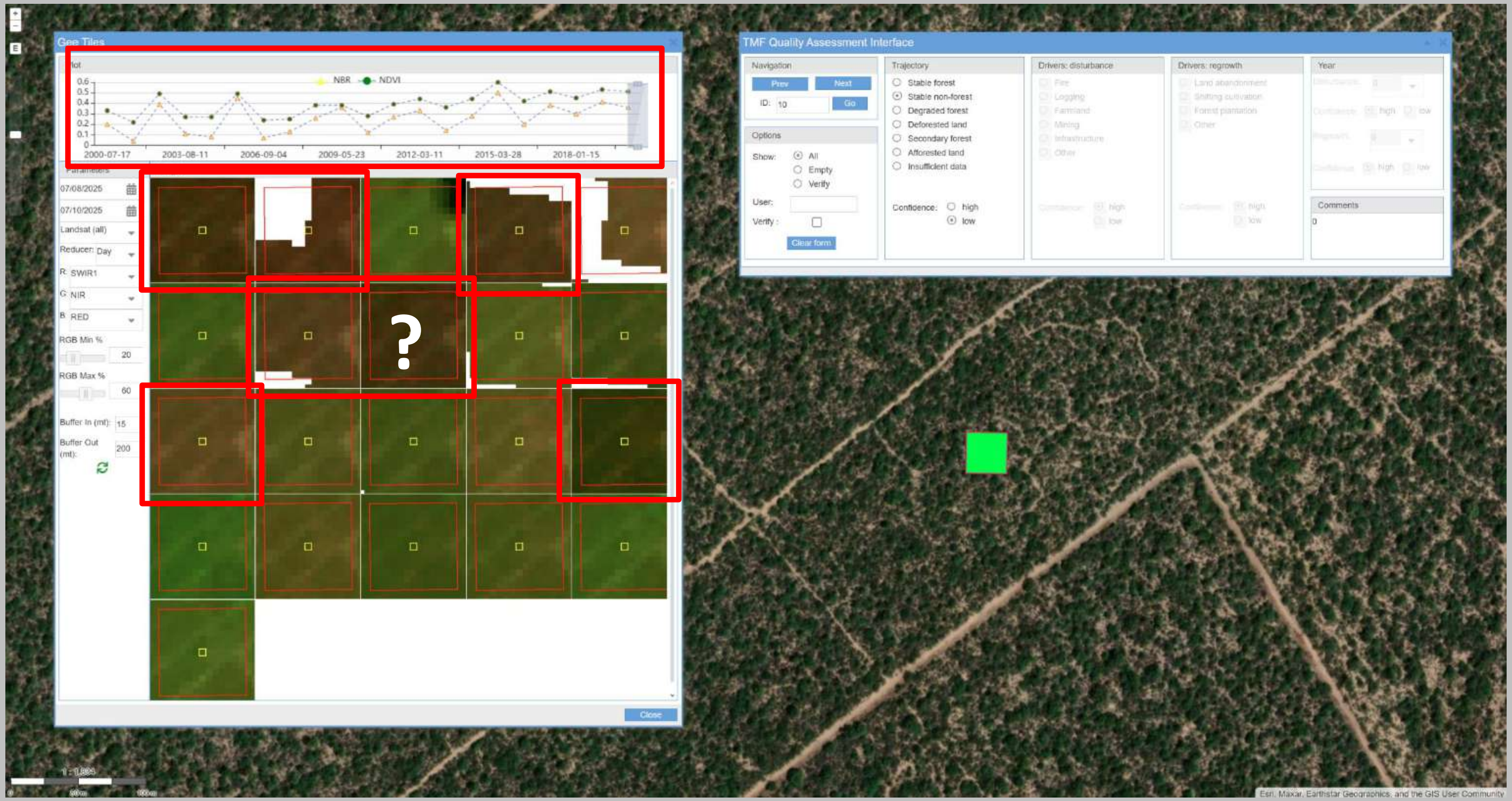
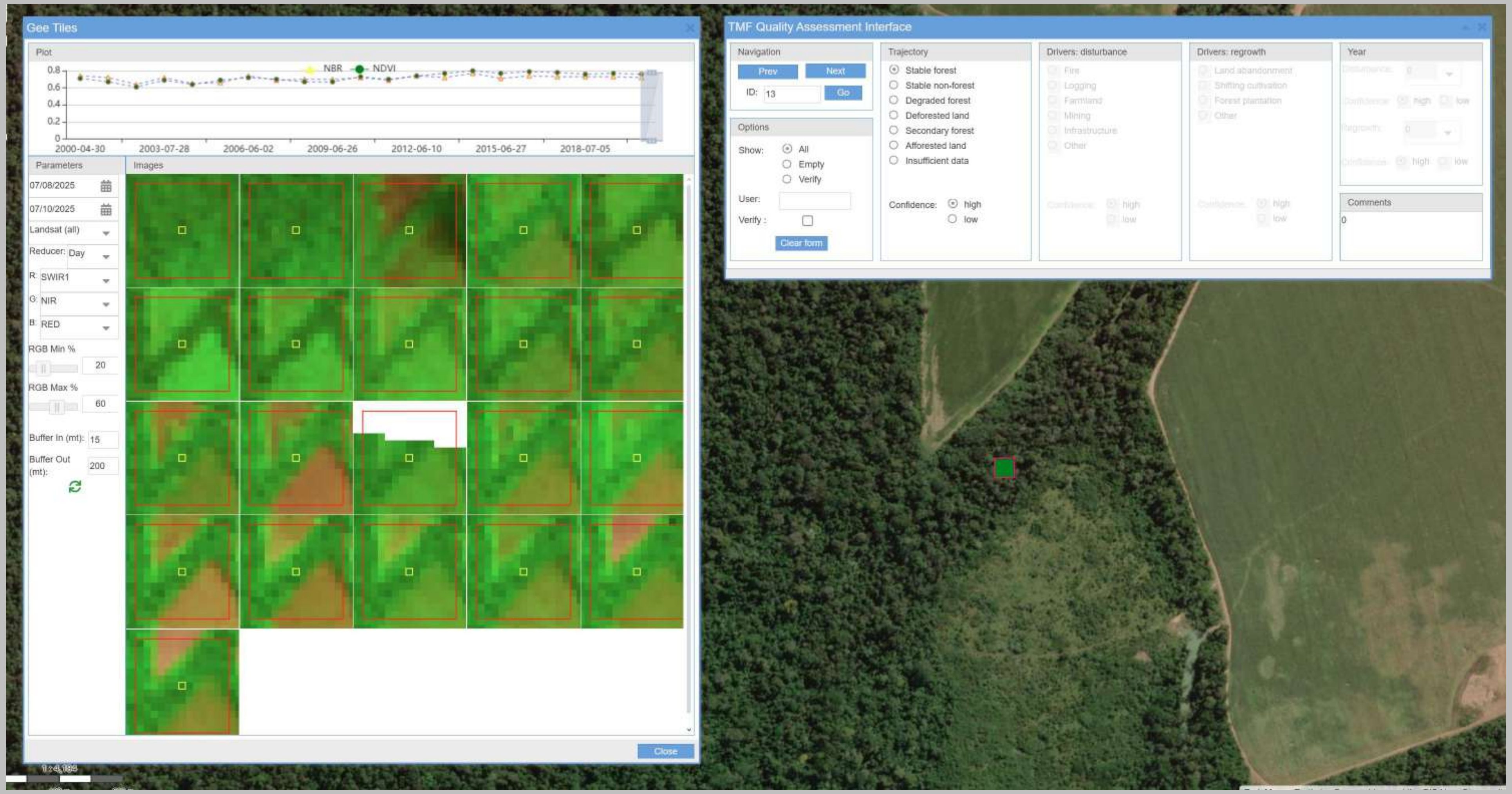
Commission Errors: Seasonality



A sample allocated to the Forest Gain stratum but interpreted as ***stable forest***

Commission Errors: Disturbance-Adjacent



A sample allocated to the Forest Gain stratum but interpreted as ***stable forest***

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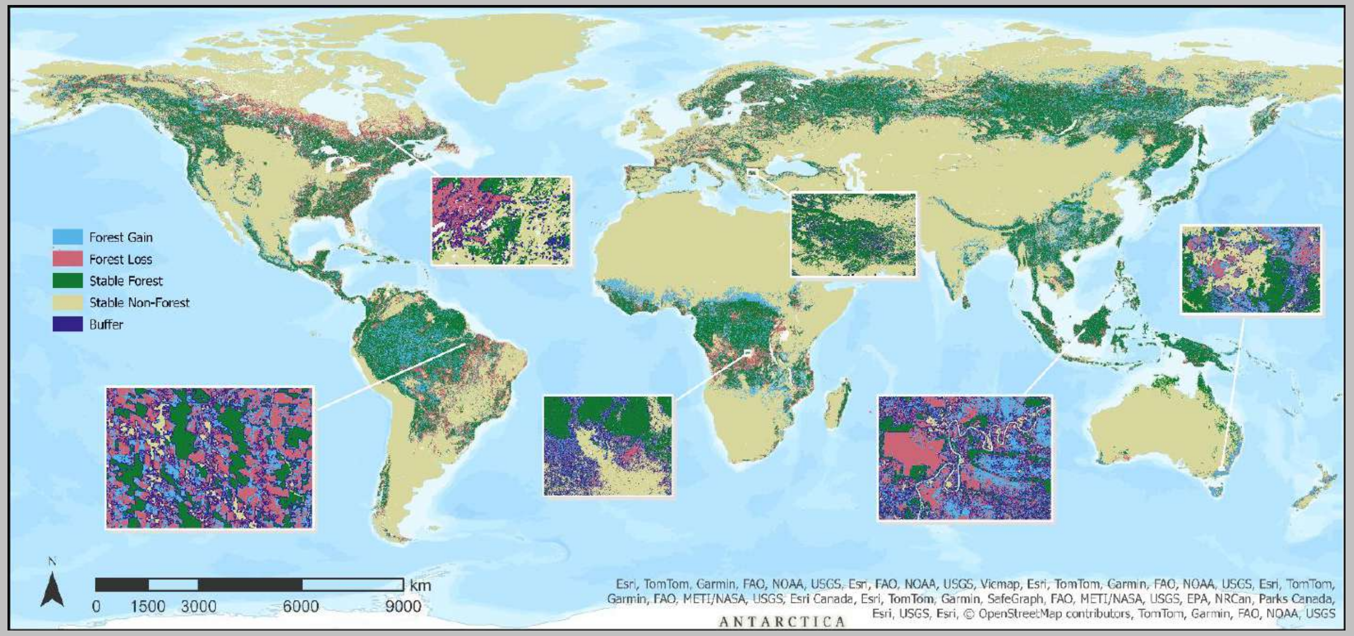
A Way Forward

- Fine-tuning stratification and interpretation strategies to improve dataset quality
  - *Open to suggestions!*
- Use reference dataset to compare regrowth products and clarify findings



Global stratification map for upscaling

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Conclusions

1. Creating a high-quality, global reference dataset is needed to ensure the ***reliability*** of remote sensing-based maps and deliver ***meaningful results*** to policymakers
2. Initial progress highlights challenges in the *quality* of the forest gain stratum and *quantity* of secondary forest interpretations
3. Eager to learn from experts and fine-tune methodology for a widely-applicable reference dataset

Conclusions

1. Creating a high-quality, global reference dataset is needed to ensure the *reliability* of remote sensing-based maps and deliver *meaningful results* to policymakers
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Conclusions

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Thank you!

Sources:

Heinrich, V.H.A., Vancutsem, C., Dalagnol, R. et al. The carbon sink of secondary and degraded humid tropical forests. Nature 615, 436–442 (2023). https://doi.org/10.1038/s41586-022-05679-w

Smith, C. C., Barlow, J., Healey, J. R., De Sousa Miranda, L., Young, P. J., & Schwartz, N. B. (2023). Amazonian secondary forests are greatly reducing fragmentation and edge exposure in old-growth forests. Environmental Research Letters, 18(12), 124016. https://doi.org/10.1088/1748-9326/ad039e

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How consistent are Secondary Forest maps?

Ricardo Dalagnol (Ctrees)

Session 1.2: Mapping Secondary Forest – where are they regrowing according to what dataset?

São José dos Campos, 29 Oct 2025

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How consistent are Secondary Forest maps?

The goal of this study was to do an intercomparison of secondary forest maps in the Brazilian Amazon Biome.

1- What is the area extent covered by secondary forests ?

2- What is their age distribution ?

3- What is the agreement between secondary forests datasets?

4- What is the contribution of Forest Plantations ?

Method

Secondary Forests definition :

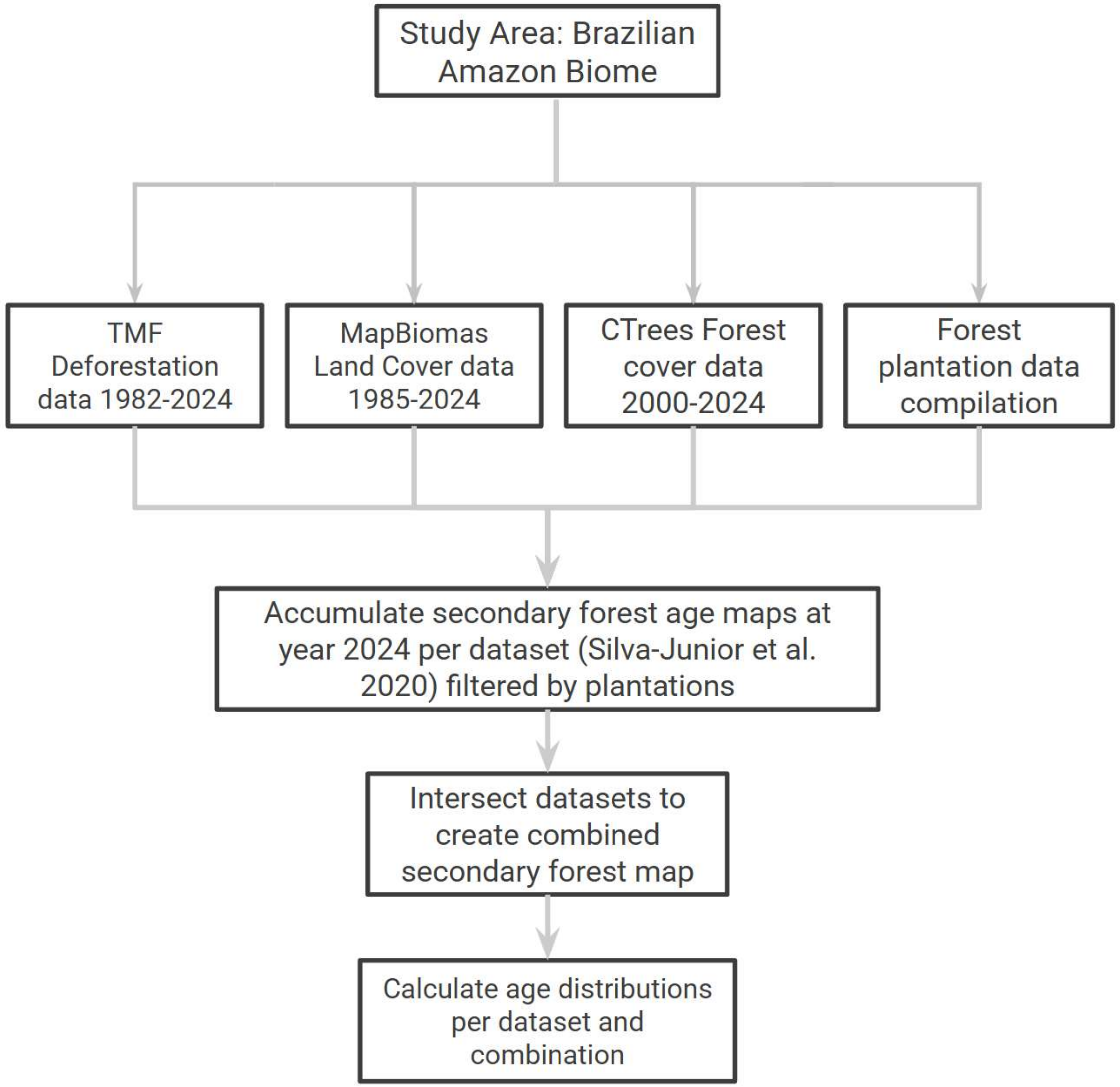
Areas changing from Non-forest to Forest, either following Deforestation or growing in areas that were Non-Forest at the start of the satellite time series ("Afforestation").

After Deforestation :

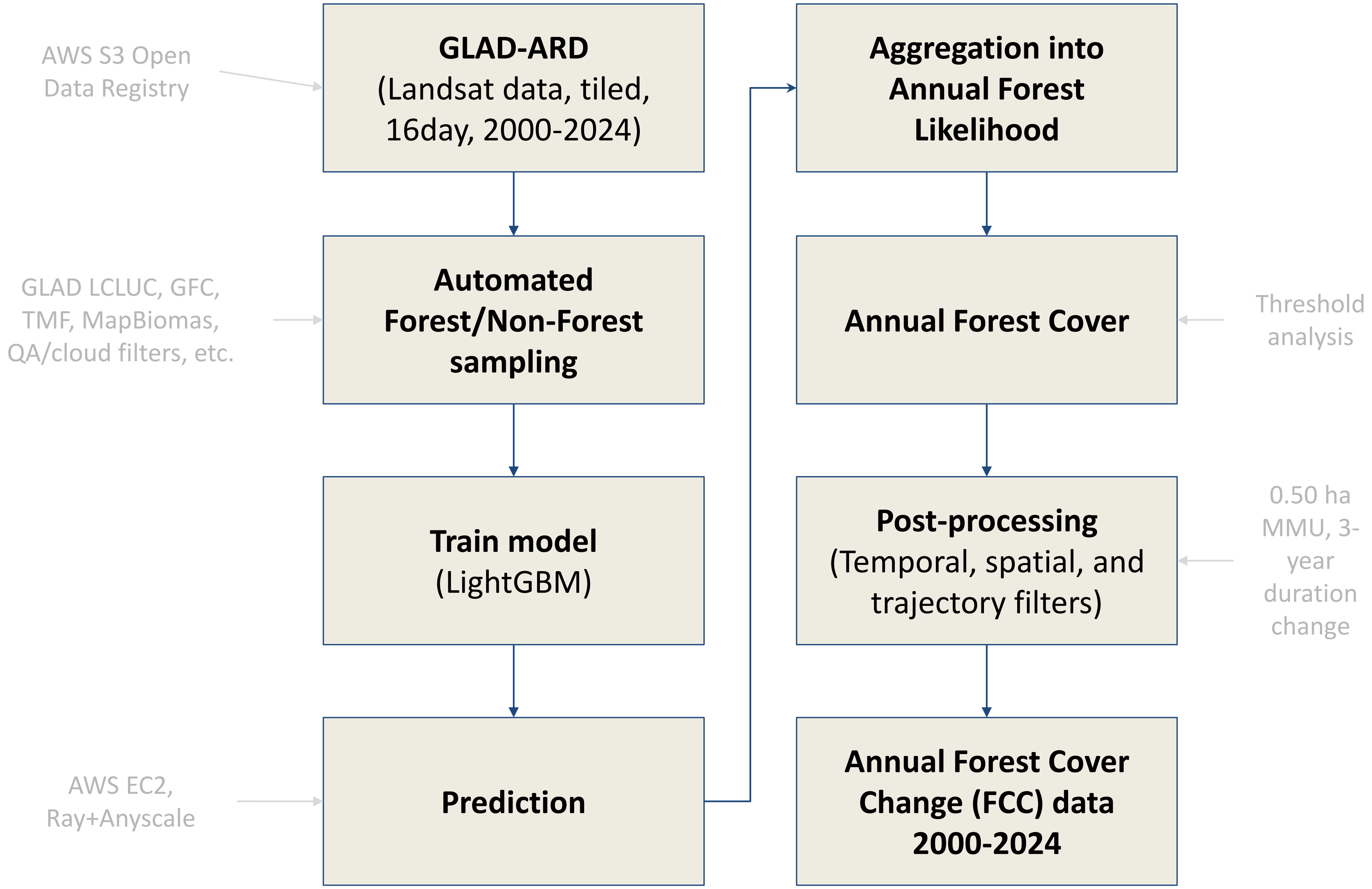
- F (start period) → NF → F (age 1) → F (age *n* in 2024)

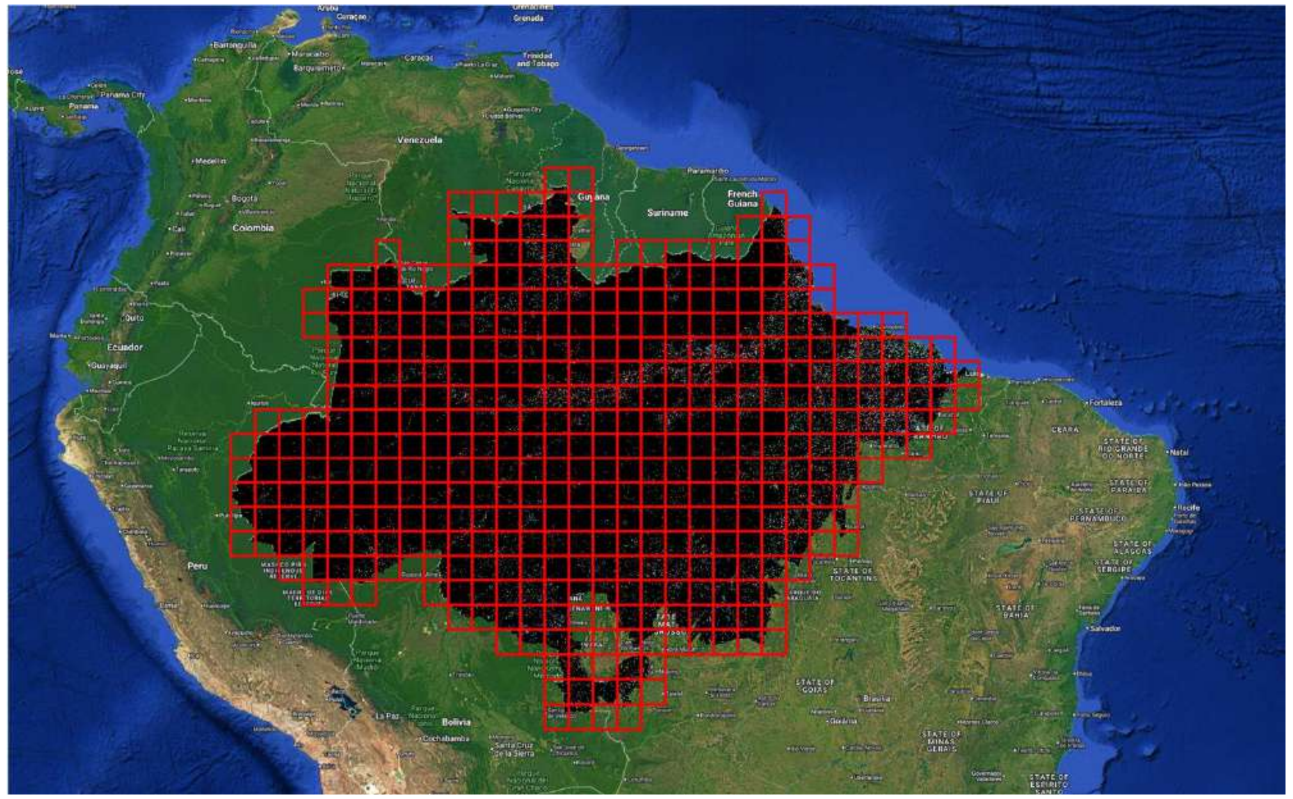
"Afforestation" :

- NF (start period) → F (age 1) → F (age *n* in 2024)



CTrees Forest Cover Change Data

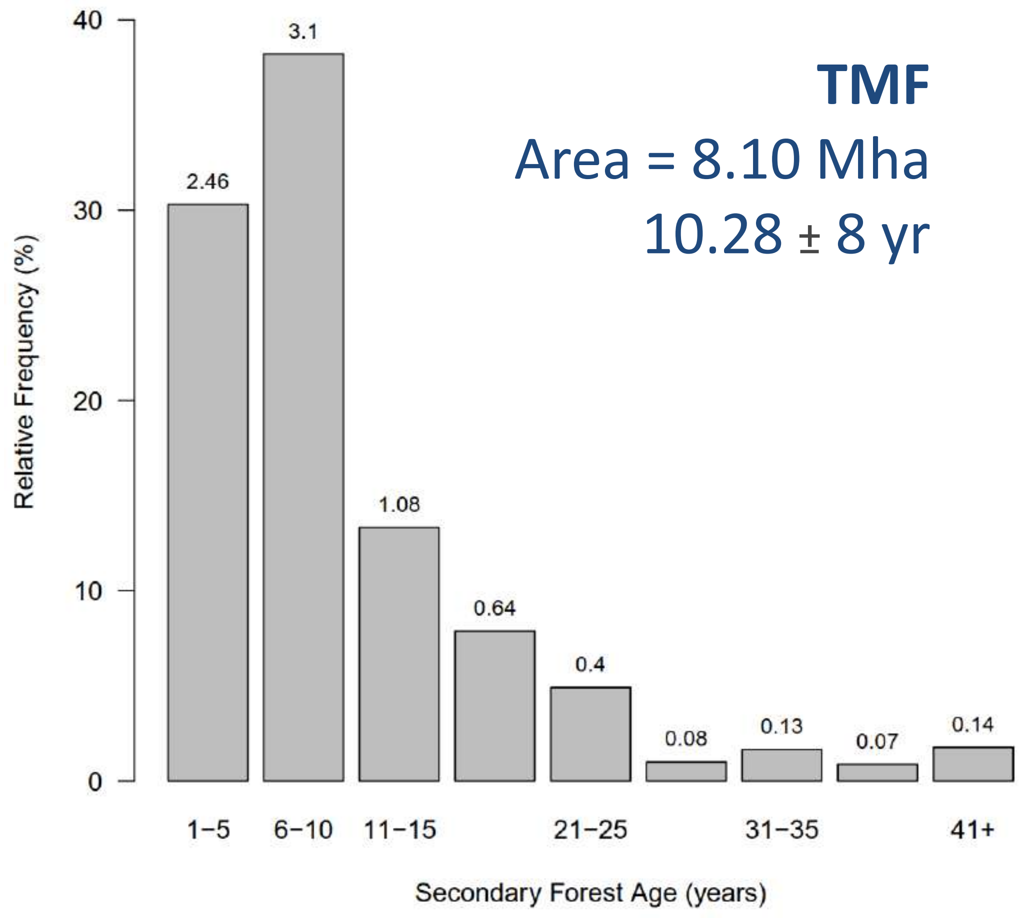




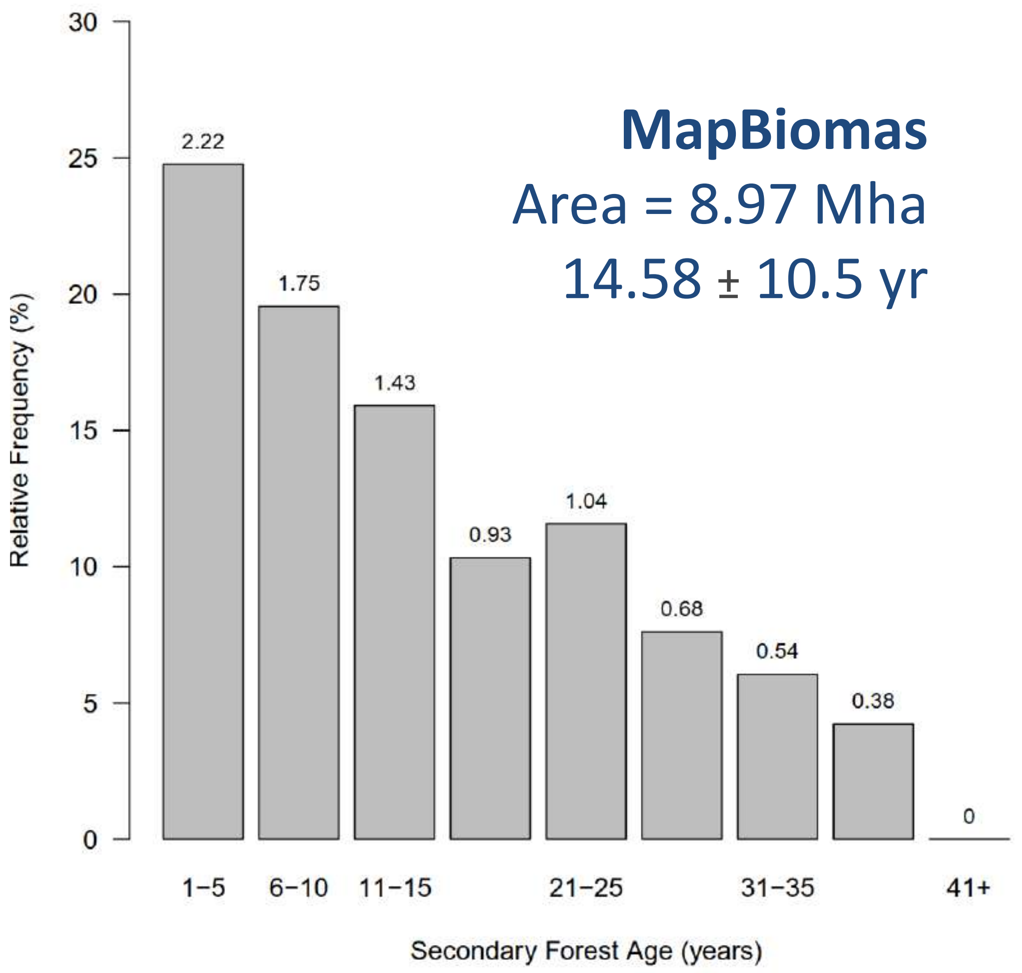
Brazilian Amazon = 423 tiles ~40Tb data

Secondary forests extent and age distribution in 2024 varies across datasets in Brazilian Amazon

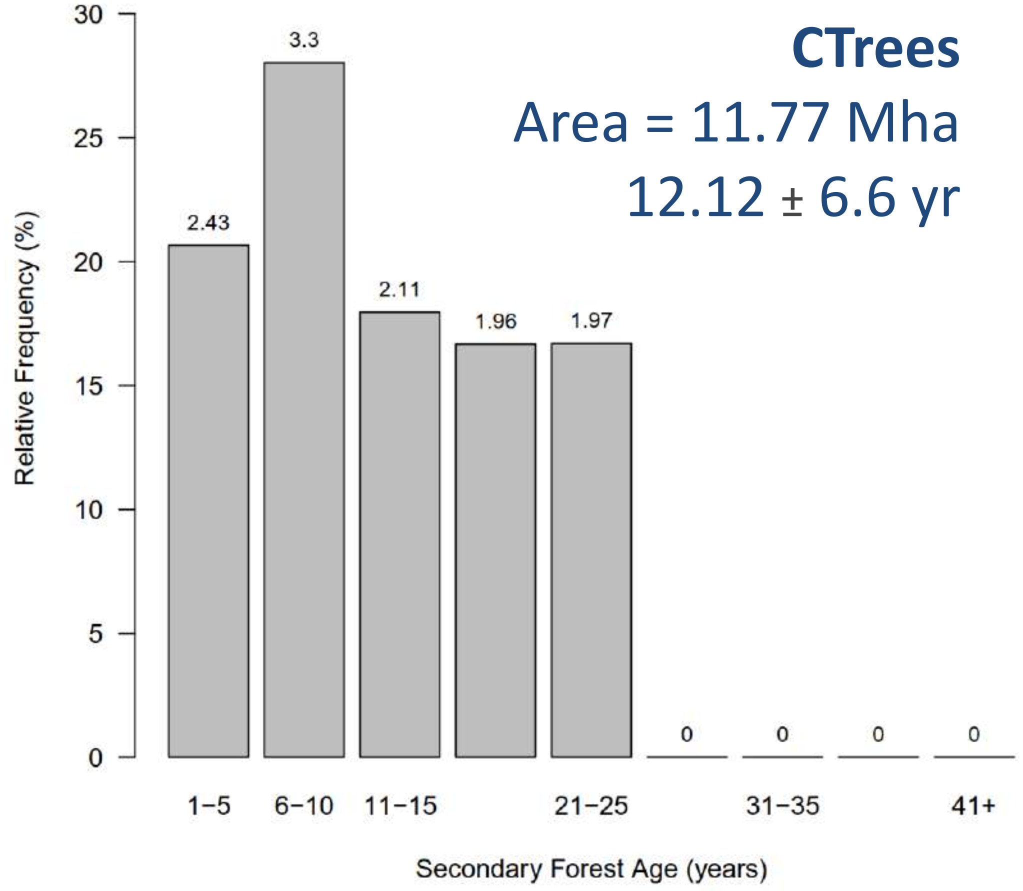
Concentrated at younger ages



Better distributed across time

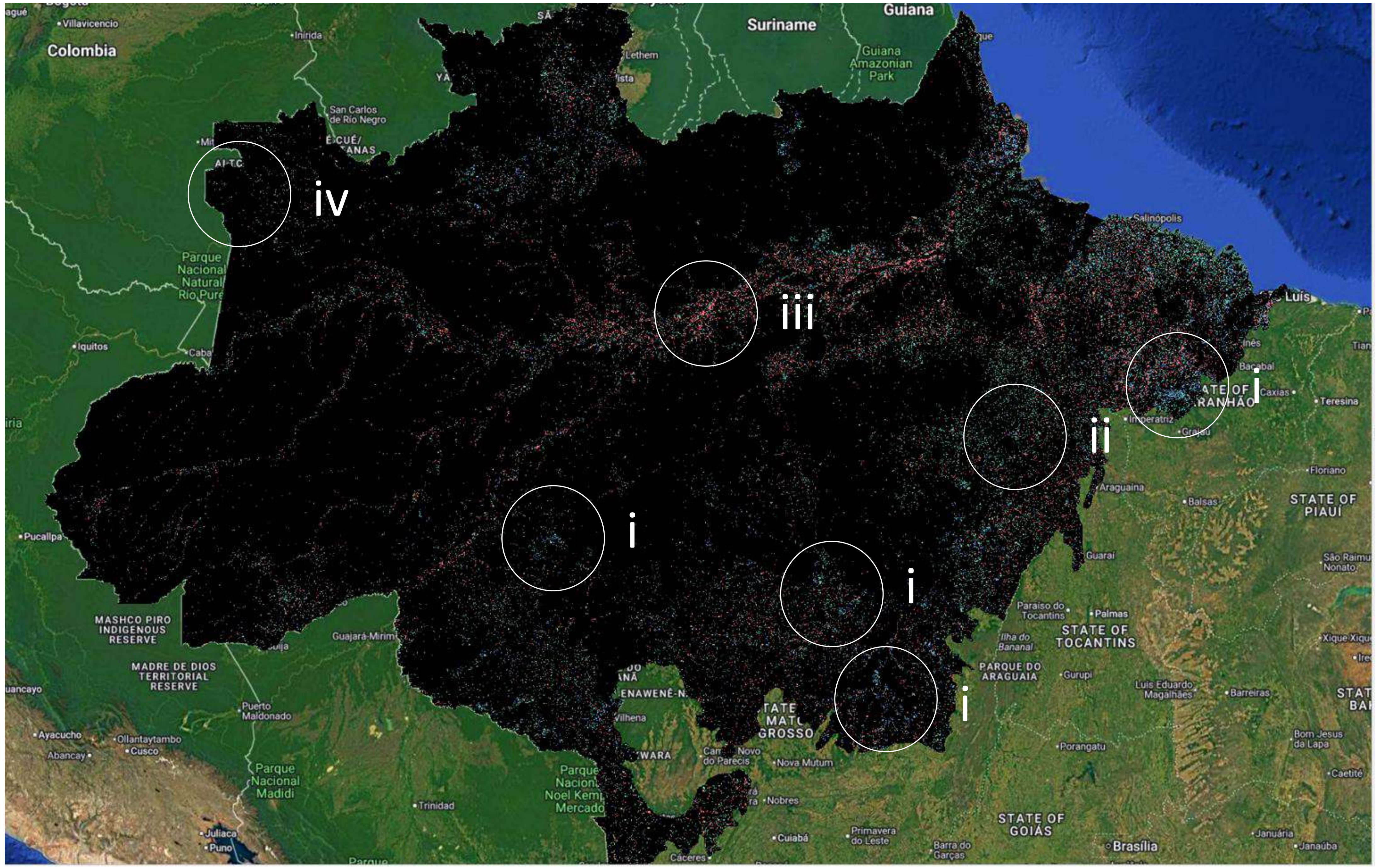


Relatively uniform, capped at 25 years because data limitation

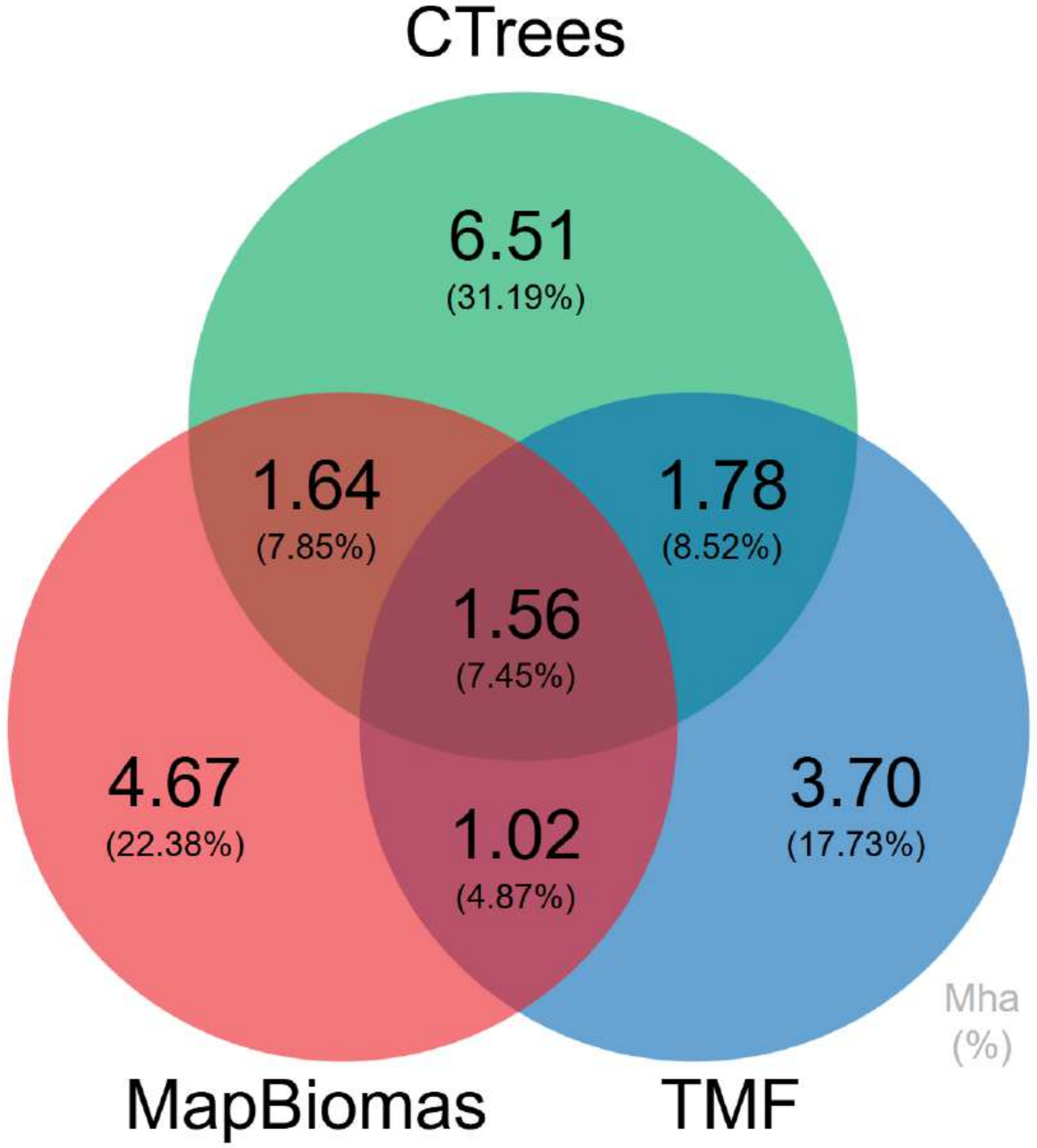


- Brazilian Amazon 13.8 Mha of secondary forests in 2017 with MapBiomas v3.1 (Heinrich et al. 2021)

High variability in between secondary forest datasets : less than 30% or 6 Mha of secondary forests overlaps

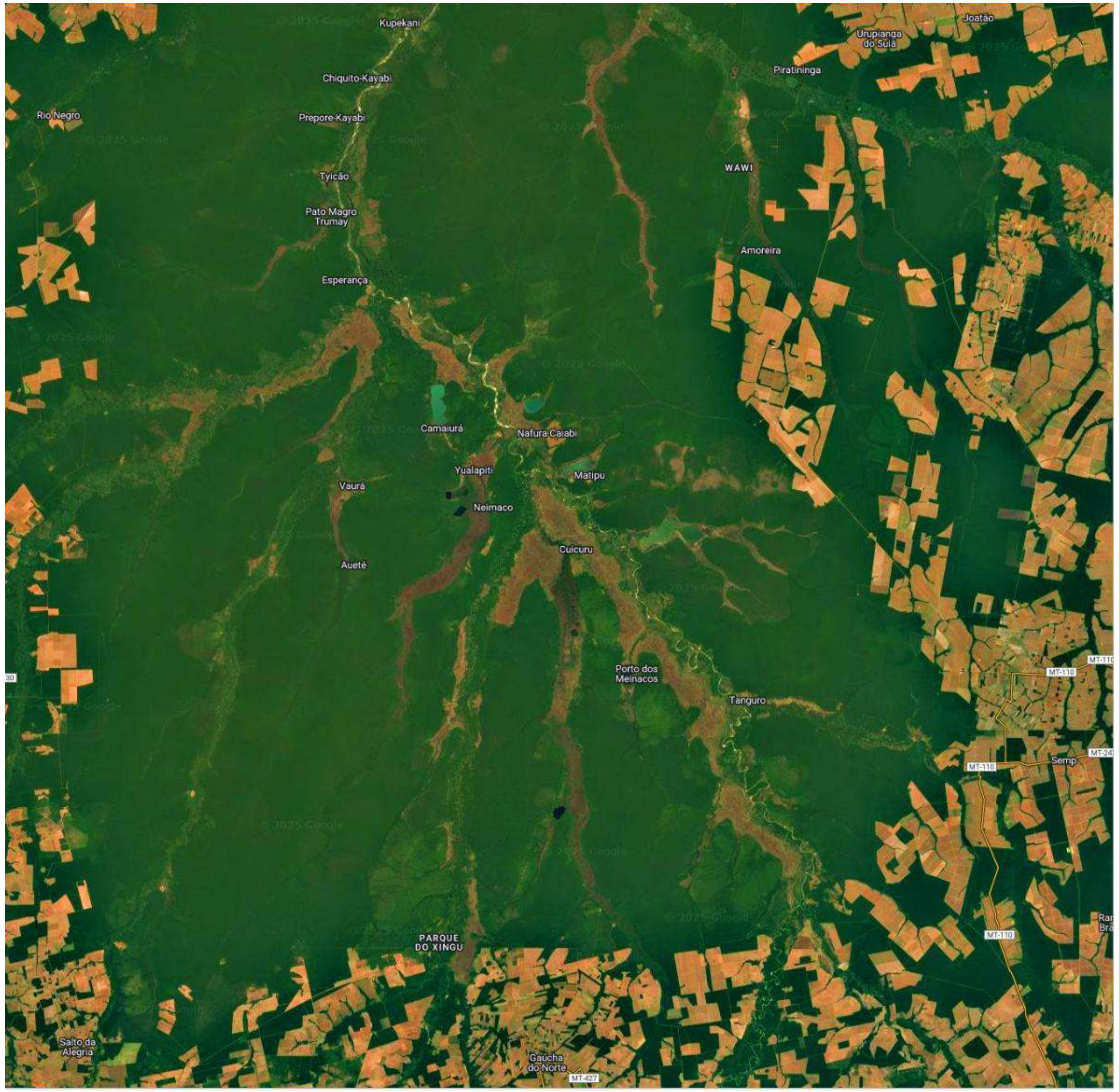


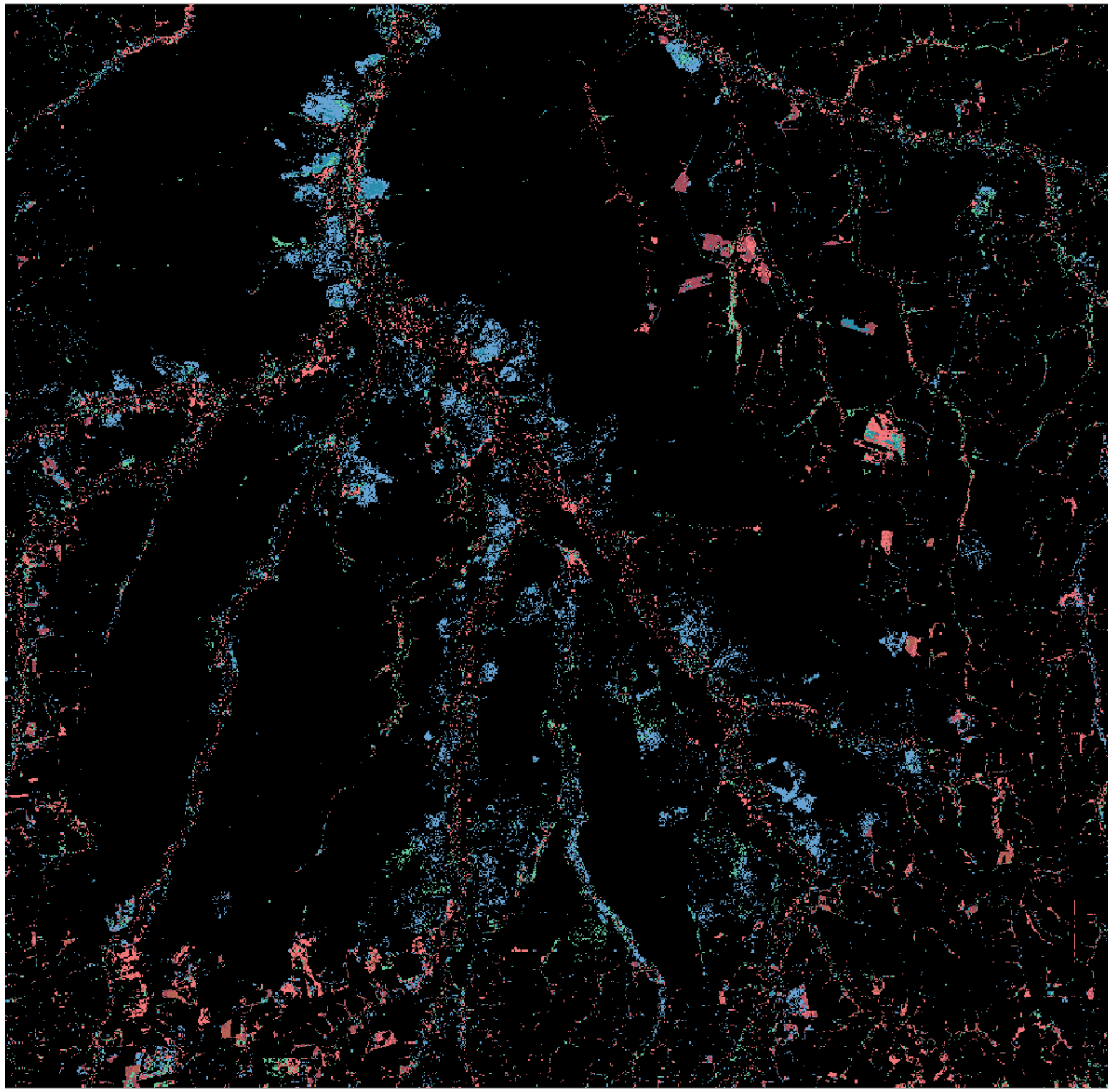
20.87 Mha combined secondary forests



- Plantations represented ~0.35Mha or 1.6% of the total combined (already excluded)

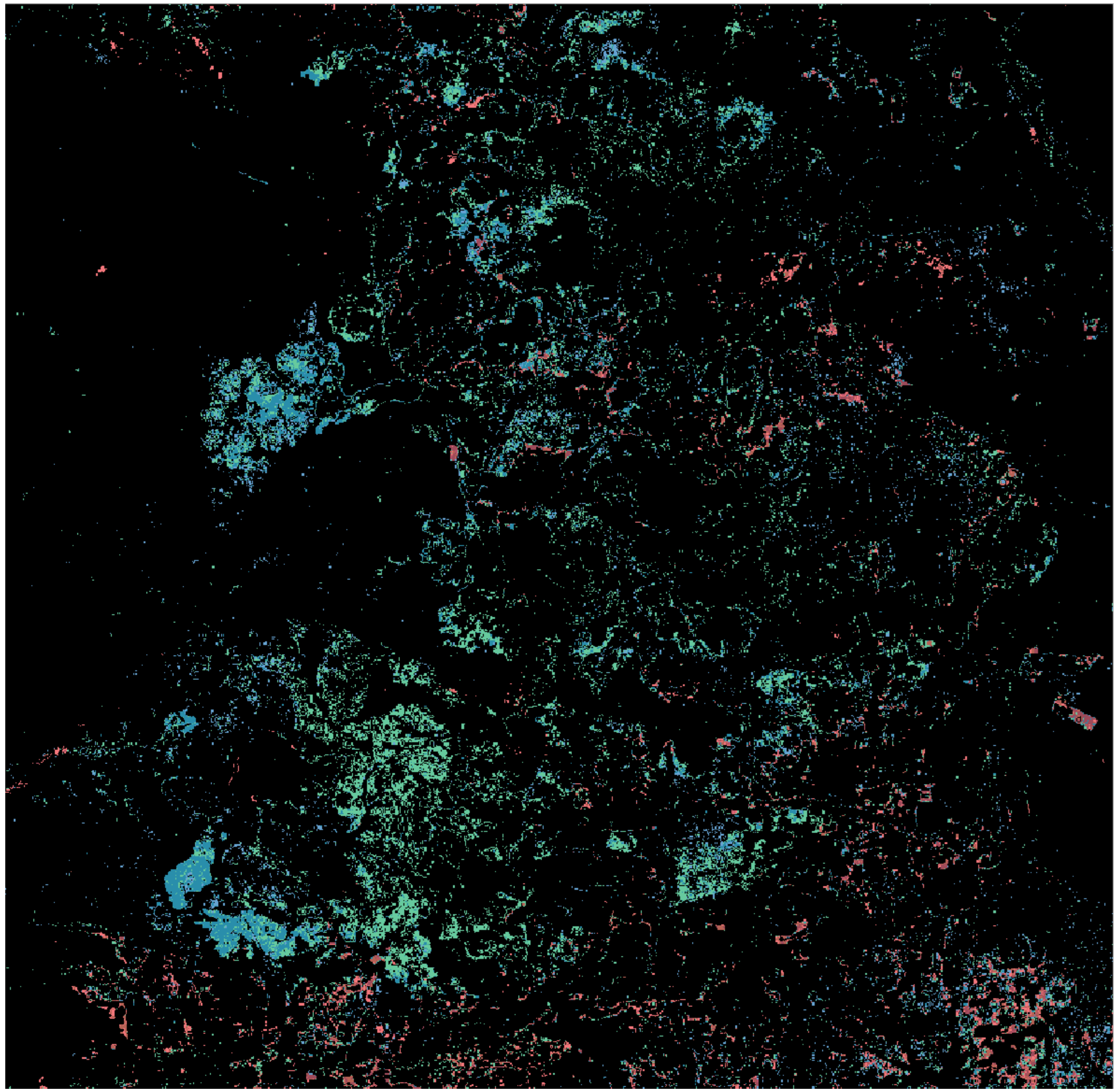
i) Fire degradation or secondary forest ?





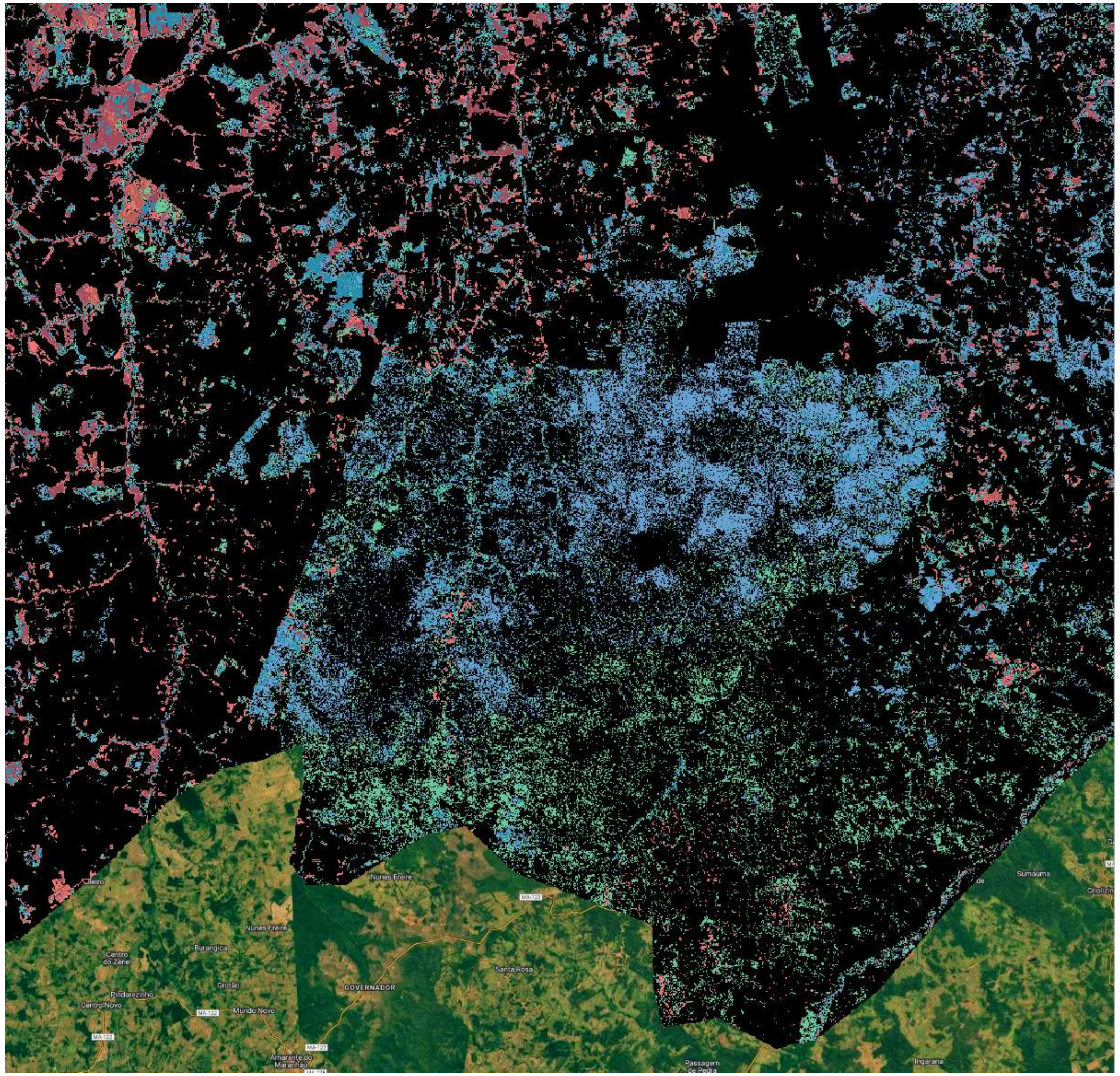
-12.29446083, -53.35759172

i) Fire degradation or secondary forest ?



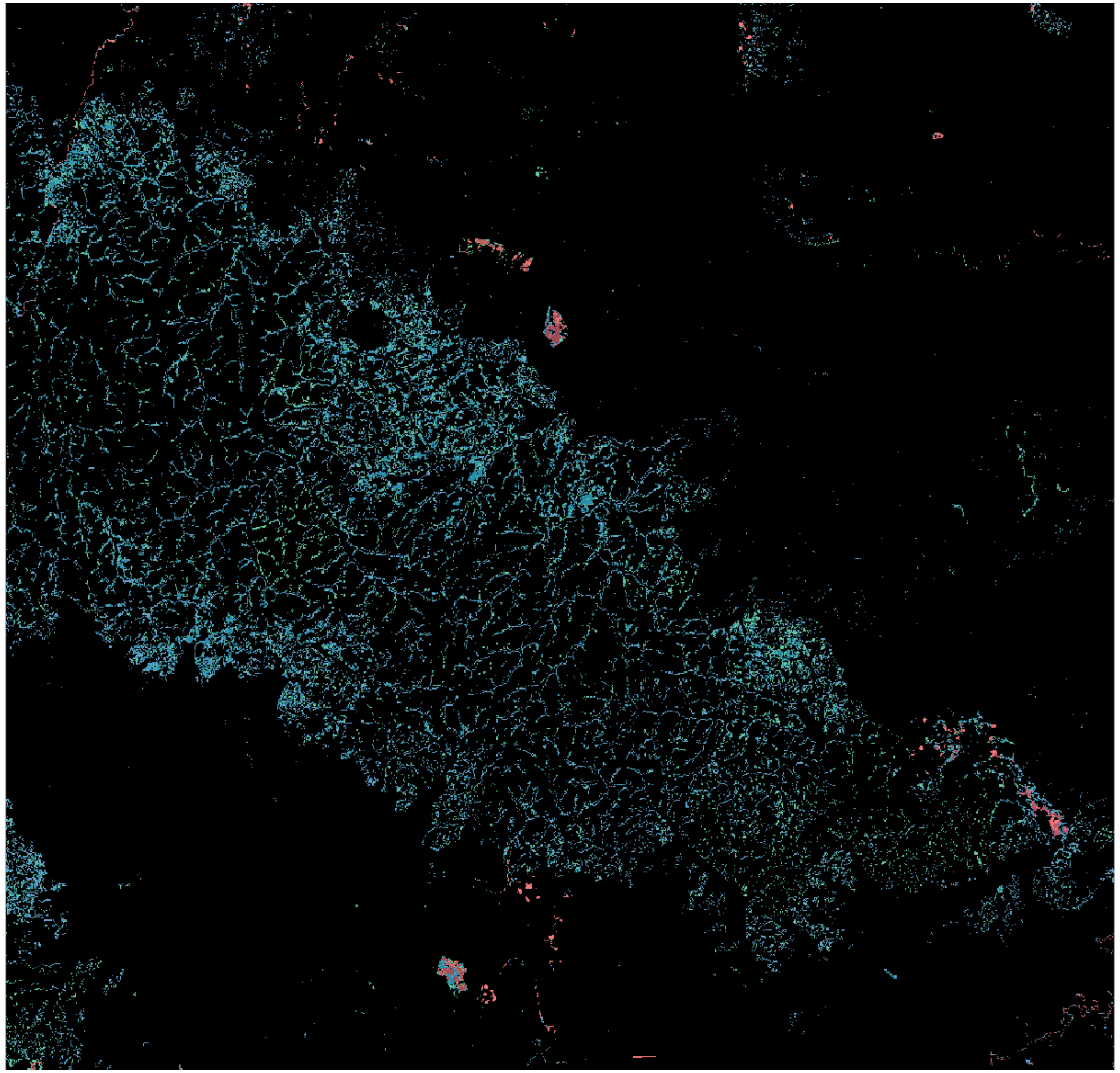
-9.12541410, -54.90591282

i) Fire degradation or secondary forest?



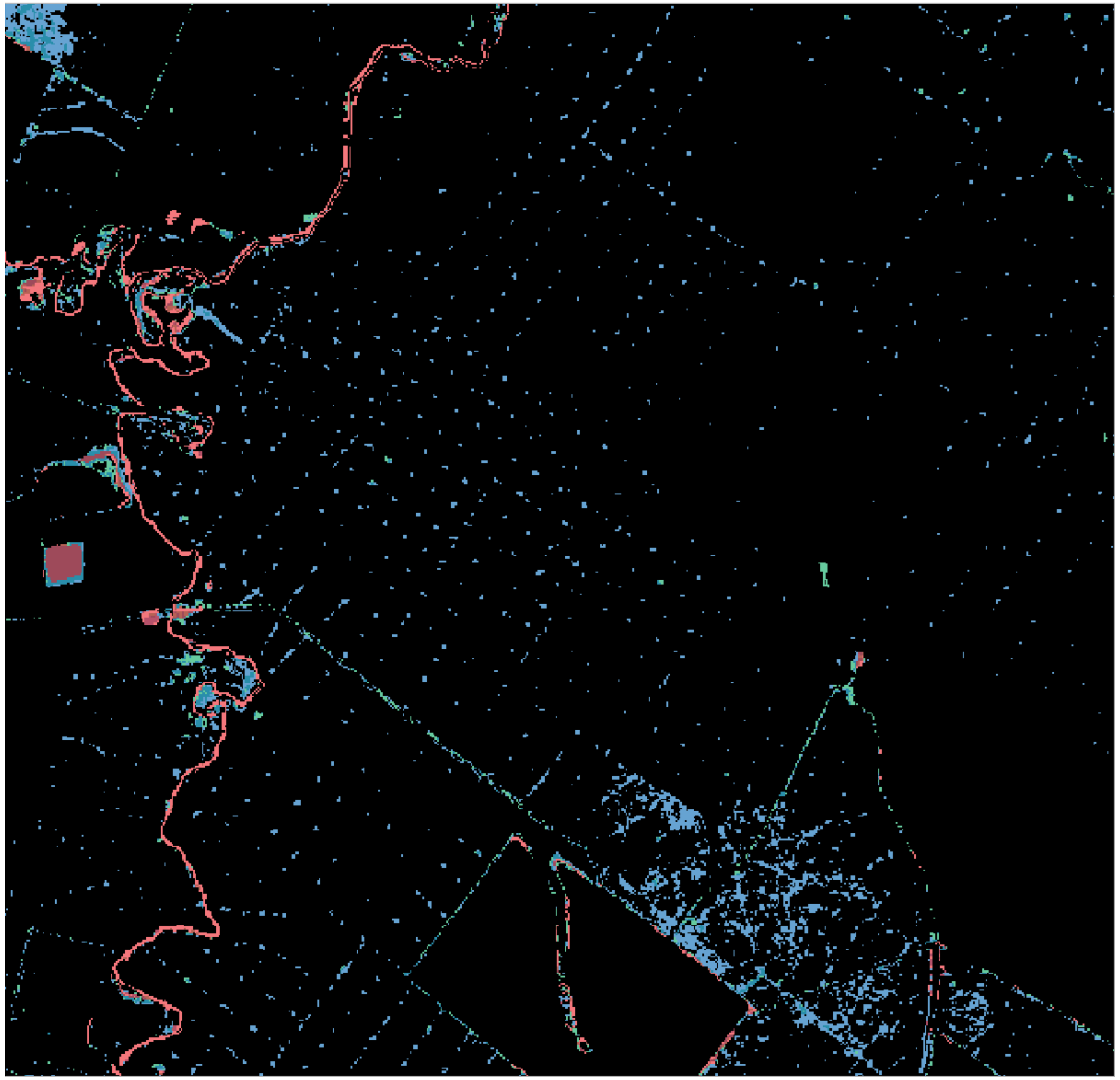
-4.97580251, -46.35459733

i) Degradation, seasonality, or what? (several areas like this in wet forest/savanna ecotone)



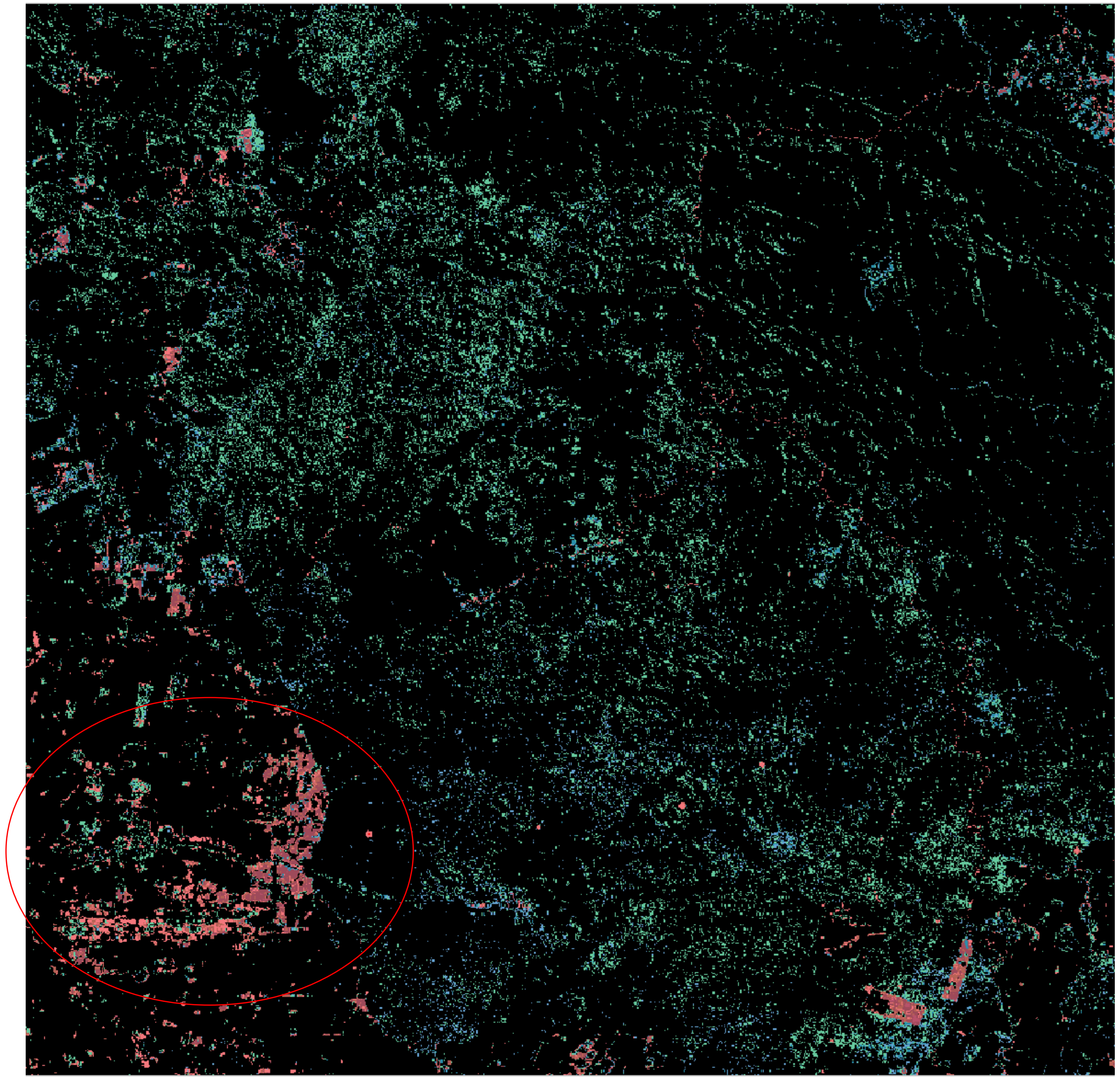
-8.46907766, -61.39454566

i) Degradation Logging



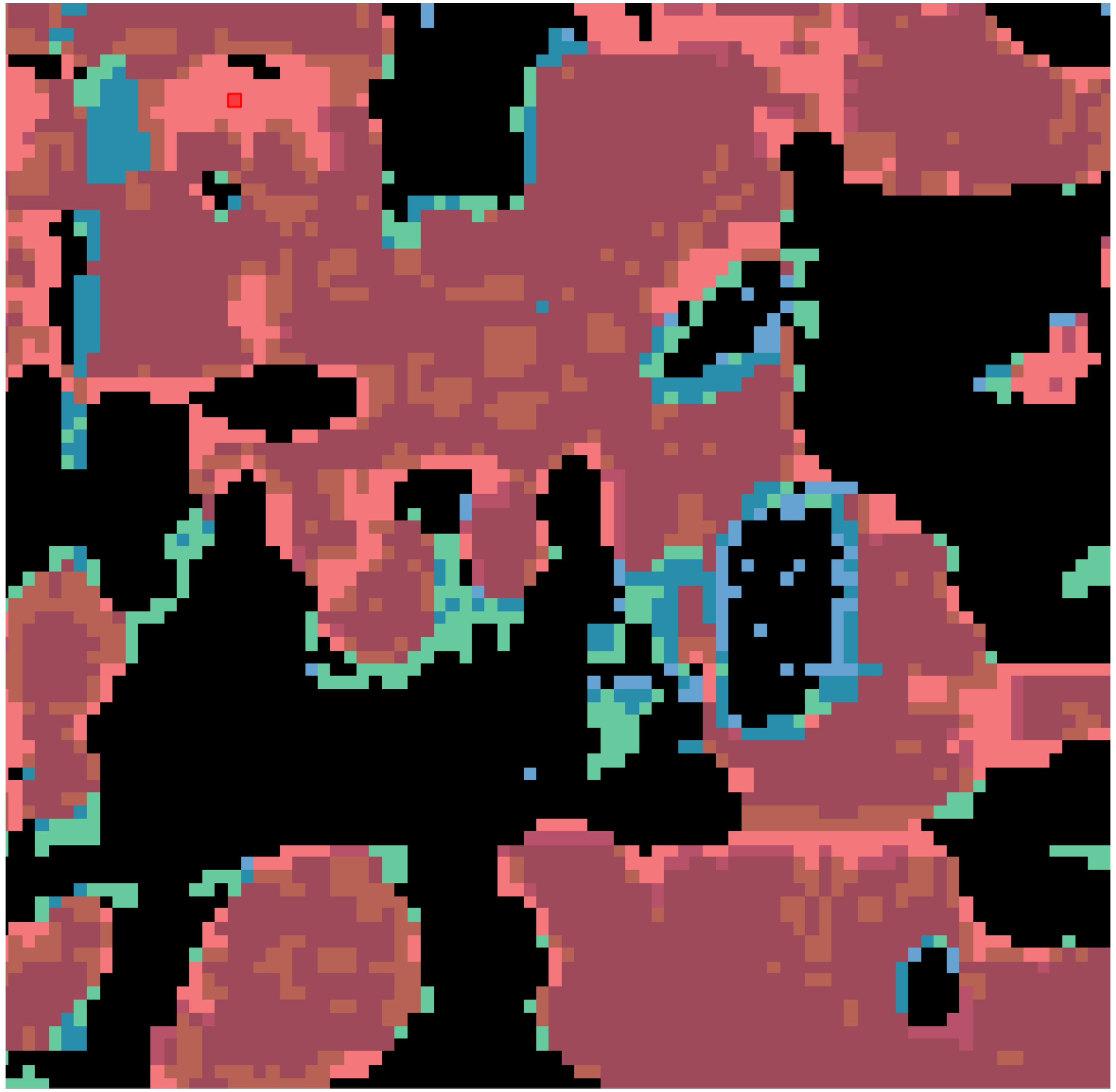
-11.28410877, -54.63726500

ii) Likely seasonality / nice agreement area (circle)



-6.28039196, -50.79260195

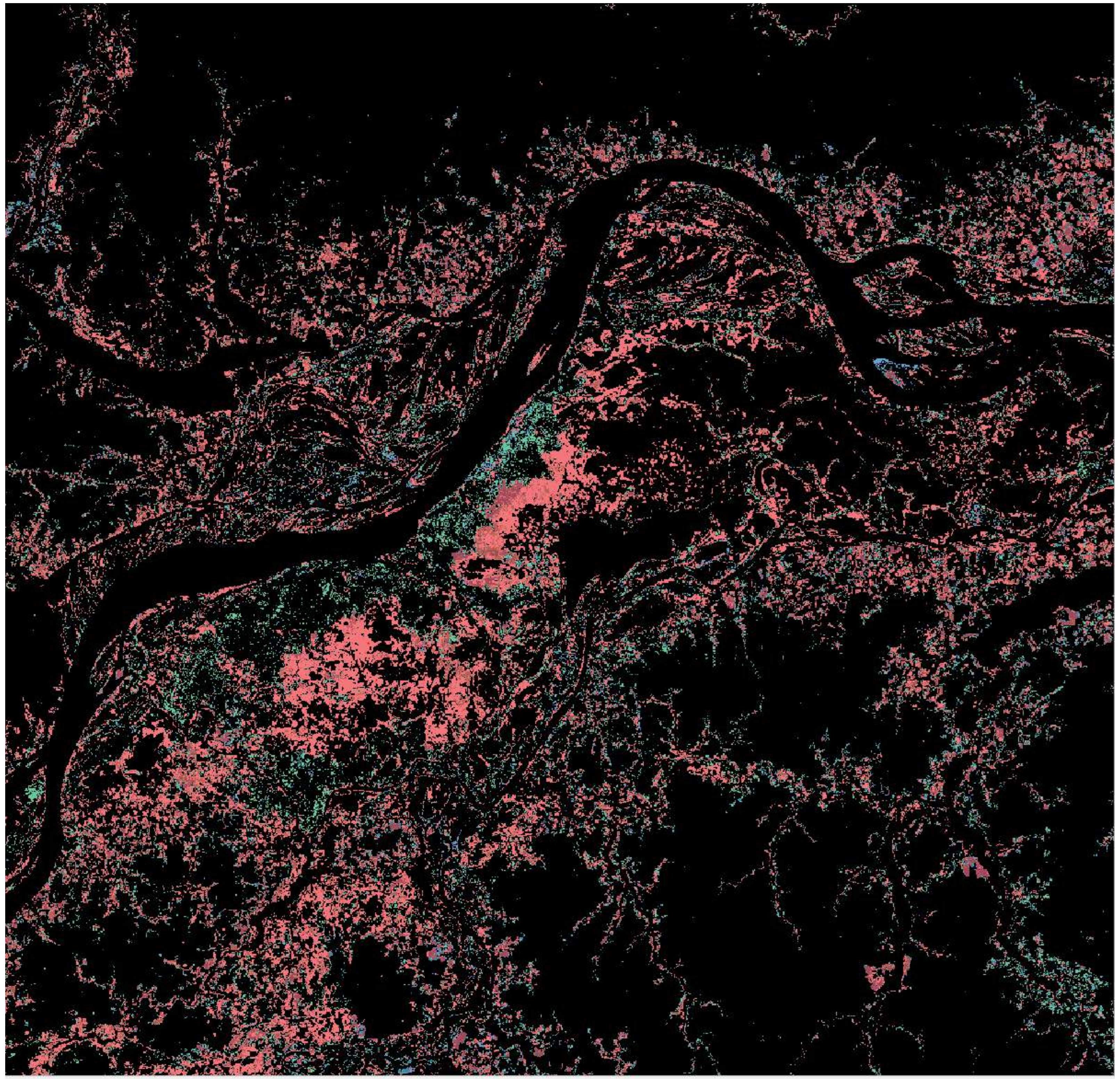
Nice agreement area zoom in



-6.28039196, -50.79260195

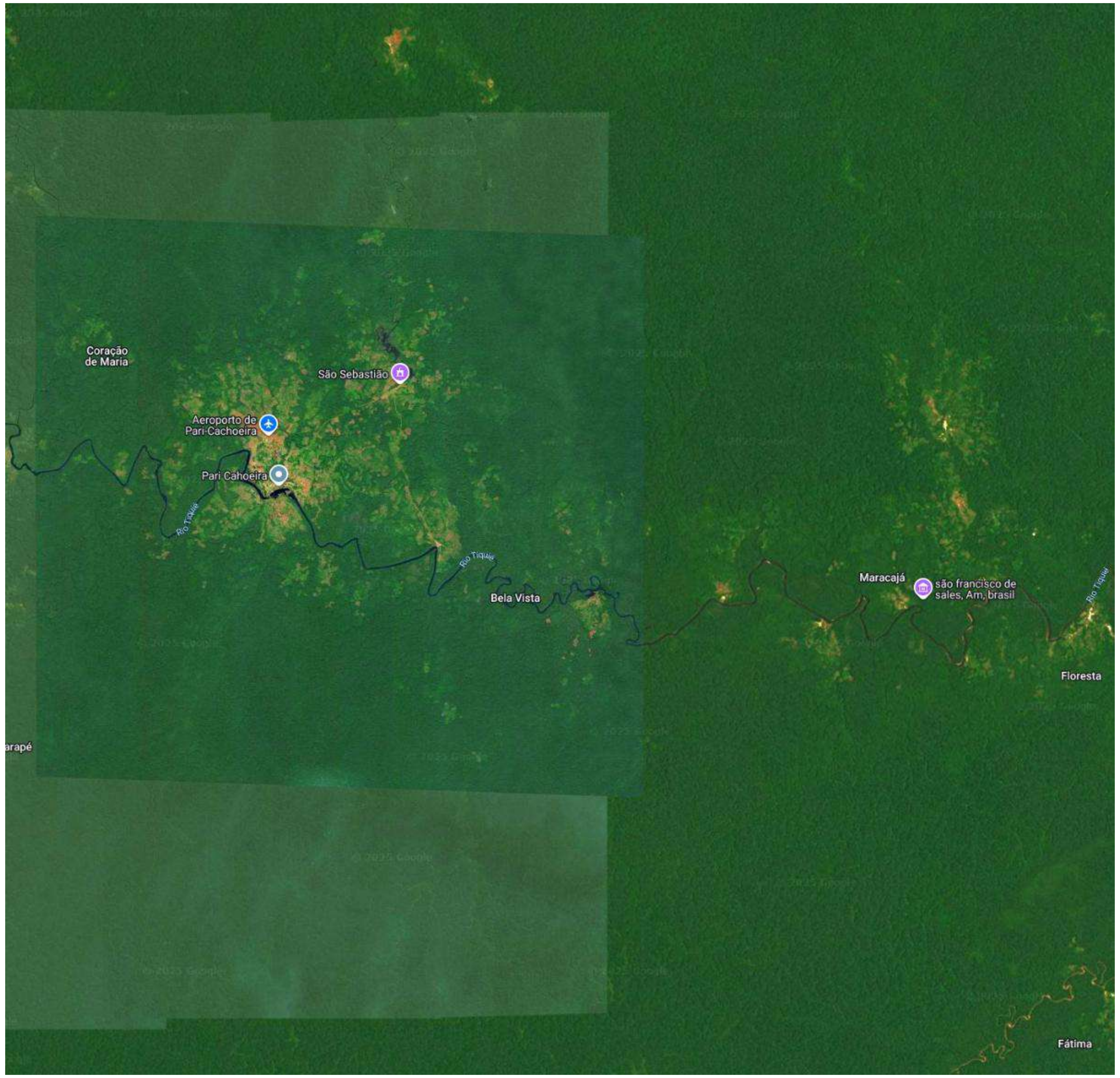
CTrees

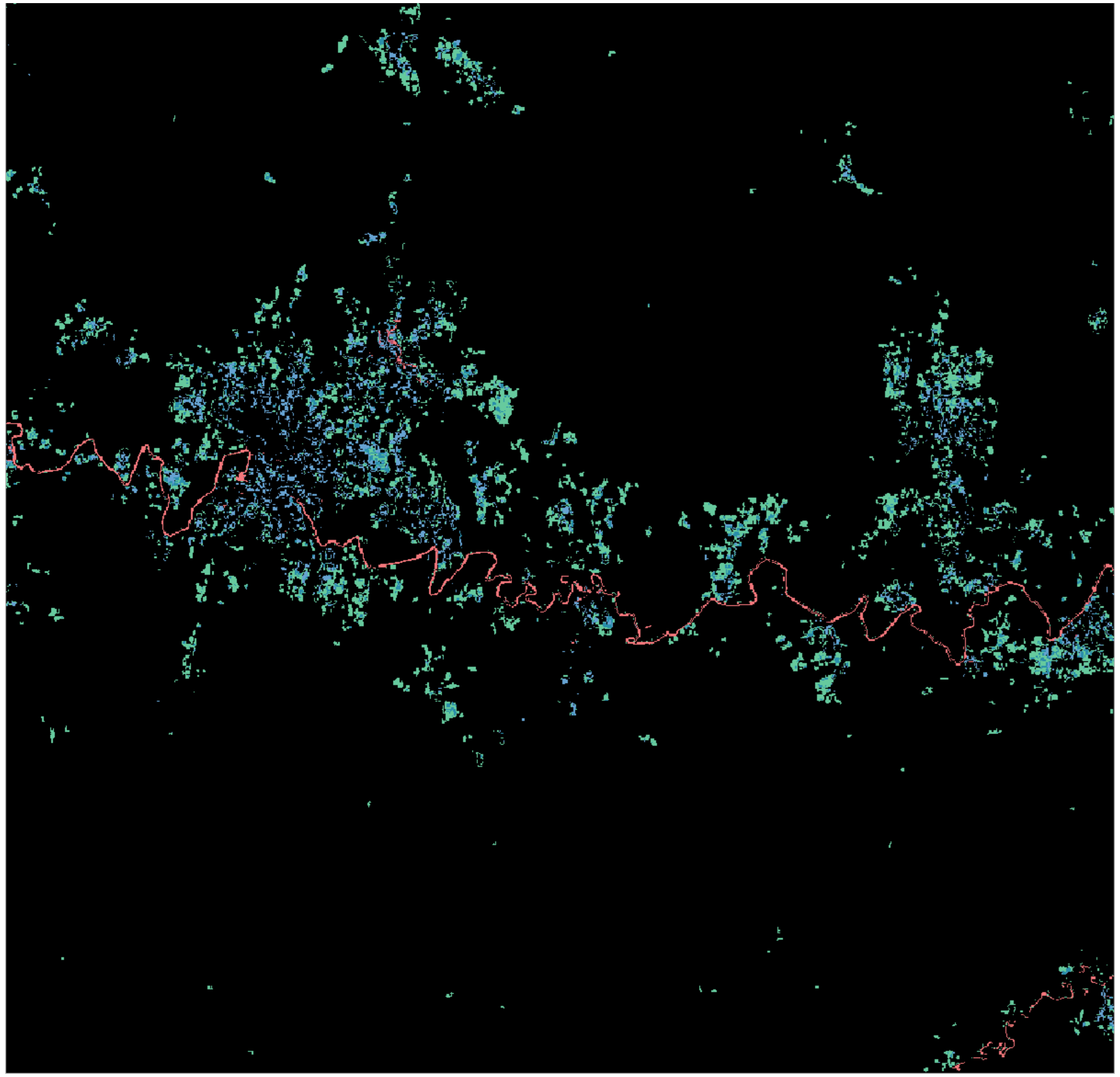
iii) All around the wetlands - not sure what to come up with this yet



-2.79580359, -57.62133608

iv) Small-scale deforestation

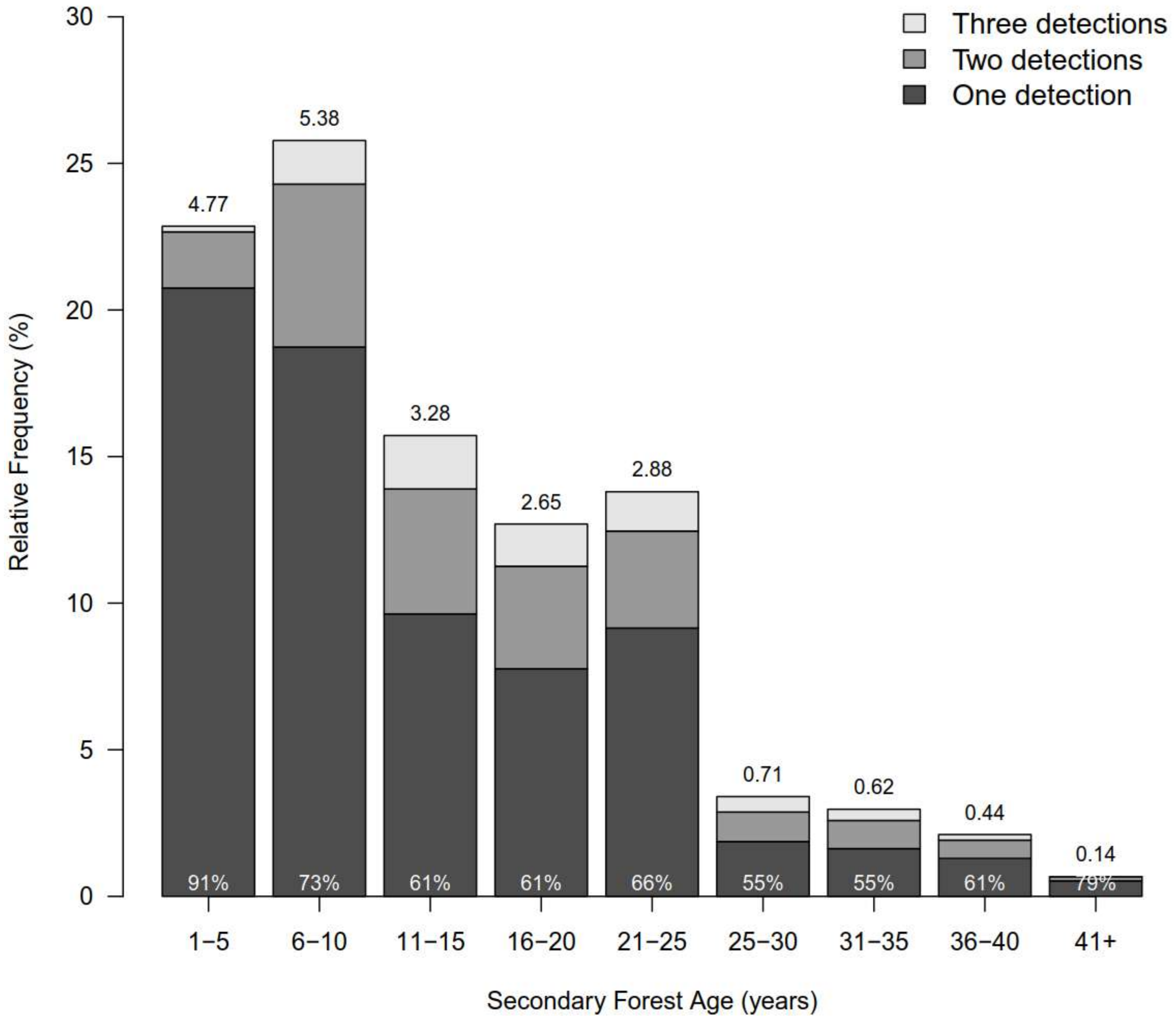




0.24924188, -69.77813611

CTrees

Less confidence on mapped younger secondary forests than older secondary forests



- More unconfirmed regrowth between 1-10 years (73-91%) compared to 11-40 (55-61%)
  - Each dataset maps 2-3 Mha of young secondary forests in the 1-5 and 6-10 age groups but they have relatively low agreement (!!!)
- On the other hand, older secondary forests >10years old have more confident mapping agreement

Number of detections → Mean Age ± SD
1 detection(s) group → 12.1 ± 9 years
2 detection(s) group → 15.7 ± 8.8 years
3 detection(s) group → 17.5 ± 8 years

Regardless of detection → 13.3 ± 9.1 years
≥ 2 detection group → 16.2 ± 8.7 years

Final considerations

- **How consistent are Secondary Forest maps? About 30%**
    - The confirmed extent of secondary forests is 6Mha but it can be as large as 21Mha

- **Why do we have such high unique detections (~70%) from single datasets ?**
    - Commission
        - How much is it simply a false positive? E.g. seasonality
        - How much is degradation misclassified as deforestation and then causing regrowth?
            - Heinrich et al (2023) show that the two cases have different regrowth pathways
            - Deforestation definition will play a key role here
    - True positive, but omission in other datasets
        - Did other data products not find deforestation?
        - Did other data products not find the regrowth?

- **Increasing the confidence :** Defining criterias to integrate different datasets for more accurate secondary forest maps beyond the 6 Mha

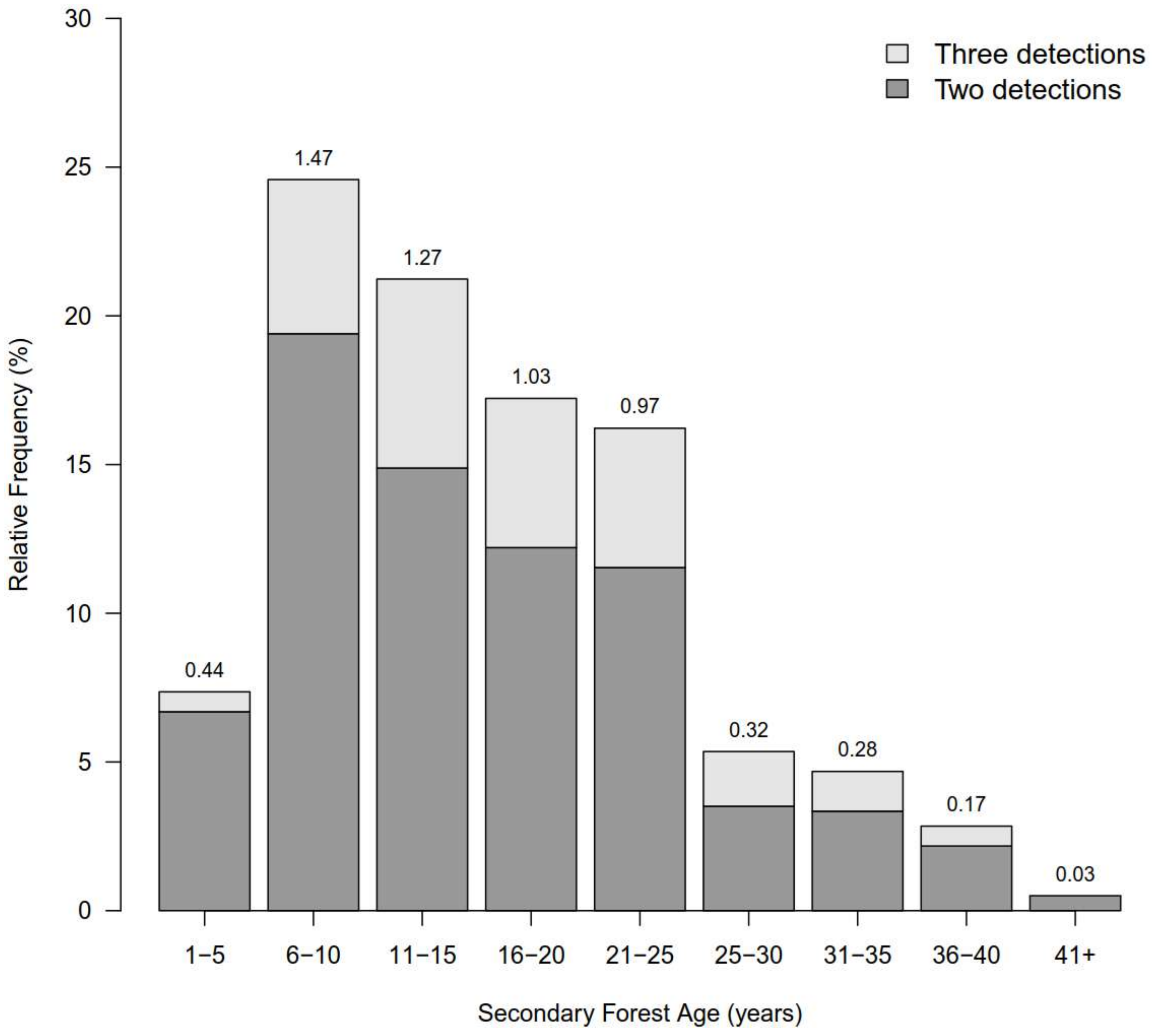
- **Less confidence on mapped younger secondary forests bring high uncertainty to carbon sequestration estimates**
    - Important because each dataset map 2-3 Mha in the first two age groups, they do not correspond spatially (!)

- Forest plantation has a small share of areas (~0.35 Mha), but still needs filtering

Ricardo Dalagnol - rdalagnol@ctrees.org

CTrees

Distribution of the confirmed secondary forests



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

(10:45-11:15) Break

São José dos Campos, 29 Oct 2025

Session 1.3: Linking field, ALS, and satellite data of secondary forests

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

São José dos Campos, 29 Oct 2025

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Bottom-up assessment of carbon removals by reforestation in the Atlantic Forest

Pedro H. S. Brancalion

Session 1.3: Linking Field, ALS + satellite data of secondary forest

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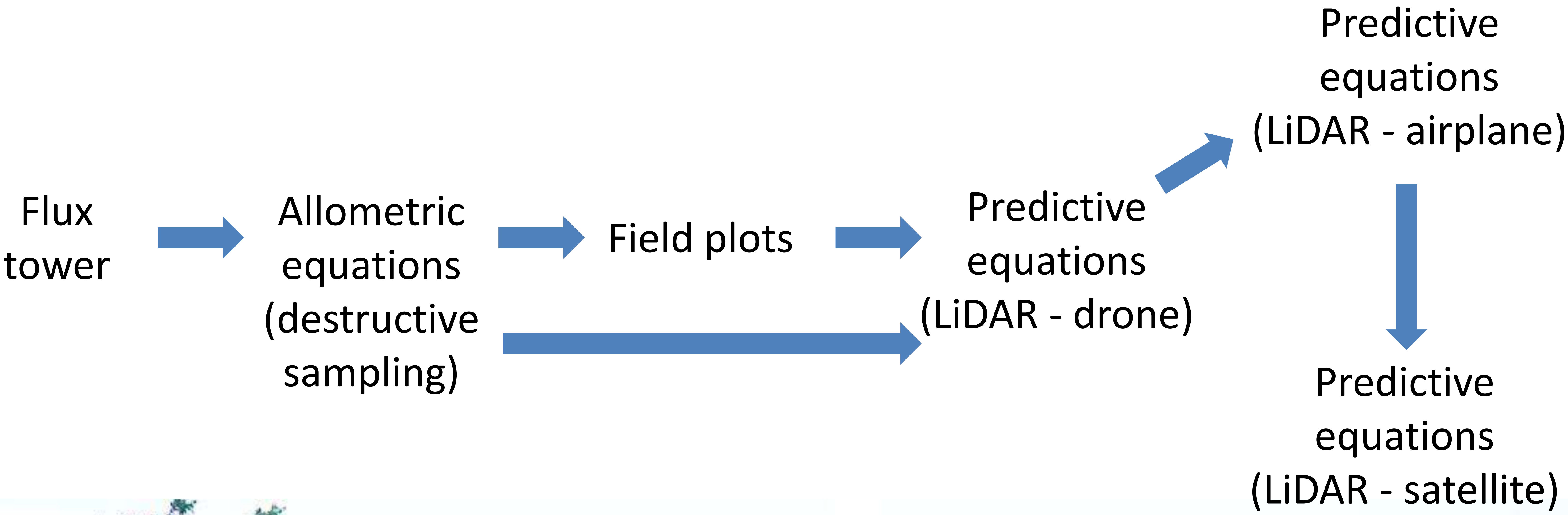
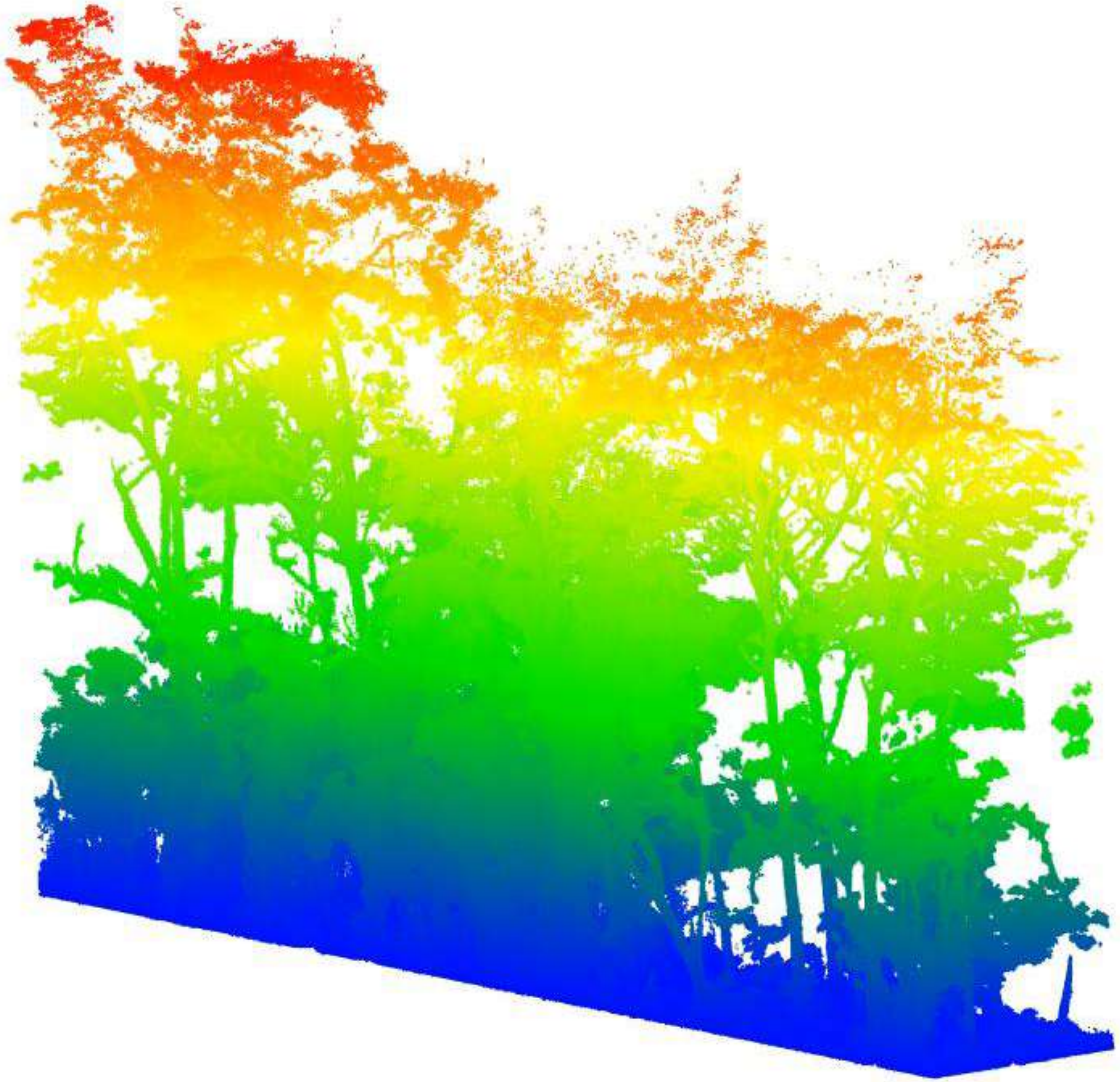
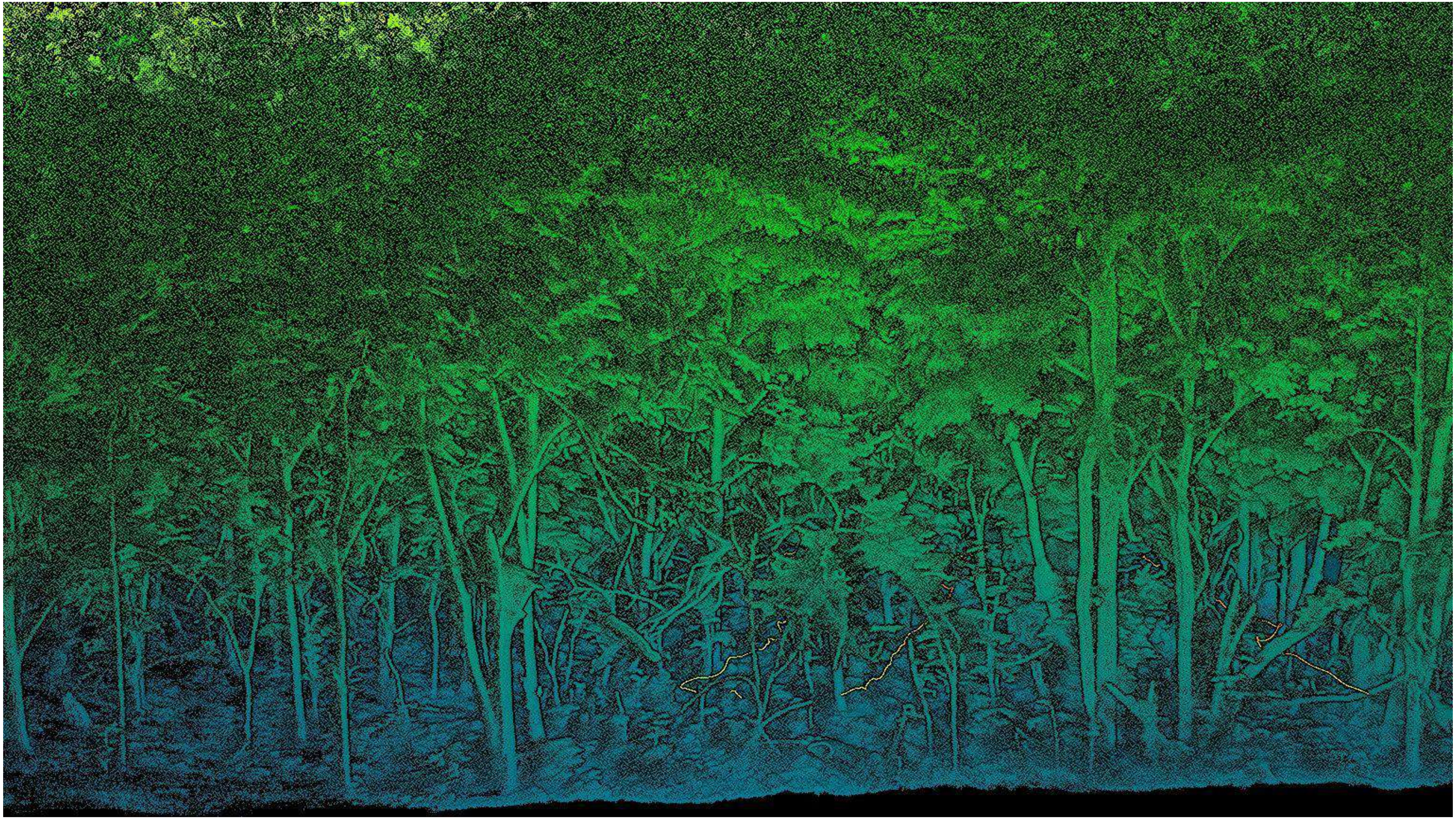

Flux tower
Allometric equations (destructive sampling)
Field plots
Predictive equations (LiDAR - drone)
Predictive equations (LiDAR - airplane)
Predictive equations (LiDAR - satellite)

Restoration experiment
- 5 ha, 20 tree species, 20 years



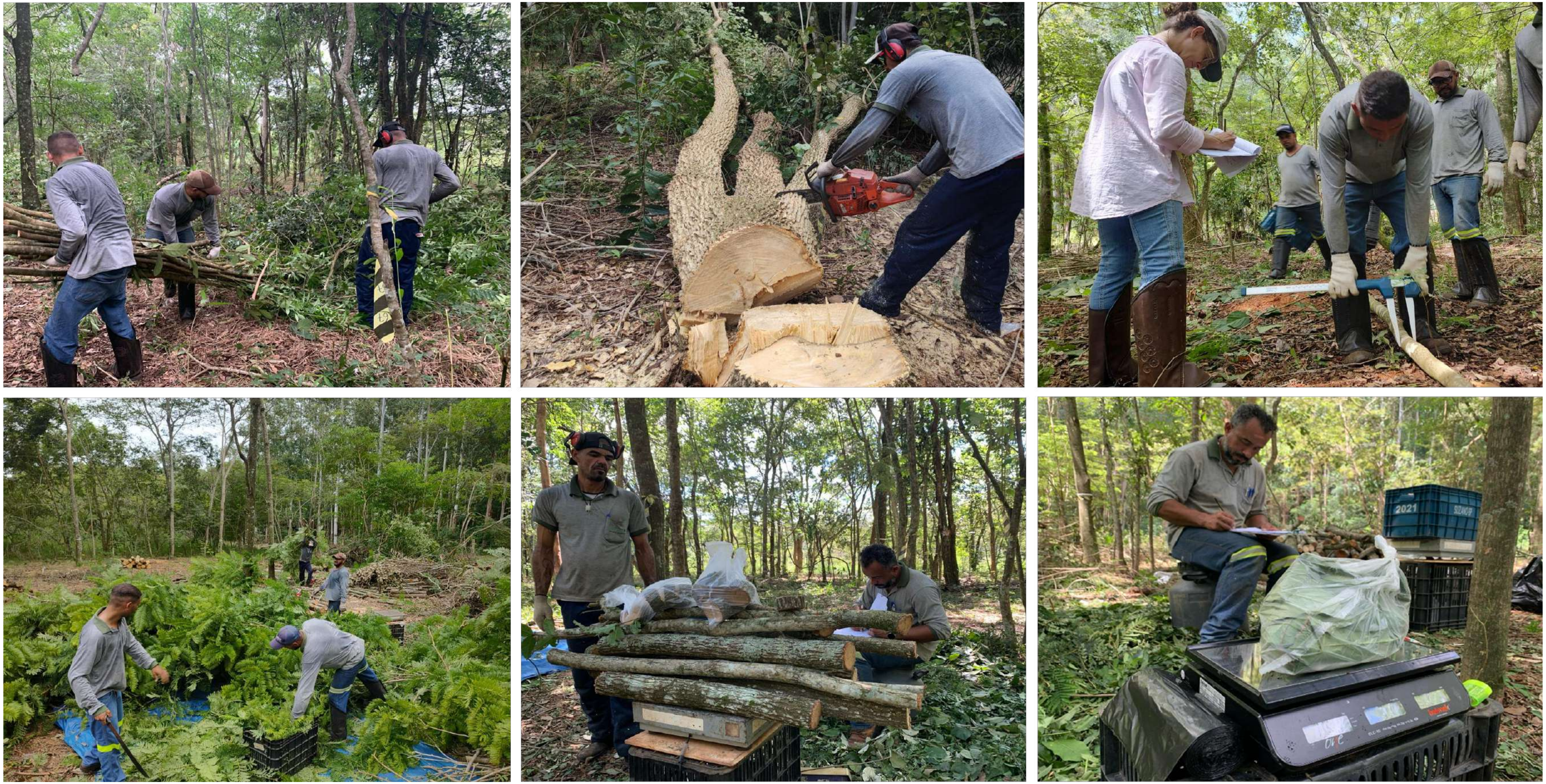


Advances in carbon monitoring

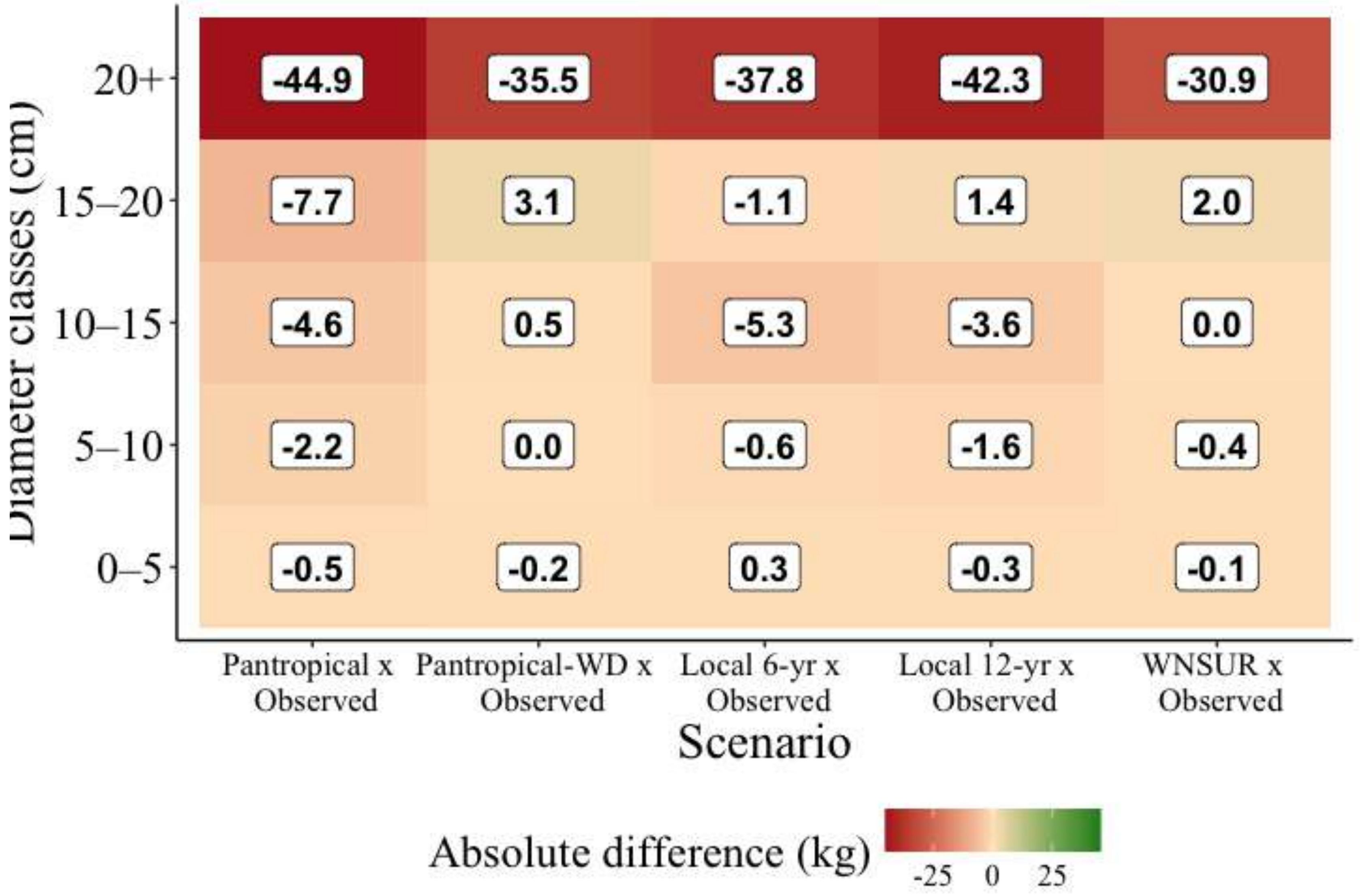
PhD: Ana Paula Ferez

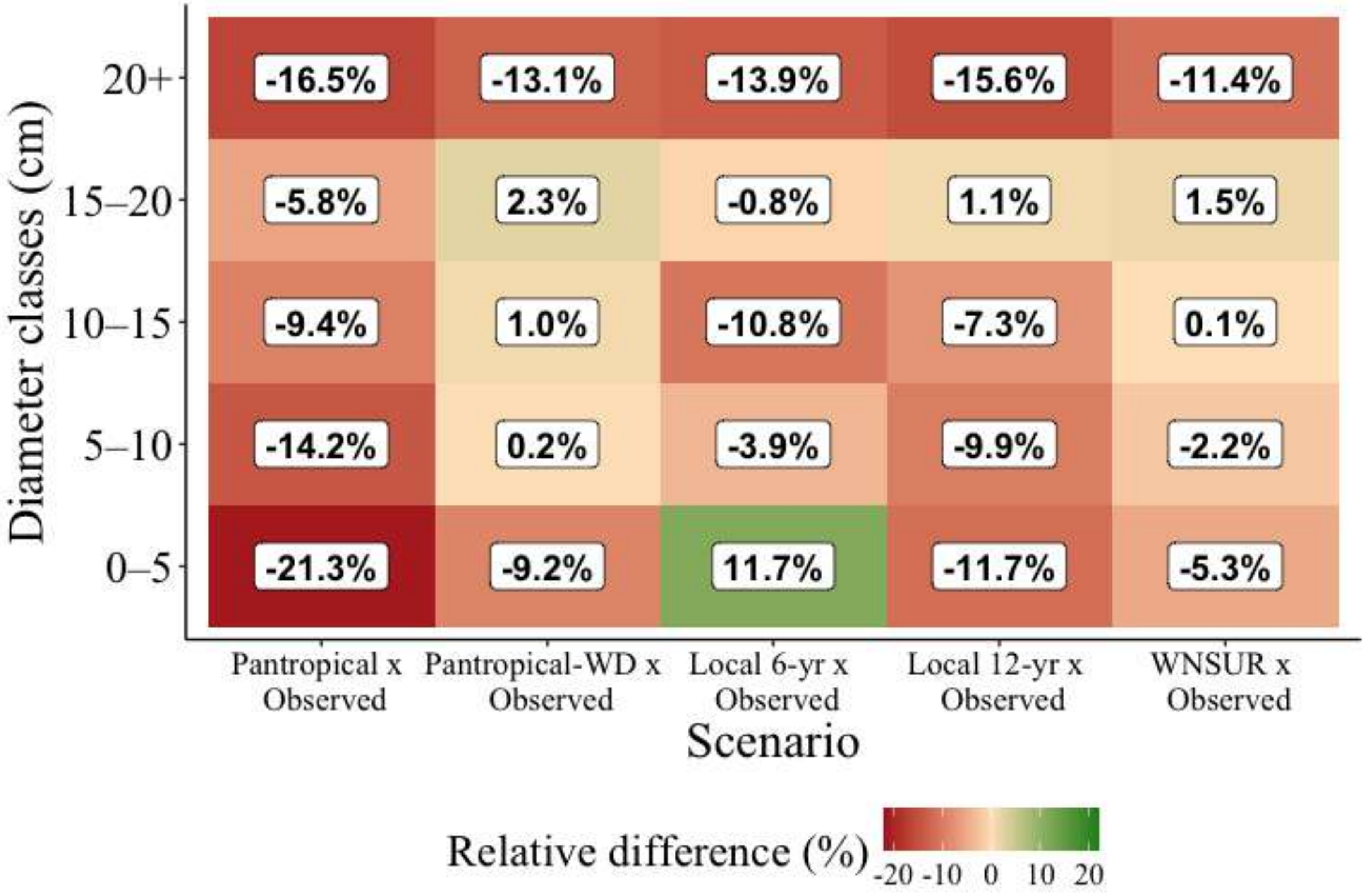
Total 176 indivíduos amostrados

- ✓ 152 árvores plantadas (parte aérea)
  - ✓ 40 com biomassa radicular
- ✓ 24 indivíduos regenerantes (parte aérea)



The specific allometric equation for restoration sites yielded ~25% more carbon compared to Chave et al. equation

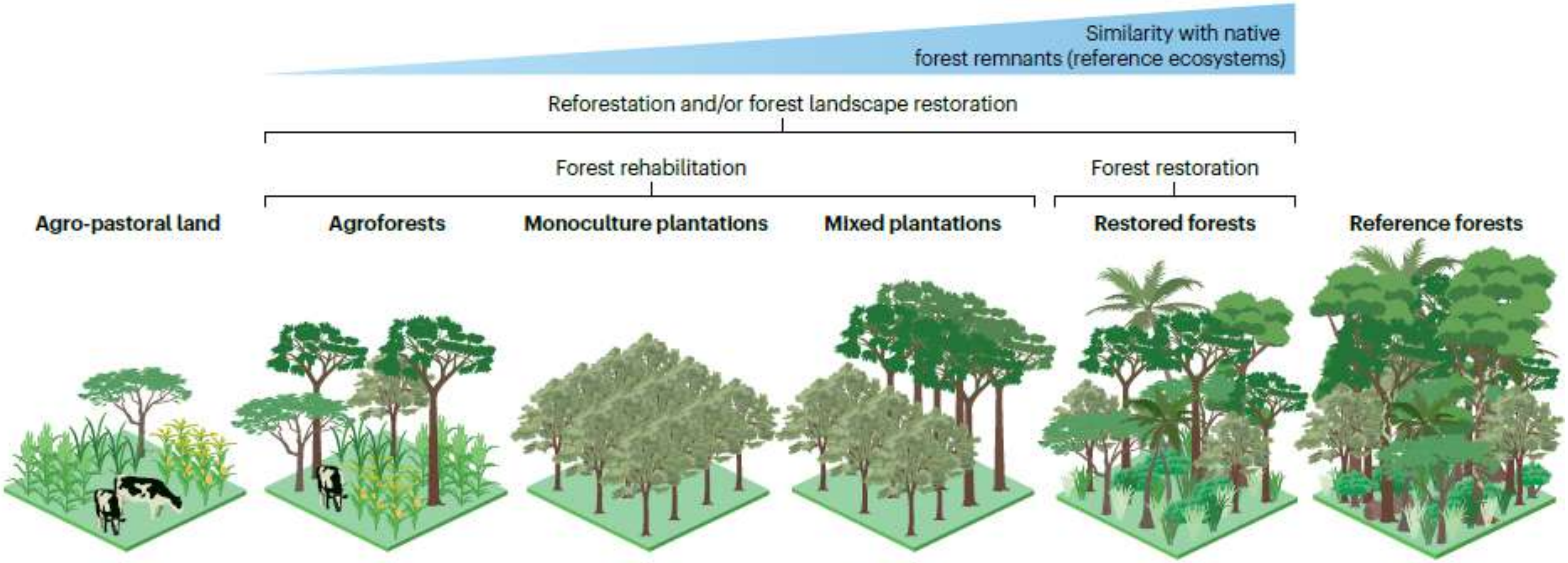




Model	Δ Absolute (Mg/ha)	Δ Relative (%)
Local 6-yr	−11,99	−10,03
Pantropical-WD	−13,37	−11,18
WNSUR	−15,39	−12,87
Local 12-yr	−17,20	−14,39
Pantropical	−22,94	−19,19

Generic equations systematically underestimate AGB, whereas site-specific additive models enhance accuracy and reliability of carbon estimates in Atlantic Forest restoration.

Biodiversity and ecosystem services across reforestation



	Agro-pastoral land	Agroforests	Monoculture plantations	Mixed plantations	Restored forests	Reference forests
Biodiversity	Low	Low	Low	Moderate	High	High
Water quality	Low	Moderate	Moderate	Moderate	High	High
Carbon	Low	Moderate	High	High	High	High
Timber	Low	Moderate	High	High	Low	Moderate
Food	High	High	Low	Low	Low	Moderate

Brancalion *et al*. 2025. *Nature Reviews Biodiversity*

Biodiversity and ecosystem services across reforestation

Biodiversity and ecosystem services across reforestation

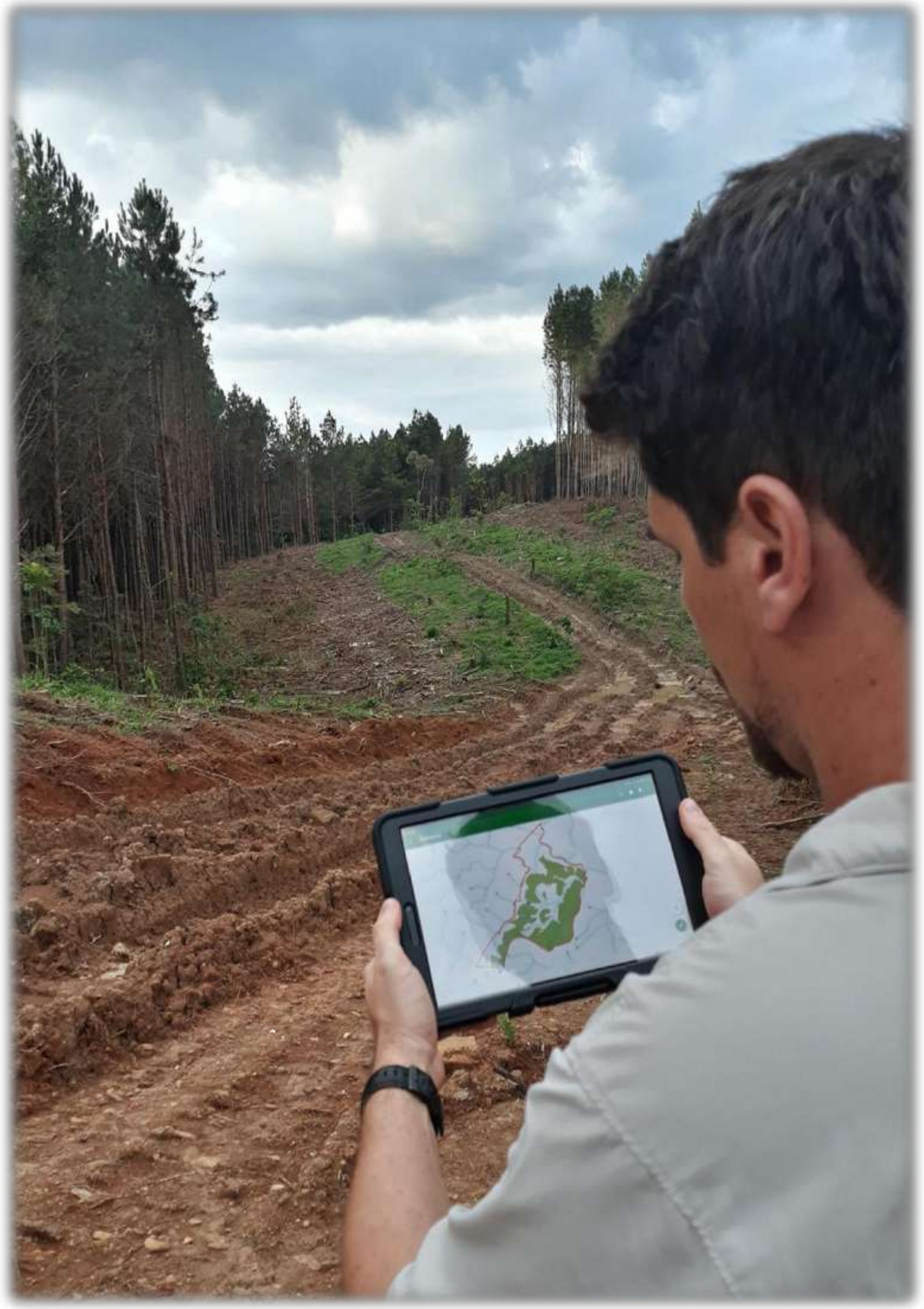
newfor

✓ **New forests polygons**

- Agropastoral land uses
- Agroforests
- Intensive monocultures
- Extensive monocultures
- Restoration plantings
- Second-growth forests
- Degraded remnants
- Conserved remnants

✓ **New forests plots**

- 30 x 30 m plots
- Forest multifunctionality protocol
- Forest inventory, dead wood, litter, fine roots, water infiltration, soil (texture, nutrients, porosity, density, carbon) & much more

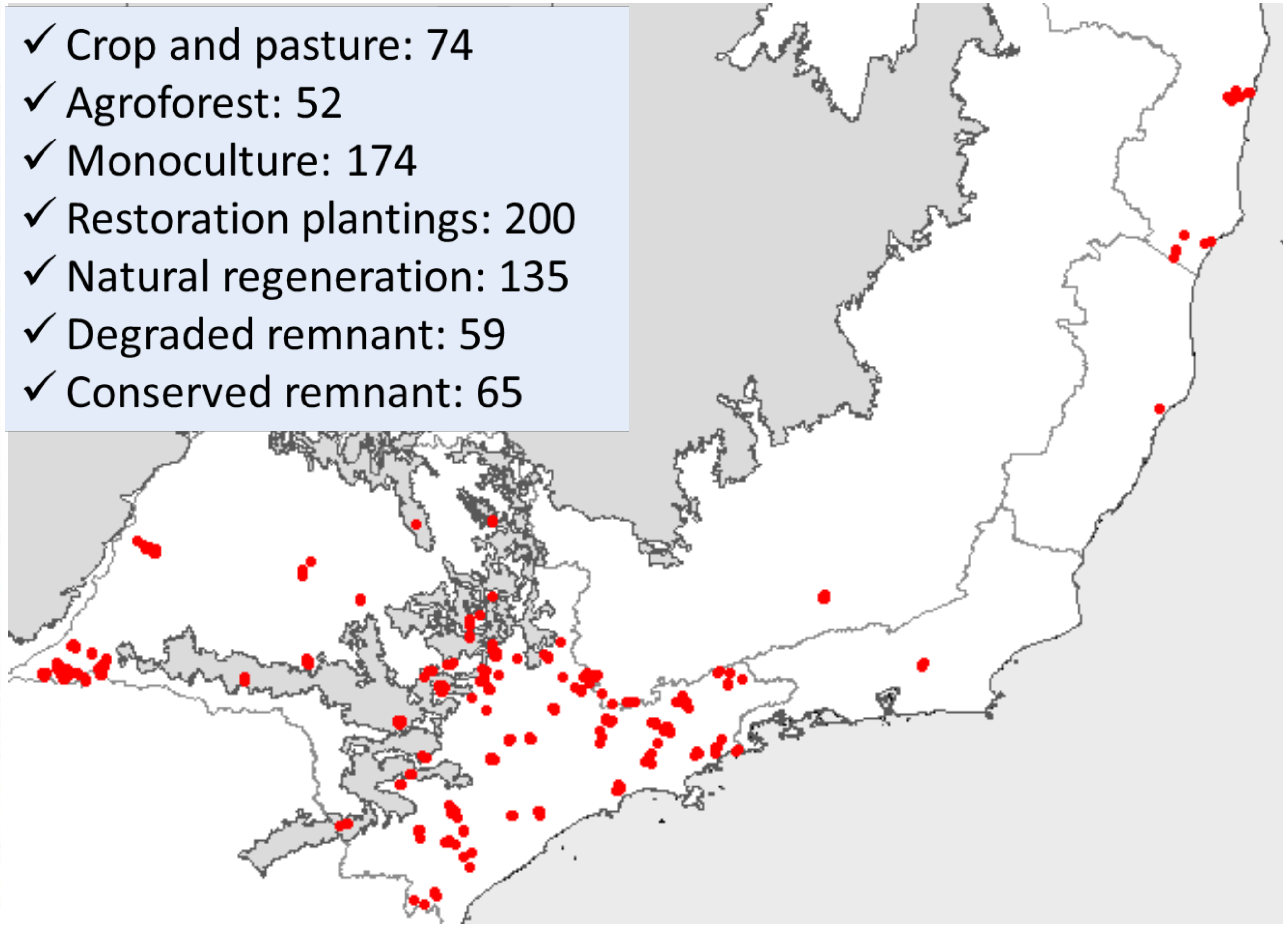


✓ **Multiscale remote sensing**

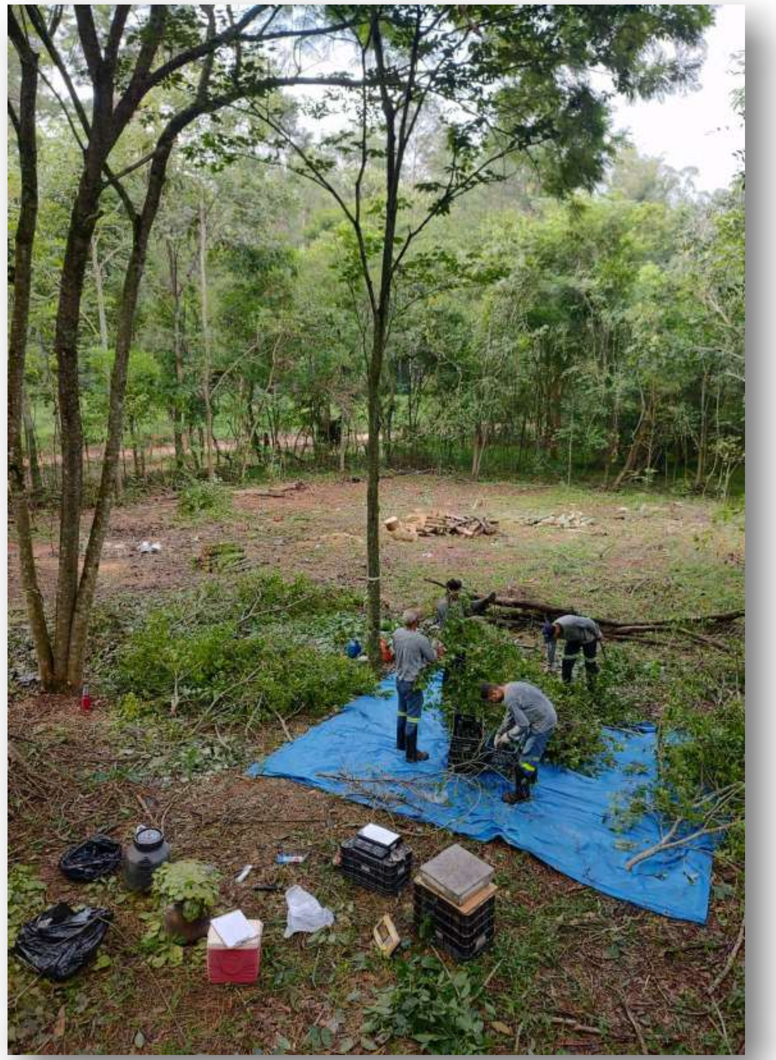
Biodiversity and ecosystem services across reforestation

5 Years of field work, ~800 plots, 70,000 trees, 1,200 tree species

- ✓ Crop and pasture: 74
- ✓ Agroforest: 52
- ✓ Monoculture: 174
- ✓ Restoration plantings: 200
- ✓ Natural regeneration: 135
- ✓ Degraded remnant: 59
- ✓ Conserved remnant: 65

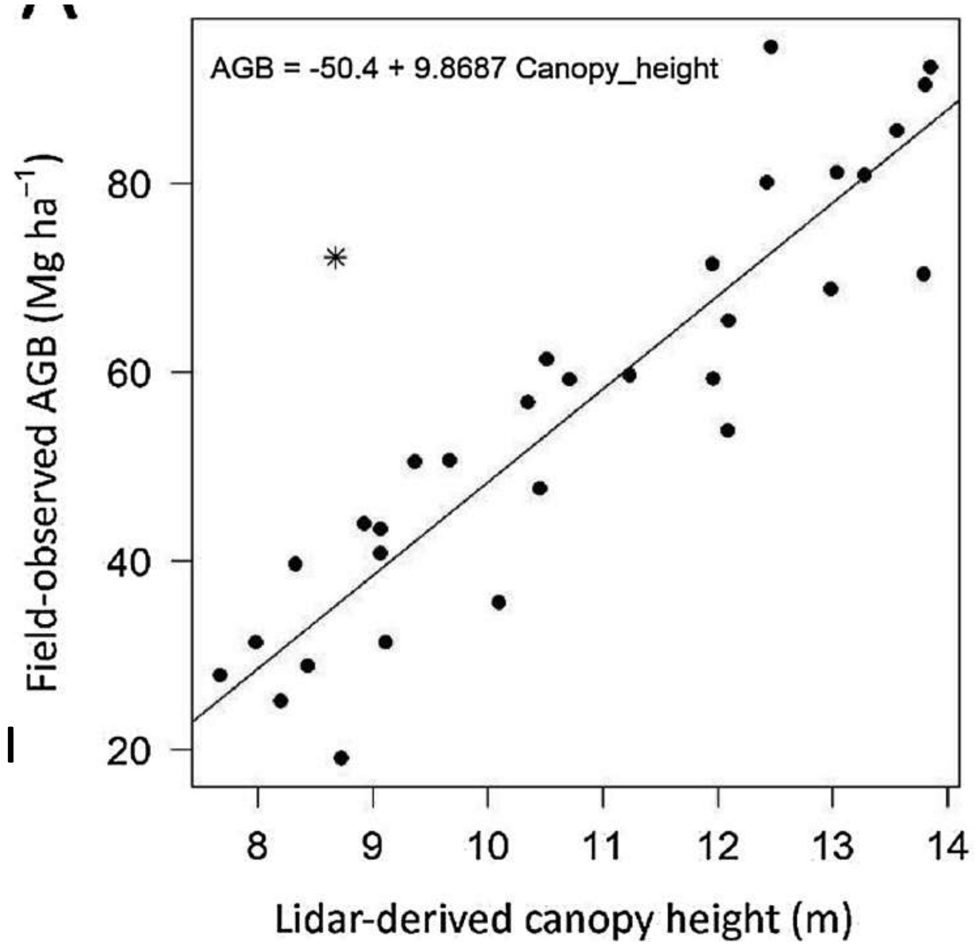


Frentes de inovação no monitoramento: estrutura e carbono

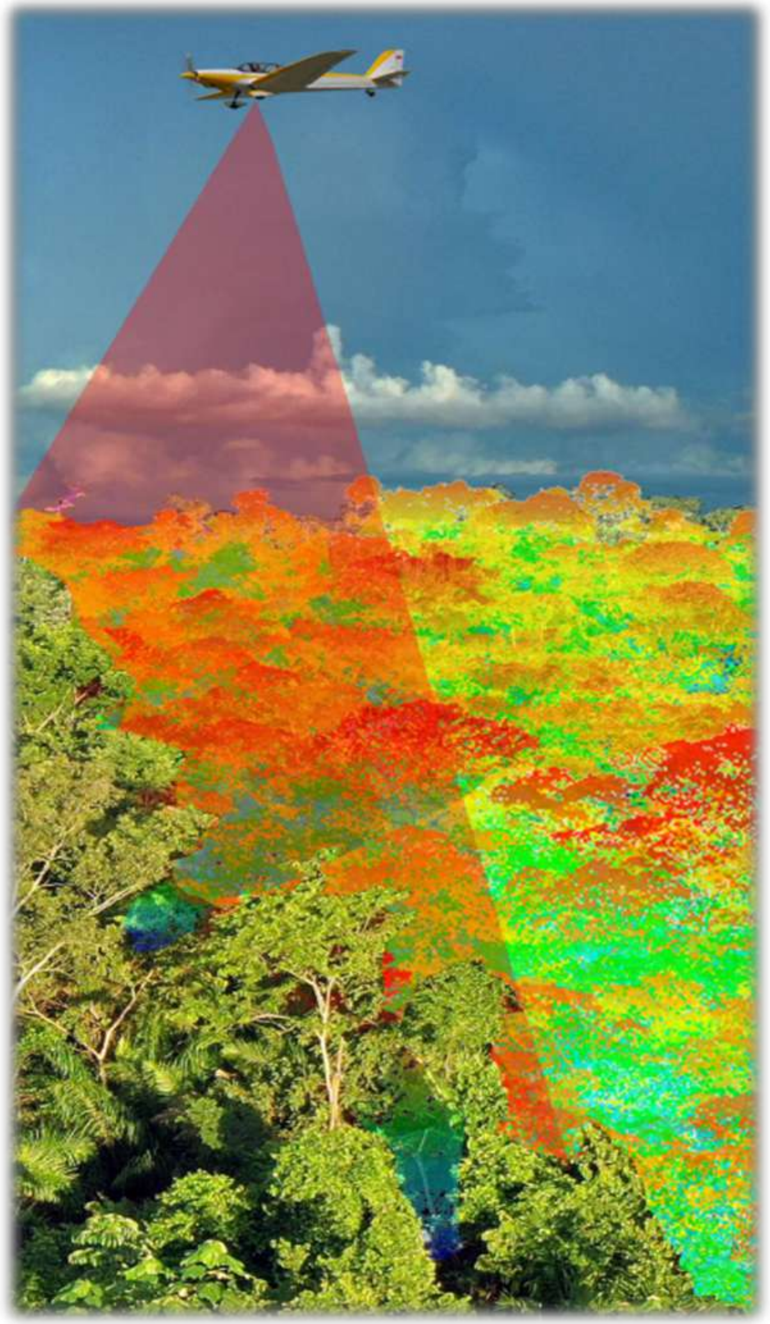


Equações de biomassa (produzidas ou existentes)

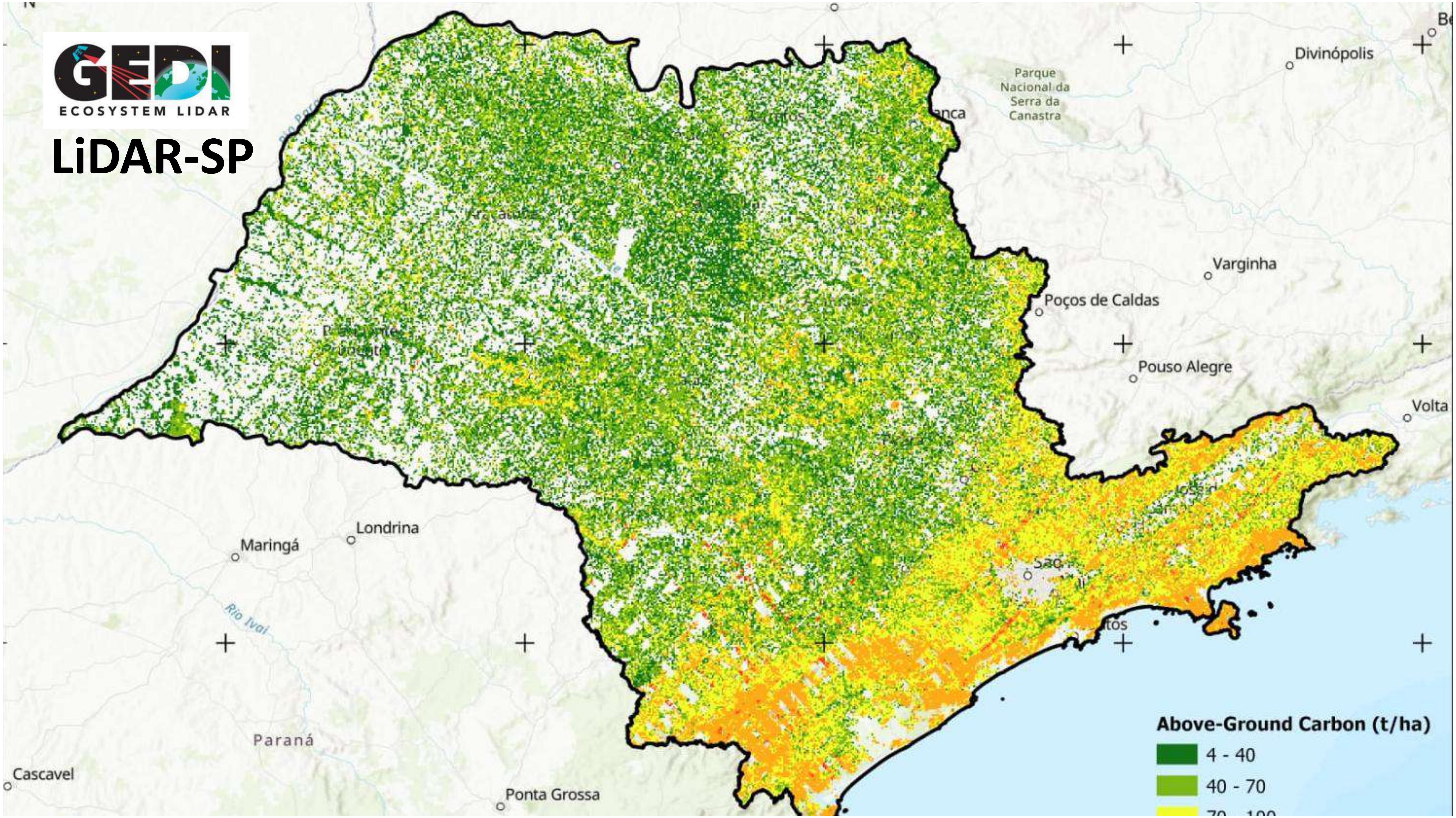
Coleta de dados Lidar em parcelas com inventário florestal



Relação entre métricas Lidar x biomassa



LiDAR-SP


Divinópolis
Parque Nacional da Serra da Canastra
Varginha
Poços de Caldas
Pouso Alegre
Volta
Londrina
Maringá
Rio Ivaí
Paraná
Cascavel
Ponta Grossa
Above-Ground Carbon (t/ha)
4 - 40
40 - 70


Thanks!
pedrob@usp.br

Forest Dynamics After Fire Disturbance: Insights from Field and Remote Sensing, and Innovations in Large-Scale Restoration

Dr. Aline Pontes Lopes

Session 1.3: Linking Field, ALS + satellite data of secondary forest

São José dos Campos, 29th Oct 2025

Summary

- Post-fire forest biomass changes in the Amazon using permanent plots
- Insights from LiDAR-based monitoring
- Biomass loss prediction based on pre-fire biomass
- Chronosequence modelling using field data
- Bookkeeping modelling for estimating net forest fire emissions
- Large-scale restoration of disturbed forests

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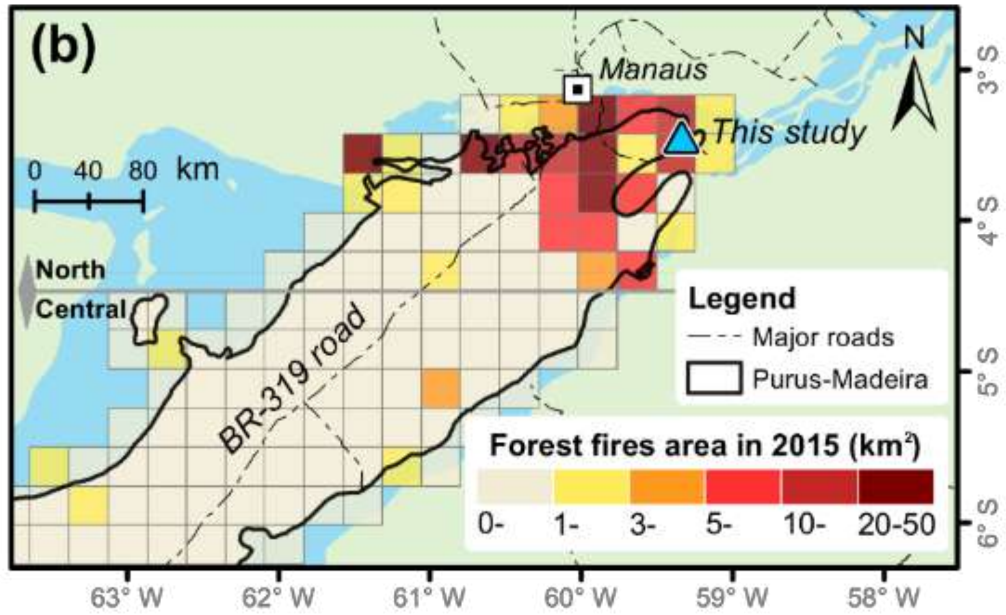
Author: Aline Pontes-Lopes

PROCEEDINGS B

Drought-driven wildfire impacts on structure and dynamics in a wet Central Amazonian forest

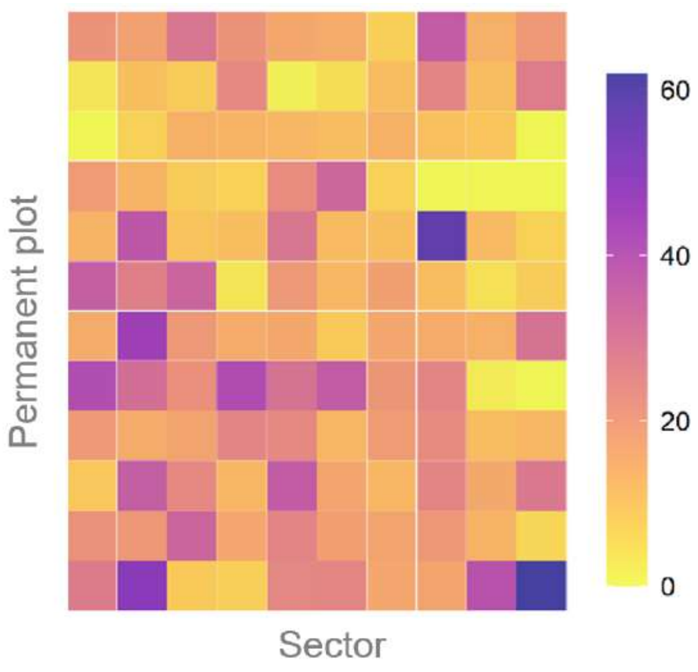
Pontes-Lopes et al., 2021



Combustion and mortality processes exhibit high spatial variability, both locally and at the biome level.

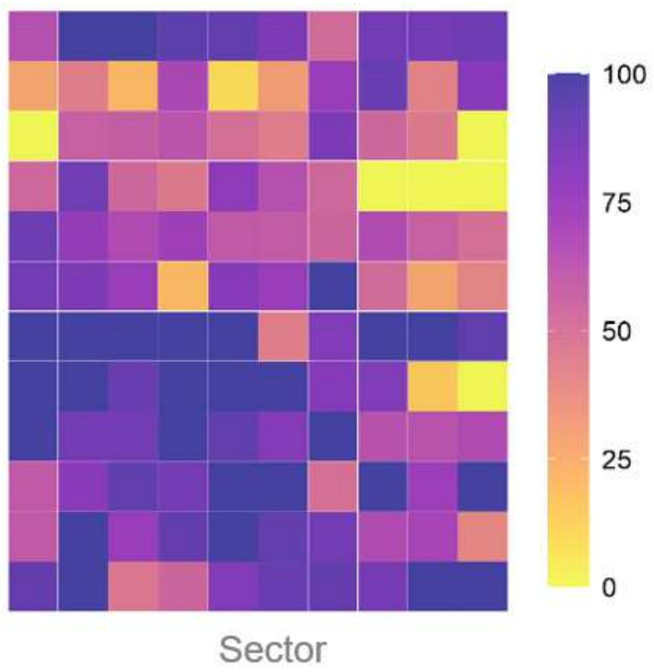
Char height (cm)

- 27 ± 4 cm
- Mostly at the stem base

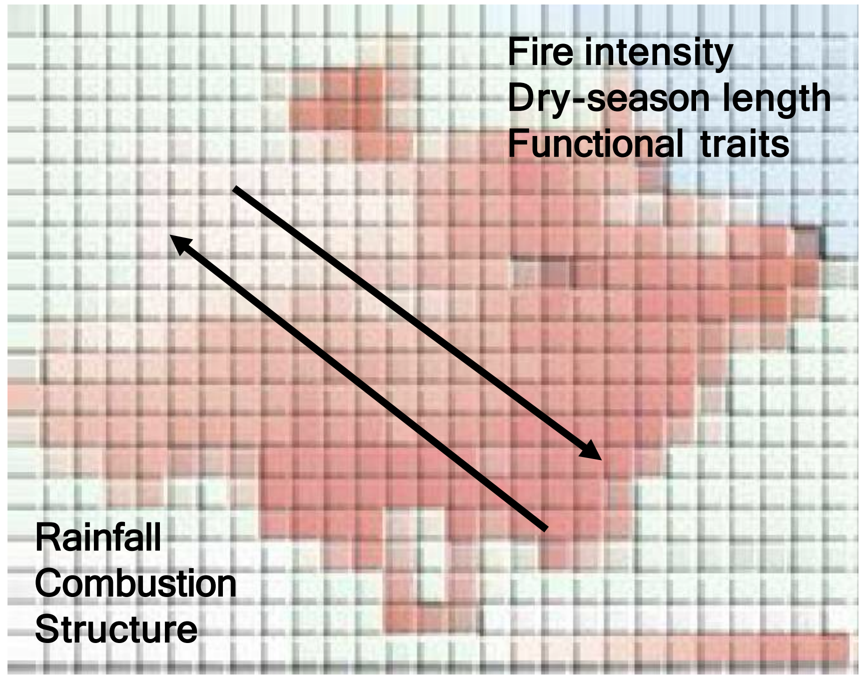


Burn coverage (cm)

- 70 ± 17%
- High heterogeneity (40-92%)



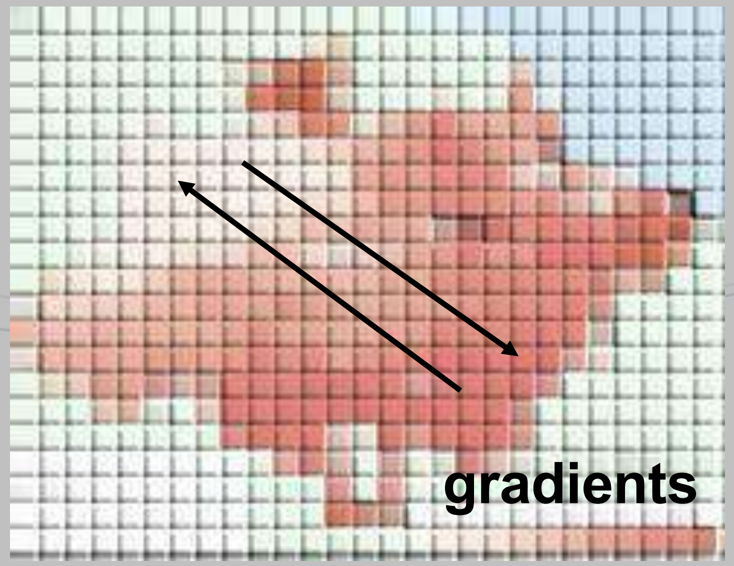
At a large scale, these processes vary according to **climatological and biological gradients.**

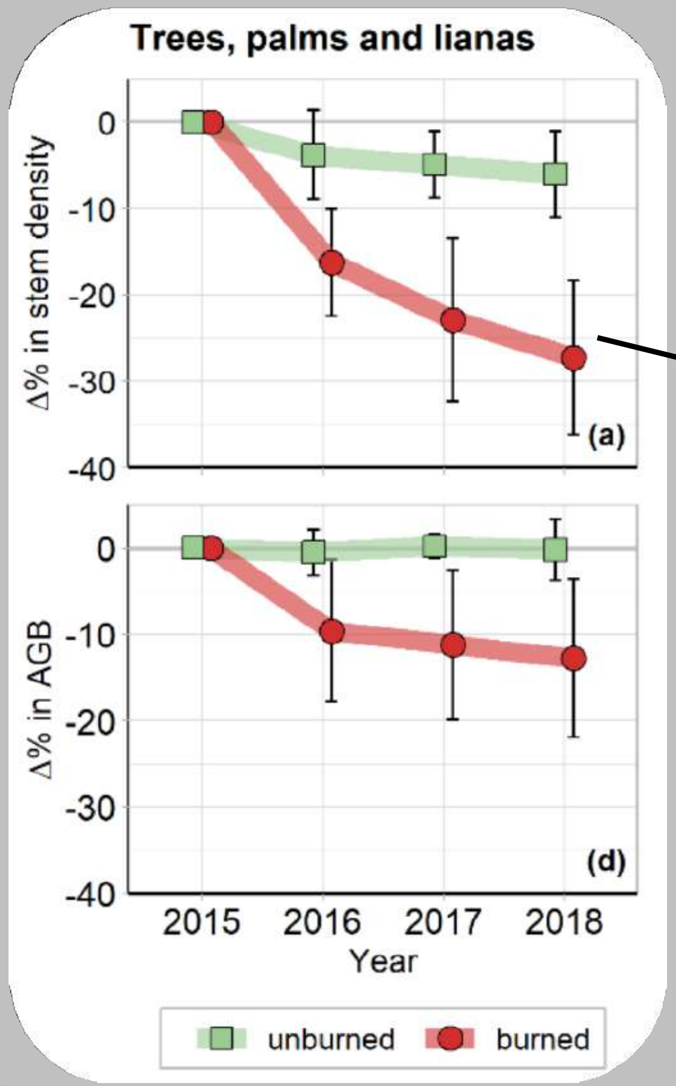


Author: Aline Pontes-Lopes

Following the 2015 fire in the Purus-Madeira region, the forest lost about 12% of biomass. Elsewhere in the Amazon, **areas with 3-4 month dry seasons can lose up to 50% of carbon stocks** within six years of fire.

Pontes-Lopes et al., 2021, *Proceeding B*





Amazonia region	Dry season months	Time since fire (y)	Loss in tree stem density	Loss in tree basal area	Loss in tree AGB
Purus-Madeira [1]	1-3	3	28 ± 8%	15 ± 9%	12 ± 9%
[2]		3-4	16 ± 16%	21 ± 13%	
Madeira-Tapajós [3]	3-4		48%		51%
Southwestern [4]	~3	3-6			21-50%
Southeastern [5]	~5	2			22%
Northern [6]	~6	0.5			8-16%

[1] Pontes-Lopes et al., 2021; [2] de Resende et al. 2014; [3] Barlow et al. 2003; [4] Barlow et al. 2012, Sato et al. 2016, da Silva et al. 2020; [5] Brando et al. 2014; [6] Barbosa e Fearnside et al. 1999, Santos et al. 1998

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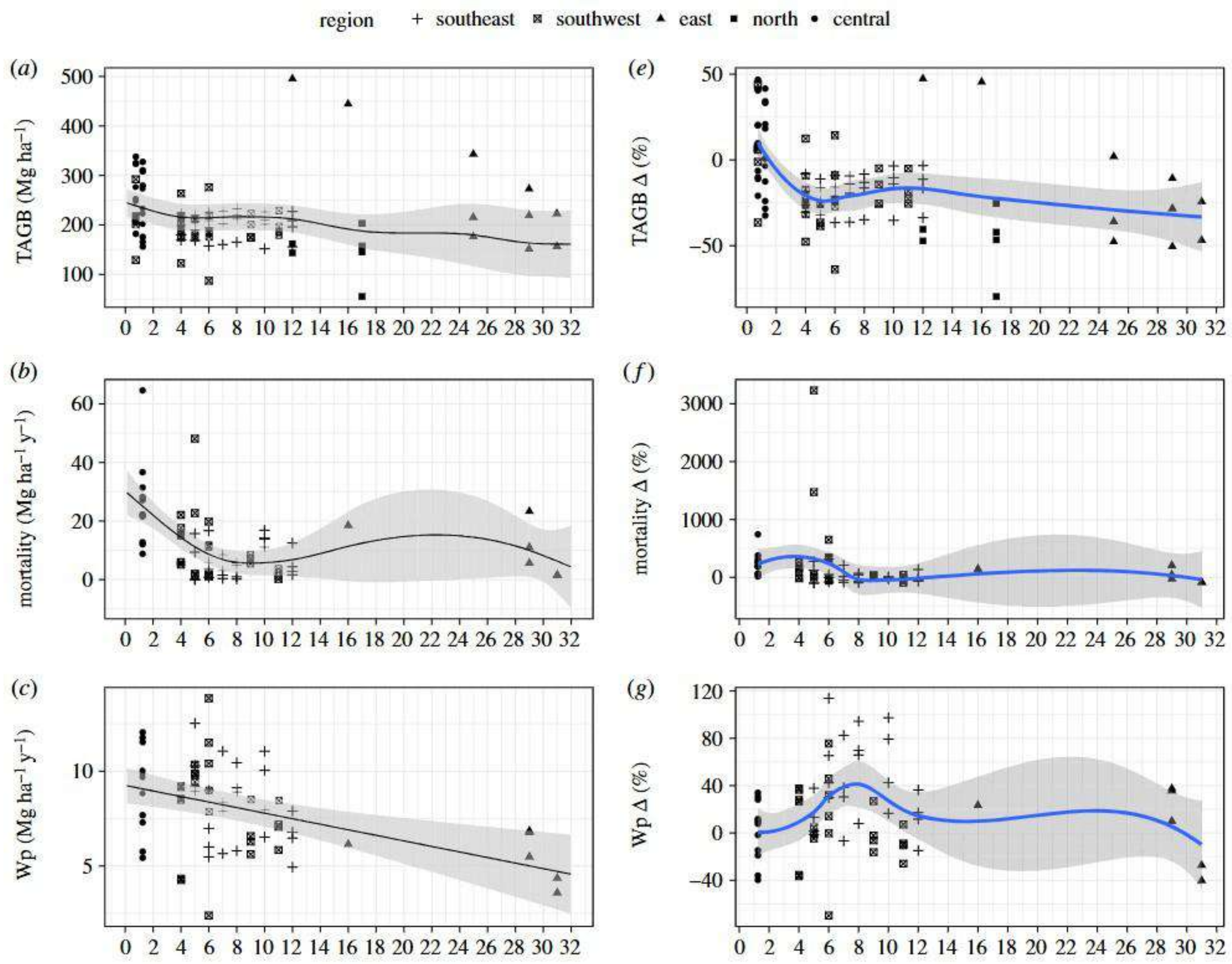
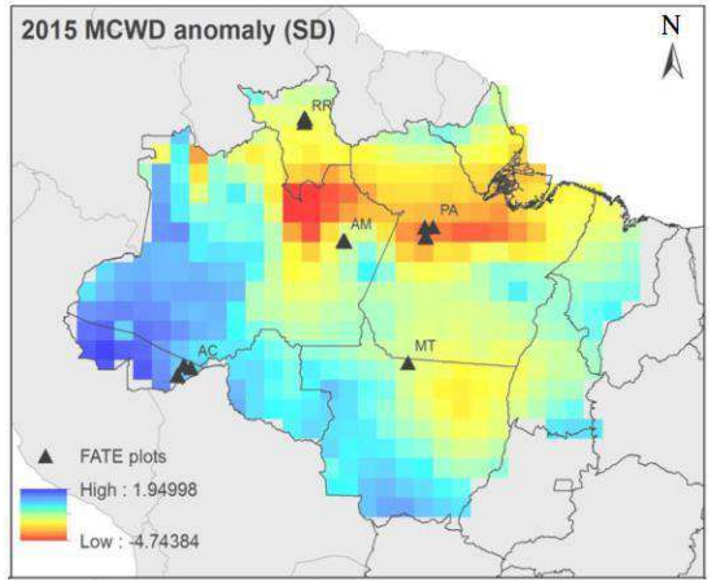
PHILOSOPHICAL
TRANSACTIONS B

Drought-induced Amazonian wildfires instigate a decadal-scale disruption of forest carbon dynamics

Silva et al., 2018

Chronosequence modeling using FATE network data shows that, even after 31 years, **fire-affected forests have biomass about 25% lower than unburned plots** due to high tree mortality not offset by growth or recruitment.



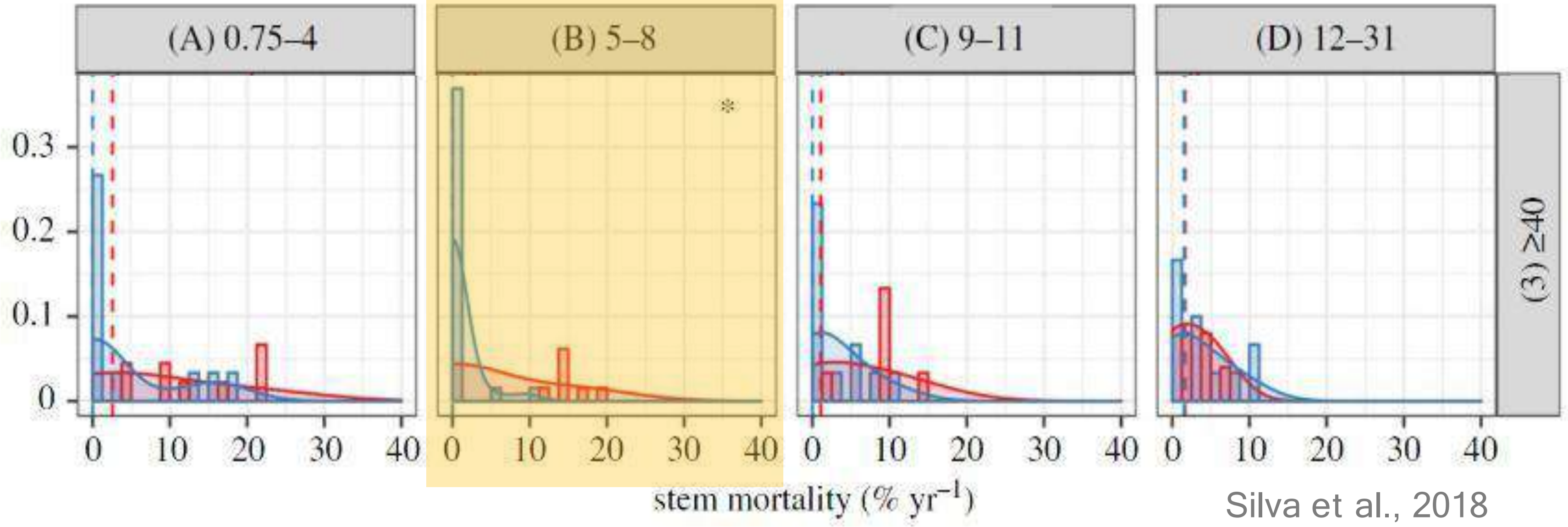


Two general patterns are, therefore, described in the literature:

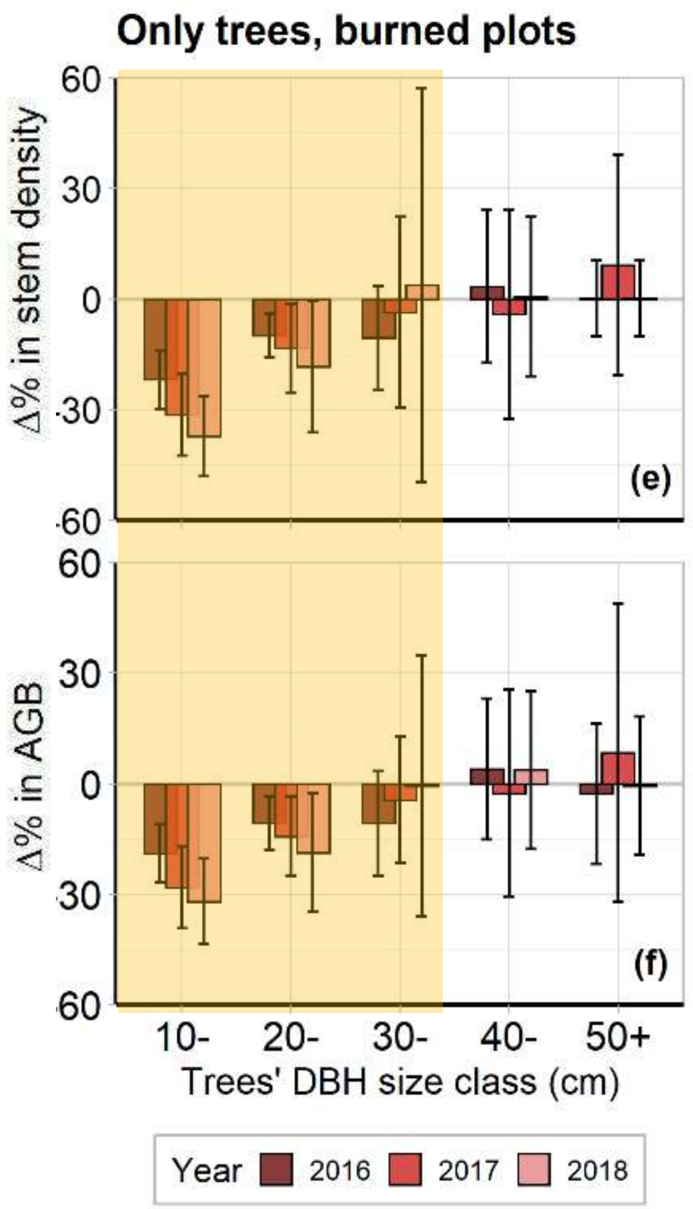
- **early mortality of small and medium-sized trees** within up to 3 years after fire [1], and
- **delayed mortality of large trees** within up to 8 years after fire. [2]

[1] de Resende et al 2014, Barlow et al 2012, 2003b, Haugaasen et al 2003, Holdsworth and Uhl 1997; [2] Barlow et al 2003b, de Resende et al 2014, Barlow et al 2012, Silva et al. 2018

Stem mortality for large trees according time since fire (years)



Silva et al., 2018



Pontes-Lopes et al., 2021

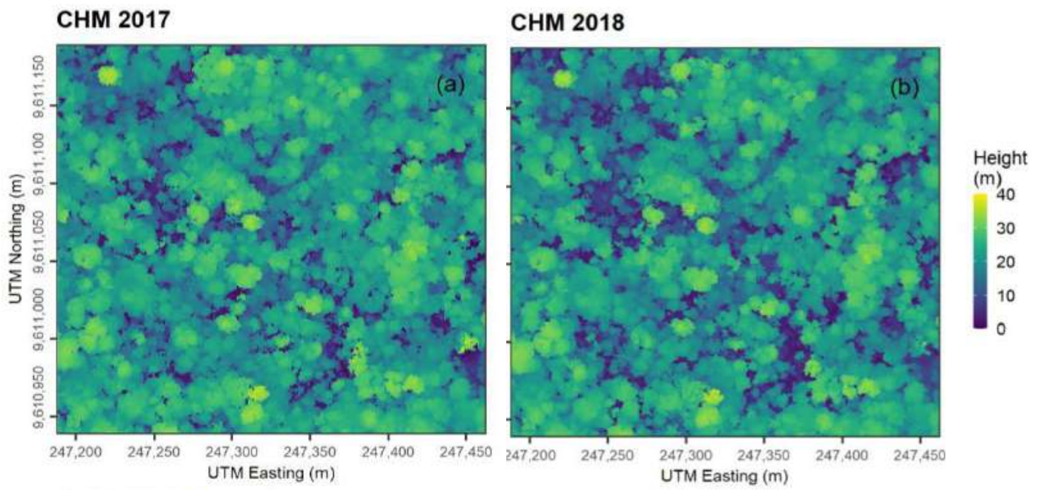
Author: Aline Pontes-Lopes

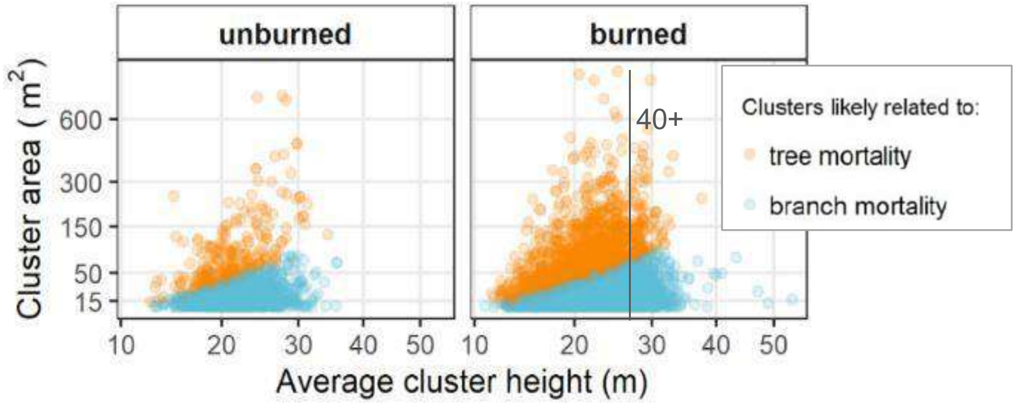
Manuscript Number: FORECO-D-25-02710

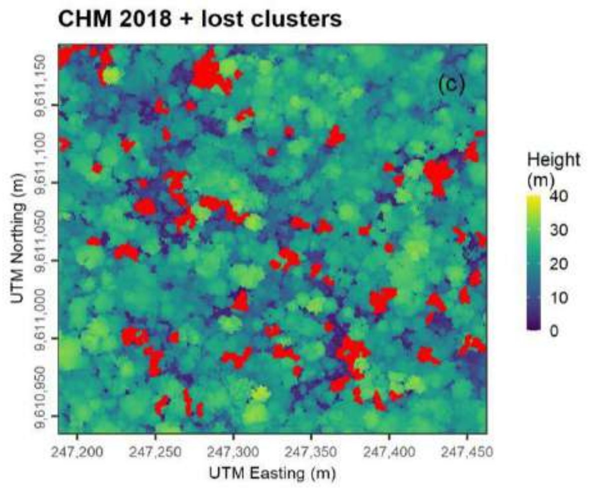
Pontes-Lopes et al., pre-print

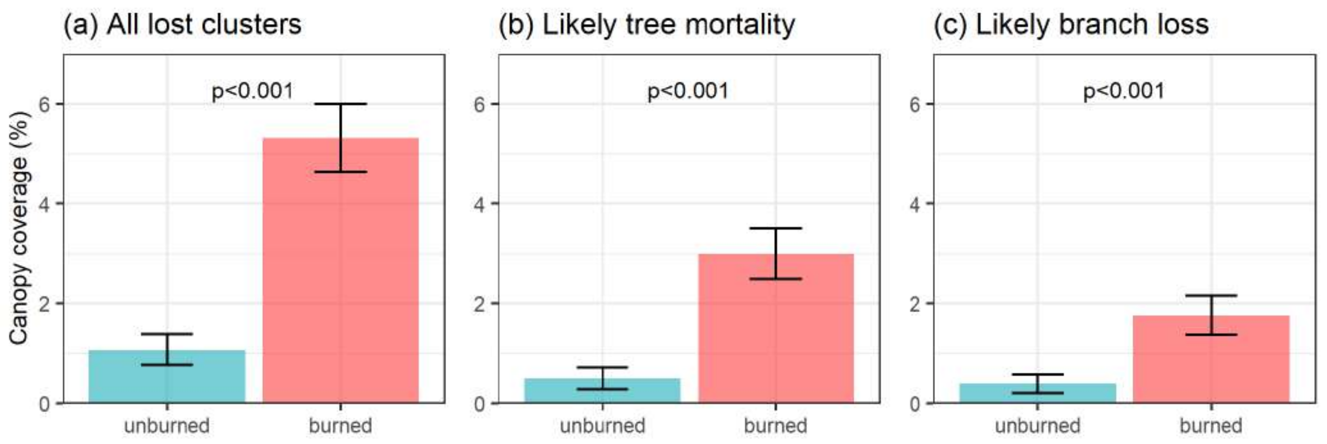
Fire in a Central Amazon forest: Lingering top canopy loss and initial understory regrowth revealed by repeated LiDAR

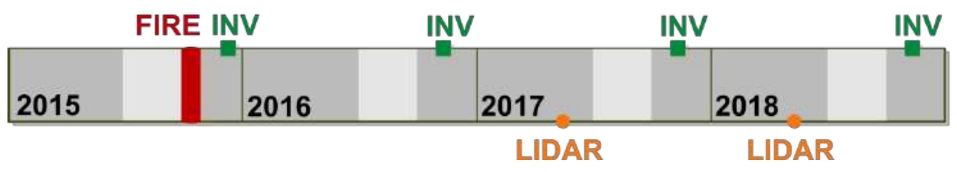
Burned forest areas had a **higher frequency of canopy cluster losses** which are likely related to mortality events of all sizes, **from branches to large trees**.

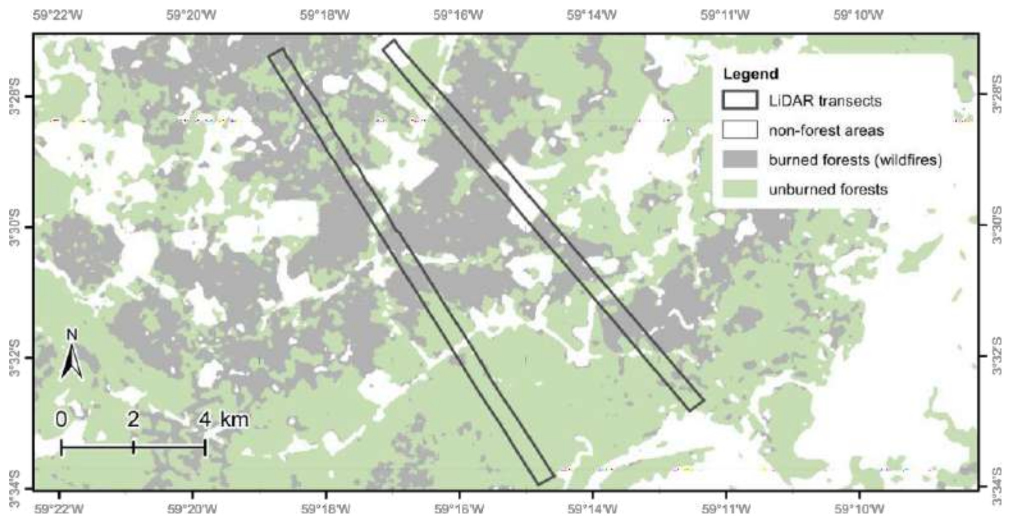












LiDAR dataset:

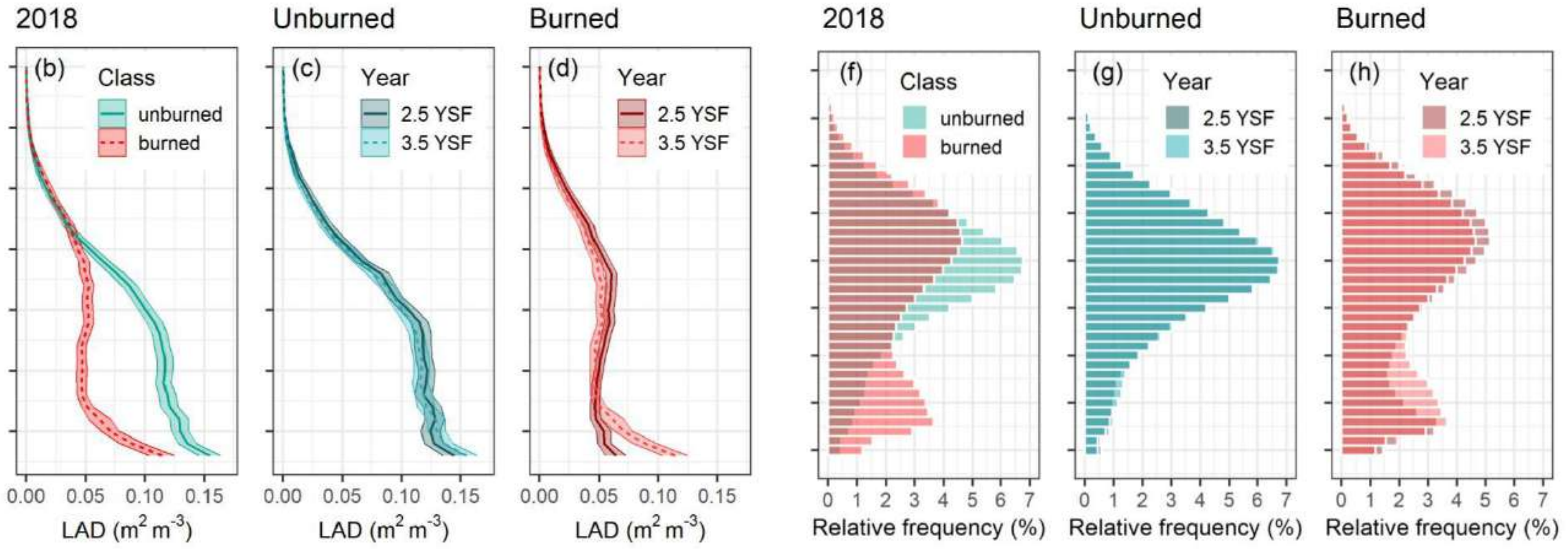
- Discrete point clouds
- Harrier 68i (Trimble) sensor
- 4.9 ± 0.41 points m^{-2}
- ~0.5 x 12 km transects (EBA project)
- 1025 ha of *terra firme* forests

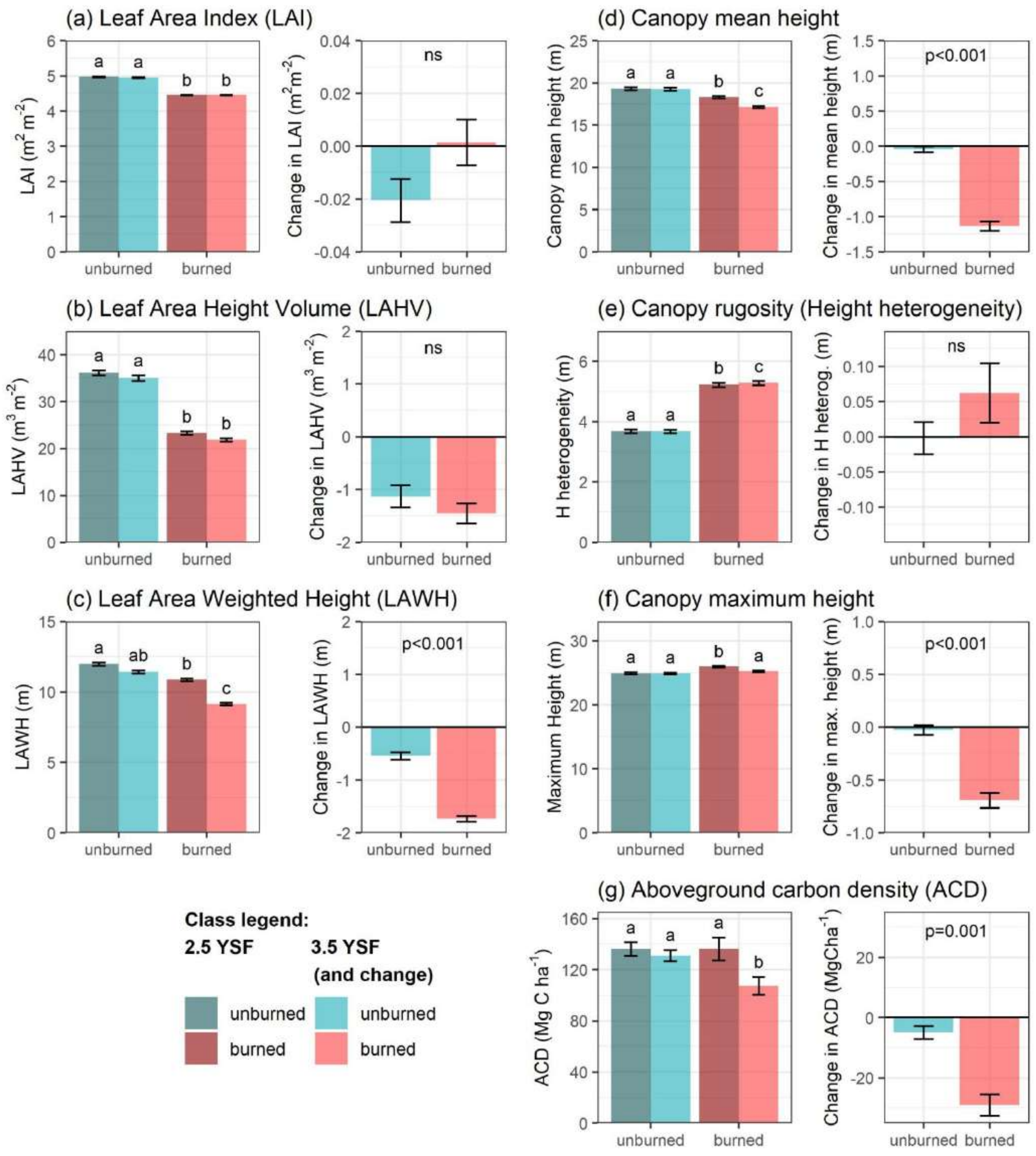
Manuscript Number: FORECO-D-25-02710 *Pontes-Lopes et al., pre-print*

Fire in a Central Amazon forest: Lingering top canopy loss and initial understory regrowth revealed by repeated LiDAR

Total leaf area in fire-affected forests remained stable in magnitude but was reorganized, showing significant temporal shifts:

- increased leaf area density in the lower canopy (<13 m),
- reduced mid-canopy density (15-25 m),
- decreased upper canopy height, and
- loss of carbon density.





remote sensing MDPI

Article

Quantifying Post-Fire Changes in the Aboveground Biomass of an Amazonian Forest Based on Field and Remote Sensing Data

Initial forest biomass is an important integrative variable for modeling the spatial variability of post-fire biomass losses.

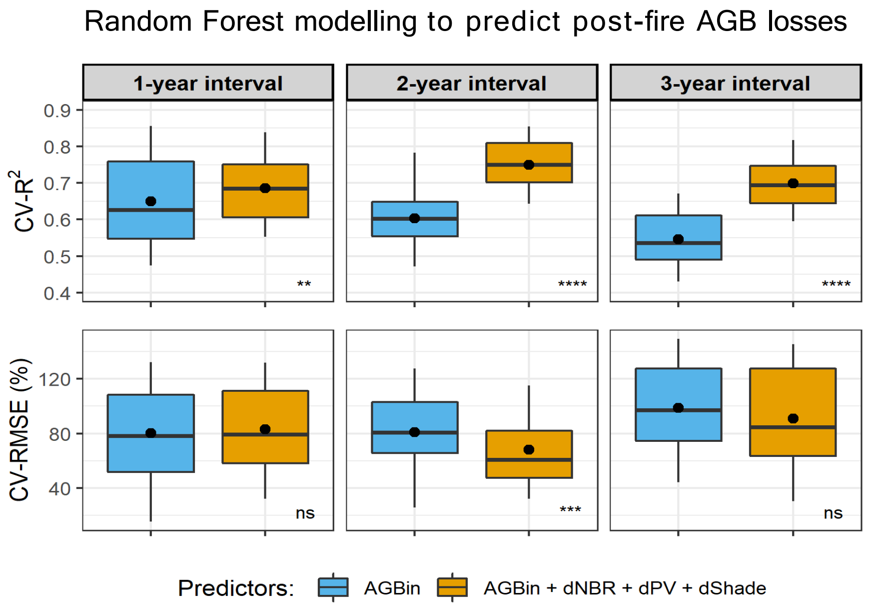
- use of intercepts and slopes
- not just percentage factors % (slopes) [1]

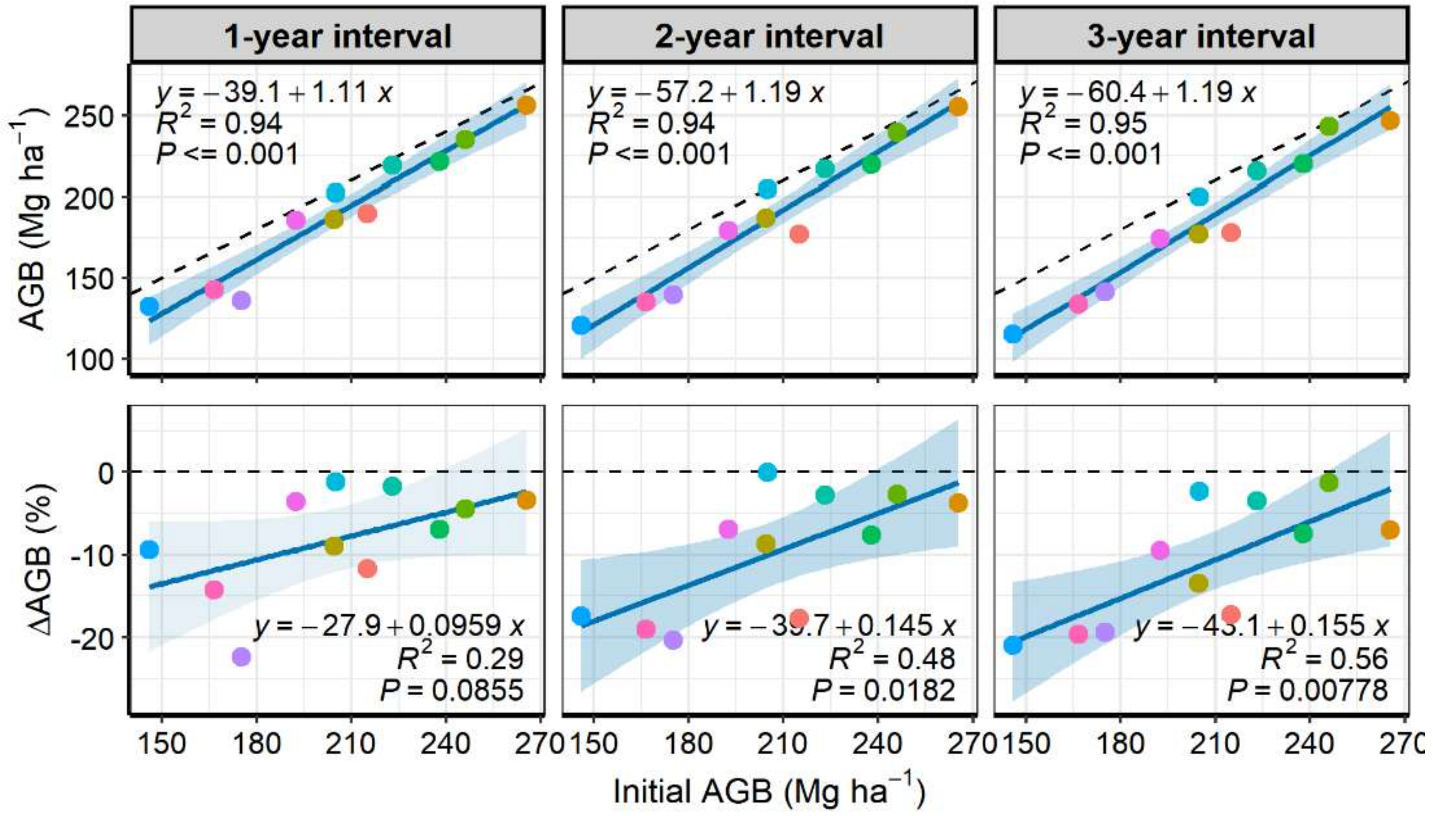
The lower the initial biomass stocks, the greater the post-fire AGB losses.

- smaller DBH and lower WD → probability of death [2]
- lower and more open canopies → drier microclimates [3]

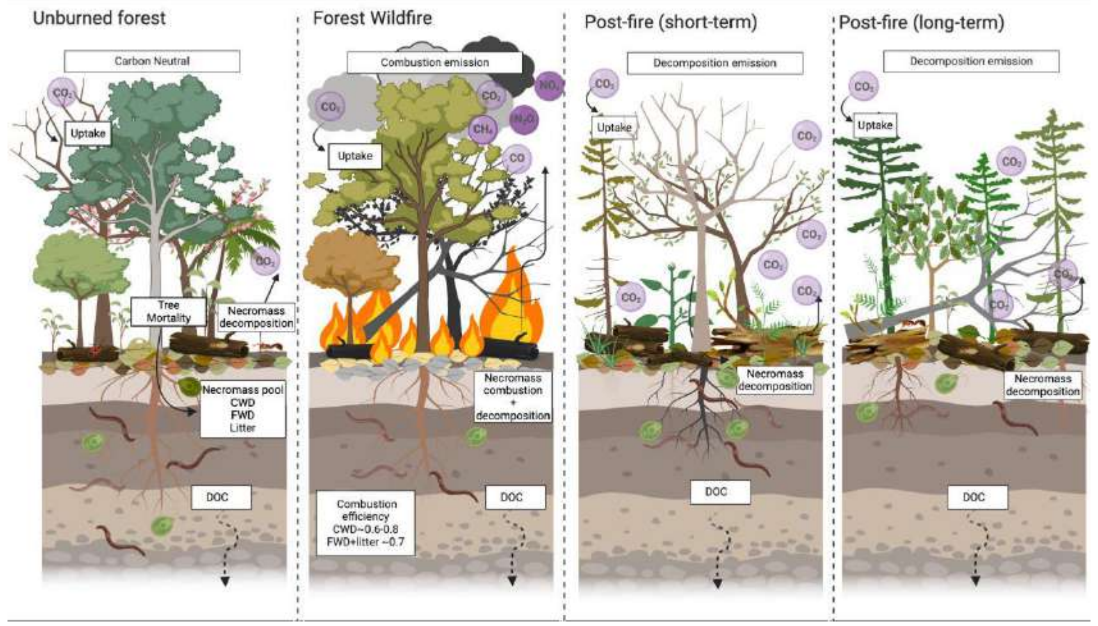
[1] Anderson et al. 2015; Alencar et al. 2006
[2] Barlow; Lagan; Peres, 2003; Pontes-lopes et al., 2021
[3] Ray; Nepstad; Moutinho, 2005

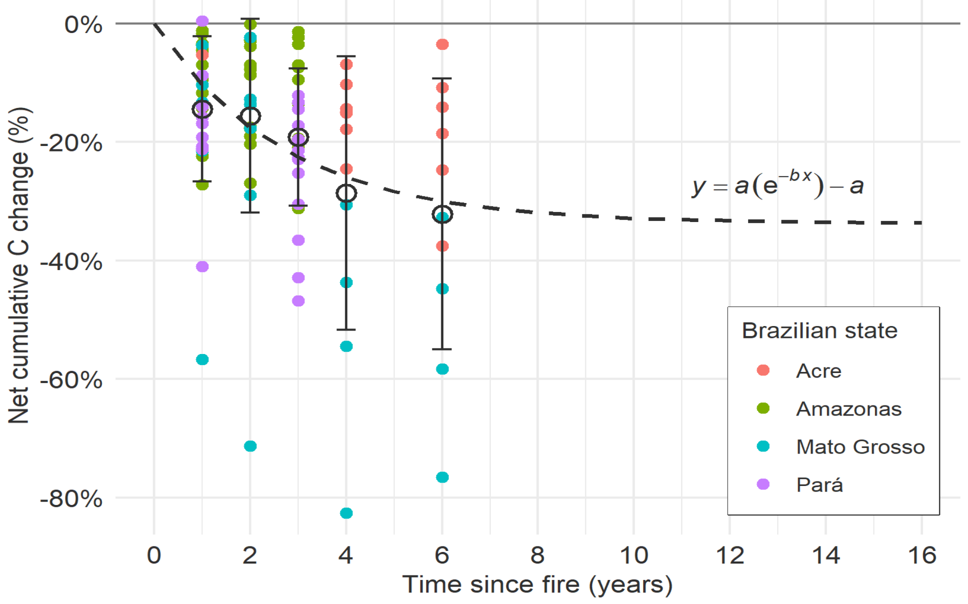
Spectral indices' changes significantly improved model accuracy for predicting post-fire biomass losses.



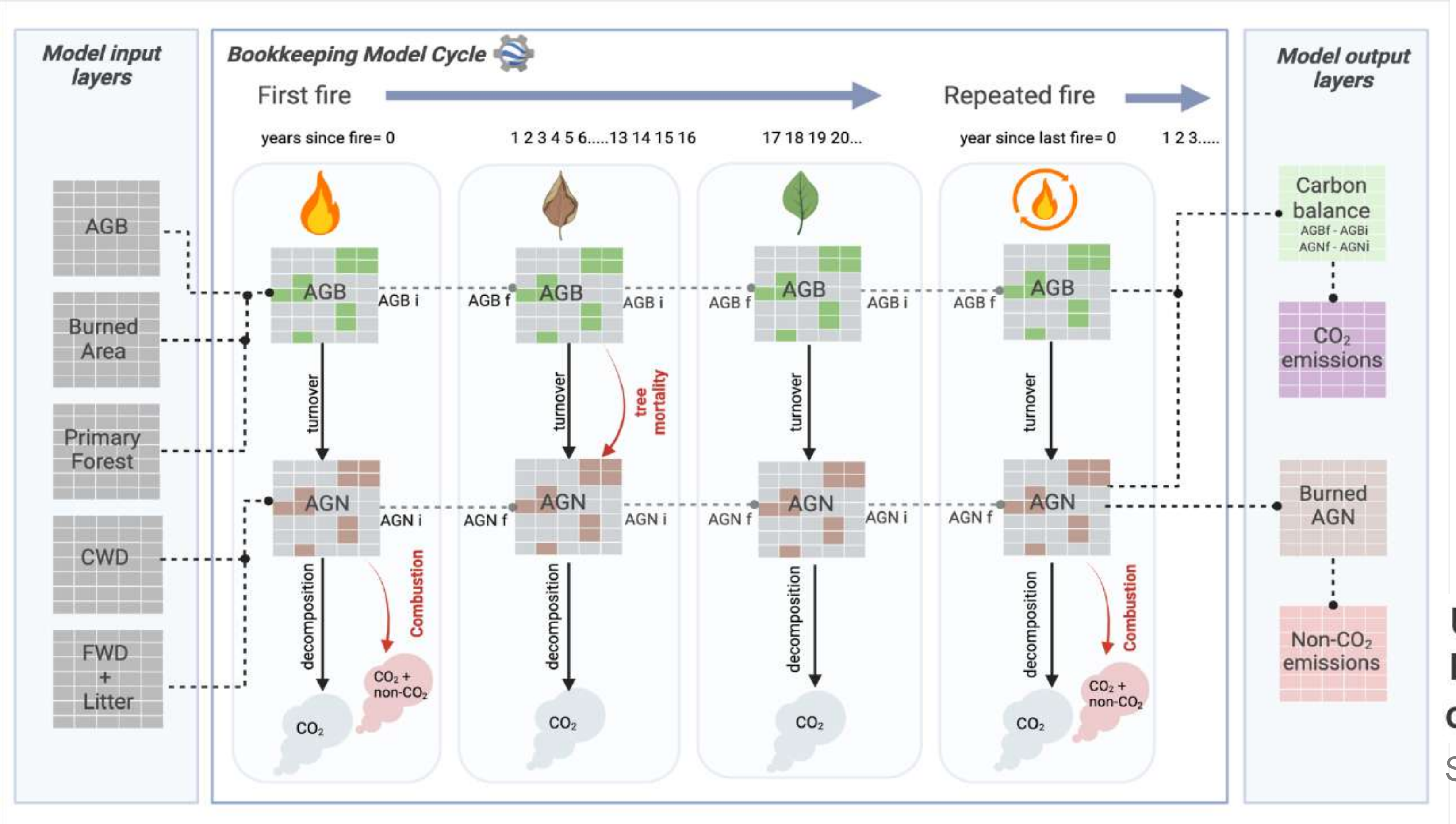


Modeling of Forest Fire Emissions



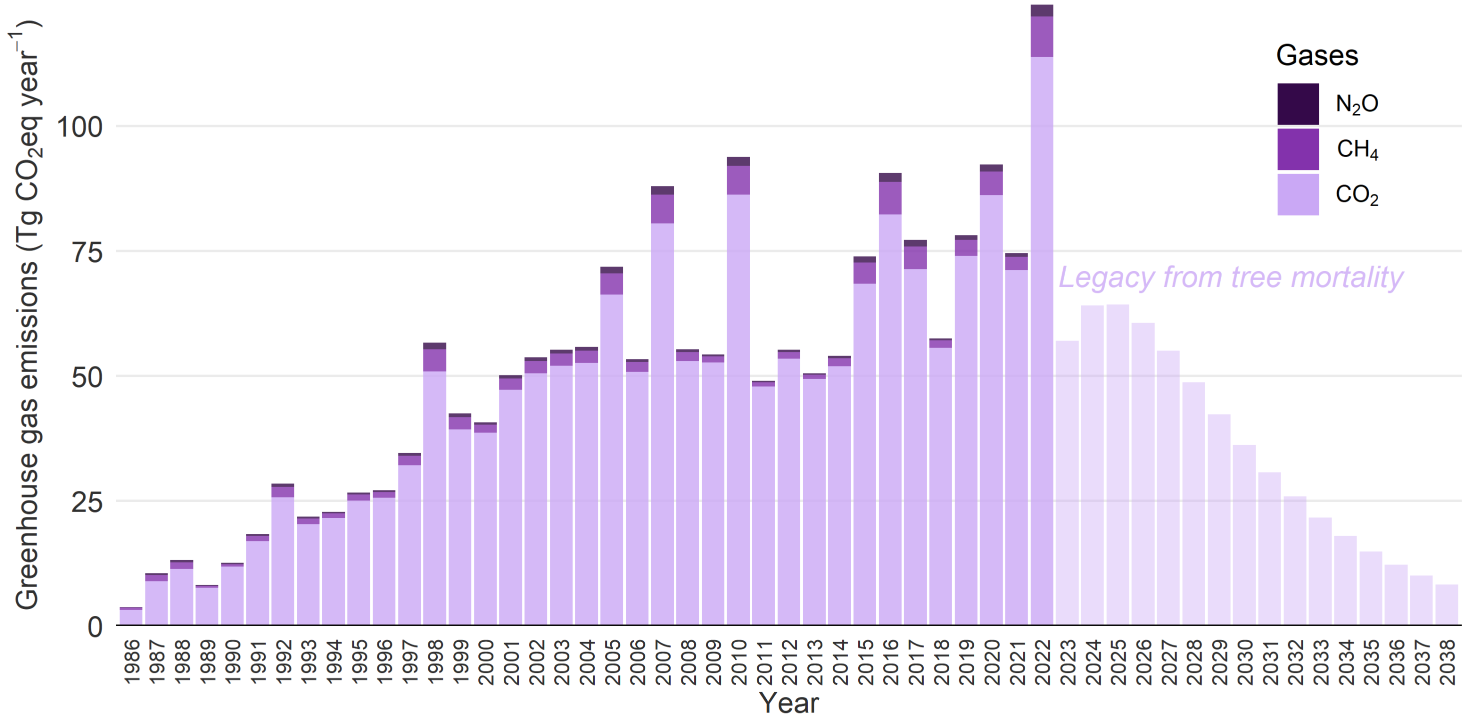


We developed a spatial-temporal **bookkeeping model for net forest fire emissions in standing forests of the Brazilian Amazon**, as these emissions are additional to deforestation emissions already included in national greenhouse gas inventories



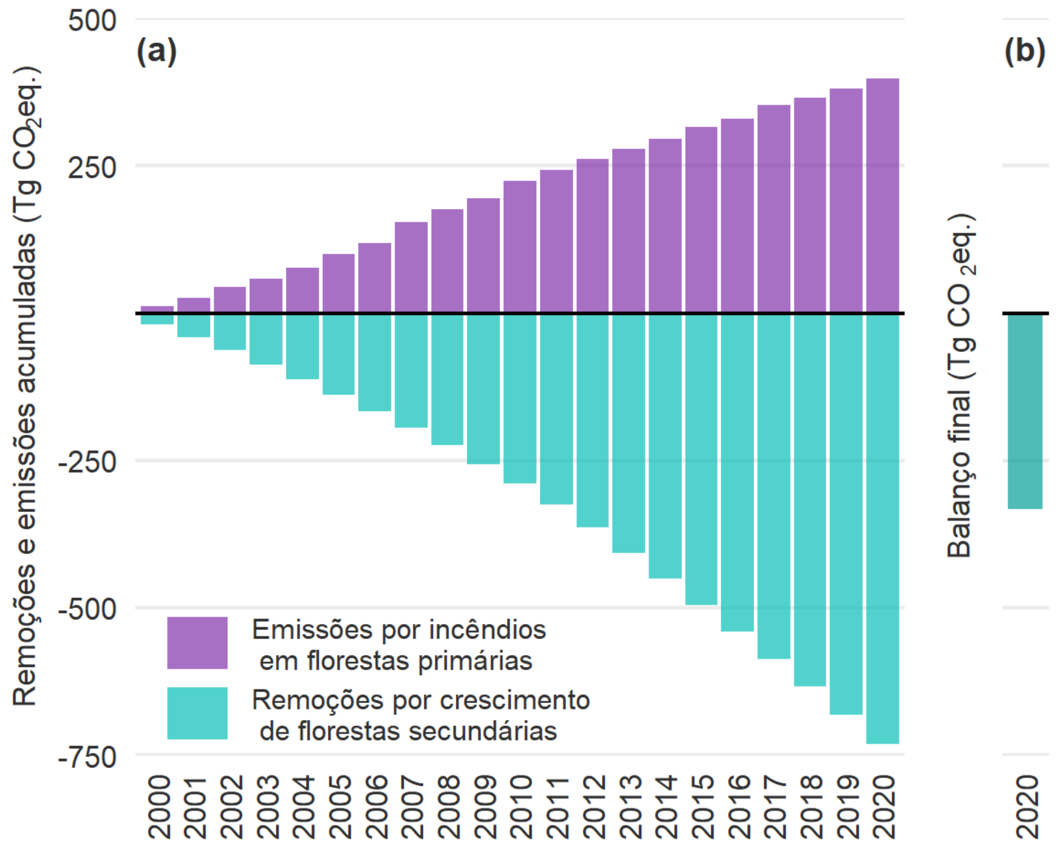
Unveiling the Hidden Green House Gases Footprint of Amazonian Forest Fires
Silva et al., preprint

About 187,900km² of remaining forests across the Brazilian Amazon in 2022 have burned at least once. Since 2010, emissions can represent **an addition of 37% of all net annual emissions to the LUC sector**.



Silva et al., preprint

In Pará, fires in primary forests may have offset about 54% (~398.4 Tg CO_2eq) of carbon removals by secondary forests over the past two decades.



Pontes-Lopes et al., 2022 SBSR

Further improvements:

- **Integration with other disturbance and regeneration processes:** Deforestation, Edge effects, Logging
- **Refinement:** decoupling mortality and wood productivity processes
- **Spatialization of the carbon balance:** e.g., as function of initial biomass and length of dry season
- **Testing and validation** against other modeling and measurement approaches

Large-scale initiatives to restore disturbed forests

in Amazônia and Mata Atlântica are emerging.

In recent years, forest restoration has emerged as one of the most reliable strategies for offsetting greenhouse gas emissions, offering transparent and measurable additionality.

re.green

- We are a private company primarily focused on forest restoration in **previously degraded agricultural lands.**
- We are expanding restoration efforts to **disturbed forests in ARR** projects, in evaluation by Verra under the VM0047 standard.
- Our goals include:

1M ha of forests by 2037

+35k ha

15M tons CO_2eq. per year

+100k tons CO2eq. per year

One for all, all for one

- We seek to combine **different strategies to build financial viability** to scale forest restoration, even where land prices are high (e.g., in Mata Atlântica).
- Disturbed forests can represent about 10–40% of our projects' total area.

Native timber production

Degraded land restoration

Other products and co-benefits

Disturbed forest restoration

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Although ensuring forest protection at large scale is challenging, the technical challenges of mapping, modeling, and monitoring cost-effectively are perhaps the greatest.

Disturbed forests
- Fire
- Logging
- Edge effect
- Secondary forests

Technical analyses
- Eligibility
- Reference biomass
- Pre-existing biomass
- Regional growth rates
- Dist. Freq. and intensity
- Disturbance age
- Forest resilience

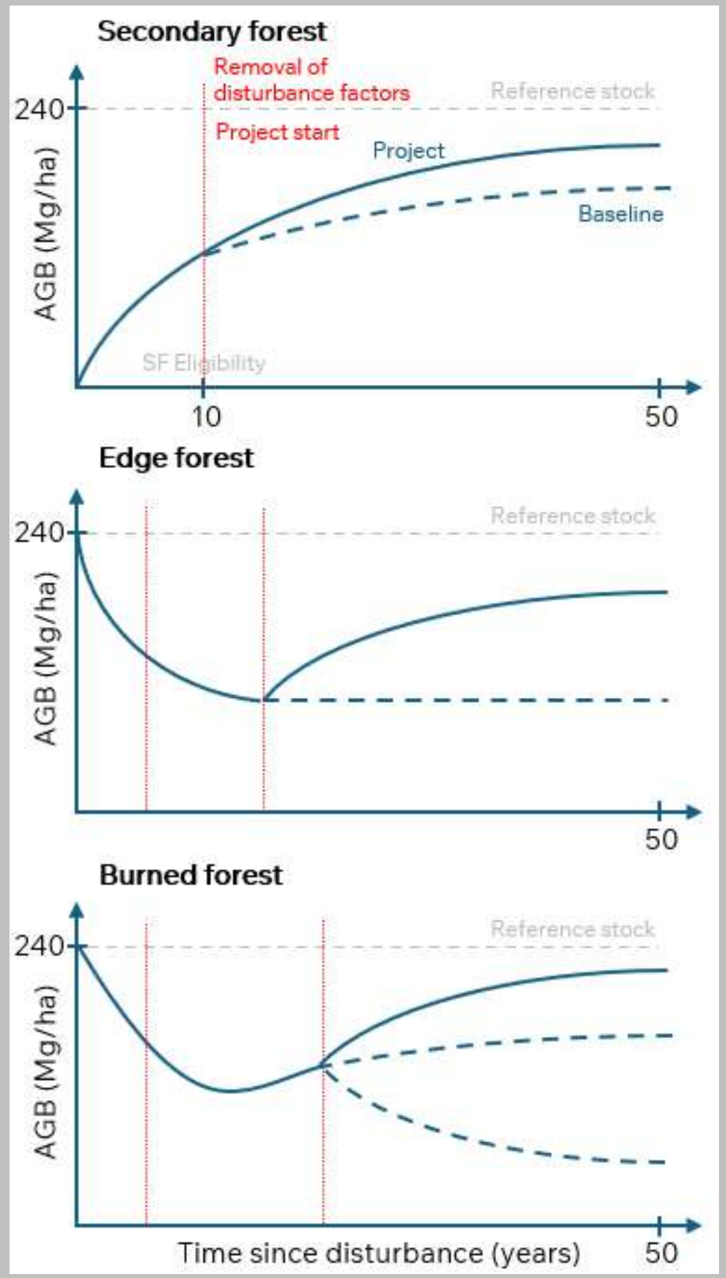
Technical challenges

- Mapping of disturbance classes
- Mapping of post-disturbance age
- Modelling of biomass changes
- Temporal sensibility of AGB products
- Tracking of additionality

Pipeline of analyses

from regional to fine-scale

Activities
- Removal of degradation factors
- Protection
- Seeding enrichment
- Other silvicultural interventions



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Obrigada!

aline.pontes@re.green alineplopes@gmail.com

Structural recovery in Amazonian secondary forests: an analysis using full-waveform LiDAR data

Aline Jacon

Session 1.3: Linking Field, ALS + satellite data of secondary forest

São José dos Campos, 29 Oct 2025

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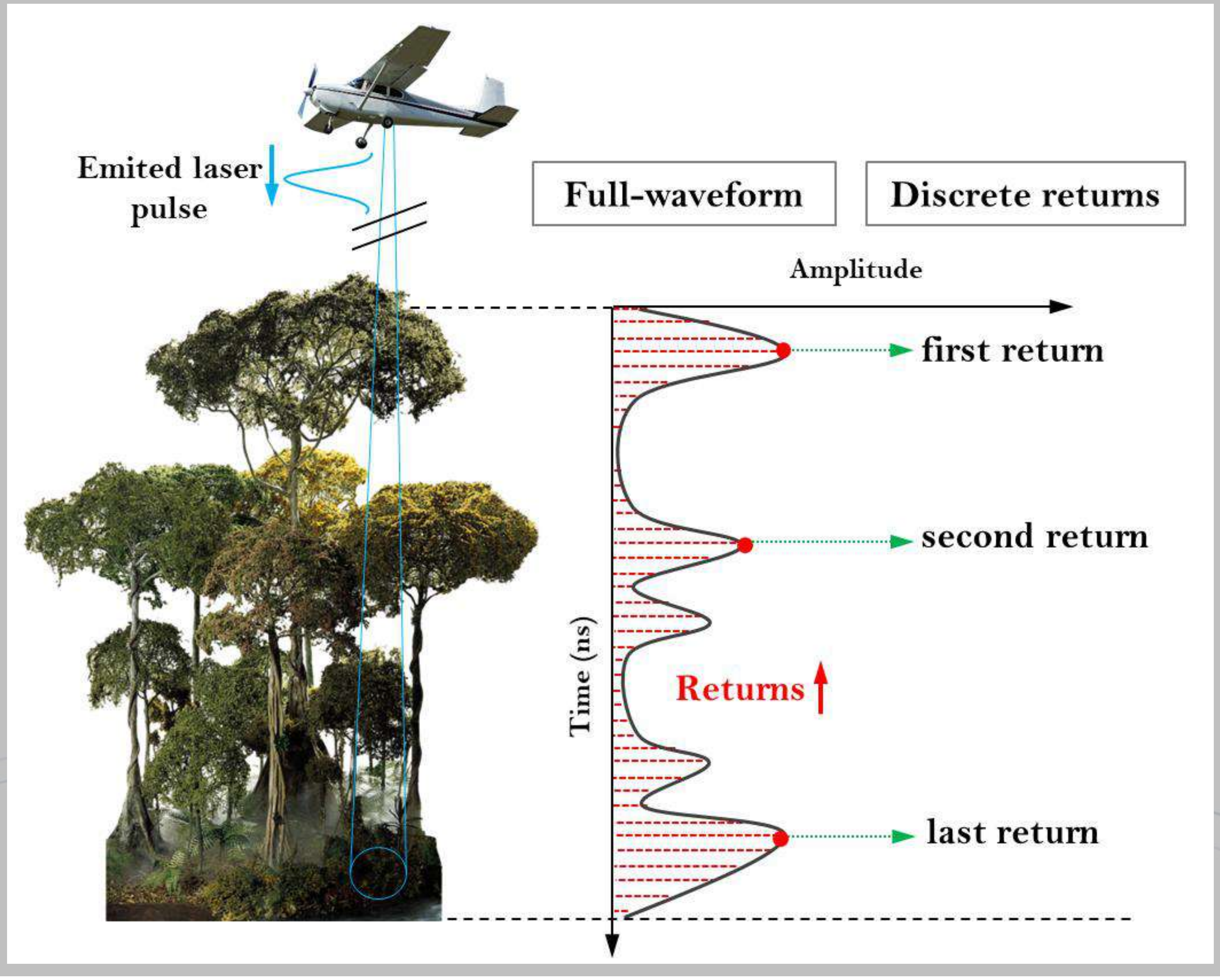
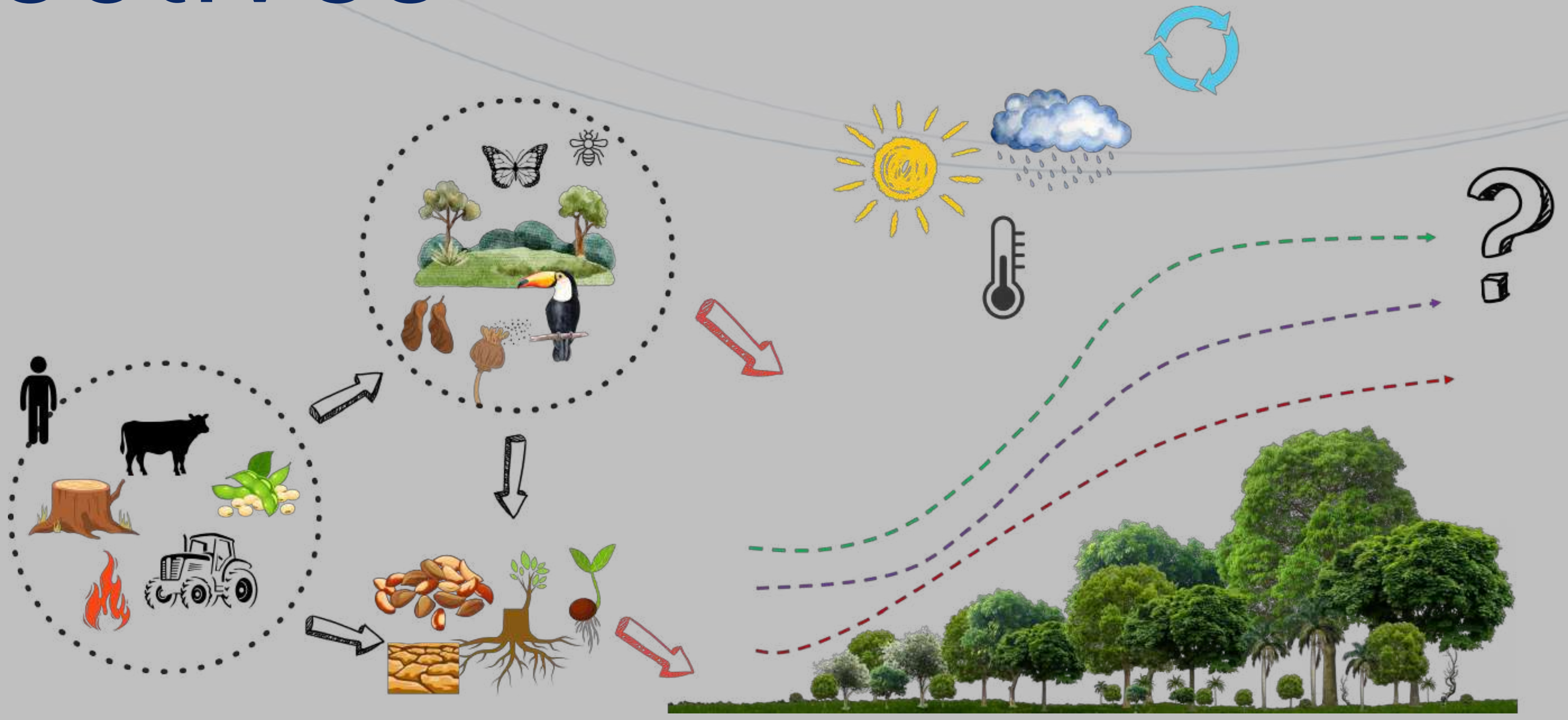
Objectives

- EBA Project(2016-2018)
- > 900 transects
- Full-waveform airborne LiDAR data

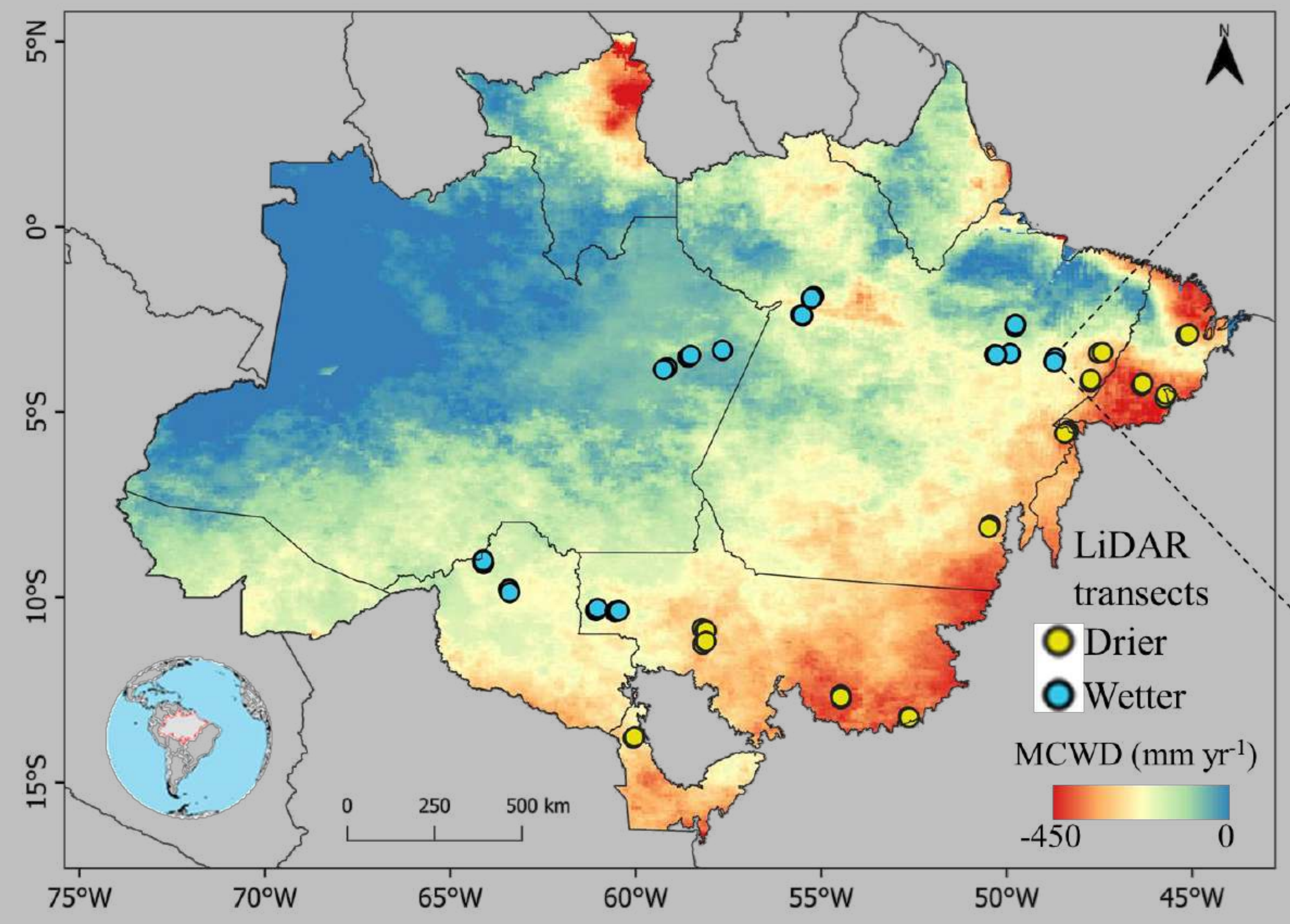


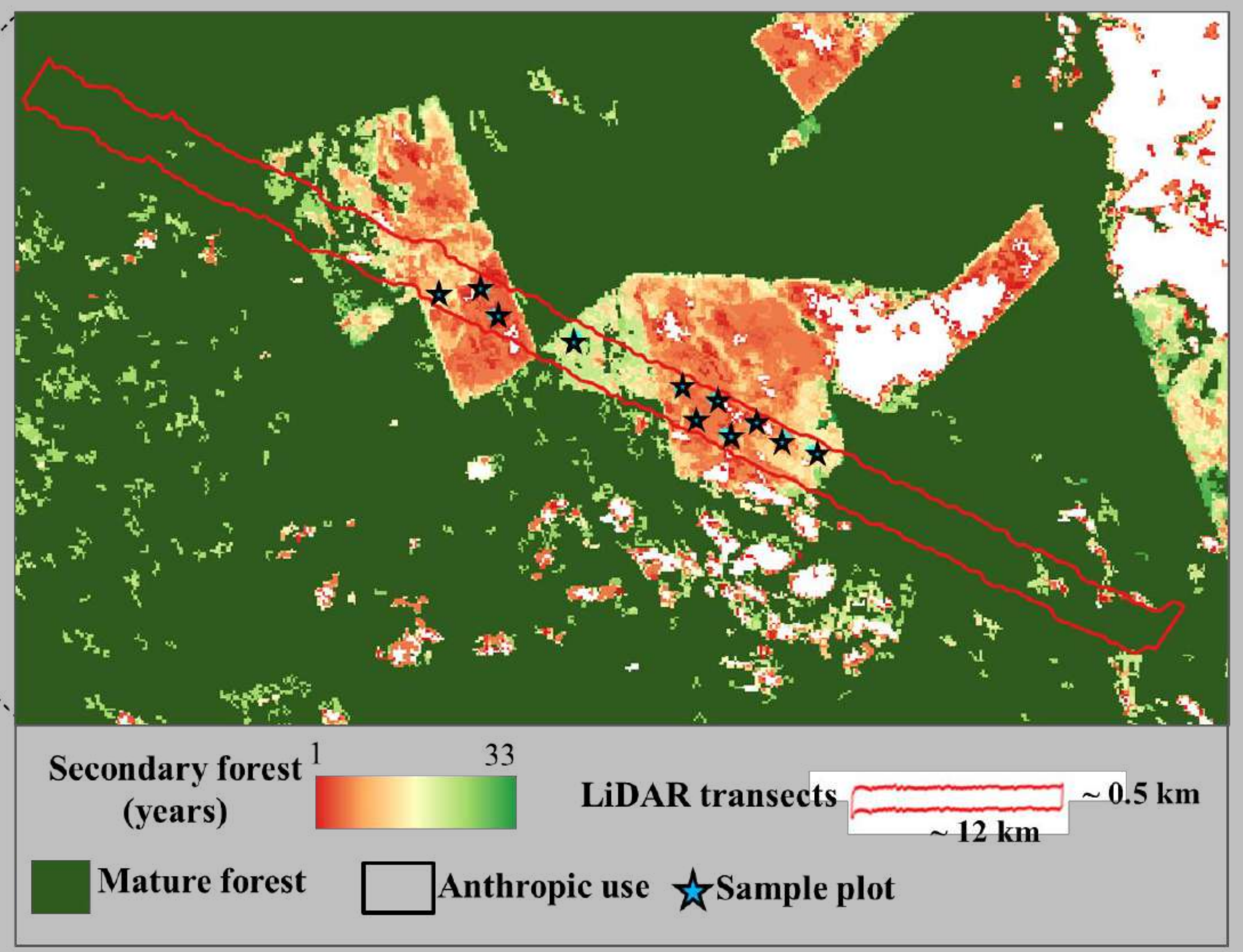


- What landscape size best predicts the effects of forest cover and fragmentation on the recovery of forest canopy structure? "scale of effect"
- What is the magnitude of the influence of climate and anthropogenic factors on the structural recovery of the forest?

Methods

Site selection





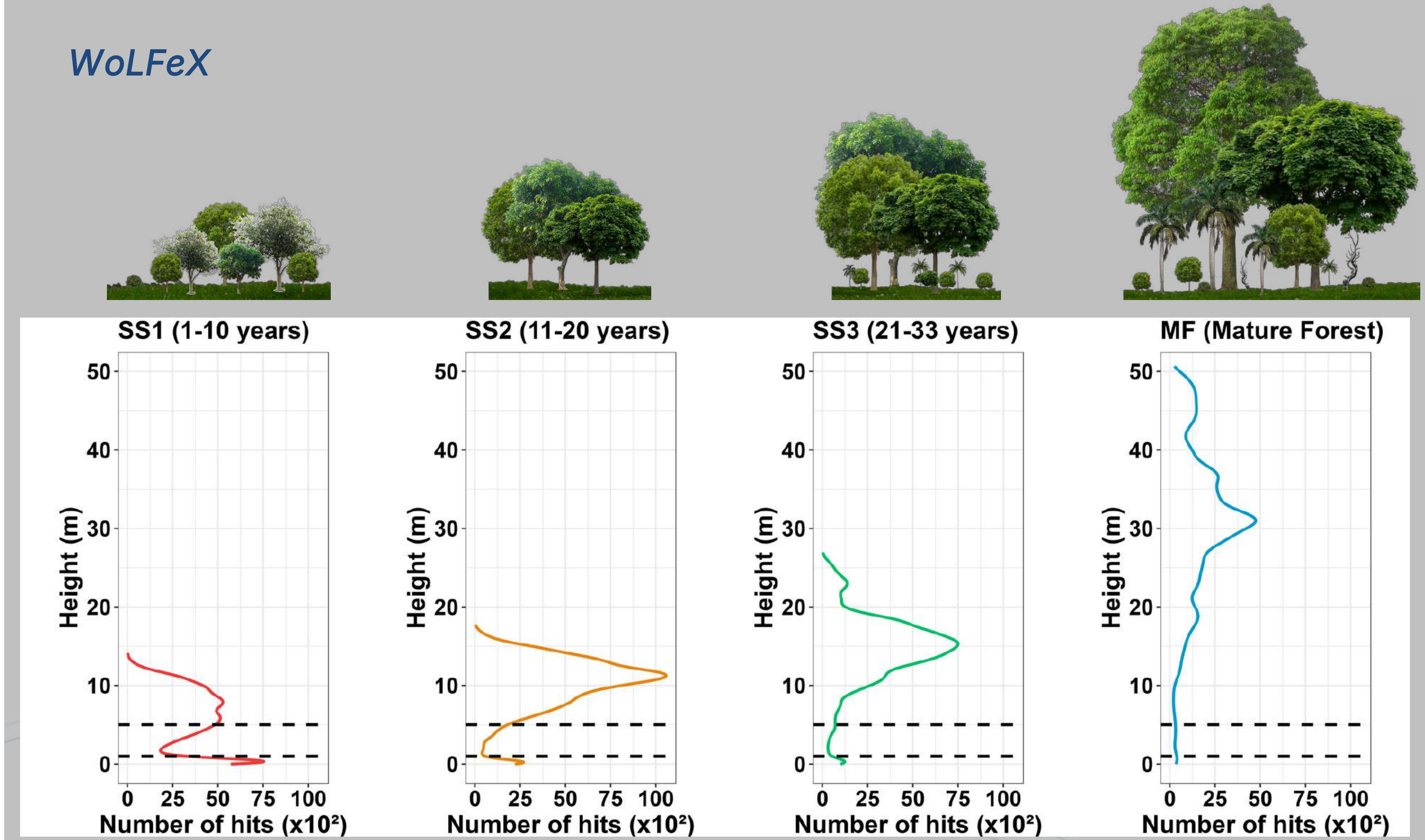
- 25 LiDAR transects (600 ha)
- 186 circular plots

- 50 m diameter
- 300 m between plots
- 60 m from the edges

Methods

LiDAR FWF data and derived metrics

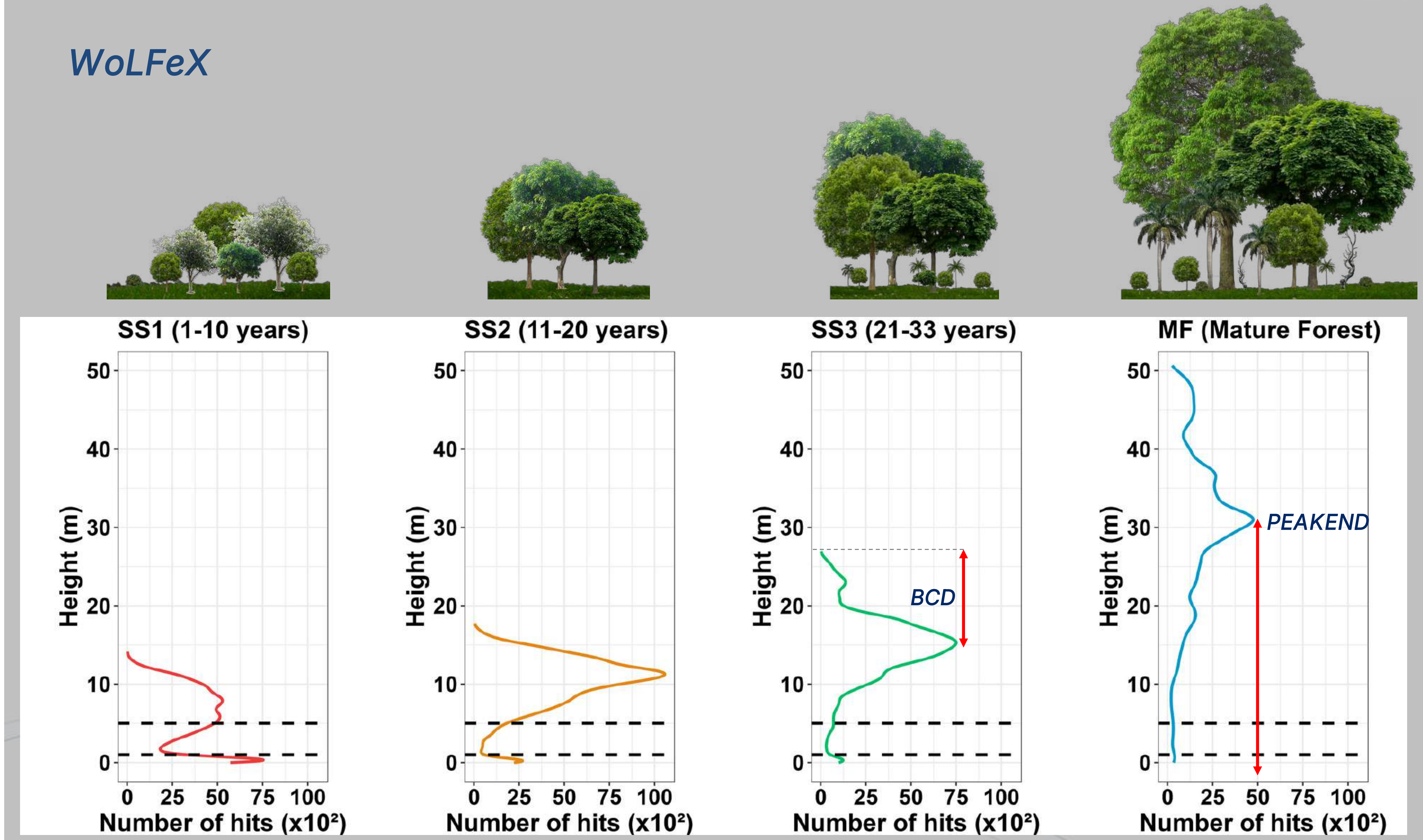
WoLFeX



Methods

LiDAR FWF data and derived metrics

WoLFeX



- PEAKEND (m)

- Distance between the height of maximum energy and the ground

- Height of the densest vegetation stratum

- BCD (m)

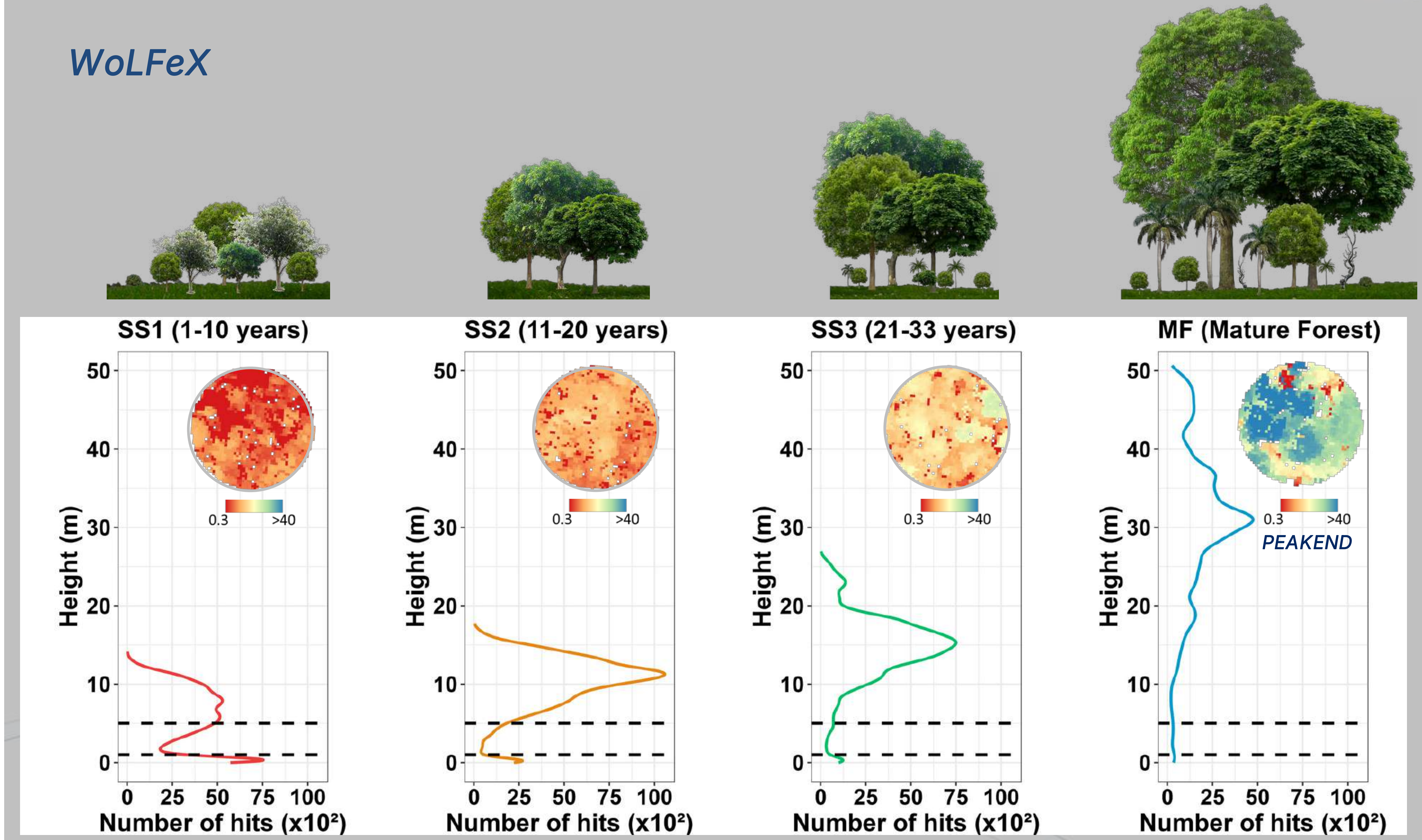
(Bottom of Canopy Distance)

- Distance from bottom to top of the canopy

Methods

LiDAR FWF data and derived metrics

WoLFeX



- PEAKEND (m)

- Distance between the height of maximum energy and the ground

- Height of the densest vegetation stratum

- BCD (m)

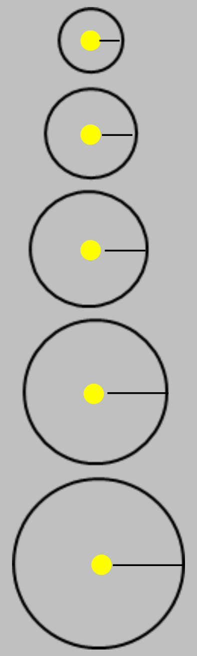
(Bottom of Canopy Distance)

- Distance from bottom to top of the canopy

Methods

Landscape variables and scale of effect

Radii from plot center



0.5 km (78.5 ha)

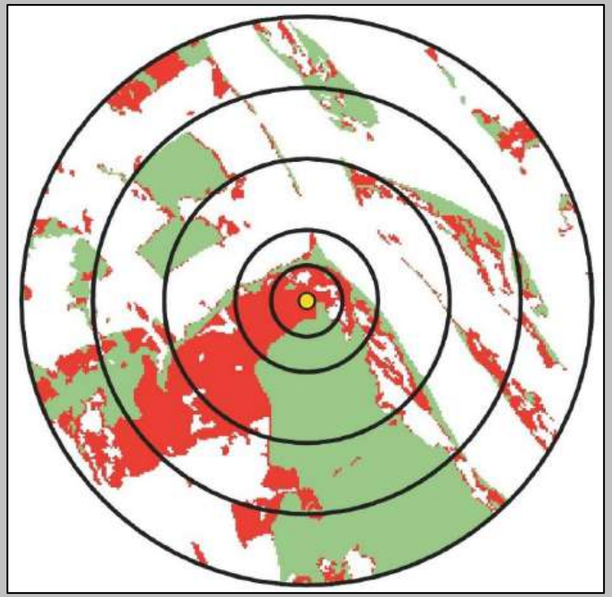
1 km (314 ha)

2 km (1,256 ha)

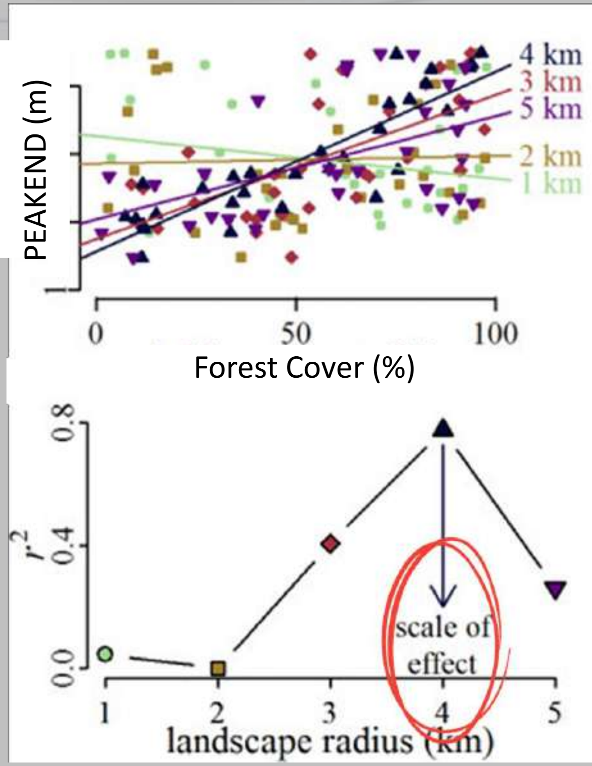
3 km (2,826 ha)

4 km (5,024 ha)

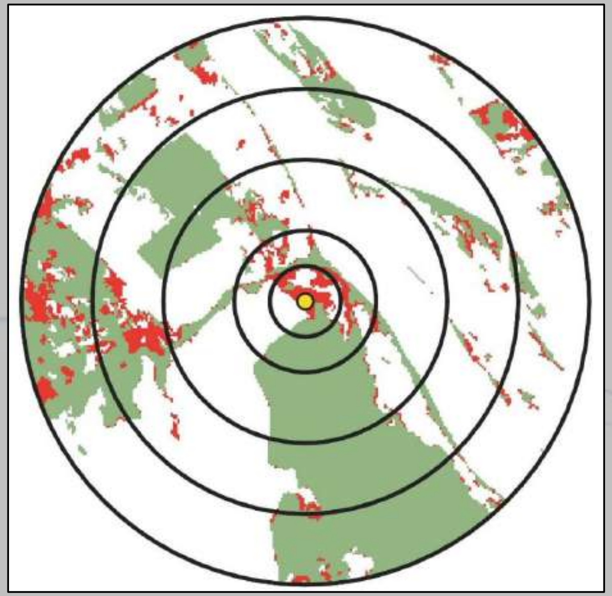
Final Time: Years of LiDAR acquisition (e.g., 2016; 12-year-old SF)



- Forest Cover – FC (%)
- Mature Forest Cover – FCmature (%)
- Forest Fragment Density – FFD (n/100ha)



Initial Time: beginning of secondary succession (e.g., 2005; one-year-old SF)



Forest (SF + MF)

Secondary forest (SF)

Mature forest (MF)

Non-forest

LiDAR sample plot

MapBiomas

- Variation in Forest Cover – VarFC (%)

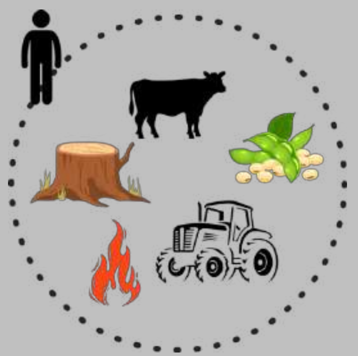
FC at the Final Time – FC at the Initial Time

If the VarFC value is positive, it means that there was a gain in forest cover (%) over time.

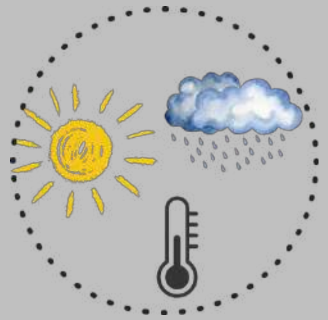
Methods

Other factors and models

- Age
- Frequency of clearing/deforestation – DefFreq
- Frequency of fire – FireFreq
- Duration of anthropogenic land use – AnthroUse



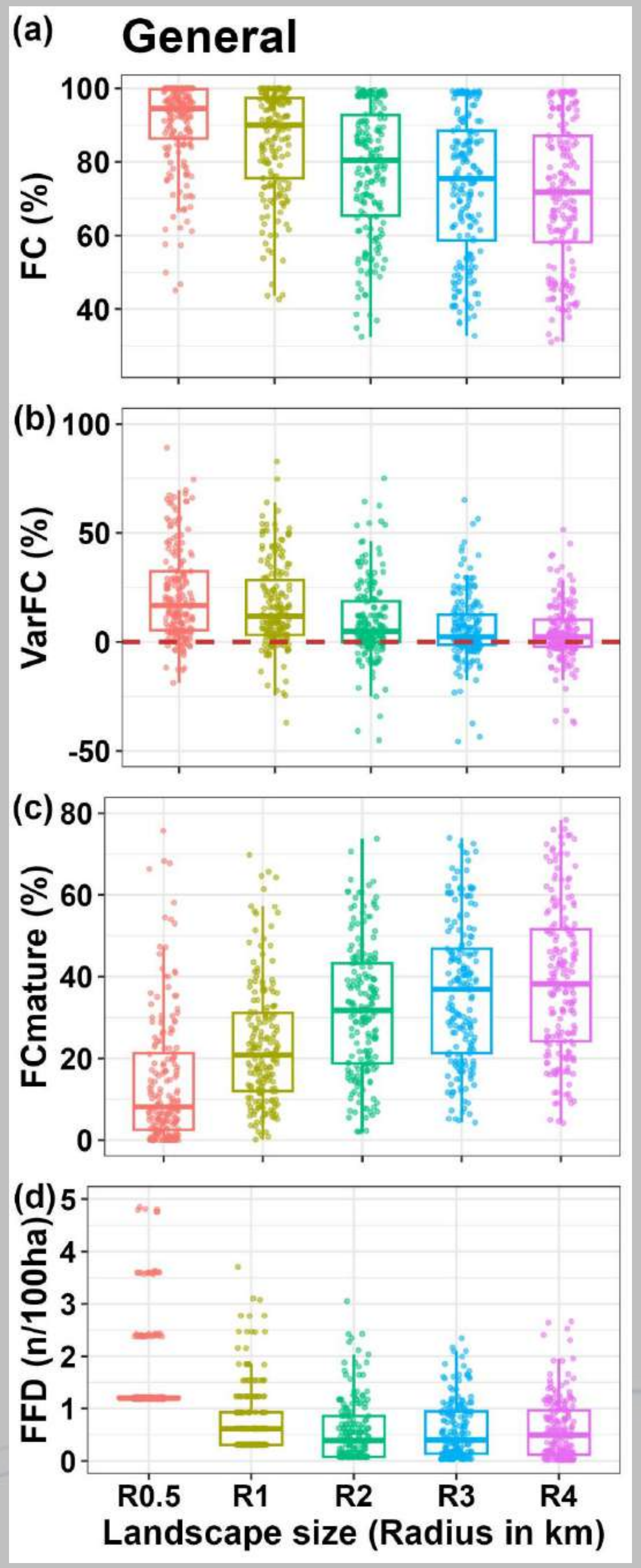
- MCWD

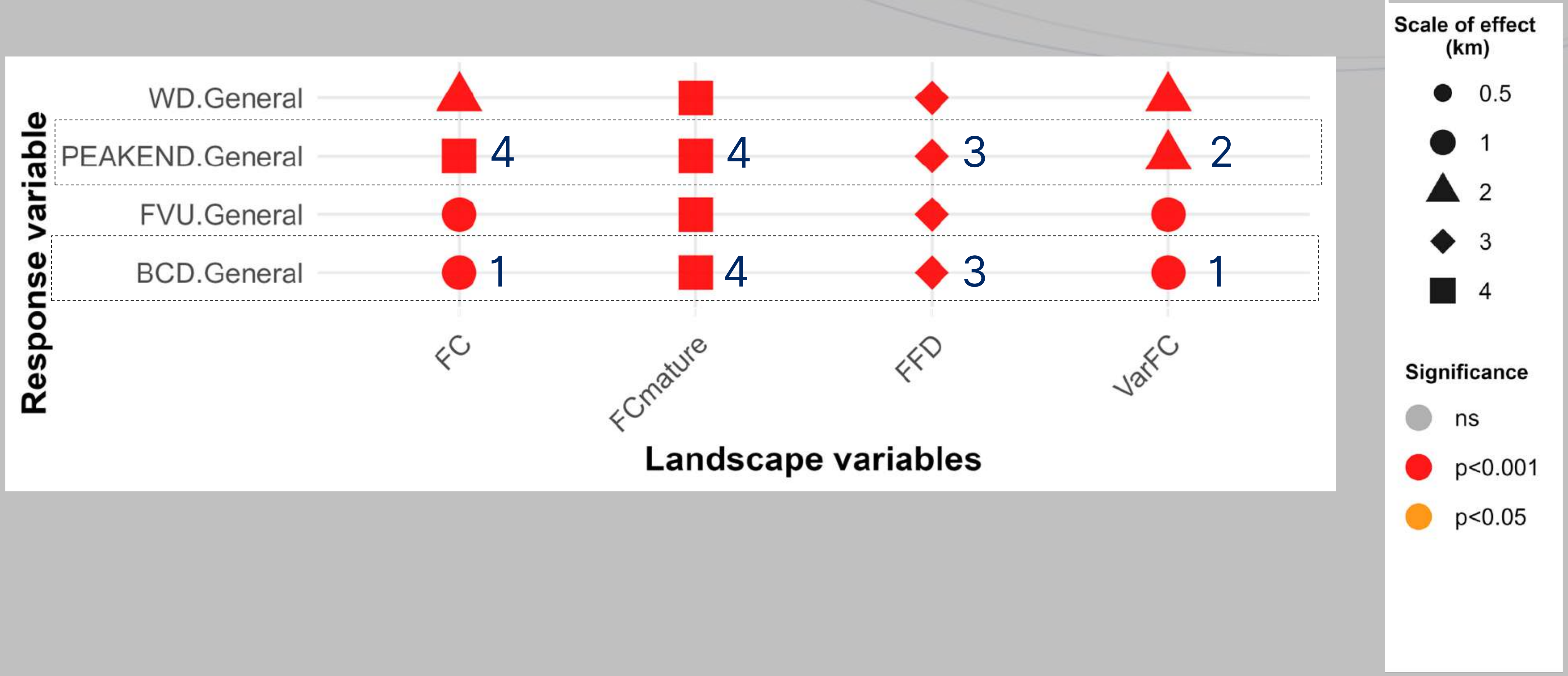


- Linear Mixed Models (LMMs)

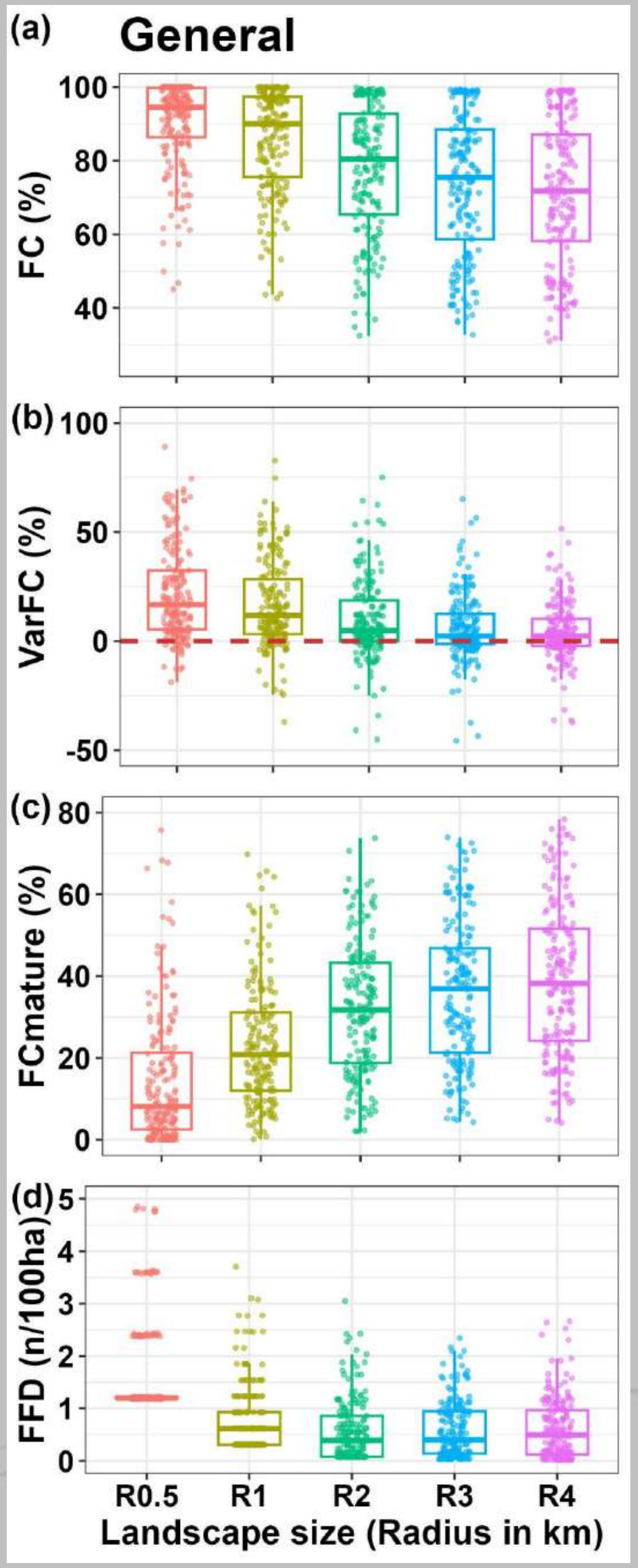
LIDAR metrics = Age + MCWD + FC + VarFC + Fcmature + FDD + DefFreq + FireFreq + AnthroUse + interaction with Age + random effect (LIDAR ID)

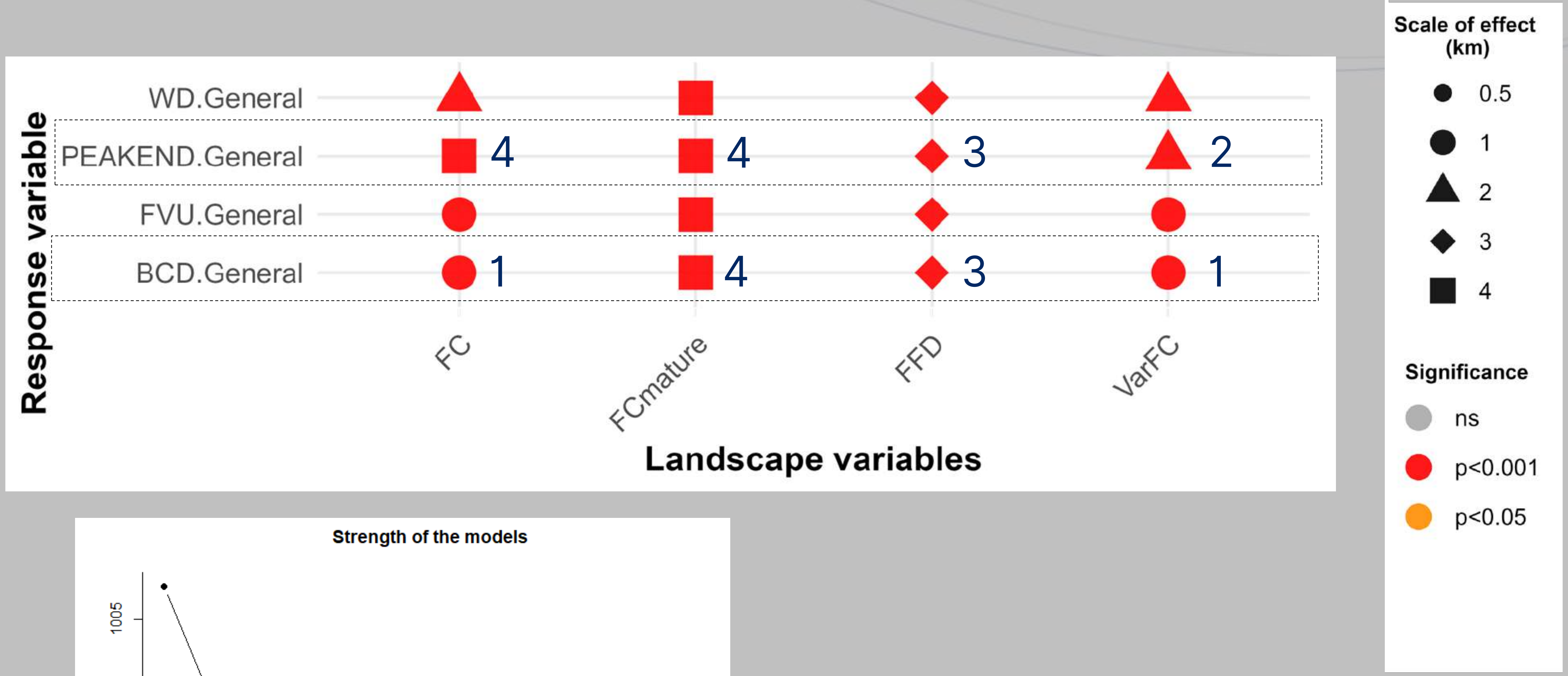
Scale of effect

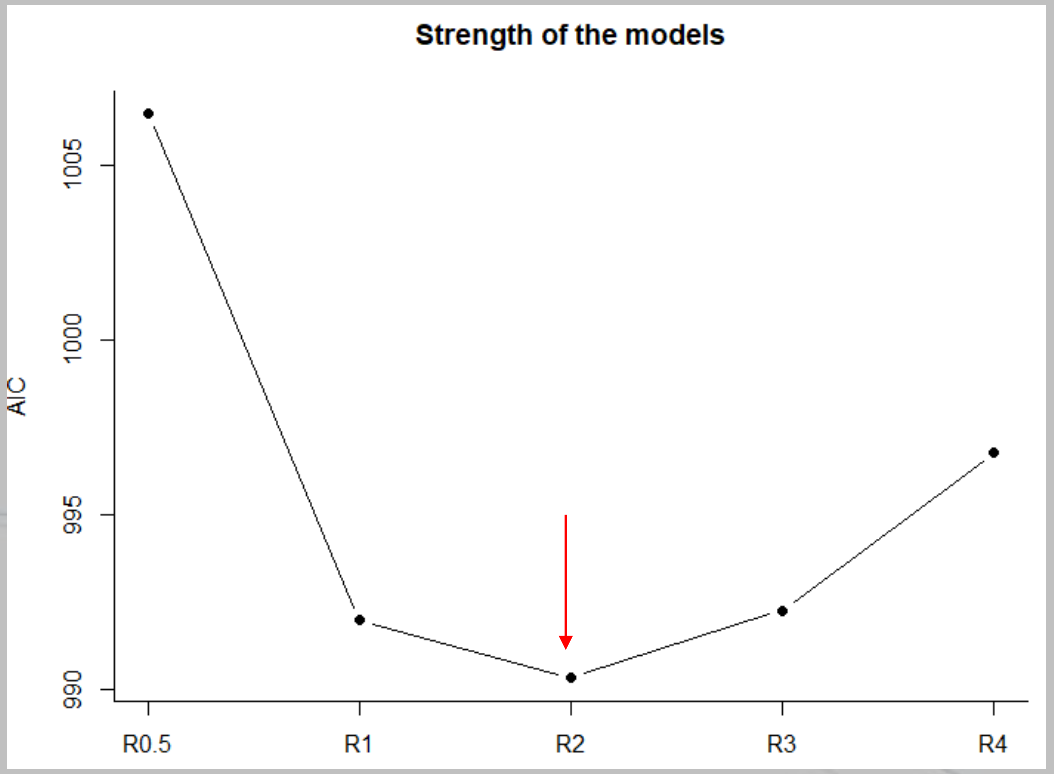




Scale of effect



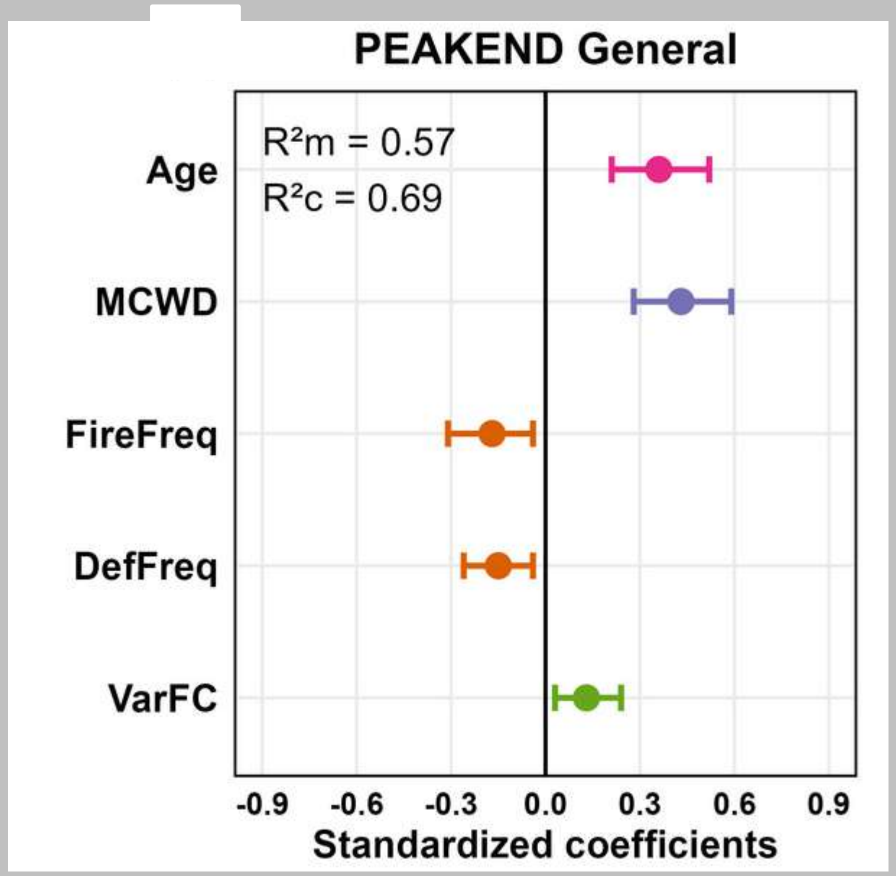


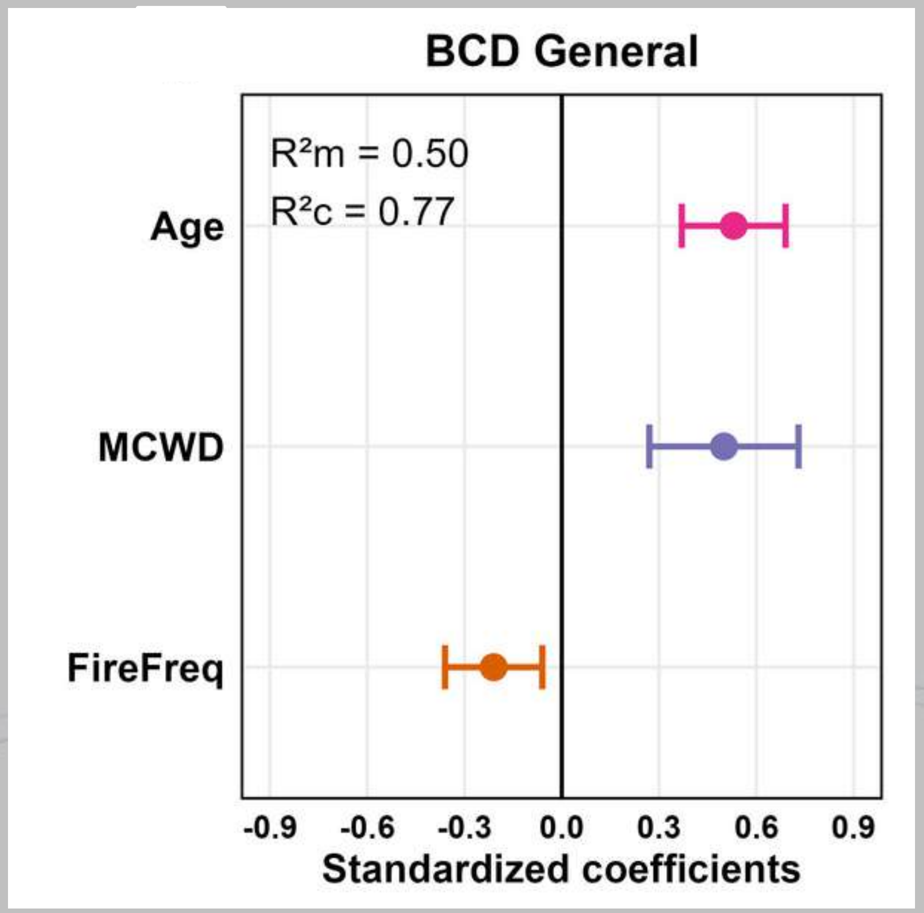


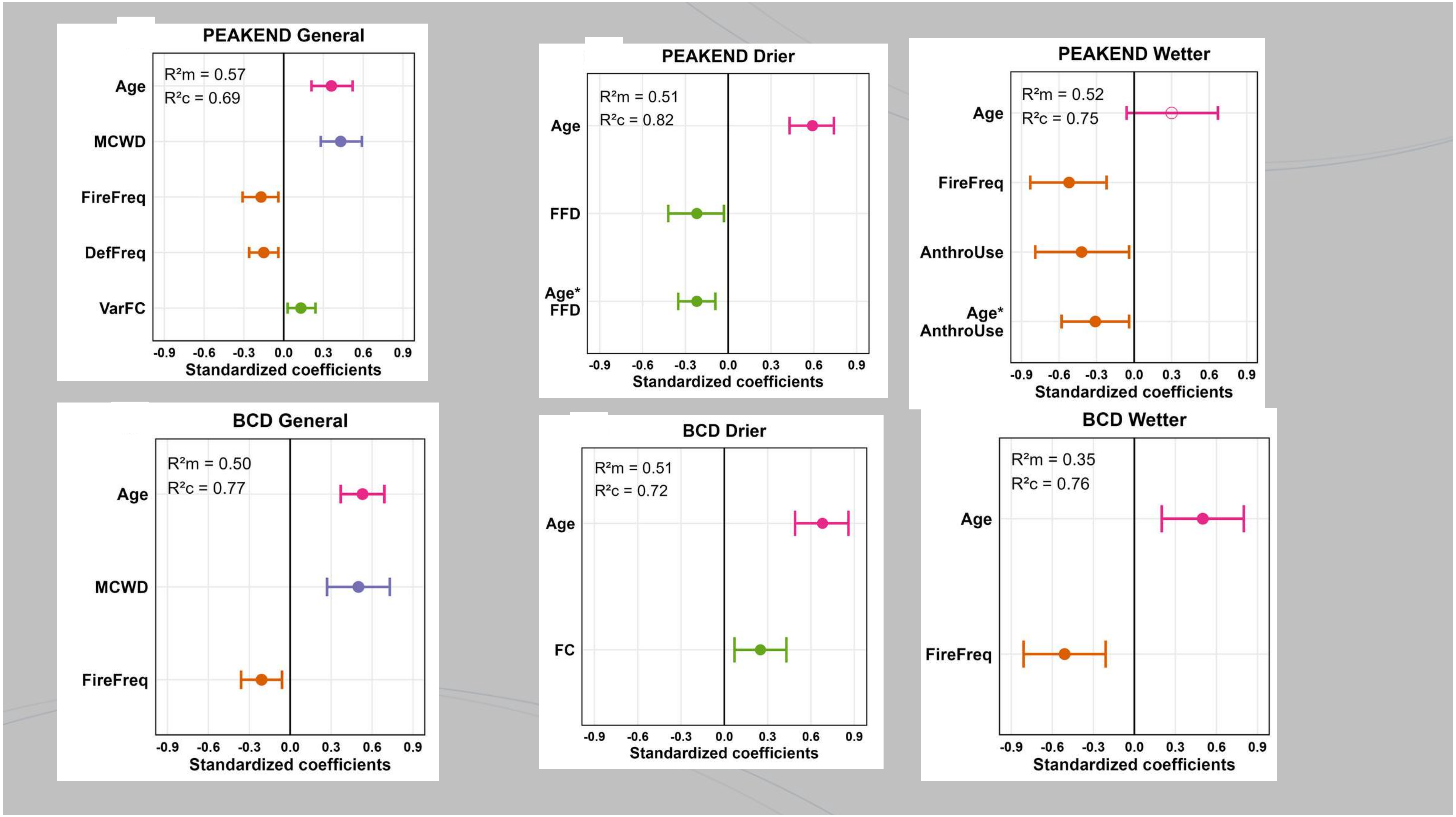
- Scale of effect

PEAKEND x VarFC = 2 km

Effect on secondary forest recovery







PEAKEND General
R²m = 0.57
R²c = 0.69
Age
MCWD
FireFreq
DefFreq
VarFC
-0.9 -0.6 -0.3 0.0 0.3 0.6 0.9
Standardized coefficients
PEAKEND Drier
R²m = 0.51
R²c = 0.82
Age
FFD
Age* FFD
-0.9 -0.6 -0.3 0.0 0.3 0.6 0.9
Standardized coefficients
PEAKEND Wetter
R²m = 0.52
R²c = 0.75
Age
FireFreq
AnthroUse
Age* AnthroUse
-0.9 -0.6 -0.3 0.0 0.3 0.6 0.9
Standardized coefficients
BCD General
R²m = 0.50
R²c = 0.77
Age
MCWD
FireFreq
-0.9 -0.6 -0.3 0.0 0.3 0.6 0.9
Standardized coefficients
BCD Drier
R²m = 0.51
R²c = 0.72
Age
FC
-0.9 -0.6 -0.3 0.0 0.3 0.6 0.9
Standardized coefficients
BCD Wetter
R²m = 0.35
R²c = 0.76
Age
FireFreq
-0.9 -0.6 -0.3 0.0 0.3 0.6 0.9
Standardized coefficients

Final considerations

- Potential of FWF LiDAR metrics to capture variations along forest succession, as well as changes driven by factors that may affect canopy structural recovery.

- Importance of assessing landscape structure at the appropriate spatial scale, as its influence may vary depending on the vegetation parameter being monitored and the type of landscape metric used.

- Importance of integrating information on anthropogenic disturbances into forest restoration policies and practices to optimize recovery processes and reduce costs.

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Forest Connectivity Boosts Carbon Recovery in Regenerating Atlantic Forests

Dr. Thais Rosan

Session 1.3: Linking Field, ALS + satellite data of secondary forest

São José dos Campos, 29 Oct 2025

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Introduction

- Brazil is acknowledged as one of the greatest global potential country for the implementation of large-scale ecosystem restoration and conservation measures to mitigate climate change
  - Vast areas of available land with potential for regeneration
  - Pledged to restore 12 million hectares of forests by 2030

- ***Atlantic Forest – a restoration hotspot***
- 21.6Mha – 36Mha of land potentially available for regeneration (Barros et al., 2023; Crouzeilles et al., 2020)

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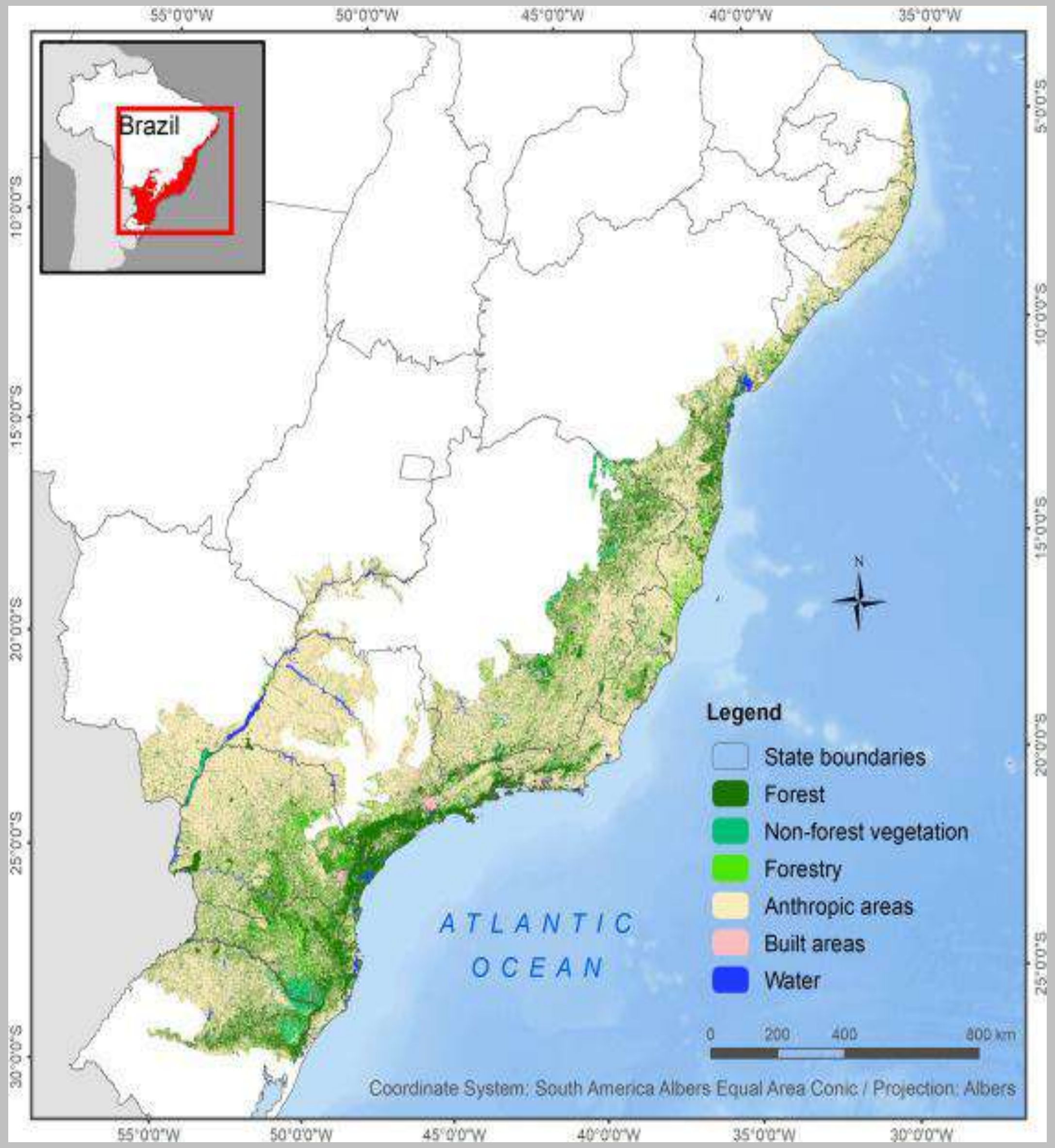
Atlantic Forest

- Biodiversity Hotspot: home to 20,000+ plant species and unique wildlife
- Deforestation & Habitat Loss: Over 85% of its original area has been lost due to urbanization and agriculture
- Highly fragmented landscape



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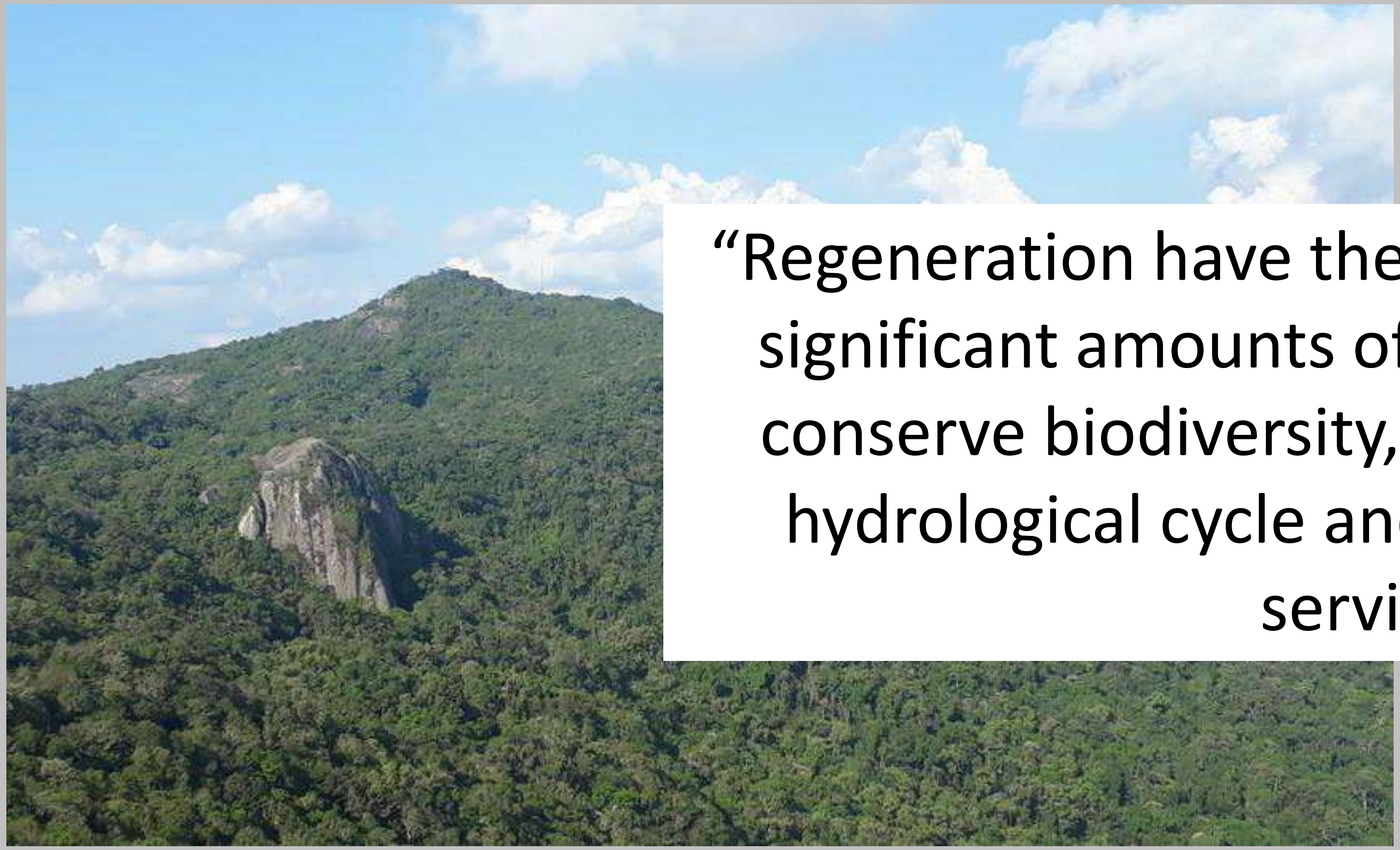
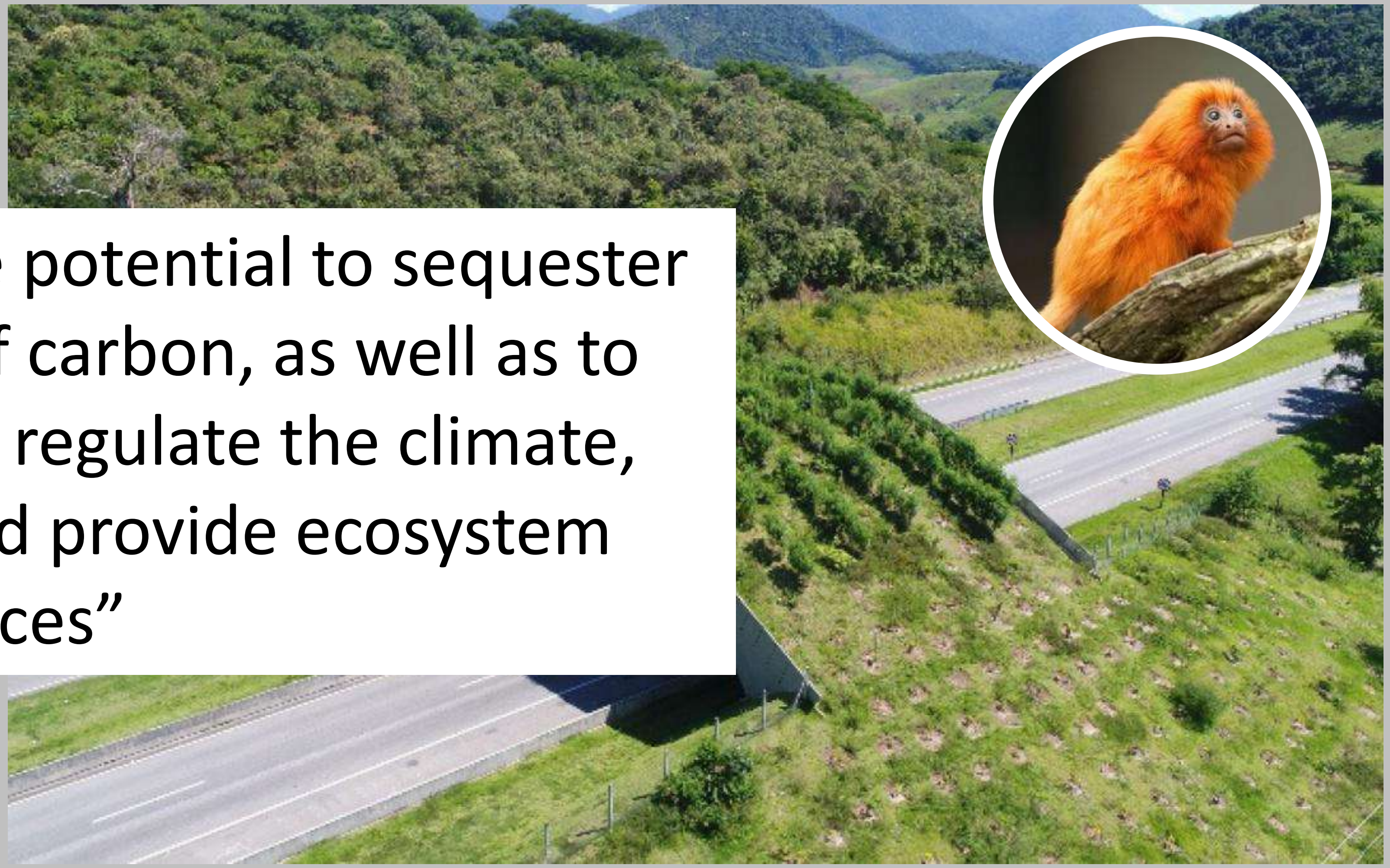
Atlantic Forest





"Regeneration have the potential to sequester significant amounts of carbon, as well as to conserve biodiversity, regulate the climate, hydrological cycle and provide ecosystem services"

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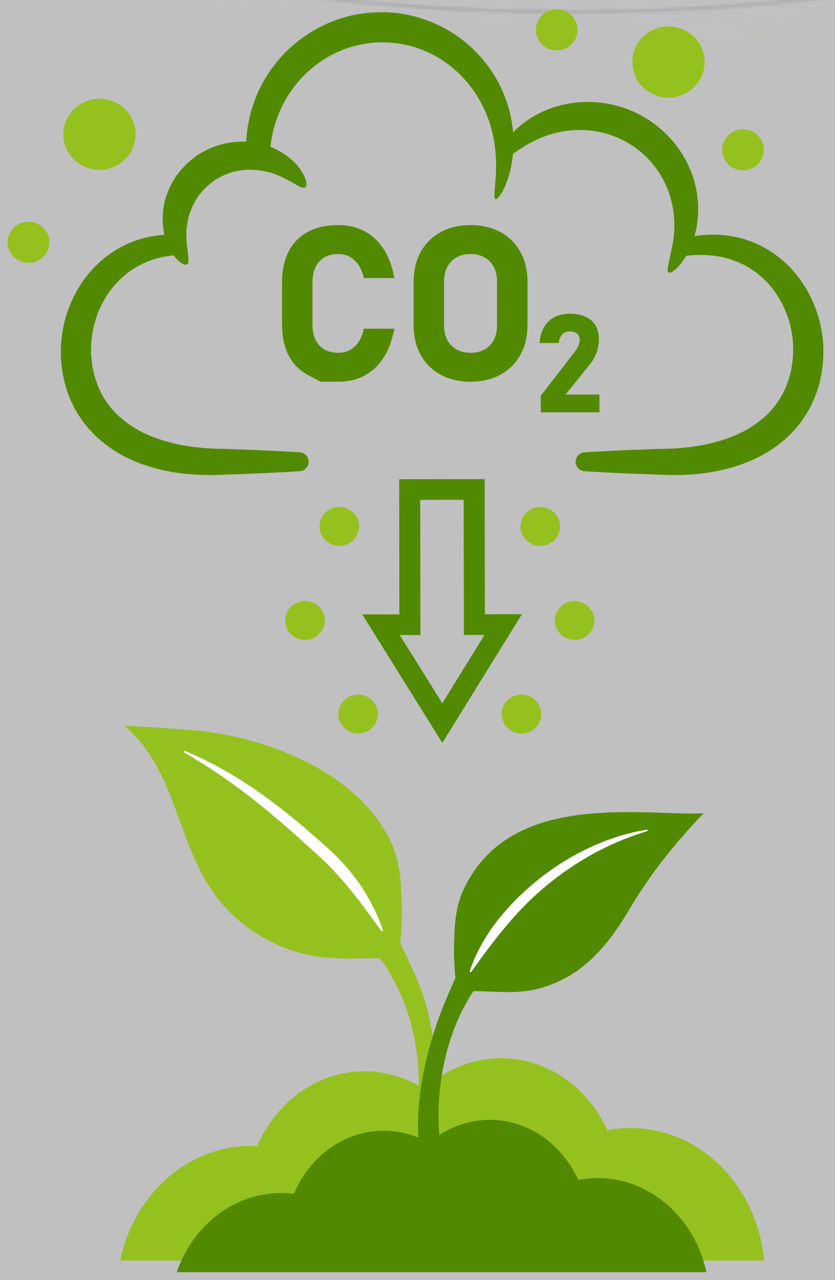
Objectives

- Remote sensing data + space-for-time substitution approach to estimate the regrowth rates across the Atlantic Forest (Chapman-Richards growth model)
- Assess the drivers of AGC in secondary forest
- Estimate the aboveground carbon sequestration capacity of 2020 standing secondary forests
- Project future carbon sequestration of 2020 standing SF



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SECONDARY FOREST AGE

Age in 2020 (1986-2020)

Estimated based on the land cover changes (GEE code) collection 7.1 MapBiomas (Silva Jr., et al, 2020; Heinrich et al., 2021)

ABOVEGROUND CARBON

ESA CCI ABOVEGROUND BIOMASS (2020)

Conversion factor of 0.47 (IPCC)

ENVIRONMENTAL VARIABLES

- Landscape fragmentation / connectivity
- MCWD
- Terrain slope
- Average maximum temperature
- Size of fragment

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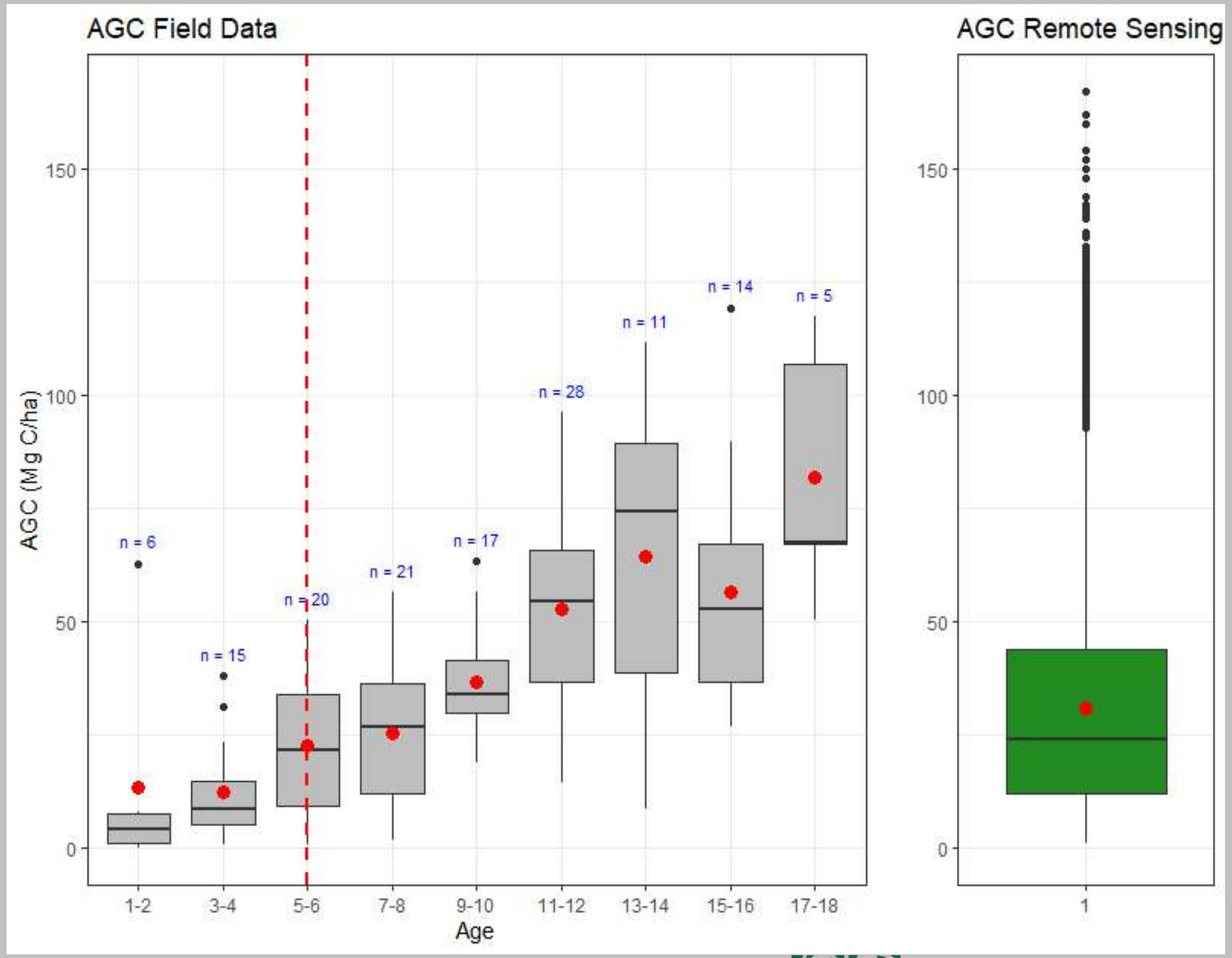
Issues with mapping early stage forest regeneration AGC

- Wilcoxon signed-rank test - AGC derived from field data x AGC from ESA CCI
- Used to correct the SF year with associated AGC from ESA CCI



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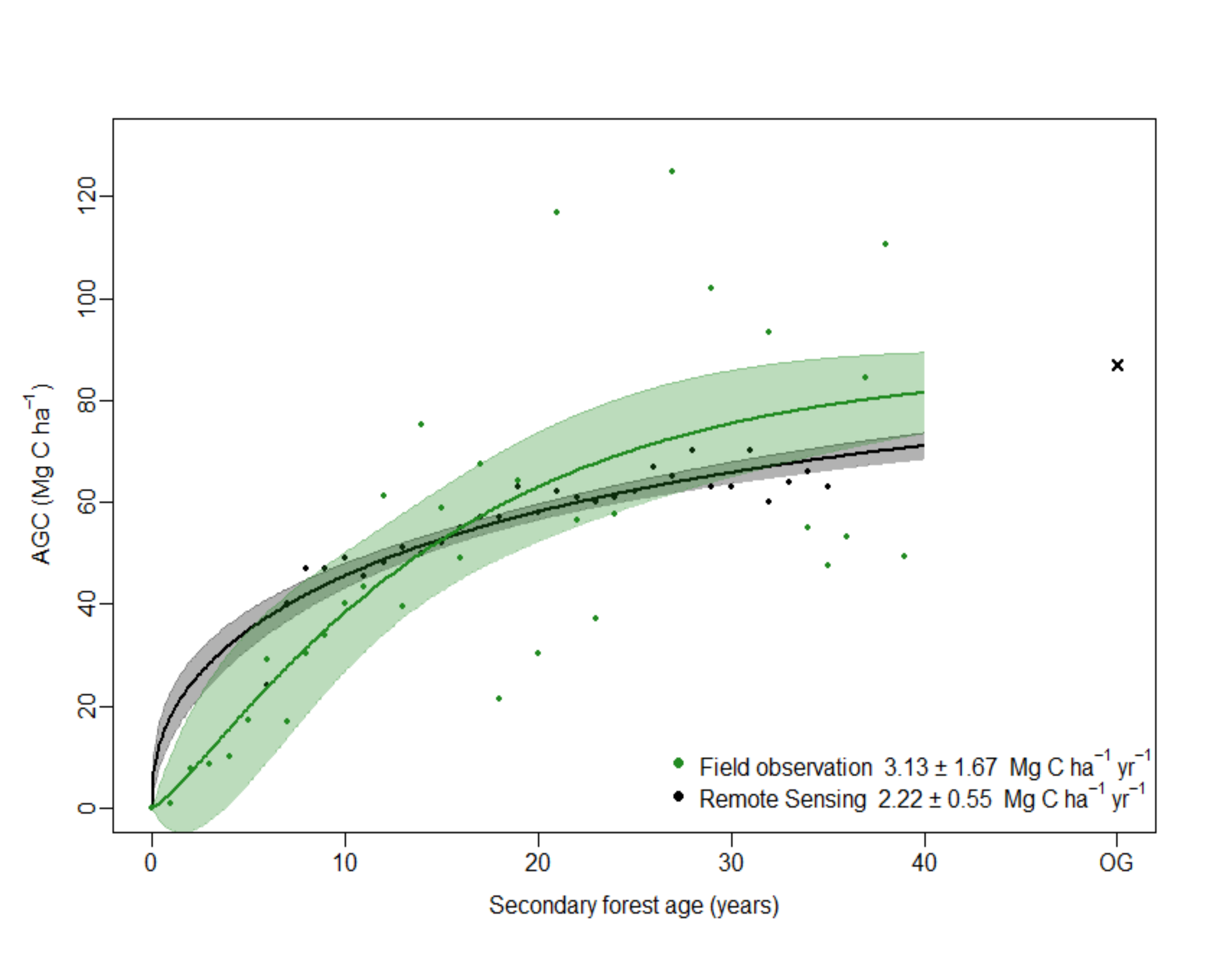
Chapman-Richards Growth Model

- A widely used sigmoidal growth function in forestry and ecological modeling



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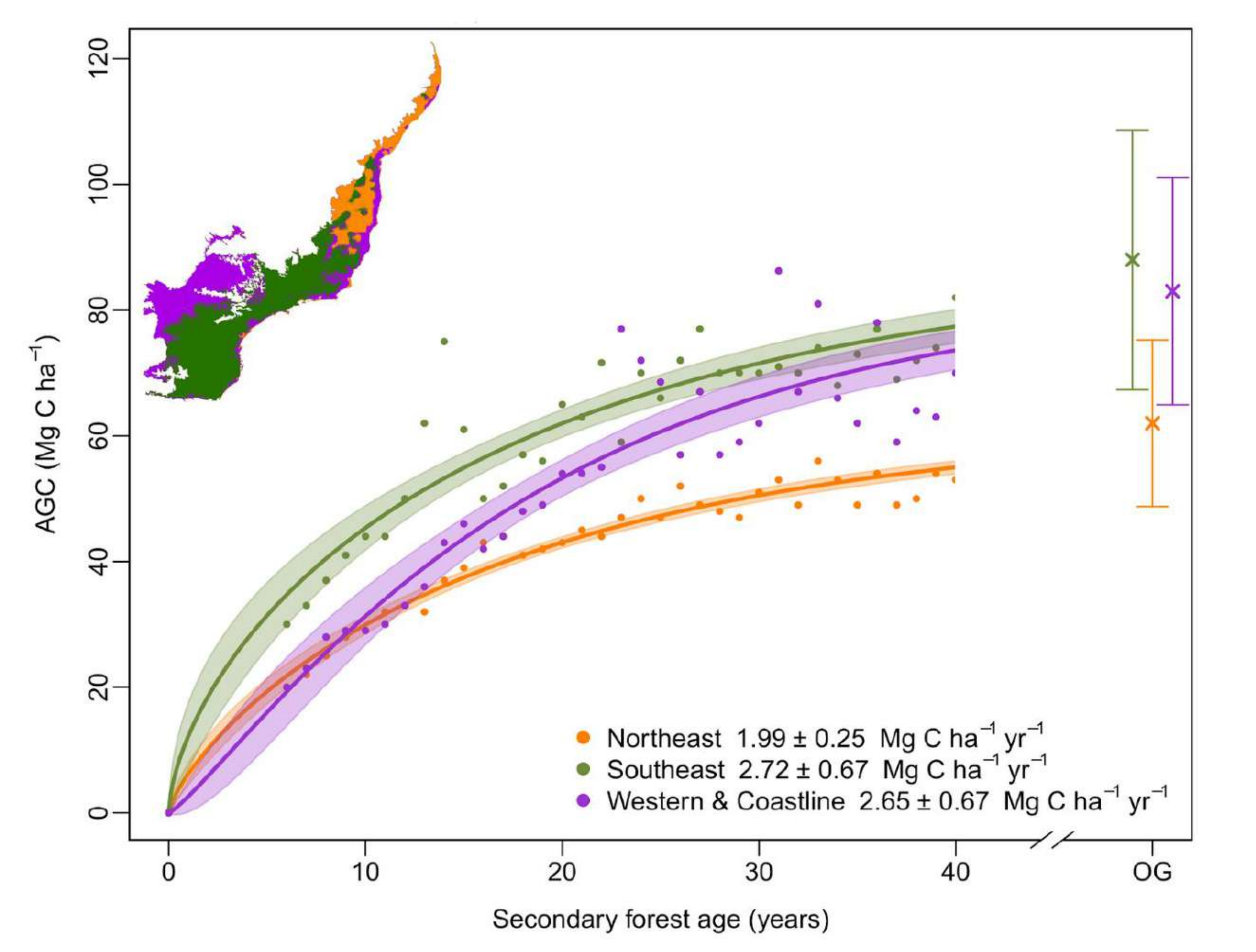
Results

Regions definition:

- MCWD (drought)
- Average maximum temperature
- Terrain slope

SE region (green) highest regrowth rates

- Greater fraction of old-growth forests
- Higher frequency of connected fragments



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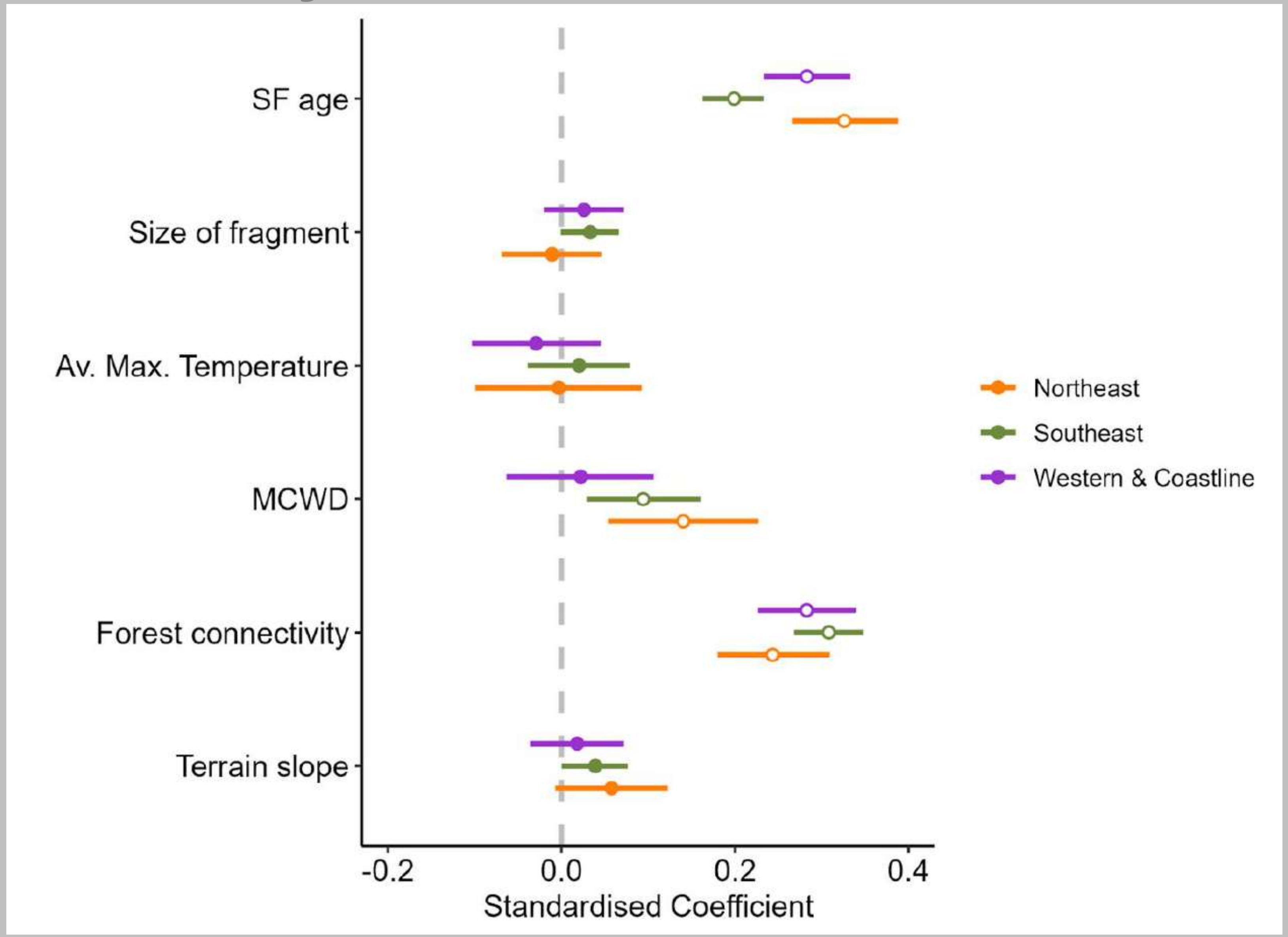
Results

Drivers of secondary forest AGC

- Multilinear analysis (GLS with spatial correlation structure)

“FOREST CONNECTIVITY WAS THE MAIN SIGNIFICANT DRIVER IN ALL REGIONS”



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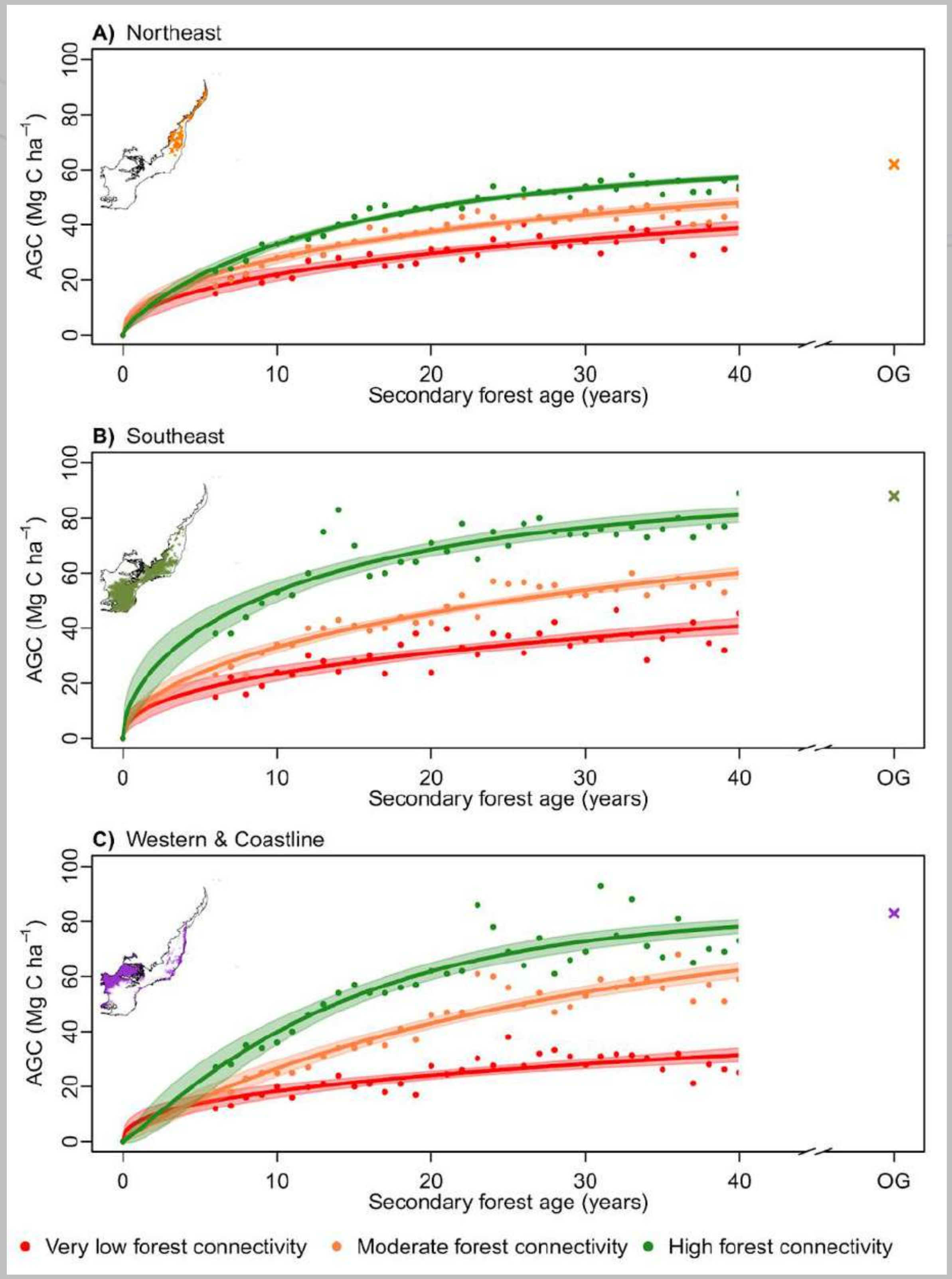
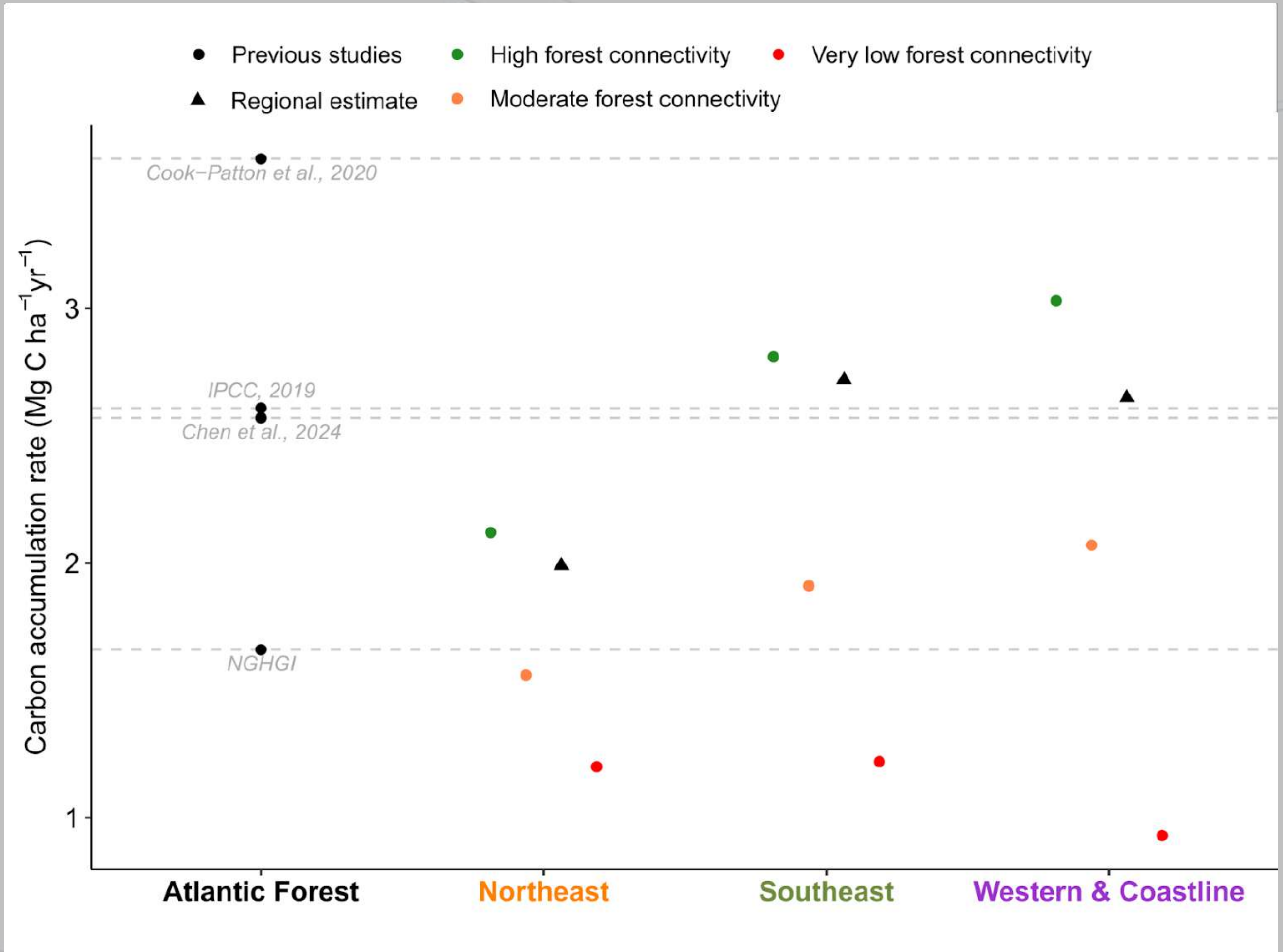
The role of landscape connectivity

W&C region: secondary forests within high-connectivity landscapes accumulate carbon at a rate more than **three times greater** than those in very low-connectivity areas (3.03 ± 0.81 Mg C ha^{-1} yr^{-1} vs. 0.93 ± 0.34 Mg C ha^{-1} yr^{-1})



Comparison of average regrowth rates (forest age <= 20 years) from this study and other literature estimates for the Atlantic Forest.



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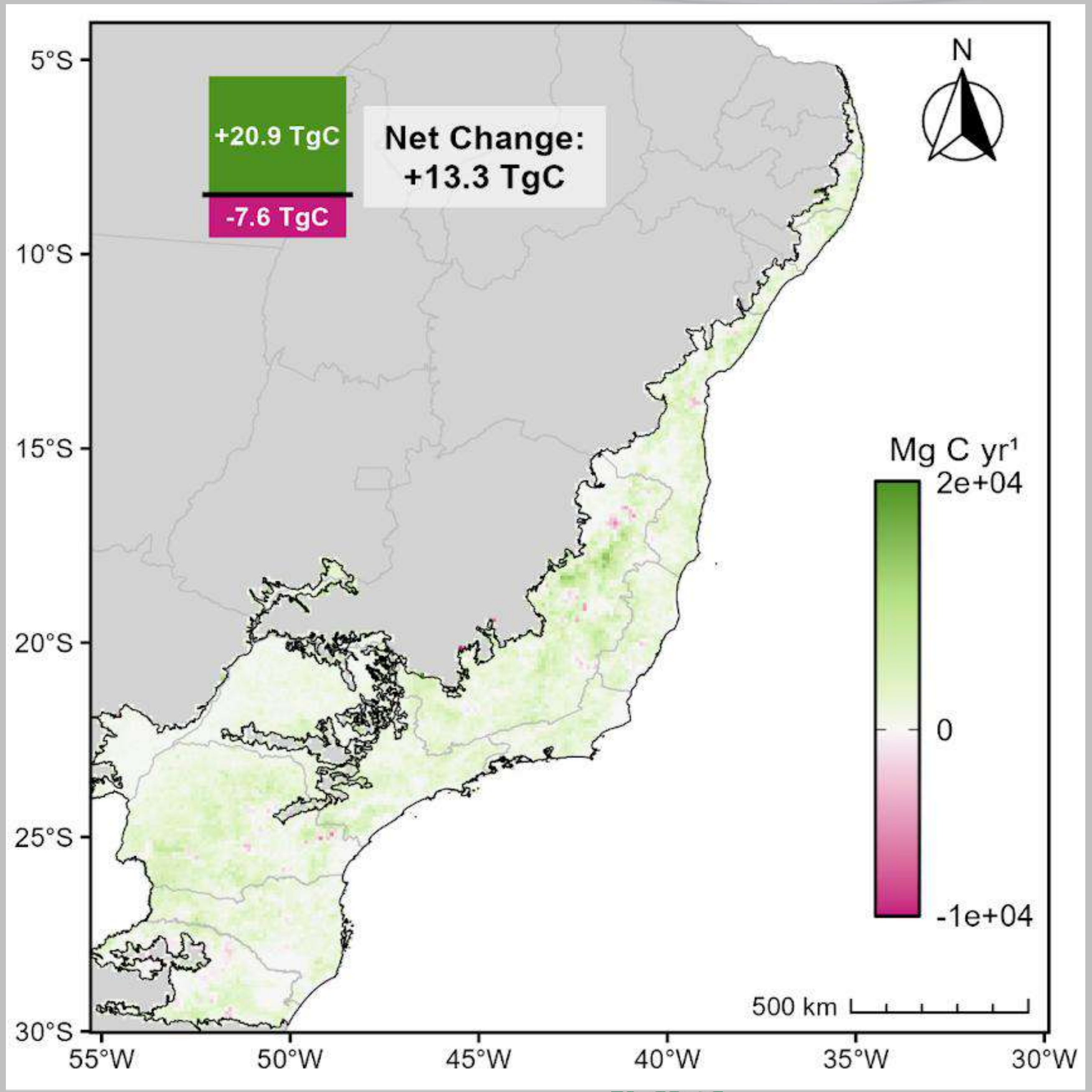
AGC of Secondary Forests

- Net aboveground carbon sink of secondary forests between 2019 and 2020 reached 13.3 TgC yr^{-1}

- Gross aboveground carbon emissions from old-growth forest loss in the Atlantic Forest was ~10.3 Tg C in 2020

- Despite this positive small net sink (3 Tg C in 2020) it is important to recognize that this apparent offset ***does not equate to broader ecological benefits***



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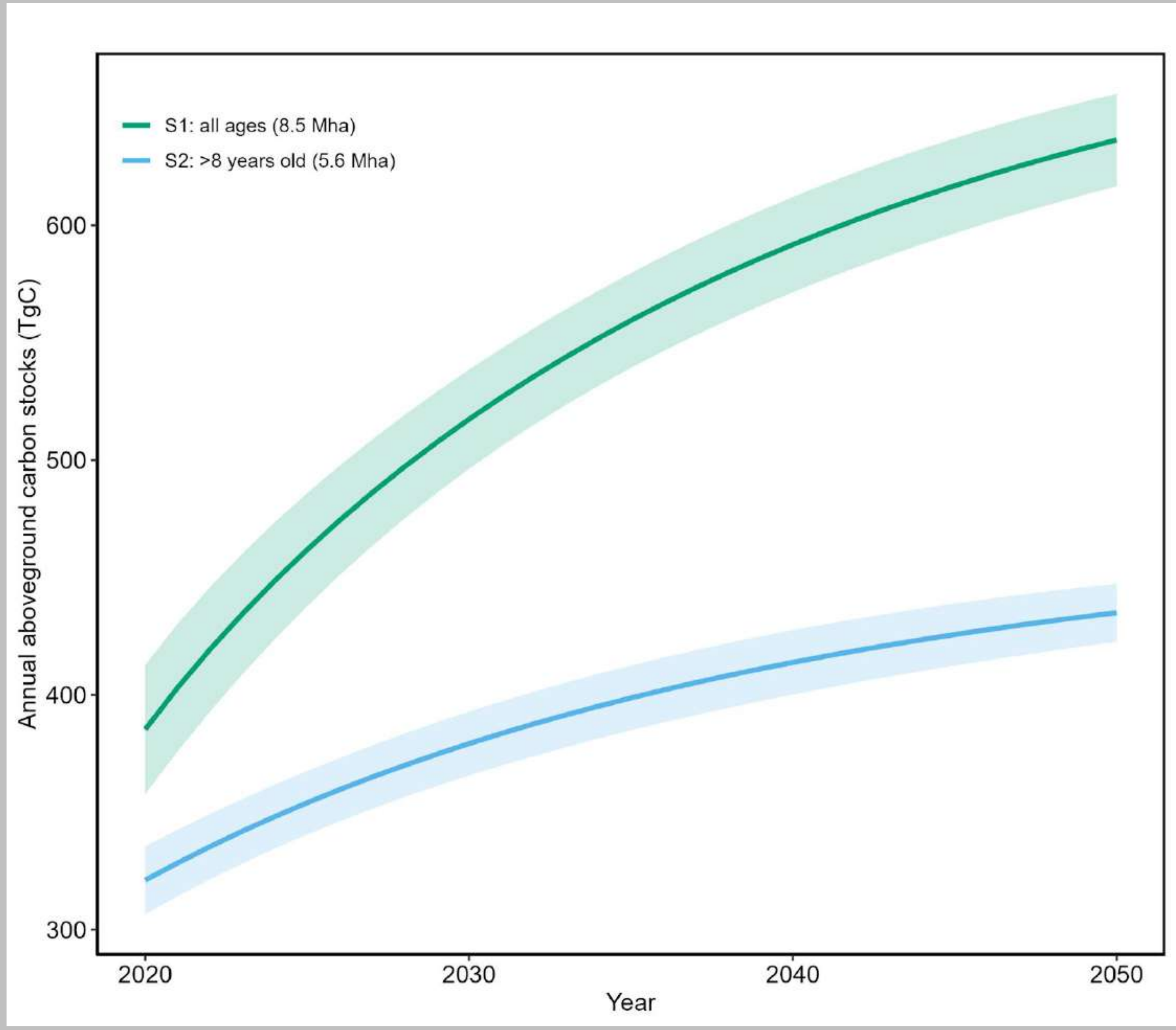
Carbon accumulation potential

- By 2030, projected carbon stocks under Scenarios 2 represent a reduction of approximately ***27%*** relative to Scenario 1. By 2050, this reduction increases to approximately ***32%***



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Take home messages

- Forest connectivity a key driver on aboveground carbon accumulation in the Atlantic Forest
- The higher regrowth rates observed in areas of higher forest landscapes connectivity align with ecological mechanisms that facilitate forest recovery e.g. seed dispersal, propagules, seed pool
- Restoration efforts should not only aim to expand forest cover but also improve connectivity between forest patches to optimize carbon sequestration, biodiversity recovery and conservation, and the long-term ecological functioning of regenerating forests.
- Strengthening conservation policies and law enforcement for all forests (old-growth and secondary) is essential to maximizing the contribution to Brazil NDC targets

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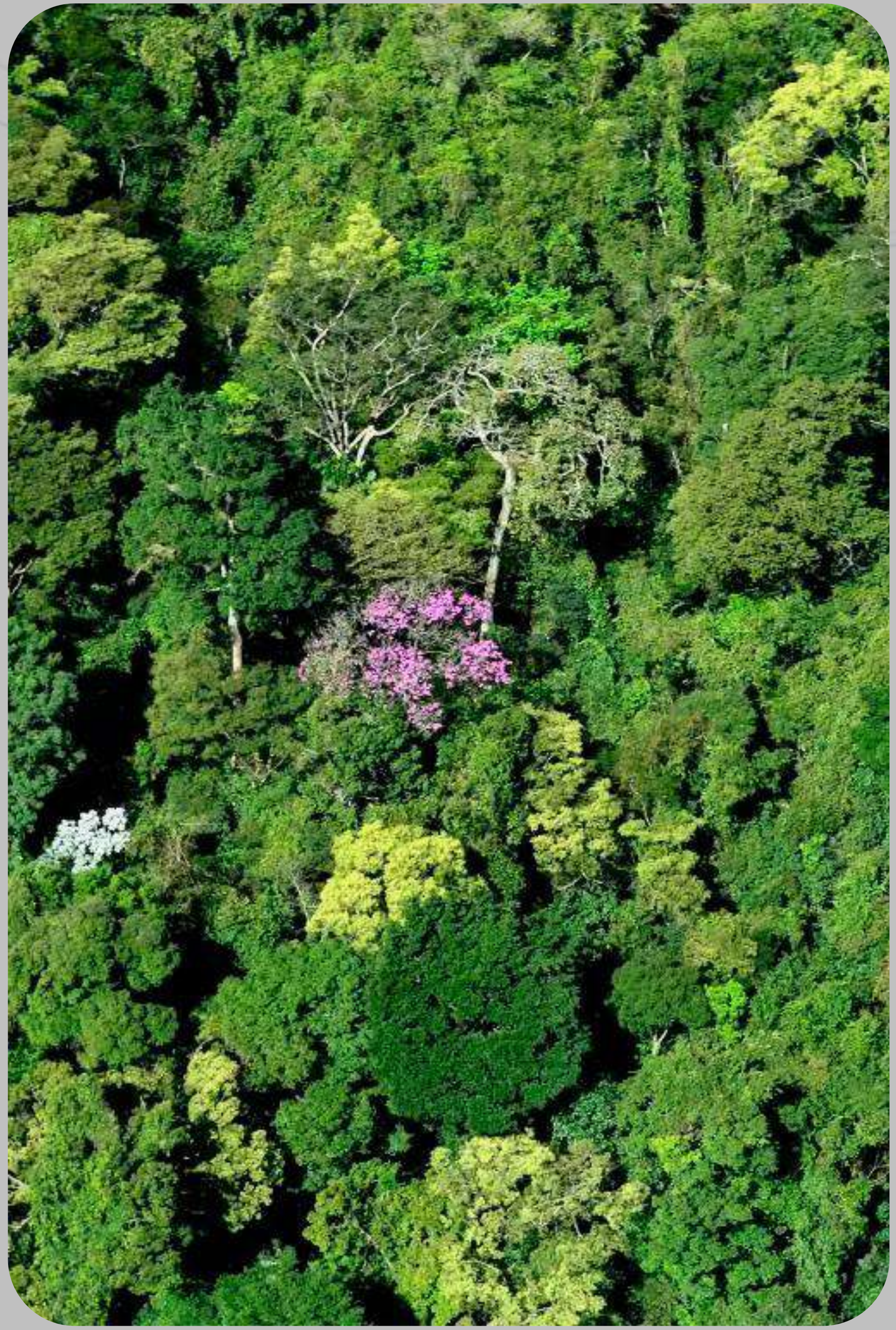
Thank You!
Obrigado!

T.Rosan@exeter.ac.uk



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Estimating Forest growth through multitemporal LiDAR and satellite imagery using deep learning approaches

Matheus Ferreira

Session 1.3: Linking field, ALS, and satellite data of secondary forest

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

(12:30-13:30) Lunch + Group Photo

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Session 1.4: Keynote address

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Forests and COP30

Thelma Krug

Session 1.4: Keynote address + group photo

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Forests and COP30

Thelma Krug
krugthelma@gmail.com

Workshop de Especialistas: síntese das emissões e remoções de carbono em florestas em regeneração no Brasil

INPE, São José dos Campos, 20-31 outubro 2025

November 17–18 elevate both planetary and community stewardship — centering on Forests, Oceans, and Biodiversity.

10 - 11/11	12 - 13/11	14 - 15/11	16/11	17 - 18/11	19 - 20/11	21/11
Mon | Tue	*Wed | Thu*	*Fri | Sat*	*Sunday*	*Mon | Tue*	*Wed | Thu*	*Friday*
Adaptation Cities Infrastructure Water Waste Local governments Bioeconomy Circular economy Science and technology Artificial intelligence	Health Jobs Education Culture Justice and Human rights Information integrity Global ethical stocktake Workers	Energy Industry Transport Trade Finance Carbon markets Non-CO2 gases		Forests Ocean Biodiversity Small and medium entrepreneurs Indigenous peoples Local and traditional communities Children and youth	Agriculture Food systems and food security Fisheries Family farming Women and Gender Afrodescendants Tourism	Closing

Tropical Forest Forever Facility (TFFF)

Tropical Forests Forever Facility (TFFF) , expected to be officially launched at COP30 proposes innovative financing model for conservation – it is a Brazil-led proposal that seeks to compensate countries for preserving tropical forests, with 20% of funds reserved for Indigenous peoples.

More than 70 developing countries with tropical forests will be eligible to receive funds from what could be one of the largest multilateral funds ever created.

“It is not a donation, but an initiative that operates according to market logic, leveraging private resources from public investments. For every dollar contributed by countries, it is expected to mobilize about four dollars from the private sector, creating a permanent trust fund. It is a new way of financing conservation, with shared responsibility and a vision for the future” (Marina Silva)

Tropical Forest Forever Facility (TFFF)

Besides Brazil, five tropical forest nations have joined: Colombia, Ghana, the Democratic Republic of Congo, Indonesia, and Malaysia.

In addition, five potential investor countries are helping shape the mechanism: Germany, the United Arab Emirates, France, Norway, and the United Kingdom.

The expectation is that investor nations will provide an initial contribution of USD 25 billion. With this injection, it should be possible to leverage an additional USD 100 billion (senior capital) from the private sector over the next few years. By accepting the role of junior capital, governments agree to take on a slightly higher risk than the private sector, thereby attracting these private investors.

Projections indicate that the mechanism should generate USD 4 billion annually for environmental preservation, which is nearly triple the amount invested globally in the protection of tropical forests through concessional resources.

Tropical Forest Forever Facility (TFFF)

HOW IT WORKS — The goal is for payments to be made from financial resources that are voluntarily invested in an investment fund to be created and maintained within the scope of the initiative. Resources from countries, sovereign funds, pensions, and other investors who make conservative investments, with good guarantees and low returns, are collected and invested in more profitable operations ensured by the TFFF.

Another innovation is to simplify monitoring and verification mechanisms — through advanced technologies such as satellite images — to monitor and estimate forest conserved areas. The model will respect each country's monitoring system, based on predefined criteria.

The mechanism's architecture also proposes that countries define national or sub regional programs to support nature; these will receive additional contributions. Among them are conserving protected areas, preventing and combating deforestation, promoting the bioeconomy, and guaranteeing financial resources for indigenous peoples and local communities that conserve tropical rainforests.

Tropical Forest Forever Facility (TFFF)

Alongside the TFFF, one of the Ministry of Finance's main proposals for COP30 is **creating a coalition of carbon credit markets**. While this mechanism would compensate actors that remove greenhouse gases from the atmosphere — such as through reforestation — the TFFF would pay sovereign states for keeping forests intact, creating complementarity.

The idea is for coalition members to establish a global emissions cap that would be gradually reduced. Brazil has already approved legislation regulating this market domestically, which is now in the implementation phase.

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National Productive Forests Program

The National Productive Forests Program (Plano Nacional de Florestas Produtivas/PNFP) will feature among the initiatives presented at COP30.

The program aims to restore degraded areas for productive use and encourage the environmental regularization of family farms, thereby increasing the production of healthy food and socio-biodiversity products.

Forest Finance Mechanisms: JREDD+, TFFF, and RDM

	JREDD+	TFFF	RDM
Object	Carbon credits from avoided deforestation	Hectares of standing forests	Credits from forest restoration carbon removals
Scope	Jurisdictional	Jurisdictional	Jurisdictional
Payments	Results-based	Results-based	Results-based
Incentives	Credits are paid against a baseline, usually computed as previously observed deforestation rates	Each deforested hectare cancels the payment of 100 hectares	Credits are computed on a net basis—carbon from forest restoration subtracted from emissions from deforestation
Potential scale	10 million hectares of yearly deforestation	1.27 billion hectares of tropical forests	186 million hectares deforested between 2001 and 2023 could be reversed
Potential carbon impact	3.77 $GtCO_2$ yearly lost	593 $GtCO_2$ stored in tropical forests in 2023	49 $GtCO_2$ of potential carbon capture in areas deforested in 2001-2023 if fully reversed
Potential revenue	Up to US$ 32 billion if all deforestation is halted	Around US$ 5 billion per year at US$ 4 per hectare of forest	Up to US$ 100 billion if implemented at full-speed with US$ 50 per ton of CO_2

Reversing Deforestation Mechanism (RDM)

Financing mechanism to drive large-scale forest restoration and transform the role of forests in the climate agenda. The RDM could generate up to US$ 100 billion in annual global revenue for countries with tropical forests.

PUC/Rio examined tropical forests in 91 countries, analyzing deforestation trends, forest cover, and restoration opportunities in each country. Together, these countries hold 1.27 billion hectares of tropical forests and store 593 Gt CO_2, approximately one-third of the world's historical emissions.

ESA's BIOMASS Mission

Frank Martin Seifert

Session 1.4: Keynote address + group photo

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Discussion: moving towards aligning field data and satellite estimates of forest extent & age

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Plenary: Feedback from discussions

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