Brazil’s National Forest Reference Emission Level for Results-based Payments for REDD+ under the United Nations Framework Convention on Climate Change

Modified submission

Brasilia, DF
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1. List of acronyms and glossary

AGB – above ground biomass: All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage - IPCC (2006)

AD – activity data: data on the magnitude of a human activity resulting in emissions or removals taking place during a given period of time. Data on land areas, management systems, fertilizer use are examples of activity data - IPCC (2006)

BGB – below ground biomass: All biomass of live roots. Fine roots of less than (suggested) 2mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter - IPCC (2006)

COEAM – **INPE's Amazon Space Coordination** (Portuguese acronym)

CCST – INPE's Earth System Science Center (Portuguese acronym)

EBA: Portuguese acronym for CCST Project "Improvement of biomass estimation methods and models of estimation of emissions by land use change"

EFCS: Enhancement of Forest Carbon Stocks

DIOTG – **INPE's Division of Earth Observation and Geoinformatics** (Portuguese acronym)

DW – **dead wood**: Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 10 cm in diameter (or the diameter specified by the country) - IPCC (2006)

DETER – INPE's Real-Time Deforestation Detection System (Portuguese acronym)

Disordered logging: for the purposes of this submission, disordered logging refers to logging activities in natural forest land that has a disordered (irregular) pattern, most likely from illegal logging activities

EF – **emission factor**: a coefficient that quantifies the emissions or removals of a gas per unit activity - IPCC (2006)

Forest Degradation: for the purpose of this submission, forest degradation refers to reduction of carbon stocks in forest land remaining forest land in the Amazon biome due to fire on managed forest land and disordered logging

FRA – Global Forest Resources Assessments

GTT MRV REDD+ – **Working Group of Technical Experts on REDD+ for MRV** (Portuguese acronym)

INPE – National Institute for Space Research (Portuguese acronym)

LI – **litter**: Includes all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for dead wood (e.g. 10 cm), lying dead, in various states of decomposition above or within the mineral or organic soil. This includes the litter layer as usually defined in soil typologies. Live fine roots above the mineral or organic soil (of less than the minimum diameter limit chosen for below-ground biomass) are included in litter where they cannot be distinguished from it empirically - IPCC (2006)

MMA - Ministry of Environment (Portuguese acronym)

MMU - Minimum mapping unit: the smallest size that determines whether a feature is captured from a remotely sensed image

NDVI – Normalized Difference Vegetation Index

PAMZ+ – Amazon and Other Biomes Monitoring Program (Portuguese acronym)

Phytophysiognomies: refer to the type of vegetation present in a given biome. In each biome or region that are predominant phytophysiognomies or vegetation

PRODES – INPE's Monitoring Program of the Brazilian Amazon Forest by Satellite (Portuguese acronym)

SINAFLOR – National System of Forest Products Origen Control (Portuguese acronym)

SRTM – Shuttle Radar Topography Mission

TACC – transparency, accuracy, completeness, and comparability

TerraClass – Land Use and Occupation Mapping System Project (Portuguese acronym)

2. Introduction

Brazil welcomes the opportunity to submit a **national forest reference emission level (FREL)** for a technical assessment under the United Nations Framework Convention on Climate Change (UNFCCC), in the context of results-based payments for reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+).

Brazil has indicated in previous submission that its national FREL would be the sum of the FRELs for each of its six biomes. This submission represents **Brazil's national FREL**.

Brazil underlines that the submission of FRELs and/or Forest Reference Levels (FRLs) and subsequent Technical Annexes to the Biennial Update Report (BUR) and Biennial Transparency Report (BTR) with REDD+ results attained are voluntary and exclusively for the purpose of obtaining and receiving results-based payments for REDD+ activities, pursuant to decisions 13/CP.19, paragraph 2, and 14/CP.19, paragraphs 7 and 8[1] and does not interfere with the Nationally Determined Contribution (NDC) submitted by Brazil to the Paris Agreement.

3. Information used in the construction of Brazil's national FREL

3.1. Brazil's biomes

Brazil's national FREL covers all six biomes in the country:

- **Amazon:** The Amazon biome is formed mainly by forest formations, with the occurrence of small enclaves of savanna and grassland formations. Considered the largest tropical forest in the world, the phytophysiognomies of the Amazon store a large amount of carbon (ARAGÃO et al., 2014).
- **Cerrado:** The second largest Brazilian biome, the Cerrado is characterized by a marked seasonal distribution of precipitation (with two well-defined seasons: dry and rainy), which results in vegetation adapted to water stress and fire conditions (RIBEIRO; WALTER, 2008). Cerrado phytophysiognomies present high environmental heterogeneity (natural grasslands, shrubs and forest formations), resulting in a high rate of endemism and species diversity, which, together with the strong conversion pressure on natural habitats, has placed the Cerrado among the hotspots global biodiversity (MMA, 2002)
- **Caatinga:** The main type of vegetation in the Caatinga is the steppe savanna, represented by different physiognomic formations (forested, arboreal, parks, grassy-woody) and contact formations, forming mosaics that are influenced by the local topography and geomorphology. Other phytophysiognomies occur in reduced areas (less than 15% of the biome), due to altitude and proximity to other biomes, such as

[1] Available at: https://unfccc.int/sites/default/files/resource/docs/2013/cop19/eng/10a01.pdf

the Atlantic Forest and the Cerrado (MCTI, 2015). The heterogeneity of the vegetation (LUETZELBURG, 1922-23; DUQUE, 1980; ANDRADE-LIMA, 1981) and the variability of rainfall and water stress give the biome high levels of diversity and endemism of fauna and flora (LEAL et al., 2005). In the Caatinga, the irregularity of the rains and the long periods of drought directly impact the survival of the population and agricultural production indices, and the accentuation of the desertification process is identified as one of its main vulnerabilities

- **Atlantic Forest:** The Atlantic Forest is mainly characterized by forest formations, although there are areas of fields, savannas, sandbanks and mangroves (Atlas dos Remanescentes Florestais da Mata Atlântica – technical report, 2019). The Atlantic Forest is also considered a biodiversity hotspot due to habitat loss and fragmentation, high rates of endemism and the large number of endangered species. Due to its history of use and occupation since the colonial period, it is the biome that has the lowest percentages of its original vegetation, despite the increase in regenerating areas (Fundação SOS Mata Atlântica/INPE, 2019). Much of the original area of the biome has given way to agricultural crops, development of industries, oil extraction centers, port areas and it is where most of the country's population live, placing the Atlantic Forest as responsible for 80% of the national GDP (IBGE, 2012).
- **Pampa:** The Pampa is mainly characterized by the presence of grassland formations, although there are forest phytophysiognomies (gallery forests) and rocky outcrops. Currently, approximately 51% of the original vegetation of the grasslands has been lost due to anthropic activities, occupation and economic use (HASENACK et al., 2007). Another point that highlights the uniqueness of the Pampa is related to the heterogeneity of characteristics due to the peculiarity of the vegetation, soils and geological and geomorphological conditions, hydrological aspects and climatic order (BOLDRINI et al., 2010).
- **Pantanal:** According to POTT & SILVA. (2016) and SILVA et al. (2021), nowadays it is recognized that the Pantanal Biome is composed of the intersection of four large phytoecological regions: Seasonal Deciduous Forest, Seasonal Semideciduous Forest, savanna (Cerrado), and Steppic savanna (Chaco). This Biome also contains elements of Ombrophylous Forest, typical of the Amazon. In addition, there are the floristic contacts and the pioneer (early successional) formations. The dynamics of flooding in the Pantanal is related to the precipitation of a large amount of water (between December and January) in the Central Plateau region of the Cerrado biome and its consequent flow to the floodplains, where it forms lakes, swamps and marshes, resulting in flooding of part of its extension (PADOVANI, 2017).

The area of each biome was defined according to the “Map of Biomes and Coastal-Marine System of Brazil” (IBGE, 2019), that have established new boundaries for the six Brazilian biomes, compatible with the scale of 1:250,000. Figure 1 presents the map with the geographical distribution of the Brazilian biomes, developed by IBGE, in 2019. Table 1 shows the geographic area covered by each biome, and the corresponding percentage contribution to the total national area (IBGE, 2019).

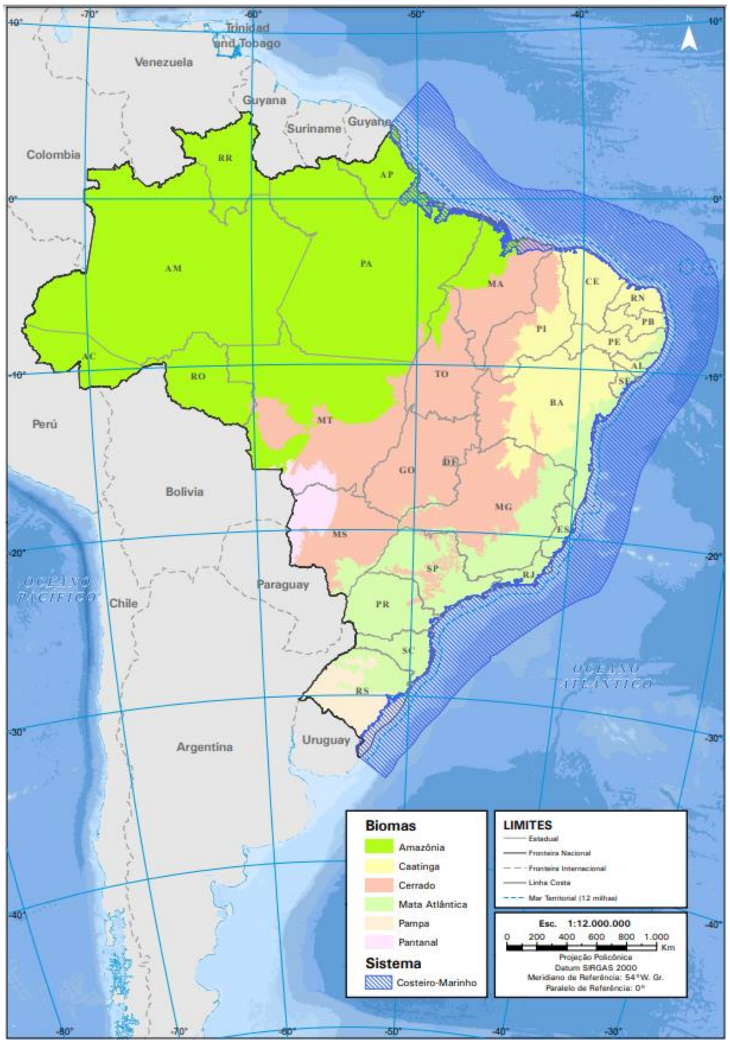

Figure 1 –Biomes and Coastal-Marine System Map of Brazil

OBS: Biomas = biomes / Amazônia = Amazon / Mata Atlântica = Atlantic Forest / Sistema Costeiro-Marinho = Marine-Coast System / Limites = Limits / Estadual = State / Fronteira Nacional = National boundary / Fronteira Internacional = International boundary / Linha Costa = Coastal line / Mar Territorial = Sea territory

Source: IBGE, 2019

Table 1 - Extent of the six Brazilian biomes and their relative contribution to the total national area

Biome	Area (ha)	Contribution to national area (%)
Amazon	421.274.200	49,5
Cerrado	198.301.700	23,3
Caatinga	86.281.800	10,1
Atlantic forest	110.741.900	13,0
Pampa	19.381.800	2,3
Pantanal	15.098.800	1,8

Biome	Area (ha)	Contribution to national area (%)
Total	**851.080.200**	**100**

OBS: please note that the area in Table 1 does not include the area of the coastal-marine system.

Source: IBGE, 2019 and Brazil, 2020

3.2. Forest definition

For the purpose of this submission, the **forest definition** adopted is the same as that used by Brazil in its latest GHG inventory (hereinafter referred to as "4th National GHG Inventory" - Brazil, 2020) and in its “Global Forest Resources Assessment - FRA” (FAO, 2020). The definition is reproduced below:

> "Minimum area of 0.5 hectares with trees of minimum height of 5 meters and minimum canopy coverage of 10 percent, or trees capable of reaching these limits in situ. Does not include areas predominantly used for agricultural or urban purpose”.

Forest area, as defined above, comprise those areas with predominance of tree species and a continuous or discontinuous canopy formation. Given this comprehensive definition, forest formations comprise various types of various phytophysiognomies in the different Brazilian biomes (Figures 2 to 7). Brazil’s national FREL adopts the official classification system for native vegetation of Brazil (NFMA - IBGE, 2012) and the categorization of these phytophysiognomies, whether forested or not, is consistent with the 4th National GHG Inventory and the FRA (**Table *2***). Please note that forest plantations (as presented in the FRA) are not included in this national FREL submission, that encompass only natural forests in its different phytophysiognomies.

Table 2 – Phytophysiognomies used in Brazil’s national FREL

4th National GHG Inventory	FRA	NFMA land use/cover classification	Vegetation typology	Phytophysiognomies	Initials
Forest (F)	Forest (F)	Evergreen Primary Forest	Open Humid Forest	Alluvial Open Humid Forest	Aa
				Lowland Open Humid Forest	Ab
				Ombrophilous Open Forest – Mountain	Am
				Sub-montane Open Humid Forest	As
		Decidual Primary Forest	Decidual Forest	Alluvial Decidual Seasonal Forest	Ca
				Lowland Deciduous Seasonal Forest	Cb
				Montane Deciduous Seasonal Forest	Cm
				Sub-montane Deciduous Seasonal Forest	Cs
			Dense Humid Forest	Alluvial Dense Humid Forest	Da
				Lowland Dense Humid Forest	Db

4th National GHG Inventory	FRA	NFMA land use/cover classification	Vegetation typology	Phytophysiognomies	Initials
		Evergreen Primary Forest		Montane Dense Humid Forest	Dm
				Sub-montane Dense Humid Forest	Ds
		Wooded	Steppes	Steppes	E
				Wooded Steppes	Ea
		Contact	Transition zone	Contact Steppes / Mixed Ombrophilous Forest	EM
				Contact Steppes / Seasonal Forest	EN
				Contact Steppes / Formations	EP
		Semi-deciduous Primary Forest	Semi-deciduous Primary Forest	Alluvial Semi-deciduous Seasonal Forest	Fa
				Lowland Semi-deciduous Seasonal Forest	Fb
				Montane Semi-deciduous Seasonal Forest	Fm
				Submontane Semi Deciduous Seasonal Forest	Fs
		Evergreen Primary Forest	*Campinarana*	*Campinarana*	L
				Forested *Campinarana*	La
				Wooded *Campinarana*	Ld
		Contact	Transition zone	Contact Campinarana / Ombrophilous Forest	LO
		Evergreen Primary Forest	Mixed Humid Forest	Alluvial Mixed Ombrophilous Forest	Ma
				Upper Montana Mixed Ombrophilous Forest	Ml
				Montane Mixed Humid Forest	Mm
				Sub-montane Mixed Ombrophilous Forest	Ms
		Contact	Transition zone	Contact Seasonal Forest / Mixed Ombrophilous Forest	NM
				Contact Seasonal Forest / Pioneer Formations – Specific for Pioneer Formation with Marine Influence (*Restinga*)	NP
				Contact Dense Ombrophilous Forest / Mixed Ombrophilous Forest	OM
				Contact Ombrophilous Forest / Seasonal Forest	ON
				Contact Ombrophilous Forest / Pioneer Formations – Specific for Pioneer Formation with Marine Influence (*Restinga*)	OP
		Evergreen Primary Forest	Pioneer Formation	Pioneer Formations Areas	P
				Pioneer Formation of Fluviomarine Influence (mangroves)	Pf
				Pioneering Formation of Marine Influence (sand banks)	Pm
		Primary Semi-deciduous Forest	Savanna	Savanna	S
				Wooded Savanna	Sa
		Wooded	Savanna	Forested Savanna	Sd
		Contact	Transition zone	Contact Savanna/ Mixed Ombrophilous Forest	SM
				Contact Savanna / Seasonal Forest	SN

4th National GHG Inventory	FRA	NFMA land use/cover classification	Vegetation typology	Phytophysiognomies	Initials
				Contact Savanna / Ombrophilous Forest	SO
				Contact Savanna / Savanna Steppes	ST
				Contact Savanna / Savanna Steppes / Seasonal Forest	STN
				Contact Savanna/Savanna Steppes	ST
		Primary Deciduous Forest	Savanna Steppes	Savanna Steppes	T
				Forested Steppe Savanna	Td
		Wooded	Savanna Steppes	Wooded Steppe Savanna	Ta
		Contact	Transition zone	Contact Savanna Steppes / Seasonal Forest	TN
Other woody areas (OFL)	Other woody areas (OFL)	Contact	*Campinarama*	*Campinarana* – shrub	Lb
		Evergreen Primary Forest	Palm Grove	Fluvial and/or lacustrine influenced Vegetation	Pa
		Wooded	Pioneer Formations	Upper Montane Refuges	Rl
				Montane Refuges	Rm
				Submontane Refuges	Rs
		Wooded Savanna	Savanna	Savanna – parque	Sp
			Savanna Est	Savanna Steppes – parque	Tp
Other land	Grassland (G)	Natural Grassland	Steppes	Steppes – Grassy-Woody	Eg
			Steppes	Steppes – Parque	Ep
			Campinarama	*Campinarana* – Grassy-Woody	Lg
			Savanna	Savanna – Grassy-Woody	Sg
			Savanna Estépica	Savanna Steppes – Grassy-Woody	Tg
			Rocks	Other Rock Outcrops	Ar
			Dunas	Dunas	Dn

Source: Brazil, 2020

Figure 2 – Pictorial representation of Lowland Open Ombrophilous Forest – Amazon biome

Source: FUNCATE / INPE

Figure 3 – Pictorial representation of Wooded Savanna – Cerrado biome

Source: FUNCATE / INPE

Figure 4 – Pictorial representation of Dense Ombrophilous Forest – Atlantic Forest biome

Source: FUNCATE WWF

Figure 5 – Pictorial representation of Contact Savanna / Seasonal Forest – Caatinga biome

Source: FUNCATE / INPE

Figure 6 – Pictorial representation of Lowland Semi-deciduous Seasonal Forest – Pampa biome

Source: FUNCATE / INPE

Figure 7 – Pictorial representation of Steppe Savanna – Pantanal biome

Source: FUNCATE / INPE

3.3. Managed forest land

Brazil has followed the IPCC's "managed land proxy" in all its national GHG inventories, as well as in this submission to determine the anthropogenic GHG emissions related to forest land.

According to the 4th National GHG inventory, **managed forest lands** include those occurring within protected areas (Conservation Unit - UC or Indigenous Lands - TI) and **unmanaged forest lands** are those occurring outside protected areas and where human action did not cause significant changes in its characteristics. Forest lands were classified based on the map of past natural vegetation considering different phytophysiognomies (as explained in the below section).

Based on the above definition, Brazil has included in this FREL submission:

i) emissions from deforestation and forest degradation (selective logging and forest fires) in forest land remaining forest land, including emissions in including in demarcated indigenous lands and protected areas regulated by domestic legislation which cover approximately 50% of the forest land in the Amazonia biome;

ii) Removals form enhancement of forest carbon stocks in secondary forests in areas previously deforested.

The focus of Brazil is on processes related to all natural forests and hence, forest plantations are not included in the FREL, although they are considered in the National GHG Inventory.

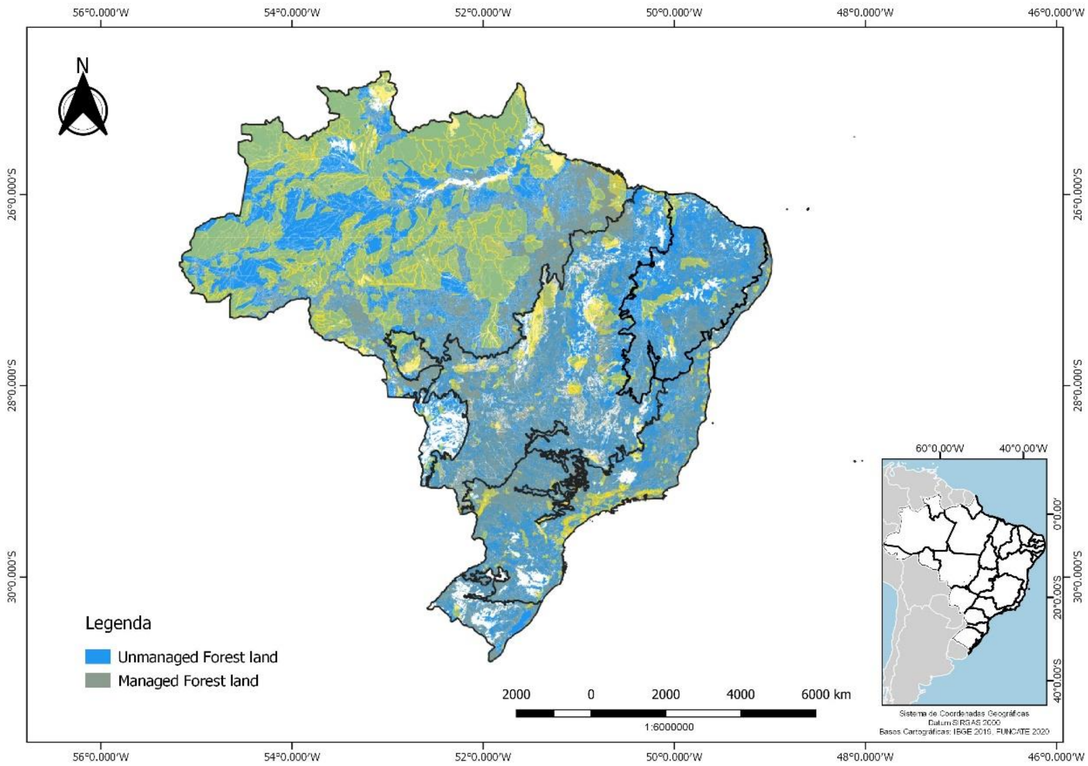

Figure 8 – Managed and unmanaged Forest land

Source: Brazil, 2020

3.4. Ancient native vegetation map and biomass data

The ancient native vegetation map used in this submission, for the purpose of phytophysiognomies identification (classification) was the same as that used in the context of the 4th National GHG Inventory (***Figure 9***). The map shows phytophysiognomies according to the IBGE classification system and the categories – forest or not forest – according to the 2020 "Global Forest Recourses Assessment - FRA". See **Box 1** for a brief description of the methodology applied to develop the "ancient native vegetation map".

Estimates of biomass stocks for the Amazon were extracted from EBA. In particular, the carbon content of selected carbon pools for different phytophysiognomies (i.e., mean values were extracted for each deforestation and degradation polygon, which are presented in **Table *4***).

EBA was developed by the Earth System Science Center from the National Institute of Space Research (CCST/INPE, for the acronym in Portuguese - see **Box 2** for a brief description of "EBA").

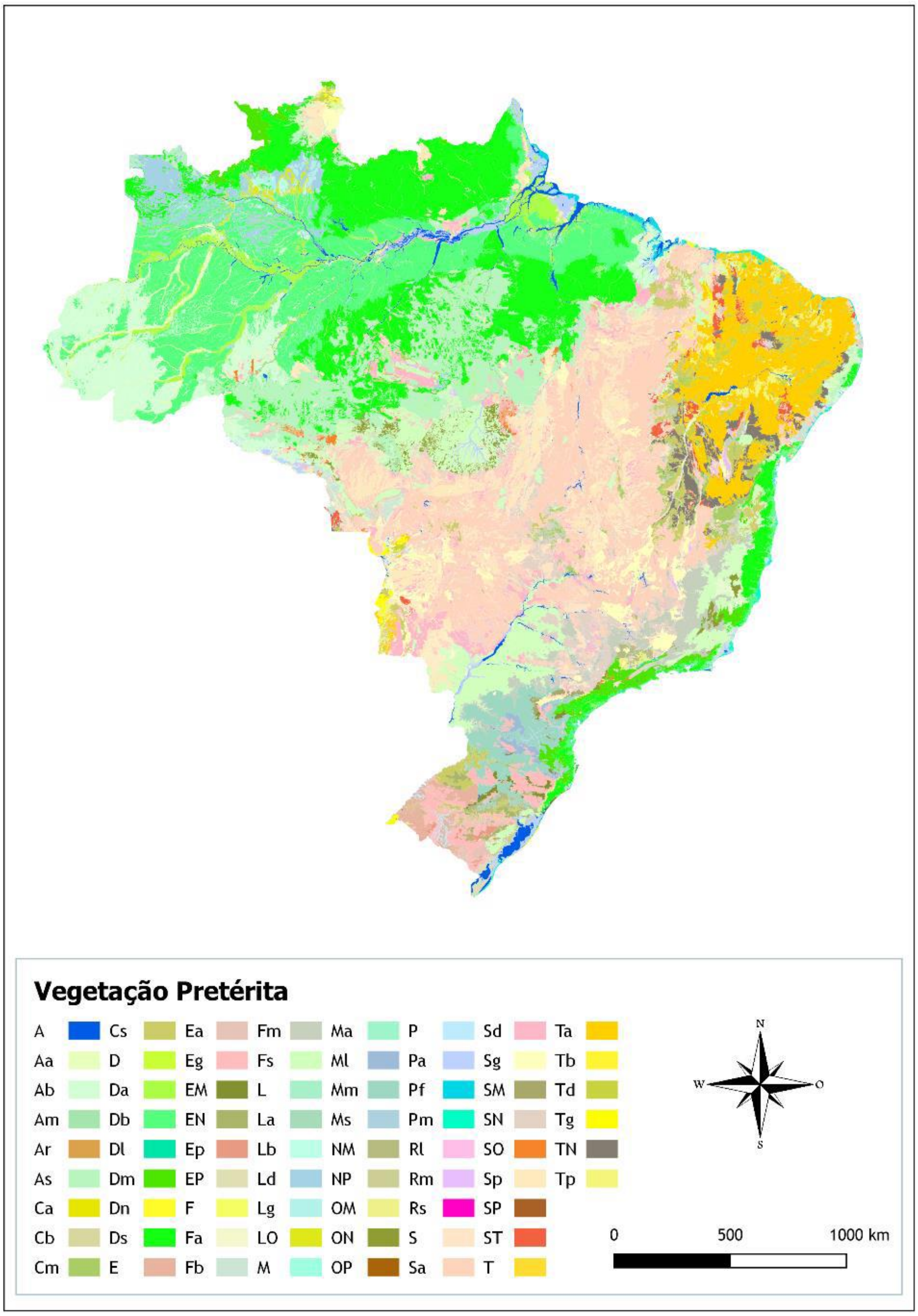

Figure 9 – Ancient native vegetation map

Source: Brazil, 2020

Box 1 – Brief description of the methodology applied to develop the "ancient native vegetation map"

"The 4th National GHG Inventory had a more up-to-date and accurate basis for the development of a map of ancient natural vegetation (i.e., distribution and classification of the various phytophysiognomies, disregarding the intervention and human occupation) for all Brazilian biomes. This basis was the result of the vegetation map provided by IBGE (2017), with adjustments made by the Brazilian Forest Service (SFB, for the acronym in Portuguese) for the anthropized areas (Brazil, 2019); comparisons with the map of natural vegetation used in the 3rd National GHG Inventory (MCTI, 2015 and Brazil, 2016); and details of predominant phytophysiognomies using secondary databases, as described below.

To verify the compatibility between the maps produced by IBGE, the SFB and the 3rd National GHG Inventory, analysis of the intersection between these maps was conducted, resulting in a single shapefile consisting only of the common areas among them. Subsequently, the phytophysiognomies classes, described in the Technical Manual of Brazilian Vegetation (IBGE, 2012), were associated.

For some of the areas currently anthropized, the SFB classified the phytophysiognomies only in relation to the dominant class. Therefore, for the 4th National GHG Inventory it was decided to cross-reference this information with other environmental databases to obtain a more detailed classification. For example, to classify the alluvial forests, hydrological data from the National Water Agency[2] were used, by identifying polygons with fluvial influence and cross-checking them with watercourses and artificial water masses vector files. To classify phytophysiognomies in relation to altitude, the 4th National GHG Inventory used the altitude data of Shuttle Radar Topography Mission - SRTM (NASA, 2019).

Thus, the ancient natural vegetation map of the 4th National GHG Inventory is the result of a combination of sources and processing of geospatial data from different maps from IBGE (2017), SFB and the 3rd National GHG Inventory (MCTI, 2015 and Brazil, 2016)".

Source: Brazil, 2020

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[2] Available at: http://metadados.ana.gov.br/geonetwork/srv/pt/main.home?uuid=2fb4464c-fc83-41d0-b63a-d020395a4a99

Box 2 – Brief description of EBA[3]

"The Earth System Science Center from the National Institute for Space Research (CCST/INPE) aims at supporting and directing research to improve the accuracy of biomass and carbon estimation in the Amazon biome. Ometto et al. (2014) compared some of the biomass maps available for the region and concluded that there are significant differences between them. Nevertheless, the carbon stock estimated by the different methodologies can be considered similar due to the high uncertainty of the estimated values. Consequently, this uncertainty is propagated to the estimated carbon dioxide emissions of the country.

Given the differences found in the biomass maps available for the Brazilian Amazon and the uncertainties associated with the methods that enabled their estimation, the CCST/INPE sought to invest in technologies that could contribute to the reduction of these uncertainties.

Studies indicate that, in addition to the use of forest inventory data, airborne laser data (ALS, acronym in English) can contribute to the increase of the sampled area and make it possible to extract metrics about the structure and height of the forest canopy (ASNER et al., 2012; ASNER & MASCARO, 2014).

Thus, the CCST/INPE, with the support of the Amazon Fund, from the National Development Bank (BNDES for the acronym in Portuguese), implemented a project referred to as "Improvement of biomass estimation methods and models for the estimation of emissions from land use change".

The aero survey covered transects with a width of 300 m and length of 12.5 km (375 ha), with no overlap between the flight ranges. Initially, the transects were randomly selected within forest areas of the Amazon biome, disregarding areas mapped by PRODES (2014), but considering secondary forest areas identified by TerraClass (2012). Some of these transects were directed to cover areas with forest inventory plots.

In the flight campaign, data from 417 transects (***Figure 10***) were collected, covering 156,522 ha".

[3] More information is available (in Portuguese) at: http://www.ccst.inpe.br/projetos/eba-estimativa-de-biomassa-na-amazonia/

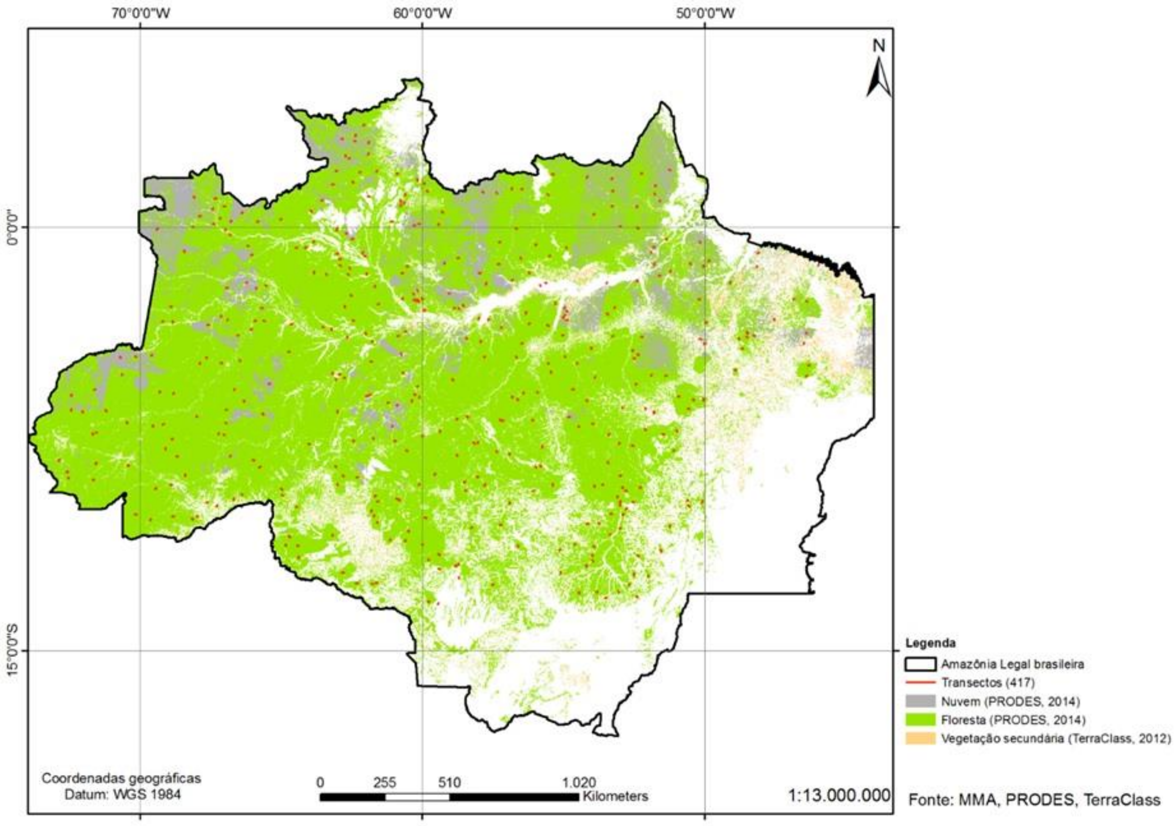


Figure 10 – Transects distribution from the first ALS campaign in red

Source: EBA (accessed on accessed on December 30, 2022)

3.5. Pools, gases, and activities included in Brazil's national FREL

The following table summarizes the carbon pools, greenhouse gases (GHG) and REDD+ activities included in the national FREL. Exclusions and/or omissions and future potential improvements are explained in subsequent sections.

Table 3 – Pools, gases and activities included in Brazil's national FREL

<table>
<tr><th>Biome/information</th><th>Amazon</th><th>Cerrado</th><th>Caatinga</th><th>Pantanal</th><th>Atlantic forest</th><th>Pampa</th></tr>
<tr><td rowspan="4">REDD+ activities</td><td colspan="6">Deforestation
(Minimum mapping unit of 1 hectare)</td></tr>
<tr><td>Degradation
(Minimum mapping unit of 3 hectare)</td><td colspan="5">Not included</td></tr>
<tr><td>Enhancement of forest carbon stocks</td><td colspan="5">Not included</td></tr>
<tr><td colspan="6"><u>Not included in this submission:</u></td></tr>
</table>

<table>
<tr><th>Biome/information</th><th>Amazon</th><th>Cerrado</th><th>Caatinga</th><th>Pantanal</th><th>Atlantic forest</th><th>Pampa</th></tr>
<tr><td></td><td colspan="6">Conservation of forest carbon stocks
Sustainable management of forest</td></tr>
<tr><td rowspan="4">Carbon pools</td><td colspan="6">Above-ground biomass (AGB)</td></tr>
<tr><td colspan="6">Below-ground biomass (BGB)</td></tr>
<tr><td colspan="6">Litter (LI)</td></tr>
<tr><td colspan="6">Dead wood (DW)</td></tr>
<tr><td rowspan="3">GHG</td><td colspan="6">CO_2</td></tr>
<tr><td colspan="2">CH_4</td><td colspan="4">Not included</td></tr>
<tr><td colspan="2">N_2O</td><td colspan="4">Not included</td></tr>
</table>

The **definition of deforestation** adopted by the National Policy on Climate Change refers to the conversion of natural areas to other land-use categories. For the purpose of this submission and consistent with previous FRELs submissions, the definition of deforestation is more restrictive. It only includes the **conversion (clear-cut) of native forest phytophysiognomies into other land use categories (non-forest land)**. "Edge effects" were not considered when estimating emissions from deforestation, since the polygons of deforestation encompass only areas where clear cut was identified.

Different estimates of deforestation could be found in the literature for each biome and are not necessary consistent/comparable with the deforestation estimates used in this submission, for a number of reasons, including:

1. Inclusion of changes in planted forests (not included in this submission) as deforestation;
2. Use of different sensors and minimum mapping unit; and
3. Different approaches from "clear-cut" used for defining deforestation; and
4. Different definitions of forests and its boundaries.

The deforestation activity data (deforestation areas) are obtained from the **PRODES Program**[4]. Additional information related to the deforestation activity data used in this submission can be found in section 8.1.

For the Amazon and Cerrado biomes, emissions from deforestation are **net emissions**, i.e., they are the result of the difference between the gross emissions from deforestation and the carbon stocks in the land use category "post-deforestation event" (i.e., Cropland or Grassland).

Enhancement of forest carbon stocks was estimated for the Amazon biomes based on **removals from the natural regeneration of areas previously deforested (secondary**

[4] More information is available (in Portuguese) at: http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes (Accessed November 9, 2022)

vegetation). Data to estimate removals were obtained from the **TerraClass Project**[5] [6]. Additional information regarding secondary vegetation data can be found in section 8.3 and **Box 4**.

In Brazil, deforestation in the Amazon and Cerrado is typically followed by biomass burning ("slash and burn" - **Figure *11***). Therefore, non-CO_2 emissions for Amazon and Cerrado biomes were considered in the construction of the national FREL.

Figure 11 – "Slash and burn" process typically used in the deforestation of the Amazon and Cerrado

Source: INPE

Presently, there is not a single **definition of forest degradation** applied in the country, nor the identification of all potential drivers of forest degradation (e.g., fire, logging, invasive species, etc.). Due to lack of a complete database related to all potential drivers, for the purpose of this submission Brazil assumes forest degradation as the **reduction of carbon stocks in forest land remaining forest land** in the Amazon biome due to fire on managed forest land and disordered logging[7].

[5] More information (in Portuguese) is available at: https://www.terraclass.gov.br/geoportal-aml/ (Accessed November 9, 2022)

[6] More information (in Portuguese) is available at: https://www.terraclass.gov.br/geoportal-aml/ (Accessed November 9, 2022)

[7] Is worth to recall that in previous submissions Brazil have presented information regarding degradation, including " preliminary thoughts" developed by the GTT-MRV (refer to Annex III of " Brazil's submission of a Forest Reference Emission Level (FREL) for reducing emissions from deforestation in the Amazonia biome for REDD+ results-based payments under the UNFCCC from 2016 to 2020", available at: https://redd.unfccc.int/files/frelc_modifiedversion_correction2019.pdf). The "definition" presented for the purpose of this submissions, have taken into consideration previous information presented, as well as, progress made in INPES' monitoring system (i.e., DETER), in order to implement a pragmatic approach to allow the GHG emissions estimation initially for the Amazon biome. Brazil recognize that further consideration is required, in particular to identify and quantify GHG emissions from other degradation drivers in all Brazilian biomes.

Degradation activity data were available at INPE's **DETER Program**[8]. Additional information related to forest degradation data is provided in section 8.2.

Box 3 – Brazilian main monitoring programs relevant to this submission

The activity data related to deforestation and forest degradation (deforestation and forest degradation areas) used in this submission for all Brazilian biomes derive from the **Amazon and Other Biomes Monitoring Program (PAMZ+**, for the acronym in Portuguese) developed by the Earth Observation and Geoinformatics Division (DIOTG, for the acronym in Portuguese) at the Amazon Space Coordination (COEAM, for the acronym in Portuguese) at the National Institute for Space Research (INPE). PAMZ+ has three operational systems to monitor land use and land cover and corresponding changes through satellite images with different temporal and spatial resolutions:

1. **Satellite Monitoring Program of the Brazilian Amazon Forest (PRODES):** since 1988, PRODES monitors the advance of deforestation in the Legal Amazon, being considered the most important tropical forest monitoring program in the world. Currently, the program was expanded and systematically monitors the annual loss of primary vegetation in all the Brazilian biomes. PRODES uses Landsat-like images (NASA/USGS), called "Landsat class" images, which ranges in spatial resolution from 20-30 meters and have at least three available spectral bands (green, red, and infra-red) within the electromagnetic spectrum. PRODES currently uses images from Landsat-8, SENTINEL-2 (European Union), and CBERS-4/4A (INPE/CRESDA, Brazil/China). In forestlands, PRODES identifies polygons of deforestation caused by clear-cut. In other phytophysiognomies, such as grasslands and savanna-like biomes, PRODES identify only polygons of complete removal of natural vegetation. Specialists map these polygons through visual photointerpretation using the TerraAmazon software. PRODES is an incremental system and identifies deforestation polygons which area is greater than 1 ha. To improve PAMZ+ data dissemination, INPE has developed an online portal (TerraBrasilis - http://terrabrasilis.dpi.inpe.br) that aggregates PRODES and DETER data.

2. **Near Real-Time Deforestation Detection System (DETER**): DETER, launched in 2004, is an surveillance support system that quickly maps deforested and degraded areas within forest formations in the Brazilian Legal Amazonia. Since 2015, DETER uses images from the WFI sensor onboarding CBERS-4, CBERS-4A/INPE, and Amazônia-1/INPE satellites (56-64 meters of spatial resolution). Photointerpreters map deforestation and forest degradation using color composites satellite images in addition to soil and shadow fraction images generated through Linear Spectral Mixture Models (LSMM), which highlight, respectively, image features related to selective logging and burning scars. Forest cover patterns identification in images are based on five main elements: tonality, color, form, texture, and context. Alerts from DETER are divided into two groups: the first refers to deforestation classified as either: (a) deforestation with exposed soil; (b) deforestation with vegetation; and

[8] More information is available (in Portuguese) at: http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/deter/deter (Accessed November 9, 2022)

(c) mining (Figure 4.2); the second group embraces degradation alerts classified as either: (a) degradation; (b) selective geometric logging; (c) selective logging; and(d) forest fire scar. DETER identifies polygons which area is greater than 3 ha.

3. **Land Use and Occupation Mapping System Project (TerraClass):** Terraclass project was launched in 2010, firstly in the Legal Brazilian Amazon and since 2020 in the Cerrado biome, with the aim of qualifying deforestation identified by PRODES project. Through visual interpretation of color composites and application of remote sensing techniques (such as Linear Spectral Mixture Models, segmentation, cloud detection and threshold slicing) to Landsat satellite images (30 m of spatial resolution), Terraclass classifies areas identified as deforestation into the following thematic classes: primary forest, secondary forest, silviculture, cultivated pasture on shrubland, cultivated pasture on herbaceous land, perennial agricultural crop, semi-perennial agricultural crop, temporary agricultural crop, mining, urban areas, 'others', not observed area, current year deforestation, non-forest vegetation, and hydrography within the Brazilian Legal Amazon. In the Cerrado, deforestation is qualified as primary forest, secondary forest, silviculture, cultivated pasture, perennial agricultural crop, semi-perennial agricultural crop, one cycle temporary agricultural crop, over one cycle temporary agricultural crop, mining, urban areas, other edified areas, others, not observed, annual deforestation, and hydrography. Terraclass has as minimum mapping area of 4 ha for both Amazon and Cerrado. The project aims to generate land use and land cover data every two years. Currently, TerraClass data are available for 2004, 2008, 2010, 2012, and 2014 for the Brazilian Legal Amazon and 2018 for the Cerrado Biome.

The systems are complementary and are designed to meet different objectives.

3.5.1. Descriptions of changes to previously submitted forest reference emission levels and/or forest reference

Paragraphs 11 and 10 of decision 12/CP.17, respectively, point out that a subnational FREL may be developed as an interim measure during the transition to a national FREL; and that a stepwise approach to a national FREL may be appropriate, allowing the Parties to improve submissions over time by incorporating more up-to-date data, refining methodologies and, where appropriate, including additional pools and activities.

The main changes included in this submission and that are detailed in the sections to follow are:

1. Inclusion of all 6 Brazilian biomes;
2. Inclusion of forest degradation in the Amazon biome;
3. Inclusion of enhancement of forest carbon stocks in the Amazon biome;
4. Estimation of net emissions from deforestation in the Amazon and Cerrado biomes;
5. Change in the biome's geographical boundaries using the most recent official data (IBGE, 2019);

6. Use of a minimum mapping area (MMU) of 1 hectare for the identification of deforestation polygons in all Brazilian biomes;
7. Reference period calculated using 5 years[9]; and
8. Inclusion of uncertainties analysis.

The status of the "areas for future improvements" identified in the reports of the technical assessment carried out in previous Brazilian submissions are provided in section 8.9.

3.5.2. Potential future improvements

In previous FREL submissions Brazil have presented subnational FRELs for the Amazon and Cerrado biomes[10]. In this submission Brazil have incorporated more up-to-date data and refined methodologies to submit a national FREL, that cover 100% of its national territory. The FREL has been developed based on the average net GHG emission estimates for Amazon and Cerrado biomes and the average gross GHG emissions for the remaining four Brazilian biomes considering the five annual periods (from 2016-2017 to 2020-2021).

Nevertheless, is important to clarify that due to its large territorial extension and forest diversity within the different biomes, it was not possible yet to include in this submission all REDD+ activities, and to estimate emissions and removals for all GHGs and all carbon pools for all biomes.

In this submission, Brazil has included uncertainty estimates for all data input and all emissions and removals results. However, it was not possible to use country specific uncertainty values for many of the emission and removal factors and other parameters. For these, uncertainty values derived from the 2006 IPCC Guidelines default values have been used. Plans for future submissions include the development of country specific uncertainty estimates for carbon content for all carbon pools in all biomes and phytophysiognomies, as already done for the Amazon biome, and country specific uncertainty estimates for the parameters used in the natural regeneration and degradation calculations (e.g. biomass growth yearly rate, combustion factor).

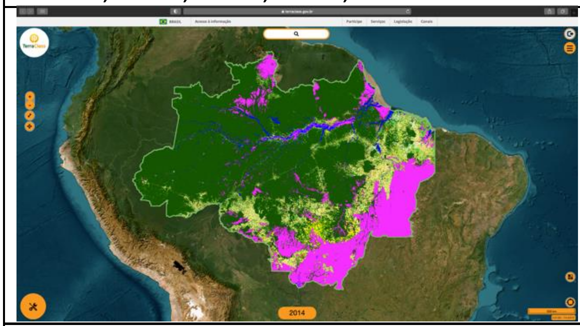
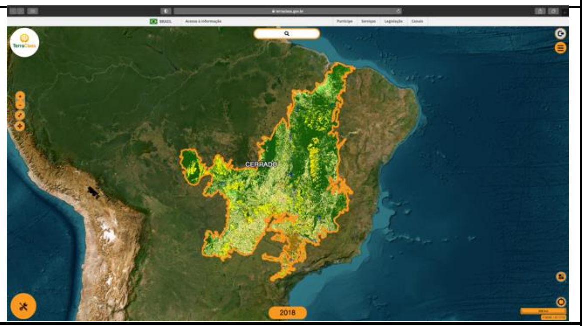
In the following boxes a justification for the non-inclusion of the soil carbon pool in the construction of the national FREL (**Box 8**) is provided, as well as an explanation of the challenges faced to estimate emissions from forest degradation from fire in managed land in the Cerrado biome (**Box 5**); from fire in forest managed land in other biomes (**Box 6**); degradation from regular selective logging (**Box 7**); and removals from natural regeneration (**Box 4**) for all biomes except Amazonia.

[9] The choice of a reference period of 5 years considered data availability, particularly with regard to DETER and forest degradation in the Amazon, and current requirements in the landscape for REDD+ results-based finance, which tend to favor reference periods not greater than 10 years (e.g., GCF scorecard), as well as reference periods as close as possible to the present and to the years a country intends to have its results measured. The choice of starting year and extent of the reference period aims to better position Brazil for accessing current REDD+ financing opportunities.
[10] Available at: https://redd.unfccc.int/submissions.html?country=bra

Box 4 – Enhancement of forest carbon stocks (EFCS)

EFCS, in this submission, refers to the annual increase in biomass from natural regeneration of areas previously deforested (**secondary vegetation growth**) and has been estimated for the Amazon biome, using data from **TerraClass Project**.

TerraClass Project was initiated in 2010 in the Amazon biome with the aim to understand the dynamics of land cover/use "post deforestation event" in the Amazon region; and to provide relevant information to allow governments at different levels to develop, for instance, policies for sustainable agricultural production, preservation of national biodiversity and maintenance of environmental services quality. In 2015, the Project was expanded to the Cerrado biome. Nowadays, secondary vegetation maps are available only for a few selected years, as indicated below:

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

Source: TerraClass

[11] More information (in Portuguese) is available at: https://www.terraclass.gov.br/geoportal-aml/ (Accessed November 9, 2022)
[12] More information (in Portuguese) is available at: https://www.terraclass.gov.br/geoportal-aml/ (Accessed November 9, 2022)

The fact that TerraClass does not provide a complete annual information prevented the estimation of removals for each single year of the reference level period. Hence, in the construction of the national FREL, a linear annual biomass growth was assumed for all years of the reference period, based on the average carbon removals (tonne of C per hectare per year) in the areas of secondary vegetation identified for the Amazon biome, as presented in the 4^{th} National GHG Inventory (additional information in section “Estimation of Brazil’s national FREL”).

Pending on additional resources for TerraClass Project, Brazil plans to estimate specific annual removals from secondary vegetation for all biomes and for each single year in future submissions.

Box 5 – Degradation due to fire in managed forest land in the Cerrado

INPE's **"Queimadas" Program**[13] uses images of low (1km) from MODIS program to monitor "fire spots" in the entire country. For each "fire spot" identified, a $1km^2$ buffer area is created to provide an approximate estimate of the "total burned area". This estimate does not correspond to the "burned area scar" since not necessarily all the vegetation included in the buffer zone might have been affected by the fire.

Presently, on an experimental basis, the "Queimadas Program" is using 30m spatial resolution data to monitor both "fire spots" and "burned area scars" in the Cerrado biome based on data from Thematic Mapper (TM) and Operational Land Imager (OLI) onboard satellites LANDSAT 5 and LANDSAT 8, assuming a maximum of 10% cloud cover. The "burned area scars" have been identified using a semi-automatic algorithm and the multi-temporal change between images (Melchiori, 2014). The results of the local evaluation depend not only on the classifier algorithm, but also on the data used as a reference. Therefore, it is essential that reference data are reliable and cover the same study period. There is no guarantee that this experimental initiative using medium spatial resolution will have continuity. Besides that, only results for years 2018 and 2019 are available.

As an example of the experimental initiative just mentioned, this box provides estimates of GHG emissions using "burned area scars" generated by INPE's Queimada Monitoring Group.

Period	Emissions from forest degradation due to fire in managed forest land in the Cerrado biome (tonnes CO_2eq)
2017-2018	29,718,968
2018--2019	60,925,571

Source: own elaboration

For the Amazon biome, the "burned area scars" derive from visual interpretation of DETER data that allows then to estimate emissions from forest degradation due to fire. Unfortunately, the DETER system has not been developed for the Cerrado biome preventing the same approach used for Amazonia to extend to the Cerrado.

The situation regarding the identification of forest degradation by fires is then the following: (1) "burned area scars", instrumental to estimate GHG emissions from fire, is not available through the national coverage 1km x 1km spatial resolution data provided by

[13] More information (in Portuguese) is available at: https://queimadas.dgi.inpe.br/queimadas/aq1km/ (Accessed November 9, 2022)

MODIS; and (2) “burned area scars” available through the ongoing experimental initiative at INPE might not have continuity in the short/medium term.

Considering these and the possibility that “burned area scars” data might not be available for future results, impacting the consistency between the national FREL and the results in the BUR Technical Annex, it was decided not to include GHG emissions from forest degradation due to fire in managed forest land occurring in the Cerrado biome.

Pending on additional resources for INPE's “Queimadas” Program, Brazil plans to include these emissions in future submissions.

Box 6 – Degradation due to fire in managed forest land in other biomes (and non-CO_2 emissions)

According the INPE´s "Queimadas" Program data the burned areas in each biome and each year of the reference period are provided in the table below. The table also includes the relative contribution (%) of each biome to the total annual area burned.

Year / Biome burned area (km²)	Amazon	Caatinga	Cerrado	Atlantic Forest	Pampa	Pantanal	Total (annual)
2016	65,139 (23%)	33,309 (12%)	151,142 (54%)	18,608 (7%)	1,527 (1%)	11,245 (4%)	280,970
2017	91,240 (30%)	29,704 (10%)	158,352 (52%)	16,260 (5%)	1,608 (1%)	9,829 (3%)	306,993
2018	43,171 (25%)	25,432 (15%)	85,374 (50%)	13,295 (8%)	615 (0%)	3,094 (3%)	170,981
2019	72,450 (23%)	55,184 (17%)	148,211 (47%)	19,405 (6%)	1,396 (0%)	20,833 (7%)	317,479
2020	77,396 (25%)	30,453 (10%)	139,644 (45%)	17,928 (6%)	6,113 (2%)	40,606 (13%)	312,140
2021	45,585 (17%)	49,869 (18%)	137,631 (50%)	20,876 (8%)	1,228 (0%)	19,219 (7%)	274,408

Source: https://queimadas.dgi.inpe.br/queimadas/aq1km/

The absolute values of the burned areas were obtained using 1km x 1km spatial resolution data but, as mentioned before, they do not necessarily represent the "burned area scars". From the table it is clear that the biome most affected by fires in the Cerrado biome (annual average of 49.5%), followed by the Amazonia biome (annual average of 24%); for the Caatinga biome, the annual average is 13.6%, whereas for Atlantic Forest, Pampa and Pantanal biomes, the annual averages are 6.7%, 0.5% and 6%, respectively. Amazonia and the Cerrado biomes comprise, on average, almost 75% of the area burned in the reference period.

Besides the areas burned in Atlantic Forest, Pampa and Pantanal being much smaller than those in Amazonia and Cerrado, for these biomes and for the Caatinga, the total carbon stock is also comparatively smaller and the potential impact on the GHG emissions is not expected to be large. This is one of the justifications of why forest degradation due to fire is not included in the estimates of the average annual emissions in these biomes.

A graphical representation of the data in the table is presented in the figure below.

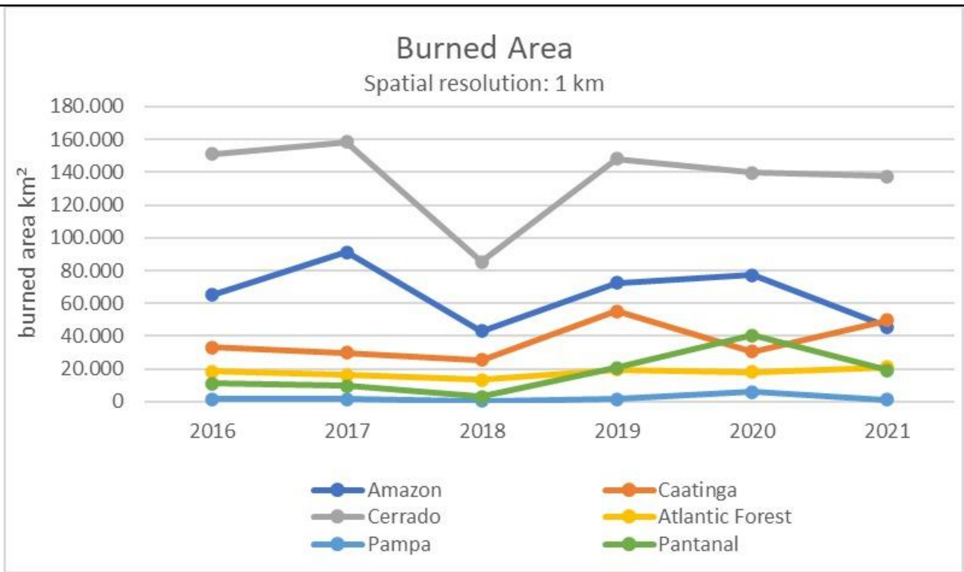


Figure 12 – Burned area per biome

Source: "Queimadas" Program

In addition, is worth to mentioning that not all fires occur in forest managed land and not all fires generate "burned area scars", as already indicated. The following figure provide examples of forest fires in dense forest areas.

Figure 13 – Examples of forest fires in dense forest areas

Source: INPE

From the above figure, it can be seen that fires affect mainly the lower portions of the canopy but depending on its intensity, it may also propagate to higher levels. When the higher levels of the canopy are not reached, the area affected by the fire will hardly leave a scar that can be identifiable in orbital images. Therefore, this submission does not include GHG emissions from degradation due to fire in managed forest land expect for the Amazon biome.

Preliminary estimates indicate that GHG emissions due to fire degradation in the Cerrado, affecting managed forest lands, may reach magnitudes of 45,6 M tCO_2eq per year (29,9 M tCO_2eq in 2017-2018 and 60,9 M tCO2eq in 2018-2019).

Pending on additional resources for the INPE's “Queimadas” Program, Brazil plans to further assess the significance of these emissions and if proved significant include these emissions in future submissions.

Box 7 – Decrease in carbon stocks due to orderly logging

DETER System maps changes in forest cover due to timber extraction considering “disordered selective cutting” (Type 1) and “orderly selective cutting” (Type 2).

In the estimates of emissions from forest degradation, the changes in carbon stocks decrease from “orderly selective cutting” (regular logging) were not included in the construction of this FREL, since the orderly pattern it is associated with activities under sustainable management plans.

The **National System of Forest Products Origin Control (SINAFLOR**, for the acronym in Portuguese)[14] is in the process of including in its database all approved sustainable management plans (including their geographic coordinates). In the absence of this information, it was not possible to identify among which of the “orderly selective cutting” areas were associated with approved sustainable management activities or not. In this submission it was assumed that all “orderly selective cutting” were associated with approved sustainable management plans, and hence not considered as forest degradation. Brazil plans to revise such classification, in future submissions, once the SINAFLOR database is fully available and fully validated. In the meantime, Brazil considers that the approach taken is a valid part of the stepwise approach. A "precise time plan" for using SINAFLOR data can't be indicated at this point in time, due to uncertainties regarding financial support to complete and validate SINAFLOR database.

Nevertheless, decreases in carbon stocks in areas associated with “orderly selective cutting” (regular logging) were considered in cases where these areas were subject subsequently to other activities (forest fires or deforestation).

It is worth noting that the shapefiles, used in this submission (see “Activity data vectorial files (shapefiles”) contain data on changes in forest cover due to “orderly selective cutting” (regular logging); but only the data related to “disordered selective cutting” (irregular logging) have been used to estimate forest degradation emissions, due to the rationale explained above.

[14] More information is available (in Portuguese) at: http://www.ibama.gov.br/sinaflor (Accessed on November 9, 2022)

Box 8 – Soil carbon

Soil Organic Carbon (SOC) was not included in the construction of the national FREL based on the following rationale:

(1) Normally, the largest changes in SOC result from the conversion of forest land to other land-use categories (e.g., Cropland, Grassland). In this submission, the identification of the land-use category post deforestation was not made, and hence there would be high uncertainties associated with the SOC changes estimates.
(2) The 4th National Inventory indicates that SOC contributed only with 2.5% to the total net emissions in the LULUCF sector during the period 2010-2016 (Brazil, 2020). The reference report of the 4th Inventory provides details about the methodology used to estimate SOC emissions, following the IPCC 2006 Guidelines and presents for each type of land use/land cover conversion the change factors used.

Considering the low contribution of SOC to the total LULUCF emissions and considering that this submission is national, it was decided that SOC would not have a significant contribution to the national FREL and hence was not considered.

3.6. Amazon biome

3.6.1. Activity data

As explained in section “Pools, gases, and activities included in Brazil’s national FREL”, the activity data used for the Amazon biome (deforestation areas, degradation areas – fire and selective logging and natural regeneration areas) were obtained from PRODES, DETER and TerraClass, respectively.

3.6.2. Emission factors

Thirty-six (36) forest phytophysiognomies are present in the vegetation map of the Amazon biome, the most abundant ones being *Submontane Dense Ombrophilous Forest* (Ds) and *Lowland Dense Ombrophilous Forest* (Db). **Table *4*** presents the average, minimum and maximum values of carbon stocks for each carbon pool considered per forest phytophysiognomies. For each type of forest phytophysiognomies, the total stock corresponds to the sum of the individual carbon stocks for the four carbon pools included: above ground biomass (AGB), below ground biomass (BGB), dead wood (DW) and litter (LI).

Table 4 – Forest phytophysiognomies considered in the Amazon biome and respective carbon stocks per carbon pool (average and ranges - in tC/ha)

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
Aa	Alluvial Open Ombrophilous Forest	90.45	9.93	7.37	5.16	112.91
		(0 - 142.65)	(0 - 113.98)	(0 - 13.34)	(0 - 16.31)	(0 - 205.91)
Ab	Alluvial Lowland Ombrophilous Forest	97.61	10.05	7.92	5.62	121.20
		(0 - 143.82)	(0 - 194.66)	(0 - 13.52)	(0 - 19.85)	(0 - 286.24)
Am	Montane Open Ombrophilous Forest	99.51	30.85	9.35	3.99	143.70
		(63.34 - 139.27)	(19.64 - 43.17)	(5.95 - 13.09)	(2.54 - 5.59)	(118.55 - 201.12)
As	Sub-montane Open Ombrophilous Forest	74.78	8.97	6.12	4.26	94.13
		(0 - 161.38)	(0 - 434.74)	(0 - 14.17)	(0 - 19.89)	(0- 594.72)
Cb	Lowland Decidual Seasonal Forest	37.28	77.24	2.11	2.44	119.07
		(4.8 - 75.2)	(4.77 - 251.17)	(0.19 - 4.1)	(0.34 - 5.25)	(23.87 - 290.83)
Cs	Sub-montane Decidual Seasonal Forest	67.15	7.94	5.44	3.94	84.47
		(1.84 - 139.27)	(0.18 - 164.75)	(0.08 - 13.09)	(0.11 - 16.31)	(2.85 - 261.23)
Da	Alluvial Dense Ombrophilous Forest	75.64	22.40	7.01	3.20	108.25
		(0 - 150.03)	(0 - 257.45)	(0 - 14.1)	(0 - 48.23)	(0 - 372.97)
Db	Lowland Dense Ombrophilous Forest	92.41	28.69	8.67	3.74	133.51
		(0 - 190.35)	(0 - 251.55)	(0 - 17.89)	(0 - 56.9)	(0 - 422.15)
Dm	Montane Dense Ombrophilous Forest	80.60	25.34	7.56	3.28	116.78
		(0 - 125.02)	(0 - 156.81)	(0 - 11.75)	(0 - 10.17)	(0 - 271.85)
Ds		86.24	26.20	8.07	3.52	124.03

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
	Sub-montane Dense Ombrophilous Forest	(0 - 199.12)	(0 - 461.28)	(0 - 18.72)	(0 - 29.25)	(0 - 604.11)
Fa	Alluvial Semi-deciduous Seasonal Forest	44.77	7.41	3.68	2.49	58.35
		(0 - 121.91)	(0 - 242.02)	(0 - 13.41)	(0 - 10.5)	(0 - 324.98)
Fb	Lowland Semi-deciduous Seasonal Forest	53.33	7.20	4.29	3.08	67.90
		(1.88 - 104.82)	(0.19 - 247.71)	(0.1 - 8.54)	(0.11 - 9.21)	(2.33 - 330.23)
Fm	Montane Semi-deciduous Seasonal Forest	101.21	10.12	8.20	5.84	125.37
		(92.83 - 106.69)	(9.28 - 10.67)	(7.52 - 8.64)	(5.36 - 6.16)	(114.99 - 132.16)
Fs	Sub-montane Semi-deciduous Seasonal Forest	55.96	6.56	4.48	3.24	70.24
		(0 - 139.27)	(0 - 245.67)	(0 - 13.09)	(0 - 16.31)	(0 - 324.98)
L	*Campinarana*	28.08	23.76	1.59	6.74	60.17
		(4.7 0 103.02)	(1.46 - 171.02)	(0 - 4.68)	(0.19 - 55.93)	96.79 - 328.91)
La	Wooded *Campinarana*	74.37	96.50	7.70	5.75	184.32
		(0 - 162.15)	(0 - 204.73)	(0 - 15.24)	(0 - 41.72)	(0 - 337.23)
Ld	Forested *Campinarana*	74.69	10.07	6.09	4.48	95.33
		(0 - 139.27)	(0 - 118.17)	(0 - 13.09)	(0 - 39-89)	(0 - 266.28)
LO	Contact *Campinarana* / Ombrophilous Forest	95.66	17.31	8.11	5.19	126.27
		(0 - 139.27)	(0 - 169.11)	(0 - 13.09)	(0 - 8.65)	(0 - 270.91)
ON	Contact Ombrophilous Forest / Seasonal Forest	47.9	5.47	3.93	2.89	60.19
		(1.18 - 139.27)	(0.12 - 113.98)	(0.1 - 13.09)	(0.07 - 16.31)	(1.16 - 201.12)
ONs	Contact Ombrophilous Forest / Seasonal Forest	68.71	15.41	5.73	7.68	97.53
		(13 - 73.3)	(1.3 - 17.45)	(1.05 - 6.13)	(0.75 - 8.63)	(13.2 - 105.51)
ONts	Contact Ombrophilous Forest / Seasonal Forest	27.02	2.7	2.19	1.56	33.47
P	Pioneer Formation	118.82	36.94	11.2	4.76	171.72
		(62.08 - 128.28)	19.94 - 39.77)	(6.02 - 12.06)	(2.45 - 5.15)	(19.24 - 185.26)
Pf	Pioneer Formation with fluvial and/or lacustrine influence	30.74	9.91	3.14	0.59	44.38
		(0 - 133.92)	(0 - 39.77)	(0 - 12.06)	(0 - 7.73)	(0 - 185.26)
S	Savanna	42.6	49.64	1.83	2.38	96.45
		(8.17 - 90.87)	(0.82 - 115.06)	(0.08 - 8.54)	(0.47 - 4.35)	(7.79 - 174.68)
Sa	Wooded Savanna	49.44	74.31	1.43	3.06	128.24
		(0 - 139.27)	(0 -273.26)	(0 - 14.01)	(0 - 20.69)	(0 - 416.33)
Sd	Forested Savanna	64.55	15.6	6.85	9.67	96.67
		(0 - 158.6)	(0 - 270.38)	(0 - 17.45)	(0 - 25.77)	(0 - 446.46)
SN	Contact Savanna / Seasonal Forest	45.55	8.7	3.61	2.81	60.67
		(0 - 106.55)	(0 - 162.65)	(0 - 11.05)	(0 - 16.31)	(0 - 238.09)
SNm	Contact Savanna / Seasonal Forest	40.54	19.74	4.64	7.1	72.02
SNs	Contact Savanna / Seasonal Forest	63.61	17.3	5.62	7.89	94.42
		(8.32 - 73.3)	(0.83 - 21.55)	(0.67 - 6.13)	(0.48 - 8.63)	(14.25 - 105.51)
SNts		50.95	12.79	4.53	5.78	74.05

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
	Contact Savanna / Seasonal Forest	(2.95 - 71.97)	(0.3 - 2011)	(0.24 - 6.07)	(0.17 - 8.57)	(0.01 - 104.15)
SO	Contact Savanna / Ombrophilous Forest	60.25	16.55	5.62	3.32	85.74
		(0.94 - 139.27)	(0.21 - 130.29)	(0.09 - 13.09)	(0.06 - 16.31)	(1.36 - 201.12)
SOs	Contact Savanna / Ombrophilous Forest	55.52	22.11	6.15	8.63	92.41
		(41.49 - 97.59)	(21.52 - 23.89)	(4.76 - 10.31)	(732 - 12.57)	(75.09 - 142.78)
SP	Contact Savanna / Pioneer Formation – Specific for Pioneer Formation com Marine Influence (*Restinga*)	13.71	45.79	0.54	0.96	61
		(10.81 - 16.01)	(36.11 - 53.48)	(0.42 - 0.63)	(0.76 - 1.12)	(48.1 - 71.24)
ST	Contact Savanna / Savanna Steppes	39.38	67.64	2.39	2.52	111.93
		(2.82 - 75.2)	(4.16 - 251.17)	(0.11 - 5.82)	(0.2 - 5.25)	(14.64 - 290.83)
Td	Forested Savanna Steppes	31.62	50.88	3.45	3.35	89.3
		(8.74 - 94.26)	(1.06 - 156.48)	(0.86 - 10.37)	(0.61 - 10.15)	(13.78 - A74.56)
TN	Contact Savanna Steppes / Seasonal Forest	39.88	14.82	3.15	2.4	60.25
		(27.4 - 65.98)	(4.77 - 25.36)	(2.02 - 5.34)	(1.75 - 3.81)	(59.07 - 78.32)

OBS: AGB – above ground biomass / BGB – below ground biomass / DW – dead wood / LI – litter

Source: EBA raster

OBS: Is worth to note that the values presented in table 23 of the 4th National GHG Inventory (Brazil, 2020) differ from the values presented in this table, even if both the inventory and the FREL use EBA values. The values in this table were extracted directly from the EBA raster file considering each deforestation polygons and hence, they are values that represent "activity data level". In the 4th National GHG Inventory, table 23 values represent the "biome level".

Other emission factors and parameter used to estimate GHG emissions and removals in the Amazon biome are presented in the following table.

Table 5 – Other emission factors and parameters used in the Amazon biome

Emission factor	Value	Unit	Source
Combustion factor (C_f)	0.368	Dimensionless	Table 49 (Brazil, 2020) – value for the Amazon biome
Emission factor (G_{ef}) CH_4	6.8	g/kg dry matter (d.m.)	Table 2.5 (IPCC, 2006) – values for Tropical Forest
Emission factor (G_{ef}) N_2O	0.2	g/kg dry matter (d.m.)	
Carbon content	0.47	tonne C/tonne d.m.	IPCC, 2006
AGB “loss factor” CS1	- 29	%	Table 30 (Brazil, 2020) - these values are relative to the remaining biomass and represent the most updated peer-reviewed estimates currently available in Brazil
AGB “loss factor” CS2	- 27	%	
AGB “loss factor” CS3	- 26	%	
AGB “loss factor” CS4	- 22	%	
Carbon removal from secondary vegetation growth	3.03	tonne C/ha year	Table 29 (Brazil, 2020) – removal factor considering secondary forest recovery following pasture land

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

OBS: CS – disordered logging.

3.7. Cerrado biome

3.7.1. Activity data

As explained in section "Pools, gases, and activities included in Brazil's national FREL", activity data (deforestation areas) for the Cerrado biome were obtained from PRODES.

3.7.2. Emission factors

Thirty-three (33) forest phytophysiognomies are present in the vegetation map of the Cerrado biome, the most abundant one being the Wooded Savanna (Sa). ***Table 6*** presents the forest phytophysiognomies considered in the Cerrado biome, for the construction of the FREL, and the respective carbon stocks for each carbon pool. For each type of forest phytophysiognomies, the total stock corresponds to the sum of the individual stocks of the four carbon pools included: above ground biomass (AGB), below ground biomass (BGB), dead wood (DW) and litter (LI).

Table 6 – Forest phytophysiognomies considered in the Cerrado biome and respective carbon stocks (tC/ha)

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
Aa	Alluvial Open Ombrophilous Forest	117.29	11.73	9.5	6.77	145.3
Ab	Alluvial Lowland Ombrophilous Forest	133.9	13.39	10.85	7.73	165.89
As	Sub-montane Open Ombrophilous Forest	71.1	7.11	5.76	4.11	88.08
Ca	Lowland Decidual Seasonal Forest	88.36	21.27	9.75	2.08	121.46
Cb	Lowland Decidual Seasonal Forest	69.38	16.65	7.63	11.21	104.87
Cm	Montane Decidual Seasonal Forest	31.1	11.5	4.67	4.67	51.94
		84.38	20.25	9.28	13.63	127.54
Cs	Sub-montane Decidual Seasonal Forest	41.4	15.3	6.21	6.1	69.01
		84.38	20.25	9.28	13.63	127.54
Da	Alluvial Dense Ombrophilous Forest	90.51	28.06	8.51	3.63	130.71
Db	Lowland Dense Ombrophilous Forest	85.73	45.38	2.98	4.11	138.2
Ds	Sub-montane Dense Ombrophilous Forest	81.99	25.42	7.71	3.29	118.41
Fa	Alluvial Semi-deciduous Seasonal Forest	52.99	5.3	4.29	3.06	65.64
		56.89	11.38	6.26	1.34	75.86
		58.05	13.66	2.98	5.24	79.93
		121.92	29.26	13.41	2.87	167.46
Fb	Lowland Semi-deciduous Seasonal Forest	65.98	6.6	5.34	3.81	81.73
		63.07	14.84	2.98	3.03	83.92
		63.07	33.4	2.98	3.03	102.48
Fm	Montane Semi-deciduous Seasonal Forest	50.48	26.73	2.98	2.42	82.61

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
		50.48	11.88	2.98	2.42	67.76
Fs	Sub-montane Semi-deciduous Seasonal Forest	39.96	7.99	4.4	2.58	54.93
		62.23	14.64	2.98	3.63	83.48
Ma	Mixed Alluvial Ombrophilous Forest	64.25	15.12	2.98	3.08	85.43
Ml	High-montane Mixed Ombrophilous Forest	78.82	18.54	2.98	3.78	104.12
Mm	Montane Mixed Ombrophilous Forest	60.11	14.15	2.98	2.88	80.12
ON	Contact Ombrophilous Forest / Seasonal Forest	72.88	15.48	6.06	7.77	102.18
P	Pioneer Formation	24.64	9.12	2.71	4	36.51
Pf	Pioneer Formation with fluvial and/or lacustrine influence	25.82	9.55	2.84	0.04	38.26
Pm	Pioneer Formation with Marine Influence (*restinga*)	23.46	8.68	2.58	0.04	34.76
S	Savanna	26.69	16.94	3.12	4.88	51.63
Sa	Wooded Savanna	12.03	24.54	1.68	3.06	41.31
Sd	Forested Savanna	46.14	10.15	5.08	7.45	68.82
		35.06	7.71	3.86	5.66	52.29
		69.2	15.22	7.61	11.17	103.21
		33.29	7.32	3.66	5.38	49.64
SM	Contact Savanna / Ombrophilous Mixed Forest	44.16	16.07	3.21	4.15	67.57
SN	Contact Savanna / Seasonal Forest	43.49	15.42	4.26	5.33	68.5
SO	Contact Savanna / Ombrophilous Forest	39.01	17.61	4.12	5.59	66.33
ST	Contact Savanna / Savanna Steppes	18.64	13.26	3.21	4.34	36.11
STN	Contact Savanna / Savanna Steppes/ Seasonal Forest	25.27	15.5	3.2	4.44	47.57
T	Savanna Steppes	17.8	7.7	2.97	2.33	30.8
Ta	Wooded Savanna Steppes	9.6	5.8	1.25	1.25	17.9
Td	Forested Savanna Steppes	26	9.6	4.68	3.05	43.33
TN	Contact Savanna Steppes / Seasonal Forest	30.03	10.28	4.46	4.15	45.83

OBS: AGB – above ground biomass / BGB – below ground biomass / DW – dead wood / LI – litter

Source: Table 24 (Brazil, 2020)

Other emission factors and parameter used to estimate GHG emissions and removals in the Cerrado biome are presented in the following table.

Table 7 – Other emission factors and parameters used in the Cerrado biome

Emission factor	Value	Unit	Source
Combustion factor (C_f)	0.379	dimensionless	Table 49 (Brazil, 2020) – value for the Amazon biome
Emission factor (G_{ef}) CH_4	6.8	g/kg dry matter (d.m.)	Table 2.5 (IPCC, 2006) – values for Tropical Forest
Emission factor (G_{ef}) N_2O	0.2	g/kg dry matter (d.m.)	
Carbon content	0.47	Tone C/tone d.m.	IPCC, 2006

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

[15] According to the reference report of the National GHG inventory, the source of the 2.85 tC/ha/yr value is an "average between abandoned pastures between 1 to 5 years and 6 to 10 years in the Amazon (FELDPAUSCH et al., 2007). Expansion factor for subterranean biomass de 9,20 (IPCC 2006, vol, 4, cap, 4, tab, 4.4)". The national GHG inventory team have consulted experts and came to the conclusion that the reference and values are applicable for the Cerrado circumstances.

FELDPAUSCH, T. R. et al. Secondary forest growth deviation from chronosequence predictions in central Amazonia. Global Change Biology, v. 13, n. 5, p. 967-979, 2007.

3.8. Caatinga biome

3.8.1. Activity data

As explained in section "Pools, gases, and activities included in Brazil's national FREL", activity data for the Caatinga biome were obtained from PRODES.

3.8.2. Emission factors

Twenty-four (24) forest phytophysiognomies are present in the vegetation map of the Caatinga biome, the most abundant one being Wooded Savanna Steppes (Sa). ***Table 8*** present the forest phytophysiognomies considered in the Caatinga biome, for the construction of the FREL, and the respective carbon stocks for each carbon pool. For each type of forest phytophysiognomies, the total stock corresponds to the sum of the individual stocks of the four carbon pools included: above ground biomass (AGB), below ground biomass (BGB), dead wood (DW) and litter (LI).

Table 8 – Forest phytophysiognomies considered in the Caatinga biome and respective carbon stocks

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
Aa	Alluvial Open Ombrophilous Forest	44.7	8.08	3.78	0.77	57.33
Ab	Lowland Open Ombrophilous Forest	44.7	8.08	3.78	0.77	57.33
Am	Montane Open Ombrophilous Forest	44.7	8.08	3.78	0.77	57.33
As	Sub-montane Open Ombrophilous Forest	76.4	28.3	11.46	11.21	127.3
Ca	Seasonal Forest Decidual Alluvial	88.6	21.3	9.75	2.08	121.72
Cb	Lowland Decidual Seasonal Forest	55.3	8.5	4.68	6.86	75.30
Cm	Montane Decidual Seasonal Forest	31.1	11.5	4.66	4.57	51.84
Cs	Sub-montane Decidual Seasonal Forest	41.4	15.3	6.21	6.08	69.05
Da	Alluvial Dense Ombrophilous Forest	149	22.5	10.90	3.43	185.70
Dm	Montane Dense Ombrophilous Forest	149	22.5	10.90	3.43	185.70
Ds	Sub-montane Dense Ombrophilous Forest	149	22.5	10.90	3.43	185.70
Fa	Alluvial Semi-deciduous Seasonal Forest	74	11.4	6.26	1.34	92.94
Fb	Lowland Semi-deciduous Seasonal Forest	80.4	14.8	6.80	3.99	106.01
Fm	Montane Semi-deciduous Seasonal Forest	59.3	22	8.90	8.71	98.89
Fs	Sub-montane Semi-deciduous Seasonal Forest	82.7	30.6	12.41	12.15	137.89
Pf	Pioneer Formation of Fluviomarine Influence (Mangroves)	123	37.8	9.53	0.18	170.54
Pm	Pioneer Formation with Marine Influence (*Restinga*)	102	21.9	22.18	1.41	147.09
Sa	Wooded Savanna	12	24.5	1.68	3.06	41.31
Sd	Forested Savanna	39.5	14.6	5.92	5.79	65.79
SN	Contact Savanna / Forest	44.7	14.7	5.32	4.89	69.66

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
ST	Contact Savanna / Pioneer Formation - Specific for Pioneer Formation com Marine Influence (*Restinga*)	13.5	9.24	1.82	1.88	26.47
Ta	Wooded Savanna Steppes (Open caatinga)	9.59	5.85	1.25	1.6	18.28
Td	Forested Savanna Steppes (Dense caatinga)	26	9.62	4.68	3.05	43.34
TN	Contact Savanna / Seasonal Forest	42.1	13.1	5.05	3.9	64.16

OBS: AGB – above ground biomass / BGB – below ground biomass / DW – dead wood / LI – litter

Source: Table 26 (Brazil, 2020)

3.9. Atlantic Forest biome

3.9.1. Activity data

As explained in section "Pools, gases, and activities included in Brazil's national FREL", activity data for the Atlantic Forest biome were obtained from PRODES.

3.9.2. Emission factors

Forty-eight (48) forest phytophysiognomies are present in the vegetation map of the Atlantic Forest biome, the most abundant ones being Submontane Semi-deciduous Seasonal Forest (FS), Montane Semi-deciduous Seasonal Forest (FM) and Montane Mixed Ombrophilous Forest (Mm). **Table *9*** present the forest phytophysiognomies considered in the Atlantic Forest biome, for the construction of the FREL, and the respective carbon stocks for each carbon pool. For each type of forest phytophysiognomies, the total stock corresponds to the sum of the individual stocks of the four carbon pools included: above ground biomass (AGB), below ground biomass (BGB), dead wood (DW) and litter (LI).

Table 9 – Forest phytophysiognomies considered in the Atlantic Forest biome and respective carbon stocks

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
Aa	Alluvial Open Ombrophilous Forest	35.06	7.19	2.98	1.86	47.09
Ab	Lowland Open Ombrophilous Forest	35.06	7.19	2.98	1.86	47.09
Am	Montane Open Ombrophilous Forest	35.06	7.19	2.98	1.68	46.91
As	Sub-montane Open Ombrophilous Forest	35.06	7.19	2.98	4.19	49.42
Ca	Alluvial Decidual Seasonal Forest	88.6	21.3	9.8	2.1	121.8
Cb	Lowland Decidual Seasonal Forest	52.08	10.68	2.98	2.5	68.24
Cm	Montane Decidual Seasonal Forest	58.14	11.92	2.98	2.79	75.83
Cs	Sub-montane Decidual Seasonal Forest	74.1	19.6	8.2	4.6	106.5

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
D	Dense Ombrophilous Forest (Pluvial Tropical Forest)	63.17	14.84	2.98	3.03	84.02
Da	Alluvial Dense Ombrophilous Forest	127.1	29.9	14	2.9	173.9
Db	Lowland Dense Ombrophilous Forest	85.73	20.15	2.98	4.11	112.97
Dl	High-montane Dense Ombrophilous Forest	64.63	15.19	2.98	3.1	85.9
Dm	Montane Dense Ombrophilous Forest	140	32.9	2.98	7	182.88
Ds	Sub-montane Dense Ombrophilous Forest	141.1	33.16	2.98	3.41	180.65
E	Steppes	0.8	0.16	0.04	0.04	1.04
EM	Contact Steppes / Mixed Ombrophilous Forest	49.26	10.1	2.98	2.36	64.70
EN	Contact Steppes / Seasonal Forest	52.17	10.69	2.98	2.5	68.34
F	Seasonal Forest Semi decidual	57.86	11.86	2.98	2.78	75.48
Fa	Alluvial Semi-deciduous Seasonal Forest	58.05	11.9	2.98	5.24	78.17
Fb	Lowland Semi decidual Seasonal Forest	63.07	14.82	2.98	3.03	83.90
Fm	Montane Semi-deciduous Seasonal Forest	75.1	17.65	2.98	3.76	99.49
Fs	Sub-montane Semi-deciduous Seasonal Forest	96.5	22.68	2.98	3.63	125.79
La	Wooded *Campinarana*	8.88	4.7	0.44	0.43	14.45
M	Mixed Ombrophilous Forest	62.51	12.81	2.98	3	81.3
Ma	Mixed Alluvial Ombrophilous Forest	64.25	15.1	2.98	3.08	85.41
Ml	High-montane Mixed Ombrophilous Forest	78.82	18.52	2.98	3.78	104.10
Mm	Montane Mixed Ombrophilous Forest	108.3	25.45	2.98	5.42	142.15
Ms	Sub-montane Mixed Ombrophilous Forest	108	19	11.9	3.8	142.7
NM	Contact Seasonal Forest / Mixed Ombrophilous Forest	58.28	11.95	2.98	2.8	76.01
NP	Contact Seasonal Forest / Pioneer Formation - Specific for Pioneer Formation com Marine Influence (*Restinga*)	57.95	11.88	2.98	2.78	75.59
OM	Contact Dense Ombrophilous Forest/ Mixed Ombrophilous Forest	62.89	14.78	2.98	3.02	83.67
ON	Contact Ombrophilous Forest / Seasonal Forest	59.13	13.89	2.98	2.84	78.84
OP	Contact Ombrophilous Forest/ Pioneer Formation - Specific for Pioneer Formation com Marine Influence (*Restinga*)	63.26	14.87	2.98	3.04	84.15
P	Pioneer Formation Areas	79.15	18.6	2.98	3.8	104.53
Pf	Vegetation with Fluviomarine Influence	62.42	14.67	2.98	2.99	83.06
Pm	Vegetation with Marine Influence (Restinga)	79.71	18.73	2.98	3.28	104.70
S	Savanna	26.69	16.94	3.12	4.88	51.63
Sa	Wooded Savanna	12.03	24.54	1.68	3.06	41.31
Sd	Forested Savanna	69.2	15.22	7.61	11.17	103.2
SM	Contact Savanna / Mixed Ombrophilous Forest	44.16	16.07	3.21	4.15	67.59
SN	Contact Savanna / Seasonal Forest	43.49	15.42	4.26	5.33	68.50
SO	Contact Savanna / Ombrophilous Forest	39.01	17.61	4.12	5.59	66.33
SP	Contact Savanna / Pioneer Formation	36.94	7.57	2.98	1.78	49.27
ST	Contact Savanna / Pioneer Formation - Specific for Pioneer Formation com Marine Influence (*Restinga*)	18.64	13.26	3.21	4.34	36.11
T	Contact Savanna / Savanna Steppes	8.13	4.31	0.4	0.39	13.23
Ta	Wooded Savanna Steppes	8.13	4.3	0.4	0.4	13.23
Td	Forested Savanna Steppes	18.94	10.03	0.93	0.91	30.81
TN	Contact Savanna Steppes/Seasonal Forest	55.88	11.7	2.98	2.68	73.24

OBS: AGB – above ground biomass / BGB – below ground biomass / DW – dead wood / LI – litter

Source: Table 25 (Brazil, 2020)

3.10. Pampa biome

3.10.1. Activity data

As explained in section "Pools, gases, and activities included in Brazil's national FREL", activity data for the Pampa biome were obtained from PRODES.

3.10.2. Emission factors

Twenty-eight (28) forest phytophysiognomies are present in the vegetation map of the Pampa biome, the most abundant one being Steppes (E). ***Table 10*** present the forest phytophysiognomies considered in the Pampa biome, for the construction of the FREL, and the respective carbon stocks for each carbon pool considered. For each type of forest phytophysiognomies, the total stock corresponds to the sum of the individual stocks of the four carbon pools included: above ground biomass (AGB), below ground biomass (BGB), dead wood (DW) and litter (LI).

Table 10 – Forest phytophysiognomies considered in the Pampa biome and respective carbon stocks

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
Ca	Alluvial Decidual Seasonal Forest	98.7	23.69	10.86	2.93	136.17
Cb	Lowland Decidual Seasonal Forest	52.08	12.25	2.98	2.5	69.80
Cm	Montane Decidual Seasonal Forest	120.58	28.94	13.26	4.51	167.29
Cs	Sub-montane Decidual Seasonal Forest	120.58	28.94	13.26	4.38	167.16
Da	Alluvial Dense Ombrophilous Forest	64.625	15.21	2.98	3.1	85.91
Db	Lowland Dense Ombrophilous Forest	85.728	20.17	2.98	4.11	112.98
Dm	Montane Dense Ombrophilous Forest	114.38	28.97	12.53	3.53	159.41
Ds	Sub-montane Dense Ombrophilous Forest	126.3	30.31	13.89	3.87	174.38
E	Steppes	1.03	4.74	0	3.63	9.40
Ea	Wooded Steppes	37.74	10.58	5.12	2.07	55.51
EM	Contact Steppes / Mixed Ombrophilous Forest	1.03	4.74	0	3.63	9.40
EN	Contact Steppes / Seasonal Forest	0.73	0.77	0	3.63	5.13
EP	Contact Steppes / Formations	37.74	10.58	5.12	2.07	55.51
Fa	Alluvial Semi-deciduous Seasonal Forest	58.04	13.66	2.98	5.24	79.92
Fb	Lowland Semi-deciduous Seasonal Forest	62.65	15.04	6.89	1.47	86.05
Fm	Montane Semi-deciduous Seasonal Forest	82.24	16.12	3.06	5.35	106.76

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
Fs	Sub-montane Semi-deciduous Seasonal Forest	78.82	18.92	8.48	3.07	109.29
Ma	Mixed Alluvial Ombrophilous Forest	64.249	15.12	2.98	3.08	85.42
Ms	Sub-montane Mixed Ombrophilous Forest	92.77	23.49	10.77	3.68	130.71
Mm*	Montane Mixed Ombrophilous Forest					142.15
NM	Contact Seasonal Forest / Mixed Ombrophilous Forest	120.58	28.94	13.26	4.38	167.16
NP	Contact Seasonal Forest / Pioneer Formation com Marine Influence (*Restinga*)	1.04	10.15	0	1.59	12.77
OM	Contact Dense Ombrophilous Forest/ Mixed Ombrophilous Forest	120.58	28.94	13.26	4.38	167.16
OP	Contact Ombrophilous Forest/ Pioneer Formation com Marine Influence (*Restinga*)	1.04	10.15	0	1.59	12.77
P	Pioneer Formation Areas	1.03	4.74	0	3.63	9.40
Pf	Vegetation with Fluviomarine Influence	1.04	10.15	0	1.59	12.77
Pm	Vegetation with Marine Influence (*Restinga*)	1.04	10.15	0	1.59	12.77
T	Savanna Steppes	120.58	28.94	13.26	4.38	167.16

OBS: AGB – above ground biomass / BGB – below ground biomass / DW – dead wood / LI – litter

Source: Table 27 (Brazil, 2020)

3.11. Pantanal biome

3.11.1. Activity data

As explained in section “Pools, gases, and activities included in Brazil’s national FREL”, activity data (deforestation areas) for the Pantanal biome were obtained from PRODES.

3.11.2. Emission factors

Fifteen (15) forest phytophysiognomies are present in the vegetation map of the Pantanal biome, the most abundant ones being Wooded Savanna (Sa) and Forested Savanna (Sd). **Table *11*** present the forest phytophysiognomies considered in the Pantanal biome, for the construction of the FREL, and the respective carbon stocks for each carbon pool. For each type of forest phytophysiognomies, the total stock corresponds to the sum of the individual stocks of the four carbon pools included: above ground biomass (AGB), below ground biomass (BGB), dead wood (DW) and litter (LI).

Table 11 – Forest phytophysiognomies considered in the Pantanal biome and respective carbon stocks

Initial	Phytophysiognomies	AGB	BGB	DW	LI	TOTAL C
Ca	Alluvial Decidual Seasonal Forest	88.62	21.27	9.75	2.08	121.72
Cb	Lowland Decidual Seasonal Forest	69.38	16.65	7.63	11.21	104.87
Cs	Sub-montane Decidual Seasonal Forest	84.38	20.25	9.28	13.63	127.54
Fa	Alluvial Semi-deciduous Seasonal Forest	121.92	29.26	13.41	2.87	167.46
Fb	Lowland Semi-deciduous Seasonal Forest	65.98	6.6	5.34	3.81	81.73
Fs	Sub-montane Semi-deciduous Seasonal Forest	62.23	14.64	2.98	3.63	83.48
SN	Contact Savanna / Seasonal Forest	12.03	24.53	1.68	3.06	41.31
TN	Contact Savanna Steppes / Seasonal Forest	121.92	29.26	13.41	2.87	167.46
S	Savanna	69.2	15.22	7.61	11.17	103.21
Sa	Wooded Savanna	12.03	24.53	1.68	3.06	41.31
Sd	Forested Savanna	69.2	15.22	7.61	11.17	103.21
ST	Contact Savanna / Savanna Steppes	59.82	13.76	6.58	1.4	81.56
T	Savanna Steppes	120.58	28.94	13.26	4.38	167.16
Ta	Wooded Savanna Steppes	4.31	7.15	0.22	0.28	11.96
Td	Forested Savanna Steppes	66.43	14.62	7.31	10.73	99.09

OBS: AGB – above ground biomass / BGB – below ground biomass / DW – dead wood / LI – litter

Source: Table 28 (Brazil, 2020)

4. Methodological information used in the construction of Brazil's national FREL

4.1. The role of the Working Group of Technical Experts on REDD+ for MRV

On April 4th, 2022, the Brazilian Ministry of the Environment (MMA, for the acronym in Portuguese) created the **Working Group of Technical Experts on REDD+ for MRV** (GTT MRV REDD+, for the acronym in Portuguese) through Ordinance No. 7/2022. This group is composed of experts in the areas of climate change and forestry from renowned Brazilian institutions.

The GTT MRV REDD+ has provided important inputs for the development of this FREL, including advise on the definition of deforestation and degradation, the forest physiognomies to be considered, the carbon pools and GHG to be included[16].

4.2. Estimation of Brazil's national FREL

4.2.1. Emissions from deforestation and forest degradation

The methodologies used to estimate greenhouse gas (GHG) emissions resulting from deforestation and forest degradation, and carbon removals are based on the 2006 IPCC Guidelines (IPCC, 2006). Overall, estimates of GHG emissions (measured in tonnes of carbon dioxide equivalent (tCO_2 equivalent) result from the multiplication of activity data and emission factors.

When degradation was considered, which is the case for the Amazon biome, emissions were calculated chronologically to allow the gradual reduction of carbon stocks in the appropriate pools over time, when appropriate. This approach ensures that emissions are not overestimated, since the carbon stock available at time *t* is the remaining stock at the time *t-1* (**Figure *14***).

[16] The GTT MRV REDD+ proceedings are registered in Portuguese and made publicly available on the website of the MMA through the following link: http://redd.mma.gov.br/pt/reunioes

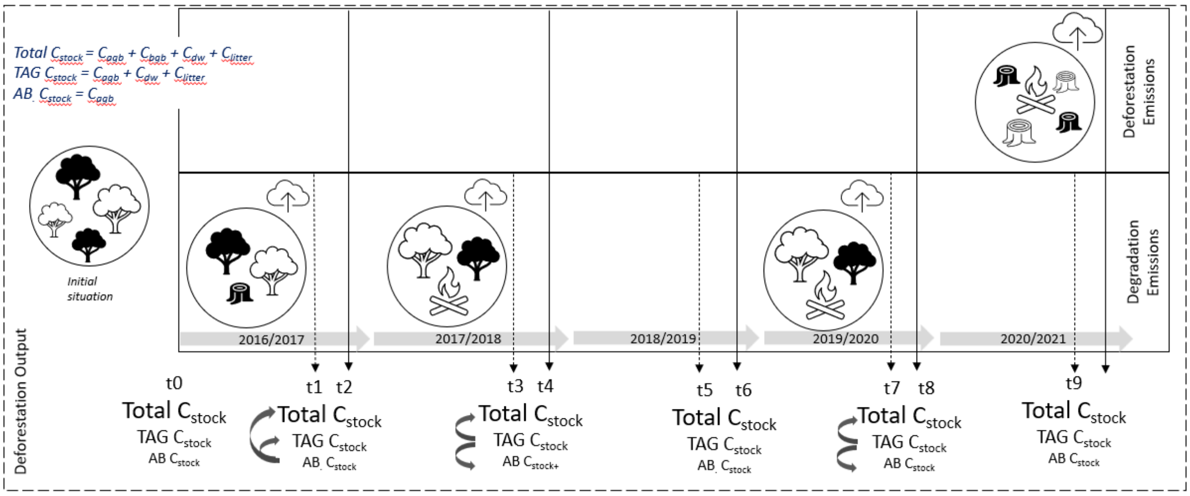


Figure 14 – Methodological approach to estimate GHG emissions from deforestation and forest degradation

Source: own elaboration

Since different types of degradation have an impact on different carbon pools, the following terms were used in the calculation spreadsheets for the Amazon biome to take emissions into account accordingly:

1. **Total carbon stock (Total C_{stock}):** sum of the four carbon pools considered – above ground biomass, below ground biomass, dead wood, and litter, relevant to the estimation of emissions associated with deforestation:

$$Total\ C_{stock} = C_{ABG} + C_{BGB} + C_{DW} + C_{LI}$$

2. **Total aerial carbon stock (T_{AG} C_{stock}):** sum of the aerial carbon pools – above ground biomass, dead wood and litter, relevant to the estimation of emissions related to fire in managed forest land:

$$TAG\ C_{stock} = C_{AGB} + C_{DW} + C_{LI}$$

3. **Carbon stock in the above ground biomass (AGB C_{stock}):** it concerns only above ground biomass, relevant to the estimation of emissions associated with disordered logging:

$$AGB.\ C_{stock} = C_{AGB}$$

The calculations can be divided into three phases:

PHASE 1 - Spatial data layers (maps) were assessed through GIS tools to check gaps, and topology, among others. Problems encountered at this stage and how they were corrected are described in “Quality control and quality assurance procedures". Since the data volume is very large, the results of this phase were exported as three different outputs (i.e., three worksheets for subsequent calculations), as detailed below:

- ***DEFORESTATION OUTPUT:*** Contains all deforested areas from 2016-2017 to 2020-2021 and corresponding trajectories, i.e. forest areas that were first subject to degradation and were subsequently deforested are included in these files and tables. In the case of the Amazon biome, these results were subdivided into two parts: i) deforested areas with minimum mapping unit (MMU) between 1 ha and 6.25 ha; and ii) deforested areas of 6.25 ha and above. This subdivision was necessary since the deforestation data produced annually by INPE for the Legal Amazon region (PRODES) uses MMU of 6.25 ha or above, to ensure consistency along the timeseries since 1988
- ***DEGRADATION OUTPUT:*** Contains all forest areas in managed land subject to degradation in the Amazon biome and that are not converted to deforestation until the last annual period of the reference period (2020-2021)

PHASE 2 – in this phase, GHG emissions calculations were performed chronologically for forest degradation and deforestation. This implies that the carbon losses from the initial carbon stock in 2016 were accounted for as each REDD+ activity occurred and the carbon stocks were progressively updated so as to avoid double counting between deforestation and degradation in the case of the Amazon biome. In other words, the process and sequence of degradation was considered for the purposes of calculating emissions in subsequent deforestation (for more details refer to section 8.4). The calculations and results of this phase were also subdivided according to three output components:

- ***DEFORESTATION OUTPUT:*** Contains GHG emissions from deforestation. The estimates of emissions from deforestation considered total carbon stock (sum of above ground in the above ground biomass
- ***DEGRADATION OUTPUT:*** Contains GHG emissions from forest degradation for the Amazon biome. Emissions from degradation by fire considered only the aerial carbon stock (sum of carbon stock in above ground biomass, dead wood and litter). The estimates of emissions from degradation due to disordered logging considered only the carbon stock in the above ground biomass

PHASE 3- Removals from land use/cover "post-deforestation event" were calculated for the Amazon and Cerrado. In the absence of annual data, land use/cover "post-deforestation event" was defined using TerraClass timeseries (2014 and 2020 for the Amazon, 2018 and 2020 to Cerrado), as a proxy to define land use/cover "post-deforestation event" in the period of the FREL (2016/2017-2020/2021).

PHASE 4 – During this phase, the results were grouped together, and the final balance of emissions and removals were estimated, representing the net GHG emissions for the Amazon and Cerrado. For the Caatinga, Atlantic Forest, Pampa and Pantanal biomes, only gross GHG emissions were estimated.

Detailed descriptions of the application of the above approaches are available in Section 8:

- “Detailed description for estimating GHG emissions/removals in the Amazon biome”;
- “Detailed description for estimating GHG emissions/removals in the Cerrado biome”; and
- "Detailed description for estimating GHG emissions/removals in the Atlantic Forest, Caatinga, Pampa and Pantanal biomes".

4.2.2. Enhancement of forest carbon stocks

PHASE 1 – GIS operations: Secondary vegetation (SV) maps provided by TerraClass for the Amazon biome (for the years 2004, 2008, 2010, 2012, **2014**, and **2020**) were used as inputs in spatial operations to identify, in each polygon, SV areas in the timeseries.

PHASE 2 – Removals: Linear interpolation was used to estimate absolute annual SV area from 2014 to 2020, and annual removals were estimated following equation presented in section 5.3.5.

PHASE 3 – Emissions: since information on SV area loss was also available, CO_2 emissions due to deforestation of these areas were estimated. From phase 1, information on SV age at loss event was identified. Linear interpolation was also applied to define annual SV loss areas from 2014 to 2020. Emissions were then estimated following equation presented in section 5.3.5.

PHASE 4 – Net EFCS: from the information on removals and emissions of SV gain and loss, net enhancement of forest carbon stocks was estimated.

Detailed descriptions of the above phases’ execution are available in Section 8.

4.3. Equations used in the construction of Brazil’s national FREL

Emission and removal estimate for the national FREL are based on the 2006 IPCC gain-loss method (IPCC, 2006). The following equations are used, taking into account the REDD+ activities and the non-CO_2 gases considered for each biome, as indicated in **Table 3**. Detailed information related to the estimation in each biome are described in the section “Estimation of Brazil’s national FREL”. Equation 1 is an adaptation of equation 2.3 in the 2006 IPCC Guidelines:

$$\Delta C_B = \Delta C_{AGB} + \Delta C_{BGB} + \Delta C_{DW} + \Delta C_{LI} \qquad \textbf{Equation 1}$$

Where:

- ΔC_B = carbon stock change
- ΔC_{AGB} = above-ground biomass stock change
- ΔC_{BGB} = below-ground stock change
- ΔC_{DW} = dead-wood stock change
- ΔC_{LI} = litter stock change

4.3.1. Gross deforestation emissions

For each deforestation polygon *i*, identified at each annual period of the reference level period, the associated CO_2 emission is estimated as the product of its area (hectares) and the total carbon stocks (sum of the carbon stocks in the carbon pools considered), multiplied by 44/12 to convert tonnes of carbon in tonnes of carbon dioxide. Erro! Fonte de referência não encontrada.

$$GE_{b,t,f,p} = A_{b,t,f,p} * \left(Ca_{b,t,f,p} + Cb_{b,t,f,p} + Cd_{b,t,f,p} + Cl_{b,t,f,p}\right) * 44/12 \qquad \textbf{Equation 2}$$

Where:

- $GE_{b,t,f,p}$ = CO_2 emissions associated with deforestation in the polygon *p,* under phytophysiognomies *f* of the biome *b*, at the annual period t; (tonnes)
- $A_{b,t,f,p}$ = area of deforestation polygon p, under phytophysiognomies *f* of the biome *b*, at the annual period t; (ha)
- $Ca_{b,t,f,p}$ = carbon stock in above ground biomass in polygon p under phytophysiognomies *f* of biome *b* at the annual period t (tC)
- $Cb_{b,t,f,p}$ = carbon stock in below ground biomass in polygon p under phytophysiognomies *f* of biome b at the annual period t (tC)
- $Cd_{b,t,f,p}$ = carbon stock in deadwood in polygon p under phytophysiognomies *f* of biome b at the annual period t (tC)
- $Cl_{b,t,f,p}$ = carbon stock in litter in polygon p under phytophysiognomies *f* of biome b at the annual period t (tC)
- $44/12$ = conversion factor from C to CO_2; (dimensionless)

For each biome b and annual period *t*, the total gross CO_2 emissions from deforestation is estimated as the sum of the CO_2 emissions from all deforested polygons identified in that period, as expressed in Equation 3:

$$GE_{bt} = \sum_{p=1}^{P_{b,t}} GE_{b,t,p} \qquad \textbf{Equation 3}$$

Where:

- GE_t = total CO_2 emissions for period *t* in biome *b*; tonnes of CO_2

- GE_i = CO_2 emissions associated with deforested polygon *p;* tonnes of CO_2
- $P_{b,t}$ = number of deforested polygons identified in the period *t* and biome *b*; dimensionless

4.3.2. Gross emissions due degradation from fire

To estimate emissions from forest degradation due to fire, the generic equation 2.14 in the 2006 IPCC GLs, was used[17], as reproduced below in equation 4:

$$L_{disturbance} = \{A_{disturbance} \times B_w \times (1 + R) \times CF \times Cf\} \qquad \textbf{Equation 4}$$

Where:

- $A_{disturbance}$ = area affected by the disturbance (hectares)
- B_w = average above-ground biomass of land areas affected by disturbances, tonnes d.m. ha^{-1}
- **R** = ratio of below-ground biomass to above-ground biomass, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$. R has been set to zero, assuming no changes of below-ground biomass
- **CF** = carbon fraction of dry matter, tonne C (tonnes d.m.)$^{-1}$
- C_f = combustion factor; dimensionless (refer to **Table *5*** and **Table *7***)

Non-CO_2 emissions are estimated following equation 2.27 in the 2006 IPCC GLs[18], reproduced in equation 5:

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3} \qquad \text{Equation 5}$$

Where:

- L_{fire} = amount of GHG emissions from fire of each GHG (CH_4 and N_2O)
- **A** = area burned; hectares
- M_B = biomass available; tonnes per hectare
- C_f = combustion factor; dimensionless
- G_{ef} = emission factor; g/kg of dry matter burned

Each tonne of GHG was converted to tonne of CO_2 equivalent, using the 100-year GWP values from the IPCC 5th Assessment Report[19]:

- CH_4 to CO_2 = 28
- N_2O to CO_2 = 265

[17] Equation 2.14 of Chapter 2 (Generic Methodologies Applicable to Multiple Land-Use Categories) of Volume 4 (Agriculture, Forestry and Other Land Use) of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf

[18] Equation 2.27 of IPCC 2006 Chapter 2

[19] Table 8.A.1 available at: https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf

4.3.3. Gross emissions due to disordered logging degradation

For each identified disordered logging polygon (CS), a trajectory was assessed (i.e., recurrences during the reference period, if any) and a singular above-ground “biomass loss factor” used accordingly - ***Table 12***. The percent losses of above ground biomass (ΔCL CS AGB) in table 12 are the same as those in table 30 of Brazil (2020). Emissions from potential "collateral tree damage" are assumed to be included in the losses.

Table 12 – Representation of possible disordered logging trajectories (recurrences) and respective above-ground “biomass loss factor”

Potential trajectory from F-CS					
Initial area	Disordered logging within the reference level period				ΔCL CS AGB (%)
F	CS1				-29%
F	CS1	CS2			-27%
F	CS1	CS2	CS3		-26%
F	CS1	CS2	CS3	CS4	-22%

Source: Table 30 (Brazil, 2020)

4.3.4. Carbon removals from land use/cover category "post-deforestation event"

Land use/cover "post-deforestation event" was defined using the distribution of land use/cover provided by TerraClass and assuming that the proportions of land under each land cover category considered is constant during the reference period. In other words, from land use/cover maps per biome provided by TerraClass (2014 and 2020 for the Amazon, 2018 and 2020 for the Cerrado), the total annual deforested area per year in the reference period was attributed to "Grassland or Cropland categories" using the proportions estimated for each from the TerraClass reference data.

For each land use/cover class *j* identified at year *t* of the reference period, the CO_2 removal was estimated as the product of its area and the mean annual biomass growth, following equation 2.9 of the 2006 IPCC GLs and reproduced in equation 6:

$$GE_{i,t} = \sum_{1}^{NR} A_{j,t} \times EF \times {}^{44}/_{12} \qquad \textbf{Equation 6}$$

Where:

- $GE_{i,j}$ = annual increase in biomass carbon stocks for each land use/cover "post-deforestation envent" *i* at time t; tonnes of CO_2 per year per hectare

- $A_{j,t}$ = area *j* under each land use/cover class at time *t*; (hectares)
- **EF** = mean annual biomass growth; tonnes of C per hectare per year
- **NR** = number of land use/cover classes identified at time *t*
- **44/12** = conversation factor from C to CO_2

4.3.5. Enhancement of forest carbon stocks

Removals:

$$GE_{i,t} = \sum_{1}^{i} A_{j,t} \times EF \times {}^{44}/_{12} \qquad \textbf{Equation 7}$$

Where:

- $GE_{i,t}$ = annual increase in biomass carbon stocks due to secondary vegetation regrowth areas *i* at time t; tonnes of CO_2
- $A_{j,t}$ = area *j* of secondary vegetation polygons *i* estimated at time *t*; hectares
- **EF** = mean annual biomass growth; tonnes of C per hectare per year
- **44/12** = conversation factor from C to CO_2

Emissions:

$$GE_{i,t} = \sum_{1}^{y} A_{j,t} \times Y_{y,t} \times EF \times {}^{44}/_{12} \qquad \textbf{Equation 8}$$

Where:

- $GE_{i,t}$ = CO_2 emissions associated with secondary vegetation loss area *i* at time t; tonnes of CO_2
- $A_{j,t}$ = area *j* of secondary vegetation loss with age *y* estimated at time *t*; hectares
- Y = age y at loss event time t; number of years
- **EF** = mean annual biomass growth; tonnes of C per hectare per year
- **44/12** = conversation factor from C to CO_2

4.3.6. Uncertainties equations

Uncertainties associated with GHG emissions were estimated using equations described in volume 1, chapter 3, page 3.28 of 2006 IPCC Guidelines:

COMBINING UNCERTAINTIES – APPROACH 1 – MULTIPLICATION

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2} \qquad \textbf{Equation 7}$$

Where:

- **U_{total}** = the percent uncertainty of the product of the quantities
- **U_i** = the percent uncertainty associated with each of the quantities

COMBINING UNCERTAINTIES – APPROACH 1 – ADDITION AND SUBTRACTION

$$U_{total} = \frac{\sqrt{(U_1 \cdot x_1)^2 + (U_2 \cdot x_2)^2 + \cdots + (U_n \cdot x_n)^2}}{|x_1 + x_2 + \cdots + x_n|} \qquad \textbf{Equation 8}$$

Where:

- **U_{total}** = the percent uncertainty of the product of the quantities
- **X_i and U_i** = the added quantities and the percentage uncertainties associated with them, respectively

Applying equations 7 for equation 2, will result in:

$$U_{GE_{ij}} = \sqrt{U_{A_{ij}}^2 + U_{EF_j}^2} \qquad \textbf{Equation 9}$$

Where:

- GE_i= CO_2 emissions due to deforestation of areas under phytophysiognomies I (t)
- A_i= Total area deforested under phytophysiognomies I (ha)
- C_i= Total carbon content of areas under phytophysiognomies I (tC/ha)
- $C_i = Cab_i + Cbb_i + Cdw_i + Cli_i$ as defined in Equation 2

Applying equation 8:

$$U_{C_i} = \frac{\sqrt{\left(U_{Cab_i} * Cab_i\right)^2 + \left(U_{Cab_i} * Cab_i\right)^2 + \left(U_{Cab_i} * Cab_i\right)^2 + \left(U_{Cab_i} * Cab_i\right)^2}}{C_i} \qquad \textbf{Equation 10}$$

The above equations assume that each component is not correlated. This is reasonable in relation to activity data (i.e., deforested area) and the total carbon content, but it does not always apply in relation to the carbon content for each carbon pool. In the case where the carbon content for below-ground biomass, litter and dead wood are estimated based on the estimate of the carbon stock in above-ground biomass, the equations should be revised. For example, in the case in which all other carbon pools were obtained from aerial biomass, equation 11 applies:

$$C_i = Cab_i + Rbb_i * Cab_i + Rdw_i * Cab_i + Rli_i * Cab_i \quad \textbf{Equation 11}$$

Where:

- $\boldsymbol{Rbb_i}$ = Ratio below ground biomass / aboveground biomass for phytophysiognomies I
- $\boldsymbol{Rdw_i}$ =Ratio dead wood biomass / above ground biomass for phytophysiognomies I
- $\boldsymbol{Rli_i}$ = Ratio litter / above ground biomass for phytophysiognomies i

Applying equations 7 and 8:

$$U_{C_i} = \sqrt{U_{Cab_i}^2 + \frac{\left(\left(Rbb_i * U_{Rbb_i}\right)^2 + \left(Rdw_i * U_{Rdw_i}\right)^2 + \left(Rli_i * U_{Rli_i}\right)^2\right)}{(1 + Rbb_i + Rdw_i + Rli_i)^2}}$$ **Equation 12**

Specific information on how activity data uncertainty (U_{Aij}) and EF uncertainties (U_{EFj}) were estimated can be found in section "Accuracy".

4.3.7. FREL

The annual emissions were obtained using the following equation, taking into account the REDD+ activities and removals considered in each biome, as indicated in ***Table 3***:

Gross/Net emissions = Gross emissions from deforestation + Gross emissions from forest degradation due to fire + Gross emissions from degradation due to disordered logging – *Removals from natural forest regeneration (only for Amazon and Cerrado biomes)*
Equation 13

Finally, the national FREL was obtained from the sum of the average of gross/net annual emissions in the reference level period:

$$\boldsymbol{MGE_p = \sum_1^b GE_t}$$ **Equation 14**

Where:
- $\boldsymbol{MGE_p}$ = average gross/net GHG emissions for biome *b*; tonnes of CO_2 eq per year
- $\mathbf{GE_t}$ = gross/net emission in year *t;* tonnes of CO_2 eq
- **b** = number of biomes

5. Transparent, complete, consistent, and accurate information

In addition to information presented in previous sections, this section follows the guidelines contained in the Annex to decision 12/CP.17[20] on submitting reference levels and IPCC principles of: **Transparency, Accuracy, Completeness and Consistency (TACC principles)**.

5.1. Transparency

For additional information aiming to enhance the transparency of the submission, refer to annexes:

- Additional information related to deforestation activity data;
- Additional information related to forest degradation activity data;
- Additional information related to the areas of natural forest regeneration (secondary vegetation);
- Detailed description for estimating GHG emissions/removals in the Amazon biome;
- Detailed description for estimating GHG emissions/removals in the Cerrado biome;
- Detailed description for estimating GHG emissions/removals in the Atlantic Forest, Caatinga, Pampa and Pantanal biomes; and
- Detail description for estimating the national FREL.

5.2. Accuracy

The uncertainty associated with CO_2 emissions was estimated based on the uncertainty associated with activity data (e.g., deforested area) and the uncertainty associated with EF (e.g., carbon content in each carbon pool) – for the general equations applied, refer to section "Uncertainties equations".

5.2.1. Activity data uncertainty

The accuracy of the deforested areas in each biome was estimated using the methodology proposed in (Olofsson, et al., 2014). To determine the accuracy of the interpreter and estimate an uncertainty to be associated with the deforested areas in each annual period from 2016/2017 to 2020/2021, a stratified random sampling was applied according to the two categories adopted (natural forest and deforestation). Reference maps were used for each year from 2016 to 2021.

Sample size, that is, the number of points sampled per stratum, was defined by applying the so-called "Neyman optimal allocation", described by (Cochran, 1977) (Congalton & Green,

[20] Available at: https://unfccc.int/sites/default/files/resource/docs/2011/cop17/eng/09a02.pdf

2009) and (Stehman, 2012). First, the total sample size was defined, considering all biomes as a single territory to be sampled:

$$n = \left[\frac{\sum_{i=1}^{H} W_i * S_i}{s(\hat{O})}\right]^2$$ **Equation 15**

Where:

- **n** = total number of samples
- W_i = proportion of category *i*
- $S_i = \sqrt{U_i * (1 - U_i)}$ = standard deviation of category *i*
- $s(\hat{O})$ = standard error expected from sampling
- U_i = estimated map accuracy (given by the interpreter)

Sample distribution per category (n_i) was estimated using:

$$n_i = n * \frac{(t_{xi})^a * N_i * \sqrt{U_i * (1 - U_i)}}{\sum_{i=1}^{H} (t_{xi})^a * \sqrt{U_i * (1 - U_i)}}$$ **Equation 16**

Where:

- $t_{xi} = P_i * N_i$; where:
  - P_i = proportion of category *i* in relation to total population
  - N_i = category *i* population (i.e., total number of pixels occupied by category *i*)
- *a=1/2 or 1/3* according to (Särndal, Swensson, & Wretman, 1992)

The following table presents the sample plots numbers per biome and category that were considered for estimating activity data accuracy.

Table 13 – Sample distribution per biome and category

Biome	Natural vegetation	Deforestation	Total
Amazon	386	208	594
Cerrado	367	202	569
Caatinga	449	116	565
Atlantic forest	368	166	534
Pampa	325	417	742
Pantanal	525	491	1016

Source: own calcultations

Once the sample size was defined for each biome and category (i.e., natural vegetation and deforestation), the sampled plots were assessed using higher spatial resolution images, allowing for the confirmation or not of the classification.

This step was carried out using a computational system developed by INPE, that allowed the interpreter to simultaneously observe the sampled plot and the high spatial resolution images, complemented by graphical data describing NDVI (Normalized Difference Vegetation Index) dynamics that allowed to identify variations associated with removal, growth or vegetation cover stability at the sample plot over time. The following figure gives an example for each biome of a sample randomly selected, with the supplementary information used to estimate the mapping accuracy: for each sampled point (image at the center) the interpreter had (on the right upside corner) additional high spatial resolution images and the NDVI graph (at the bottom).

Figure 15 – Sample example in each biome for estimating mapping accuracy

Source: INPE

Based on the results of the sample plots process, an error matrix was elaborated for each biome and category – Table 14.

Table 14 – Error matrix for each biome and category

Biome	Category	Error		
		Deforestation	Natural vegetation	Total
Amazon	Deforestation	201	8	209
	Natural vegetation	7	378	385
	Total	208	386	594
Cerrado	Deforestation	174	20	194
	Natural vegetation	28	347	375
	Total	202	367	569
Caatinga	Deforestation	108	13	121
	Natural vegetation	8	436	444
	Total	116	449	565
Atlantic forest	Deforestation	159	50	209
	Natural vegetation	7	318	325
	Total	166	368	534
Pampa	Deforestation	408	36	444
	Natural vegetation	9	289	298
	Total	417	325	742
Pantanal	Deforestation	487	20	507
	Natural vegetation	4	505	509
	Total	491	525	1016

Source: own calcultations

From the above matrices it is possible to calculate producer's accuracy (omission) and user's accuracy (inclusion) and the 95% confidence intervals of the classification of the deforested area. The results are presented in following table.

Table 15 – Accuracy matrix for each biome and category

Biome	Category	User's accuracy %	Deforestation area uncertainty %
Amazon	Deforestation	96.2	20.0
	Natural vegetation	98.2	
Cerrado	Deforestation	89.7	21.6
	Natural vegetation	92.5	
Caatinga	Deforestation	89.3	36.5
	Natural vegetation	98.2	
Atlantic forest	Deforestation	76.1	41.7
	Natural vegetation	97.8	
Pampa	Deforestation	91.9	8.4
	Natural vegetation	97.0	
Pantanal	Deforestation	96.1	9.3
	Natural vegetation	99.2	

Source: own calcultations

5.2.2. Emission factors uncertainty

Above ground biomass uncertainty

For the Amazon biome, uncertainty values for above ground biomass were directly obtained from the EBA project[21], with uncertainty values associated with each pixel in the EBA raster file.

For the other biomes, uncertainty values associated with each phytophysiognomies vegetation in the biome were used, collected from either bibliographic reference or estimated based on IPCC default values (Table 4.7 in page 4.53 of chapter 4, volume 4 of the 2006 IPCC Guidelines)[22]. Uncertainty default values were estimated using the predominant, minimum, and maximum limits, assuming a triangular distribution (as suggested by the 2006 IPCC Guidelines). **Table *16*** shows the values used from table 4.7 and the associated 95% confidence interval.

Table 16 – Confidence interval and estimated uncertainty for above ground biomass for Cerrado, Atlantic Forest, Caatinga, Pampa and Pantanal biomes

Domain	Ecological zone	Continent	Above-ground biomass (t d.m. ha^{-1})	Uncertainty (%)
Tropical	Tropical rain forest (TRF)	North and South America	300 (120-400)	-43/+37
	Tropical moist deciduous forest (TMDF)	North and South America	220 (210-280)	-10/+14
	Tropical dry forest (TDF)	North and South America	210 (200-410)	-24/+38
	Tropical shrubland (TS)	North and South America	80 (40-90)	-33/+24
	Tropical mountain systems	North and South America	60-230	-46/+46

Source: own calcultations based on Table 4.7 of 2006 IPCC Guidleines

To estimate phytophysiognomies uncertainties, each phytophysiognomies was associated with an ecological zone of **Table *16***.

[21] http://www.ccst.inpe.br/projetos/eba-estimativa-de-biomassa-na-amazonia/ (in Portuguese)
[22] Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf

Table 17 – Association of each phytophysiognomies with the ecological zone of Table 4.7 of 2006 IPCC Guidelines

Phytophysiognomies	Sigla	Ecological zone
Alluvial Open Humid Forest	Aa	TRF
Lowland Open Humid Forest	Ab	TRF
Ombrophilous Open Forest – Mountain	Am	TRF
Sub-montane Open Humid Forest	As	TRF
Alluvial Decidual Seasonal Forest	Ca	TDF
Lowland Deciduous Seasonal Forest	Cb	TDF
Montane Deciduous Seasonal Forest	Cm	TDF
Sub-montane Deciduous Seasonal Forest	Cs	TDF
Alluvial Dense Humid Forest	Da	TRF
Lowland Dense Humid Forest	Db	TRF
Montane Dense Humid Forest	Dm	TRF
Sub-montane Dense Humid Forest	Ds	TRF
Steppes	E	TS
Wooded Steppes	Ea	TDF
Contact Steppes / Formations	EP	TS
Alluvial Semi-deciduous Seasonal Forest	Fa	TMDF
Lowland Semi-deciduous Seasonal Forest	Fb	TMDF
Montane Semi-deciduous Seasonal Forest	Fm	TMDF
Submontane Semi Deciduous Seasonal Forest	Fs	TMDF
Campinarana	L	TS
Forested Campinarana	La	TS
Wooded Campinarana	Ld	TMDF
Contact Campinarana / Ombrophilous Forest	LO	TMDF
Alluvial Mixed Ombrophilous Forest	Ma	TRF
Upper Montana Mixed Ombrophilous Forest	Ml	TRF
Montane Mixed Humid Forest	Mm	TRF
Sub-montane Mixed Ombrophilous Forest	Ms	TRF
Contact Seasonal Forest / Mixed Ombrophilous Forest	NM	TRF
Contact Seasonal Forest / Pioneer Formations – Specific for Pioneer Formation with Marine Influence (*Restinga*)	NP	TMDF*
Contact Dense Ombrophilous Forest / Mixed Ombrophilous Forest	OM	TRF
Contact Ombrophilous Forest / Seasonal Forest	ON	TRF
Contact Ombrophilous Forest / Pioneer Formations – Specific for Pioneer Formation with Marine Influence (*Restinga*)	OP	TRF*
Pioneer Formations Areas	P	TMDF
Pioneer Formation of Fluviomarine Influence (mangroves)	Pf	TMDF
Pioneering Formation of Marine Influence (sand banks)	Pm	TS
Savanna	S	TS
Wooded Savanna	Sa	TS
Forested Savanna	Sd	TDF

Phytophysiognomies	Sigla	Ecological zone
Contact Savanna/ Mixed Ombrophilous Forest	SM	TS
Contact Savanna / Seasonal Forest	SN	TS
Contact Savanna / Ombrophilous Forest	SO	TS
Contact Savanna / Savanna Steppes	ST	TS
Contact Savanna / Savanna Steppes / Seasonal Forest	STN	TS
Contact Savanna/Savanna Steppes	ST	TS
Savanna Steppes	T	TS
Wooded Steppe Savanna	Ta	TS
Forested Steppe Savanna	Td	TS
Contact Savanna Steppes / Seasonal Forest	TN	TS

OBS: TS for the Pampa biome

Source: own calcultations

Other carbon pools uncertainty (below ground biomass, litter, and dead wood)

Currently, Brazil doesn't have country specific uncertainties values for other carbon pools: below-ground biomass, litter, and dead wood. Therefore, IPCC default values were used, as described below.

Below ground biomass

Table 4.4 of the 2006 IPCC Guidelines provides default values for the ratio below ground biomass/above ground biomass (root-to shoot ratio - R). However, the table does not provide ranges for all ecological zones. As the ratio “0,20” is used for many phytophysiognomies, and also in order to be conservative, the value 38% was assumed as the uncertainty value for R in this submission.

Table 18 – Below ground uncertainty values

Ecological zone	Above-ground biomass	R [tonne root d.m. (tonne shoot d.m.)$^{-1}$]	Uncertainty (%)
Tropical rainforest		0.37	
Tropical moist deciduous forest	above-ground biomass <125 tonnes ha-1	0.20 (0.09 - 0.25)	38
	above-ground biomass >125 tonnes ha-1	0.24 (0.22 - 0.33)	19
Tropical dry forest	above-ground biomass <20 tonnes ha-1	0.56 (0.28 - 0.68)	34
	above-ground biomass>20 tonnes ha-1	0.28 (0.27 - 0.28)	2
Tropical shrubland		0.40	
Tropical mountain systems		0.27 (0.27 - 0.28)	2

Source: own calcultations based on Table 4.4 of 2006 IPCC Guidleines

Dead wood

Table 3.2.2 of the 2003 IPCC GPG LULUCF[23] has the value 0.11 as the ratio for dead wood and above ground biomass for "Tropical forest", associating a value of 150% for the uncertainty. This uncertainty estimate was considered for all cases in which dead wood was estimated from above ground biomass using an expansion factor.

<u>Litter</u>

Table 3.2.1 of the 2003 IPCC GPG LULUCF[24] indicate the value of 2.1 tC/ha (1-3) for litter in “tropical broadleaf deciduous forests”. Based on a triangular distribution, an uncertainty value of 39% was estimated to be used in all phytophysiognomies. However, in most cases the carbon content in litter is estimated from above ground biomass carbon content using an expansion factor. Hence, a value of 22% of uncertainty was associated with the expansion factor in order to be consistent, on average, with the default value provided in the 2003 IPCC GPG LULUCF.

Uncertainty of carbon removals in land use/cover "post-deforestation event"

The annual removal value is calculated multiplying the estimated area under each land use/cover "post-deforestation event" by a removal factor (tC/ha year or tC/ha, depending on the use).

The accuracy of the identification of land use areas was carried out using the same methodology described for deforestation. The results are presented in the following table.

Table 19 – Carbon removals uncertainty values

Land use/cover	Uncertainty (Confidence interval of 95%)
Cerrado biome	
Secondary Vegetation	10.8
Pasture	2.2
Perennial agriculture	30.6
Amazon biome	
Secondary Vegetation	2.9
Pasture (arbustive)	11.0
Pasture (herbaceous)	3.4
Perennial agriculture	30.6*

OBS: * Amazon biome value not available. Value from Cerrado biome used
Source: own calcultations based on Table 4.4 of 2006 IPCC Guidleines

The values of the removal factors used in the 4th National GHG Inventory were adopted. For forest regeneration (VS) the values used are 3.03 tC/ha/year for the Amazon biome and 2.85 tC/ha/year for the Cerrado biome. Typical uncertainty values are described in table 4.9 of the

[23] Available at: https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp3/Chp3_2_Forest_Land.pdf
[24] Available at: https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp3/Chp3_2_Forest_Land.pdf

"2006 IPCC Guidelines". However, that table does not show ranges for all ecological zones. Based on the values in the table, an uncertainty of 50% was adopted for both the Amazon and the Cerrado biomes.

For pastures the values used are 10 tC/ha for the Amazon biome and 7.57 tC/ha for the Cerrado biome. For perennial agriculture the values used are 0.91 tC/ha year for the Amazon biome and 2.6 tC/ha year in the Cerrado biome. Tables 5.1 (Cropland) and 6.4 (Grassland) of the "2006 IPCC Guidelines" show values of uncertainty of 75% for the removal factors in all climate zones. That value is adopted in the present submission.

Uncertainty of gross emissions due to degradation from fire

The annual gross emissions due to degradation from fire are estimated applying equations 4 and 5 described above.

The accuracy of the forest areas subject to degradation from fire was carried out using the same methodology described for deforestation, providing an estimated uncertainty of 22% for the Amazon biome.

The combustion factor uncertainty was obtained from table 2.6 of the 2006 IPCC Guidelines for "all primary forests" (0,36 with a 71% uncertainty) consistent with the value used in this submission (0.368).

The uncertainty of the emission factors for non-CO_2 gases were obtained from table 2.5 of the 2006 IPCC guidelines (58% for CH_4 and 53% for N_2O).

Uncertainty of gross emissions due to irregular logging degradation

For each polygon where irregular logging has been identified, emissions have been estimated multiplying its area by a biomass loss factor. Logging recurrences are possible for the same polygon. As shown before, biomass loss factors decrease for recurrent loggings.

The uncertainty of the areas subject to irregular logging has been estimated as 20% based on expert evaluation.

The uncertainty of the biomass loss factors (0.29, 0.27, 0.26 and 0.22 for first, second, third and fourth recurrences) were considered to be 8% based on expert evaluation.

5.3. Completeness

Complete information, for REDD+ purposes, means the provision of data and information that allows for the reconstruction of the FREL.

Additional information is meant only to enhance clarity and transparency of Brazil's National FREL. Brazil recalls paragraph 2 of Decision 13/CP.19 on guidelines and procedures for the technical assessment of FREL submissions and paragraph 4 of the Annex of the same decision.

In general, all information related to land use environmental monitoring is publicly available at **TerraBrasilis[25],** a geographic data platform developed by INPE and EMBRAPA for the organization, access and use through a web portal of all information produced by its environmental monitoring programs.

The data and information, used in this submission, are available at: http://redd.mma.gov.br/en/submissions

5.3.1. Activity data vectorial files (shapefiles)

The following vectorial files containing activity data (i.e., deforestation, degradation and revegetation polygons) and supporting material (i.e., biomes limits, forest physiognomies and managed land areas) are available:

File name	Content	Source
1. **Biomes_map**	Revised biomes limits	(IBGE, 2019)
2. **Ancient_vegetation_ map**	Ancient vegetation map with forest phytophysiognomies	4th National GHG Inventory
3. **Amazon_Deforestation_1to6ha**	Deforestation polygons for Amazon biome for the period 2016/2017-2020/2021	PRODES[26]
4. **Amazon_Deforestation_greater_6ha**	Deforestation polygons for Amazon biome for the period 2016/2017-2020/2021	PRODES[3]
5. **Amazon_Degradation**	Degradation polygons for Amazon for the period 2016/2017-2020/2021	DETER[27]
6. **2014_Amazon_secondary_vegetation**	Secondary vegetation map for 2014 in the Amazon biome	TerraClass[28]
7. **2020_Amazon_secondary_vegetation**	Secondary vegetation map for 2020 in the Amazon biome	
8. **2018_Cerrado secondary_vegetation**	Secondary vegetation map for 2018 in the Cerrado biome	

[25] More information is available (in Portuguese) at: http://terrabrasilis.dpi.inpe.br/en/home-page/ (accessed on November 9, 2022)

[26] http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes (in Portuguese)

[27] http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/deter/deter (in Portuguese)

[28] https://www.terraclass.gov.br (in Portuguese)

File name	Content	Source
9. **2020_Cerrado_secondary_vegetation**	Secondary vegetation map for 2020 in the Cerrado biome	
10. **Cerrado_Deforestation**	Deforestation polygons for Cerrado biome for the period 2016/2017-2020/2021	
11. **Atlantic_Forest_Deforestation**	Deforestation polygons for Atlantic_Forest biome for the period 2016/2017-2020/2021	
12. **Caatinga_Deforestation**	Deforestation polygons for Caatinga biome for the period 2016/2017-2020/2021	
13. **Pampa_Deforestation**	Deforestation polygons for Pampa biome for the period 2016/2017-2020/2021	
14. **Pantanal_Deforestation**	Deforestation polygons for Pantanal biome for the period 2016/2017-2020/2021	
15. **Managed_land_Amazon**	Map of all “managed land” for Amazon	4th National GHG Inventory
16. **Managed_land_Cerrado**	Map of all “managed land” for Cerrado	4th National GHG Inventory
17. **Managed_land_Caatinga**	Map of all “managed land” for Caatinga	4th National GHG Inventory
18. **Managed_land_atlantic_forest**	Map of all “managed land” for Atlantic Forest	4th National GHG Inventory
19. **Managed_land_Pampa**	Map of all “managed land” for Pampa	4th National GHG Inventory
20. **Managed_land_Pantanal**	Map of all “managed land” for Pantanal	4th National GHG Inventory
21. **Scenes_in_Biome**	Map based on landsat satellite grid scenes crossed with biomes	FUNCATE

5.3.2. Activity data Geotiff (raster)

The following raster files containing supporting material (i.e., carbon stocks per pool for the Amazon biome) are available at: http://redd.mma.gov.br/en/submissions.

File name	Content	Source
1. **EBA_AB**	Above-ground carbon stocks for the Amazon biome	
2. **EBA_BB**	Below-ground carbon stocks for the Amazon biome	
3. **EBA_DW**	Dead wood carbon stocks for the Amazon biome	EBA[29]
4. **EBA_LI**	Litter carbon stocks for the Amazon biome	
5. **EBA_uncertainty**	Uncertainty values of the carbon stocks for the Amazon biome	

5.3.3. Calculation shapefiles

[29] http://www.ccst.inpe.br/projetos/eba-estimativa-de-biomassa-na-amazonia/ (in Portuguese)

The following vectorial files containing data used in the calculation's spreadsheet are available:

File name	Content
1. **Data4Emissions_Amazon_deforestation_1to6ha**	Deforestation areas estimated in 1 hectare and for 6.25 hectares in the Amazon biome, for the period 2016/2017-2020/2021, and related forest phytophysiognomies and carbon stocks
2. **Data4Emissions_Amazon_deforestation_greater6ha**	Deforestation areas estimated in more than 6.25 hectares in the Amazon biome, for the period 2016/2017-2020/2021, and related forest phytophysiognomies and carbon stocks
3. **Data4Emissions_Amazon_SV**	Secondary vegetation areas for the Amazon biome for 2014 and 2020
4. **Data4Emissions_Amazon_degradation**	Degradation areas related to fire and disordered logging in the Amazon biome, for the period 2016/2017-2020/2021, and related forest phytophysiognomies and carbon stocks
5. **Data4Emissions_Cerrado_deforestation**	Deforestation areas in the Cerrado biome, for the period 2016/2017-2020/2021, and related forest phytophysiognomies and carbon stocks
6. **Data4Emissions_Cerrado_SV**	Secondary vegetation areas for the Cerrado biome for 2018 and 2020
7. **Data4Emissions_Atlantic_forest_deforestation**	Deforestation areas in the Atlantic Forest biome, for the period 2016/2017-2020/2021, and related forest phytophysiognomies and carbon stocks
8. **Data4Emissions_Caatinga_deforestation**	Deforestation areas in the Caatinga biome, for the period 2016/2017-2020/2021, and related forest phytophysiognomies and carbon stocks
9. **Data4Emissions_Pampa_deforestation**	Deforestation areas in the Pampa biome, for the period 2016/2017-2020/2021, and related forest phytophysiognomies and carbon stocks
10. **Data4Emissions_Pantanal_deforestation**	Deforestation areas in the Pantanal biome, for the period 2016/2017-2020/2021, and related forest phytophysiognomies and carbon stocks

5.3.4. Calculation spreadsheet

The following calculations spreadsheets are available:

File name	Content
1. **Amazon_Emissions_Output_Deforestation_1to6**	Emissions from deforestation in the Amazon biome from polygons of 1 hectare and 6.25 hectare for the period 2016/2017-2020/2021
2. **Amazon_Emissions_Output_Deforestation_greater6ha**	Emissions from deforestation in the Amazon biome from polygons greater than 6.25 hectare for the period 2016/2017-2020/2021
3. **Amazon_Emissions_Output_Degradation**	Emissions from forest degradation due to fire and disordered logging in the Amazon biome for the period 2016/2017-2020/2021
4. **4and5_Amazon_Net_Emissions_modified**	Removals from post-deforestation land use and Net Emissions from deforestation in the Amazon biome for the period 2016/2017-2020/2021
5. **Cerrado_Net_Emissions_modified**	Removals from post-deforestation land use and Net emissions from deforestation in the Cerrado biome for the period 2016/2017-2020/2021
6. **Atlantic_forest_Gross_Emissions_Deforestation**	Gross emissions from deforestation in the Atlantic Forest biome for the period 2016/2017-2020/2021
7. **Caatinga_Gross_Emissions_Deforestation**	Gross emissions from deforestation in the Caatinga biome for the period 2016/2017-2020/2021
8. **Pampa_Gross_Emissions_Deforestation**	Gross emissions from deforestation in the Pampa biome for the period 2016/2017-2020/2021
9. **Pantanal_Gross_Emissions_Deforestation**	Gross emissions from deforestation in the Pantanal biome for the period 2016/2017-2020/2021
10. **National_FREL_modified**	Brazil's national FREL for the period 2016/2017-2020/2021
11. **ECS_secondary_vegetation_NEW**	Net enhancement of forest carbon stocks due to secondary vegetation regrowth in the Amazon considering the reference period from 2014 to 2020.

5.4. Consistency

5.4.1. Consistency with the latest National Greenhouse Gas Inventory

Paragraph 8 of Decision 12/CP.17 indicates that the reference levels should keep consistency with the country's latest National GHG Inventory. The 4th National GHG Inventory was submitted by Brazil to the UNFCCC in December 2020 and reports net GHG emissions for the

LULUCF sector for the period 1990-2016 (Brazil, 2020). Estimates of CO_2 emissions and removals due to land use and land-cover change and Harvested Wood Products, as well as non-CO_2 gases emissions used the 2006 IPCC GLs as a basis for the approaches and methodologies used.

Brazil applied IPCC's definition of consistency (IPCC, 2006) and in the construction of this national FREL used methodologies and datasets consistent with those applied to estimates CO_2 and non-CO_2 emissions from the conversion of forest areas (managed and unmanaged) to other land-use categories in the 4th National GHG Inventory.

It should be pointed out, however, that there are differences between the estimates provided in the 4th National GHG Inventory and this FREL submission, due to more updated and accurate data and information that were available at the time of construction of the FREL, in particular:

1. Change in the biome's geographical boundaries; and
2. Use of minimum mapping area (MMU) of 1 hectare for the identification of deforestation polygons in the Amazon biome.

Is also necessary to highlight that for the latest biennial update report (BUR4[30]) the activity data used (described in Box 4 of page 106 of the BUR4) is not the same when comparing with the activity data used in this submission. The national GHG inventory presented in the BUR was based in land use/cover maps for the years 1994, 2002, 2005 (including only Amazon biome), 2010 and 2016, whereas the FREL submission is constructed considering yearly deforestation and degradation maps. Brazil plans to consider the improvements included in the FREL when developing the next national GHG inventory, in order to improve the consistency.

5.4.1.1. Change in biomes' geographical boundaries

IBGE (2019) updated the geographical boundaries of the national biomes which were not available by the time of the development of the 4th National GHG Inventory. The Inventory thus used the boundaries defined in the 2004 IBGE map and that present some differences when compared to the new limits established in 2019 IBGE map, as indicated in **Table *20***.

Table 20 – Comparison between the geographical areas defined in IBGE (2019) and IBGE (2004) and the corresponding biome percent cover in the Brazilian territory

Biome	Area IBGE (2019) (ha)	Contribution to national area (%)	Area IBGE (2004) / 4th National GHG Inventory (ha)	Contribution to national area (%)
Amazon	421.274.200	49,5	420.877.900	49,4
Cerrado	198.301.700	23,3	203.582.600	23,9
Caatinga	86.281.800	10,1	82.784.500	9,7
Atlantic forest	110.741.900	13,0	111.557.200	13,1

[30] Available at: https://unfccc.int/documents/267661

Biome	Area IBGE (2019) (ha)	Contribution to national area (%)	Area IBGE (2004) / 4th National GHG Inventory (ha)	Contribution to national area (%)
Pampa	19.381.800	2,3	17.882.600	2,1
Pantanal	15.098.800	1,8	15.130.300	1,8
Total	**851.080.200**	**100**	**851.815.000**	**100**

OBS: please note that the difference in the geographical area of Brazil from IBGE (2004) (851,815,000 ha) and IBGE (2019) (851,080,200 ha) results from the elimination of areas that are now considered under the so called Coastal Marine System.

Source: IBGE, 2019 and Brazil, 2020

Tables 21 to 26 provide the implication of the of the change in each biome limit on the estimates of the gross GHG emissions from deforestation for Caatinga, Atlantic Forest, Pampa and Pantanal, respectively. For the Amazon, the changes in deforested area and consequent emissions are not significant.

Table 21 – CO_2 emissions from gross deforestation, MMU 6,25ha, based in the former (IBGE, 2004) and in the current (IBGE, 2019) biome limit for Amazon

Period	2004 limit		2019 limit		Change in area 2019/2004	Change in emissions 2019/2004
	Deforestation area (ha)	Gross emission (tCO_2/ha)	Deforestation area (ha)	Gross emission (tCO_2/ha)		
2016-2017	665,821.49	295,787,546.69	672,853.72	297,211,456.19	1.06%	0.48%
2017-2018	696,589.84	317,127,695.68	692,431.08	301,865,997.55	-0.60%	-4.81%
2018-2019	1,064,179.34	476,284,434.39	1,067,613.09	474,543,048.25	0.32%	-0.37%
2019-2020	1,038,806.82	461,063,907.52	1,031,985.74	443,258,448.53	-0.66%	-3.86%
2020-2021	1,212,868.69	556,489,285.94	1,215,904.49	546,613,958.95	0.25%	-1.77%

Source: own estimates

Table 22 – CO_2 emissions from gross deforestation based in the former (IBGE, 2004) and in the current (IBGE, 2019) biome limit for Cerrado

Period	2004 limit		2019 limit		Change in area 2019/2004	Change in emissions 2019/2004
	Deforestation area (ha)	Gross emission (tCO_2/ha)	Deforestation area (ha)	Gross emission (tCO_2/ha)		
2016-2017	600,141.45	108,508,958.58	569,967.98	103,183,642.91	-5.03%	-4.91%
2017-2018	536,438.13	97,433,138.48	550,809.22	101,775,493.28	2.68%	4.46%
2018-2019	531,278.93	95,623,692.67	494,315.49	88,886,236.32	-6.96%	-7.05%
2019-2020	602,798.37	106,842,798.79	603,072.06	108,662,302.47	0.05%	1.70%
2020-2021	648,277.57	115,451,945.66	632,946.89	114,670,094.80	-2.36%	-0.68%

Source: own estimates

Table 23 – CO_2 emissions from gross deforestation based in the former (IBGE, 2004) and in the current (IBGE, 2019) biome limit for Caatinga

Period	2004 limit		2019 limit		Change in area 2019/2004	Change in emissions 2019/2004
	Deforestation area (ha)	Gross emission (tCO_2/ha)	Deforestation area (ha)	Gross emission (tCO_2/ha)		
2016-2017	188,728.60	22,910,435.87	213,662.91	28,318,171.77	13.21%	23.60%
2017-2018	214,048.22	28,240,728.05	206,501.48	25,191,250.31	-3.53%	-10.80%
2018-2019	147,212.90	17,152,017.82	176,297.51	23,870,541.00	19.76%	39.17%
2019-2020	201,102.29	27,639,350.08	209,054.43	28,416,932.63	3.95%	2.81%
2020-2021	183,418.70	22,497,567.21	198,817.41	25,414,848.62	8.40%	12.97%

Source: own estimates

Note that the area of the Caatinga biome increased from IBGE (2004) to IBGE (2019) - from 82,784,500 ha to 86,281,800 ha. The deforestation areas in the Caatinga are shown in **Figure *16*** – in red, the deforestation areas "lost" to the Cerrado biome due to the new boundaries and in green, the deforestation areas inherited from the Cerrado biome. Quantitatively, the area lost is equal to 77,978.21 ha and the area "gained" is 136,942.27 ha, a difference of 58,964.06 ha.

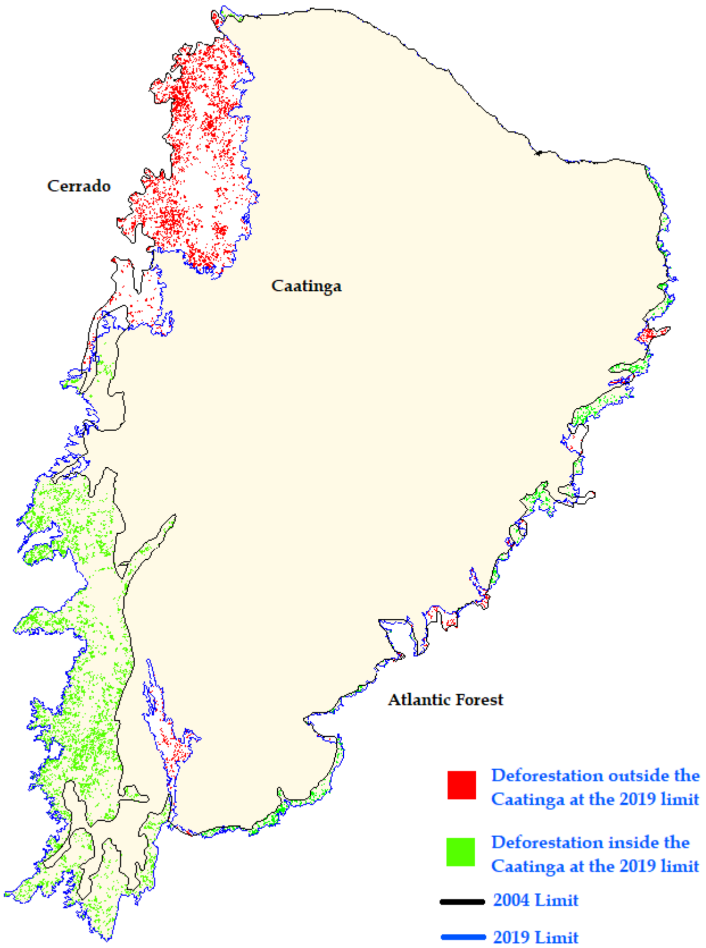


Figure 16 – Deforestation areas in the Caatinga "lost" to the Cerrado biome (in red) and the deforestation areas inherited from the Cerrado biome (in green) due to the new boundaries

Source: own calcultations

Table 24 – CO_2 emissions from gross deforestation based in the former (IBGE, 2004) and in the current (IBGE, 2019) biome limit for Atlantic Forest

Period	2004 limit		2019 limit		Change in area 2019/2004	Change in emissions 2019/2004
	Deforestation area (ha)	Gross emission (tCO_2/ha)	Deforestation area (ha)	Gross emission (tCO_2/ha)		
2016-2017	90,314.95	36,776,886.09	85,870.10	36,434,019.13	-4.92%	-0.93%
2017-2018	118,244.12	44,592,425.10	117,209.42	45,100,212.60	-0.88%	1.14%
2018-2019	90,449.21	39,189,284.79	89,850.38	39,463,223.90	-0.66%	0.70%
2019-2020	63,404.89	23,410,615.21	62,142.54	23,544,177.11	-1.99%	0.57%
2020-2021	73,255.71	29,285,094.32	68,964.58	28,761,217.90	-5.86%	-1.79%

Source: own estimates

The Atlantic Forest boundaries were reduced from IBGE (2004) (122,557,200 ha) to IBGE (2019) (110,741,900 ha) but this change had a very small impact in the average annual emissions, which ranged from –1,79% to 1,14% during the reference period.

Table 25 – CO_2 emissions from gross deforestation based in the former (IBGE, 2004) and in the current (IBGE, 2019) biome limit for Pampa

Period	2004 limit		2019 limit		Change in area 2019/2004	Change in emissions 2019/2004
	Deforestation area (ha)	Gross emission (tCO_2/ha)	Deforestation area (ha)	Gross emission (tCO_2/ha)		
2016-2017	35,425.69	3,709,137.07	35,948.28	3,629,784.82	1.48%	-2.14%
2017-2018	34,691.03	3,999,802.73	34,986.84	3,798,003.85	0.85%	-5.05%
2018-2019	38,132.31	3,583,817.00	39,058.02	3,574,669.24	2.43%	-0.26%
2019-2020	32,598.77	3,521,888.02	33,197.97	3,460,472.47	1.84%	-1,74%
2020-2021	55,738.82	5,892,710.46	56,665.90	5,850,601.61	1.66%	-0.71%

Source: own estimates

The Pampa boundaries were reduced from IBGE (2004) (17,882,600 ha) to IBGE (2019) (19,381,800 ha) but this change had a very small but consistent decrease in emissions, which ranged from – 5.05% to –0.26% during the reference period.

Table 26 – CO_2 emissions from gross deforestation based in the former (IBGE, 2004) and in the current (IBGE, 2019) biome limit for Pantanal

Period	2004 limit		2019 limit		Change in area 2019/2004	Change in emissions 2019/2004
	Deforestation area (ha)	Gross emission (tCO_2/ha)	Deforestation area (ha)	Gross emission (tCO_2/ha)		
2016-2017	32,036.69	6,979,761.01	34,286.50	7,296,713.06	7.02%	4.54%
2017-2018	25,882.18	5,608,315.32	23,976.11	5,101,430.68	-7.36%	-9.04%
2018-2019	17,489.73	3,906,089.98	21,684.31	4,684,070.20	23.98%	19.92%
2019-2020	25,173.13	5,937,112.64	24,558.11	5,655,515.57	-2.44%	-4.74%
2020-2021	27,462.26	7,600,592.87	27,760,72	7,446,456.25	1.09%	-2.03%

Source: own estimates

The Pantanal boundaries were slightly reduced from IBGE (2004) (15,130,300 ha) to IBGE (2019) (15,098,800 ha) but the changes in emissions was second to the Caatinga biome. The change in emissions ranged from –9.04% to 19.92% during the reference period.

Is important to note that none of the observed changes imply under or over estimations of the FREL, since there is no overlap between the geographical areas of the biomes or gaps in Brazil's geographical coverage, and all emissions are estimated. It just a matter of allocation within the biomes. Nevertheless, the change in the boundaries of the biomes resulted in the selection of different EF per phytophysiognomies and consequently in different impacts on the emissions. For example, in the Pantanal biome in 2020-2021 area deforested have increased by 1%; but emissions have decreased by 2%.

5.4.1.2. Implications of the use of the MMU of 1 ha in the estimation of the area deforested in the Amazon biome

The most significant difference between the estimates of gross deforestation in this national FREL submission and those in the 4th National GHG Inventory refers to the use of a MMU of 1 ha for the Amazon biome, instead of the MMU of 6.25 ha used in the 4th National GHG Inventory. The PRODES program conducted by INPE and that provides the official annual estimates of gross deforestation for the Legal Amazonia area uses MMU of 6.25 ha to ensure consistency in the timeseries since 1988. At that time, the estimates were obtained from the analysis of the deforestation polygons copied from the satellite image to transparent overlays, and 6.25 ha MMU corresponded to 1 mm^2 in paper. To ensure consistency throughout the entire annual time series since 1988, INPE continues to use the MMU of 6.25 ha.

The use of a MMU of 1 hectare responds to the one of the areas for future improvements identified during previous technical analysis[31]. The impact of including deforested areas between 1 ha and 6.25 ha is an average increase of 11.3 % in total deforested area and an average increase in CO_2e emissions of 11.2 % in the period from 2016/2017 to 2020/2021 (Figures below).

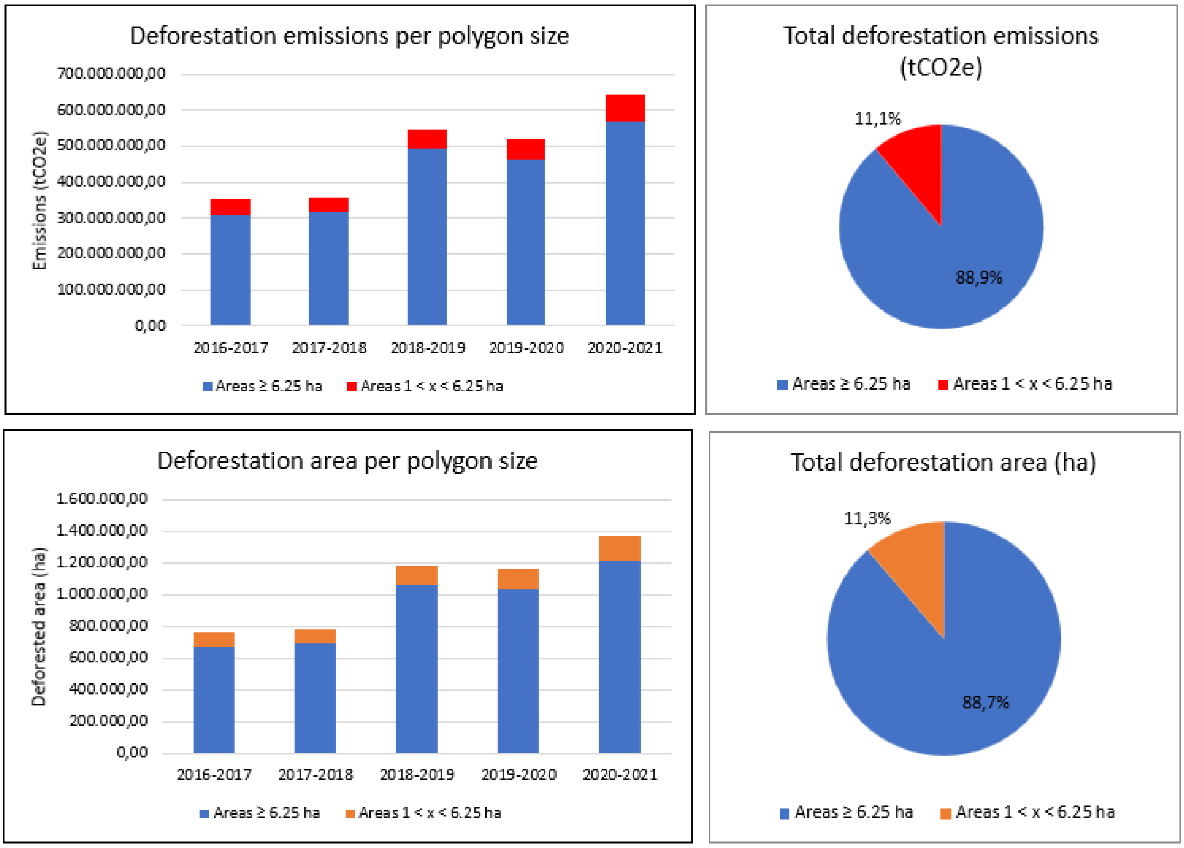


Figure 17 – Impact of including deforested areas between 1 ha and 6.25 ha in deforested areas and GHG emission estimates

Source: own calcultations

5.4.2. Consistency with other forest information reported internationally by Brazil

Although there is no requirement under the UNFCCC REDD+ that Brazil ensures consistency with forest information reported to other international bodies, Brazil plans to ensure this consistency in future submissions, in particular, between the he national inventory report of anthropogenic emissions by sources and removals by sinks of GHG to the Paris Agreement, future REDD+ submissions, and information reported to the Global Forest Resources Assessments (FRA - refer to **Box 9**).

[31] Paragraph 20 of Report of the technical assessment of the proposed forest reference emission level of Brazil submitted in 2018 (FCCC/TAR/2018/BRA). Available at: https://unfccc.int/sites/default/files/resource/tar2018_BRA.pdf

Brazil plans to evaluate the use, across all submissions, of biomass and carbon stocks derived from the **National Forest Inventory (NFI)**[32]. Nowadays, the NFI has been developed at the sub-national level. The following States have completed and validated the results (53% of the data has been collected, but not yet fully validated):

- Ceará
- Federal District
- Espírito Santo
- Paraíba
- Paraná
- Rio de Janeiro
- Rio Grande do Norte
- Rondônia
- Rio Grande do Sul
- Santa Catarina
- Sergipe

Results are updated regularly at NFI website[33] and the Global Forest Resources Assessments (FRA) platform[34].

Box 9 – Brazil's participation in the Global Forest Resources Assessments (FRA)

Forest Resources Assessments (FRA) are produced by countries reports based on data analysis done approximately every two years in advance of a reference year. Countries must carry out projections for the reference year based on the data available up to the date of preparation of the report.

In 2018, the Brazilian National Forest Inventory (NFI) had collected data approximately in 53% of the national territory. Data were collected in all biomes with the exception of the Pantanal biome.

Although the first NFI collection cycle was not completed, Brazil opted to use the NFI data for the FRA 2020 communication. The data used for biomass and carbon stocks estimation were obtained from Brazil NFI, collected until and available by December 2018. This was the first time that the FRA carbon stocks were calculated with data from the NFI.

In the NFI, information on carbon stocks is presented by forest typology according to IBGE Brazilian vegetation map and considering the boundaries of the 6 Brazilian biomes (Amazonia, Cerrado, Atlantic Forest, Caatinga, Pampa and Pantanal). For forest extension,

[32] More information about the NFI (in Portuguese) is available at: https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/ifn-inventario-florestal-nacional

[33] Latest NFI information is available at: https://snif.florestal.gov.br/pt-br/inventario-florestal-nacional-ifn/ifn-dados-abertos

[34] Information presented by Brazil to the FRA is available at: https://fra-data.fao.org/BRA/fra2020/home/

data from IBGE Brazilian vegetation map was also used, which gives the information about the original vegetation cover all over the country according to the national vegetation classification categories.

The NFI is based on a systematic sampling design, with clusters of four sub unities of 20m x 50m each, distributed in a national grid of 20 km x 20 km. Data of living trees over 10 cm DBH were processed for calculating average carbon stocks (ton/ha) for each biome and for each forest type within each biome, using available and published allometric equation fitted for forest types. For the vegetation types with low number of clusters in the biome, total samples for all biomes of that specific forest type were used. Carbon stock was estimated using the default IPCC factor of 0.49 applied to the biomass values. To retrieve field data for forest type, NFI used the same vegetation map used to estimate forest extension; and for estimating the total biomass carbon stock each forest type, values were multiplied by its correspondent area given by the map. Although the NFI has information collected on soil and litter pools, such data were not used because it was not proper analyzed up to December 2018.

Only for the Pantanal biome, where there was no NFI data collected, the data used was the same used for the 2015 FRA submission (i.e., data based on bibliography references).

There is methodological consistency between the national GHG inventory and the Brazil's FRA. The vegetation map used is the same, as well as the definition of forest; both coincide with those used by the Brazilian Forestry Service. Nevertheless, There is a time difference in the preparation and reference dates of these reports, which causes some delay in the alignment of these activities. Usually, the FRA are made on advance and the national GHG inventory are made after the reference year.

It should be noted that the NFI is still under development; and its preliminary results for carbon stocks need to be further assessed, in under to better understand the differences with the current values used in the national GHG inventory.

The use of data (biomass and carbon stocks) derived from the National Forest Inventory could potentially result in more accurate GHG emissions estimates, but it is expected to result in differences compared to the current estimates. To illustrate the impact of using biomass and carbon stocks values derived from the NFI, a preliminary analysis was made using current available NFI values for selected phytophysiognomies in Pampa and Atlantic Forest biomes. The results are presented in the following tables.

At the present moment, the differences presented in the mentioned tables can't be confirmed. Once NFI data is completed and validated; Brazil plans to further evaluate the differences and the reasons for such differences.

Table 27 – Gross emissions from deforestation estimated in this national FREL and using data from the NFI to estimate total carbon stocks and related CO_2 emissions in Decidual Seasonal Forest in the Pampa biome, and the percent differences

Period	Gross emissions due to deforestation (t CO_2)		Difference
	FREL	NFI/FRA	
2016-2017	577,399	397,224	-31.20%
2017-2018	490,971	346,827	-29.36%
2018-2019	618,398	413,814	-33.08%
2019-2020	1,025,863	665,818	-35.10%
2020-2021	1,220,998	841,923	-31.05%

Source: own estimates

Table 28 – Gross emissions from deforestation estimated in this national FREL and using data from the NFI to estimate total carbon stocks and related CO_2 emissions in Semi Decidual Seasonal Forest in the Pampa biome, and the percent differences

Period	Gross emissions due to deforestation (t CO_2)		Difference
	FREL	NFI/FRA	
2016-2017	861,105	508,955	-40.90%
2017-2018	1,076,098	640,186	-40.51%
2018-2019	833,665	493,778	-40.77%
2019-2020	546,397	322,216	-41.03%
2020-2021	1,834,345	1,092,614	-40.44%

Source: own estimates

Table 29 – Gross emissions from deforestation estimated in this national FREL and using data from the NFI to estimate total carbon stocks and related CO_2 emissions in Decidual Seasonal Forest in the Atlantic Forest biome, and the percent differences

Period	Gross emissions due to deforestation (t CO_2)		Difference
	FREL	NFI/FRA	
2016-2017	2,920,464	1,956,509	-33.01%
2017-2018	6,648,687	4,802,191	-27.77%
2018-2019	3,002,620	1,990,977	-33.69%
2019-2020	2,869,147	2,055,625	-28.35%
2020-2021	2,815,634	1,872,648	-33.49%

Source: own estimates

Table 30 – Gross emissions from deforestation estimated in this national FREL and using data from the NFI to estimate total carbon stocks and related CO_2 emissions in Semi Decidual Seasonal Forest in the Atlantic Forest biome, and the percent differences

Period	Gross emissions due to deforestation (t CO_2)		Difference
	FREL	NFI/FRA	
2016-2017	7,418,204	5,195,614	-29.96%
2017-2018	13,450,046	9,783,804	-27.26%
2018-2019	11,958,518	8,392,139	-29.82%
2019-2020	6,664,709	4,878,819	-26.80%
2020-2021	9,138,749	6,440,005	-29.53%

Source: own estimates

6. Results

Brazil's national FREL is the sum of the estimated GHG emissions for each of the six Brazilian biomes. The following sections presents the results of GHG emissions for each of the Brazilian biomes, estimated according to the methodology and information previously described.

6.1. Amazon biome

6.1.1. Net emissions from deforestation and degradation

The following table present the area deforested in each annual period of the reference period and corresponding net GHG emissions associated with deforestation and forest degradation in the Amazon biome.

Table 31 – CO_2 removals and GHG emissions associated with gross deforestation and degradation in the Amazon Biome

Period	Removals from land use post deforestation (tonnes CO_2 yr^{-1})	Deforestation emissions (tonnes CO_2 eq yr^{-1})	Degradation emissions due to fire in managed land (tonnes CO_2 eq yr^{-1})	Degradation emissions due to disordered logging (tonnes CO_2 yr^{-1})
2016-2017	-14,794,576	351,761,332	42,106,962	7,160,053
2017-2018	-15,219,016	358,570,690	12,392,615	4,991,741
2018-2019	-22,754,258	546,556,362	16,644,245	17,376,069
2019-2020	-22,368,985	521,394,985	45,787,916	20,682,306
2020-2021	-26,534,987	645,425,486	9,144,334	29,253,071

OBS: the differences with results presented in previous REDD+ technical annex is due to changes made in this submission (listed in section 3.5.1), including response to recommendations from past technical analysis (presented and explained in section 8.9). In particular, due to the use of updated values of emission factors from EBA, changes in the biome boundaries and the inclusion of deforestation areas smaller than 6.25 ha.

Source: own calcultations

Table 32 – Net GHG emissions associated with deforestation and degradation in the Amazon Biome

Period	Annual area deforested (ha yr^{-1})	Gross GHG emissions (tonnes CO_2 eq yr^{-1})	Net GHG emissions (tonnes CO_2 eq yr^{-1})
2016-2017	767,091	401,028,346	386,233,770
2017-2018	789,489	375,955,047	360,736,031
2018-2019	1,180,965	580,576,676	557,822,418
2019-2020	1,161,545	587,865,207	565,496,223
2020-2021	1,378,554	683,822,891	657,287,904
Average			505,515,269

Source: own calcultations

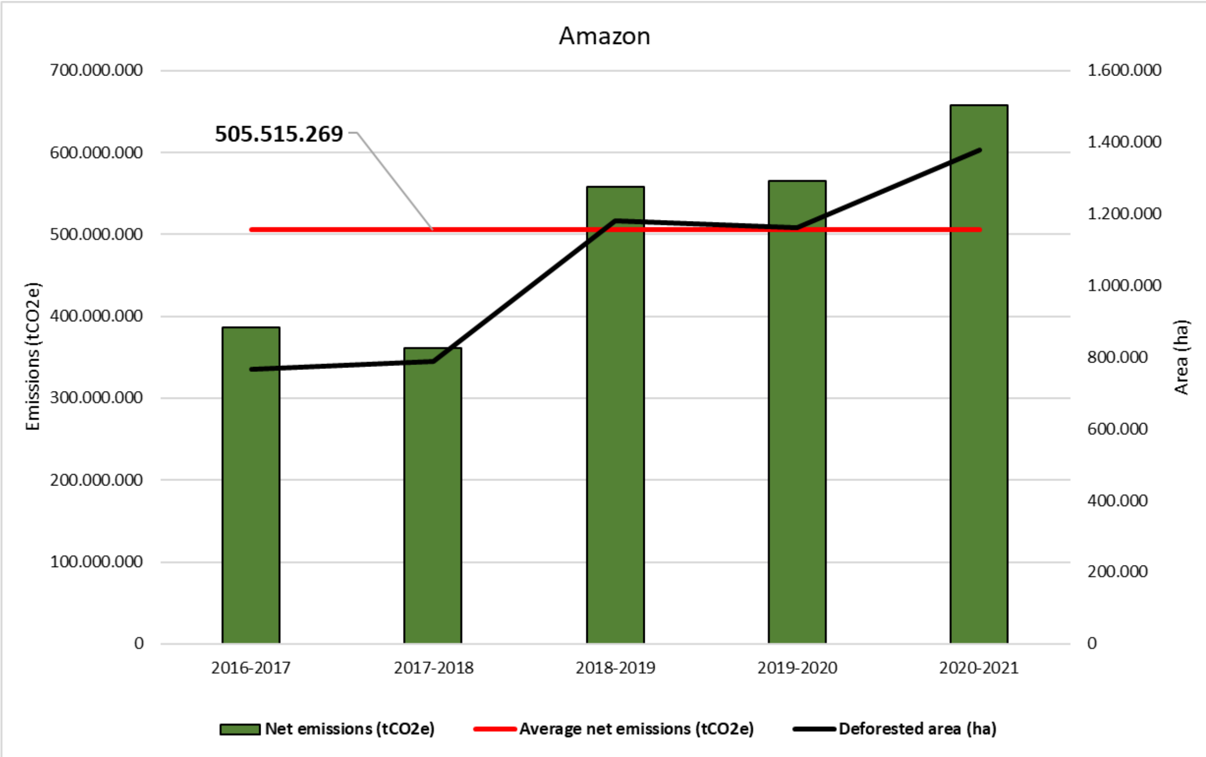


Figure 18 – Net GHG emissions from deforestation in the Amazon biome (2016/2017 – 2020/2021)

Source: own calcultations

The following figure shows the forest cover distribution at year 2021 and the polygons deforested between 2016 and 2021 in the Amazon biome.

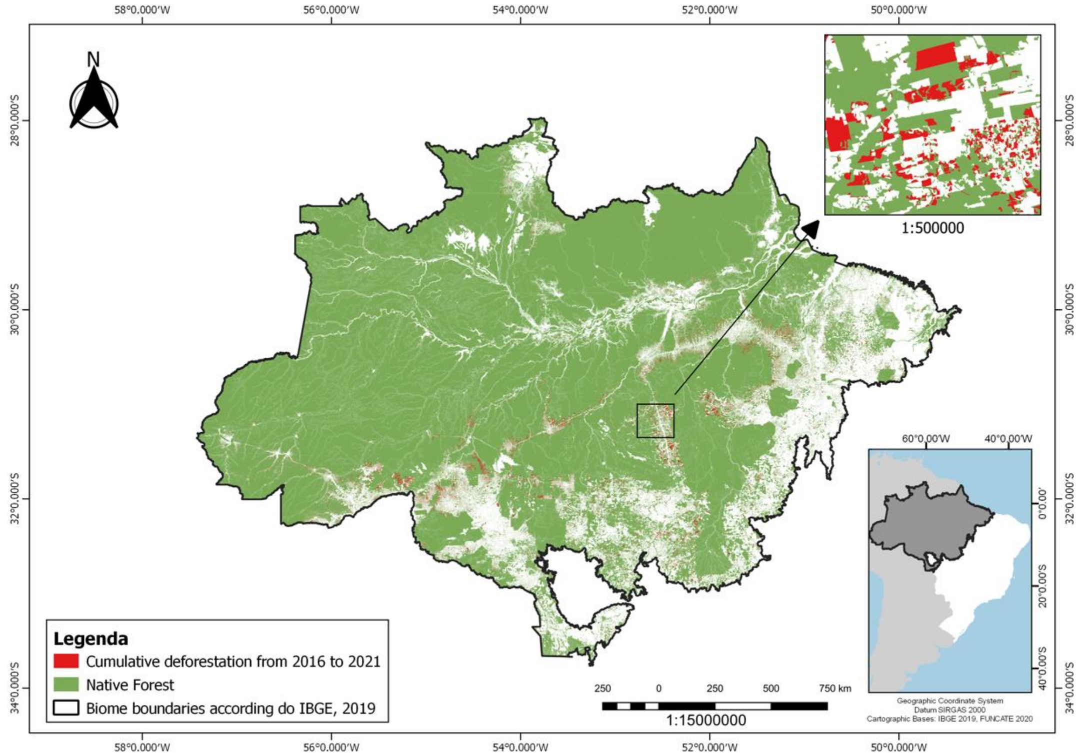


Figure 19 – Forest cover (in green) and deforested polygons (in red) in the Amazon biome (2016/2017 – 2020/2021)

Source: own calcultations based on PRODES data

6.1.2. Removals and emissions from enhancement of forest carbon stocks

The net EFCS due to secondary vegetation regrowth in the Amazon, for the reference period from 2014 to 2020, was estimated at -59,395,580 $tCO2.yr^{-1}$.

Table 33: Removals and emissions from EFCS in the Amazon, reference period from 2014 to 2020

Year	Removals - SV gain (tCO_2)	Emissions - SV loss (tCO_2)
2014	-178,115,232	116,840,838
2015	-177,692,504	79,498,166
2016	-177,269,776	94,720,196
2017	-176,847,049	109,942,226
2018	-176,424,321	125,164,255
2019	-176,001,594	140,386,285
2020	-175,578,866	155,608,315
Average	-176,847,049	117,451,469

6.2. Cerrado biome

The following table and figure present the area deforested in each annual period of the reference period and corresponding net GHG emissions associated with deforestation and forest degradation in the Cerrado biome.

Table 34 – Annual area deforested and corresponding net GHG emissions associated with deforestation in the Cerrado Biome

Period	Annual area deforested (ha yr^{-1})	Removals from land use post deforestation (tonnes CO_2 yr^{-1})	Deforestation emissions (tonnes CO_2 eq yr^{-1})	Net emissions (tonnes CO_2 eq yr^{-1})
2016-2017	569,968	-9,513,627	106,175,202	96,661,575
2017-2018	550,809	-9,129,247	104,768,029	95,638,7812
2018-2019	494,315	-8,134,940	91,442,096	83,307,156
2019-2020	603,072	-9,854,024	111,753,842	101,899,818
2020-2021	632,947	-10,267,947	118,004,276	107,736,329
Average				97,048,732

OBS: the differences with results presented in previous REDD+ technical annex is due to changes made in this submission (listed in section 3.5.1), including response to recommendations from past technical analysis (presented and explained in section 8.9). In particular, due to the use of updated values of emission factor from EBA and changes in the biome boundaries.

Source: own calcultations

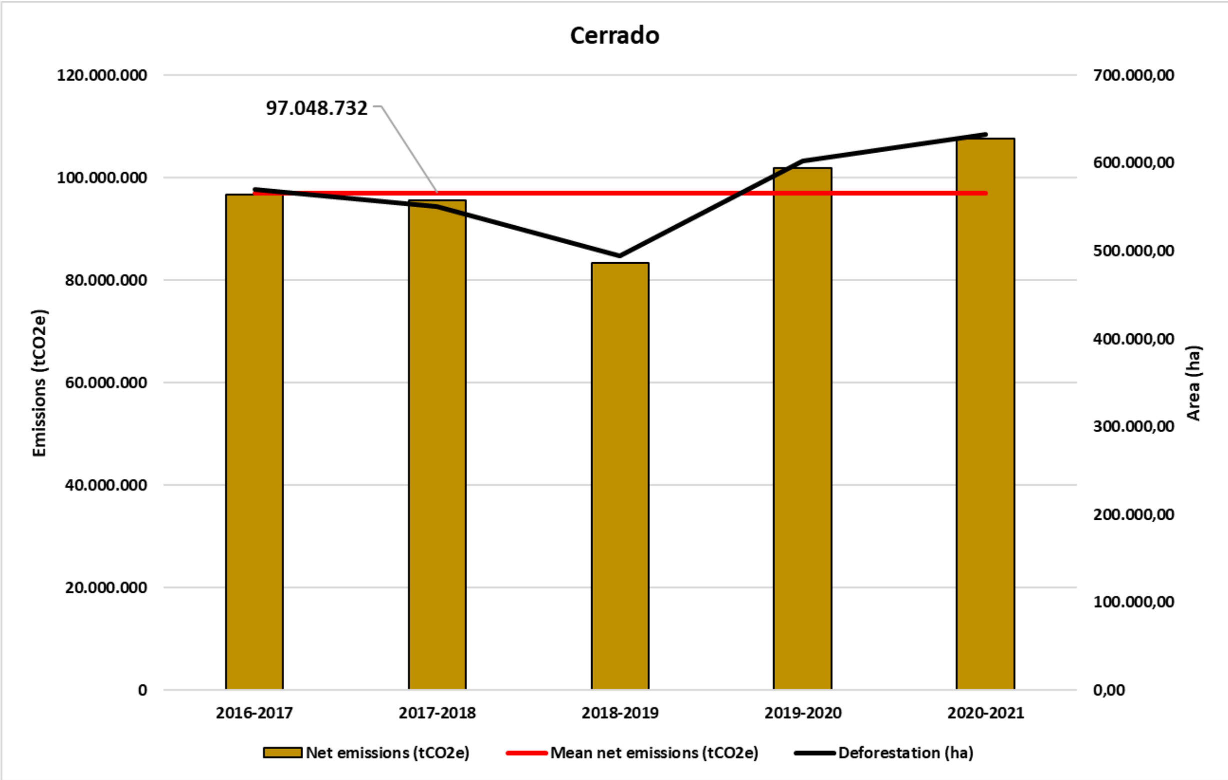


Figure 20 – Net GHG emissions and deforestation in the Cerrado biome (2016/2017 – 2020/2021)

Source: own calcultations

The following figure shows the forest cover at year 2021 and the polygons deforested between 2016 and 2021 in the Cerrado biome.

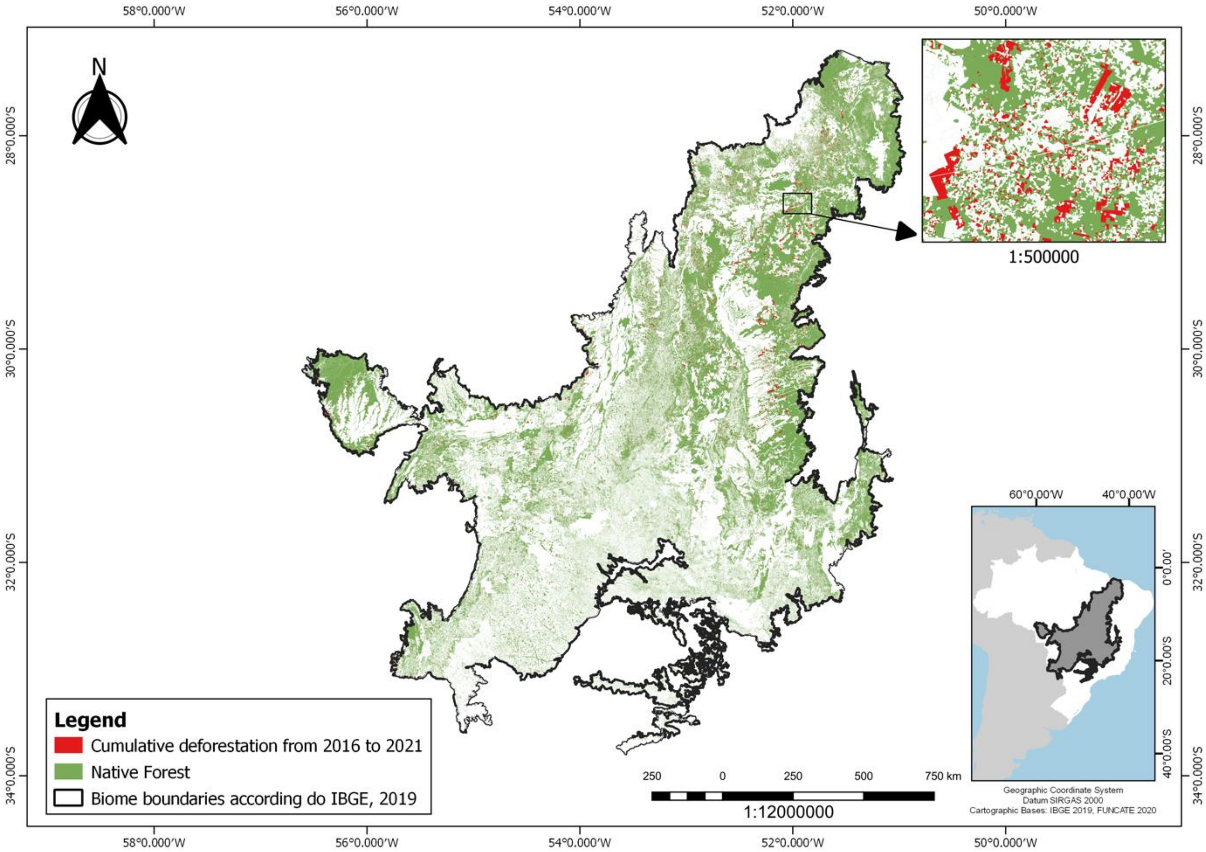


Figure 21 – Forest cover (in green) and deforested polygons (in red) in the Cerrado biome (2016/2017 – 2020/2021)

Source: own calcultations based on PRODES data

6.3. Caatinga biome

The following table and figure present the area deforested in each annual period of the reference period and corresponding CO_2 emissions associated with gross deforestation in the Caatinga biome.

Table 35 – Gross GHG emissions associated with deforestation in the Caatinga Biome

Period	Annual area deforested (ha yr^{-1})	Gross CO_2 emissions (tonnes CO_2 yr^{-1})
2016-2017	213,663	28,318,172
2017-2018	206,501	25,191,250
2018-2019	176,298	23,870,541
2019-2020	209,054	28,416,933
2020-2021	198,817	25,414,849
Average		26,242,349

Source: own calcultations

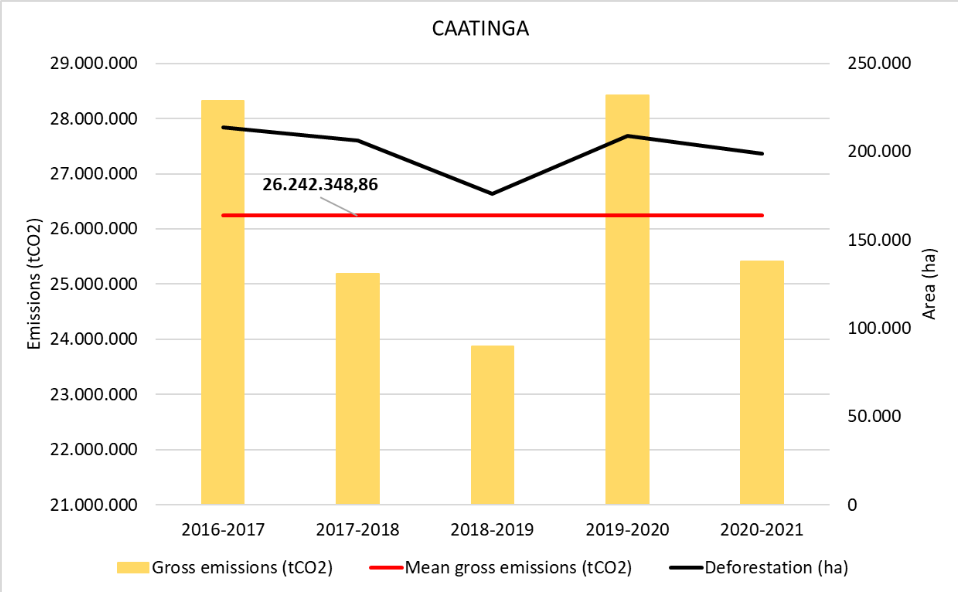


Figure 22 – Gross CO_2 emissions and annual deforestation in the Caatinga biome (2016/2017 – 2020/2021)

Source: own calcultations

The following figure shows the forest cover at year 2021 and the polygons deforested between 2016 and 2021 in the Caatinga biome.

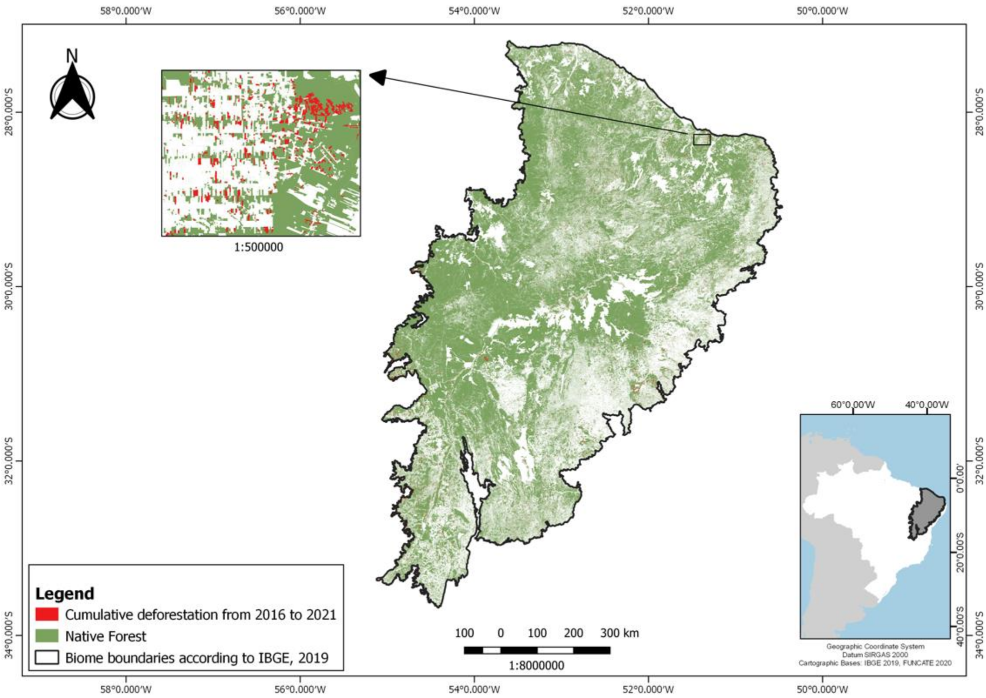


Figure 23 – Forest cover (in green) and deforested polygon (in red) in the Caatinga biome (2016/2017 – 2020/2021)

Source: own calcultations based on PRODES data

6.4. Atlantic Forest biome

The following table and figure present the area deforested in each annual period of the reference period and corresponding CO_2 emissions associated with gross deforestation in the Atlantic Forest biome.

Table 36 – Annual area deforested and corresponding gross GHG emissions associated with deforestation in the Atlantic Forest Biome

Period	Annual area deforested (ha yr^{-1})	Gross CO_2 emissions (tonnes CO_2 yr^{-1})
2016-2017	85,870	36,434,019
2017-2018	117,209	45,100,213
2018-2019	89,850	39,463,224
2019-2020	62,143	23,544,177
2020-2021	68,965	28,761,218
Average		34,660,570

Source: own calcultations

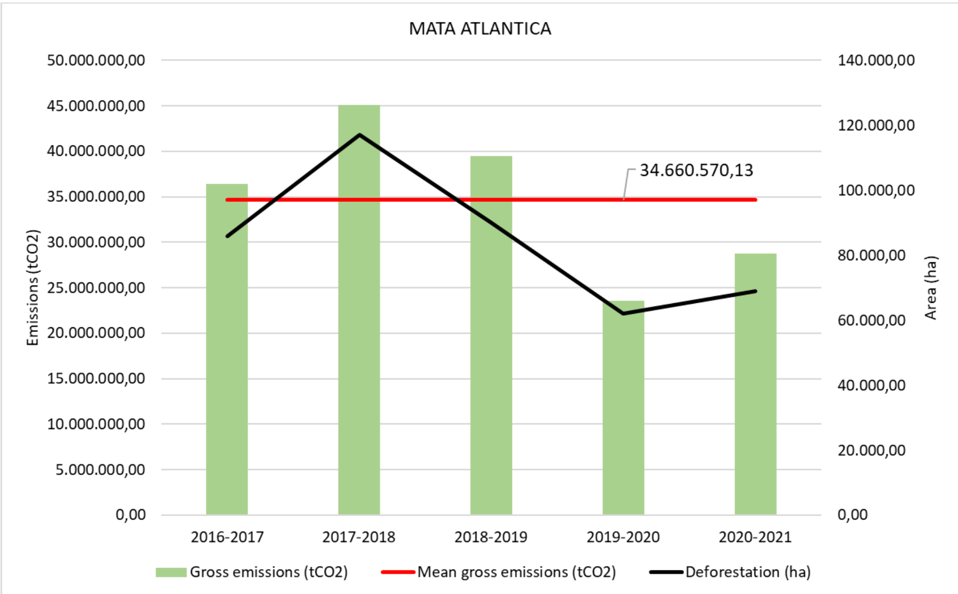


Figure 24 – Gross CO_2 emissions and annual deforestation in the Atlantic Forest biome (2016/2017 – 2020/2021)

Source: own calcultations

The following figure shows the forest cover distribution at year 2021 and the polygons deforested between 2016 and 2021 in the Atlantic Forest biome.

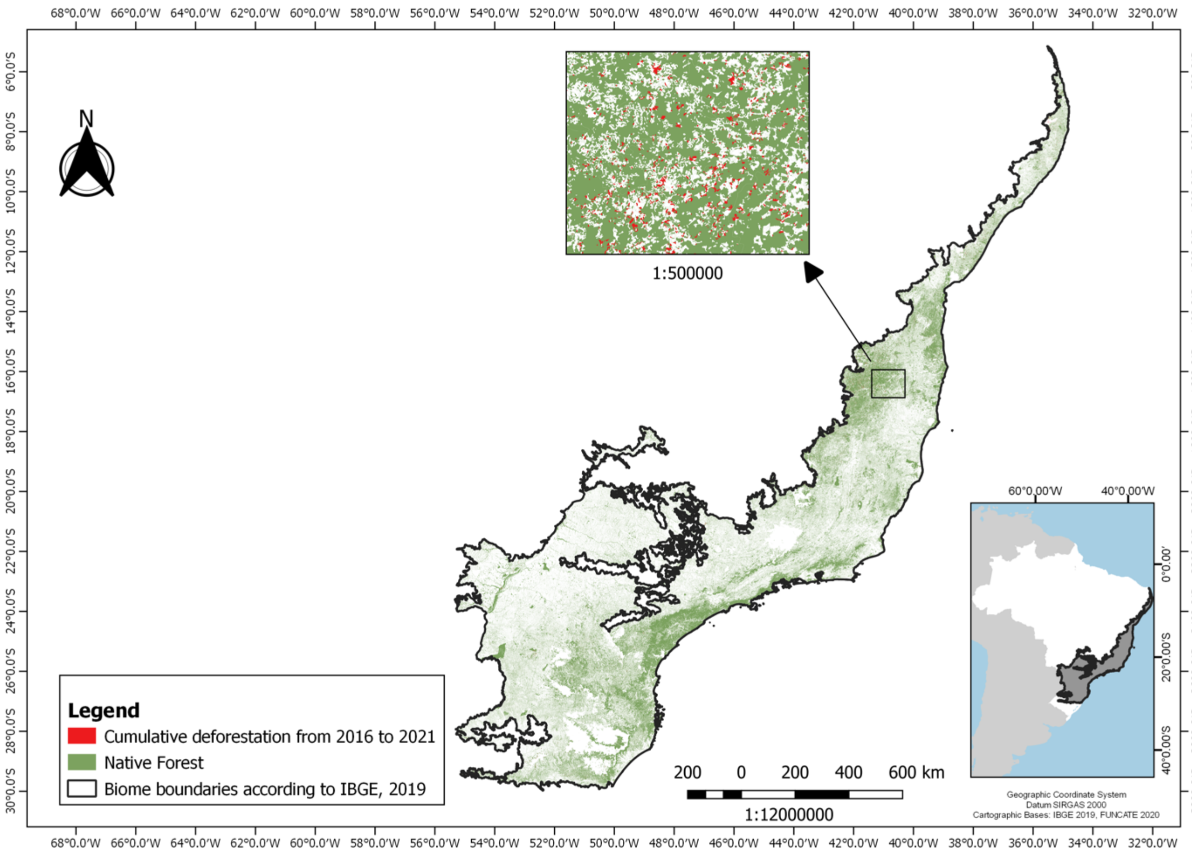


Figure 25 – Forest cover (in green) and deforested polygon (in red) in the Atlantic Forest biome (2016/2017 – 2020/2021)

Source: own calcultations based on PRODES data

6.5. Pampa biome

The following table and figure the area deforested in each annual period of the reference period and corresponding CO_2 emissions associated with gross deforestation in the Pampa biome.

Table 37 – Annual area deforested and corresponding gross GHG emissions associated with deforestation in the Pampa Biome

Period	Annual area deforested (ha yr^{-1})	Gross CO_2 emissions (tonnes CO_2 yr^{-1})
2016-2017	35,948	3,629,785
2017-2018	34,987	3,798,004
2018-2019	39,058	3,574,669
2019-2020	33,198	3,460,472
2020-2021	56,666	5,850,602
Average		4,062,706

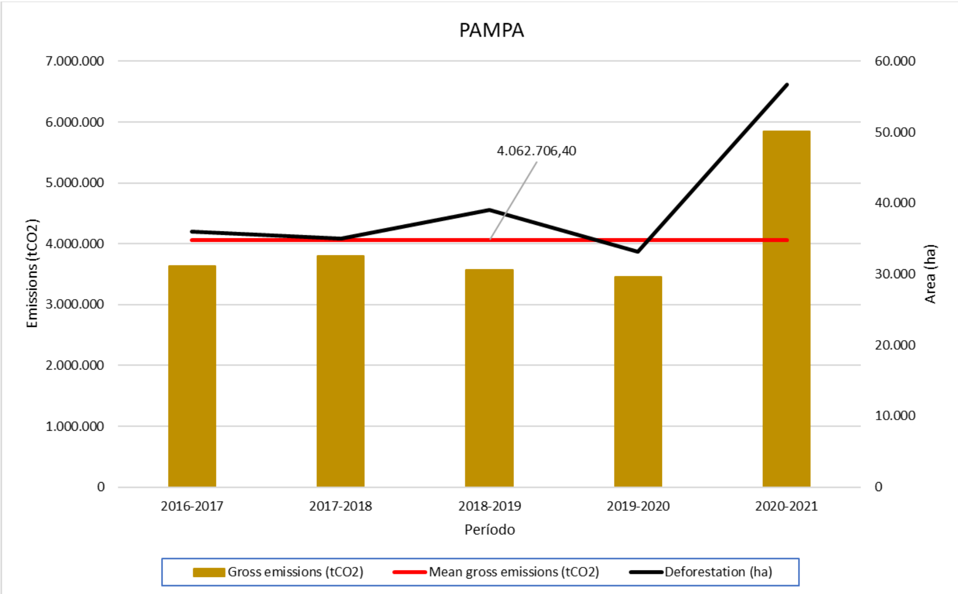


Figure 26 – Gross CO_2 emissions and annual deforestation in the Pampa biome (2016/2017 – 2020/2021)

Source: own calcultations

The following figure shows the forest cover distribution at year 2021 and the polygons deforested between 2016 and 2021 in the Pampa biome.

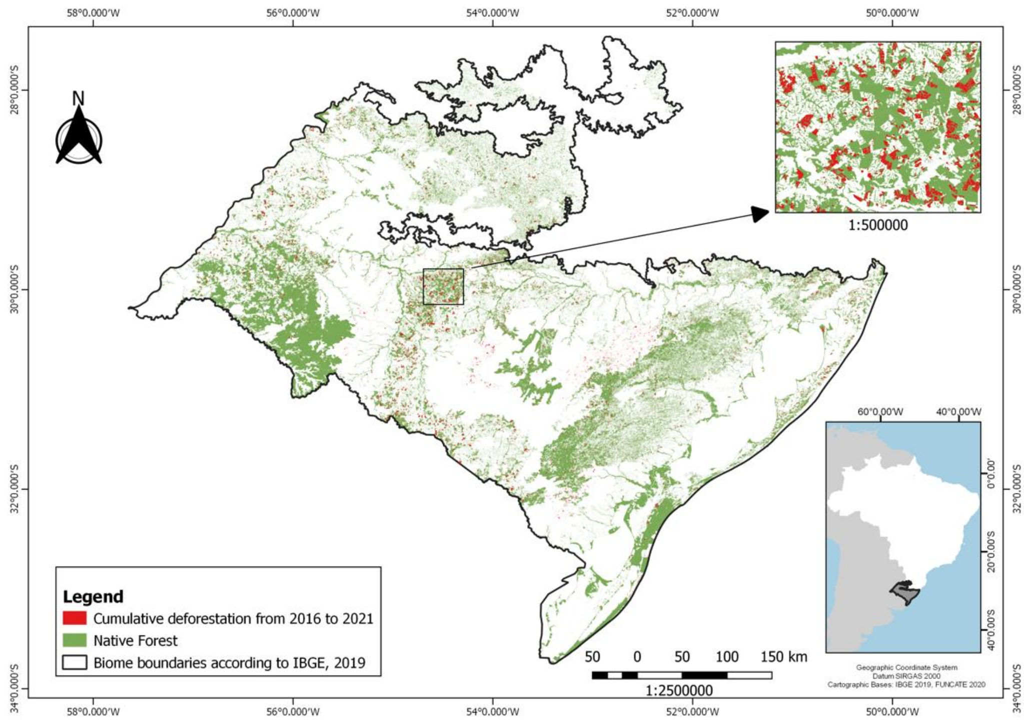


Figure 27 – Forest cover (in green) and deforested polygons (in red) in the Pampa biome (2016/2017 – 2020/2021)

Source: own calcultations based on PRODES data

6.6. Pantanal biome

The following table and figure the area deforested in each annual period of the reference period and corresponding CO_2 emissions associated with gross deforestation in the Pantanal biome.

Table 38 – Annual area deforested and corresponding gross GHG emissions associated with deforestation in the Pantanal Biome

Period	Annual area deforested (ha yr^{-1})	Gross CO_2 emissions (tonnes CO_2 yr^{-1})
2016-2017	34,287	7,296,713
2017-2018	23,976	5,101,431
2018-2019	21,684	4,684,070
2019-2020	24,558	5,655,516
2020-2021	27,761	7,446,456
Average		6,036,837

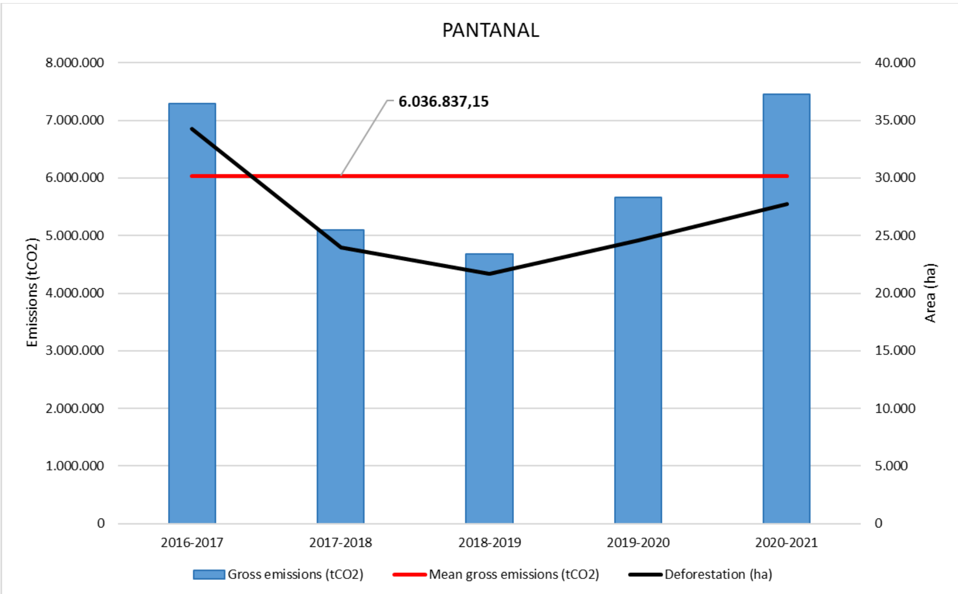


Figure 28 – Gross CO_2 emissions and annual deforestation in the Pantanal biome (2016/2017 – 2020/2021)

Source: own calcultations

The following figure shows the forest cover distribution at year 2021 and the polygons deforested between 2016 and 2021 in the Pantanal biome.

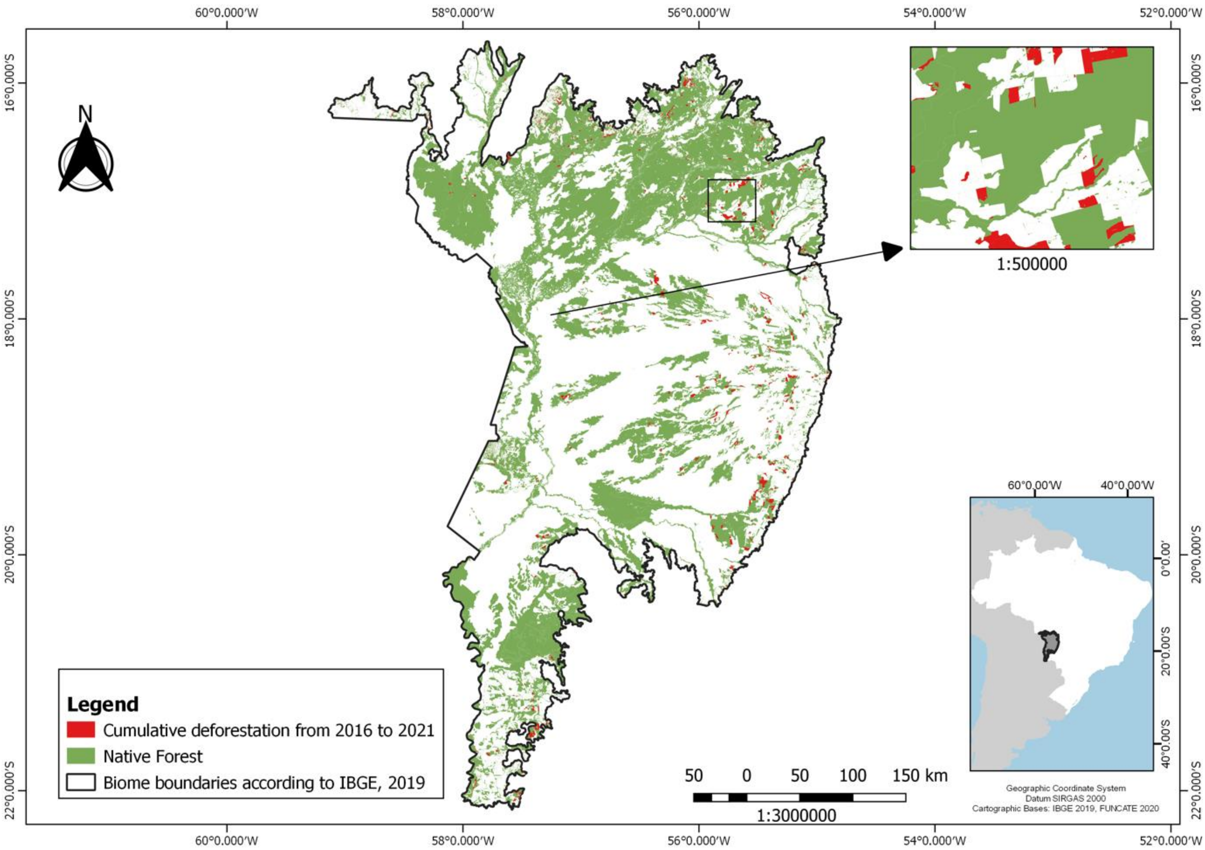


Figure 29 – Forest cover (in green) and deforested polygons (in red) in the Pantanal biome (2016/2017 – 2020/2021)

Source: own calcultations based on PRODES data

6.7. Brazil's National FREL

6.7.1. Emissions from deforestation and forest degradation

Brazil's national FREL is estimated as the sum of the gross average GHG emissions from Atlantic Forest, Caatinga and Pantanal biomes and the net GHG emissions (in tonnes CO_2e-eq) from Amazon and Cerrado biomes - **Table *39*** and **Figure *30***.

Table 39 – Brazil's national FREL for 2016-2017 / 2020-2021 period

Biome	Average annual emissions (tCO_2eq/yr)	Contribution (%)	Type
Amazon	505.515.269	75%	Net emissions
Cerrado	97.048.732	14%	
Atlantic forest	34.660.570	5%	Gross emissions
Caatinga	26.242.349	4%	
Pampa	4.062.706	1%	
Pantanal	6.036.837	1%	

FREL *(sum)*	**673.566.464**

Source: own calcultations

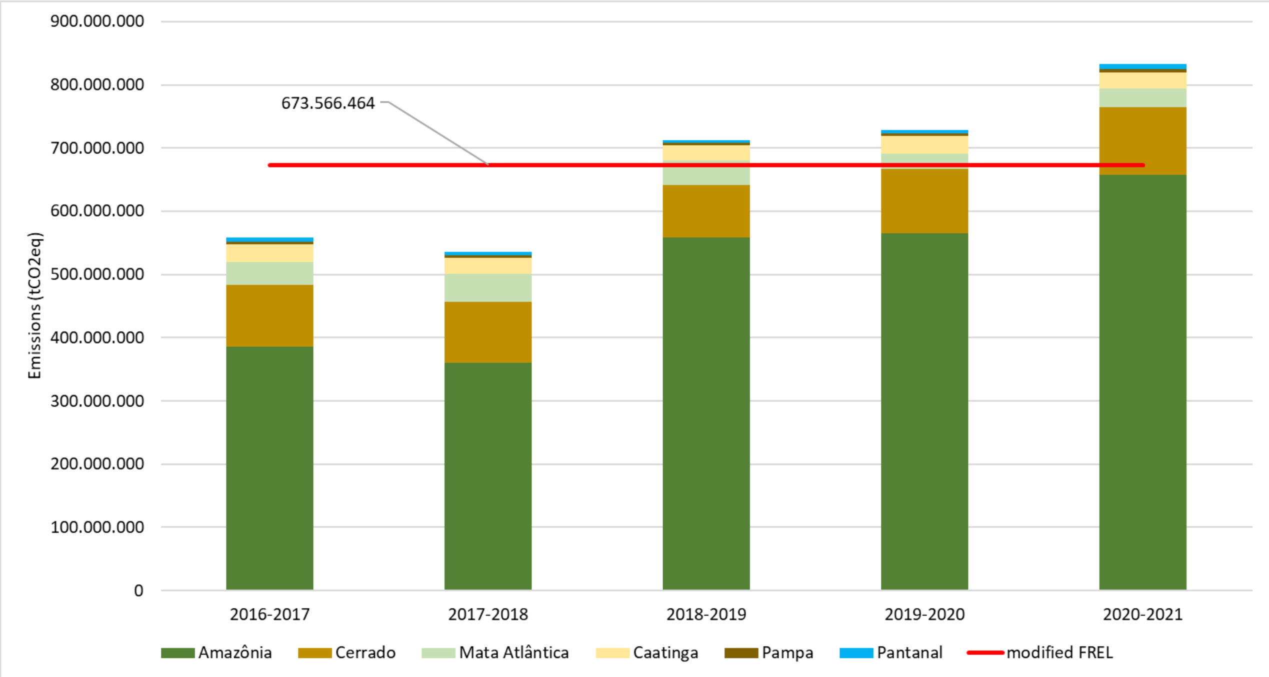


Figure 30 – Brazil's national FREL for 2016-2017 / 2020-2021 period

Source: own calculations

Based on this FREL, Brazil intends to seek for results-based payments resulting from the implementation of its policies and plans for REDD+.

6.7.2. Enhancement of forest carbon stocks

The net EFCS due to secondary vegetation regrowth in the Amazon, for the reference period from 2014 to 2020, was estimated at -59,395,580 $tCO_2\ yr^{-1}$.

Table 40: Net emissions from EFCS in the Amazon, reference period from 2014 to 2020.

Year	Removals - SV gain (tCO_2)	Emissions - SV loss (tCO_2)	NET enhancements of forest carbon stocks (tCO_2)
2014	-178,115,232	116,840,838	-61,274,394
2015	-177,692,504	79,498,166	-98,194,338
2016	-177,269,776	94,720,196	-82,549,581
2017	-176,847,049	109,942,226	-66,904,823
2018	-176,424,321	125,164,255	-51,260,066
2019	-176,001,594	140,386,285	-35,615,308
2020	-175,578,866	155,608,315	-19,970,551

Average	-176,847,049	117,451,469	-59,395,580

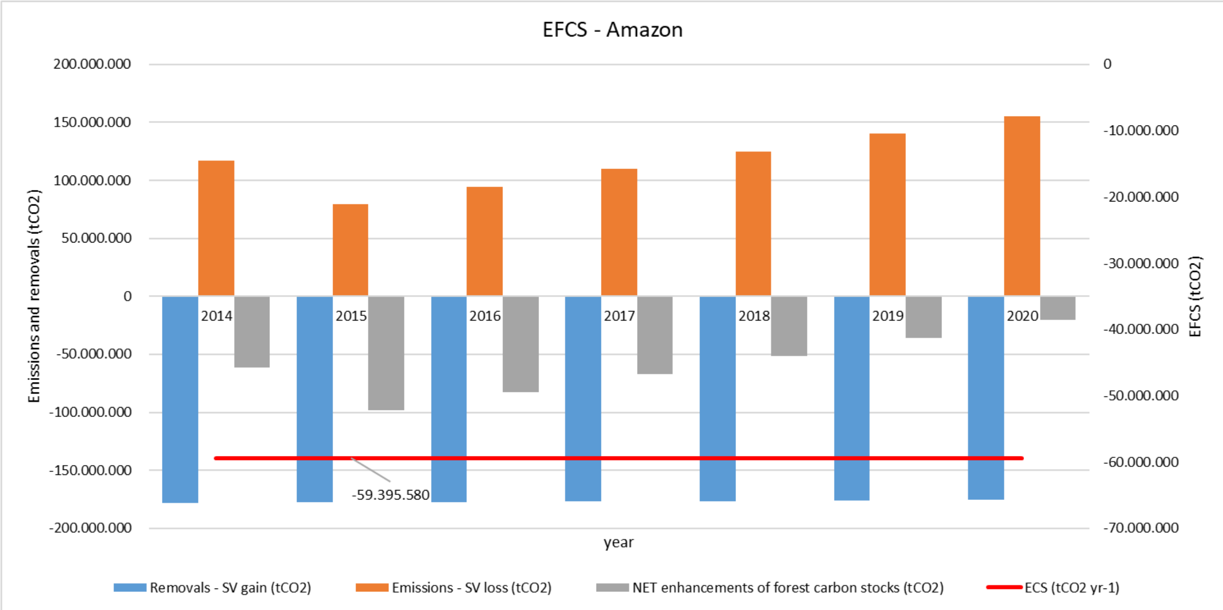


Figure 31: Net emissions from EFCS in the Amazon, reference period from 2014 to 2020

Source: own calculations

Box 10- Relevant policies and plans for REDD+

Brazil's sovereign commitment to the protection of native vegetation and the integrity of the climate system for the well-being of present and future generations was reiterated by Law No. 12.651/2012 (Forest Code). Also, a series of policies, laws, regulations, actions and initiatives from various stakeholders contribute to REDD+ implementation, both at the national and biome/regional level. The National Strategy for REDD+ (ENREDD+) was set out in 2015 with the objective to contribute to scale up the implementation of policies to reduce deforestation and forest degradation from the Amazon and Cerrado biomes to the national level.

The action plans to prevent and control deforestation in the Amazon and in the Cerrado were the main mediators instruments of public policies in the territory. Since 2004 (in the case of the Amazon) and since 2010 (in the case of the Cerrado), the efforts made have shown meaningful results in terms of reducing deforestation rates. Nevertheless, there has been an upward trend in deforestation in the Amazon, which reflects a certain exhaustion of previous plans, with the need to develop more effective solutions to prevent and counter illegal deforestation. In this context, considering the search for new solutions in addition to those that had been performing well, in 2019 there was a transition to the new Plan for the Control of Illegal Deforestation and Recovery of Native Vegetation, which encompasses the entire territory, approved by the Commission for the Control of Illegal Deforestation and Recovery of Native Vegetation – CONAVEG (Decree No. 10.142/2019). In 2023 this Decree was revoked and Decree No. 11.367/2023 was established, setting a mandate to develop specific Action Plans for the Prevention and Control of Deforestation in all Brazilian Biomes, currently the Plan for the Amazon (PPCDAm) is established and the Plans for the remaining biomes are under development.

The Plan consolidates the contributions of the various ministries that make up the Interministrial Commission and the Executive Subcommittee of the PPCDAm. It was built based on the experience accumulated by the federal government in the four previous phases and the success achieved in reducing deforestation by 83% between 2004 and 2012, according to data from the PRODES data. The development of the plan also benefited from dialogue with civil society and academia during the X Technical-Scientific Seminar on Data Analysis on Deforestation in the Amazon, from the public consultation process and from frequent meetings with representatives of states of the Legal Amazon and members of organized civil society.

It is also worth to mention the approval of the National Policy for Payments for Environmental Services (Law 14.119/2021) witch has been under discussion within the Technical Committee for its regulatory procedures.

Specifically about results-based payments, the National REDD+ Committee (Decree No. 10.144/2019) took important steps in the implementation of REDD+ beyond the Amazon, with the approval, in 2022, of the fundraising limits and eligibility criteria for the entities of the Cerrado biome, based on the results for reducing deforestation in this biome verified by the UNFCCC.

6.8. Uncertainties

The following tables presents the uncertainty estimates for gross GHG emissions associated with deforestation, degradation, and removals from secondary vegetation. Values presented in percent uncertainties around the estimated value, representing a 95% confidence interval.

Table 41 – Uncertainty of gross CO_2 emissions from deforestation

Year	Amazon %	Cerrado % %	Caatinga	Atlantic Forest %	Pampa %	Pantanal %
2017	12	14	20	21	18	24
2018	11	13	22	18	18	25
2019	12	14	20	20	18	24
2020	11	14	20	17	19	24
2021	11	13	20	19	15	26
Average	11	13	20	19	17	24

Source: own calculations

Table 42 – Uncertainty of CO_2 removals from land use/cover "post deforestation event" and CO_2 emissions from degradation

Year	Removals		Degradation due to fire	Degradation due to logging
	Amazon	Cerrado	Amazon	
	%	%	%	%
2017	58	72	39	15
2018	58	73	58	12
2019	58	73	37	11
2020	58	74	35	10
2021	58	74	33	10
Average	58	73	35	10

Source: own calculations

Table 43 – Uncertainty of CH_4 emissions

Year	Deforestation		Degradation due to fire
	Amazon	Cerrado	Amazon
	%	%	%
2017	92	93	99
2018	92	93	110
2019	92	93	98
2020	92	93	98
2021	92	92	97
Average	92	93	98

Source: own calculations

Table 44 – Uncertainty of N_2O emissions

Year	Deforestation		Degradation due to fire
	Amazon	Cerrado	Amazon
	%	%	%
2017	89	90	96
2018	89	89	110
2019	89	90	96
2020	89	89	95
2021	89	89	95
Average	89	89	95

Source: own calculations

Table 45 – Uncertainty of net emissions

Year	Amazon %	Cerrado %
2016-2017	17	17
2017-2018	16	17
2018-2019	15	17
2019-2020	16	17
2020-2021	15	17
Average	15	17

Source: own calculations

The uncertainty can also be expressed as 95% intervals as shown in the following table.

Table 46 – Uncertainty of net emissions expressed as 95% interval around the mean

Year	Confidence Interval Amazon (tonnes CO_2 eq)		Confidence Interval Cerrado (tonnes CO_2 eq)	
2016-2017	319.495.531	452.972.010	80.017.732	113.305.418
2017-2018	304.779.931	416.692.130	79.582.712	111.694.851
2018-2019	472.616.687	643.028.148	68.960.663	97.653.649
2019-2020	475.751.831	655.240.615	84.476.429	119.323.206
2020-2021	559.299.594	755.276.215	89.830.370	125.642.287
Average	428.227.891	582.802.648	80.676.062	113.421.401

Source: own calculations

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8. Annex: Additional Information

8.1. Additional information related to deforestation activity data

The mapping of the areas deforested in each biome followed the methodology developed and used in **PRODES-Amazônia** (Almeida, et al., 2020) and **PRODES-Cerrado** (INPE, 2018)**,** in order to ensure that the identification of deforestation polygons is consistent throughout all Brazilian territory. In general, the methodology involves visual analysis followed by manual vectorization of deforestation using medium-resolution satellite images (Landsat type) - **Figure *32***.

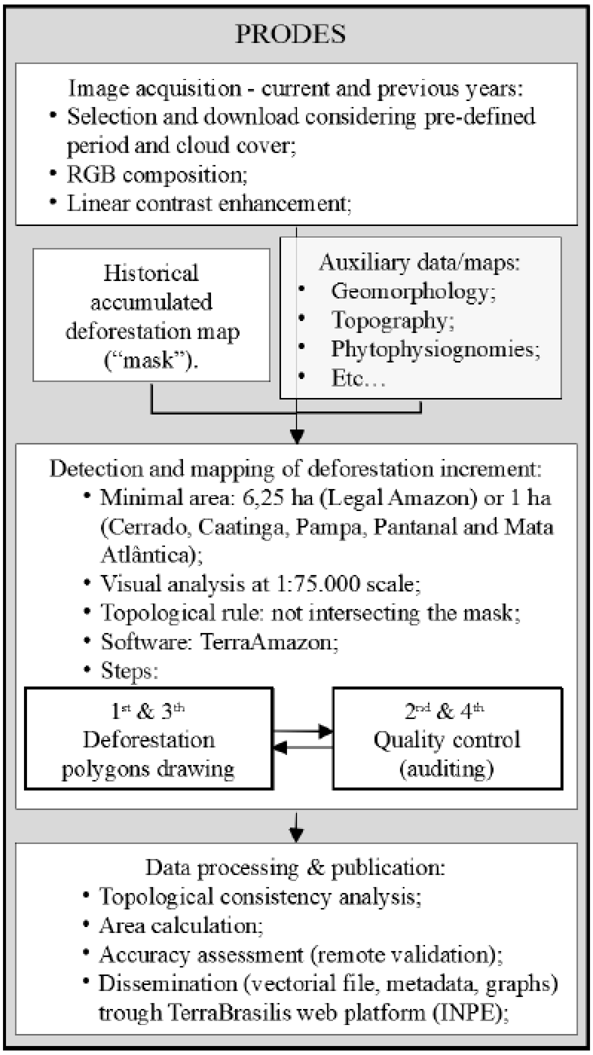

Figure 32 – General description of PRODES methodology

Source: Adapted from Almeida, et al., 2020

The images used to identify the deforested polygons were selected following a priority period in order to have regular annual intervals. The defined periods include a priority quarter associated with an extended period - which adds one or two months beyond the priority quarter.

Table 47 – Satellite images selection period

Biome	Priority period	Extended period
Amazon	July-August-September	July-August-September-October-November
Cerrado	July-August-September	June-July-August-September
Caatinga	August-September-October (ASO)	July-August-September-October-November-December
Pampa	September-October-November (SON)	August-September-October-November-December
Pantanal	July- August-September (JAS)	July-August-September-October
Atlantic Forest - north	October-November -December (OND)	September-October-November-December
Atlantic Forest south-center	June-July-August (JJA)	June-July-August-September

Source: INPE/FUNCATE

Table 48 – Average interval of days considered in the selection of images, for each biome, and period of analysis period

Period	Average interval of days					
	Amazon	Cerrado	Atlantic Forest	Caatinga	Pampa	Pantanal
2016-2017	361	370	377	408	360	364
2017-2018	364	352	374	358	369	368
2018-2019	389	378	356	388	381	363
2019-2020	362	369	343	356	323	367
2020-2021	367	365	360	330	392	369

Source: FUNCATE

For each of the biomes, there was a team of qualified interpreters that generated deforestation data for each of the periods, thus reducing potential inconsistencies in the identification of deforestation patterns in each of the maps produced.

A reference map was generated from satellite imagery for the reference period and each biome, indicating the accumulated areas of deforestation and non-deforestation (considered natural areas). From this reference map, according to the methodology presented in **Figure *32***, areas were identified and mapped at the scale of 1:100,000. **Table *49*** shows the number of scenes for each biome for each year analyzed. The sum of the areas of the deforestation polygons identified within a given geographical extent (e.g., biome) is referred to as increment of deforestation.

Deforestation increments in forest areas in the period 2016 to 2021 constitute the activity data to estimate CO_2 emissions from deforestation. Brazil's National FREL considers the increments of deforestation (ha/yr) for each of the following periods: 2016-2017, 2017-2018, 2018-2019, 2019-2020, 2020-2021.

Table 49 – Number of scenes analyzed in each annual period of the historical series, for each biome

Biome	Number of Landsat scenes used to cover the biome
Amazon	203
Cerrado	126
Atlantic Forest	89
Caatinga	52
Pampa	17
Pantanal	16

8.2. Additional information related to forest degradation activity data

Spatial data on forest degradation are available through INPE's DETER System, whose methodology is described in Almeida et al. (2022). In summary, DETER's methodology is based on the visual analysis of CBERS WFI satellite images in color composites of bands 5 (R), 4 (G) and 3 (B) and shadow fraction and vegetation images acquired through linear model analysis of spectral mixture, in addition to multi-time series of Landsat and CBERS images (Almeida, et al., 2022).

Degradation polygons in the DETER system are associated with logging (orderly/geometric and irregular/disordered) and "fire scars". The area of the polygons identified as degradation in each annual period may continue to be exploited or burned in subsequent years and may eventually be deforested, either partially or totally. Therefore, a given polygon classified as degraded may be reclassified as deforested in subsequent years.

Areas of selective logging and "fire scars" in Amazon biome are available for all years of the reference period.

Brazil consider that DETER is an adequate tool to monitor degradation. Latest data/results from previous monitoring program DEGRAD (i.e., 2016) mapped 23,778 polygons of degradation due to fire, with a total area o 27,221 km^2 (average of 114 ha / polygon). Is important to stress that DEGRAD has mapped the areas 1 time per year using images from the Landsat satellite (with 30 m spatial resolution).

In 2016, mapping of forest fire degradation by DETER started, using images from the CBERS 4 and 4A satellites (with 64 m spatial resolution). In that year, 17,121 polygons totaling 23,403 km^2 (average of 136 ha/polygon) were mapped by DETER. Even though DETER mapped 28%

less in the number of polygons than DEGRAD, the area mapped by DETER was 14% smaller, which may indicate that the difference in spatial resolution between the Landsat satellite (used by DEGRAD) and the CBERS satellite (used by DETER) does not cause great loss of information. The reduction in spatial resolution can be compensated by the high temporal resolution of the CBERS images used in DETER (i.e., 5 days revisit), allowing several degradation events to be mapped systematically over the same year, thus fulfilling the main objective of DETER, which is the issuance of information for environmental inspection.

Nevertheless, Brazil plans to continue to improve DETER by evaluating the possibility to elaborate daily deforestation/degradation alerts produced from using Sentinel2/Landsat 8 and 9 images based on semi-automated image classification processes.

In addition, INPE maintains a daily system for validating DETER data, through a specific GIS web platform (**Erro! Fonte de referência não encontrada.**). In the platform, the analyst evaluates a set of deforestation/degradation polygons based on current and better resolution images provided by the Planet Scope constellation (with 5 m resolution), identifying each one as Right ("confirmed alert") or Error ("false positive alert").

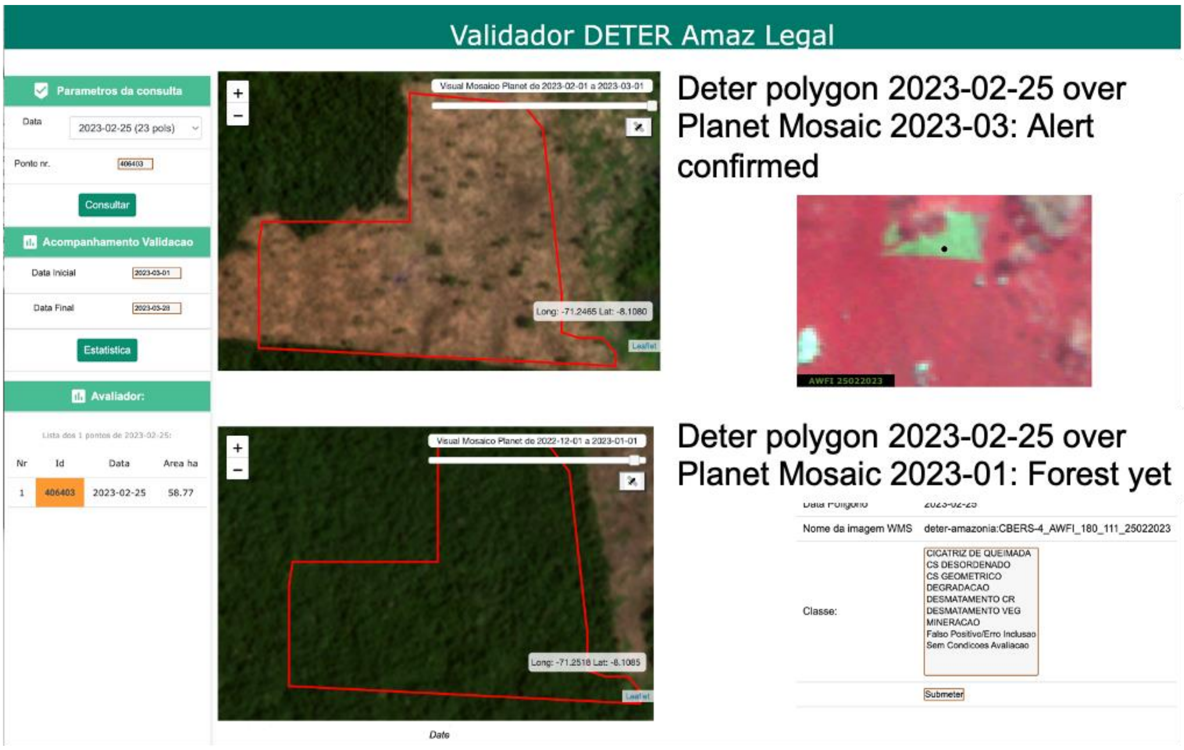

Figure 33 – Illustration of the GIS web platform used to validate DETER data

Source: DETER

From 2020-08-01 to 2023-02-28 a total of 41,999 DETER polygons were validated (only 45% of the total), and 86% of the polygons were considered as correct answers. For the classes of degradation due to fire, 2,818 (only 17% of the total) polygons were validated, 47% of which were considered correct in the same period. Brazil will continue to validate DETER polygons, to obtain a more precise estimate of right/error.

8.2.1. Orderly and disordered logging

Mapping classes for logging follow distinct patterns that result from the very the way the wood exploration is carried out. DETER classified the logging activities (using "image interpreter") into two categories: irregular/disordered logging and regular/orderly (Almeida, et al., 2022).

1. **Irregular/disordered logging:** it is considered a common type of wood extraction, where trees of commercial interest are removed without prior planning, identified unorderly shape of roads and extensions inside the forest and with the presence of storage patios with disordered dimensions and arranged randomly arranged.
2. **Regular/orderly logging:** it is considered to be related to an exploration based on some type of management plan (legal or not), in which one perceives the spatial organization of elements such as roads and storage patios inside the forest.

Only logging with disordered geometric patterns available in the DETER System was considered in this FREL submission as part of forest degradation. Once the SINAFLOR data are available (see **Box 7**), it will be possible to verify if the non-regular logging is indeed associated with forest degradation and not to management plans. The data will be instrumental to further discriminate forest degradation activities from those associated with approved management plans.

It is noteworthy that the definition of the logging classes is based only on the interpretation of the image based on the observed patterns of logging, and there is a limited capacity to identify the number of trees felled per hectare, volume extracted and secondary impact inside the forest or the legality of the intervention. ***Figure 34*** presents examples of alerts related to logging activities following DETER methodology (Almeida et al., 2022).

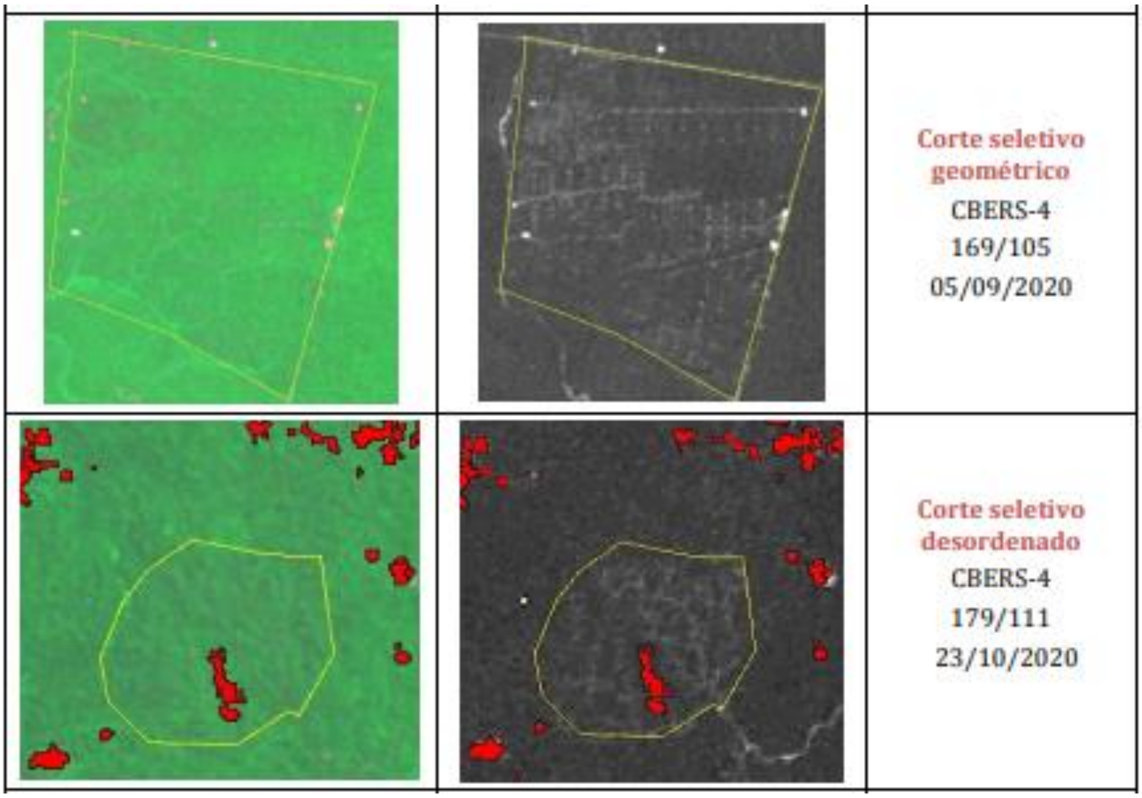

Figure 34 – Example of orderly (up) and disordered (bottom) logging from DETER system

Source: DETER

8.2.2. Fire scar

According to Valeriano et al. (2016) a **"fire scar"** an area that presents spectral characteristics associated with a fire occurrence. **Figure *35*** presents an example of an area affected by fire that was mapped under as a DETER "fire scar".

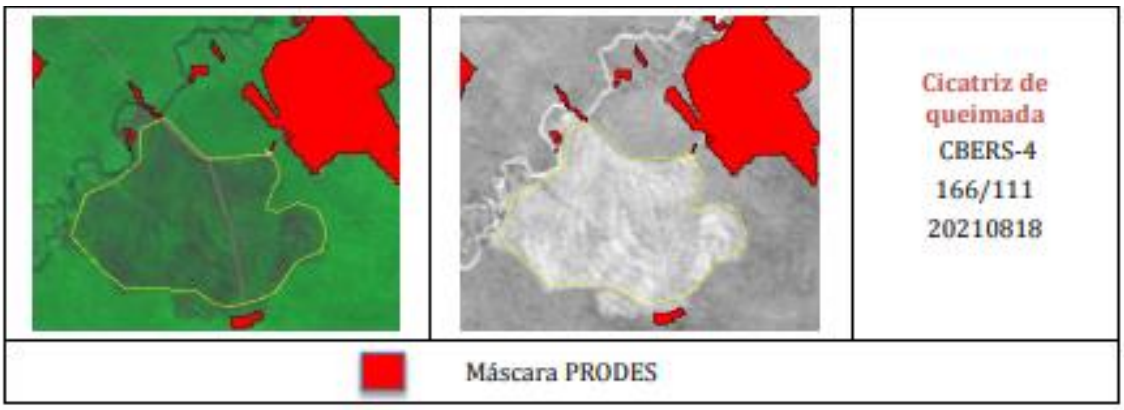

Figure 35 – Example of a "fire scar" in the DETER system

Source: DETER

8.3. Additional information related to the areas of natural forest regeneration (secondary vegetation)

8.3.1. Secondary vegetation – Amazon

To estimate net emissions in the Amazon biome, the areas of natural forest regeneration in areas previously deforested in the Amazon biome were first obtained from the **TerraClass Project**, were assessed. Unlike PRODES and DETER, such mapping is not produced with the same frequency as PRODES and DETER data, and information is only available for years 2014 and 2020.

According to Almeida, et al. (2016), areas of secondary vegetation consist of those forest areas that have been deforested and later abandoned for natural regeneration. Areas mapped as secondary vegetation may be in different stages of regeneration: initial, when the canopy is homogeneous and few species are found; or advanced, when the heterogeneity of the canopy and the diversity of species is similar to the original forest (Vieira, et al., 2003).

For 2014, the methodology used to map areas of secondary vegetation was based on the use of fraction images and color composites of Landsat-5/TM 3, 4 and 5 bands. Using the images and a linear mixing model, it was possible to identify a threshold above which the soil cover is dominated by secondary vegetation. These values varied for each image and once the spectral pattern was identified, image slicing technique was applied to create a thematic image (Almeida C. A., Valeriano, Escada, & Rennó, 2010).

For 2020 the methodology was based on a random stratified sampling in two stages. Initially, the Amazon biome was stratified by state and, later, by percentage of deforested area. To obtain the strata, the percent data of secondary vegetation mapped by TerraClass in the years 2014, 2012 and 2010 were used. After the stratification, parcels with 20 km by 20 km were randomly selected and training samples collected and subject to automatic classification, performed by a machine learning algorithm on cloud-based geospatial analysis platform Google Earth Engine (GEE). The classification used all available images for the period between June 2020 and October 2020, obtained by Sentinel-2/MSI satellite. Based on the area mapped in each of the parcels, the areas of secondary vegetation for the nine Amazon States and, later, for the Legal Amazon were estimated by direct expansion. Next, a subset of these data was used to map the secondary vegetation for the entire deforested area of the state.

8.3.2. Secondary vegetation – Cerrado

Secondary vegetation defined by TerraClass Cerrado is related to a natural vegetation formation, with predominance of savanna forest (“*cerradão*”) with trees with height between 15 and 18 meters and characterized by trees and shrubs with tortuous trunks that had been previously deforested. In the Cerrado biome, secondary vegetation data are available only for the years 2018 and 2020.

8.4. Detailed description for estimating GHG emissions/removals in the Amazon biome

The operational procedures, based on the methodological approach described in page 54, used to estimate GHG emissions due to deforestation, forest degradation and removals from secondary vegetation growth in the Amazon biome are detailed below. Overview of phase 1 is presented in **Figure *36***, where spatial data is assembled and spreadsheets are acquired to next calculation steps.

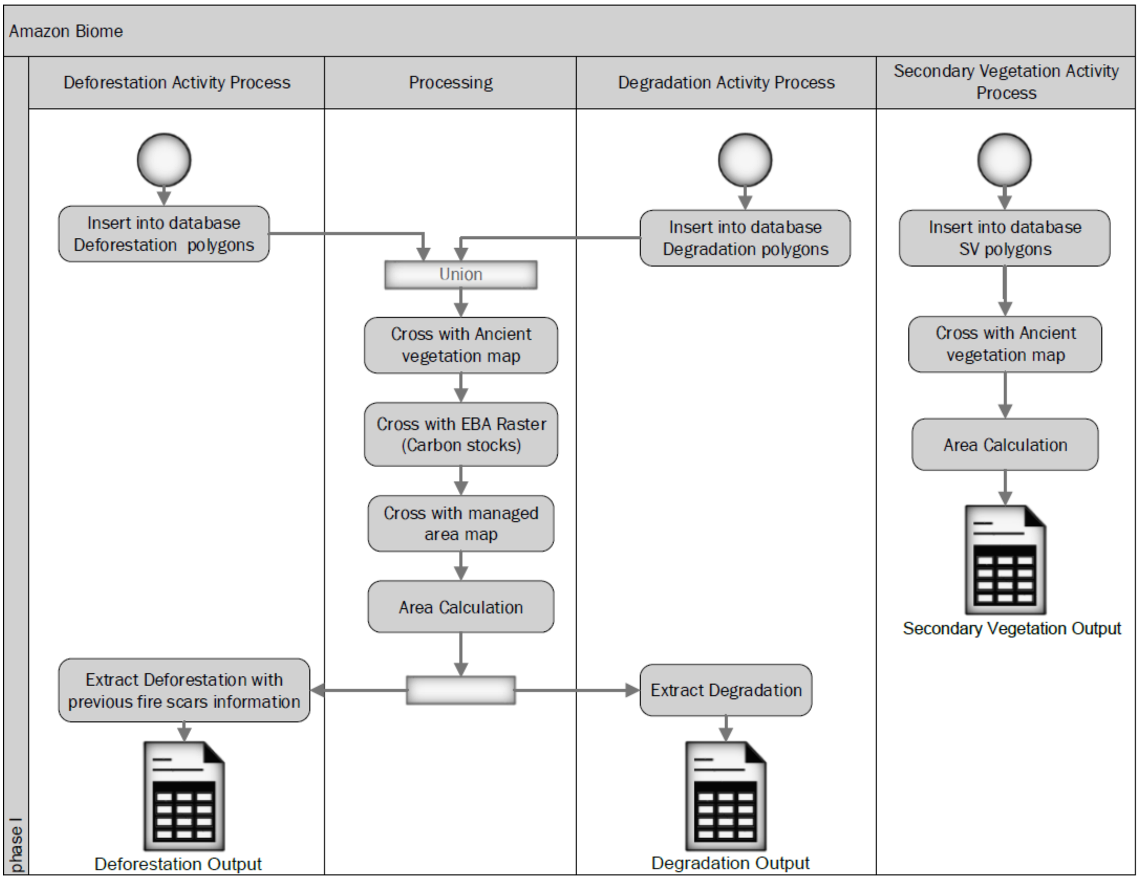

Figure 36 – Phase 1 workflow in GIS to deliver deforestation, degradation and secondary vegetation outputs to further phases

Source: own elaboration

8.4.1. Deforestation output – Amazon biome

- **PHASE 1 – GIS operations**

The 1st phase involves several spatial operations in a GIS environment (especially TerraAmazon software), with the aim to consolidate and merge maps presenting deforestation areas and other important information. The following steps (**Erro! Fonte de referência não encontrada.**) summarize these operations:

- **Step 1**: **Vectorial data gathering and verification (database creation), considering:**
    a. PRODES maps presenting polygons of native vegetation conversion increments for the periods 2016-2017, 2017-2018, 2018-2019, 2019-2020 and 2020-2021
    b. DETER degradation maps presenting fire scars and selective logging areas
    c. Biomes boundaries (***Figure 1***)
    d. Ancient native vegetation map (***Figure 9***)
    e. Managed areas map

    Verifications consists in a routine of procedures to identify topology errors (such as overlaps and gaps) and lack of information.

- **Step 2**: Spatial operations execution to join step 1 data and then to filter only deforestation polygons (i.e., native vegetation clearing occurring in forest phytophysiognomies according to the ancient native vegetation map).

- **Step 3**: Association of the emission factors (i.e., carbon stocks per unit area) to each deforestation polygon through the extraction of the spatial average value from the EBA raster map (4th National GHG Inventory maps presenting each carbon pool).

- **Step 4**: Exportation of an electronic spreadsheet containing, for each annual period of the reference period, the deforestation polygons and their corresponding phytophysiognomies and associated carbon stocks for above-ground biomass, below-ground biomass, dead wood and litter - **Table *50***.

Table 50 – Outcome of phase 1 "GIS operations" for the Amazon deforestation component, which is the input for next phases.

Variable name	Description	Unit	Spreadsheet column	Source
Biome	Biome classification: Amazon	n/a	A	IBGE, 2019
main_class	REDD+ activity classification: Deforestation	n/a	B	PRODES
class_name	REDD+ activity/year classification	n/a	C	
year	Year where the REDD+ activity have occurred	n/a	D	
deter2017		n/a	E	DETER

Variable name	Description	Unit	Spreadsheet column	Source
deter2018	Degradation classification in corresponding year: - Fire (“burn scar”) - Disordered logging (“CS”) - orderly logging (“CSR")	n/a	F	
deter2019		n/a	G	
deter2020		n/a	H	
deter2021		n/a	I	
status			J	
source_inv	Corresponding biome classification in the 4th GHG National Inventory	n/a	K	4th GHG National Inventory
phytophysiognomy	Ancient vegetation phytophysiognomies	n/a	L	
category	Vegetation category: Forest (F)	n/a	M	
managed_land	indicates whether the polygon is situated in a managed area (“t” = true) or not (“f” = falsa)	n/a	N	
EBA_cagb	Carbon content – above ground biomass carbon pool	tC/ha	O	EBA (4th GHG National Inventor)
EBA_cbgb	Carbon content – below ground biomass carbon pool	tC/ha	P	
EBA_cdw	Carbon content – dead wood carbon pool	tC/ha	Q	
EBA_clitter	Carbon content – litter carbon pool	tC/ha	R	
EBA_c4	Total carbon	tC/ha	S	
area_ha	Polygon area	ha	T	Own estimates

Source: Electronic spreadsheet “P3h_FREL_AMAZONIA_EMISSOES_DESMATAMENTO_1ha-6ha_Cenario3_v20201030.xlxs”

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	biome	main_class	class_name	year	deter2017	deter2018	deter2019	deter2020	deter2021	status	source_inv	phytophysiognomy	category	managed_land	eba_cagb	eba_cbgb	eba_cdw	eba_clitter	eba_ctotal	area_ha
2	Amazonia	DESMATAMENTO	d2017	2017	CQ1					DETER	Amazonia	Aa	F	f	17,09	1,71	1,38	0,99	21,17	0,834
3	Amazonia	DESMATAMENTO	d2017	2017			CQ1			DETER	Amazonia	Aa	F	f	40,19	4,02	3,26	2,32	49,79	0,0032

Figure 37 – Illustrative representation of the electronic spreadsheet output from Phase 1

Source: own elaboration

Each line of the spreadsheet represents a group of polygons with the same characteristics, except for their individual area. The “area_ha” attribute represents the sum of the individual deforested polygons areas. Such aggregation was necessary due to the large amount of data generated for the Amazon biome, which are not supported by Excel.

- **PHASE 2 – Emissions calculations**

Emissions calculations were performed in chronological order, according to the occurrence of degradation and/or deforestation activities, always applying the degradation losses before losses due to deforestation within the same year. The following steps were followed[35]:

- **Step 1**: Calculation of carbon stocks available in *t0* (in tonnes of C, i.e., tC/ha stock values already multiplied by areas in ha) by total and carbon pools:
  - Column U: total C stock *t0* [=S3*T3]
  - Column V: aerial C stock *t0* [=(O3+Q3+R3)*T3]
  - Column W: above ground C stock *t0* [=O3*T3]

- **Step 2**: Calculation of C, CH_4 and N_2O emissions and other losses due to degradation in 2017:
  - Column X: C emissions due to fire in managed lands
  - Column Y: CH_4 emissions due to fire in managed lands
  - Column Z: N_2O emissions due to fire in managed lands
  - Column AA: C emissions due to disordered logging (CS)
  - Column AB: C loss due to fire in unmanaged lands
  - Column AC: C loss due to orderly logging (CSR)

- **Step 3**: Calculation of remaining carbon stocks after degradation in 2017, representing carbon stocks available for deforestation in 2017:
  - Column AD: total C stock *t1*
  - Column AE: aerial C stock *t1*
  - Column AF: above ground C stock t1

- **Step 4**: Calculation of C, CH_4 and N_2O emissions due to deforestation in 2017:
  - Column AG: C emissions due to deforestation
  - Column AH: CH_4 emissions due to deforestation (resulting from slash and burn)
  - Column AI: N_2O emissions due to deforestation (resulting from slash and burn)

- **Step 5**: Calculation of carbon stocks available after 2017, representing carbon stocks available for degradation in 2018:
  - Column AJ: aerial C stock *t2*
  - Column AK: above ground C stock *t2*

- **Step 6**: Calculation of C, CH_4 and N_2O emissions and other losses due to degradation in 2018:
  - Column AL: C emissions due to fire in managed lands
  - Column AM: CH_4 emissions due to fire in managed lands
  - Column AN: N_2O emissions due to fire in managed lands
  - Column AO: C emissions due to disordered logging (CS)
  - Column AP: C carbon loss due to fire in unmanaged lands
  - Column AQ: C carbon loss due to orderly logging (CSR)

[35] Refer to file: "P3h_FREL_AMAZONIA_EMISSOES_DESMATAMENTO_1ha-6ha_Cenario3_v20201030.xlxs"

- **Step 7**: Calculation of carbon stocks available after 2018 degradation, representing carbon stocks available for deforestation in 2018:
  - Column AR: total C stock t3
  - Column AS: aerial C stock t3
  - Column AT: above ground C stock t3

- **Step 8**: Calculation of C, CH_4 and N_2O emissions due to deforestation in 2018:
  - Column AU: C emissions due to deforestation
  - Column AV: CH_4 emissions due to deforestation (resulting from slash and burn)
  - Column AW: N_2O emissions due to deforestation (resulting from slash and burn)

- **Step 9**: Calculation of carbon stocks available after 2018, representing carbon stocks available for degradation in 2019:
  - Column AX: aerial C stock *t4*
  - Column AY: above ground C stock *t4*

- **Step 10**: Calculation of C, CH_4 and N_2O emissions due to degradation in 2019:
  - Column AZ: C emissions due to fire
  - Column BA: CH_4 emissions due to fire
  - Column BB: N_2O emissions due to fire
  - Column BC: C emissions due to disordered logging (CS)
  - Column BD: C carbon loss due to fire in unmanaged lands
  - Column BE: C carbon loss due to orderly logging (CSR)

- **Step 11**: Calculation of carbon stocks available after 2019 degradation, representing the carbon stocks available for deforestation in 2019:
  - Column BF: total C stock t5
  - Column BG: aerial C stock t5
  - Column BH: above ground C stock t5

- **Step 12**: Calculation of C, CH_4 and N_2O emissions due to deforestation in 2019:
  - Column BI: C emissions due to deforestation
  - Column BJ: CH_4 emissions due to deforestation (resulting from slash and burn)
  - Column BK: N_2O emissions due to deforestation (resulting from slash and burn)

- **Step 13**: Calculation of carbon stocks available after 2019, representing carbon stocks available for degradation in 2020:
  - Column BL: aerial C stock *t6*
  - Column BM: above ground C stock *t6*

- **Step 14**: Calculation of C, CH_4 and N_2O emissions due to degradation in 2020:
  - Column BN: C emissions due to fire
  - Column BO: CH_4 emissions due to fire
  - Column BP: N_2O emissions due to fire
  - Column BQ: C emissions due to disordered logging (CS)
  - Column BR: C loss due to fire in unmanaged lands
  - Column BS: C loss due to orderly logging (CSR)

- **Step 15**: Calculation of carbon stocks available after 2020 degradation, representing the carbon stocks available for deforestation in 2020:
  - Column BT: aerial C stock t7
  - Column BU: above ground C stock t7
  - Column BV: above ground C stock t7

- **Step 16**: Calculation of C, CH_4 and N_2O emissions due to deforestation in 2020:
  - Column BW: C emissions due to deforestation
  - Column BX: CH_4 emissions due to deforestation (resulting from slash and burn)
  - Column BY: N_2O emissions due to deforestation (resulting from slash and burn)

- **Step 17**: Calculation of carbon stocks available after 2020, representing carbon stocks available for degradation in 2021:
  - Column BZ: aerial C stock *t8*
  - Column CA: above ground C stock *t8*

- **Step 18**: Calculation of C, CH_4 and N_2O emissions due to fire degradation in 2021:
  - Column CB: C emissions due to fire
  - Column CC: CH_4 emissions due to fire
  - Column CD: N_2O emissions due to fire
  - Column CE: C emissions due to disordered logging (CS)
  - Column CF: C loss due to fire in unmanaged lands
  - Column CG: C loss due to orderly logging (CSR)

- **Step 19**: Calculation of carbon stocks available after 2021 degradation, representing the stocks available for deforestation in 2021:
  - Column CH: Total C stock *t9*
  - Column CI: above ground C stock t*9*
  - Column CJ: above ground C stock t*9*

- **Step 20**: Calculation of C, CH_4 and N_2O emissions due to deforestation in 2021:
  - Column CK: C emissions due to deforestation
  - Column CL: CH_4 emissions due to deforestation (resulting from slash and burn)
  - Column CM: N_2O emissions due to deforestation (resulting from slash and burn)

The following table presents a numerical example of the calculations that have been carried out. Is important to note the evolution of total carbon stocks. In green: initial total carbon stocks; in blue: total carbon stocks after degradation events or not; in yellow: emissions due to deforestation whose values are associated with the reduced carbon stocks after previous degradation.

2583 **Table 51 – Example of GHG emissions for an area presenting a trajectory that passes**
2584 **through degradation by fire to deforestation**[36]

Column	Phase, Step	Attribute	Value
A	Phase 1	biome	Amazon
B	Phase 1	main_class	DESMATAMENTO
C	Phase 1	class_name	d2021
D	Phase 1	year	2021
E	Phase 1	deter2017	CQ1
F	Phase 1	deter2018	CQ2
G	Phase 1	deter2019	CQ3
H	Phase 1	deter2020	CQ4
I	Phase 1	deter2021	CQ5
J	Phase 1	status	DETER
K	Phase 1	source_inv	Amazonia
L	Phase 1	phytophysiognomy	Fs
M	Phase 1	category	F
N	Phase 1	managed_land	t
O	Phase 1	eba_cagb	71.74
P	Phase 1	eba_cbgb	7.17
Q	Phase 1	eba_cdw	5.81
R	Phase 1	eba_clitter	4.14
S	Phase 1	eba_ctotal	88.86
T	Phase 1	area_ha	3.83
U	Phase 2, Step 1	Total carbon stock (t C) - t0	340.18
V	Phase 2, Step 1	Total aerial carbon stock (t C) - t0	312.73
W	Phase 2, Step 1	Above ground living carbon stock (t C) - t0	274.64
X	Phase 2, Step 2	Emissions due to fire in 2017 in managed lands (tC)	115.09
Y	Phase 2, Step 2	Emissions due to fire in 2017 in managed lands (tCH_4)	1.67
Z	Phase 2, Step 2	Emissions due to fire in 2017 in managed lands (tN_2O)	0.05
AA	Phase 2, Step 2	Emissions due to selective logging in 2017 (tC)	0.00
AB	Phase 2, Step 2	Carbon stock decrease due to fire in unmanaged lands in 2017 (tC)	0.00
AC	Phase 2, Step 2	Carbon stock decrease due to selective regular logging in 2017 (tC)	0.00
AD	Phase 2, Step 3	Total carbon stock (t C) - t1	225.10
AE	Phase 2, Step 3	Total aerial carbon stock (t C) - t1	197.65

[36] Extracted from: "P3h_FREL_AMAZONIA_EMISSOES_DESMATAMENTO_1ha-6ha_Cenario3_v20201030.xlsx"

Column	Phase, Step	Attribute	Value
AF	Phase 2, Step 3	Above ground living carbon stock (t C) - t1	101.07
AG	Phase 2, Step 4	Emissions due to deforestation in 2017 (tC)	0.00
AH	Phase 2, Step 4	Emissions due to post-fire deforestation in 2017 (tCH_4)	0.00
AI	Phase 2, Step 4	Emissions due to post-fire deforestation in 2017 (tN_2O)	0.00
AJ	Phase 2, Step 5	Total aerial carbon stock (t C) - t2	197.65
AK	Phase 2, Step 5	Above ground living carbon stock (t C) - t2	101.07
AL	Phase 2, Step 6	Emissions due to fire in 2018 in managed lands (tC)	72.73
AM	Phase 2, Step 6	Emissions due to fire in 2018 in managed lands (tCH_4)	1.05
AN	Phase 2, Step 6	Emissions due to fire in 2018 in managed lands (tN_2O)	0.03
AO	Phase 2, Step 6	Emissions due to selective logging in 2018 (tC)	0.00
AP	Phase 2, Step 6	Carbon stock decrease due to fire in unmanaged lands in 2018 (tC)	0.00
AQ	Phase 2, Step 6	Carbon stock decrease due to selective regular logging in 2018 (tC)	0.00
AR	Phase 2, Step 7	Total carbon stock (t C) - t3	152.36
AS	Phase 2, Step 7	Total aerial carbon stock (t C) - t3	124.91
AT	Phase 2, Step 7	Above ground living carbon stock (t C) - t3	37.19
AU	Phase 2, Step 8	Emissions due to deforestation in 2018 (tC)	0.00
AV	Phase 2, Step 8	Emissions due to post-fire deforestation in 2018 (tCH_4)	0.00
AW	Phase 2, Step 8	Emissions due to post-fire deforestation in 2018 (tN_2O)	0.00
AX	Phase 2, Step 9	Total aerial carbon stock (t C) - t4	124.91
AY	Phase 2, Step 9	Above ground living carbon stock (t C) - t4	37.19
AZ	Phase 2, Step 10	Emissions due to fire in 2019 in managed lands (tC)	45.97
BA	Phase 2, Step 10	Emissions due to fire in 2019 in managed lands (tCH_4)	0.67
BB	Phase 2, Step 10	Emissions due to fire in 2019 in managed lands (tN_2O)	0.02
BC	Phase 2, Step 10	Emissions due to selective logging in 2019 (tC)	0.00
BD	Phase 2, Step 10	Carbon stock decrease due to fire in unmanaged lands in 2019 (tC)	0.00
BE	Phase 2, Step 10	Carbon stock decrease due to selective regular logging in 2019 (tC)	0,00

Column	Phase, Step	Attribute	Value
BF	Phase 2, Step 11	Total carbon stock (t C) - t5	106.39
BG	Phase 2, Step 11	Total aerial carbon stock (t C) - t5	78.95
BH	Phase 2, Step 11	Above ground living carbon stock (t C) - t5	13.69
BI	Phase 2, Step 12	Emissions due to deforestation in 2019 (tC)	0.00
BJ	Phase 2, Step 12	Emissions due to post-fire deforestation in 2019 (tCH_4)	0.00
BK	Phase 2, Step 12	Emissions due to post-fire deforestation in 2019 (tN_2O)	0.00
BL	Phase 2, Step 13	Total aerial carbon stock (t C) - t6	78.95
BM	Phase 2, Step 13	Above ground living carbon stock (t C) - t6	13.69
BN	Phase 2, Step 14	Emissions due to fire in 2020 in managed lands (tC)	29.05
BO	Phase 2, Step 14	Emissions due to fire in 2020 in managed lands (tCH_4)	0.42
BP	Phase 2, Step 14	Emissions due to fire in 2020 in managed lands (tN_2O)	0.01
BQ	Phase 2, Step 14	Emissions due to selective logging in 2020 (tC)	0.00
BR	Phase 2, Step 14	Carbon stock decrease due to fire in unmanaged lands in 2020 (tC)	0.00
BS	Phase 2, Step 14	Carbon stock decrease due to selective regular logging in 2020 (tC)	0.00
BT	Phase 2, Step 15	Total carbon stock (t C) - t7	77.34
BU	Phase 2, Step 15	Total aerial carbon stock (t C) - t7	49.89
BV	Phase 2, Step 15	Above ground living carbon stock (t C) - t7	5.04
BW	Phase 2, Step 16	Emissions due to deforestation in 2020 (tC)	0.00
BX	Phase 2, Step 16	Emissions due to post-fire deforestation in 2020 (tCH_4)	0.00
BY	Phase 2, Step 16	Emissions due to post-fire deforestation in 2020 (tN_2O)	0.00
BZ	Phase 2, Step 17	Total aerial carbon stock (t C) - t8	49.89
CA	Phase 2, Step 17	Above ground living carbon stock (t C) - t8	5.04
CB	Phase 2, Step 18	Emissions due to fire in 2021 in managed lands (tC)	18.36
CC	Phase 2, Step 18	Emissions due to fire in 2021 in managed lands (tCH_4)	0.27
CD	Phase 2, Step 18	Emissions due to fire in 2021 in managed lands (tN_2O)	0.01
CE	Phase 2, Step 18	Emissions due to selective logging in 2021 (tC)	0.00

Column	Phase, Step	Attribute	Value
CF	Phase 2, Step 18	Carbon stock decrease due to fire in unmanaged lands in 2021 (tC)	0.00
CG	Phase 2, Step 18	Carbon stock decrease due to selective regular logging in 2021 (tC)	0.00
CH	Phase 2, Step 19	Total carbon stock (t C) - t9	58.98
CI	Phase 2, Step 19	Total aerial carbon stock (t C) - t9	31.53
CJ	Phase 2, Step 19	Above ground living carbon stock (t C) - t9	1.85
CK	Phase 2, Step 20	Emissions due to deforestation in 2021 (tC)	58.98
CL	Phase 2, Step 20	Emissions due to post-deforestation fire in 2021 (tCH_4)	0.17
CM	Phase 2, Step 20	Emissions due to post-deforestation fire in 2021 (tN_2O)	0.00

- **Step 21**: Through dynamic tables, the sum of GHG emissions per REDD+ activity considered and annual period was calculated. The values obtained in this phase are in tonnes of C, CH_4 and N_2O.

	A	B	C	D	E	F	G
1	Soma de EM por queimada em 2017 (tC) AREAS MANEJADAS	Soma de EM por queimada em 2017 (tCH4) AREAS MANEJADAS	Soma de EM por queimada em 2017(tN2O) AREAS MANEJADAS	Soma de EM por CS em 2017 (tC)	Soma de EM por desmatamento 2017 (tC)	Soma de EM por desmatamento em 2017 (tCH4)	Soma de EM por desmatamento em 2017 (tN2O)
2	32.376,37	468,42	13,78	1.523,80	10.871.135,25	47.440,38	1.395,31

Figure 38 – Emission results by the year 2017 according to the sources/activities in the Deforestation Outputs

Source: own elaboration

- **Step 22:** Emissions are converted into tones of CO2 equivalent. These values are used in the final calculation, added to the other outputs, to obtain the average net emission for the relevant biome. Figure 39 presents an example of CO2 eq emissions by REDD+ activity for the biome.

Período	Emissões C por desmatamento (tC)	Emissões CH4 por desmatamento (tCH4)	Emissões N2O por desmatamento (tN2O)	Área de desmatamento (ha)
2016-2017	10.871.135,25	47.440,38	1.395,31	94.237,38
2017-2018	11.349.332,44	50.024,04	1.471,30	97.057,75
2018-2019	13.418.112,34	58.945,81	1.733,70	113.352,39
2019-2020	15.341.770,94	67.855,28	1.995,74	129.559,16
2020-2021	19.565.811,53	86.566,70	2.546,08	162.649,97

Período	Emissões CO2 por desmatamento (tCO2)	Emissões CH4 por desmatamento (tCO2e)	Emissões N2O por desmatamento (tCO2e)
2016-2017	39.860.829,24	1.328.330,55	369.755,88
2017-2018	41.614.218,93	1.400.673,22	389.893,28
2018-2019	49.199.745,26	1.650.482,64	459.430,57
2019-2020	56.253.160,11	1.899.947,92	528.872,06
2020-2021	71.741.308,96	2.423.867,66	674.711,06

Período	Emissões CO2 por desmatamento (tCO2e)
2016-2017	41.558.915,68
2017-2018	43.404.785,43
2018-2019	51.309.658,46
2019-2020	58.681.980,09
2020-2021	74.839.887,68

Período	Emissões C por queimada em área manejada (tC)	Emissões CH4 por queimada em área manejada (tCH4)	Emissões N2O por queimada em área manejada (tN2O)	Área de queimada (ha)
2016-2017	32.376,37	468,42	13,78	5.177,04
2017-2018	6.273,09	90,76	2,67	3.372,97
2018-2019	14.137,42	204,54	6,02	5.251,09
2019-2020	20.431,50	295,60	8,69	4.871,09
2020-2021	1.805,27	26,12	0,77	663,70

Período	Emissões CO2 por queimada em área manejada (tCO2)	Emissões CH4 por queimada em área manejada (tCO2e)	Emissões N2O por queimada em área manejada (tCO2e)
2016-2017	118.713,36	13.115,87	3.650,95
2017-2018	23.001,32	2.541,27	707,39
2018-2019	51.837,21	5.727,16	1.594,22
2019-2020	74.915,49	8.276,93	2.303,98
2020-2021	6.619,33	731,33	203,57

Período	Emissões CO2 por queimada em área manejada (tCO2e)
2016-2017	135.480,18
2017-2018	26.249,97
2018-2019	59.158,58
2019-2020	85.496,40
2020-2021	7.554,23

Período	Emissões C por corte seletivo irregular (tC)	Área de corte seletivo (ha)
2016-2017	1.523,80	51,1583
2017-2018	355,76	15,729
2018-2019	4.672,03	198,7124
2019-2020	3.861,93	188,9693
2020-2021	4.171,89	181,9592

Período	Emissões CO2 por corte seletivo irregular (tCO2e)	Área de corte seletivo (ha)
2016-2017	5.587,26	51,1583
2017-2018	1.304,44	15,729
2018-2019	17.130,79	198,7124
2019-2020	14.160,40	188,9693
2020-2021	15.296,95	181,9592

Figure 39 – Emission results for gross deforestation

Source: own elaboration

8.4.2. Degradation output – Amazon biome

- **PHASE 1 – GIS operations**

The 1st phase involves several "georeferenced operations" using SIG tools, with the aim to consolidate all different degradation activity data. As result, a spreadsheet was obtained, containing the information presented in ***Table 52***. Each line of the spreadsheet represents a group of polygons with the same characteristics, with the exception of the area (hectares). The area represents the sum of the individual polygons. Such aggregation was necessary due to the large amount of data.

Table 52 – Amazon degradation output main parameters

Variable name	Description	Unit	Spreadsheet column	Source
Biome	Biome classification: Amazon	n/a	A	IBGE, 2019
Main_class	REDD+ activity classification: "DEGRAD" meaning "degradation"	n/a	B	DETER
deter2017	Degradation classification in corresponding year: - Fire ("burn scar") - Disordered logging ("CS") - orderly logging ("CSR")	n/a	C	
deter2018		n/a	D	
deter2019		n/a	E	
deter2020		n/a	F	
deter2021		n/a	G	
status			H	
source_inv	Corresponding biome classification in the 4th GHG National Inventory	n/a	I	4th GHG National Inventory
Phytophysiognomy	Ancient vegetation phytophysiognomies	n/a	J	
category	Vegetation category: Forest (F)	n/a	K	
Managed_land	indicates whether the polygon is situated in a managed area ("t" = true) or not ("f" = falsa)		L	

Variable name	Description	Unit	Spreadsheet column	Source
EBA_cagb	Carbon content – above ground biomass carbon pool	tC/ha	M	EBA
EBA_cbgb	Carbon content – below ground biomass carbon pool	tC/ha	N	
EBA_cdw	Carbon content – dead wood carbon pool	tC/ha	O	
EBA_clitter	Carbon content – litter carbon pool	tC/ha	P	
EBA_ctotal	Total carbon	tC/ha	Q	
area_ha	Polygon area	ha	R	Own estimates

Source: Electronic spreadsheet "1c_Amazon_Emissions_Output_Degradation.xls"

- **PHASE 2 – Emissions calculations**

Emissions calculations were performed in chronological order, according to the occurrence of degradation processes (fire and/or disordered logging). The following steps have been followed[37]:

- **Step 1**: Calculation of carbon stocks available in *t0* (tons of C, i.e., tC/ha stock values already multiplied by areas (in ha)) by total and carbon pools:
  Column S: total C stock *t0*
  Column T: aerial C stock *t0*
  Column U: above ground C stock *t0*

- **Step 2**: Calculation of C, CH_4 and N_2O emissions from degradation due to fire in managed forest areas or disordered logging (CS) in 2017:
  Column V: C emissions due to fire in managed lands
  Column W: CH4 emissions due to fire in managed lands
  Column X: N2O emissions due to fire in managed lands
  Column Y: C emissions due to disordered logging (CS)
  Column Z: C loss due to fire in unmanaged lands
  Column AA: C loss due to orderly logging (CSR)

- **Step 3**: Calculation of remaining carbon stocks after degradation processes in 2017, definining the carbon stocks available for potential degradation in 2018:
  Column AB: aerial C stock *t1*
  Column AC: above ground C stock *t1*

[37] Refer to file: "1c_Amazon_Emissions_Output_Degradation.xls "

- **Step 4**: Calculation of C, CH_4 and N_2O emissions from degradation due to fire in managed forest areas or disordered logging (CS) in 2018:
  - Column AD: C emissions due to fire
  - Column AE: CH_4 emissions due to fire
  - Column AF: N_2O emissions due to fire
  - Column AG: C emissions due to disordered logging (CS)
  - Column AH: C loss due to fire in unmanaged lands
  - Column AI: C loss due to orderly logging (CSR)

- **Step 5**: Calculation of carbon stocks available after degradation processes in 2018, definining the carbon stocks available for potential degradation in 2019:
  - Column AJ: aerial C stock *t2*
  - Column AK: above ground C stock *t2*

- **Step 6**: Calculation of C, CH_4 and N_2O emissions due to degradation by fire in managed forest areas or disordered logging (CS) in 2019:
  - Column AL: C emissions due to fire
  - Column AM: CH_4 emissions due to fire
  - Column AN: N_2O emissions due to fire
  - Column AO: C emissions due to disordered logging (CS)
  - Column AP: C loss due to fire in unmanaged lands
  - Column AQ: C loss due to orderly logging (CSR)

- **Step 7**: Calculation of the remaining carbon stocks available after degradation in 2019, defining the carbon stocks available for potential degradation in 2020:
  - Column AR: aerial C stock *t3*
  - Column AS: above ground C stock *t3*

- **Step 8**: Calculation of C, CH_4 and N_2O emissions due to degradation by fire in managed forest areas or disordered logging (CS) in 2020:
  - Column AT: CO_2 emissions due to fire
  - Column AU: CH_4 emissions due to fire
  - Column AV: N_2O emissions due to fire
  - Column AW: C emissions due to disordered logging (CS)
  - Column AX: C loss due to fire in unmanaged lands
  - Column AY: C loss due to orderly logging (CSR)

- **Step 9**: Calculation of carbon stocks available after degradation processes in 2020, defining the carbon stocks available for potential degradation in 2021:
  - Column AZ: aerial C stock *t4*
  - Column BA: above ground C stock *t4*

- **Step 10**: Calculation of CO_2, CH_4 and N_2O emissions from degradation due to fire in managed forest areas or disordered logging (CS) in 2021:
  - Column BB: CO_2 emissions due to fire
  - Column BC: CH_4 emissions due to fire
  - Column BD: N_2O emissions due to fire

Column BE: C emissions due to disordered logging (CS)

- **Step 11**: Through dynamic tables, the sums of GHG emissions were calculated. The values obtained in this phase are in tons of C, CH_4 and N_2O.

- **Step 12:** Emissions are converted into tones of CO2 equivalent. These values will be used in the final calculation and added to the other outputs, to obtain average net emission from the biome.

8.4.3. Net GHG emission – Amazon biome[38]

- **PHASE 3 – Removals from land use/cover "post-deforestation event"**

  - **Step 1**: Land use/cover from TerraClass was gathered and restricted to the Amazon biome boundaries, since original data covers the larger area of Legal Amazon (except for the 2020 data, which is originally restricted to the biome). Total area per land use and year were calculated.

Table 53: Land use/land cover within the Amazon biome according to TerraClass timeseries (ha)

Classes	2004	2008	2010	2012	2014	2020
VEGETACAO_NATURAL_FLORESTAL_PRIMARIA	316.619.085,74	313.729.326,59	313.158.305,51	312.835.168,20	312.555.351,72	307.858.310,87
VEGETACAO_NATURAL_FLORESTAL_SECUNDARIA	9.713.998,59	14.131.179,91	15.689.831,94	15.813.803,45	16.223.285,94	16.022.788,96
SILVICULTURA	36.160,56	52.930,47	74.125,34	63.554,82	59.396,93	316.843,35
PASTAGEM_CULTIVADA_ARBUSTIVA	5.339.569,44	5.100.809,89	4.134.293,67	3.058.982,97	3.292.535,74	13.305.461,11
PASTAGEM_CULTIVADA_HERBACEA	5.991.620,64	5.702.913,86	5.973.943,91	5.868.828,73	6.930.572,80	37.044.769,55
CULTURA_AGRICOLA_PERENE	272,27	26.893,39	28.533,92	12.919,19	26.806,84	353.355,78
CULTURA_AGRICOLA_SEMIPERENE	1.778,49	10.963,86	12.316,93	12.493,08	13.265,00	135.499,04
CULTURA_AGRICOLA_TEMPORARIA	19.645,53	60.316,14	115.639,57	176.439,90	320.215,81	757.626,24
CULT. AGRÍCOLA TEMP. > DE 1 CICLO						4.868.995,20
MINERACAO	18.990,87	15.749,12	21.977,19	26.847,14	34.279,45	205.276,33
URBANIZADA	27.150,19	41.421,27	46.543,53	60.300,91	79.009,44	477.211,62
OUTROS	214.066,06	30.495,54	88.836,47	206.297,15	323.343,43	
NAO_OBSERVADA	2.021.291,03	1.744.766,52	1.448.624,96	2.805.258,40	1.159.399,57	
DESFLORESTAMENTO_NO_ANO	1.063.040,35	418.904,47	273.696,99	125.777,21	49.216,60	1.035.450,98
NAO_FLORESTA	28.025.227,28	28.025.228,07	28.025.227,55	28.025.227,45	28.025.224,34	27.971.576,78
CORPOS_DAGUA	580.292,22	580.290,15	580.291,77	580.290,66	580.285,64	11.279.265,35
TOTAL	369.672.189,26	369.672.189,25	369.672.189,25	369.672.189,26	369.672.189,25	421.632.431,16
TOTAL deforested	22.426.292,99	25.592.577,92	26.459.739,46	25.426.244,55	27.351.927,98	74.523.278,16

OBS: Yellowish lines indicate "post-deforestation event" classes

Source: TerraClass

  - **Step 2**: An average participation, per land use/cover class, was determined considering the most recent years in the timeseries: 2014 and 2020.

[38] Refer to file “3_Amazon_net_emissions.xlxs”

Table 54: Land use/land cover distribution in the Amazon according to TerraClass timeseries (%)

Classes	2004	2008	2010	2012	2014	2020	Average participation
VEGETACAO_NATURAL_FLORESTAL_SECUNDARIA	0,43	0,55	0,59	0,62	**0,59**	**0,22**	**40,41%**
SILVICULTURA	0,00	0,00	0,00	0,00	**0,00**	**0,00**	**0,32%**
PASTAGEM_CULTIVADA_ARBUSTIVA	0,24	0,20	0,16	0,12	**0,12**	**0,18**	**14,95%**
PASTAGEM_CULTIVADA_HERBACEA	0,27	0,22	0,23	0,23	**0,25**	**0,50**	**37,52%**
CULTURA_AGRICOLA_PERENE	0,00	0,00	0,00	0,00	**0,00**	**0,00**	**0,29%**
CULTURA_AGRICOLA_SEMIPERENE	0,00	0,00	0,00	0,00	**0,00**	**0,00**	**0,12%**
CULTURA_AGRICOLA_TEMPORARIA e 1 CICLO	0,00	0,00	0,00	0,01	**0,01**	**0,08**	**4,36%**
MINERACAO	0,00	0,00	0,00	0,00	**0,00**	**0,00**	**0,20%**
URBANIZADA	0,00	0,00	0,00	0,00	**0,00**	**0,01**	**0,46%**
OUTROS	0,01	0,00	0,00	0,01	**0,01**	**0,00**	**0,59%**
DESFLORESTAMENTO_NO_ANO	0,05	0,02	0,01	0,00	**0,00**	**0,01**	**0,78%**
TOTAL	*1,0*	*1,0*	*1,0*	*1,0*	***1,0***	***1,0***	*1,0*

Source: TerraClass

- **Step 3:** Land use/cover "post-deforestation event" areas were defined by applying the mean participation acquired in the previous steps to the deforestation increment from 2106-2017 to 2020-2021:

Table 55: Land use/cover "post-deforestation event" areas in the Amazon biome

		Land use post deforestation (ha)				
Classes	***Land use proportion (%)***	***2016-2017***	***2017-2018***	***2018-2019***	***2019-2020***	***2020-2021***
VEGETACAO_NATURAL_FLORESTAL_SECUNDARI	*40,41%*	309.956,6	319.006,8	477.189,9	469.342,6	557.029,2
SILVICULTURA	*0,32%*	2.463,6	2.535,5	3.792,8	3.730,4	4.427,4
PASTAGEM_CULTIVADA_ARBUSTIVA	*14,95%*	114.648,6	117.996,1	176.505,8	173.603,2	206.037,2
PASTAGEM_CULTIVADA_HERBACEA	*37,52%*	287.841,4	296.245,8	443.142,6	435.855,2	517.285,4
CULTURA_AGRICOLA_PERENE	*0,29%*	2.194,5	2.258,6	3.378,5	3.323,0	3.943,8
CULTURA_AGRICOLA_SEMIPERENE	*0,12%*	883,4	909,2	1.360,0	1.337,6	1.587,5
CULTURA_AGRICOLA_TEMPORARIA e 1 CICLO	*4,36%*	33.448,5	34.425,2	51.495,3	50.648,5	60.111,0
MINERACAO	*0,20%*	1.537,2	1.582,1	2.366,5	2.327,6	2.762,5
URBANIZADA	*0,46%*	3.564,0	3.668,0	5.486,9	5.396,6	6.404,9
OUTROS	*0,59%*	4.534,1	4.666,5	6.980,4	6.865,7	8.148,4
DESFLORESTAMENTO_NO_ANO	*0,78%*	6.019,3	6.195,0	9.266,9	9.114,5	10.817,3
TOTAL		767.091,10	789.488,82	1.180.965,48	1.161.544,90	1.378.554,45

Source: Own estimates

- **Step 4:** Activity data acquired in the Step 3 were multiplied by specific emission factors for "Cropland" and "Grassland" land use categories. Results are presented in tonnes of carbon in one year.

Table 56: Removals per year in land use/cover "post-deforestation event" areas - Amazon biome (tC)

Classes	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
VEGETACAO_NATURAL_FLORESTAL_SECUNDARIA	IE	IE	IE	IE	IE
SILVICULTURA	NA	NA	NA	NA	NA
PASTAGEM_CULTIVADA_ARBUSTIVA	1.146.485,7	1.179.961,1	1.765.057,7	1.736.031,9	2.060.371,9
PASTAGEM_CULTIVADA_HERBACEA	2.878.413,7	2.962.458,4	4.431.425,8	4.358.552,5	5.172.853,8
CULTURA_AGRICOLA_PERENE	1.997,0	2.055,3	3.074,5	3.023,9	3.588,8
CULTURA_AGRICOLA_SEMIPERENE	0,0	0,0	0,0	0,0	0,0
CULTURA_AGRICOLA_TEMPORARIA e 1 CICLO	0,0	0,0	0,0	0,0	0,0
MINERACAO	NA	NA	NA	NA	NA
URBANIZADA	NA	NA	NA	NA	NA
OUTROS	NA	NA	NA	NA	NA
DESFLORESTAMENTO_NO_ANO	NA	NA	NA	NA	NA

Source: Own estimates

- **Step 5:** Results from step 4 were converted into CO_2 and multiplied by number of years until the end of the time series for "perennial agriculture", since an annual increment must be considered.

Table 57: Removals per year in land use/cover "post-deforestation event" areas - Amazon biome (tCO_2)

Classes	2016-2017 to 2021	2017-2018 to 2021	2018-2019 to 2021	2019-2020 to 2021	2020-2021
VEGETACAO_NATURAL_FLORESTAL_SECUNDARIA	IE	IE	IE	IE	IE
SILVICULTURA	NA	NA	NA	NA	NA
PASTAGEM_CULTIVADA_ARBUSTIVA	4.203.780,8	4.326.523,9	6.471.878,1	6.365.450,2	7.554.697,0
PASTAGEM_CULTIVADA_HERBACEA	10.554.183,7	10.862.347,6	16.248.561,2	15.981.359,1	18.967.130,5
CULTURA_AGRICOLA_PERENE	36.611,6	30.144,5	33.819,0	22.175,2	13.159,1
CULTURA_AGRICOLA_SEMIPERENE	0,0	0,0	0,0	0,0	0,0
CULTURA_AGRICOLA_TEMPORARIA e 1 CICLO	0,0	0,0	0,0	0,0	0,0
MINERACAO	NA	NA	NA	NA	NA
URBANIZADA	NA	NA	NA	NA	NA
OUTROS	NA	NA	NA	NA	NA
DESFLORESTAMENTO_NO_ANO	NA	NA	NA	NA	NA

Source: Own estimates

- **Step 6:** The removals per class are added up per year.

Table 58: Removals from land use post-deforestation per year - Amazon biome (tCO_2)

Base year	*Removals from base year to 2021 (tCO2e)*
2016-2017	14.794.576,16
2017-2018	15.219.015,98
2018-2019	22.754.258,28
2019-2020	22.368.984,50
2020-2021	26.534.986,63

Source: Own estimates

- **PHASE 4 – Net emissions**

    - **Step 1**: Calculation of the annual net GHG emission: sum of gross GHG emissions by deforestation and degradation minus removals from "post-deforestation event" land use
    - **Step 2**: Calculation of average annual net emissions in the period

8.5. Detailed description for estimating GHG emissions/removals in the Cerrado biome

The operational procedures, based on the methodological approach described in page 54, used to estimate GHG emission due to deforestation and removals from growth of natural forest regeneration in the Cerrado biome are presented in sequence.

8.5.1. Deforestation output – Cerrado biome

- **PHASE 1 – GIS operations**

The 1st phase involves several spatial operations using GIS tools, with the aim to consolidate all different deforestation activity data. As result, a spreadsheet was obtained, containing the information presented in **Table *59***. Each line of the spreadsheet represents a single deforestation polygon.

Table 59 – Cerrado deforestation output main parameters

Variable name	Description	Unit	Spreadsheet column	Source
fid		n/a	**A**	
Biome	Biome classification: Cerrado	n/a	**B**	IBGE, 2019
State	Brazilian political-administrative state	n/a	**C**	
Main_class	REDD+ activity	n/a	D	PRODES
Class_name	REDD+ activity/year classification		E	
Year	Mapping year	n/a	F	
Image_date	Image date of each polygon	n/a	G	
source_inv	Corresponding biome classification in the 4th GHG National Inventory	n/a	H	4th GHG National Inventory
phytophysiognomies	Ancient vegetation phytophysiognomies	n/a	I	
Category	Land use category: Forest (F)	n/a	J	
rr_cagb	Above ground carbon stock	tC/ha	K	
rr_cbgb	Below ground carbon stock	tC/ha	L	
rr_cdw	Dead wood carbon stock	tC/ha	M	
rr_clitter	Litter carbon stock	tC/ha	N	
rr_ctotal	Total carbon stock	tC/ha	O	
Area_ha	Polygon area	ha	P	Own calculations

- **PHASE 2 – Emissions calculations**

  - **Step 1**: Calculation of C and CO_2 due to deforestation:
    Column Q: C emissions due to deforestation
    Column R: CO_2 emissions due to deforestation

  - **Step 2**: Calculation of the mass of fuel available for fire combustion in the "slash and burn" type deforestation
    Column S: above ground C stock

  - **Step 3:** Calculation of CH_4 and N_2O emissions due to "slash and burn" deforestation:

Column T: CH_4 emissions due to deforestation
Column U: N_2O emissions due to deforestation

- **Step 4**: Through pivot tables, the sum of emissions per year and GHG are calculated. The values obtained at this stage are in tonnes of CO_2, tonnes of CH_4 and tonnes of N_2O.

- **Step 5**: Emissions are converted into tones of CO_2 equivalent. These values will be used in the final calculation and added to the other outputs, to obtain the average net emission for the biome.

8.5.2. Net GHG emission – Cerrado biome

- **PHASE 3 – Removals from land use/cover "post-deforestation event"**
  - **Step 1:** Land use/cover from TerraClass mapping Program was gathered.

Table 60: Land use/land cover within the Cerrado biome according to TerraClass timeseries (ha)

Classes	2018	2020
VEGETAÇÃO PRIMÁRIA	1.007.505,67	991.320,54
VEGETAÇÃO SECUNDÁRIA	95.112,04	85.298,02
SILVICULTURA	36.636,64	35.793,30
PASTAGEM	588.751,56	598.793,91
AGRICULTURA PERENE	12.067,89	13.114,32
AGRICULTURA SEMIPERENE	58.300,63	55.724,27
AGRICULTURA TEMPORÁRIA 1 CICLO	57.901,73	48.549,10
AGRICULTURA TEMPORÁRIA > 1 CICLO	146.327,91	172.755,54
MINERACAO	463,31	519,05
URBANIZADA	9.281,40	9.479,27
OUTRAS ÁREAS EDIFICADAS	3.279,30	3.329,16
OUTROS USOS	509,64	713,07
NÃO OBSERVADO	0,14	34,89
DESFLORESTAMENTO DO ANO	6.638,11	7.341,14
CORPOS D'ÁGUA	17.005,35	17.015,75
TOTAL	2.039.781,32	2.039.781,33
TOTAL deforested	1.015.270,16	1.031.410,15

OBS: Yellowish lines indicate "post-deforestation event" classes

Source: TerraClass

  - **Step 2**: An average distribution per land use/cover class was determined considering the most recent years in the timeseries: 2018 and 2020.

Table 61: Land use/land cover distribution in the Cerrado according to TerraClass timeseries (%)

Classes	2018	2020	Average participation 2018-2020 (%)
VEGETAÇÃO SECUNDÁRIA	0,09	0,08	8,82%
SILVICULTURA	0,04	0,03	3,54%
PASTAGEM	0,58	0,58	58,02%
AGRICULTURA PERENE	0,01	0,01	1,23%
AGRICULTURA SEMIPERENE	0,06	0,05	5,57%
AGRICULTURA TEMPORÁRIA 1 CICLO	0,06	0,05	5,21%
AGRICULTURA TEMPORÁRIA > 1 CICLO	0,14	0,17	15,58%
MINERACAO	0,00	0,00	0,05%
URBANIZADA	0,01	0,01	0,92%
OUTRAS ÁREAS EDIFICADAS	0,00	0,00	0,32%
OUTROS USOS	0,00	0,00	0,06%
DESFLORESTAMENTO DO ANO	0,01	0,01	0,68%
TOTAL	***1,00***	***1,00***	***1,00***

Source: TerraClass

- **Step 3:** Land use/cover "post-deforestation event" areas was estimated using the distribution defined in step 2:

Table 62: Land use/cover "post-deforestation event" areas in the Cerrado biome

		Land use post deforestation (ha)				
Class	***Land use proportion (%)***	***2016-2017***	***2017-2018***	***2018-2019***	***2019-2020***	***2020-2021***
VEGETAÇÃO SECUNDÁRIA	*8,82%*	50.266,02	48.576,39	43.594,15	53.185,50	55.820,19
SILVICULTURA	*3,54%*	20.173,70	19.495,58	17.496,02	21.345,40	22.402,80
PASTAGEM	*58,02%*	330.711,07	319.594,64	286.815,42	349.918,97	367.253,17
AGRICULTURA PERENE	*1,23%*	7.010,98	6.775,32	6.080,41	7.418,19	7.785,67
AGRICULTURA SEMIPERENE	*5,57%*	31.761,76	30.694,13	27.545,98	33.606,50	35.271,29
AGRICULTURA TEMPORÁRIA 1 CICLO	*5,21%*	29.667,25	28.670,02	25.729,48	31.390,34	32.945,35
AGRICULTURA TEMPORÁRIA > 1 CICLO	*15,58%*	88.807,16	85.822,02	77.019,69	93.965,13	98.619,95
MINERACAO	*0,05%*	273,47	264,27	237,17	289,35	303,68
URBANIZADA	*0,92%*	5.224,44	5.048,83	4.530,99	5.527,88	5.801,72
OUTRAS ÁREAS EDIFICADAS	*0,32%*	1.840,36	1.778,49	1.596,08	1.947,25	2.043,71
OUTROS USOS	*0,06%*	340,08	328,65	294,94	359,83	377,66
DESFLORESTAMENTO DO ANO	*0,68%*	3.891,70	3.760,88	3.375,15	4.117,73	4.321,71
TOTAL	***100,00%***	***569.967,98***	***550.809,22***	***494.315,49***	***603.072,06***	***632.946,89***

Source: *Own estimates*

- **Step 4:** Activity data acquired in the Step 3 were multiplied by specific emission factors for "Cropland" and "Grassland" land use/cover. Results are presented in tonnes of carbon for one year.

Table 63: Removals per year in land use/cover "post-deforestation event" areas - Cerrado biome (tC)

Class	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
VEGETAÇÃO SECUNDÁRIA	IE	IE	IE	IE	IE
SILVICULTURA	NA	NA	NA	NA	NA
PASTAGEM	2.503.482,8	2.419.331,4	2.171.192,8	2.648.886,6	2.780.106,5
AGRICULTURA PERENE	18.228,6	17.615,8	15.809,1	19.287,3	20.242,7
AGRICULTURA SEMIPERENE	0,0	0,0	0,0	0,0	0,0
AGRICULTURA TEMPORÁRIA 1 CICLO	0,0	0,0	0,0	0,0	0,0
AGRICULTURA TEMPORÁRIA > 1 CICLO	0,0	0,0	0,0	0,0	0,0
MINERACAO	NA	NA	NA	NA	NA
URBANIZADA	NA	NA	NA	NA	NA
OUTRAS ÁREAS EDIFICADAS	NA	NA	NA	NA	NA
OUTROS USOS	NA	NA	NA	NA	NA
DESFLORESTAMENTO DO ANO	NA	NA	NA	NA	NA

Source: Own estimates

- **Step 5:** Results were converted in CO_2 and multiplied by number of years until the end of the time series were convenient (perennial agriculture), since an annual increment must be considered.

Table 64: Removals per year in land use/cover "post-deforestation event" areas - Cerrado biome (tCO_2)

Class	2016-2017 to 2021	2017-2018 to 2021	2018-2019 to 2021	2019-2020 to 2021	2020-2021
VEGETAÇÃO SECUNDÁRIA	IE	IE	IE	IE	IE
SILVICULTURA	NA	NA	NA	NA	NA
PASTAGEM	9.179.437,1	8.870.881,9	7.961.040,1	9.712.584,3	10.193.723,8
AGRICULTURA PERENE	334.190,2	258.365,5	173.899,7	141.440,1	74.223,3
AGRICULTURA SEMIPERENE	0,0	0,0	0,0	0,0	0,0
AGRICULTURA TEMPORÁRIA 1 CICLO	0,0	0,0	0,0	0,0	0,0
AGRICULTURA TEMPORÁRIA > 1 CICLO	0,0	0,0	0,0	0,0	0,0
MINERACAO	NA	NA	NA	NA	NA
URBANIZADA	NA	NA	NA	NA	NA
OUTRAS ÁREAS EDIFICADAS	NA	NA	NA	NA	NA
OUTROS USOS	NA	NA	NA	NA	NA
DESFLORESTAMENTO DO ANO	NA	NA	NA	NA	NA

Source: Own estimates

- **Step 6:** The removals per class were added up per year.

Table 65: Removals from land use post-deforestation per year - Cerrado biome (tCO_2)

Base year	*Removals from land use post deforestation (tCO2e)*
2016-2017	9.513.627,3
2017-2018	9.129.247,4
2018-2019	8.134.939,8
2019-2020	9.854.024,4
2020-2021	10.267.947,2

Source: Own estimates

- **PHASE 4 – Consolidation of results**

  - **Step 1**: Calculation of the annual net GHG emission: sum of gross GHG emissions by deforestation minus removals from land use/cover "post-deforestation event"

  - **Step 2**: Calculation of average annual net emissions in the period

8.6. Detailed description for estimating GHG emissions/removals in the Atlantic Forest, Caatinga, Pampa and Pantanal biomes

- **PHASE 1 – GIS operations**

The 1st phase involves several spatial operations using GIS tools, with the aim to consolidate all different deforestation activity data. As result, a spreadsheet was obtained, containing the information presented in **Table *66***. Each line of the spreadsheet represents a single deforestation polygon.

Table 66 – Atlantic Forest, Caatinga, Pampa and Pantanal biomes deforestation output main parameters

Variable name	Description	Unit	Spreadsheet column	Source
fid		n/a	**A**	
Biome	Biome classification	n/a	**B**	IBGE, 2019
Main_class	REDD+ activity	n/a	C	PRODES
Year	Mapping year	n/a	D	
Image_date	Image date of each polygon	n/a	E	
source_inv	Corresponding biome classification in the 4th GHG National Inventory	n/a	F	4th GHG National Inventory
phytophysiognomies	Ancient vegetation phytophysiognomies	n/a	G	
Category	Land use category: Forest (F)	n/a	H	
rr_cagb	Above ground carbon stock	tC/ha	I	
rr_cbgb	Below ground carbon stock	tC/ha	J	
rr_cdw	Dead wood carbon stock	tC/ha	K	
rr_clitter	Litter carbon stock	tC/ha	L	
rr_ctotal	Total carbon stock	tC/ha	M	
Area_ha	Polygon area	ha	N	Own calculations

- **PHASE 2 – Emissions calculations**

- **Step 1**: Calculation of C and CO2 due to deforestation:
  Column Q: C emissions due to deforestation
  Column R: CO_2 emissions due to deforestation

- **Step 2**: Through pivot tables, the sums of emissions per year and GHG are calculated. The values obtained at this stage are in tons of CO_2, tons of CH_4 and tons of N_2O.

- **Step 3**: Emissions are converted into tones of CO_2. These values will be used in the final calculation, added to the other outputs, to obtain average net emission from the biome.

- **PHASE 4 – Consolidation of results**

  - **Step 1**: Calculation of the gross CO_2 emissions per period as the sum of individual emissions per polygon

  - **Step 2**: Calculation of average gross emissions in the period and biome

8.7. Detail description for estimating the national FREL

8.7.1. Detailed description for estimating emissions from deforestation and forest degradation in all biomes

- **Step 1:** Calculation of the average annual emissions per biome in tonnes of CO2eq/yr

Table 67: average annual emissions per biome in tonnes of CO_2eq

Período	Amazônia	Cerrado	Mata Atlântica	Caatinga	Pampa	Pantanal
2016-2017	386.233.770,26	96.661.574,97	36.434.019,13	28.318.171,77	3.629.784,82	7.296.713,06
2017-2018	360.736.030,83	95.638.781,84	45.100.212,60	25.191.250,31	3.798.003,85	5.101.430,68
2018-2019	557.822.417,61	83.307.156,01	39.463.223,90	23.870.541,00	3.574.669,24	4.684.070,20
2019-2020	565.496.222,91	101.899.817,59	23.544.177,11	28.416.932,63	3.460.472,47	5.655.515,57
2020-2021	657.287.904,25	107.736.328,61	28.761.217,90	25.414.848,62	5.850.601,61	7.446.456,25
Average annual emissions	***505.515.269,17***	***97.048.731,80***	***34.660.570,13***	***26.242.348,86***	***4.062.706,40***	***6.036.837,15***

Source: Own estimates

- **Step 2:** Sum of the average biomes values, which was considered as the National FREL

Table 68: National FREL as the sum of the average biome values

Biome	Average emissions (tCO2eq)	%	Type
Amazônia	*505.515.269,17*	*75%*	Net emissions
Cerrado	*97.048.731,80*	*14%*	
Mata Atlântica	*34.660.570,13*	*5%*	Gross emissions
Caatinga	*26.242.348,86*	*4%*	
Pampa	*4.062.706,40*	*1%*	
Pantanal	*6.036.837,15*	*1%*	
(sum)	***673.566.463,52***		

Source: Own estimates

8.7.2. Detailed description for estimating EFCS in the Amazon biome

a. Removals from 2014 to 2020

Step 1: From TerraClass data, secondary vegetation total area was gathered for relevant years, which are 2014 and 2020:

- SV total area in 2014: 16,031,974 ha
- SV total area in 2020: 15,803,678 ha

Step 2: Linear interpolation was applied to estimate the total SV area loss annually: 38,049 ha/year.

Step 3: Estimations of annual carbon removals were obtained by multiplying the remaining SV area in each year by the emission factor of 3,03 tC/ha. Results were converted to CO_2 by multiplying the previous results by the factor of 44/12.

Table 69: Annual removals due to secondary regrowth

Year	SV total area (ha)	Removal (tC)	Removal (tCO2)
2014	16.031.974,05	- 48.576.881,37	- 178.115.231,68
2015	15.993.924,76	- 48.461.592,02	- 177.692.504,07
2016	15.955.875,47	- 48.346.302,67	- 177.269.776,47
2017	15.917.826,18	- 48.231.013,33	- 176.847.048,87
2018	15.879.776,89	- 48.115.723,98	- 176.424.321,26
2019	15.841.727,60	- 48.000.434,63	- 176.001.593,66
2020	15.803.678,31	- 47.885.145,29	- 175.578.866,06

Source: Own estimates

b. SV emissions from 2015 to 2021

- **Step 1**: Through spatial combination of SV maps for the years 2014 and 2020, SV area lost in the period was estimated. For the SV polygons occurring in 2014, the age was obtained through spatial operations allowing to combine the entire time series of TerraClass, since 2004 until 2014. The summary table acquired as the output of the spatial analyses is presented below.

Table 70: Summary table presenting SV in 2014 with respective age and its situation in 2020 (persistence or loss)

Year since when SV occuring in 2014 was first detected	SV age in 2014	SV loss (VS loss) or persistence (VS2020) from 2014 to 2020	Area (ha)
2014	1	VS2020	1.941.703,11
2014	1	VS loss	3.218.005,89
2012	2	VS2020	666.324,64
2012	2	VS loss	908.985,57
2010	4	VS2020	653.405,23
2010	4	VS loss	737.165,84
2008	6	VS2020	1.756.425,63
2008	6	VS loss	1.709.416,34
2004	10	VS2020	2.793.397,20
2004	10	VS loss	1.647.144,61
		VS2020	7.992.422,52

Source: Own estimates

From the table above, the total SV area lost in 2020 was estimated, per age category:

Table 71: SV area lost in 2020, per age category

SV age in 2014 (yr)	SV area loss in 2020 (ha)
10	1.647.144,61
6	1.709.416,34
4	737.165,84
2	908.985,57
1	3.218.005,89

Source: Own estimates

Step 2: linear interpolation was performed allowing to define an annual SV loss between 2015 to 2020, per age:

Table 72: linear interpolation to define yearly SV area loss from 2015 to 2020

SV age in 2014 (yr)	SV area loss (ha)						total (ha)
2014	2015	2016	2017	2018	2019	2020	
10	274.524,10	274.524,10	274.524,10	274.524,10	274.524,10	274.524,10	1.647.144,61
6	284.902,72	284.902,72	284.902,72	284.902,72	284.902,72	284.902,72	1.709.416,34
4	122.860,97	122.860,97	122.860,97	122.860,97	122.860,97	122.860,97	737.165,84
2	151.497,60	151.497,60	151.497,60	151.497,60	151.497,60	151.497,60	908.985,57
1	536.334,32	536.334,32	536.334,32	536.334,32	536.334,32	536.334,32	3.218.005,89

Source: Own estimates

Step 3: Considering the information on the age of SV in 2014, SV age was determined for the subsequent years:

Table 73: SV age at loss event year from 2015 to 2020

SV age in 2014 (yr)	Age at loss event (years)					
2014	2015	2016	2017	2018	2019	2020
10	11	12	13	14	15	16
6	7	8	9	10	11	12
4	5	6	7	8	9	10
2	3	4	5	6	7	8
1	2	3	4	5	6	7

Source: Own estimates

Step 4: By multiplying values from the two previous tables – SV area lost in each year and its age – by the removal factor of 3,03 tC/ha.yr, annual emissions due to SV loss were estimated:

Table 74: Carbon emissions due to SV annual loss from 2015 to 2020

SV age in 2014 (yr)	SV stock loss (tC)					
2014	2015	2016	2017	2018	2019	2020
10	9.149.888,28	9.981.696,31	10.813.504,33	11.645.312,36	12.477.120,39	13.308.928,41
6	6.042.786,77	6.906.042,02	7.769.297,27	8.632.552,53	9.495.807,78	10.359.063,03
4	1.861.343,75	2.233.612,50	2.605.881,24	2.978.149,99	3.350.418,74	3.722.687,49
2	1.377.113,14	1.836.150,86	2.295.188,57	2.754.226,29	3.213.264,00	3.672.301,71
1	3.250.185,95	4.875.278,92	6.500.371,90	8.125.464,87	9.750.557,85	11.375.650,82

Source: Own estimates

Step 5: Conversion of carbon emissions into CO_2 by multiplying the previous results by the factor of 44/12.

Table 75: CO_2 emissions due to SV annual loss from 2015 to 2020

SV age in 2014 (yr)	SV stock loss (tCO2)					
2014	2015	2016	2017	2018	2019	2020
10	33.549.590,37	36.599.553,13	39.649.515,89	42.699.478,65	45.749.441,41	48.799.404,18
6	22.156.884,82	25.322.154,08	28.487.423,34	31.652.692,60	34.817.961,86	37.983.231,12
4	6.824.927,07	8.189.912,48	9.554.897,90	10.919.883,31	12.284.868,73	13.649.854,14
2	5.049.414,86	6.732.553,14	8.415.691,43	10.098.829,72	11.781.968,00	13.465.106,29
1	11.917.348,48	17.876.022,72	23.834.696,96	29.793.371,20	35.752.045,44	41.710.719,68
total	79.498.165,60	94.720.195,56	109.942.225,52	125.164.255,48	140.386.285,44	155.608.315,40

Source: Own estimates

c. SV emissions in 2014

Step 1: Total SV loss accounted for 4,043,005 ha in 2014 according to TerraClass timeseries. Through spatial explicit operations, it was defined since when each polygon of SV lost in 2014 was part of the TerraClass timeseries, which was considered a proxy of its age:

Table 76: SV area loss in 2014 and year since when these areas were part of the TerraClass timeseries.

TerraClass mapping year (*yr*)	Amount of SV loss between 2012-2014 per year since first detection/start of recovery (ha)
2012	1.379.353,85
2010	560.114,90
2008	1.250.269,58
2004	853.266,93
total	***4.043.005,27***

Source: Own estimates

Step 2: Considering that there is an interval of 2 years between observations (maps) for 2012 and 2014, a linear interpolation was use to estimate SV area loss per year in 2013 and 2014 (Table below).

Step 3: Once SV area loss in 2014 was estimated, together with its age, emissions due to SV loss in 2014 were estimated by multiplying those two first by the removal factor of 3,03 tC/ha.yr (Table below).

Step 4: Conversion of carbon emissions into CO_2 were made by multiplying the previous results by the factor of 44/12 (Table below).

Table 77: SV area loss in 2013 and 2014 and age in loss event according to TerraClass data

TerraClass mapping year (*yr*)	Amount of SV loss between 2012-2014 per year since first detection/start of recovery (ha)	SV age at loss event in 2013 (years)	SV stock loss in 2013 (tC)	SV stock loss in 2013 (tCO2)	SV age at loss event in 2014 (years)	SV stock loss in 2014 (tCO2)	SV stock loss in 2014 (tCO2)
2012	1.379.353,85	1	2.089.721,08	7.662.310,64	2	4.179.442,17	15.324.621,28
2010	560.114,90	3	2.545.722,24	9.334.314,89	4	3.394.296,32	12.445.753,18
2008	1.250.269,58	5	9.470.792,07	34.726.237,58	6	11.364.950,48	41.671.485,10
2004	853.266,93	9	11.634.294,61	42.659.080,23	10	12.926.994,01	47.398.978,04
total	***4.043.005,27***			***94.381.943,34***			***116.840.837,60***

Source: Own estimates

d. net EFCS

Step 1: The results of the three previous phases were compiled:

- Removals from annual SV existing areas from 2014 to 2020
- Emission from annual SV loss from 2015 to 2020
- Emissions from annual SV loss in 2014

Step 2: EFCS reference level was obtained as the average annual net emissions considering the 2014-2020 period:

Table 78: EFCS reference level for the Amazon biome

Year	Removals - SV gain (tCO2)	Emissions - SV loss (tCO2)	NET enhancements of forest carbon stocks (tCO2)
2014	-178.115.232	*116.840.837,60*	- 61.274.394,08
2015	-177.692.504	79.498.165,60	- 98.194.338,47
2016	-177.269.776	94.720.195,56	- 82.549.580,91
2017	-176.847.049	109.942.225,52	- 66.904.823,35
2018	-176.424.321	125.164.255,48	- 51.260.065,78
2019	-176.001.594	140.386.285,44	- 35.615.308,22
2020	-175.578.866	155.608.315,40	- 19.970.550,65
Average	***-176.847.048,87***	***117.451.468,66***	***-59.395.580,21***

Source: Own estimates

8.8. Quality control and quality assurance procedures

The following figure, summarize the quality control (QC) and quality assurance (QA) procedures that were adopted and implemented, by different actors, during the elaboration of Brazil's national FREL proposal. Is worth to recall that INPE's monitoring programs, also have they own QA/QC procedures, ensuring that activity data used in this submission is highly accurate.

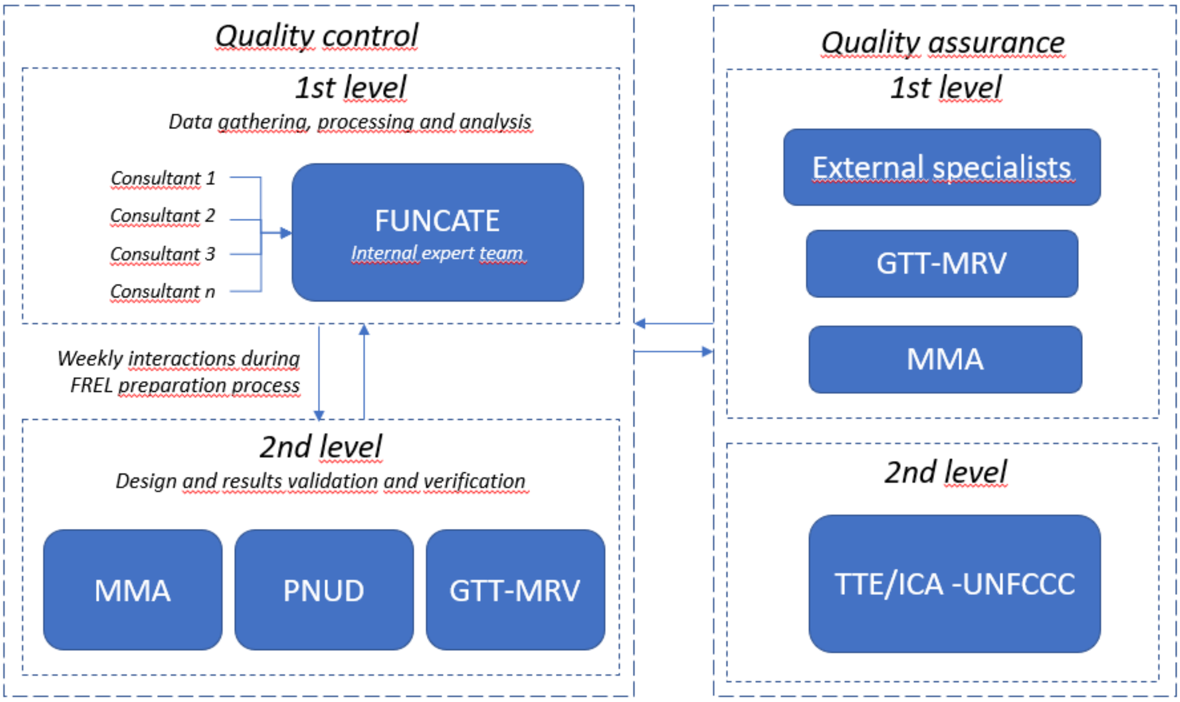

Figure 40 –QA and QC procedures adopted/implemented during the elaboration of Brazil's National FREL

8.8.1. Quality control

Throughout the preparation of Brazil's National FREL, technical QC procedures were implemented to evaluate and correct (when necessary) the quality of the results, as recommended by the 2006 IPCC Guidelines.

These procedures were implemented at two different levels (**Figure *40***): at a first level within FUNCATE expert team directly involved in the preparation of the GHG estimates; and at a second level within MMA expert team, technical coordinator and selected GTT-MRV members directly involved in the elaboration of the FREL submission document, but not directly involved in the calculation of the estimates.

From this perspective, the quality control system has been delineated for (non-exhaustive list to date):

(i) Routine checks to ensure the integrity, correctness and completeness of all data used in the FREL elaboration:

- Level 1: All data necessary for estimating emissions/removals (i.e., activity data and EF) were subject to completeness checks, to ensure that all necessary data have been gathered. Maps used have undergone integrity assessments (i.e., topological analyses relevant to this type of data), and corrections have been applied when necessary.

- Level 2: All data were examined by the MMA, technical coordinator, and UNDP team.

(ii) Calculation checks:

- Level 1: Calculations were carried out, in parallel, by two different experts to ensure the consistency and accuracy of the results.

- Level 2: All results were examined by the MMA, technical coordinator, and UNDP team.

(iii) Documentation and archiving:

- Level 1: Several reports were produced throughout the project detailing the input data and procedures adopted.

- Level 2: Weekly meetings were held between FUNCATE, MMA and UNDP to discuss and decide on the process, gaps, assumptions, preliminary results, etc. Meetings were recorded.

The main errors and/or gaps identified during the QC procedures, and corrections applied are presented in the following tables.

Table 79 – Errors and/or gaps identified during the quality control check – Amazon biome

Error/gap	Description	Possible cause	Impact	Significance	Correction applied
Overlap of polygons	Same polygons have different classification in terms of phytophysiognomies	Error due to the large amount of information to be assessed	Overlaps can be generated emissions overload	0,24% of the total area deforested on Forest category	A TerraAmazon tool was used to eliminate polygon overlap in the ancient vegetation map
Gaps in the ancient vegetation map	Polygons without information of the forest phytophysiognomies and/or category	Gasps may have been created due to differences in the biome's limits	Without the forest phytophysiognomies emissions can't be estimated	1% of the total area deforested	Due to its insignificance, missing area was not considered in the final estimates

Table 80 – Errors and/or gaps identified during the quality control check – Cerrado biome

Error/gap	Description	Possible cause	Impact	Significance	Correction applied
Gaps in the ancient vegetation map	Polygons without information of the forest phytophysiognomies and/or category	Gasps may have been created due to differences in the biome's limits	Without the forest phytophysiognomies emissions can't be estimated	0.0033% of the total area deforested	Due to its insignificance, missing area was not considered in the final estimates
Inconsistencies between carbon stocks included in the shapefile and the ones reported in the 4th National GHG Inventory	Sum of carbon stocks pools in the shapefile differs from values reported in the 4th National GHG Inventory	Most likely due to human errors when inserting data	Reduction of the estimate accuracy	3.2% of the total area deforested	Values from the 4th National GHG Inventory were used, adjusted per biome

Table 81 – Errors and/or gaps identified during the quality control check – Atlantic Forest biome

Error/gap	Description	Possible cause	Impact	Significance	Correction applied
Gaps in the ancient vegetation map	Polygons without information of the forest phytophysiognomies and/or category	Gasps may have been created due to differences in the biome's limits	Without the forest phytophysiognomies emissions can't be estimated	1.6% of the total area deforested	Due to its insignificance, missing area was not considered in the final estimates
Inconsistencies between carbon stocks included in the shapefile and the	Sum of carbon stocks pools in the shapefile differs from values	Most likely due to human errors when inserting data	Reduction of the estimate accuracy	3.2% of the total area deforested	Values from the 4th National GHG Inventory

Error/gap	Description	Possible cause	Impact	Significance	Correction applied
ones reported in the 4th National GHG Inventory	reported in the 4th National GHG Inventory				were used, adjusted per biome
PRODES residue class	PRODES residue class refers to deforestation areas identified after the occurrence. For example, a 2018 residue class, implies that the deforestation has been reported in 2018, but have occurred before 2018	This class is part of the PRODES Cerrado data transferred to Atlantic Biome. This means this is not an error, is part of the methodology	Deforestation and corresponding emission may have occurred “outside” the reference level period	0.5% of the emissions	Residue class was not included in the final estimates
Unknown forest phytophysiognomies	Ancient vegetation map present’s unknown forest phytophysiognomies: SNm, SMm, SNs, SNtm and TNm	Most likely due to human errors when inserting data	Reduction of the estimate accuracy	0.5% of the emissions	Carbon stocks values from the “higher” forest phytophysiognomies have been used

Table 82 – Errors and/or gaps identified during the quality control check – Caatinga biome

Error/gap	Description	Possible cause	Impact	Significance	Correction applied
Gaps in the ancient vegetation map	Polygons without information of the forest phytophysiognomies and/or category	Gasps may have been created due to differences in the biome’s limits	Without the forest phytophysiognomies emissions can’t be estimated	85% of the total area deforested	Forest phytophysiognomies were identified (based on information reported in the 4th National GHG Inventory) and included in the ancient vegetation map
Inconsistencies between carbon stocks included in the shapefile and the ones reported in the 4th National GHG Inventory	Sum of carbon stocks pools in the shapefile differs from values reported in the 4th National GHG Inventory	Most likely due to human errors when inserting data	Reduction of the estimate accuracy	0,93% of the total area deforested	Values from the 4th National GHG Inventory were used, adjusted per biome

Error/gap	Description	Possible cause	Impact	Significance	Correction applied
PRODES residue class	PRODES residue class refers to deforestation areas identified after the occurrence. For example, a 2018 residue class, implies that the deforestation has been reported in 2018, but have occurred before 2018	This class is part of the PRODES Cerrado data transferred to Atlantic Biome. This means this is not an error, is part of the methodology	Deforestation and corresponding emission may have occurred "outside" the reference level period	3% of the emissions	Residue class was not included in the final estimates
Unknown forest phytophysiognomies	Ancient vegetation map present's unknown forest phytophysiognomies: SNm, SNs, SNtm, SNts, STNtm, STNts, STs, STts, STtm , TNm, TNs, TNtm, TNts	Most likely due to human errors when inserting data	Reduction of the estimate accuracy	3.3% of the emissions	Carbon stocks values from the "higher" forest phytophysiognomies have been used

Table 83 – Errors and/or gaps identified during the quality control check – Pampa biome

Error/gap	Description	Possible cause	Impact	Significance	Correction applied
Gaps in the ancient vegetation map	Polygons without information of the forest phytophysiognomies and/or category	Gasps may have been created due to differences in the biome's limits	Without the forest phytophysiognomies emissions can't be estimated	0.03% of the total area deforested	Forest phytophysiognomies from the neighbor polygon were used
Inconsistencies between carbon stocks included in the shapefile and the ones reported in the 4th National GHG Inventory	Sum of carbon stocks pools in the shapefile differs from values reported in the 4th National GHG Inventory	Most likely due to human errors when inserting data	Reduction of the estimate accuracy	10,3% of the total area deforested	Values from the 4th National GHG Inventory were used, adjusted per biome
New forest phytophysiognomies	A new forest phytophysiognomies (Mm) were identified	New forest phytophysiognomies due to new biome's limits	Reduction of the estimate accuracy	0.003% of the emissions	Carbon stocks values from other biome (Atlantic forest) have been used

Table 84 – Errors and/or gaps identified during the quality control check – Pantanal biome

Error/gap	Description	Possible cause	Impact	Significance	Correction applied
Gaps in the ancient vegetation map	Polygons without information of the forest phytophysiognomies and/or category	Gasps may have been created due to differences in the biome's limits	Without the forest phytophysiognomies emissions can't be estimated	0.04% of the total area deforested	Forest phytophysiognomies were identified (based on information reported in the 4th National GHG Inventory) and included in the ancient vegetation map
Inconsistencies between carbon stocks included in the shapefile and the ones reported in the 4th National GHG Inventory	Sum of carbon stocks pools in the shapefile differs from values reported in the 4th National GHG Inventory	Most likely due to human errors when inserting data	Reduction of the estimate accuracy	24,86% of the total area deforested	Values from the 4th National GHG Inventory were used, adjusted per biome
PRODES residue class	PRODES residue class refers to deforestation areas identified after the occurrence. For example, a 2018 residue class, implies that the deforestation has been reported in 2018, but have occurred before 2018	This class is part of the PRODES Cerrado data transferred to Atlantic Biome. This means this is not an error, is part of the methodology	Deforestation and corresponding emission may have occurred "outside" the reference level period	0.06% of the emissions	Residue class was not included in the final estimates

8.8.2. Quality assurance

As described in section "The role of the Working Group of Technical Experts on REDD+ for MRV", all key inputs for the development of this submission have been presented and discussed by the GTT MRV REDD+.

The GTT MRV REDD+ also was instrumental in the process of quality assurance of the results, by performing expert judgment assessment in order to identify potential outliers that could result in under or over estimation.

A draft proposal of the submission (including preliminary results) was presented to the GTT MRV REDD+ and "technical validation processes" happened on October 30, November 1st, and December 12 2022.

As result of the "technical validation process", is worth to mention that the GTT-MRV considered the data, information and results presented in this FREL submission complete, methodological robust, and representing the most up to set of information available in the country.

Finally, since REDD+ submissions are subject to technical analysis by LULUCF experts from the UNFCCC roster of experts, it can be expected that additional QA procedures will be carried out during the technical analysis.

8.9. Status of recommendations/encouragements from previous technical analysis

Table 85 – Status of recommendations/encouragements from previous technical analysis - FREL Amazônia A, B[39]

Recommendations / encouragements from previous technical analysis[40]	Status in the current submission
Digitalization of deforestation maps: it was noted that estimates of deforestation for the years 1996–1997 are less accurate than the rest of the time series. The AT considers that a better estimation of estimates for the years 1996–1997 may be achieved through digitalization of the deforestation maps	All thematic maps used in this FREL submission were designed in digital format according to the same criteria of extracting information from orbital images, thus avoiding possible inconsistencies and inaccuracies between maps elaborated by different methodologies. It is understood that the 1996 and 1997 maps have no impact on the accuracy of the FREL proposed here, since Brazil have decided for a shorten reference level period (i.e., 5 years), aligned with other international guidance's. In addition, quality control procedures have been implemented to exclude "less accurate AD" – refer to section "Quality control and quality assurance procedures"
Continuation of improvement of the carbon map: the AT acknowledges the significant efforts made thus far by Brazil to assess the spatial distribution in carbon densities in the Amazonia biome and commends Brazil for continuing to work on updating and improving the carbon map based on new and improved ground data from its first national forest inventory	Brazil continues to improve the estimates and spatial distribution of carbon stocks in all biomes. These efforts have been mainly conducted within the scope of the LULUCF sector of the National GHG Inventory In addition, updated data/information from the EBA project have been used to estimate the "carbon map", particularly for the Amazon biome – refer to Box 2. Future additional improvements are expected once the NFI is fully completed and validated.
Treatment of emissions from dead wood (i.e. the inclusion of this pool or the provision of more information on the justification of its omission);	Dead wood poll has been included – refer to section "Pools, gases and activities included in Brazil's national FREL"
Treatment of non-CO_2 gases, to maintain consistency with the GHG inventory included in the national communication	Non-CO_2 gases have been included in the estimates for: 1) Deforestation in the Amazon and Cerrado biomes 2) Degradation by forest fires in the Amazon biome Nevertheless, due to current limitations non-CO_2 gases that may occur in other biomes have not yet been included – refer to Box 6

[39] Available at: https://redd.unfccc.int/files/redd_brazil_frel_final_19nov.pdf

[40] Paragraphs 37, 38 and 39 of the "Report of the technical assessment of the proposed forest reference emission level of Brazil submitted in 2014" (FCCC/TAR/2014/BRA) Available at: https://unfccc.int/resource/docs/2014/tar/bra01.pdf

Recommendations / encouragements from previous technical analysis[40]	Status in the current submission
In assessing the activities included in the FREL, the AT considers that degradation is a significant activity based on the estimates provided by Brazil. The justification provided by Brazil to omit this activity is that the time series available is too short to allow an adequate understanding of the degradation process. Based on the available information, the AT notes that, so far, there is no evidence of displacement of emissions (i.e., decreased deforestation in the Amazonia biome resulting in increasing degradation). In addition, the AT notes that the current exclusion of degradation appears to be conservative in the context of constructing the FREL. Overall, the AT considers better understanding of the relationship between degradation and deforestation as an area for future technical improvement of the FREL. The AT notes that, when emissions from degradation are included in the FREL, Brazil will need to demonstrate how double counting of emissions included under degradation and deforestation is avoided (e.g. for forests that were subject to selective logging and subsequently clear cut)	National discussions about "forest degradation" and "deforestation" have been quite exhaustive over the last few years in the context of the GTT-MRV. In this new submission, due to available data, forest degradation was included in the Amazon biome only. The selected drivers of degradation were fires in managed forest land and disordered logging. For the Cerrado biome, it was not possible to take into account degradation due to fire because of lack of activity data and high uncertainties. For other Biomes it was recognized that fires do not play a significant role in forest degradation (see **Box 5** and **Box 6**) and disordered logging, when it occurs, presents low intensity, and its identification in orbital images is not feasible with spatial resolutions currently used by INPE. Regarding the relationship between degradation and deforestation, it should be noted that the process and sequence of degradation was considered for the purposes of calculating emissions in subsequent deforestation. That is, although the relationship has not been thoroughly analyzed, its consequences in terms of reducing carbon stocks for the purposes of calculating emissions associated with deforestation have been taken into account

Table 86 – Status of recommendations/encouragements from previous technical analysis - FREL Amazônia C[41]

Recommendations / encouragements from previous technical analysis[42]	Status in the current submission
Exclude the less accurate AD	Unlike other submissions, no analog data was used for estimating Brazil's National FREL In addition, quality control procedures have been implemented to exclude "less accurate AD" – refer to section "Quality control and quality assurance procedures"
Provide information on the extent of deforested areas that are detected at the 1 ha threshold but not retrieved later by the PRODES project using a 6.25 ha threshold, with the aim of showing that no significant deforestation is excluded from the FREL	Deforestation have been estimated used a minimum map unit of 1 hectare – refer to section "Calculation of Brazil's national FREL"

[41] Available at: https://redd.unfccc.int/files/frelc_modifiedversion_correction2019.pdf

[42] Paragraphs 41 and 42 of the "Report of the technical assessment of the proposed forest reference emission level of Brazil submitted in 2018" (FCCC/TAR/2018/BRA). Available at: https://unfccc.int/sites/default/files/resource/tar2018_BRA.pdf

Recommendations / encouragements from previous technical analysis[42]	Status in the current submission
Provide information on how the EFs were derived for the five vegetation types that were not included in the 22 forest types of the FREL	Information on how EFs were derived for each biome have been included – refer to section "Calculation of Brazil's national FREL"
Provide a territorial matrix of the Amazonia biome in the FREL with the distribution considered by the national communication and by the FREL, along with a clear description of any methodological differences	Currently, it is not possible to present a "territorial matrix" since INPE methodology for monitoring deforestation does not include procedures for the identification of land use after deforestation. In other words, it can only be said that the deforestation areas presented here relate to forest conversions (F) to another non-forest land category, as defined as "deforestation", but without a clear definition if the land is Cropland, Grassland, etc.
Better explain the difference of 5,573,793.6 ha between the PRODES deforestation increments in the third national communication and in the FREL	The difference is potentially explained by the fact that in PRODES deforestation estimated are included Other Woody Formations (OFL) which are not considered forest phytophysiognomies in the 4th National Inventory. There is also the fact that PRODES considers the territory of the Legal Amazon, while the National Inventory considered the Amazon biome, whose limits are different
Strengthen the quality control of the submission to eliminate inconsistencies	In this submission all steps taken were supervised both by internal FUNCATE experts, as well as by other external experts with relevant expertise During activity data collection using orbital images, external consultants with specific expertise in each one of the biomes were hired, to guide the team of interpreters, drawing attention to relevant aspects to be considered in the spatial distribution of phytophysiognomies and in their phenological dynamics, seeking to minimize possible misunderstandings of interpretation During data processing, considering the large volume and control needs for the elaboration of spreadsheets for future calculations, all work was concentrated in a single expert who interacted with those responsible for the calculations. The occurrence of inconsistencies was promptly reported, and further processing followed After the completion of the calculations, even of those intermediaries, the results were discussed in meetings, with the participation of FUNCATE experts, MMA team, technical coordinator and UNDP team For more information, refer to section "Quality control and quality assurance procedures"
Include non-CO_2 gases to improve consistency with the GHG inventory included in the national communication	Non-CO_2 gases have been included in the estimates for: 1) Deforestation in the Amazon and Cerrado biomes 2) Degradation by forest fires in the Amazon biome

Recommendations / encouragements from previous technical analysis[42]	Status in the current submission
	Nevertheless, due to current limitations non-CO_2 gases that may occur in other biomes have not yet been included – refer to Box 6

Table 87 – Status of recommendations/encouragements from previous technical analysis - FREL Cerrado[43]

Recommendations / encouragements from previous technical analysis[44]	Status in the current submission
Estimate emissions from net deforestation	Net deforestation has been estimated for the Amazon and Cerrado biomes – refer to section "Additional information "
Include emissions from forest degradation by forest fires	GHG emission from forest degradation by forest fires in the Amazon biome have been included – refer to section "Gross emissions due degradation" Nevertheless, due to current limitations GHG emission from forest degradation by forest fires in the Cerrado biome have not yet been included – refer to Box 5
Quantify uncertainties associated with the FREL	Uncertainties have been estimated – refer to section "Accuracy"
Explore the possibility of including the soil organic carbon pool	Due to current limitations soil organic carbon pool have not yet been included – refer to Box 8

[43] Available at: https://redd.unfccc.int/files/frelcerrado_en_20170629_br_v.2.pdf

[44] Paragraph 35 of the "Report of the technical assessment of the proposed forest reference emission level of Brazil submitted in 2017" (FCCC/TAR/2017/BRA). Available at: https://unfccc.int/sites/default/files/resource/bra.pdf