



Brazil's Forest Reference Emission Level for Reducing Emissions from Deforestation in the Cerrado biome for Results-based Payments for REDD+ under the United Nations Framework Convention on Climate Change

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Introduction

Brazil welcomes the opportunity to submit another 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+).

On February 4, 2014, the Brazilian Ministry of the Environment (MMA, for the acronym in Portuguese) created the Working Group of Technical Experts on REDD+ (GTT REDD+, for the acronym in Portuguese) through Ordinance N^o. 41/2014. This group is composed of experts in the areas of climate change and forestry from renowned Brazilian institutions.

In 2014 Brazil submitted a FREL for reducing emissions from deforestation in the Amazon biome (FREL Amazonia), based on technical inputs from the GTT REDD+. Brazil has indicated in that submission that its national FREL would be the sum of the FRELs for each of its six biomes. This submission demonstrates Brazil's efforts in this regard. This FREL submission for the Cerrado biome (FREL Cerrado) and the FREL Amazonia cover approximately 73% of the Brazilian territory.

The GTT REDD+ has provided important inputs for the development of this FREL, including the definition of deforestation, the forest physiognomies to be considered, the carbon pools and gases to be included. The GTT 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>.

Brazil underlines that the submission of FRELs and/or Forest Reference Levels (FRLs) and subsequent Technical Annexes to the Biennial Update Report (BUR) 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.

Therefore, this submission does not modify, revise or adjust in any way the Nationally Appropriate Mitigation Actions (NAMAs) that are being undertaken by Brazil under the Bali Action Plan (FCCC/AWGLCA/ 2011/INF.1), nor does it interfere with the Nationally Determined Contribution (NDC) submitted by Brazil to the UNFCCC.

Area and activity covered by the FREL

Paragraphs 11 and 10 of decision 12/CP.17 (FCCC/CP/2011/9/Add.2), 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.

In this submission, Brazil proposes a subnational FREL for emissions from gross deforestation in the Cerrado biome (see **Figure 1**), which covers an area of 2,036,448 km² (203,644,800 ha or about 24% of the national territory).

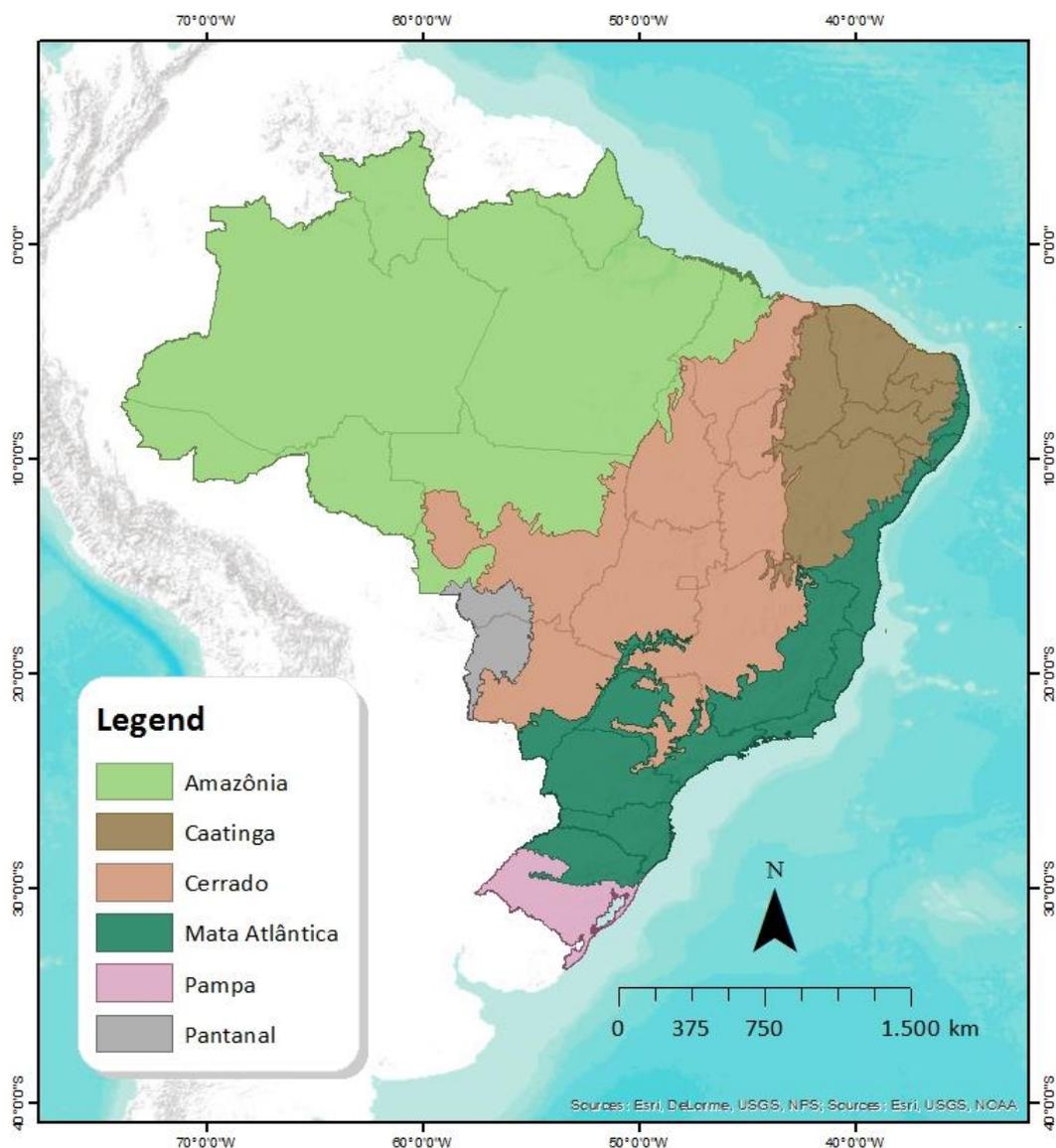


Figure 1. Distribution of the six biomes in the Brazilian territory. Source: IBGE, 2004.

The Cerrado is Brazil's second largest biome. It is in the geological formation known as *Planalto Central* (Central Plateau) and covers a wide range of latitude, from the north of the State of Maranhão – MA to the south of Mato Grosso do Sul – MS (**Figure 2**). The geographical boundaries of the Cerrado biome and the definition of forest adopted in this submission are consistent with Brazil's Map of Biomes (IBGE, 2004) and Brazil's Vegetation Map (IBGE, 2004)¹.

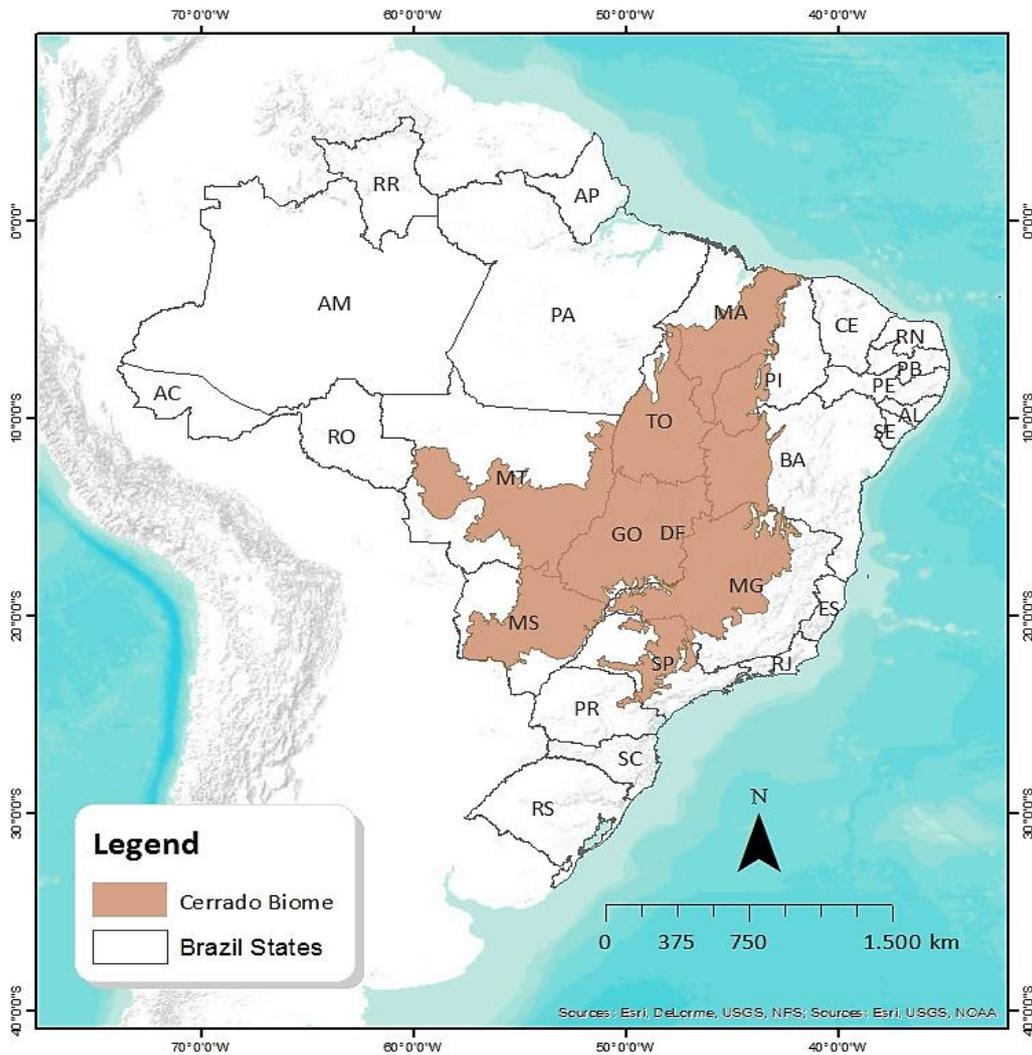


Figure 2. Geographical distribution of the Cerrado biome by Brazilian states. Source: IBGE, 2004. Note: MA (state of Maranhão); PI (state of Piauí); TO

¹ The Vegetation Map (see Figure 10) produced for the Second National GHG Inventory (BRASIL, 2010) and also used in the Third National GHG Inventory, was the result of combining the maps from the Brazilian Institute of Geography and Statistics (IBGE, for the acronym in Portuguese) and those produced under the Project for the Conservation and Sustainable Use of Brazilian Biological Diversity (PROBIO, for the acronym in Portuguese), as well as visual interpretation of Landsat Images. This process was carried out to simplify the attribution of carbon stock values to phytophysionomies. Further details can be found in the Third National Communication Volume III, Appendix I available at <http://sirene.mcti.gov.br/publicacoes>. The Vegetation Map is available in folder (4) at <http://redd.mma.gov.br/en/infohub>.

(state of Tocantins); BA (state of Bahia); GO (state of Goiás); DF (Federal District); MT (state of Mato Grosso); MS (Mato Grosso do Sul); SP (state of São Paulo); MG (state of Minas Gerais).

The Cerrado biome is characterized by dry winters and rainy summers, a climate classified predominantly as Aw (tropical wet and dry or savanna climate), according to the Köppen-Geiger classification. The average annual precipitation for the area is about 1,600 mm, varying from 750 mm to 2,000 mm (Adámoli *et al.*, 1987). To the south of the biome, the Cwa climate (Eiten, 1994) can occur, which also characterizes the region's highest sites, above 1,200 m high.

As previously noted, the Cerrado and the Amazon biomes together make up approximately 73% of the national territory. With this submission, Brazil demonstrates its commitment to quickly evolve towards a national FREL. The presentation of FRELs per biome can facilitate the evaluation of the effectiveness and impact of policies, measures and actions that in the case of Brazil are implemented at the biome level.

The National Policy on Climate Change, set by Law No. 12,187, of December 29, 2009 and regulated by Decree No. 7,390, of December 9, 2010, establishes, among the mitigation activities planned up to 2020, a 40% reduction in deforestation in the Cerrado biome compared to the average annual deforestation observed between 2002 and 2008. Currently in its third phase, the Action Plan for the Prevention and Control of Deforestation and Forest Fires in the Cerrado (PPCerrado, for the acronym in Portuguese) seeks to contribute to this goal (more information can be found in **Annex, section I**). These activities will be monitored under the Brazilian Biomes Environmental Monitoring Program (PMABB, for the acronym in Portuguese), detailed in **Annex, section II**, which will provide systematic data on deforestation, forest degradation and fires in the Cerrado biome up to 2020.

The definition of deforestation adopted by the National Policy on Climate Change and PPCerrado refers to the conversion of **natural areas** to other land-use categories. The Cerrado biome is formed by a vegetation complex composed of forest, savanna and grassland phytophysionomies.

For this submission, the definition of deforestation is more restrictive. It only includes the conversion of natural areas with forest formations into other categories of land use. Consequently, deforestation estimates for the Cerrado biome that were generated by different sources may exhibit discrepancies with the values presented in this submission (more information can be found in **Annex, section III**).

For the Cerrado biome, the classification of the vegetation in the field is supported by Ribeiro and Walter (2008) who define forests as environments with a predominance of tree species and continuous or discontinuous canopy formation (see **Figure 3**), while

savanna formations are characterized by the coexistence of arboreal, shrub and herbaceous layers (see **Figure 4**). The grassland formations are characterized by the prevalence of herbaceous and shrub species, with fewer trees and a lack of canopy formation (see **Figure 5**). **Figure 6** provides a pictorial representation of different vegetation phytophysiognomies typical of the Cerrado, including: Riparian Forest² (*Mata Ciliar*), Gallery Forest³, a Dry Forest⁴, Tall Woodland (*Cerradão*)⁵, Dense Cerrado⁶, Typical Cerrado⁷, Sparse Cerrado⁸, Savanna park⁹, Palmland¹⁰, Vereda¹¹, Rupestrian Cerrado¹², Shrub Grassland¹³ and Open Grassland (low-grass savanna)¹⁴.

² **Riparian forest** is defined as forest vegetation alongside medium and large rivers in the Cerrado region, where the arboreal vegetation does not form galleries.

³ **Gallery Forest** is characterized by forest vegetation found alongside small rivers and streams of Central Brazilian plateaus, forming closed corridors (galleries) over the watercourse.

⁴ **Dry Forest** (Seasonal Deciduous Forest) is forest vegetation type with the prevalence of deciduous trees that lose their leaves during the dry season. The average height of the arboreal stratum varies between 15 and 25 meters.

⁵ **Tall Woodland** is a forest formation with sclerophyllous characteristics (large occurrence of hard plant organs, mainly leaves) and xeromorphic (with characteristics such as reduced leaves, succulence, dense pilosity or with thick cuticles for conserving water, rendering them suitable to endure dry conditions). It is characterized by the occurrence of species found in the Typical Cerrado (*Cerrado Stricto Sensu*) and also in forests, particularly Dry Forest and *Mata de Galeria não-inundável*. It is a forest from a physiognomic point of view, but floristically it resembles more closely the *Typical Cerrado*. It is a denser type of vegetation.

⁶ **Dense Cerrado** is a subtype with predominance of arboreal vegetation, with tree coverage of 50% to 70% and an average height of 5 to 8 meters. Represents the densest and highest form of the Cerrado Stricto Sensu.

⁷ **Typical Cerrado** is characterized by tree cover of 20% to 50% and outstanding tree stratum, with average height of 3 to 6 meters, and usually with evidences of forest fires.

⁸ **Sparse Cerrado** another subtype of vegetation consisting of trees and shrubs (arboreal-shrub), with tree cover of 5% to 20% and an average height of 2 to 3 meters. Represents the lowest and least dense form of the Cerrado Stricto Sensu.

⁹ **Cerrado Park** also known as **Savanna Park** (IBGE, 2004) is a savanna formation subgroup consisting essentially of a grass stratum, composed of hemicryptophytes and geophytes of natural or anthropic origin interspersed with isolated nanofanerophytes, resembling typical parkland.

¹⁰ **Palmland** a savanna-like formation characterized by the remarkable presence of a single species of palm trees.

¹¹ **Vereda** a phytophysiognomy with emerging Buriti palms (*Mauritia flexuosa*) found amid more or less dense clusters of shrub-herbaceous species.

¹² **Rupestrian Cerrado** an arboreal-shrub vegetation subtype that occurs in rocky or lithographic rock environments (areas of outcropped rocks). It has a variable tree cover of 5% to 20% and an average height of 2 to 4 meters, with additional shrub-herbaceous cover.

¹³ **Shrub Grassland** is a physiognomic type of exclusively herbaceous shrub, with sparse shrubs and sub-shrubs whose plants are often made up of less developed individuals from the Cerrado Stricto Sensu tree species.

¹⁴ **Open Grassland** are areas without woods, covered by herbaceous plants, primarily grasses.



Figure 3. Pictorial representation of forest physiognomies of the Cerrado biome: Riparian forest (on the left) and Tall Woodland (on the right). Source: ICMBio, available at <http://www.icmbio.gov.br/projetojalapao/en/biodiversity/phytophysiognomy.html>.

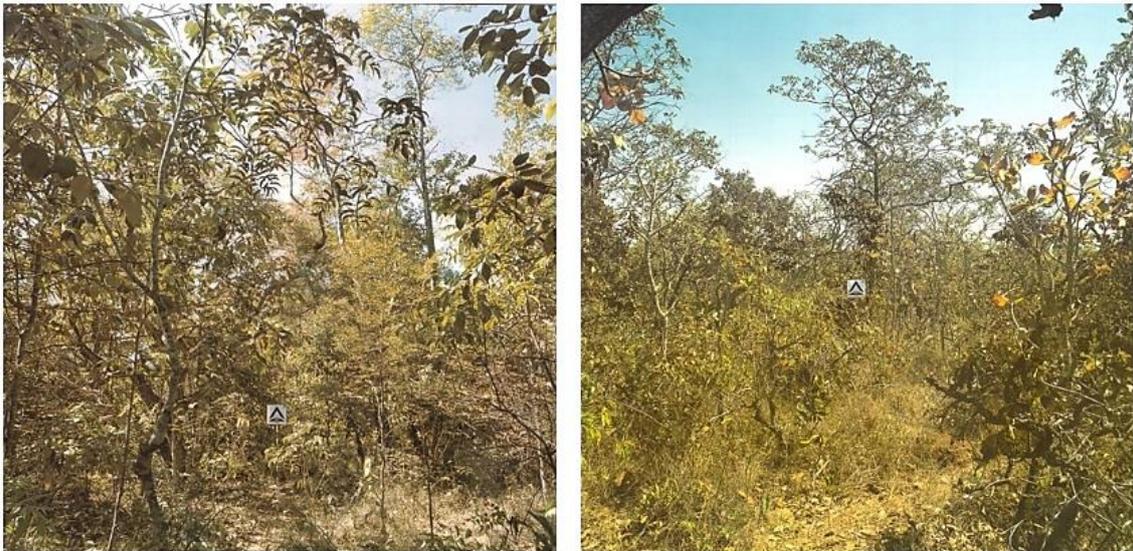


Figure 4. Pictorial representation of savanna phytophysiognomies in the Cerrado biome: Dense Cerrado (on the left) and Typical Cerrado (on the right). Source: Adapted from Ottmar et al. (2001).



Figure 5. Pictorial representation of grassland phytophysiognomies in the Cerrado biome: Rough Savanna (on the left) and Low-Grass Savanna (on the right). Source: Adapted from Ottmar et al. (2001).

Section d of this submission provides further details on the forest definition adopted in the construction of this FREL Cerrado, following the guidance provided by the GTT REDD+. **Annex, section IV** also provides an identification key of the physiognomic types in the Cerrado biome.

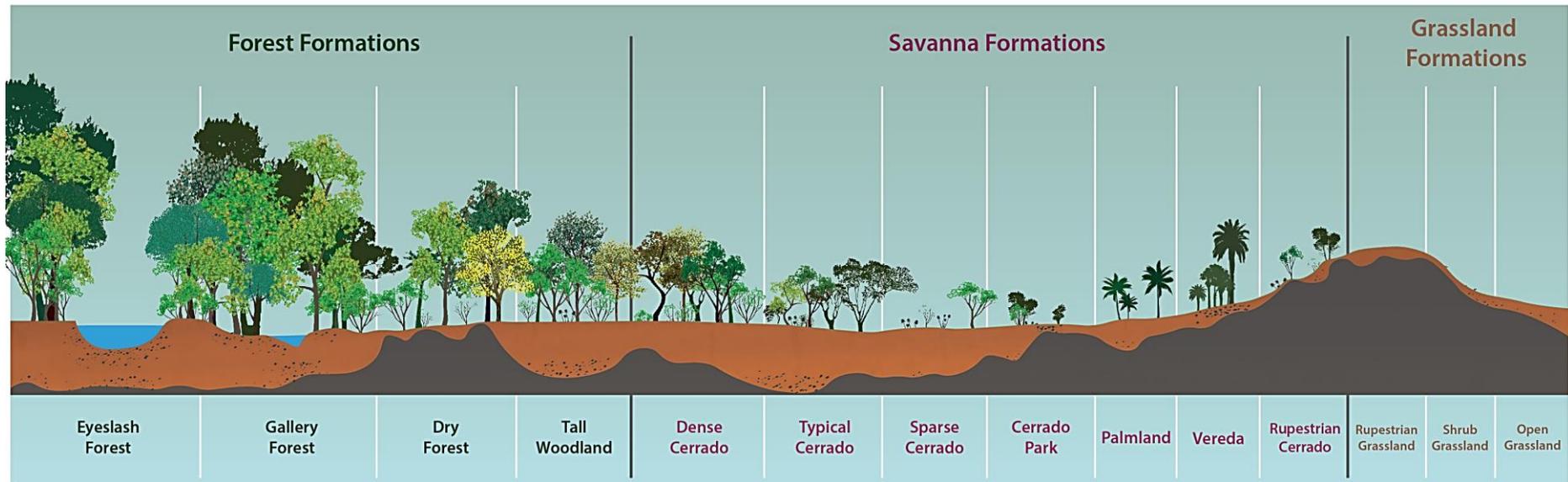


Figure 6. Pictorial representation of the main vegetation phytophysionomies in the Cerrado biome, in a biomass gradient (from the largest forest formations, on the left, to the smallest ones - savannas and grasslands, on the right). Source: Adapted from Ribeiro and Walter, 2008.

Despite the relative reduction of its share in the total national emissions over the last few years, Land Use, Land-Use Change and Forestry (LULUCF) remains a significant source of emissions – 42.01% of the total Brazilian emissions according to the Third National GHG Inventory, part of the Third National Communication of Brazil to the UNFCCC (see Table 2.1 in Volume 3, page 45). Of the total greenhouse gas emissions associated with LULUCF (42.01%), 22.02% is related to the Amazon biome and 7.94% to the Cerrado biome (*Figure 7*).

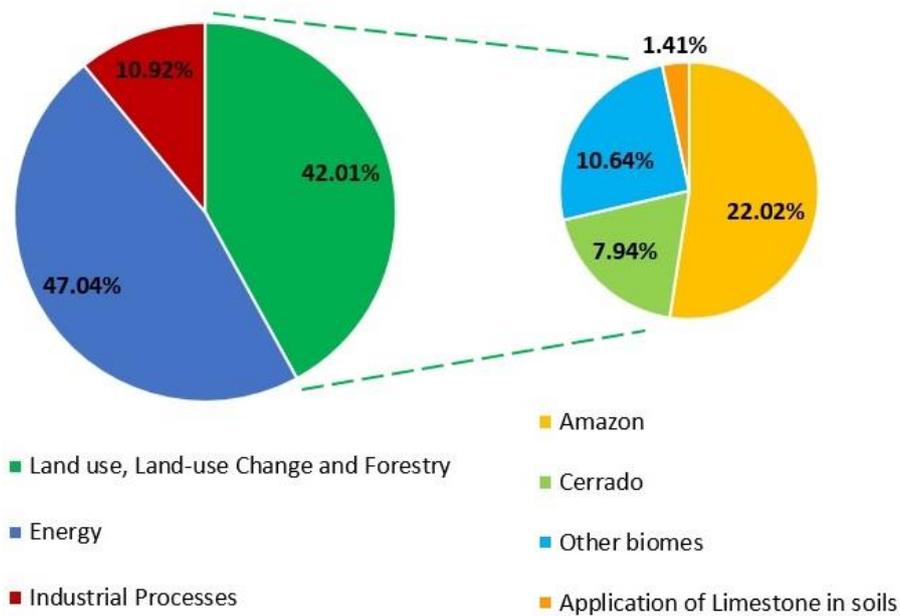


Figure 7. Percent contribution of the different sectors to the total net CO₂ emissions in 2010 and the corresponding percent contribution of the Brazilian biomes to the total net emissions from LULUCF. Note: The Waste sector is not represented in the diagram because it represents a mere 0.02% of national emissions in 2010. Therefore, the sum of the percentages shown in the diagram to the left does not add to 100%. Source: Third National Communication (MCTI, 2016).

To estimate emissions associated with deforestation in the Cerrado biome, this submission adopts the same emission factors used in the Third National GHG Inventory – the latest National GHG Inventory at the time of this submission. The data is also broadly consistent with those reported by Brazil to the Food and Agriculture Organization of the United Nations (FAO) for the Global Forest Resources Assessment (FRA).

This submission includes CO₂ emissions from gross deforestation and non-CO₂ emissions (methane (CH₄) and nitrous oxide (N₂O)) from fires resulting from deforestation in the Cerrado biome.

Brazil followed the guidelines contained in the Annex to decision 12/CP.17 on submitting reference levels and structured this submission accordingly:

- a) Information used in the construction of the FREL;
- b) Transparent, complete, consistent and accurate information, including methodological information used in the construction of the FREL;
- c) Pools, gases and activities included in the FREL; and
- d) The forest definition used in the construction of the FREL.

Details can be found below.

a) Information used in the construction of the FREL

The construction of the FREL for *reducing emissions from deforestation in the Cerrado biome* was based on a historical time series of gross deforestation data produced by the National Institute for Space Research (INPE, for the acronym in Portuguese) of the Ministry of Science, Technology, Innovation and Communications (MCTIC, for the acronym in Portuguese), covering the period from 2000 to 2010, with 2000 as the reference year.

Deforestation estimates for the Cerrado biome have been generated by different studies and projects in the past, such as the Satellite Deforestation Monitoring of the Brazilian Biomes (PMDBBS, for the acronym in Portuguese), the result of a technical cooperation between the MMA, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA, for the acronym in Portuguese) and the United Nations Development Program (UNDP).

Nevertheless, the historical time series developed and used in this submission was the first to ensure consistent and regular (biennial) estimates of deforestation in the Cerrado biome for the 2000-2010 period. The same team of interpreters was responsible for producing the deforestation data for the entire time series, divided per eco-region (as presented in **Figure 8**) therefore reducing potential inconsistencies in the identification of deforestation patterns in a complex biome like the Cerrado.

Deforested areas were estimated from the analysis of the Landsat-5 satellite data, with adequate spatial resolution (about 30 meters by 30 meters) covering the entire biome (wall-to-wall). The year 2000 was defined as the reference year for identifying and mapping new polygons of deforestation in the following periods: 2000-2002; 2002-2004; 2004-2006; 2006-2008; and 2008-2010.

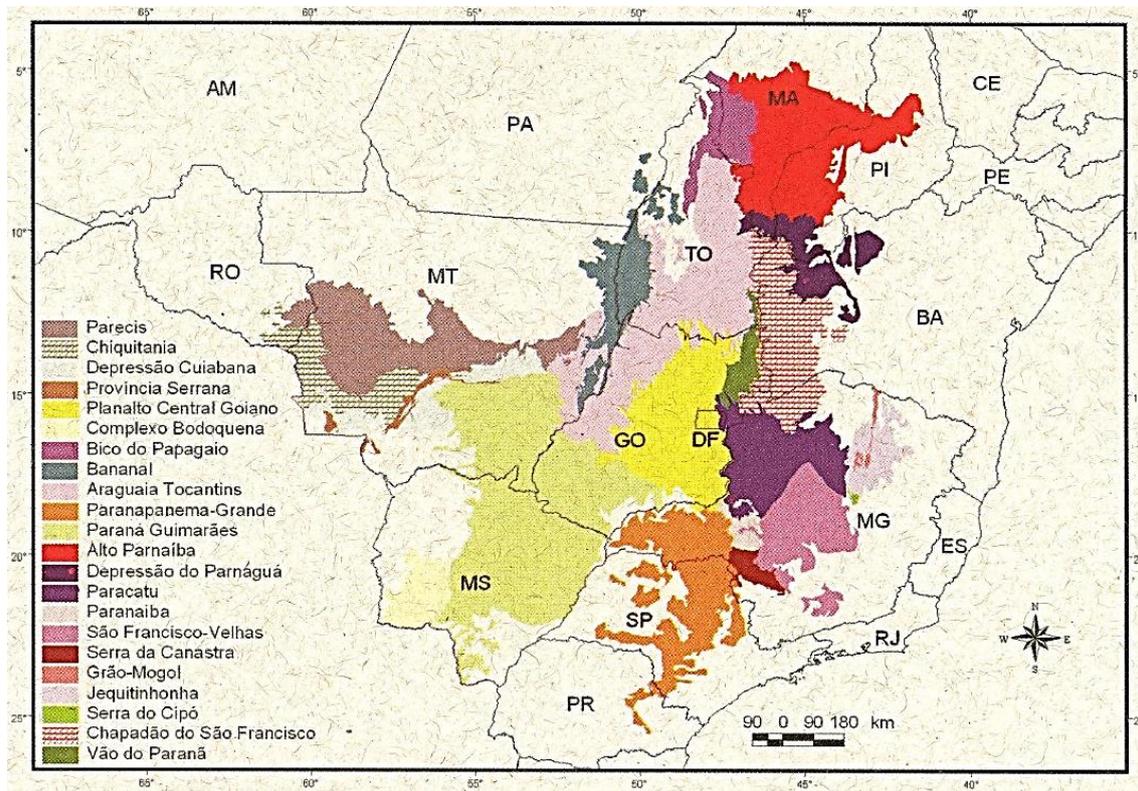


Figure 8. Map of the eco-regions in the Cerrado biome. Source: Arruda et al., 2008.

The Vegetation Map used to identify the forest physiognomies affected by deforestation and the references used to generate the carbon estimates were the same as those used in the Third National GHG Inventory, submitted to the UNFCCC in April 2016, hence ensuring complete consistency between this FREL and the Third National GHG Inventory.

The methodology used to estimate emissions from deforestation (the conversion of forest formations to other land uses) was based on the IPCC Good Practice Guidance for LULUCF (IPCC, 2003). Emissions, in tonnes of carbon (tC), resulted from the product of activity data (deforested areas, in hectares) and emission factors (carbon stock per unit area of forest vegetation affected by deforestation, in tonnes of carbon per hectare ($tC \cdot ha^{-1}$)). Only gross emissions were considered – i.e., carbon removals resulting from the land category after conversion were not included. Non- CO_2 emissions from fire resulting from deforestation were estimated using the 2006 IPCC guidelines, applying country-specific data, where available.

Finally, as detailed in **section c.2**, the following pools were considered in this submission: aboveground biomass, belowground biomass, litter, and dead wood. The exclusion of the soil organic matter is justified in **section c.2**.

A more detailed description of the information used to estimate emissions in the Cerrado biome for this FREL is presented below.

a.1. Estimates of deforested areas (activity data) in the Cerrado biome

A reference map was generated from the analysis of Landsat-5 satellite images for the year 2000 (reference year) indicating the areas already converted to other land uses (accumulated human-induced change) and the remaining natural areas. From the reference map, according to the methodology synthesized in **Figure 9**, natural areas (including savannas, grasslands and forests) converted for other land uses in the periods 2000-2002; 2002-2004; 2004-2006; 2006-2008 and 2008-2010 were then identified and mapped at the scale of 1:75,000¹⁵. The files containing the deforestation polygons maps for each of these periods (natural areas with forest formations converted for other land uses) are part of the material made available to allow for the reconstruction of this FREL, and are presented in *shapefile* format (see folder **(3) Maps with all Conversions** available in the Info Hub Brasil (<http://redd.mma.gov.br/en/infohub>)).

Overlaying the deforestation polygons with the Vegetation Map (**Figure 10**) allows for the identification of the forest physiognomy affected by deforestation. This identification is important to define the carbon stock in each pool considered in the construction of this FREL, information necessary to estimate emissions from deforestation.

¹⁵ A list of all Landsat images used in each of the five periods is provided at <http://redd.mma.gov.br/en/infohub> (see folder (5) **Other relevant information and data**). The link to download the images is <https://earthexplorer.usgs.gov/>.

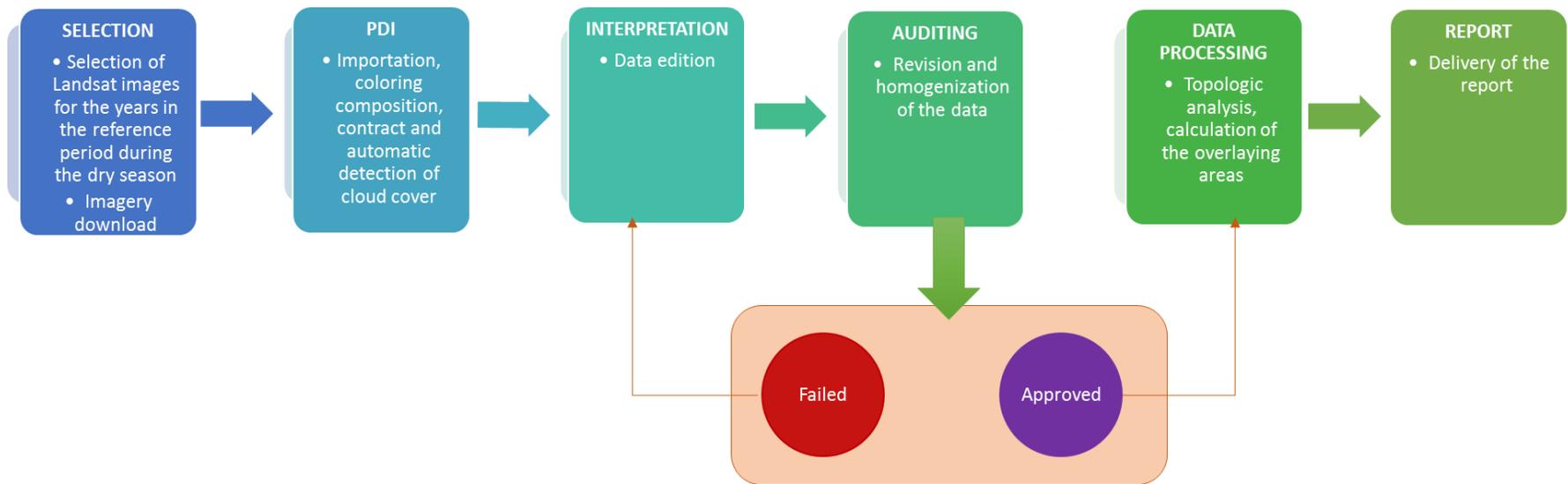


Figure 9. Methodology adopted to identify deforested areas in the Cerrado biome.

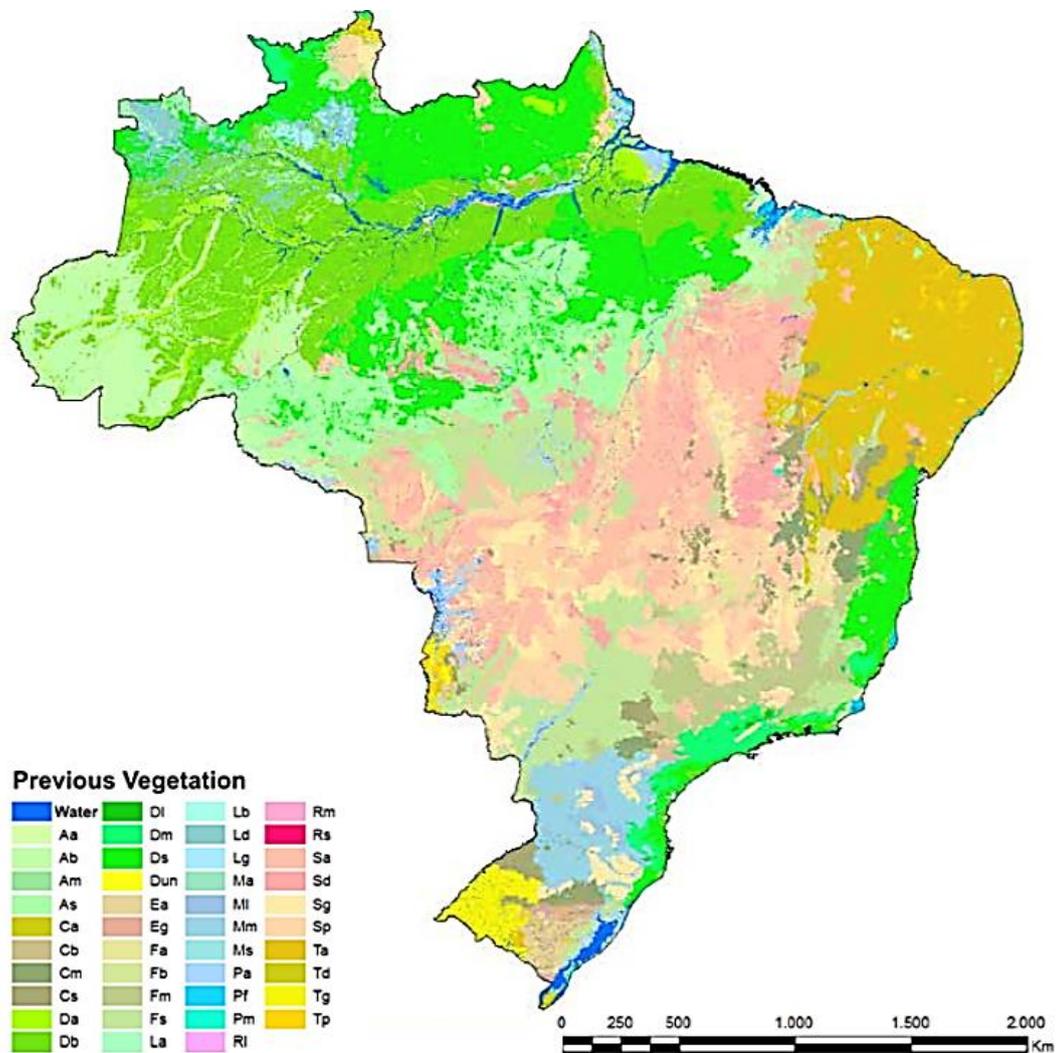


Figure 10. Vegetation Map. Source: *Third National Communication of Brazil, Volume III, page 223.*

The sum of the areas of all the deforestation polygons observed within a given geographic extension is referred to as **deforestation increment**. This geographical extension can be defined as the boundaries of a satellite image, for example. In this submission, **deforestation increment** refers to the sum of the **deforestation increments calculated for each image** comprising the Cerrado biome (in the case of the Cerrado biome, a total of 118 Landsat-5 satellite images) for each analyzed period.

It is worth noting that the presence of clouds affects the ability of the sensor on-board the Landsat-5 satellite to observe the territory¹⁶. However, in the Cerrado biome the total area under cloud cover was quite small in all periods considered. For example, the cloud covered adjusted deforestation increments for the 2000-2002, 2002-2004, 2004-2006 and 2006-2010 periods differed from the deforestation increments by 0.16%; 0.09%; 0.06% and 0.01% (in hectares, 3,538/2,098,155; 2,025/2,151,777; 840/1356,658; and 140/1,000,721, respectively).

a.2. Estimates of emission factors for the Cerrado biome

The emission factors in this submission are defined as the carbon stocks in living biomass (above and below-ground biomass) and in dead organic matter (litter and dead wood) and are consistent with those adopted by the Third National GHG Inventory.

Twenty-three forest phytophysionomies were defined, with the two most abundant ones being the Wooded Savanna (Sa) and the Submontane Semi Deciduous Seasonal Forest (Fs), which cover approximately 29% and 12% of the biome, respectively. Other forest phytophysionomies, such as the Lowland Deciduous Seasonal Forest (Cb), were also included in the FREL, despite their low occurrence in the biome (0.003%), to maintain consistency with the definition of forest formations in the Cerrado biome adopted by the Third National GHG Inventory. **Box 1** summarizes the approaches to estimate the carbon stocks in aboveground biomass in forests in the Cerrado biome.

Box 1. *Regionalization of the carbon stock estimates for forest physiognomies in the Cerrado biome.*

The Cerrado is the second largest biome in Brazil and borders four other Brazilian

¹⁶ When there is a significant portion of the territory covered by clouds, as it was the case for the Amazonia biome, the deforestation increment in a given period may be underestimated because it does not include potential deforestation under cloudy areas (unobserved). The deforestation increment in a subsequent year can be overestimated because it includes deforested areas that could be partially or totally attributed to a year when cloud cover occurred. This fact led to the definition of an **adjusted deforestation increment** in the submission of the FREL Amazonia, based on the distribution of the observed deforested area at year t that was under cloud cover in the previous year(s), in a way to minimize the over or under estimation of the annual deforestation, thus in accordance with the IPCC good practice guidance for LULUCF (IPCC, 2003). This was not the case for the Cerrado biome.

biomes (Amazonia, Atlantic Forest, Caatinga and Pantanal). This biome comprises a wide latitudinal range, which extends from the coast of the state of Maranhão to the south of Mato Grosso do Sul. Such vast extension justified regionalizing the carbon stock of forest phytophysionomies per Brazilian state whenever there were scientific studies available demonstrating considerable variation among them. Factors such as geographic distance between patches of vegetation and environmental characteristics, such as rainfall and seasonality, were also considered, since these abiotic characteristics also influence the characteristics of vegetation.

The six phytophysionomies with regionalized values by state are: (1) Wooded Savanna (Sa); (2 and 3) Montane Deciduous Seasonal Forest (Cm) and Submontane Deciduous Seasonal Forest (Cs); (4, 5 and 6) Alluvial Semi Deciduous Seasonal Forest (Fa), Lowland Semi Deciduous Seasonal Forest (Fb) and Submontane Semi Deciduous Seasonal Forest (Fs).

The Cerrado biome is second only to the Atlantic Forest in terms of number of phytophysionomies (a total of 28) in Brazil. Approximately 29% and 35% of the Cerrado biome is covered predominantly by herbaceous vegetation (the main ones being Savanna Park (Sp) and Woody-grass Savanna (Sg), both considered as grassland formations in the Third National GHG Inventory) and Wooded Savanna (Sa) respectively. The latter is typical of the Cerrado *Stricto Sensu*, formed by tortuous trees with thick bark.

Table 1 provides information about the share of coverage of the different forest phytophysionomies of the Cerrado biome included in the FREL Cerrado.

Table 1. Share (%) of coverage of the different forest phytophysionomies of the Cerrado biome considered in this FREL and their respective acronym. Source: Table 15, Reference Report to the Third National GHG Inventory¹⁷ (MCTI, 2016).

Abv.	Phytophysionomy	%
Sa	Wooded Savanna	29.46
Fs	Submontane Semi Deciduous Seasonal Forest	11.95
Sd	Forested Savanna	9.30
Fm	Montane Semi Deciduous Seasonal Forest	3.55

¹⁷ Available at

http://sirene.mcti.gov.br/documents/1686653/1706165/RR_LULUCF_Mudan%C3%A7a+de+Uso+e+Flor+esta.pdf/11dc4491-65c1-4895-a8b6-e96705f2717a (Portuguese only).

Fa	Alluvial Semi Deciduous Seasonal Forest	2.86
Cs	Submontane Deciduous Seasonal Forest	2.64
Ab	Lowland Open Humid Forests	1.26
Cm	Montane Deciduous Seasonal Forest	1.11
Ta	Wooded Steppe Savanna	0.90
As	Open Submontane Humid Forest	0.57
Pa	Fluvial and/or lacustre influenced Vegetation	0.30
Pm	Pioneering Formation of Marine Influence (sand banks)	0.27
Td	Forested Steppe Savanna	0.25
Ds	Submontane Dense Humid Forest	0.16
Fb	Lowland Semi Deciduous Seasonal Forest	0.15
Mm	Montane Mixed Humid Forest	0.10
Pf	Pioneering Formation of Fluviomarine Influence (mangroves)	0.06
Aa	Alluvial Open Humid Forest	0.03
Dm	Montane Dense Humid Forest	0.03
MI	Montane Mixed High Humid Forest	0.01
Da	Alluvial Dense Humid Forest	0.01
Ea	Wooded Steppe	0.01
Cb	Lowland Deciduous Seasonal Forest	0.003

The percentages shown in **Table 1**, which add to around 65%, correspond to the percentage of the Cerrado biome territory covered by each forest physiognomy; the remaining 35% are distributed among natural grassland and savanna formations that have not been included in the FREL Cerrado.

Section a.2.1 presents a summary of the sequence of steps taken to construct this FREL.

a.2.1. The sequence of steps to construct the FREL

a.2.1.1. Average CO₂ emissions in the period 2000-2010

The steps to estimate the annual average CO₂ emissions used to calculate the FREL Cerrado are provided below.

Step 1: Producing the reference map for the year 2000, through the analysis of Landsat-5 satellite images, mapping the areas subjected to human activities (accumulated up to year 2000) and the areas still covered by natural vegetation.

Step 2: Identifying, by overlaying the map produced in **Step 1** with the Vegetation Map, the areas covered with the different vegetation formations – grasslands, savannas and forests – over the area still covered with natural vegetation. The Vegetation Map is based on the Technical Manual of Brazilian Vegetation (IBGE, 2012) and FAO’s Land Cover Classification System and Global Forest Resources Assessment (FAO, 2015) – the same map used for the Third National GHG Inventory.

Step 3: Identifying the areas of natural vegetation converted to other land uses in the following periods: 2000-2002; 2002-2004; 2004-2006; 2006-2008 and 2008-2010, using satellite images from 2002, 2004, 2006, 2008 and 2010.

Step 4: Identifying the different types of forest phytophysiological types that originally covered the areas with natural vegetation converted to other land uses, identified in **Step 3**, using the Vegetation Map.

Step 5: Constructing a database listing, for each year, the deforested polygons mapped, the corresponding forest phytophysiological types, and the carbon stocks applicable to each pool: aboveground biomass, belowground biomass, litter and dead wood (see **section b.4.3** for more details).

Step 6: Assessing the need to adjust the annual deforestation increments, considering the percentage of areas under cloud cover.

Step 7: Calculating the CO₂ emissions from gross deforestation (conversion of areas of natural vegetation formations with forest phytophysiological types to other land uses) for each period (2000-2002; 2002-2004; 2004-2006; 2006-2008; 2008-2010).

Step 8: Calculating the average annual CO₂ emissions for each period, obtained by dividing the emissions estimated for the biennial period by 2 (the length of the period).

Step 9: Calculating the CO₂ component of the FREL as the mean of the average annual emissions in the period from 2000 to 2010 (10 years).

The diagram below depicts the sequence of steps to calculate the FREL and **section a.2.2** provides the calculation in equation format.

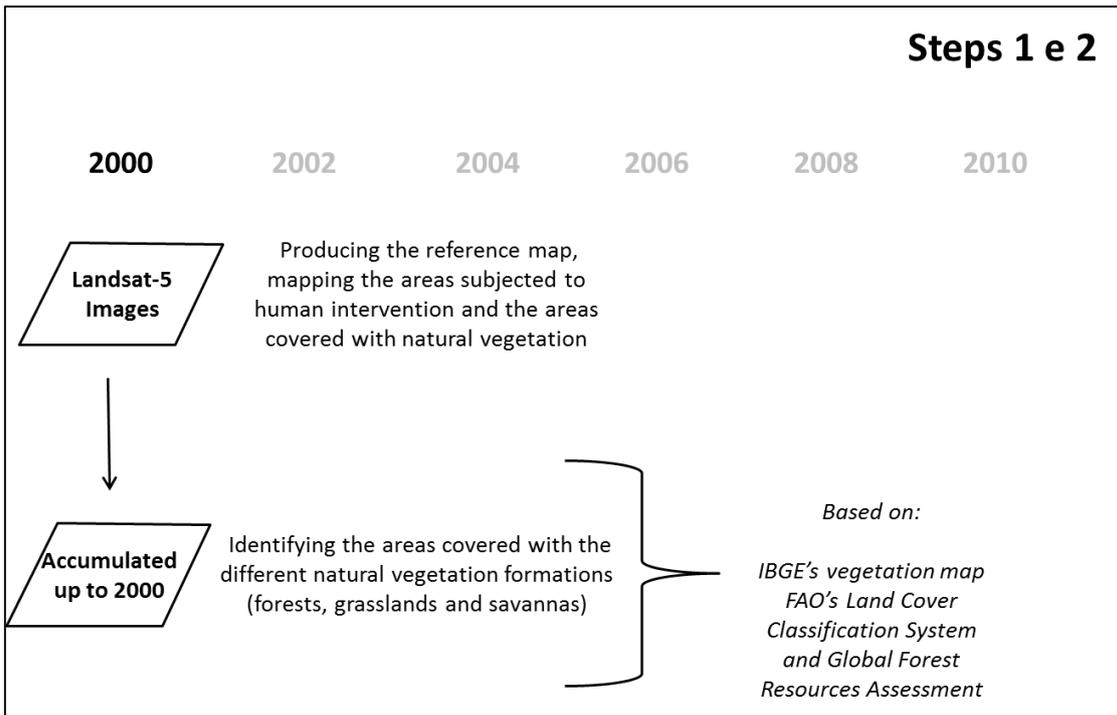


Figure 11. Steps 1 and 2 for estimating the average annual emissions.

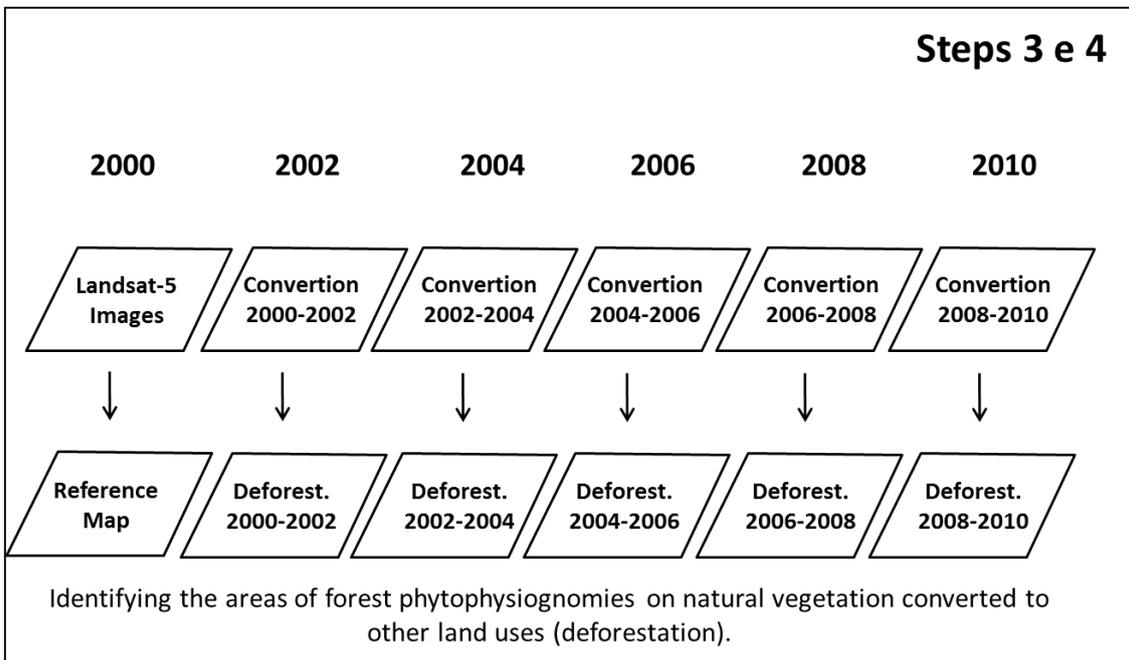


Figure 12. Steps 3 and 4 for estimating the average annual emissions.

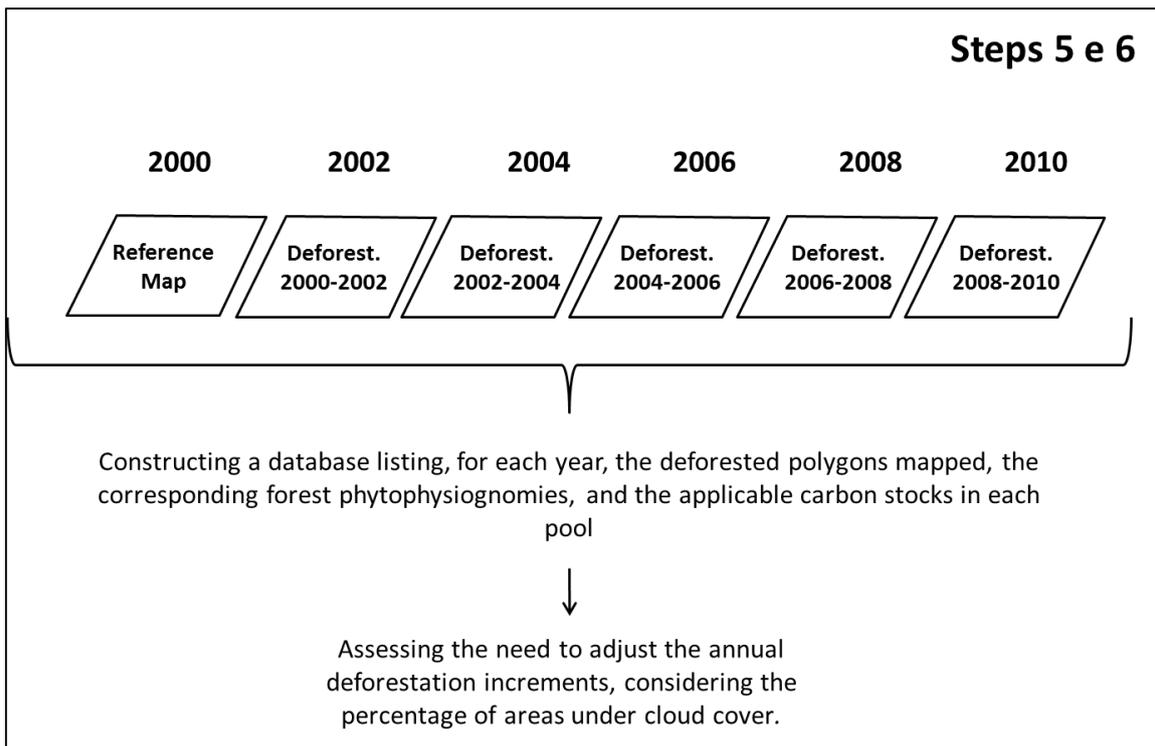


Figure 13. Steps 5 and 6 for estimating the average annual emissions.

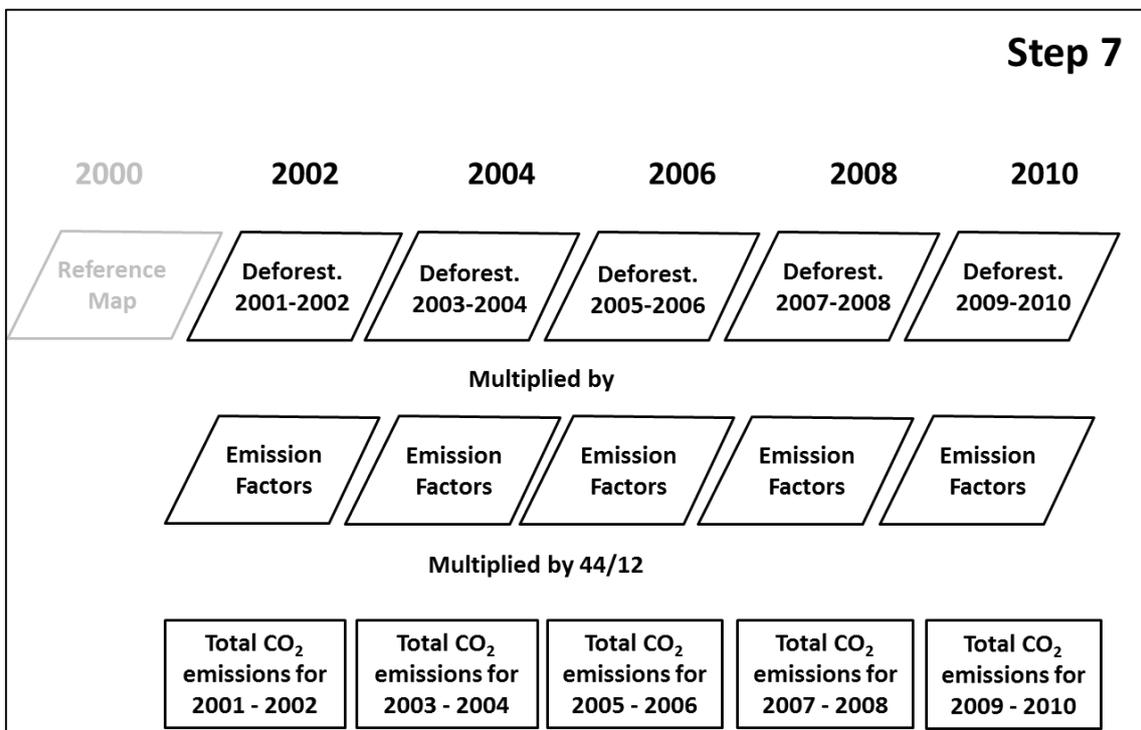


Figure 14. Step 7 for estimating the average annual emissions.

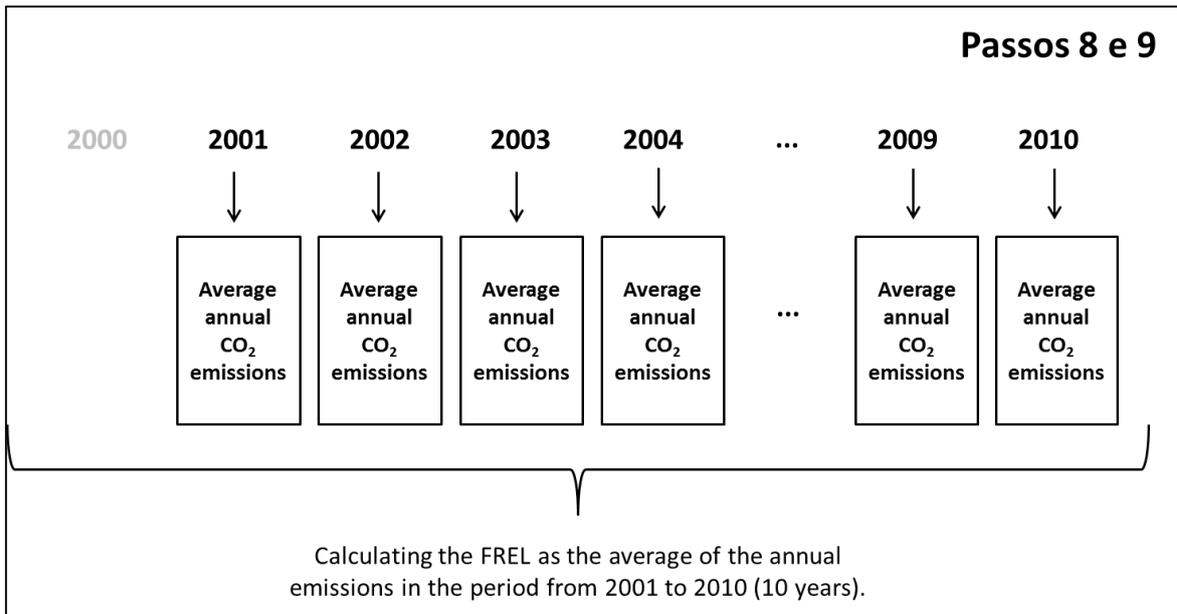


Figure 15. Steps 8 and 9 for estimating the average annual emissions

a.2.1.1.1. Equations used to estimate the CO₂ emissions from deforestation

For each deforestation polygon *i* identified in the period *t* to *t+2*, the associated CO₂ emission is estimated as the product of its area and the sum of the carbon stocks in the living biomass and dead organic matter associated to the type of forest physiognomy affected by deforestation, regionalized by state where relevant (see **Equation 1**).

$$GE_{i,j} = A_{ij} * \sum_{K=1}^4 EF_K * 44/12 \tag{Equation 1}$$

where:

$GE_{i,j}$ = CO₂ emission associated with deforestation polygon *i* with forest phytophysiology *j*; in tCO₂.

A_{ij} = area of deforestation polygon *i* associated with forest phytophysiology *j*; in ha.

EF_K = carbon stock in pool *K* associated with the forest phytophysiology *j*; *K* = (1) above-ground biomass, (2) below-ground biomass, (3) biomass in the litter, and (4) biomass in dead wood; in tC ha⁻¹.

44/12 = factor to convert carbon into carbon dioxide (CO₂); dimensionless.

Note: for all carbon reservoirs, the conversion of biomass in dry matter to carbon used the default value from the 2006 IPCC Manual, equal to 0.47.

For each period, pt , the total emission resulting from deforestation is estimated from **Equation 2**:

$$GE_{pt} = \left[\sum_{i=1}^N GE_{ij} \right]_{pt} \quad \text{Equation 2}$$

where:

GE_{pt} = total CO₂ emissions in period pt ($t = 1, \dots, 5$); $p_1 = 2000-2002$; $p_2 = 2002-2004$; ... $p_5 = 2008-2010$; in tCO₂.

GE_{ij} = CO₂ emission associated with deforestation polygon i with forest phytophysiognomy j ; in tCO₂.

N = number of deforestation polygons in period pt ($t = 1, \dots, 5$); $p_1 = 2000-2002$; $p_2 = 2002-2004$; ... $p_5 = 2008-2010$; $p(t, t+2)$; dimensionless.

For any period, pt , the average annual CO₂ emission from deforestation is calculated as indicated in **Equation 3**:

where:

$$MGE_{pt} = \frac{GE_{pt}}{2} \quad \text{Equation 3}$$

MGE_{pt} = average annual CO₂ emission from deforestation in period pt ; $t = 1, \dots, 5$; t CO₂/year.

GE_{pt} = total CO₂ emissions in period pt ($t = 1, \dots, 5$); $p_1 = 2000-2002$; $p_2 = 2002-2004$; ... $p_5 = 2008-2010$; in tCO₂.

Note: MGE_{p1} provides the average annual emission for each year of period p_1 (2000-2002), i.e., for 2001 (MGE_{11}) and 2002 (MGE_{12}) the average annual emission is the same. So, for each MGE_{pt} there are two identical values.

The FREL is calculated as expressed in **Equation 4**:

$$MGE_{FREL} = \frac{\sum_{t=1}^5 MGE_{pt}}{10} \quad \text{Equation 4}$$

where:

MGE_{FREL} = average CO₂ emissions in the period 2000-2010, tCO₂

MGE_{pt} = average annual CO₂ emission from deforestation in period p_t , $t = 1, \dots, 5$; t CO₂/year

10 = number of years in the reference period

a.2.1.2. Average non-CO₂ emissions from fire resulting from deforestation in the period 2000-2010

The GTT REDD+ recommended and the technical assessment experts endorsed that estimates of non-CO₂ emissions from fire resulting from deforestation be included in this FREL Cerrado submission.

The methodology in the IPCC 2006 guidelines was used, following Equation 2.27, page 2.42, Chapter 2, volume 4 (reproduced in **Equation 5**), and assuming that all forest conversions would lead to fire, *post-conversion*. Hence, all the area converted was assumed to have been subject to fire. The mass of fuel available for combustion was calculated from the values presented in **Table 6** for aboveground biomass, litter and dead wood, converted to dry mass (d.m.) using a factor of 0.47 tC (t d.m.)⁻¹, i.e. sum of the carbon in aboveground biomass, in litter and in dead wood, divided by 0.47.

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

Equation 5

where:

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH₄, N₂O, etc.

A = area burnt, ha

M_B = mass of fuel available for combustion¹⁸, tonnes of dry matter ha⁻¹

C_f = combustion factor, dimensionless

¹⁸ This includes aboveground biomass, litter and dead wood. Belowground biomass has not been included.

G_{ef} = emission factor, $g\ kg^{-1}$ dry matter burnt

Default emission factors (G_{ef}) for tropical forests in Table 2.5 in the IPCC 2006 guidelines have been used (Chapter 2, volume 4, page 2.47). For the combustion factor, C_f , the value 0.435 was applied (from Castro and Kauffman, 1998) – this value is similar to the default value in Table 2.6 of the IPCC 2006 guidelines, equal to 0.5 (Chapter 2, volume 4, page 2.48), for primary tropical moist forests.

The following steps were carried out for each period to estimate the non-CO₂ component of the FREL:

Step 1: Calculating the sum of the following carbon pools: aboveground biomass, litter and dead wood, for each deforestation polygon.

Step 2: Estimating the CH₄ emission associated with each polygon, multiplying its area by the total carbon stock produced in **Step 1**, the combustion factor (0.435), the emission factor (6.8) and 10^{-3} (following equation 5).

Step 3: Estimating the N₂O emission associated with each polygon, multiplying its area by the total carbon stock produced in **Step 1**, the combustion factor (0.435), the emission factor (0,20) and 10^{-3} (following equation 5).

Step 4: Calculating the total CH₄ and N₂O emissions in the period by summing up the emissions associated with all deforestation polygons. The result is provided in units of mass of GHG.

Step 5: Adjusting the total result for CH₄ and N₂O by dividing by 0.47 ($tC\ (t\ d.m.)^{-1}$) since the sum of the carbon pools produced in **Step 1** is in tonnes of carbon per hectare, and the mass of available fuel in equation 5 is in tonnes of dry matter. Note: due to the non-conversion of the units in tonnes of carbon to tonnes of dry matter in **Step 1**, which would be the most logical, this was carried out after the calculations have been performed. Obviously, from the numerical point of view, this does not make any difference, but the logical step would have been to carry out the conversion already in Step 1.

Step 6: Converting the CH₄ and N₂O emissions into CO₂-eq, by multiplying the result in (4) for CH₄ by 21 and for N₂O by 310.

Step 7: Calculating the average annual CO₂-eq for each period, by dividing by 2 the emissions estimated for the biennial periods (result in **Step 6**).

Step 8: Calculating the non-CO₂ component of the FREL as the mean of the average annual emissions in the period from 2000-2010 (10 years).

a.2.2. Calculation of the FREL Cerrado

Brazil's proposed FREL is the **sum** of the mean of the average annual CO₂ emissions from gross deforestation in the Cerrado biome **and** the mean of the average annual CH₄ and N₂O emissions from fire resulting from deforestation, from 2000 to 2010. The average annual CO₂ emissions have been calculated according to the methodology presented in **sections a.1 (Estimates of deforested areas (activity data) in the Cerrado biome)** and **a.2 (Estimates of emission factors for the Cerrado biome)**. The non-CO₂ emissions (CH₄ and N₂O) from fires resulting from deforestation have been calculated following the methodology provided in **section a.2.1.2**. The FREL does not include assumptions pertaining to possible future changes in internal policies.

The value of the FREL Cerrado for results-based payments for reducing emissions from deforestation in the Cerrado biome in the period 2011-2020 results from the figures presented in **Table 2** and represented pictorially in **Figure 16**.

The annual deforestation increments observed in the Cerrado biome from 2000 to 2010, presented in **Table 2** have been obtained by dividing the total deforested area identified in the biennial assessments by the length of the biennial period (2 years). The deforested polygons in each of the five biennial periods, their area, forest phytophysiology, emission factors used for each pool (living biomass and dead organic matter) and CO₂, CH₄ and N₂O emissions associated with the polygon are available in the file calculation sheets **CO₂ and non-CO₂ Emission**, available in folder (2) at <http://redd.mma.gov.br/en/infohub>. When the number of polygons in a given period exceeded the acceptable total number of rows in an excel spreadsheet (1,048,576 rows), the deforestation polygons were included in a separate tab, for a particular state of the Cerrado biome – as shown in the topic IV of the Annex (**Guide to the Excel files**).

The REDD+ decisions under the UNFCCC value the continuous improvement of relevant data and information over time. Hence, this submission has been prepared with the most updated and consistent data available and has considered the most significant pools. As always, Brazil presents its data in a transparent and verifiable manner, allowing the reconstruction of the FREL Cerrado.

Brazil invests considerable human and financial resources in improving its historical time series and directs resources from international cooperation projects to this end. Estimates of emissions from deforestation in the Cerrado biome are being generated for the periods 2012-2013 and 2013-2015 and will be generated annually thereafter up to 2020. In 2018, Brazil intends to submit its third Biennial Update Report (BUR), which should include a Technical Annex with REDD+ results for reducing GHG emissions from deforestation in the Cerrado biome for the 2011-2017 period.

Table 2. Annual increments of deforestation and associated emissions in the Cerrado biome, from 2000 to 2010

PERIOD	AVERAGE ANNUAL INCREMENTS OF DEFORESTATION (ha/yr⁻¹)	AVERAGE ANNUAL CO₂ EMISSIONS FROM DEFORESTATION (tCO₂/yr⁻¹)	AVERAGE ANNUAL CH₄ EMISSIONS FROM DEFORESTATION (tCO₂-eq/yr⁻¹)	AVERAGE ANNUAL N₂O EMISSIONS FROM DEFORESTATION (tCO₂-eq/yr⁻¹)	TOTAL AVERAGE ANNUAL EMISSIONS FROM DEFORESTATION (tCO₂-eq/yr⁻¹)
2000-2001	2,087,304	465,970,129	12,178,766	5,287,700	483,436,595
2001-2002	2,087,304	465,970,129	12,178,766	5,287,700	483,436,595
2002-2003	2,124,167	471,978,963	12,248,373	5,317,921	489,545,256
2003-2004	2,124,167	471,978,963	12,248,373	5,317,921	489,545,256
2004-2005	1,343,484	302,901,230	8,008,462	3,477,063	314,386,755
2005-2006	1,343,484	302,901,230	8,008,462	3,477,063	314,386,755
2006-2007	990,019	220,010,901	5,858,795	2,543,735	228,413,431
2007-2008	990,019	220,010,901	5,858,795	2,543,735	228,413,431
2008-2009	751,923	156,192,837	3,992,941	1,733,630	161,919,407
2009-2010	751,923	156,192,837	3,992,941	1,733,630	161,919,407
TOTAL	14,593,794	3,234,108,120	84,574,674	36,720,098	3,355,402,892
ANNUAL AVERAGE 2000-2010	1,459,379	323,410,812	8,457,467	3,672,010	335,540,289
FREL = sum of the annual average emissions of CO₂, CH₄ and N₂O (in CO₂-eq) for 2000-2010					335,540,289

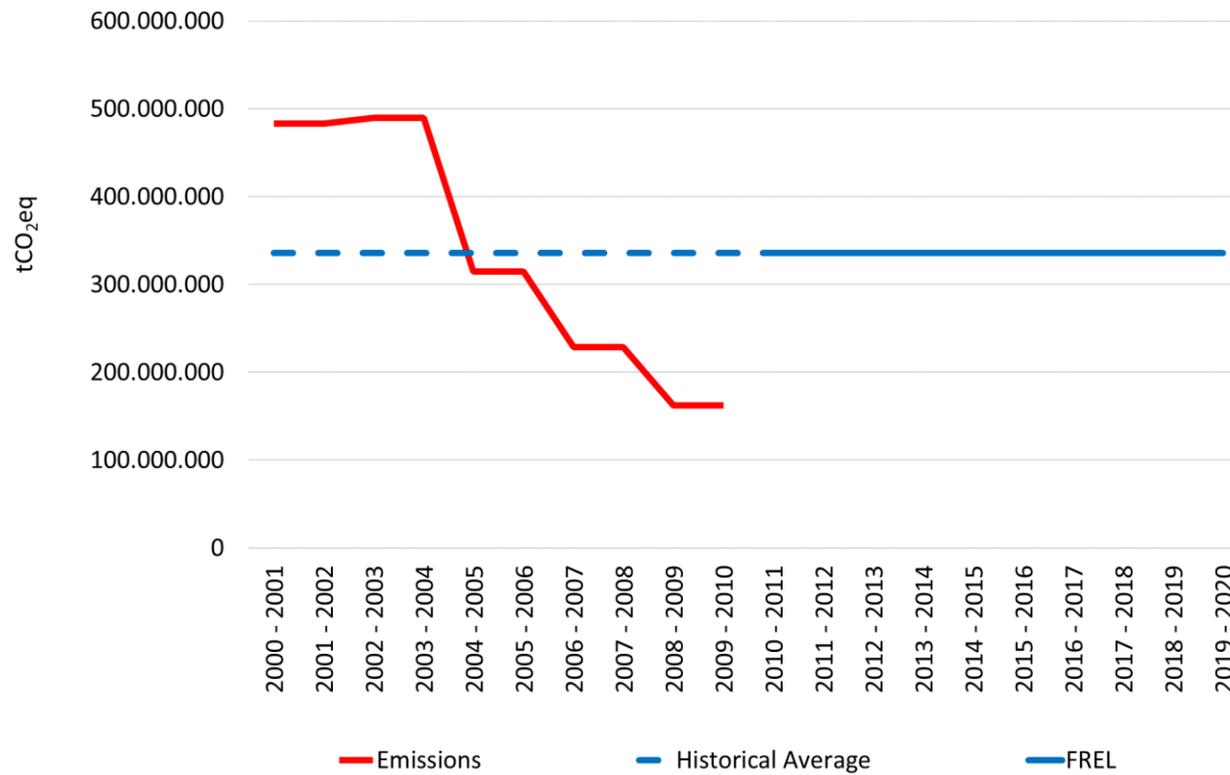


Figure 16. Pictorial representation of Brazil's FREL for the Cerrado biome, where the continuous line refers to the mean of the average annual CO₂-eq emissions from deforestation from 2000 to 2010 (335.540.289 tCO₂-eq year⁻¹).

b) Transparent, complete, consistent and accurate information, including methodological information used in the construction of the FREL

b.1. Complete Information

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

The data and information described below was used in the construction of this FREL and are available for download at the Info Hub Brasil (<http://redd.mma.gov.br/en/infohub>):

- (1) Satellite images from 2000, 2002, 2004, 2006, 2008 and 2010 that were used in **steps 1 and 3 of section a.2.1 (The sequence of steps to construct the FREL)** to identify deforestation polygons in the Cerrado biome from 2000-2010. See folder (5), **List of Images**.
- (2) Reference map containing the aggregated deforestation in areas of forest physiognomies up to and including 2000 (corresponding to **steps 1 and 2 of section a.2.1**). See folder (1), **Reference Map**.
- (3) Maps with the deforestation polygons identified in each period (2000-2002, 2002-2004, 2004-2006, 2006-2008, 2008-2010) (corresponding to **step 3 of section a.2.1**). See folder (3), **Maps with all Conversions**.

IMPORTANT NOTE 1: The maps mentioned in (2) and (3) are available in *shapefile* format, ready to be imported into a geographic database for analysis. Any individual deforestation polygon can be checked against the corresponding satellite image.

- (4) Database listing all deforestation polygons in each period, their area, forest phytophysiology, emission factors used for live biomass and dead organic matter pools and CO₂ and non-CO₂ emissions associated with each polygon (corresponding to **steps 4 and 5 of section a.2.1**);
- (5) Carbon stock values per unit area of different phytophysiology in the Cerrado biome, consistent with those used in the Third National GHG Inventory (corresponding to **step 7 of section a.2.1**). See folder (5), **Table 5 - Carbon Stocks**; and

- (6) Bibliographical references used to estimate carbon stocks in aboveground biomass; in below ground biomass; in litter; and in dead wood.

b.2. Transparent Information

This section provides more detailed information on the items indicated in **section b.1.**

b.2.1. Satellite Images

The satellite images from the optical sensor onboard Landsat-5 satellite are the main source of data for identifying deforested areas in the different Brazilian biomes, including the Cerrado. The process begins with the selection of the images, with priority given to those that show a low incidence of cloud cover and that have been taken at closer dates, in order to minimize seasonal and temporal variations between them.

Landsat images were selected directly from the United States Geological Survey (USGS) (<http://earthexplorer.usgs.gov>) and are therefore already orthorectified (that is, dispensing the need for registering/georeferencing). For the year 2000, all the areas of the Cerrado biome affected or not by human intervention were mapped, in addition to the water bodies (rivers and lakes). The thematic data were produced through a vectorization (delimitation) and a classification of the homogenous features.

From the reference map produced for year 2000, all the new conversions of natural areas to other land uses were delimited and classified, including those occurring in forest, savanna and grassland formations. Other sources of data such as Google Earth and maps produced under other studies and projects (such as the PMDBBS and the PROBIO) were also consulted, as appropriate. The entire thematic mapping process was performed using the interpretation scale of 1:75,000 and minimum mapping unit of 1 hectare.

b.2.2. Identification of deforested areas in the Cerrado biome

The identification of the deforested areas in the Cerrado biome was done by applying the definition of deforestation adopted for REDD+ purposes, i.e. **the conversion of natural areas with forest formations to other land-use categories** (for example, agriculture, pasture, urban areas). A detailed example is available at the Info Hub Brasil (<http://redd.mma.gov.br/en/infocenter>) with a section taken from a Landsat scene of a partially deforested area (see folder (5): ***Identifying deforestation in a Forest Formation***).

To ensure the completeness of this submission, thus allowing for the reconstruction of this FREL, all the deforestation polygons identified in each period were entered into a

database that compiled the following information for each polygon: the type of forest physiognomy, the state where it occurred, the carbon in the living biomass and in the dead organic matter and the corresponding CO₂, CH₄ and N₂O emission estimates. Consequently, deforested areas and total CO₂, CH₄ and N₂O emissions for each period can be verified, as well as their corresponding average annual emissions, the basis for calculating the FREL Cerrado.

b.2.3. Other relevant information and data

The carbon values in the living biomass and in the dead organic matter used for constructing the FREL Cerrado were the same as those used in the Third National GHG Inventory (MCTI, 2016) and are presented in **Table 5**, sorted by carbon pool. The same table presents the references used for defining the emission factors. The emission factors used, along with other relevant information, are presented in **section b.4.3**.

b.3. Consistent information

b.3.1. Consistency with the latest National Greenhouse Gas Inventory

Paragraph 8 of Decision 12/CP.17 indicates that reference levels should keep consistency with the country's latest National GHG Inventory.

Brazil applied IPCC's definition of consistency (IPCC, 2006) and used the same methodologies and datasets for constructing this FREL as those used to develop the estimates of CO₂ and non-CO₂ emissions from the conversion of forest areas (managed and unmanaged) to other land uses in the Third National GHG Inventory.

Since the Second National GHG Inventory that covered the period 1994-2002, Brazil has been following IPCC's Good Practice Guidance for Land Use, Land-use Change and Forestry (IPCC, 2003), applying approach 3 for land representation (Spatially Explicit Data). The Third National GHG Inventory reports Brazil's emissions for the LULUCF sector for the period 2002-2010. In addition to that, some data from the 1994-2002 period were recalculated to apply updated emission factors and/or to correct previous image classifications. The Third National GHG Inventory applied the same methodologies as those used in the Second National GHG Inventory, which were already based on the IPCC Good Practice Guidance for Land Use, Land-use Change and Forestry (IPCC, 2003). The Third National GHG Inventory used some emission factors based on regionalized data to replace IPCC default values previously used, thus enhancing the accuracy of the individual estimates (refer to Box 1).

It should be pointed out, however, that there are differences between the estimates presented in the Third National GHG Inventory for the period 2002-2010, displayed in Table 67 (***Áreas das transições de uso e cobertura da terra identificadas no bioma***

Cerrado no Período de 2002 a 2010) of the Reference Report for LULUCF (MCTI, 2016), and the forest areas converted to other land uses in the same period presented in the historical time series of this FREL Cerrado.

Table 3 presents data from the Third National GHG Inventory, as shown in Table 67 of the Reference Report for LULUCF (MCTI, 2016), for the conversion of unmanaged forests (FNM) and managed forests (FM) to pasture (Ap), agriculture (Ac), reforestation (Ref), urban areas (S), reservoirs (Res) and others (O), for the period 2002-2010.

Table 3. Areas (total converted to each category, overall total, and average annual area converted; in hectares) of land use transitions identified in the Cerrado biome in the 2002- 2010 period. Unmanaged forest (FNM), managed forest (FM), pasture (Ap), agriculture (Ac), reforestation (Ref), urban areas (S), reservoirs (Res) and others (O). Source: Third National GHG Inventory (MCTI, 2016).

	Area for 2002-2010 (ha)						
	Ap	Ac	Ref	S	Res	O	Total (ha)
FNM	6,798,389	2,078,315	177,833	23,798	154,258	5,808	9,238,401
FM	329,392	45,522	8,599	2,269	24,947	374	411,102
Overall Total for the Period						9,649,503	
Average annual area converted in the 2002-2010 period (ha)						1,206,188	

Estimates of natural areas converted to other land-use categories in the 2000-2010 period, particularly the conversion of natural forest areas used in constructing this FREL, are displayed in Table 4.

There is a percent difference of less than 8.0% between the data in **Table 3**, which presents the area of forest conversion (managed and unmanaged) in the Third National GHG Inventory, and **Table 4**, which presents the area of forest conversion from the historical time series used in the FREL Cerrado.

This difference is because the Third National GHG Inventory and the historical time series of this FREL Cerrado adopted different minimum mapping areas. While in the former the minimum mapping area was 6.0 ha (at a 1:125,000 scale), in the later the scale was 1:75,000 and the mapping included **all** the deforestation polygons with areas larger than 1 hectare. Note that in the Excel files, areas smaller than 1 hectare may be indicated. This occurs whenever the original deforestation polygon contained more than one vegetation physiognomy and was split accordingly. Note also that the original

submission mapped all the deforestation polygons identified by the interpreter. However, an analysis of the accuracy of the mapping of polygons smaller than 1 hectare led to the decision to consider only those with areas larger than 1 hectare.

Table 4. Forest and natural areas converted for each period. Note: for completeness sake, data for the period 2000-2002 is included in this table. However, the comparison between the forest area converted as presented in the historical time series and in the Third National Inventory is carried out using only data from the period 2002-2010.

	Area (ha)		Percentage of forest formation conversions relative to total natural areas converted
	Forest Formation Converted	Natural Areas Converted (grasslands, savannas and forests)	
2000-2002	4,174,608	6,098,544	68
Average annual area (2000-2002)	2,087,304	3,049,272	68
2002-2004	4,248,334	6,180,212	69
Average annual area (2002-2004)	2,124,167	3,090,106	69
2004-2006	2,686,968	3,670,682	73
Average annual area (2004-2006)	1,343,484	1,835,341	73
2006-2008	1,980,038	2,681,148	74
Average annual area (2006-2008)	990,019	1,340,574	74
2008-2010	1,503,846	2,046,839	73
Average annual area (2008-2010)	751,923	1,023,420	73
Total area (2002-2010)	10,419,186	14,578,881	71
Average annual area converted (2002-2010)	1,302,398	1,822,360	71

b.4. Accurate information

b.4.1. Activity data

In the mapping phase, the uncertainties are associated with **omission errors** (pixels that should be assigned to a given class but were assigned to another) and **commission errors** (pixels that should not be assigned to a given class but were). These errors are due to a misclassification by the interpreter during the thematic classification phase. The following factors may contribute to such errors:

(i) **Image quality:** the presence of noise or improper contrast makes it difficult to delimit and classify targets.

(ii) **Image date:** some targets have more visible patterns when analyzed in a time series. Having a single image available for a given period may not suffice to identify such targets.

(iii) **Ground conditions:** in rocky terrain conditions, shadows may cover greater areas, thus causing equal features to display different behaviors or different features to display similar behaviors.

(iv) **Visual sharpness of the interpreter:** thematic mapping involves the analysis of a number of elements such as the color, hue, shape, size, pattern, texture and location (association) of a target. The analysis is more or less accurate according to the interpreter's experience, but also depends on his/her visual abilities.

(v) **Availability of supplementary data:** other mappings, tabular information and studies are important peripheral elements. It is possible to draw regional profiles from this information, enabling quicker decision making.

By their very nature, some classes are associated with greater uncertainties. This is the case of mapping regions with natural fields and managed pastures, due to the similarity of the spectral responses from these targets.

The deforestation data on the Cerrado biome was subjected to strict quality control by INPE/ MCTIC researchers in order to reduce uncertainties. These researchers verify the quality of the work, the consistency of image classification among different interpreters and provide guidance to the project coordinator when appropriate.

The deforestation classification is focused solely on the identification of conversion of natural forest formations and is analyzed and mapped on the screen (visual interpretation). The Cerrado deforestation project is coordinated by an experienced professional in remote sensing, who ensures that the work is delivered to INPE/MCTIC with the expected quality and in a timely manner. All data is duly archived, with copies

kept both at INPE/MCTIC and at its support foundation, responsible for carrying out the work. More details on potential uncertainties associated with mapping of land use and land cover were detailed on the reference report to the Third National GHG Inventory and are presented below on **Box 2**.

Box 2. The uncertainties associated with mapping land use and land cover

The Reference Report for LULUCF of the Third National GHG Inventory, available at http://sirene.mcti.gov.br/documents/1686653/1706165/RR_LULUCF_Mudan%C3%A7a+de+Uso+e+Floresta.pdf/11dc4491-65c1-4895-a8b6-e96705f2717a (Portuguese only), presents, in section 5 (page 279), an estimate of the uncertainty associated with mapping land use and land cover in the Cerrado biome, based on 2,411 randomly selected sample points. Each of these points was analyzed (point and vicinity) by an experienced interpreter using the same set of Landsat-5 images adopted for the original mapping, along with GoogleEarth, which provides images with better spatial resolution. After this analysis, the interpreter associated a validation class to the point of interest. This class was then compared to the class designated in the original mapping to generate a confusion matrix. An estimate of the global accuracy of the mapping was then generated based on this matrix. Table 144 of the Reference Report estimates a 99.6% and 99.8% accuracy for the conversion of unmanaged forest and managed forest to other land-use categories, respectively. It is important to note that the minimum mapping area was equal to 6 ha (on a scale of 1:125,000). Most of the interpreters responsible for the mapping in the Third National GHG Inventory were also engaged in mapping deforestation in the Cerrado biome for the FREL historic time series, thus ensuring greater consistency.

b.4.2. Uncertainties associated with the biomass values of phytophysiognomies

Uncertainties associated with the biomass values used in constructing this FREL are the same as those described in the Third National GHG Inventory, since the same values were used. The causes of such uncertainties are usually related to the following:

- (i) **Absence of studies for some particular phytophysiognomies**, entailing the use of values from other biomes and phytophysiognomies with similar structure and composition.
- (ii) **Limitations in the spatial representativeness of the secondary data obtained in the scientific literature** when compared to the geographic extent of the biome under study in association with the environmental variations found within the biome and, at

times, even within a given phytophysiology.

The environmental heterogeneity and territorial coverage of some biomes (such as the Cerrado biome) mean that there are significant variations of biomass in different parts of the biome even within a given phytophysiology. This justified the use of some emission factors regionalized by state.

b.4.3. Emission factors

The emission factors used for the phytophysiological types listed in **Table 1 (Share of coverage of the different forest phytophysiological types of the Cerrado biome considered in this FREL and their respective acronym)** are displayed below in **Table 6**. A spreadsheet with more detailed data is available in folder (5) **Table 5 - Carbon Stocks** at <http://redd.mma.gov.br/en/infohub> (Info Hub Brasil).

Table 5. Carbon stock per unit area for the following carbon pools: aboveground biomass (AGB); below-ground biomass (BGB); biomass in litter (LT); biomass in dead wood (DW); and total biomass (ABG+BGB+LT+DW).

Phyto (initial)	State	AGB (tC/ha)	References AGB	BGB (tC/ha)	References BGB	LT (tC/ha)	References LT	DW (tC/ha)	References DW	Total (tC/ha)
Sa	Single value for all states	13.63	Ottmar <i>et al.</i> , 2001	22.63	Root:shoot = 1.66 from Miranda <i>et al.</i> , 2014 for savanna	0.28	Ottmar <i>et al.</i> , 2001	3.37	Ottmar <i>et al.</i> , 2001	39.92
Fs	Piauí Maranhão Bahia	39.96	Haidar, 2008 and França <i>et al.</i> , 2013; allometric equation from Brown, 1997	7.99	Root:shoot = 0.20 - Table 4.4 (IPCC, 2006)	4.40	Ratio LT/ABG = 0.066 - Amaro <i>et al.</i> 2013	2.64	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	54.98
	M. Gerais Tocantins Goiás São Paulo M. Grosso M.G. Sul	61.83	Scolforo <i>et al.</i> , 2008	14.84	Root:shoot = 0.24 - Table 4.4 (IPCC, 2006)	6.80	Ratio LT/ABG = 0.066 - Amaro <i>et al.</i> 2013	4.08	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	87.55
Sd	São Paulo	46.14	Pinheiro, 2008	10.15	Root:shoot = 0.22 from Miranda <i>et al.</i> , 2014 for Forest	5.08	Ratio = 0.165 from Morais <i>et al.</i> 2013 for Cerradão	7.61	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	68.99
	M. Gerais Goiás D. Federal Bahia	35.06	Scolforo <i>et al.</i> 2008	7.71	Root:shoot = 0.22 from Miranda <i>et al.</i> , 2014 for forest	3.86	Ratio = 0.165 from Morais <i>et al.</i> 2013 for Cerradão	5.79	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	52.42

Phyto (initial)	State	AGB (tC/ha)	References AGB	BGB (tC/ha)	References BGB	LT (tC/ha)	References LT	DW (tC/ha)	References DW	Total (tC/ha)
Sd	M. Grosso M.G. Sul	60.20	Embrapa Pantanal; allometric equation from Melo <i>et al.</i> , 2007 (in Pinheiro, 2008)	15.22	Root:shoot = 0.22 from Miranda <i>et al.</i> , 2014 for forest	7.61	Ratio = 0.165 from Morais <i>et al.</i> 2013 for Cerradão	11.42	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	103.45
	Tocantins Maranhão Piauí	33.29	Haidar <i>et al.</i> 2013; allometric equation from Brown, 1997	7.32	Root:shoot = 0.22 from Miranda <i>et al.</i> , 2014 for forest	3.66	Ratio = 0.165 from Morais <i>et al.</i> 2013 for Cerradão	5.49	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	49.76
Fm	Single value for all states	82.24	Amaro <i>et al.</i> , 2013	16.12	Amaro <i>et al.</i> , 2013	3.06	Amaro <i>et al.</i> , 2013	5.46	Amaro <i>et al.</i> , 2013	106.88
Fa	Tocantins Pará	71.52	Haidar <i>et al.</i> , 2013; allometric equation from Brown, 1997	17.16	Root:shoot = 0.24 - Table 4.4 (IPCC, 2006)	7.87	Ratio = 0,024 from Moreira-Burger and Delitti, 1999	1.72	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	98.27
	M. Gerais Goiás D.Federal Bahia	56.89	Scolforo <i>et al.</i> , 2008	11.38	Root:shoot = 0.20 - Table 4.4 (IPCC, 2006)	6.26	Ratio = 0,024 from Moreira-Burger and Delitti, 1999	1.37	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	75.89
	São Paulo Paraná	62.65	Moreira-Burger and Delitti, 1999	15.04	Root:shoot = 0.24 - Table 4.4 (IPCC, 2006)	6.89	Moreira-Burger and Delitti, 1999	1.50	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	86.08
	M. Grosso M.G. Sul	121.92	Wittman <i>et al.</i> , 2008	29.26	Root:shoot = 0.24 - Table 4.4 (IPCC, 2006)	13.41	Ratio = 0,024 from Moreira-Burger and Delitti, 1999	2.93	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	167.52

Phyto (initial)	State	AGB (tC/ha)	References AGB	BGB (tC/ha)	References BGB	LT (tC/ha)	References LT	DW (tC/ha)	References DW	Total (tC/ha)
Cs	M. Gerais Bahia Goias Tocantins Piaui D. Federal Maranhão	42.51	Scolforo <i>et al.</i> 2008	8.50	Root:shoot = 0.20 - Table 4.4 (IPCC, 2006)	4.68	Ratio = 0.165 from Morais <i>et al.</i> 2013 for Cerradão	7.01	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	62.70
	M.G. Sul São Paulo M. Grosso	84.38	Lima et al., 2009; allometric equation from Brown, 1997	20.25	Root:shoot = 0.24 - Table 4.4 (IPCC, 2006)	9.28	Ratio = 0.165 from Morais <i>et al.</i> 2013 for Cerradão	13.92	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	127.83
Ab	Single value for all states	135.71	RadamBrasil; allometric equation from Brown, 1997	11.82	Root:shoot = 0.10 from Nogueira <i>et al.</i> , 2008 for non- dense forests	9.57	Ratio = 0.059 from Nogueira <i>et al.</i> 2008, for non-dense forests	6.97	Ratio = 0.081 from Nogueira <i>et al.</i> 2008, for non-dense forests	164.08
Cm	M. Gerais Bahia Goias	42.51	Scolforo <i>et al.</i> , 2008	8.50	Root:shoot = 0.20 - Table 4.4 (IPCC, 2006)	4.68	Ratio = 0.165 from Morais <i>et al.</i> 2013 for Cerradão	7.01	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	62.70
	M.G. Sul São Paulo	84.38	Lima et al., 2009; allometric equation from Brown, 1997	20.25	Root:shoot = 0.24 - Table 4.4 (IPCC, 2006)	9.28	Ratio = 0.165 from Morais <i>et al.</i> 2013 for Cerradão	13.92	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	127.83
Ta	Single value for all states	10.20	Albuquerque, 2015	3.43	Albuquerque, 2015	Litter included	Albuquerque, 2015	1.59	Albuquerque, 2015	15.23

Phyto (initial)	State	AGB (tC/ha)	References AGB	BGB (tC/ha)	References BGB	LT (tC/ha)	References LT	DW (tC/ha)	References DW	Total (tC/ha)
As	Single value for all states	71.10	Haidar et al., 2013; allometric equation from Brown, 1997	7.11	Root:shoot = 0.10 from Nogueira et al., 2008 for non-dense forests	5.76	Ratio = 0.059 from Nogueira et al. 2008, for non-dense forests	4.20	Ratio = 0.081 from Nogueira et al. 2008, for non-dense forests	88,17
Pa	Single value for all states	25.63	Bahia et al.; 2009; allometric equation from Brown, 1997. Fidelis et al., 2013	7.28	Root:shoot = 0.22 arboreous from Miranda et al., 2014 for forests; Fidelis et al., 2013 for Vereda	2.29	Ratio = 0,024 for arboreous from Moreira-Burger and Delitti, 1999. Ratio = 0,10 from Ottmar et al., 2001 for Vereda	1.03	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	36,24
Pm	Single value for all states	78.16	Assis et al., 2011	28.92	Root:shoot = 0.37 Table 4.4 (IPCC, 2006)	22.18	Veiga, 2010	1.44	Pires et al., 2006	130,70
Td	Single value for all states	19.28	Albuquerque, 2015	8.59	Albuquerque, 2015	Litter included	Albuquerque, 2015	2.66	Albuquerque, 2015	30,54
Ds	Single value for all states	81.99	Haidar et al. 2013; allometric equation from Brown, 1997	25.42	Root:shoot = 0.30 from Nogueira et al., 2008 for dense forests	7.71	Ratio = 0.041 from Nogueira et al. 2008, for dense forests	3.36	Ratio = 0.094 from Nogueira et al. 2008, for dense forests	118,48
	Mato Grosso	104.28	Nogueira et al., 2008	24.11	Nogueira et al. 2008	9.82	Nogueira et al., 2008	7.15	Nogueira et al., 2008	145,37

Phyto (initial)	State	AGB (tC/ha)	References AGB	BGB (tC/ha)	References BGB	LT (tC/ha)	References LT	DW (tC/ha)	References DW	Total (tC/ha)
Fb	Goias M. Gerais	61.83	Scolforo <i>et al.</i> , 2008	14.84	Root:shoot = 0.24 - Table 4.4 (IPCC, 2006)	6.80	Ratio = 0.066 from Amaro <i>et al.</i> , 2013	4.08	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	87,55
Mm	Single value for all states	108.01	Watzlawick <i>et al.</i> , 2012	19.01	Watzlawick <i>et al.</i> , 2012	11.88	Watzlawick <i>et al.</i> , 2012	3.76	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	142,66
Pf	Single value for all states	79.29	Hutchison <i>et al.</i> , 2013	29.80	Hutchison <i>et al.</i> , 2013	7.93	Ramos e Silva <i>et al.</i> , 2007	0.19	Ratio = 0,10 from Fernandes, 1997	117,20
Aa	Single value for all states	151.61	RadamBrasil; allometric equation from Brown, 1997	13.21	Root:shoot = 0.10 from Nogueira <i>et al.</i> , 2008 for non- dense forests	10.70	Ratio = 0.059 from Nogueira <i>et al.</i> 2008, for non-dense forests	7.79	Ratio = 0.081 from Nogueira <i>et al.</i> 2008, for non-dense forests	183,30
Dm	Single value for all states	127.70	Alves <i>et al.</i> ,2011	28.28	Vieira <i>et al.</i> , 2011; Souza Neto <i>et al.</i> , 2011	19.13	Vieira <i>et al.</i> , 2011; Souza Neto <i>et al.</i> , 2011	2.64	Vieira <i>et al.</i> , 2011	177,75
MI	Single value for all states	108.01	Watzlawick <i>et al.</i> , 2012	19.01	Watzlawick <i>et al.</i> , 2012	11.88	Watzlawick <i>et al.</i> , 2012	3.76	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	142,66

Phyto (initial)	State	AGB (tC/ha)	References AGB	BGB (tC/ha)	References BGB	LT (tC/ha)	References LT	DW (tC/ha)	References DW	Total (tC/ha)
Da	Single value for all states	160.18	RadamBrasil; allometric equation from Brown, 1997	45.22	Root:shoot = 0.10 from Nogueira <i>et al.</i> , 2008 for non-dense forests	13.71	Ratio = 0.059 from Nogueira <i>et al.</i> 2008, for non-dense forests	5.98	Ratio = 0.081 from Nogueira <i>et al.</i> 2008, for non-dense forests	225,09
Ea	Single value for all states	9.44	Scolforo <i>et al.</i> , 2008	15.67	Root:shoot = 1.66 from Miranda <i>et al.</i> , 2014 for Savanna	0.09	Ratio = 0.28 from Ottmar <i>et al.</i> , 2001	2.64	Ratio = 0.01 from Ottmar <i>et al.</i> , 2001	27,85
Cb	Single value for all states	69.38	Lima <i>et al.</i> , 2009; allometric equation from Brown, 1997	16.65	Root:shoot = 0.24 – Table 4.4 (IPCC, 2006)	7.63	Ratio LT/AGB = 0.165 from Morais <i>et al.</i> 2013 for Tall Cerrado	11.45	Ratio = 0.11 – Table 3.2.2 (IPCC, 2003)	105,11

Note: the color key provides the biome from where the emission factors originate (Amazon: dark green, Cerrado: orange, Atlantic Forest: light green, Pantanal: blue, and Caatinga: yellow). In the column named state, where a **single value is provided for all states**, it implies that a regionalization of the emission factor was not carried out. The references and the ratios that were used are shown for each carbon pool. More detailed data can be found in **Cerrado_carbono_REDD.xlsx** at: (<http://redd.mma.gov.br/en/infohub>). The **Total** value in the last column is the sum of the carbon stocks of the four pools considered in this submission.

As previously mentioned, some emission factors used in this FREL stem from studies on Cerrado forest formations, such as the Wooded Savanna (Sa), Submontane Semi Deciduous Seasonal Forest (Fs), Forested Savanna (Sd), Alluvial Semi Deciduous Seasonal Forest (Fa), Open Submontane Humid Forest (As), Fluvial and/or lacustre influenced Vegetation (Pa), Submontane Dense Humid Forest (Ds) and Wooded Steppe (Ea).

It should be noted that, together, the Sa, Fs and Sd phytophysionomies make up around 51% of the forest formations in the Cerrado biome.

Some of the emission factors were regionalized (see **section b.4.2**, **section b.4.3** and **Table 5**), as in the case of the Fs physiognomy, where different emission factors were applied for deforestation occurring in two blocks of states (Piauí, Maranhão and Bahia, with value 54.98 tC ha⁻¹, obtained from studies in the Cerrado; and Minas Gerais, Tocantins, Goiás, São Paulo, Mato Grosso and Mato Grosso do Sul, with value 87.55 tC ha⁻¹, obtained from studies on Cerrado formations in the Atlantic Forest).

For the Sd phytophysionomy, the regionalization was done in four blocks of states, three of them with studies in Cerrado areas: São Paulo, with a value of 68.99 tC ha⁻¹; Minas Gerais, Goiás, Federal District and Bahia, with a value of 52.42 tC ha⁻¹; and Tocantins, Maranhão and Piauí, with a value of 49.76 tC ha⁻¹. The last block, with the states of Mato Grosso and Mato Grosso do Sul, has a value of 103.45 tC ha⁻¹, derived from studies on similar formations in the Pantanal biome.

Regionalization took several factors into account, including the differences between the phytophysionomy structure within the biome itself and the proximity to other biomes, such as the Amazon biome, the Atlantic Forest, the Caatinga and the Pantanal.

It is therefore understood that the regionalization introduced by the Third National GHG Inventory led to greater accuracy in the emission factors, when compared with those used in the Second National GHG Inventory. As a result, the associated level of uncertainty has decreased.

There is an inherent difficulty in associating uncertainties with emission factors, given the natural heterogeneity of the conditions that influence the way vegetation formations develop in a biome. Apart from this, the use of country-specific emission factors (tier 2) is expected to produce estimates that are less uncertain than those that rely on the use of IPCC default values (tier 1).

In the Second National GHG Inventory, default values from the IPCC Good Practice Guidance for LULUCF (IPCC, 2003) were the primary source for estimating belowground biomass and dead organic matter, as can be seen in Table 150 of the Third National GHG Inventory. This table provides the average carbon stocks for the Cerrado phytophysionomies and the data sources used on the Second and Third National GHG Inventories.

For example, for the Sa phytophysiology, the average carbon stocks per unit area on the Second and the Third National GHG Inventories were 47.10 and 39.92 tC ha⁻¹, respectively. The values for the Fs and Sd phytophysiology used on the Second National GHG Inventory were 140.09 and 77.80 tC ha⁻¹, respectively, while these values were regionalized for the Third National GHG Inventory, as can be seen in the **Table 5**. Two regionalized values were developed for the Fs phytophysiology: 87.55 tC ha⁻¹ and 54.98 tC ha⁻¹. For the Sd phytophysiology, four values were used: 52.42 tC ha⁻¹; 49.76 tC ha⁻¹; 103.45 tC ha⁻¹; and 68.99 tC ha⁻¹.

For these more frequent forest physiologies in the Cerrado biome, the values from the Third National GHG Inventory are, in general, smaller than those used in the Second National GHG Inventory. This difference is associated with the use of emission factors that are more representative of the biome (country-specific data).

To sum up, the regionalization of emission factors by state and the use of country- and Cerrado biome- specific data, particularly for the root:shoot ratio (below-ground biomass) and dead organic matter, indeed represent advances in the development of emission factors by the Third National GHG Inventory and a lower uncertainty than that associated with the use of the emission factors from the Second National GHG Inventory. These improvements have been incorporated into the FREL Cerrado.

It is also important to note that Brazil is implementing, since 2005, its National Forest Inventory, which consists of sampling points distributed systematically in the territory according to a grid set up by the Brazilian Forest Service (SFB, for the acronym in Portuguese) of the MMA. This grid consists of points equidistant with 20 km intervals, which can be further concentrated in some specific cases, reaching 10 km or even 5 km intervals in some regions. Once collected and made available, the data from the National Forest Inventory will be an important source for validating and improving the emission factors that will be used in the construction of a national FREL.

c) Pools, gases and activities included in the FREL

c.1. Activities included

The FREL Cerrado has been constructed for the activity of ***"Reducing emissions from Deforestation"***. It represents an important step towards the construction of a national FREL for this activity. As mentioned in the Introduction of this submission, the FREL Cerrado and the FREL Amazonia (submitted in 2014) combined cover approximately 73% of the national territory. Efforts to develop FRELS for the remaining biomes (Caatinga, Atlantic Forest, Pantanal and Pampa) are already underway as part of the activities included in the Brazilian Biomes Environmental Monitoring Program (PMABB, for the acronym in Portuguese) (see **Annex, section II** for more information on this

program). Planned activities include, among others, the development of consistent and verifiable historical time series for all Brazilian biomes (except for Amazonia, which already has one). Producing the historical time series for deforestation in the Cerrado biome, used in the construction of this FREL, is the first major achievement under the PMABB.

Data on land-use dynamics in the Amazonia and the Cerrado (*TerraClass Amazônia* and *TerraClass Cerrado*) are produced by INPE's Regional Center in the Amazonia, in partnership with EMBRAPA Eastern Amazonia (CPATU, for the acronym in Portuguese). Satellite images from the Landsat series are analyzed to monitor and map subsequent land use in the areas identified as deforested.

The PMABB will provide information biennially on land-use dynamics for all Brazilian biomes up to 2020. This will be instrumental to inform land-use planning policies, particularly those related to reducing deforestation and forest degradation in Brazil.

c.2. Pools included

The Annex to decision 12/CP.17, in item (c), notes that significant pools and activities should not be excluded from the construction of FRELs. It also indicates that the reasons for the exclusion of a pool should be provided.

In this submission, the pools included are: aboveground biomass, belowground biomass, litter and dead wood. The soil organic carbon pool was not included.

There is an extensive bibliography on the impact on soils from the conversion of native vegetation to other land-use categories in the Cerrado biome. The ability of soils to accumulate carbon is intrinsically related to sustainable management practices. However, more in-depth knowledge on the matter is still needed. EMBRAPA is currently conducting research to that end. For more details, see **Box 3**.

Box 3: *Soil organic carbon pool*

Abdala *et al.* (1998) estimated the carbon stocks in the different components of a Typical Cerrado area and identified that the total carbon stock in the vegetation and the soil up to 1 meter was 265 Mg ha⁻¹ and that organic soil (185 Mg ha⁻¹) had a 70% share of this total. The carbon stock in the soil under native vegetation in the Cerrado biome (0-20 cm layer) was estimated to be approximately 50 Mg ha⁻¹ (Bustamante *et al.*, 2006). Nevertheless, according to Sano *et al.* (2008), organic soils represent only 1.6% of the soils in the biome, and affect Humid Clean Grassland, Vereda (see footnote 11), and Gallery Forest.

The Third National GHG Inventory included emissions from the soil organic carbon pool following the IPCC methodology that considers specific emission factors depending on land use after conversion (e.g. pasture, agriculture, reforestation) and a default time interval of 20 years.

The FREL Cerrado however only included gross emissions. So only the changes in the soil organic carbon due to the conversion were included, regardless of subsequent land use. Despite the non-inclusion of carbon losses due to the oxidation of organic matter in the soil at the time of conversion, it is important to stress that **there is robust evidence to support the potential that management practices have to recover soil carbon stocks in pasture and/ or agriculture land use.**

For example, Maia *et al.* (2009), when studying pastures in the northwestern region of the Cerrado biome, found that reformed pastures showed rates of soil carbon accumulation ranging from 0.61 to 0.72 Mg ha⁻¹ year⁻¹. In contrast, degraded pastures presented losses of 0.28 Mg ha⁻¹ year⁻¹. The rate of carbon accumulation in soils under no-till farming compared to the traditional system in the Cerrado region varied between 0.3 and 1.91 Mg C ha⁻¹ year⁻¹ (Batlle-Bayer *et al.*, 2010).

The conversion of native Cerrado into conventional farming (with soil tilling) induced a soil carbon loss (0-40 cm) of about 17% after 26 years of continuous soy/maize cultivation as single crops per season (Corbeels *et al.*, 2016). A series of factors may have contributed to the historical losses of in soil carbon after the conversion to conventional farming in the Cerrado biome, including an increase in physical soil disturbance, a soil environment more prone to carbon decomposition and increased soil erosion. Soil disturbance through soil tillage diminishes the aggregation of soil; however, soil erosion may be the most important factor for the decrease in soil carbon after cultivation.

The Brazilian government intends to increase the cultivated area under no-tillage (NT) from 32 to 40 million hectares by 2020, to mitigate CO₂ emissions (Low Carbon Agriculture Plan). Corbeels *et al.* (2016) estimated soil carbon accumulation in two municipalities in the state of Goiás, representative of the Cerrado biome, using chronosequences of no-till fields with different ages since the conversion from conventional cultivation systems. Samples were collected in 2003 and 2011. The levels of soil carbon in the natural vegetation in the Cerrado biome were measured for comparison. After about 11 to 14 years, the soil carbon stocks in the no till systems were higher, achieving levels similar to those of the natural Cerrado. The average annual rates of soil carbon accumulation estimated in the chronosequence were 1.61 and 1.48 Mg C ha⁻¹ year⁻¹ for years 2003 and 2011, respectively. The

conversion of an additional 8 million ha of agricultural land under traditional cultivation system to no-till systems represents a carbon stock increase of about 8 Tg C year⁻¹ for 10 to 15 years.

Data from TerraClass 2013 indicates that pasture is the prevailing land-use for converted areas in the Cerrado biome, corresponding to 67,9% of the converted area and 29.5% of the total area. Agriculture (perennial and annual) occupies a percentage area of 11.7%. These two land uses combined account for 94,8% of the total converted area.

The literature indicates that the conversion of forest formations in the Cerrado biome to pasture can result either in carbon emissions or removals from soils. In the case of a well-managed pasture, the literature points out to carbon removals, but the same does not apply to pastures that are not well managed.

Studies by Rosendo and Rosa (2012) indicate that the soil carbon stock (0 to 20 cm) in improved pastures was equal to 43.92 MgC ha⁻¹, whereas this stock was 38.05 Mg ha⁻¹ under native Cerrado vegetation and 34.63 Mg ha⁻¹ in degraded pastures. They concluded that well-established and managed pastures can contribute to increasing the rate of soil carbon accumulation. In contrast, the lack of soil correction, adequate fertilization, erosion process control and adequate management, with overgrazing, lead to the degradation of pastures, compromising their ability to accumulate carbon.

Other bibliographic references also indicate an increase in the soil carbon stock. Queiroz *et al.*, 2012, provide the following estimates for the carbon stock at different soil depths (0-10 cm, 10-20 cm, 20-40 cm) for pastures and soybean, relative to the carbon stock per unit area in the Cerrado (**Table 6**):

Table 6. Estimates of average carbon stock in the soil for different agricultural crops and native vegetation. Source: Queiroz *et al.* (2012).

Carbon Stock in the Soil (Mg ha⁻¹)			
	0-10 (cm)	10-20 (cm)	20-40 (cm)
Soy	32.46	19.55	39.56
Pastures	33.36	23.59	42.46
Cerrado	21.53	20.07	37.96

Carvalho (2006) reports that the conversion of native vegetation in the Cerrado biome into agricultural areas with soybean cultivation under no-till systems resulted in an annual rate of carbon accumulation of 2.58 Mg ha⁻¹. Carbon accumulation was

identified in all years after the conversion of native vegetation to agriculture, except for the first year after conversion.

In summary, although soil has the potential to be a source of CO₂ emissions or a carbon sink, the existing data on management practices for the Cerrado biome is not yet well established. Better understanding¹⁹ on the impacts of different pasture and agriculture management practices (such as no-till) on soil emissions or removals is still necessary. Therefore, the soil organic carbon pool was not included in this FREL.

Brazil will continue its efforts to continually improve the estimates of emissions and removals as part of the stepwise approach adopted for REDD+.

c.3. Gases included

This FREL Cerrado includes CO₂ emissions and non-CO₂ (CH₄ and N₂O) emissions from fires that result from deforestation. The Cerrado biome has a long history of fires, both natural and human induced. Fires are considered one of the natural factors determining the structure and functioning of the biome. Klink and Moreira (2002) state that, since the 1990s, fires occur almost annually in the majority of native areas of the Cerrado.

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The Reference Report for LULUCF of the Third National GHG Inventory included a section (section 4.9, *Net annual anthropogenic CO₂ emissions for the period 1990 to 2010*) that presents data and considerations regarding emissions from forest fires. The burned areas in forest and grassland formations in the Cerrado biome are presented for 2010, detailed by state (**Table 8** and **Figure 17**). The affected forest and grassland areas were 2,846,980 and 1,874,565.5 ha, respectively, corresponding to 4,721,545 or 2.3% of the total area of the Cerrado biome (203,648,800 ha).

The percentage of forest formations affected by forest fires in 2010 was 1.4% of the total Cerrado biome area. The fires seem to be less prevalent in the areas covered with

¹⁹ Although the Third National GHG Inventory included CO₂ emissions associated with changes in the carbon stock of soil from the conversion to other land use categories in the Cerrado biome for the periods from 1994 to 2002 and 2002 to 2010 (Tables 62 and 68, respectively, in the Reference Report for LULUCF (MCTI, 2016)), it is important to point out that this is an area of the Inventory that needs to be further developed in order to better capture the real implications of native vegetation conversions and, in particular, the important role of management practices.

forest formations with higher carbon density (Aa, Ab, Da, Dm, Ds, Fa, Fm, Fb, see **Table 1**) as presented in **Table 5**, in shades of green.

Table 7. Quantification of burned areas in the Cerrado biome in 2010. Source: Third National GHG Inventory, Volume III, Table A2.2. MCTI, 2016

FIRES IN THE CERRADO BIOME IN 2010					
STATE	ABBREVIATION	GRASSLAND	FOREST	TOTAL AREA	PERCENTAGE OF THE BIOME
		(ha)			
Bahia	BA	232,734.2	671,010.3	903,744.5	0.443%
Distrito Federal	DF	18,509.9	10,888.5	29,398.4	0.014%
Goiás	GO	244,576.9	200,090.3	444,667.3	0.218%
Maranhão	MA	162,157.5	260,959.9	423,117.4	0.207%
Minas Gerais	MG	198,265.9	52,331.6	250,597.5	0.123%
Mato Grosso do Sul	MS	2,086.2	1,644.8	4,731.0	0.002%
Mato Grosso	MT	294,952.7	527,530.7	822,483.4	0.403%
Piauí	PI	1,707.7	516,953.4	528,661.1	0.259%
São Paulo	SP		459.1	459.1	0.000%
Tocantins	TO	719,574.5	594,109.0	1,313,683.5	0.644%
TOTAL		1,874,565.5	2,546,979.7	4,721,545.2	2.315%

d) Forest definition

Brazil is a country with a vast territory and a great diversity of forest types. The definition of forest broadly applicable in Brazil is the one reported to the Food and Agriculture Organization of the United Nations (FAO) for the purposes of the Global Forest Resources Assessment (FRA). The classification of vegetation typologies as Forest or Other Wooded Land in the FRA was defined by Brazilian experts involved in the preparation of FRA 2015. The definition of forest used in the construction of the FREL Cerrado is the same as that adopted in the Third National GHG Inventory (**Table 1**) and that maintains consistency with the reporting by Brazil to FRA 2015.

The forest definition thresholds are those included in the FRA/FAO, as contained in the Country Report to the Global Forest Resource Assessment 2015, as follows:

Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.

It is important to note that the number of vegetation typologies classified as "Forest" under the FRA is larger than the aggregate forest types defined for the purposes of this

FREL. The identification of forest physiognomies in the Cerrado biome for estimating emissions from deforestation applied a set the criteria described in **Box 4**.

Box 4. Definition of forest under the FREL Cerrado.

The Cerrado biome encompasses different vegetation formations with forest, savanna and grassland phytophysiomies. Its coverage is expressive - about 24% of the Brazilian territory – with broad latitudinal and longitudinal variations. Contact zones with the other major Brazilian biomes (Amazonia, Caatinga, Atlantic Forest and Pantanal) result in significant environmental heterogeneity as described in Ratter *et al.* (2003). The forest area for the FREL encompasses the forest physiognomies in Table 1 of the submission.

The SFB/MMA, when preparing national and international reports related to the forest resources in Brazil, considers the typologies of woody vegetation that are closest to the FAO definition of forest for its definition of forest. These correspond to the following vegetation categories from the Classification System of the Brazilian Institute of Geography and Statistics (IBGE):

- Dense Humid Forest;
- Open Humid Forest;
- Mixed Humid Forest;
- Semi deciduous Seasonal Forest;
- Deciduous Seasonal Forest;
- Forested Campinarana;
- Savanna (forested and wooded);
- Forested Steppe Savanna and Wooded Steppe Savanna Steppe;
- Wooded Steppe;
- Fluvial and/or lacustre influenced Vegetation (wooded);
- Remaining vegetation in contacts where at least one formation is a forest;
- Secondary vegetation in forest areas;
- Reforestation.

The physiognomies considered in the FRA for the FREL are presented on the table on pages 10-13 in the Country Report to the Global Forest Resource Assessment 2015. The criterion used by the SFB/MMA was partially adopted for the FREL Cerrado with the inclusion of all wooded predominantly formations with predominantly continuous canopy in the Cerrado (Ribeiro and Walter, 2008) as well as discontinuous canopy formations with a wooded cover of between 10

and 70% and trees that can reach the minimum height of between 2 to 5 meters.

This category contains the so called Dense Cerrado, Typical Cerrado and Sparse Cerrado by Ribeiro and Walter (2008) which are aggregated in the Wooded Savanna (Sa) category to correspond to the IBGE classification (IBGE, 2012) used in the Third National GHG Inventory (MCTI, 2016). The Wooded Savanna formation represents about 29.5% of the area of the Cerrado biome.

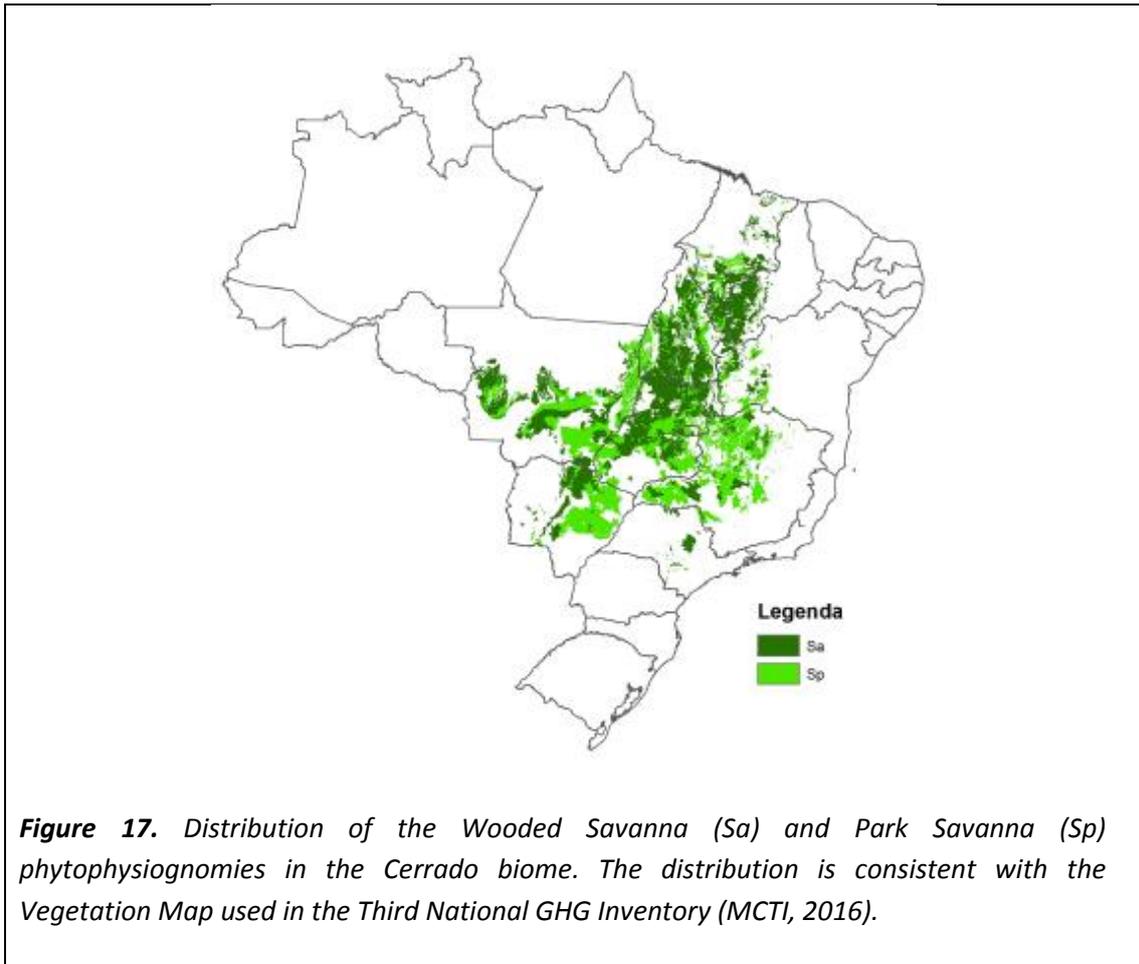
The FREL includes additional physiognomies which correspond, altogether, to 1.5% of the total forest formations in the Cerrado (Ab – 1.26%, Mm – 0,10%, Pf – 0.06%, Aa – 0.03%, Dm – 0.03%, MI -0.01%, Ea – 0.01%, Cb – 0.003%). The physiognomies included in the FREL are consistent with those used in the 3rd National Inventory and agreed by the GTT REDD+.

It is important to highlight that other vegetation typologies with significant carbon stocks were excluded from this FREL, due to its non-adherence to the definition of forest explained above. **Box 5** below presents the specificities of the tree-shrub vegetation in the Cerrado, particularly the Park Savanna (Sp) formation and its potential impact on GHG emissions.

Box 5. Emissions from the Park Savanna formation

The FREL Cerrado does not include the Park Savanna formation (Sp, according to the classification by IBGE, 2012) which comprises shrub-grass formations from Ribeiro and Walter's classification (2008). However, it should be emphasized that this phytophysiognomy presents a total carbon stock (approximately 27 tC/ha) similar to that of the Wooded Savanna formation (included in the FREL) and cover approximately 25% of the total Cerrado biome area.

Additionally, **Figure 17** shows that there is a strong spatial correlation between the distribution of Wooded Savanna and Park Savanna in the biome, reinforcing the perspective that they constitute an ecological continuum with fine-scale variation.



References

- ABDALA, G.C. *et al.* Above and belowground organic matter and root: shoot ratio in a cerrado in Central Brazil. *Brazilian Journal of Ecology*, São Paulo, v.2, n.1, p.11–23, 1998.
- ADÂMOLI, J. *et al.* Caracterização da região dos cerrados. In: GOEDERT, W. J. (Ed.) *Solos dos cerrados: tecnologias e estratégias de manejo*. [Planaltina: Embrapa-CPAC] São Paulo: Nobel, 1987. p. 33-98.
- ALBUQUERQUE, E. R. G. M. Biomassa de raízes em áreas com diferentes usos da terra e tipos de solos. Tese de Doutorado (Botânica), Universidade Federal Rural de Pernambuco, Recife, 2015.
- ALVES, A.R. Quantificação de biomassa e ciclagem de nutrientes em áreas de vegetação de Caatinga no município de Floresta, Pernambuco. Tese de Doutorado (Manejo Florestal), Universidade Federal Rural de Pernambuco, Recife, 2011.
- AMARO, M.A. *et al.* Estoque volumétrico, de biomassa e de carbono em uma floresta estacional semidecidual em Viçosa, Minas Gerais. *Revista Árvore*, Viçosa, n.37, v.5, p.849-857, 2013.
- ARRUDA, M.B. *et al.* Ecorregiões, Unidades de Conservação e Representatividade Ecológica do Bioma Cerrado. In: SANO, S.M., ALMEIDA, S.P. e RIBEIRO, J. F. *Cerrado: Ecologia e Flora*, Volume 1, p. 229-272. 2008.
- ASSIS, M.A. *et al.* Florestas de restinga e de terras baixas na planície costeira do sudeste do Brasil: vegetação e heterogeneidade ambiental; Restinga and Lowland forests in coastal plain of southeastern Brazil: vegetation and environmental heterogeneity. *Biota neotropical*, v.11, n.2, p.103–121, 2011.
- BAHIA, T.O. *et al.* "Florística e fitossociologia de veredas em diferentes estágios de conservação na APA do Rio Pandeiros, norte de Minas Gerais." *MG. Biota*, Belo Horizonte, v.2, n.3, p. 14-21, 2009.
- BATLLE-BAYER, L.; BATJES, N.H. & BINDRABAN, P.S. Changes in organic carbon stocks upon land use conversion in the Brazilian Cerrado: A review. *Agric. Ecosyst. Environ.*, 137:47-58, 2010.
- BRASIL – Ministério da Ciência e Tecnologia. Coordenação-Geral de Mudanças Globais de Clima. Relatório de Referência "Emissões de Gases do Efeito Estufa no Setor Uso da Terra, Mudança do Uso da Terra e Florestas – Emissões de CO₂ pelo Uso da Terra, Mudança do Uso da Terra e Florestas". Brasília: MCT, 2010. 105p. Disponível em: http://www.mct.gov.br/upd_blob/0213/213346.pdf.

- BROWN, S. Estimating biomass and biomass change of tropical forests: a primer (Vol. 134). Food & Agriculture Org. 1997.
- BUSTAMANTE, M.M.C.; CORBEELS, M.; SCOPEL, E. & ROSCOE, R. Soil carbon and sequestration potential in the Cerrado Region of Brazil. In: LAL, R.; CERRI, C.C.; BERNOUX, M.; ETCHEVERS, J. & CERRI, C.E.P. Carbon sequestration in soils of Latin America. New York, Haworth, 2006. p.285-304.
- CARVALHO, Jr A. Conversão do Cerrado para fins agrícolas na Amazônia e seus impactos no solo e no ambiente. Soc. & Nat., Uberlândia, ano 24 n. 2, 359-376. 2006.
- CASTRO, E.A. e KAUFFMAN, J.B. Ecosystem structure in the Brazilian Cerrado: a vegetation gradient of aboveground biomass, root mass and consumption by fire. Journal of tropical ecology, Sussex, v.14, n.03, p.263-283, 1998.
- CORBEELS, M. et al. Evidence of limited carbon sequestration in soils under no-tillage systems in the Cerrado of Brazil. Scientific Reports. 2016. Disponível em <http://www.nature.com/articles/srep21450>.
- EITEN, G. Vegetação do Cerrado. In: PINTO, M. N. (Ed.). Cerrado: caracterização, ocupação e perspectivas. 2. ed. Brasília: UnB: SEMATEC, 1994. p. 17-73.
- FAO – Food and Agriculture Organization, United Nations. Global Forest Resources Assessment 2015: Desk Reference. 2015. Rome: FAO, 2015. 253 p. Available at <http://www.fao.org/3/a-i4808e.pdf>.
- FERNANDES, M.E. The ecology and productivity of mangroves in the Amazon region, Brazil. Tese de Doutorado – York University, 1997.
- FIDELIS, A. *et al.* Above - and below - ground biomass and carbon dynamics in Brazilian Cerrado wet grasslands. Journal of Vegetation Science, v.24, n.2, p.356-364, 2013.
- FRANÇOSO, R.D. *et al.* Análise biogeográfica de espécies arbóreas do Cerrado como subsídio à criação de unidades de conservação. Relatório Técnico não publicado. Brasília: Laboratório de Planejamento para Conservação da Biodiversidade, Universidade de Brasília. 2013. 6p.
- H AidAR, R.F. Fitossociologia, Diversidade e sua relação com variáveis ambientais em florestas estacionais do bioma Cerrado no Planalto Central e Nordeste do Brasil. Dissertação (Mestrado em Engenharia Florestal). Departamento de Engenharia Florestal, Universidade de Brasília. Brasília, 2008.
- H AidAR, R.F. *et al.* Mapeamento das Regiões Fitoecológicas e Inventário Florestal do estado do Tocantins. Escala 1:100.000. Palmas: SEPLAN/DZE, 2013. 156p.

HERINGER, E. P.; BARROSO, G. M.; RIZZO, J. A.; RIZZINI, C. T. A flora do Cerrado. In: Simpósio sobre o Cerrado, 4., 1976. Brasília, DF. Bases para utilização agropecuária. São Paulo: EDUSP; Belo Horizonte: Itatiaia, 1977. p. 211-232 (Reconquista do Brasil, 38).

HUTCHISON, J. *et al.* Predicting global patterns in mangrove forest biomass. *Conservation Letters*, v.7, n.3, p.233-240, 2013.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Mapa de Biomas do Brasil, primeira aproximação. Rio de Janeiro, IBGE, 2004. Available at <http://mapas.ibge.gov.br/biomas2/viewer.htm>.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Manual técnico da vegetação brasileira. Rio de Janeiro, Séries Manuais Técnicos em Geociências, n. 1, 2012.

IPCC – Intergovernmental Panel On Climate Change. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Kanagawa: Institute for Global Environmental Strategies, 2003.

IPCC – Intergovernmental Panel On Climate Change. IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Kanagawa: Institute for Global Environmental Strategies, 2006.

KLINK, C. A.; MOREIRA, A. G. Past and current human occupation, and land-use. In: Oliveira, P. S.; Marquis, R. J. (Ed.). *The Cerrado of Brazil: ecology and natural history of a neotropical savanna*. New York: Columbia University, 2002. v. 1, p. 69-88.

LIMA, J.R. *et al.* Composição florística da floresta estacional decídua montana de Serra das Almas, CE, Brasil. *Acta Botanica Brasilica*, Belo Horizonte, v.23, n.3, p.756-763, 2009.

MAIA, S.M.F.; OGLE, S.M.; CERRI, C.E.P. ; CERRI, C.C. Effect of grassland management on soil carbon sequestration in Rondônia and Mato Grosso states, Brazil. *Geoderma*, Amsterdam, v.149, p.84–91, 2009. DOI:10.1016/J.GEODERMA.2008.11.023

MCTI – Ministério de Ciência, Tecnologia e Inovação. Terceira Comunicação do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima. 2016.

MMA – Ministério do Meio Ambiente. Projeto TerraClass: Mapeamento do Uso e Cobertura Vegetal do Cerrado. 69p. MMA, 2015. Available at <http://www.mma.gov.br/publicacoes/biomas/category/62-cerrado>.

MIRANDA, S.C. *et al.* Regional Variations in Biomass Distribution in Brazilian Savanna Woodland. *Biotropica*, v.46, n.2, p.125-138, 2014.

MORAIS, V.A. *et al.* Carbon and biomass stocks in a fragment of cerradão in Minas Gerais state, Brazil. *Cerne*, Lavras, v.19, n.2, p.237-245, 2013.

MOREIRA-BURGER, D. e DELITTI, W.B. Fitomassa epigéa da mata ciliar do Rio Mogi-Guaçu, Itapira-SP. *Brazilian Journal of Botany*, São Paulo, v.22, n.3, p.429-435, 1999.

NOGUEIRA, E.M. *et al.* Estimates of forest biomass in the Brazilian Amazon: New allometric equations and adjustments to biomass from wood-volume inventories. *Forest Ecology and Management*, v.256, n.11, p.1853-1867, 2008.

OTTMAR, R.D. *et al.* Stereo photo series for quantifying cerrado fuels in Central Brazil – Volume I, Portland, Forest Service, U.S. Department of Agriculture, 2001. 87p.

PINHEIRO, E.D.S. Análises ecológicas e sensoriamento remoto aplicados à estimativa de fitomassa de Cerrado na estação ecológica de Assis, SP. Tese de Doutorado (Doutorado em Ciências da Engenharia Ambiental) – Universidade de São Paulo, USP, São Carlos, 2008.

RATTER, J.A., BRIDGEWATER, S. & RIBEIRO, J.F. 2003. Analysis of the floristic composition of the Brazilian cerrado vegetation iii: comparison of the woody vegetation of 376 areas. *Edinburgh Journal of Botany* 60: 57-109.

RIBEIRO, J.F.; SANO, S.M.; MACÊDO, J.; SILVA, J. Os principais tipos fisionômicos da região dos Cerrados. Planaltina, DF: Embrapa-CPAC, 1983. 28p. (Embrapa-CPAC. Boletim de Pesquisa, 21).

RIBEIRO, J.F. e WALTER, B.M.T. As Principais Fitofisionomias do Bioma Cerrado. In: SANO, S.M., ALMEIDA, S.P. e RIBEIRO, J. F. Cerrado: Ecologia e Flora, Volume 1, p. 151-212. 2008.

ROSENDO, J.S.; ROSA, R. Comparação do estoque de C estimado em pastagem e vegetação nativa de cerrado. *Sociedade & Natureza*, v.24, n.2, p.359-379, 2012. DOI: <http://dx.doi.org/10.1590/S1982-45132012000200014>.

SANO, S. M.; ALMEIDA, S. P.; RIBEIRO, J.F. Soils in the Cerrado Biome: Pedological Aspects. In: SANO, S.M., ALMEIDA, S.P. e RIBEIRO, J. F. Cerrado: Ecologia e Flora, Volume 1, p. 107-149. 2008.

SCOLFORO, J.R. *et al.* Volumetria, peso de matéria seca e carbono. In: SCOLFORO, J.R.; MELLO, J.M.; OLIVEIRA, A.D. (Ed.). Inventário Florestal de Minas Gerais: Cerrado - Florística, Estrutura, Diversidade, Similaridade, Distribuição Diamétrica e de Altura, Volumetria, Tendências de Crescimento e Áreas Aptas para Manejo Florestal. Lavras: UFLA, 2008a. p.361-438.

SOUSA NETO, E. *et al.* Soil-atmosphere exchange of nitrous oxide, methane and carbon dioxide in a gradient of elevation in the coastal Brazilian Atlantic forest. *Biogeosciences*, v.8, p.733-742, 2011.

VEIGA, L.G. Estoque de madeira morta ao longo de um gradiente altitudinal de Mata Atlântica no nordeste do estado de São Paulo. Dissertação de Mestrado (Mestrado em Biologia Vegetal) – Universidade Estadual de Campinas, UNICAMP, Campinas, 2010.

VELOSO, H.P. & GÓES-FILHO, L. 1982. Classificação fisionômico-ecológica da vegetação neotropical. Bol. Téc. Proj. Radambrasil v.7.

VIEIRA, S.A. *et al.* Stocks of carbon and nitrogen and partitioning between above - and belowground pools in the Brazilian coastal Atlantic Forest elevation range. Ecology and evolution, v.1, n.3, p.421-434, 2011.

WATZLAWICK, L.F. *et al.* Stock of biomass and carbon in the montane mixed shade forest, Paraná. Scientia Forestalis, Piracicaba, v.40, n.95, p.353-362, 2012.

WITTMANN, F. *et al.* Tree species composition, structure, and aboveground wood biomass of a riparian forest of the Lower Miranda River, southern Pantanal, Brazil. Folia Geobotânica, v.43, n.4, p.397-411, 2008.

Annex: Additional Information

I. Action Plan for the Prevention and Control of Deforestation and Forest Fires in the Cerrado (PPCerrado)

The Cerrado biome hosts 5% of the world's biodiversity and is considered the most biodiverse savanna in the world. It is, nonetheless, one of Brazil's most threatened biomes. The biome has already lost 44% of its original native vegetation of 204 million hectares by 2013 (MMA, 2015).

The conversion of native vegetation areas (forests or not) in the Cerrado biome is intense, due to characteristics that are conducive to agriculture and livestock and the demand for charcoal for the steel industry, predominantly in the hubs of Minas Gerais and, more recently, Mato Grosso do Sul. According to TerraClass Cerrado, 54 million hectares are occupied by cultivated pastures and 21.56 million hectares by agricultural crops (MMA, 2015).

In 2004, Brazil approved the Action Plan for the Prevention and Control of Deforestation in the Legal Amazonia region. The Legal Amazonia is an area of approximately 5,217,423 km² (521,742,300 ha) that covers the totality of the following states: Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins; and part of the states of Mato Grosso and Maranhão. **37% of the Cerrado biome is within the Legal Amazonia.** The area of the Cerrado biome that borders the Amazon biome and is within the Legal Amazonia was under the positive influence of this policy that considerably reduced deforestation, starting in 2005/06. In 2010 a specific Action Plan for the Cerrado biome was enacted.

In order to tackle this problem, the MMA, in September 2009, launched the first phase of the Action Plan for the Prevention and Control of Deforestation and Forest Fires in the Cerrado – PPCerrado. PPCerrado seeks to reduce deforestation and forest degradation and to promote conservation and sustainable use of natural resources in the Cerrado biome through strategic guidelines and actions under three axes: Monitoring and Control, Land Use, Territorial Planning and Protected Areas and the Promotion of Sustainable Productive Activities. The plan lays out initiatives to be carried by the MMA and by other federal institutions including the Brazilian Institute of Environment and Renewable Natural Resources - IBAMA; the Chico Mendes Institute for Biodiversity Conservation - ICMBio; National Water Agency – ANA and the Brazilian Forest Service – SFB.

The specific causes and effects of the actions within the Plan still require a more detailed analysis. To address that, one of the main lines of action of the National REDD+ Strategy, launched in 2015, is to develop an **impact matrix** to analyze the effectiveness and efficacy of several public policies that contribute to the achievement of REDD+ results. This information will be crucial to support decision-making regarding the investment of new resources in different initiatives and to explore the potential for complementarity among existing policies and initiatives.

During the 15th Conference of the Parties (COP -15) to the United Nations Framework Convention on Climate Change, held in Copenhagen in December 2009, the Brazilian government voluntarily submitted a national commitment to reduce between 36.1% and 38.9% of the projected greenhouse gas emissions by 2020. Reducing emissions from deforestation in the Cerrado biome by at least 40% was one of the targets set to meet the voluntary commitment made. This target included the conversion of any native vegetation area (forest or non-forest) to other land uses (not limited to deforestation).

In 2009, Law No. 12.187 established the National Policy on Climate Change (PNMC, for the acronym in Portuguese). Article 12 renders the voluntary commitments to mitigate emissions made under the UNFCCC into national law and indicates that Brazil's Second National Communication to the UNFCCC, submitted in 2010, should be the reference for the accounting of emission reductions. Article 6 defines the action plans for the prevention and control of deforestation in the Brazilian biomes as instruments of the PNMC.

Other sectoral plans that make up the PNMC, such as the National Plan for Low Carbon Emission in Agriculture (ABC Plan) and the Sustainable Charcoal for Iron and Steel Production, widely compliment and reinforce the PPCerrado, as the Cerrado hosts considerable economic activity from both agriculture and steel production sectors.

Defining priority areas for intervention is a major part of each planning period of the Action Plans. Firstly, the areas that hold the most remnants of native vegetation and are under heavy anthropogenic pressure are considered priorities. At the same time, areas important for biodiversity conservation (as defined by the process of Updating Priority Areas and Actions for Conservation, Sustainable Use and the Distribution of Benefits of Brazilian Biodiversity) and those of high relevance for the conservation of water resources, primarily the sources from the main hydrological basins, are considered priorities.

For the medium and long term horizon (up to 2020), converted areas that are not in compliance with the Forest Code, Law No. 12,651, as well as degraded pastures will be the targets for recovery as a means to prevent the conversion of native vegetation. There is also particular emphasis on the conservation of water resources, with the

understanding that the Cerrado biome has a unique role for preserving this natural resource.

The Permanent Interministerial Working Group (GPTI, for the acronym in Portuguese) is the governance body responsible for overseeing the implementation of the Action Plans to Prevent and Combat Deforestation, in both the Amazonia and the Cerrado biomes. The GPTI is assisted by an Executive Committee, whose goal is to manage and coordinate activities from the federal government to reduce deforestation. Both the GPTI and the Executive Committee are coordinated by the MMA via the Department on Policies to Fight Deforestation (DPCD, for the acronym in Portuguese) as its Executive Secretariat. The Plan includes activities from more than 10 federal governmental agencies and institutions.

The State Governments' participation is key for the effective implementation of policies to reduce deforestation. In order to achieve their engagement, several state environmental agencies have their own policies to reduce deforestation in place, which are in line with federal efforts. The same goes for the municipal environmental agencies, especially in the case of municipalities that are under greater pressure from the main drivers of deforestation.

In addition to governmental actions, the engagement of other sectors is also of utmost importance to protect the Cerrado biome, especially the agriculture sector, both from the agribusiness and smallholders. The PPCerrado should serve as an instrument to engage these stakeholders and collectively build an agenda that reconciles conservation and sustainable production.

Besides the PNMC, PPCerrado is also part of the REDD+ institutional framework. The National Strategy for Reducing Emissions from Deforestation and Forest Degradation, the Conservation of Forest Carbon Stocks, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks (ENREDD+, for the acronym in Portuguese), launched in 2015, also considers the Plan as a key instrument to promote integration and consistency of REDD+ initiatives in the Cerrado biome.

In 2016, the PPCerrado entered its third phase that will be effective up to 2020. It is worth noting that this time frame has been defined to promote consistency with three key instruments: the multiannual budget plan (2016-2019), which contains all the federal government's programming for the next few years; Brazil's National REDD+ Strategy; and Brazil's Nationally Determined Contribution (NDC) under the Paris Agreement.

II. Brazilian Biomes Environmental Monitoring Program (PMABB)

The Ministry of the Environment has established the Brazilian Biomes Environmental Monitoring Program for the monitoring of deforestation, land cover and land use, selective logging, forest fires and recovery of native vegetation, through [MMA Ordinance no. 365, of November 27, 2015](#).

Historically, with the development of geoprocessing and remote sensing technologies, Brazil has become a benchmark in the development and deployment of land cover and land use monitoring systems. The resulting intelligence on the dynamics of land-use change has been a key element for curbing deforestation in the Amazon.

Since the 1970's, the National Institute for Space Research (INPE, for the acronym in Portuguese), the Brazilian Agricultural Research Corporation (EMBRAPA, for the acronym in Portuguese) and the Brazilian Institute of Geography and Statistics (IBGE, for the acronym in Portuguese) have established and strengthened strategic partnerships to develop technologies and methodologies to monitor the Brazilian territory through, for example, the monitoring of forests and wildfires. This enabled an ongoing flow of qualified data to inform firefighting activities, as well as the integrated management of species, territories, ecosystems and fire.

Mapping and monitoring initiatives have been undertaken to provide the government with official data on the remaining vegetation cover of Brazilian biomes. The MMA, through the Project for the Conservation and Sustainable Use of Brazilian Biological Diversity (PROBIO), conducted significant mappings based on satellite imagery, which were later refined under the Project of Satellite Deforestation Monitoring of the Brazilian Biomes (PMDBBS). This project was developed through a cooperation agreement between the MMA, the IBAMA and the United Nations Development Program (UNDP), which carried out a series of assessments between 2008 and 2011 on the Cerrado, the Caatinga, the Pampa, the Pantanal and the Atlantic Forest biomes, taking the PROBIO map as a basis.

Research and innovation in the field of remote sensing have helped in the mapping of land cover and land-use change dynamics at local, regional, and national levels. This has been essential for better understanding the spatial aspects related to the expansion, retraction, transition, intensification, conversion and diversification of Brazilian agricultural production. Being aware of the dynamics of the changes taking place on earth's surface is important not only for assessing the condition of different ecosystems, but also for estimating the impacts caused by different human activities on biodiversity and climate change.

Through these monitoring initiatives Brazil tracks its progress in achieving its targets to reduce greenhouse gas emissions by 37% by 2025 and by 43% by 2030, having the

emission level observed in 2005 as the benchmark, as stated on its NDC under the UNFCCC Paris Agreement. Furthermore, information on deforestation and forest degradation will be fundamental for the implementation of Brazil's National REDD+ Strategy.

The scope of these monitoring activities represents a major challenge. Brazil has an extensive territory of over 8.5 million square kilometers - with approximately 60-70% of the surface covered by natural vegetation. Brazil currently has five systems in place to monitor deforestation and forest degradation in the Amazon: PRODES, DETER, QUEIMADAS, DEGRAD/DETEX and TerraClass. TerraClass Cerrado, launched in 2013, is the first Land Use and Land Cover Mapping of the Cerrado biome.

For the Amazon and the Cerrado biomes, the Program provides for the assessment of deforestation in previous years, proving inputs for the construction of Forest Reference Emission Levels for REDD+.

The Program also provides for gradually extending the monitoring conversion of natural vegetation, land cover and land use to cover all of the Brazilian biomes. The monitoring of forest fires outbreaks throughout the national territory is being upgraded, in order to produce numeric data on the area affected by fire. Monitoring selective logging in the Amazon will be strengthened. Monitoring of native vegetation restoration will be devised and implemented for the Amazonia, Cerrado and the Atlantic Forest biomes.

This information will support decision-making regarding activities to foster the conservation of Brazilian biodiversity, along with informing a strategic vision for territorial management that reconciles diverse interests related to land use and enable Brazil to develop on a more sustainable basis.

The Program coordinates the efforts by several Federal Government agencies engaged with satellite based monitoring of land cover and land use (such as EMBRAPA, IBGE, IBAMA, INPE and research institutions) seeking to promote joint actions to produce various mappings for all the Brazilian biomes at different cartographic and time scales, according to the characteristics of each theme, in order to produce and make standardized, systematic and updated official information available.

The complexity of the Program is reflected in the number of deliverables planned (**Figure 18**). Considering that there are seven types of distinct mappings, six biomes and a long historical time series, prioritizing actions and organizing specific schedules is required. In order to achieve that, it has been structured in three phases, as defined in MMA Ordinance No. 365/2015: I) Amazon and Cerrado (2016-2017); II) Atlantic Forest (2016-2017) and III) Caatinga, Pampa and Pantanal (2017-2018).

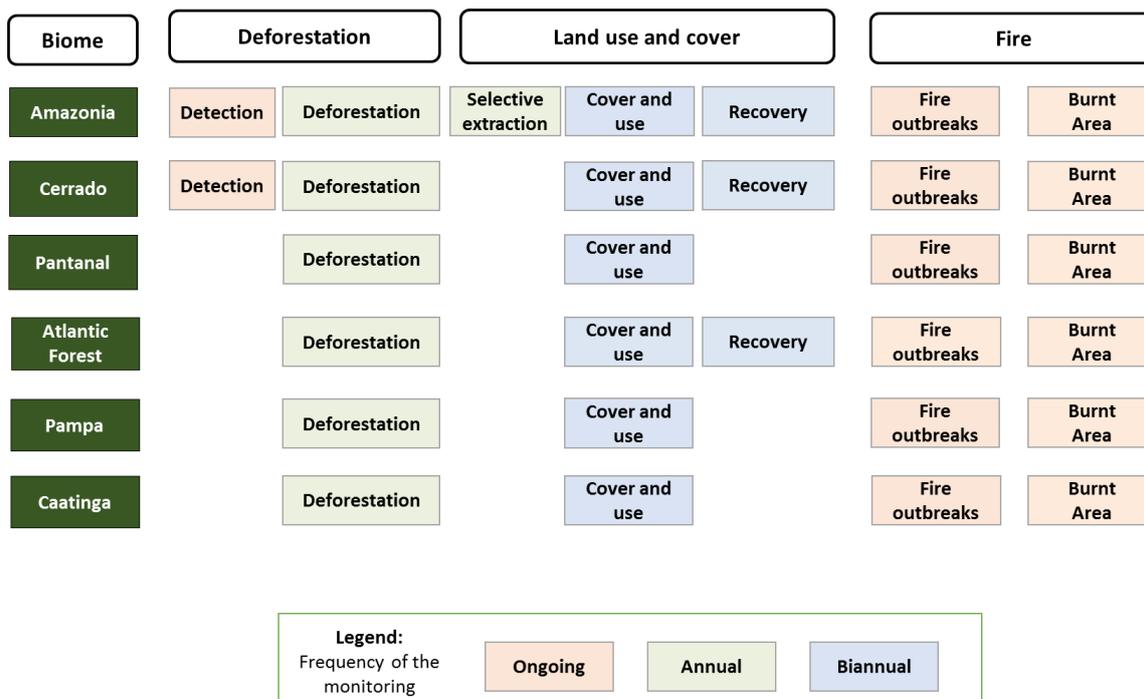


Figure 18. Monitoring types and frequency for Brazilian biomes.

As part of the first phase of the Program, support for the construction of historical time series of nearly three decades for the Amazon biome is assured, as well as almost all of the financial resources needed to support activities in upcoming years. One of the enhancements planned is the expansion of deforestation monitoring for grassland and savanna areas in the Amazon region, an area equivalent to the territory of Uruguay but not yet mapped by the existing programs.

In the next phases of the Program, the priority will be to generate a historical time series of deforestation in the Atlantic Forest and the Caatinga biome, schedule to be finalized by the middle 2018. The Pampa and Pantanal biomes will follow.

The upcoming mappings will be planned and presented in annual implementation plans to be presented by the different institutions involved, due to the specificity of each task, i.e. different methodologies, status of implementation and deadlines. Each annual plan may contain several ongoing mappings that, in turn, will have specific work plans established under interinstitutional technical cooperation agreements. The annual plan should report the general status of each mapping and its work plan, those being: the planning, development or implementation phase.

III. Satellite Deforestation Monitoring of the Brazilian Biomes (PMDBBS)

As previously mentioned, other initiatives to estimate the deforested area in the Cerrado biome have been carried out in the past. The Satellite Deforestation Monitoring of the Brazilian Biomes, the result of a technical cooperation agreement between the MMA/IBAMA and the UNDP, is probably the most significant one.

A total of 121 digital images from the LANDSAT TM orbital sensor of 2009 were obtained in order to monitor the Cerrado biome. These images were obtained from INPE's website and registered (geometric positioning adjustments).

The analysis used the Vegetation Cover Map of the Brazilian Biomes at a 1:250,000 scale, base year 2002, prepared by a group of institutions under PROBIO. This map was made available by the MMA in 2007 and was considered the "base map" to initiate the monitoring, along with PROBIO's mask of areas subjected to human activities.

Note: this is one of the differences between PMDBBS data and the historical time series of deforestation used in the construction of the FREL Cerrado, which was developed at a 1:75,000 scale and had the year 2000 as the "reference year". The forest definition is also different.

Table 8 from the PMDBBS publication, displayed below, demonstrates the project results for 2008-2009. It should be noted that deforestation was broadly defined as the conversion of native vegetation (both forest and non-forest) to other uses.

Table 8. Deforestation status by state from 2008 to 2009, based on the total original area of the Cerrado biome in each state.

State	Cerrado cover (km ²)	Deforestation 2008-2009 (km ²)	%
Maranhao	212,092	2,338	1.10
Tocantins	252,799	1,311	0.52
Bahia	151,348	1,000	0.66
Mato Grosso	358,837	833	0.23
Piaui	93,424	701	0.75
Goias	329,595	664	0.20
Minas Gerais	333,710	534	0.16
Mato Grosso do Sul	216,015	241	0.11
São Paulo	81,137	7,5	0.01
Parana	3,742	1	0.03
Federal District	5,802	1	0.02
Rondonia	452	0,8	0.19
Total		7,636	

Box 5: Differences between the monitoring data from the PMDBBS and the data used in this FREL

Between 2008 and 2009 the PMDBBS identified that a total area of 763,600 ha of native vegetation was converted to other uses. The historical time series used in the construction of the FREL Cerrado identified an area of 1,033,346 ha of both forest and non-forest converted in the same period (taken from the average of the 2008-2010 period).

There is a difference of approximately 9.2% between the data in Table 3, which presents the area of forest conversion (managed and unmanaged) in the Third National GHG Inventory, and Table 4, which presents the area of forest conversion from the historical time series used in the FREL Cerrado.

This difference is because the Third National GHG Inventory and the historical time series of this FREL Cerrado adopted different minimum mapping areas. While in the former the minimum mapping area was 6.0 ha (at a 1:125,000 scale), in the later the scale was 1:75,000 and the mapping included all the deforestation polygons with areas larger than 1 hectare. Note that in the Excel files, areas smaller than 1 hectare may be indicated. This occurs whenever the original deforestation polygon contained more than one vegetation physiognomy and was split accordingly. Note

also that the original submission mapped all the deforestation polygons identified by the interpreter. However, an analysis of the accuracy of the mapping of polygons smaller than 1 hectare led to the decision to consider only those with areas larger than 1 hectare (Table 4). Hence, there is a difference of approximately 35% between these two assessments.

Results from the PMDBBS indicate that the average annual area converted in the periods from 1994 to 2002 and 2002 to 2008 were 1,570,100 ha/year and 1,417,900 ha/year, respectively.

As can be noted, the results from the PMDBBS and the historical time series used in the construction of the FREL Cerrado present differences, due to definition issues, scale, minimum area mapped and reference map used. The PMDBBS used maps from the PROBIO as the reference maps, whereas the time series for the FREL developed its own reference map for reference year 2000. The absence of a long time series with consistent and transparent data was one of the reasons that triggered the interest to develop the time series for the FREL Cerrado.

IV. Identification key of the Cerrado physiognomic types

Based on Ribeiro *et al.* (1983), a dichotomous key for identifying the Cerrado physiognomic types is presented in this Annex. The key differentiates the vegetation formations based on structural parameters, such as average tree height, vertical stratification, canopy cover, deciduous and geographical position. In addition to these parameters, soil characteristics, such as the degree of water saturation and whether or not there are rock outcrops, have been considered for savanna and grassland formations. For the three major categories of formations, elements of the flora were also included (floristic composition).

Woody plants with a height greater than 2m that do not have branches close to the base (Heringer *et al.*, 1977) are considered "trees". "Shrubs" are defined as woody or semi-woody plants between 0.2m and 2m that may or may not have branches near the base. A "subshrub" is considered a plant with a persistent underground system during the dry season and aerial parts up to 0.5m in the rainy season (Heringer *et al.*, 1977). "Herbs" are non-woody plants, represented by annual and bi-annual plants and eventually some perennials.

1. Forest formation. Forest structure. Presence of dicotyledonous trees or palms. A predominantly continuous canopy; average canopy cover from 50% to 95%.....2

- 1'. Savanna or grassland formation.....9
2. Forest associated with a defined watercourse.....3
- 2'. Forest not associated with a defined watercourse.....5
3. Woodland found alongside streams or small rivers. Forming a gallery over the watercourse. Usually surrounded by swaths of non-forest vegetation. Upright standing trees; average height from 20m to 30m. Perennial or sparsely deciduous tree stratum. Tree cover from 70% to 95%.....4
- 3'. Woodland found alongside medium and large rivers. No gallery formation over the watercourse. Usually has a smooth transition to other forest physiognomies. Predominantly upright standing trees; average height of 20m to 25m. Tree stratum with varying degree of deciduous degrees in the dry season. Tree cover from 5% to 90%.....**Mata Ciliar**
4. Woodland where the water table is not close to the surface of the terrain in most parts throughout the year, even in the rainy season. It features long stretches with rugged topography and a few flat sites. Drainage is good. Presence of many arboreal legume species.....**Mata de Galeria Não-Inundável**
- 4'. Woodland where the water table is near or over the surface of the terrain in most parts throughout the year, even in the dry season. It features long stretches with flat topography and few rugged areas. Drainage is poor. Presence of a few arboreal legume species.....**Mata de Galeria Não-Inundável**
5. Forest composed of several species, primarily dicotyledons.....6
- 5'. Forest with a total predominance of palms from the genus *Mauritia* in poorly drained soils and lacking a water course or a clearly defined drainage line. Insignificant presence of dicotyledons. Tree cover of 60% to 80%, forming a continuous canopy. No associated grassland formations.....**Palmeiral ("Buritizal")**
6. Tree stratum with prevalence of upright standing individuals. It features different degrees of deciduousness in the dry season. Average height from 15m to 25m. Tree cover varies from 50% (or less) to 95%. Flora composed of essentially

Woodland species.....	7
6'. Tree stratum with tortuous and standing individuals. Few species with deciduous in the dry season. Average height from 8m to 15m. Tree cover of 50% to 90%. Flora with elements of Cerrado (strict sense) and woodland.....	
Cerradão	
7. Presence of evergreen and deciduous species, considerably varying tree cover between dry and rainy season.....	8
7'. Prevalence of evergreen species, slight variance in tree cover throughout the year.....	Mata Seca Sempre-Verde
8. Balanced presence of evergreen and deciduous species. Tree cover rarely below 50% in the dry season.....	Mata Seca Semidecídua
8'. Complete prevalence of deciduous species. Tree cover is less than 50% in the dry season. Generally occurs in areas with rock outcrops or limestone soils.....	Mata Seca Decídua
9. Savanna structure. Flora predominantly woody-shrub, spread out over an herb stratum, which can be not clearly defined. Tree cover from 5% to 70%. A usually discontinuous canopy, if present.....	10
9'. Grassland structure. Flora predominantly herbaceous-shrub. Absent or undefined tree cover.....	17
10. Only in well-drained terrain.....	11
10'. On poorly drained terrain or poorly drained terrain with spots of well-drained soil.....	15
11. Arboreal Flora composed of several species, mainly dicotyledons.....	12
11'. Arboreal Flora with total predominance of a single species of palm from the genus <i>Acrocomia</i> or <i>Attalea</i> or <i>Syagrus</i> . Insignificant presence of dicotyledonous trees.....	Palmeiral ("Macaubal", "Babaçual", "Guerobal")
12. Less than 50% of tree cover. Average height of the tree layer from 2m to 6m. Never forms a continuous canopy. Tree stratum with predominantly tortuous individuals.....	13
12'. Tree cover from 50% to 70%. Average height of the tree stratum from 5m to 8m. Can form strips with continuous canopy. Tree stratum with upright standing and	

tortuous individuals.....	Cerrado
Denso	
13. Tree cover of 5% to 20%. Low density tree stratum. Average height of the trees from 2m to 4m.....	14
13'. Tree cover of 20% to 50%. Bulging tree layer. Average height of the tree layer from 3m to 6m.....	Cerrado Típico
14. Trees and shrubs grow in soils with little depth, but lacking rock outcrops. Flora typical of the Cerrado.....	Cerrado Ralo
14'. Trees and shrubs grow in places where there are characteristic rock outcrops with little or no soil. Flora with characteristic elements, adapted to the rupicolous environment.....	Cerrado rupestre
15. Arboreal Flora with a marked presence of buriti (<i>Mauritia flexuosa</i>), in poorly drained terrain.....	16
16. The buritis form a discontinuous canopy and grow scattered among a grass-like field. Tree cover of 5% to 10%. The buritis are concentrated in places where there are poorly defined drainage lines, with characteristically associated grassland formations.....	Vereda
16'. The buritis form a discontinuous canopy and grow scattered over a grass-like field. Tree cover of 40% to 70%. The buritis are distributed over terrain where there are no defined drainage lines.....	Palmeiral ("Buritizal")
17. With shrubs or a few isolated short trees.....	18
17'. Without shrubs or trees	21
18. Shrubs grow in areas with some soil and not in rock outcrops. Flora with elements of the Cerrado (strict sense).....	19
18'. Shrubs grow directly in the crevices of rock outcrops, in areas with little or no soil. Distinct flora with a high level of endemism.....	Campo Rupestre
19. Poorly drained terrain or well drained solely in slight concentric elevations.....	20
19'. Poorly drained terrain or well drained solely in slight concentric elevations.....	Campo Sujo Seco

20. Only in poorly drained soils.....**Campo Sujo Úmido**
- 20'. Poorly drained soils with well drained elevations of terrain
(*murundus*).....**Campo Sujo com
Murundus**
21. Poorly drained terrain or well drained only in slight concentric
elevations.....22
- 21'. Only well-drained terrains.....**Campo Limpo Seco**
22. Only in poorly drained soils.....**Campo Limpo Úmido**
- 22'. Poorly drained soils with well drained elevations of terrain
(*murundus*).....**Campo Limpo com
Murundus**

V. Guide to the Excel files

This guide aims at providing information regarding the access to activity data, emission factors, and CO₂, CH₄ and N₂O emissions for the Cerrado biome. Working sheets in the format .xlsx are provided for each one of the periods considered: 2000-2002, 2002-2004, 2004-2006, 2006-2008 and 2008-2010, totaling five files.

Each file has two tabs: (1) TAB PERIOD provides a list of all deforestation polygons and all the information to calculate the associated CO₂ and non-CO₂ emissions (e.g., forest type affected and corresponding emission factors for above and below-ground biomass, litter and dead wood), and the associated CO₂ and non-CO₂ emissions; (2) and a TAB CONSOLIDATED with the aggregated values from TAB PERIOD, by state of the Cerrado, the total area deforested and the emissions (in units of mass) of CO₂, CH₄ and N₂O. Exception made for the period 2002-2004, in which the number of polygons exceeded the maximum number of lines allowed in the excel sheet (1.048.576 rows) and, in this case, the tab was split into two, where data from Goiás state were provided in an additional tab, called GOIAS.

The data in the tab PERIOD provides data for polygons of all natural vegetation converted to other land use. However, column D (c_pret) has a filter that is activated to list only the polygons of natural forest converted. The values in TAB CONSOLIDATED refer only to the filtered values (i.e., those that are presently listed in tab (1)).

All the Excel files contain the following information:

Columns A (linkcolumn), **B** (cell_oid) and **C** (classname) are for internal reference only.

Column D (c_{pret}) indicates the vegetation type associated with the natural vegetation polygon converted to other land-use category (refer to table 1 in the submission for the **forest** types considered). When an observed polygon was covered by more than one type of vegetation, then it was split into smaller polygons so that each would be represent only a single vegetation type.

Column E (c_{v_3i}) presents the sum of the carbon in the belowground biomass (column H, *belowgr*), dead wood (column I), litter (column J) and aboveground biomass (column K), in tonnes of carbon per unit area ($tC\ ha^{-1}$) associated with each of the vegetation types indicated in **column D**.

Column F (*ufdescrica*) indicates the state of the federation where the converted polygon occurred (refer to Figure 2 in the submission).

Column G provides the area associated with each deforestation polygon, in hectares (ha).

Columns H, I, J and K provide the carbon in the belowground biomass (*belowgr*), dead wood, litter and aboveground biomass (*abovegr*), respectively, in $tC\ ha^{-1}$, associated with each of the vegetation types indicated in **column D**.

Column L provides the carbon emission associated with the converted polygon that results from the product of the area (**column G**) and the total carbon in biomass (**column E**), in tonnes of carbon (tC).

Column M presents the emission associated with each converted polygon, in tonnes of CO_2 , ($t\ CO_2$).

Column N provides the sum of the carbon in litter, dead wood and aboveground biomass (columns J, J and K). For the calculation of non- CO_2 emissions from fire, one entry in the equation is the mass of fuel available, which includes only aboveground biomass, litter and dead wood, following the IPCC guidelines. The unit should be tonnes of dry matter. To convert tonnes of carbon to tonnes of dry matter, the value 0,47 was applied at the end of the calculations.

Column O is the default emission factor used, equal to 0.435.

Column P provides a single number (10^{-3}) in the equation for the calculation of non- CO_2 emissions. It is used to convert kilograms to tonnes.

Column Q ($f(emis_CH_4)$) provides the CH_4 emission associated with each polygon of deforestation. Each value is the result of the product between the area of the deforested polygon (column G), the mass of available fuel (column N), the combustion factor (0,435, column O), the value 10^{-3} (column P) and the emission factor for methane (6.8). The total in the column is divided by 0.47 to correct for the use of the mass of available fuel in tonnes of carbon (column N) to tonnes of dry matter.

Column R (f(emiss_N2O)) provides the N2O emission associated with each polygon of deforestation. Each value is the result of the product between the area of the deforested polygon (column G), the mass of available fuel (column N), the combustion factor (0,435, column O), the value 10^{-3} (column P) and the emission factor for methane (0,20). The total in the column is divided by 0.47 to correct for the use of the mass of available fuel in tonnes of carbon (column N) to tonnes of dry matter.

TAB CONSOLIDATED

Column A provides the list of the states of the federation covered by the Cerrado biome.

Column B (sum_area_hectares) provides the area **deforested** (in ha) within each state of the federation in the Cerrado biome.

Column C (sum _emiss_CO2), **D** (Soma de f(emiss_CH4)), **E** (Soma de f(emiss_N2O)), provides the emission associated with each **deforestation** polygon (in tonnes of mass) within each state of the federation in the Cerrado biome.

Example:

Consider the data in file CO2 and non-CO2 emissions_2000-2002.

The general total shown in line 15 of column A of **TAB CONSOLIDATED** (4,174,608 ha) represents the total area of the deforested polygons observed in the period 2000-2002. This value is equal to the sum of the values listed in column G in **TAB 2000-2002**. The value in Table 2 of the submission, is half of the general total in line 15, to provide the average area annually converted for 2000-2001 and 2001-2002.

The general total shown in line 17 column B (931,940,258 t CO₂) corresponds to the sum of the values in column M in **TAB 2002**. Table 2 in the submission shows this value divided by 2 to provide the average annual CO₂ emission for 2000-2001 and 2001-2002.

The total in line 15, column C (545,144 t CH₄) corresponds to the sum of the values in column Q in **TAB 2002**. To reproduce the value in Table 2, the following operations are carried out:

1. Divide the total in line 15 by 0.47 (since the mass of available fuel that originated the value 545,144 was in tonnes of carbon and not in tonnes of dry matter, as required by the equation). The result is 1,159,883 t CH₄.
2. Multiply the result in (1) by 21, the GWP from the IPCC Second Assessment Report (SAR) to convert t CH₄ into t CO₂-eq. The result is 24,357,533 t CO₂-eq.
3. Divide the result in (2) by 2, to generate the average annual emission of CH₄ in CO₂-eq for each period 2000-2001 and 2001-2002. The result is 12,178,769 t CO₂-eq.