Brazil's submission of a forest reference emission level for deforestation in the Amazonia biome for results-based payments for REDD+ under the UNFCCC

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1. Introduction

Brazil welcomes the opportunity to submit a forest reference emission level (FREL) for a technical assessment 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+) under the United Nations Framework Convention on Climate Change (UNFCCC).

Brazil underlines that the submission of FRELs and/or forest reference levels (FRLs) and subsequent Technical Annexes with results are voluntary and exclusively for the purpose of obtaining and receiving payments for REDD+ actions, pursuant to decisions 13/CP.19, paragraph 2, and 14/CP.19, paragraphs 7 and 8.

This submission, therefore, does not modify, revise or adjust in any way the nationally appropriate mitigation actions currently being undertaken by Brazil pursuant to the Bali Action Plan (FCCC/AWGLCA/2011/INF.1), neither prejudges any nationally determined contribution by Brazil in the context of the protocol, another legal instrument or an agreed outcome with legal force under the Convention currently being negotiated under the Ad Hoc Working Group on the Durban Platform for Enhanced Action.

2. Area and activity covered by this forest reference emission level

Brazil recalls paragraphs 11 and 10 of Decision 12/CP.17 that indicate that a subnational forest reference emission level may be developed as an interim measure, while transitioning to a national forest reference emission level; and that a step-wise approach to a national forest reference emission level may be useful, enabling Parties to improve the forest reference emission level by incorporating better data, improved methodologies and, where appropriate, additional pools, respectively.

The **national** forest reference emission level to be submitted by Brazil in the future will be calculated as the sum of the forest reference emission levels constructed for each of the six biomes in the national territory (refer to ***Figure 1***). This will allow the country to assess and evaluate the effect of the implementation of policies and measures developed at the biome level (refer to ***Annex 1*** for the Amazonia biome and ***Annex 3*** for the other biomes).

Brazil proposes through this submission a subnational forest reference emission level for the Amazonia biome (refer to ***Figure 1***) that comprises approximately 4,197,000 km^2 and corresponds to 49.29 per cent of the national territory[1]. Considering the significant relative contribution of the net CO_2 emissions from Land Use, Land-Use

[1] As presented in ***Figure 1***, in addition to the Amazonia biome, the national territory has five other biomes: Cerrado (2,036,448 km^2 – 23.92 per cent of the national territory), Mata Atlântica (1,110,182 km^2 – 13.04 per cent of the national territory), Caatinga (844,453 km^2 – 9.92 per cent of the national territory), Pampa (176,496 km^2 – 2.07 per cent of the national territory), and Pantanal (150,355 km^2 – 1.76 per cent of the national territory) (BRASIL, 2010, Volume 1, Table 3.85).

Change and Forestry (LULUCF) (particularly from the Amazonia biome) to the total national net CO_2 anthropogenic emissions (refer to ***Figure 2***), Brazil deemed appropriate to initially focus its mitigation actions in the forest sector through "*reducing emissions from deforestation*" in the Amazonia biome for the purposes of receiving results-based payments for REDD+, as an interim measure, while transitioning to a national forest reference emission level that will include all biomes.

Figure 1: Distribution of the biomes in the Brazilian territory. ***Source:*** IBGE, 2011.

Regardless of the fact that this forest reference level submission for results-based payments includes only the Amazonia biome, preliminary information is provided in ***Annex 3*** for the remaining biomes, to indicate efforts already under development in Brazil to transition to a national forest reference emission level.

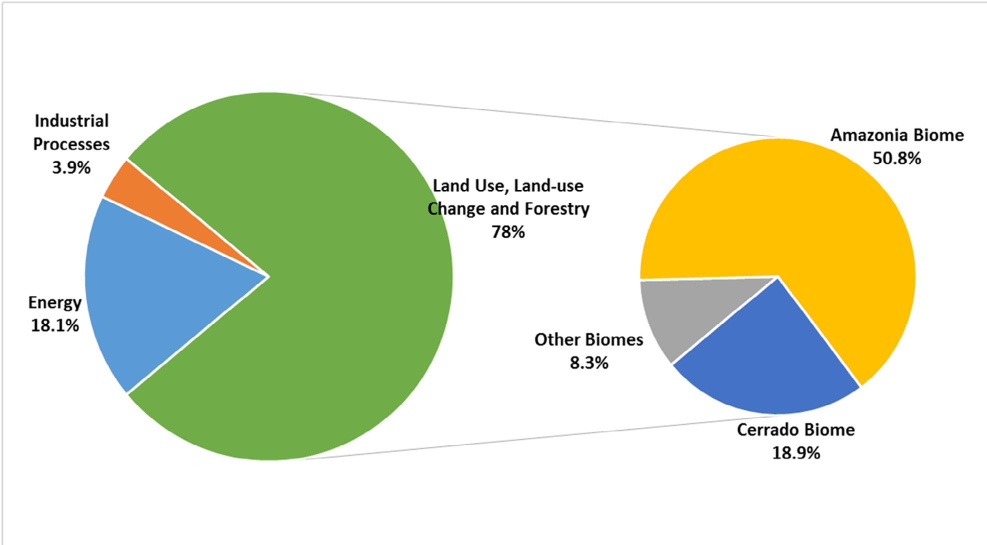

Figure 2: The relative contribution of the sectors Energy, Industrial Processes and LULUCF[2] to the total CO_2 emissions in year 2000[3]; and the relative contribution of the Brazilian biomes to the total relative CO_2 emissions from LULUCF. ***Source:*** BRASIL, 2010, Volume 1, Part 2, Chapter 2.

This submission of the forest reference emission level focuses only on CO_2 emissions from gross deforestation and includes emissions from the above and below-ground biomass and litter carbon pools. Section (c) in this submission (*Pools, gases and activities included in the construction of the forest reference emission level*) provides more detailed information regarding other pools and gases. ***Annex 2*** (*The development of forest reference emission levels for other REDD+ activities in the Amazonia biome*) provides some preliminary information regarding forest degradation and introduces some ongoing initiatives to address associated emissions, so as not to exclude significant activities from consideration. There is recognition of the need to continue improving the estimates of emissions associated with REDD+ activities, pools and gases. However, the material in the Annexes to this submission is not meant for results-based payments.

Brazil followed the guidelines for submission of information on reference levels as contained in the Annex to Decision 12/CP.17 and structured this submission accordingly, i.e.:

a) Information that was used in constructing a forest reference emission level;

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[2] The relative contribution of CO_2 emissions from liming and waste to the total CO_2 emissions in 2000 were less than 1 per cent (0.5 and 0.006 per cent, respectively) and hence have been excluded from ***Figure 2***.

[3] The Guidelines for the preparation of national communications from Parties not included in Annex I to the Convention in the Annex of Decision 17/ CP.8 states that non-Annex I Parties shall estimate national GHG inventories for the year 1994 for the initial national communication or alternatively may provide data for the year 1990. For the second national communication, non-Annex I Parties shall estimate national GHG inventories for the year 2000 (UNFCCC, 2002). This submission focuses only on CO_2 emissions.

b) Transparent, complete, consistent, and accurate information, including methodological information used at the time of construction of forest reference emission levels;

c) Pools and gases, and activities which have been included in forest reference emission level; and

d) The definition of forest used.

a) Information that was used in constructing the proposed forest reference emission level

The construction of the forest reference emission level for *reducing emissions from deforestation* in the Amazonia biome was based on a historical time series developed for the Legal Amazonia[4] since 1988. The annual assessment of gross deforestation for the Legal Amazonia, known as PRODES (Gross Deforestation Monitoring Program in Amazonia), is carried out under the Amazonia Program at the National Institute for Space Research (INPE, Instituto Nacional de Pesquisas Espaciais) from the Ministry of Science, Technology and Innovation (MCTI). The Legal Amazonia encompasses three different biomes: the entire Amazonia biome; 37 per cent of the Cerrado biome; and 40 per cent of the Pantanal biome (refer to ***Figure 3***). For the construction of the reference level for the Amazonia biome, the areas from the Cerrado and Pantanal biomes in the Legal Amazonia were excluded.

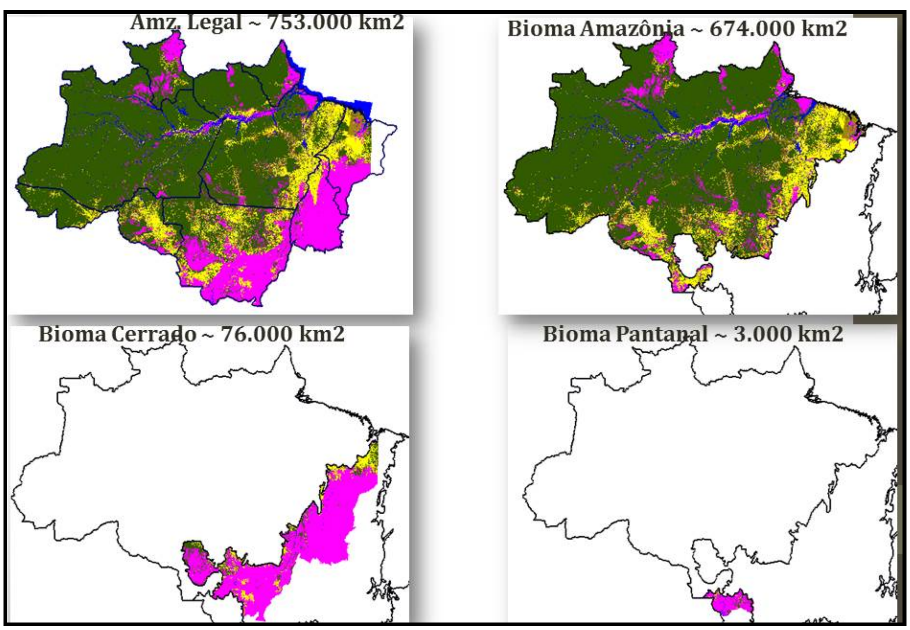

Figure 3: Aggregated deforestation (in yellow) until year 2012 in the Legal Amazonia and the Amazonia, Cerrado and Pantanal biomes. Forest areas in green; non-forest areas in pink; water bodies in blue. ***Source:*** Data from PRODES, INPE, 2014.

[4] 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 (refer to ***Figure a.1*** in ***Annex 1***).

Gross deforestation in the Legal Amazonia area is assessed annually through PRODES using Landsat-class satellite data on a wall-to-wall basis. The minimum mapped area is 6.25 hectares. Consistent data for gross deforestation are available on an annual basis since 1988. The consistency of the time series is ensured by using the same definitions, same minimum assessed area, similar satellite spatial resolution[5], same forest/non-forest boundaries, and same methodological approach based on the use of remotely sensed data at every new assessment. For more details about PRODES refer to ***Annex 1***.

The area of the annual gross deforestation by forest type (in km^2 or hectares) is the ***activity data*** necessary for the application of the first order approximation to estimate emissions[6] as suggested in the IPCC Good Practice Guidance for Land Use, Land-use Change and Forestry (GPG LULUCF) (IPCC, 2003). These areas have been obtained from PRODES, adjusting to consider only deforestation within the Amazonia biome.

The other necessary element is the ***emission factor*** that, here, consists of the carbon stock associated with forest types in the Amazonia biome, provided in tonnes of carbon per unit area (tC ha^{-1}).

The carbon stock was estimated using an allometic equation developed by Higuchi (1998) from the National Institute for Amazonia Research (INPA, Instituto Nacional de Pesquisas da Amazônia) from MCTI, to estimate the aboveground fresh mass[7] of trees from distinct forest types (or physiognomies)[8] in the Amazonia biome as well as data from a scientific literature review, when necessary (refer to ***Box 1*** and ***section b.2***).

Box 1: Choice of the Allometric Equation to Estimate Aboveground Biomass
Four statistical models (linear, non-linear and two logarithmics) selected from thirty-four models in Santos (1996) were tested with data from 315 trees destructively sampled to estimate the aboveground fresh biomass of trees in areas near Manaus, Amazonas State, in the Amazonia biome (central Amazonia). This area is characterized by typical dense "terra firme" moist forest in plateaus dominated by yellow oxisols. In addition to the weight of each tree, other measurements such as the diameter at breast height, the total height, the merchantable height, height and diameter of the canopy were also collected. The choice of the best statistical model was made on the basis of the largest coefficient of determination, smaller standard error of the estimate, and best distribution of residuals (Santos, 1996). For any model, the difference between the observed and estimated biomass was consistently below 5 per cent. In addition, the logarithm model using a single independent variable (diameter at breast height) produced results as consistent as and as precise as those with two variables (diameter at breast height and height) (Higuchi, 1998).

[5] Spatial resolution is the pixel size of an image associated with the size of the surface area being assessed on the ground. In the case of the Landsat satellite, the spatial resolution is 30 meters.

[6] "In most first order approximations, the "activity data" are in terms of area of land use or land-use change. The generic guidance is to multiply the activity data by a carbon stock coefficient or "emission factor" to provide the source/or sink estimates." (IPCC, 2003; section 3.1.4, page 3.15).

[7] Hereinafter referred simply as aboveground fresh biomass.

[8] These forest types, or vegetation classes, totaled 22 and were derived from the Vegetation Map of Brazil (1:5.000.000), available at: ftp://ftp.ibge.gov.br/Cartas_e_Mapas/Mapas_Murais/, last accessed on May 5th, 2014.

Silva (2007) also demonstrated that the total fresh weight (above and below-ground biomass) of primary forest can be estimated using simple entry (DBH) and double entry (DBH and height) models and stressed that the height added little to the accuracy of the estimate. The simple entry model presented percent coefficient of determination (r2) of 94 per cent and standard error of 3.9 per cent. For the double entry models, these values were 95 per cent and 3.7 per cent, respectively. It is recognized that the application of the allometric equation developed for a specific area of Amazonia may increase the uncertainties of the estimates when applied to other areas.

The input data for applying the allometric equation have been collected during the RADAM (RADar in AMazonia) Project (later also referred to as RADAMBRASIL project or simply RADAMBRASIL)[9]. RADAMBRASIL collected georeferenced data from 2,292 sample plots in Amazonia (refer to ***Figure 11*** for the spatial distribution of the samples), including circumference at breast height (CBH) and height of all trees above 100 cm in the sample plots. More details regarding the allometric equation are presented in ***section b.2***.

The forest reference emission level proposed by Brazil in this submission uses the IPCC methodology as a basis for estimating changes in carbon stocks in forest land converted to other land-use categories as described in the GPG LULUCF (IPCC, 2003). For any land-use conversion occurring in a given year, GPG LULUCF considers both the carbon stocks in the biomass immediately before and immediately after the conversion.

Brazil assumes that the biomass immediately after the forest conversion is zero and does not consider any subsequent CO_2 removal after deforestation (immediately after the conversion or thereafter). This assumption is made since Brazil has a consistent, credible, accurate, transparent, and verifiable time-series for gross deforestation for the Legal Amazonia (and hence, for the Amazonia biome), but has limited information on subsequent land-use after deforestation.

The text that follows provides detailed information about the construction of Brazil´s forest reference emission level.

The basic data for estimating annual gross emissions from deforestation in the Amazonia biome derives from the analysis of remotely sensed data from sensors of adequate spatial resolution (mostly Landsat-5, of spatial resolution up to 30 meters). Images from the Landsat satellite acquired annually over the entire Amazonia biome (refer to ***Figure 4***), on as similar as possible dates (so as to avoid over or under estimating the deforestation) are selected, processed and visually interpreted to identify new deforestation increments (or deforested polygons) since the previous assessment (for details regarding the selection, processing and analysis phases, refer to ***Annex 1***).

[9] The RADAMBRASIL project was conducted between 1970 and 1985 and covered the entire Brazilian territory (with special focus in Amazonia) using airborne radar sensors. The results from RADAMBRASIL Project include, among others, texts, thematic maps (geology, geomorphology, pedology, vegetation, potential land use, and assessment of natural renewable resources), which are still broadly used as a reference for the ecological zoning of the Brazilian Amazonia.

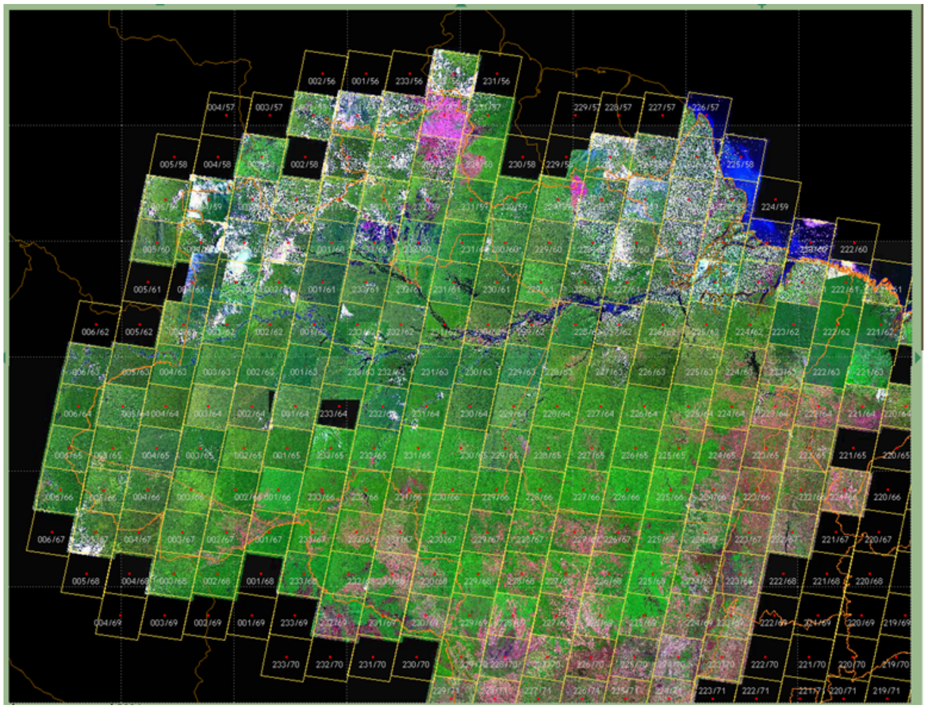

Figure 4: Landsat coverage of the Brazilian Legal Amazonia area. ***Source*****:** PRODES, 2014

Deforestation in the Amazonia biome is associated with a clear-cut pattern on primary forest cover (*i.e.*, areas of forest that have not been impacted by human activities or natural events, as far as these can be assessed using remotely sensed data).

The annual CO_2 emission from gross deforestation for any year is calculated as the sum of the CO_2 emission associated with each new deforestation increment.

For each deforested polygon *i*, the associated CO_2 emission is estimated as the product of its area and the associated carbon stock in the living biomass[10] present in the forest type affected by deforestation (refer to ***Equation 1***).

Equation 1:

$$GE_{i,j} = A_{i,j} \times EF_j \times 44/12 \qquad \textbf{\textit{Equation 1}}$$

where:

$GE_{i,j}$ = CO_2 emission associated with deforested polygon *i* under forest type *j*; tonnes of CO_2 (t CO_2)

$A_{i,j}$ = area of deforested polygon *i* under forest type *j*; hectares (ha)

[10] Living biomass, here, means above and below-ground biomass, including palms and vines, and litter mass.

EF_j = carbon stock in the living biomass of forest type *j* in deforested polygon *i* per unit area; tonnes of carbon per hectare (tC ha^{-1})

44/12 is used to convert tonnes of carbon to tonnes of CO_2

For any year *t*, the total emission from gross deforestation, GE_t, is estimated using **Equation 2**:

$$GE_t = \sum_{i=1}^{N}\sum_{j=1}^{p} GE_{i,j} \qquad \textbf{\textit{Equation 2}}$$

where:

GE_t = total emission from gross deforestation at year *t*; tonnes CO_2 (t CO_2)

$GE_{i,j}$ = CO_2 emission associated with deforested polygon *i* under forest type *j*; t CO_2

N = number of new deforested polygons in year *t* (from year t-1 and t); adimensional

p = number of forest types, adimensional

For any period *P*, the mean emission from gross deforestation, MGE_p, is calculated as indicated in ***Equation 3***:

$$MGE_P = \frac{\sum_{t=1}^{T} GE_t}{T} \qquad \textbf{\textit{Equation 3}}$$

where:

MGE_p = mean emission from gross deforestation in period *p*; t CO_2

GE_t = total emission from gross deforestation at year *t*; t CO_2

T = number of years in period *p*; adimensional.

The total emission from deforestation in the Amazonia biome for any year *t* is estimated using two layers of data in a Geographical Information System (GIS):

(1) a layer with the spatially explicit deforested polygons since the previous year (t-1); and

(2) a layer with the carbon density associated with distinct forest types in the Amazonia biome, referred in this submission as “carbon map”.

The carbon map is the same as that used to estimate emissions from forest conversion in the Second National Inventory (details of the carbon map are presented in ***section b.2***).

Figures 5 to ***Figure 7*** present the sequence to estimate the total emission from deforestation for any year in the period from 1996 to 2010, used in the construction of the FREL. Due to the fact the digital (georeferenced) information on the deforested polygons only became annually available from 2001 onwards; that for the period 1998-2000 inclusive, only an aggregated digital map with the deforestation increments for years 1998, 1999 ad 2000 is available; and that no digital information is available individually for years 1996 and 1997, the figures seek to clarify how the estimates of the total emissions were generated.

Step 1: available maps (in digital or analogical format) with deforestation increments for the period 1996 and 2010. Each one of these maps correspond to the layer indicated in (1) above, with the spatially explicit deforested polygons since the previous year (***t-1***).

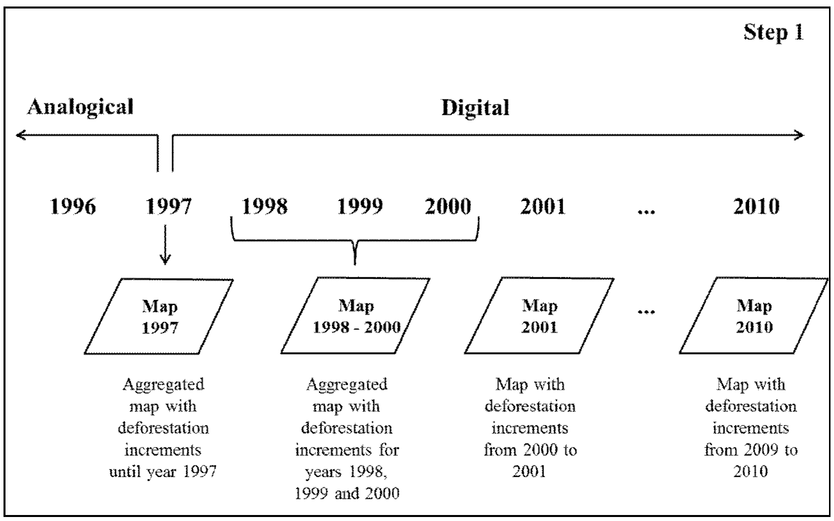

Figure 5: Pictoral representation of ***Step 1***.

Step 2 indicates the integration of layers (1) and (2) in a GIS (deforestation increments - layer (1), with the carbon map - layer (2)). For each year, this integration provides an estimate of the total emission in tonnes of carbon which, multiplied by 44/12, provides the total emissions in tonnes of CO_2.

For the period 1998-2000, the total CO_2 emissions refer to those associated with the aggregated deforestation increments for years 1998, 1999 and 2000 that, when divided by 3, provide the average annual CO_2 emission.

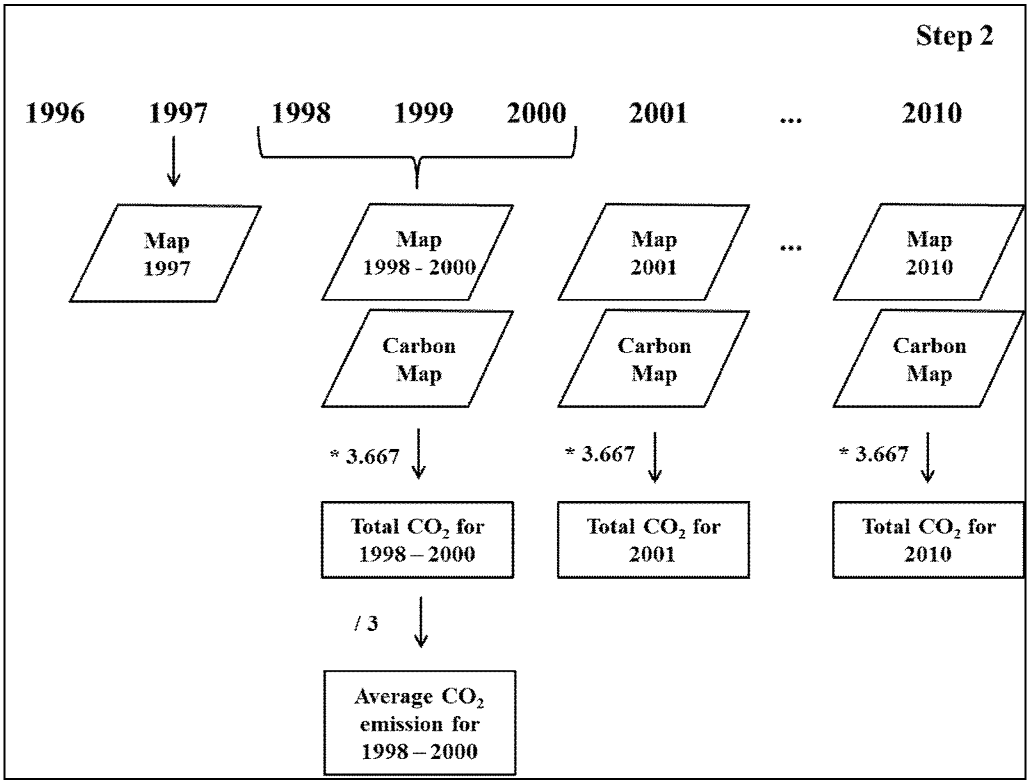

Figure 6: Pictoral representation of ***Step 2***.

Step 3 indicates the estimated CO_2 emissions for each year from 1998 (inclusive) until 2010; and ***Step 4*** indicates the CO_2 emissions for years 1996 and 1997.

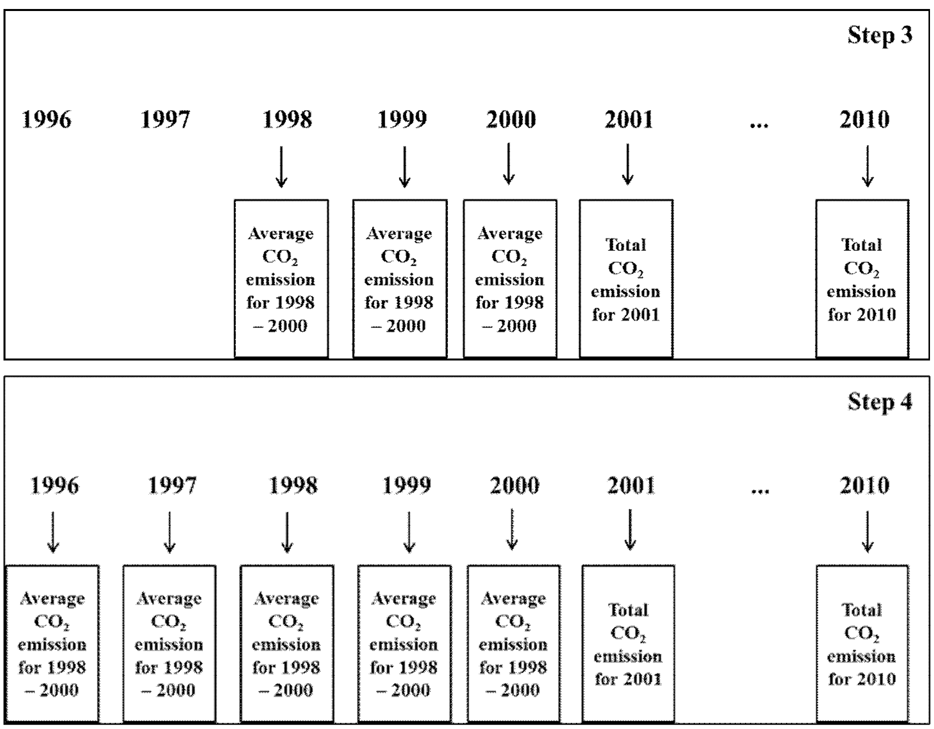

Figure 7: Pictoral representation of ***Step 3*** and ***Step*** 4.

Brazil´s Forest Reference Emission Level from gross deforestation in the Amazonia biome

The forest reference emission level proposed by Brazil is a dynamic mean of the CO_2 emissions associated with gross deforestation since 1996[11], updated every five years, using the best available historical data and consistent with the most recent National GHG Inventory submitted by Brazil to the UNFCCC at the time of the construction of the FREL.

This dynamic construct is meant to reflect the effects of policies and plans implemented in the Amazonia biome[12], as well as improvements in data quality and availability. **Brazil's forest reference emission level does not include assumptions on potential future changes to domestic policies.**

In summary, for results based payments the following applies:

- For results in the period from 2006 to 2010, inclusive, the FREL is equal to the mean annual CO_2 emissions associated with gross deforestation from the period 1996 to 2005, inclusive (refer to ***Figure 7, Figure 8*** and ***Table 1***).
- For results in the period from 2011 to 2015, inclusive, the FREL is equal to the mean annual CO_2 emissions associated with gross deforestation from 1996 to 2010, inclusive (refer to ***Figure 7, Figure*** and ***Table 1***).
- For results in the period from 2016 to 2020, the FREL is equal to the mean annual CO_2 emissions associated with gross deforestation from 1996 to 2015, inclusive.

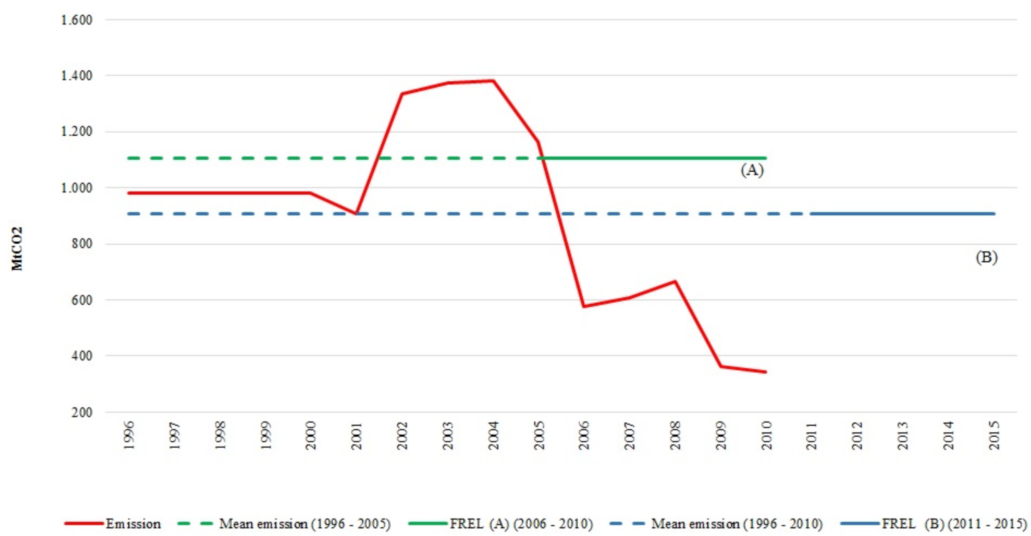

Figure 8. Figure 8: Pictoral representation of Brazil's Forest Reference Emission Level and annual emissions from gross deforestation from 1996 to 2010. FREL (A) refers to the mean annual CO_2 emissions from the period 1996 to 2005 (1,106,040,000 tCO_2); FREL (B) refers to the mean annual CO_2

[11] This year was chosen to leave out the high deforestation that occurred in 1995 and also to maintain consistency with other initiatives in Brazil (e.g. Amazon Fund (www.amazonfund.gov.br) and the National Climate Change Policy (Presidential Decree no. 7390 of December 9, 2010).

[12] For details regarding relevant policies and plans for the Amazonia biome, refer to ***Annex 1***.

emissions from the period 1996 to 2010 (907,970,000 tCO_2).

Table 1. Annual area deforested and associated mean CO_2 emissions from deforestation in the Amazonia biome from 1996 to 2010

YEAR	DEFORESTATION (km^2)	EMISSIONS FROM GROSS DEFORESTATION (t CO_2)
1996	18,740	979,612,461
1997	18,740	979,612,461
1998	18,740	979,612,461
1999	18,740	979,612,461
2000	18,740	979,612,461
2001	19,493	909,046,773
2002	24,666	1,334,578,771
2003	25,588	1,375,348,234
2004	24,794	1,380,266,413
2005	21,762	1,163,979,146
2006	10,336	576,149,498
2007	10,874	608,321,694
2008	12,330	666,065,861
2009	5,963	364,373,599
2010	5,831	344,437,822
1996 – 2005	---	1,106,040,000 (FREL (A))
1996 - 2010	---	907,970,000 (FREL (B))

Note: The figures presented in this table refer to deforestation increments in the Amazonia biome. Those from PRODES relate to deforestation rates for the Legal Amazonia. The grey lines in this table correspond to years for which data are not available from Digital PRODES. For any year in the period from 1996 to 2010, the CO_2 emissions presented here have been calculated following ***Steps 1-4*** in ***Figures 5 to 7.*** INPE has submitted a project proposal to the Amazon Fund to expand Digital PRODES to years before 2001 which, if approved, will lead to more precise estimates.

b) Transparent, complete, consistent and accurate information used in the construction of the forest reference emission level

b.1. Complete Information

Complete information, for the purposes of REDD+, means the provision of information that allows for the reconstruction of the forest reference emission level.

For developing the forest reference emission level for each year of the period for which results-based payments are sought (2006 – 2010), the following data and information for the Amazonia biome were used and are made available for download through the website (http://www.mma.gov.br/redd/):

(1) All the satellite images used for any particular year in the period 1996 to 2010 to map the deforestation increments in the Amazonia biome (in geotiff format in full spatial resolution).

(2) Aggregated deforestation increments mapped until 1997 (inclusive), to be referred to as the ***digital base map*** (see ***Annex 1*** for more details).

(3) Aggregated deforestation increments for years 1998, 1999 and 2000 on the ***digital base map***; and annual deforestation increments from 2001 to 2010, inclusive (***annual maps***). All the data are provided in shapefile/ ESRI format.

> **IMPORTANT REMARK 1:** The information in all maps and the satellite images are available in formats ready to be imported into a Geographical Database for analysis. This implies that any individual deforestation increment in any of the above mentioned maps can be validated against the satellite image. The areas (individually per increment and total) can also be calculated.
>
> **IMPORTANT REMARK 2:** The maps referred in (2) and (3) above are a subset of those produced by INPE as part of the Amazonia Program (refer to ***Annex 1*** for additional information about PRODES). Since 2003, all maps for the time series of gross deforestation for 1997-2000 (aggregated) and yearly thereafter are made available at INPE's website for the Legal Amazonia **(**http://www.obt.inpe.br/prodes/index.php). The data provided in (2) and (3) refer only to the Amazonia biome that, as a subset of a larger set, are also available.

(4) The area of annual gross deforestation from 1996 until 2010.

> **IMPORTANT REMARKS** for (3) and (4): The data sets and methods used in the construction of the forest reference emission level are available from public sources. Since 2003 INPE makes available the annual gross deforestation rate for the Legal Amazonia on its website, along with all the satellite imagery used to identify the deforestation increments and the corresponding map with the spatially explicit location of the deforested polygons.

(5) A map with the carbon densities of different forest physiognomies in the Amazonia biome (carbon map), consistent with that used in the Second National Inventory, the latest submitted by Brazil to the UNFCCC at the time of construction of the forest reference emission level (refer to ***footnote 9***).

(6) Relevant data collected by RADAMBRASIL used as input in the allometric equation used to estimate the carbon density of the different forest types considered.

b.2. Transparent information

A detailed description of the items indicated above is now provided.

Regarding (1):

Since the beginning of 2003, INPE adopted an innovative policy to make satellite data publicly available online. The first step in this regard was to make available all the satellite images from the China-Brazil Earth Resources Satellite (CBERS 2 and CBERS

2B) through INPE's website (http://www.dgi.inpe.br/CDSR/). Subsequently, data from the North American Landsat satellite and the Indian satellite Resourcesat 1 were also made available. With this policy INPE became the major distributor of remotely sensed data in the world.

Regarding (2) and (3):

All deforestation increments and annual PRODES estimates of gross deforestation in the Legal Amazonia are publicly available since 2003 at INPE´s website (www.obt.inpe.br/prodes).

For each satellite image used (see (1) above), a vector map in Shape File/ESRI format is generated and made available, along with all the previous deforestation polygons, the areas not deforested, the hydrology network and the area of non-forest. This information is provided for each State of the Federation and for Legal Amazonia. Summary data at municipality level can also be generated. ***Figure 9*** shows the screen as viewed by the users when accessing INPE´s website to download images and data.

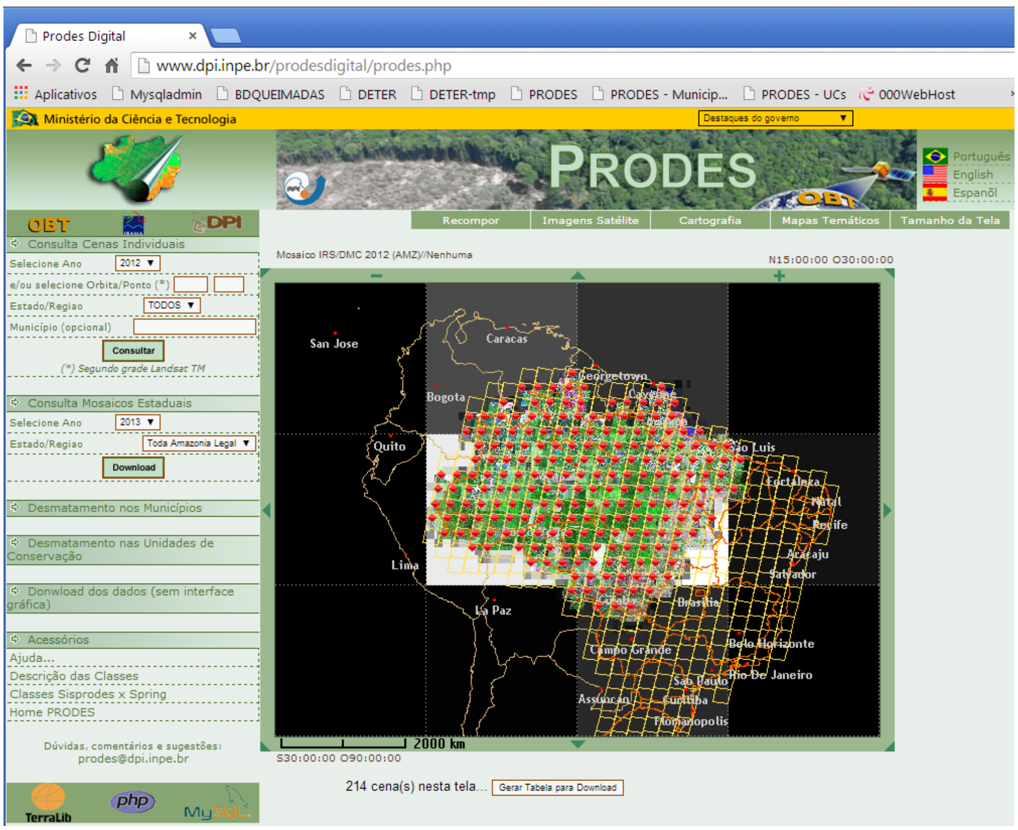

Figure 9. A sample of a window to download the information generated by PRODES. ***Source:*** *www.obt.inpe.br/prodes*

Regarding (4):

The total area of annual deforestation increments for the Amazonia biome for each year in the period from 1996 to 2010 is provided in ***Table 1***.

Regarding (5):

The map with the biomass density of living biomass (including palms and vines) and litter mass used to estimate the CO_2 emissions necessary in the construction of the FREL (***carbon map***) is the same as that used in the Second National Inventory to estimate CO_2 emissions from conversion of forest to other land-use categories.

As already mentioned, it was constructed using an allometric equation by Higuchi *et al*. (1998) and data (diameter at breast height derived from the circumference at breast height) collected by RADAMBRASIL on trees in the sampled plots. The data collected by RADAMBRASIL were documented in 38 volumes distributed as shown in ***Figure 10*** over the RADAMBRASIL vegetation map (refer to ***footnote 9***). The CBH of all trees sampled and the corresponding latitude-longitude information are provided for each volume within the Amazonia biome.

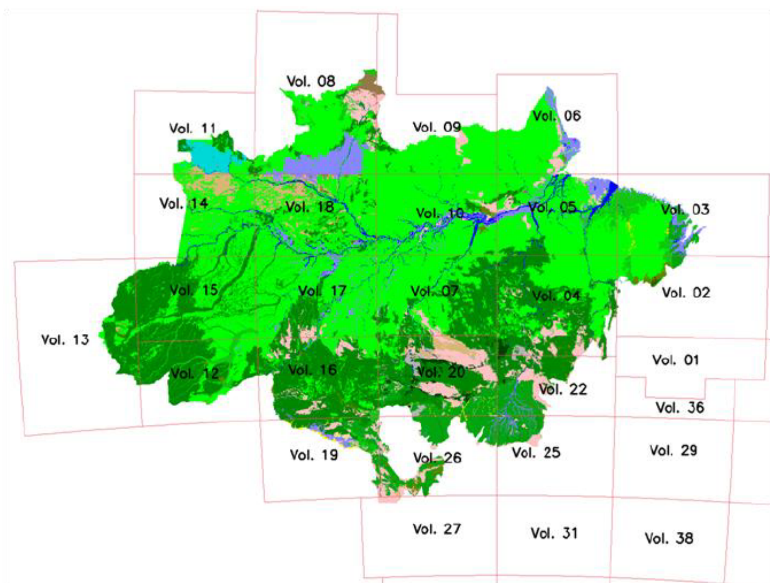

Figure 10: RADAMBRASIL Vegetation map with the distribution of the 38 volumes in the Amazonia biome. ***Source***: BRASIL, 2010.

The RADAMBRASIL sample plots in the rainforest (*Ombrophyllous Forest*) consisted of transects of 20 meters by 500 meters (hence, area of 1 hectare); and for the other forest types, transects of size 20 by 250 meters (hence, half hectare). ***Figure 11*** presents the distribution of the sample plots in the biome Amazonia.

RADAMBRASIL collected data on trees in 2.292 sample plots. For the Second National Inventory, sample plots were eliminated if:

- after the lognormal fit, the number of trees per sample unit contained less than 15 or more than 210 trees (less than 1 per cent of the samples);
- the forests physiognomies were not found in the IBGE (Brazilian Institute for Geography and Statistics) charts;
- no geographical information on the location of the sample unit was available.

The application of this set of rules led to the elimination of 582 sample plots from analysis (BRASIL, 2010).

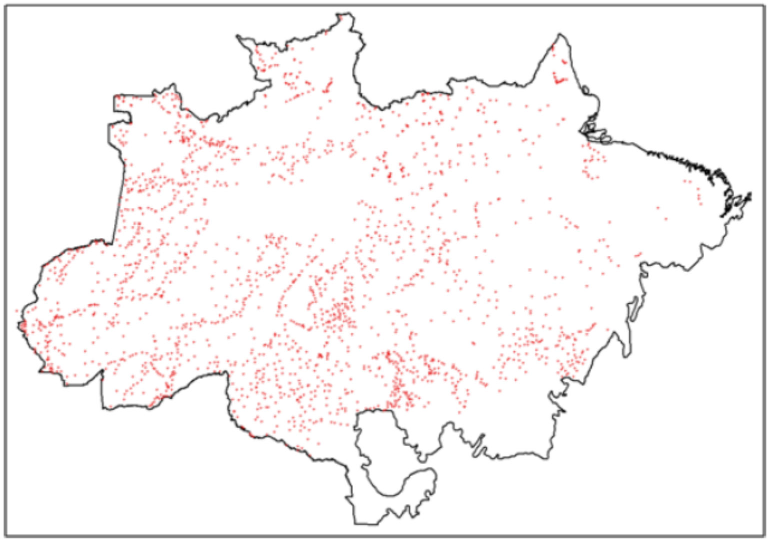

Figure 11. Distribution of the RADAMBRASIL forest inventory plots. ***Source:*** BRASIL, 2010

To facilitate the understanding regarding the construction of the carbon map, the steps are summarized below:

1. Definition of the forest physiognomies in the Amazonia biome.
2. Identification of RADAMBRASIL samples in the RADAMBRASIL vegetation map.
3. Allometric equation used to estimate aboveground fresh mass from DBH.
4. Conversion of aboveground fresh mass to dry mass and then carbon in dry mass.
5. Inclusion of the carbon from trees with CBH less than 100 cm (considering that RADAMBRASIL collected data only on trees with CBH larger than 100 cm).
6. Inclusion of carbon in palms and vines.
7. Inclusion of carbon in belowground biomass and litter.
8. Application of extrapolation rules to estimate the carbon density associated with the forest physiognomies in each volume of RADAMBRASIL, noting that the same physiognomy in different volumes may have different values.
9. Literature review to estimate the carbon in forest physiognomies not sampled by RADAMBRASIL.

Each of the above steps is now detailed.

Step 1: Definition of the forest physiognomies in the Amazonia biome.

The forest physiognomies in the Amazonia biome have been defined taking into account the availability of reliable data, either from RADAMBRASIL or from the literature to estimate its associated carbon density. As such, twenty two forest typologies[13] (forest types) were considered, consistent with both the forest types in the Initial and Second National Inventories of Greenhouse Gases submitted by Brazil to the UNFCCC. ***Table 2*** provides the list of physiognomies.

Table 2: Forest typologies considered in the Amazonia biome.

Description (IBGE Vegetation Typologies)	
Aa	Aluvial Open Humid Forest
Ab	Lowland Open Humid Forest
As	Submontane Open Humid Forest
Cb	Lowland Deciduos Seasonal Forest
Cs	Submontane Deciduous Seasonal Forest
Da	Alluvial Dense Humid Forest
Db	Lowland Dense Humid Forest
Dm	Montane Dense Humid Forest
Ds	Submontane Dense Humid Forest
Fa	Alluvial Semi deciduous Seasonal Forest
Fb	Lowland Semi-deciduous Seasonal Forest
Fm	Montane Semi-deciduous Seasonal Forest
Fs	Submontane Semi deciduous Seasonal Forest
La	Forested Campinarana
Ld	Wooded Campinarana
Pa	Vegetation with fluvial influence and/or lake
Pf	Forest Vegetation Fluviomarine influenced
Pm	Pioneer influenced Marine influenced
Sa	Wooded Savannah
Sd	Forested Savannah
Ta	Wooded Steppe Savannah
Td	Forested Steppe Savannah

Step 2: Identification of RADAMBRASIL samples in the RADAMBRASIL vegetation map.

The information collected by RADAMBRASIL on the sample plots (refer to ***Figure 11***) did not include the associated forest typology. It did, however, include the coordinates

[13] Also referred to in this document as forest types or forest physiognomies.

of the sampled trees which, when plotted against the RADAMBRASIL vegetation map, led to the identification of the corresponding forest type. Data from RADAMBRASIL sample plots did not cover all 22 forest types, as indicated in ***Table 3***.

Table 3: Identification of the Forest Types sampled by RADAMBRASIL.

Description (IBGE Vegetation Typologies)		**Source**
Aa	Aluvial Open Humid Forest	RADAMBRASIL
Ab	Lowland Open Humid Forest	RADAMBRASIL
As	Submontane Open Humid Forest	RADAMBRASIL
Cb	Lowland Deciduos Seasonal Forest	
Cs	Submontane Deciduous Seasonal Forest	
Da	Alluvial Dense Humid Forest	RADAMBRASIL
Db	Lowland Dense Humid Forest	RADAMBRASIL
Dm	Montane Dense Humid Forest	RADAMBRASIL
Ds	Submontane Dense Humid Forest	RADAMBRASIL
Fa	Alluvial Semi deciduous Seasonal Forest	
Fb	Lowland Semi-deciduous Seasonal Forest	
Fm	Montane Semi-deciduous Seasonal Forest	
Fs	Submontane Semi deciduous Seasonal Forest	
La	Forested Campinarana	RADAMBRASIL
Ld	Wooded Campinarana	RADAMBRASIL
Pa	Vegetation with fluvial influence and/or lake	
Pf	Forest Vegetation Fluviomarine influenced	
Pm	Pioneer influenced Marine	
Sa	Wooded Savannah	
Sd	Forested Savannah	
Ta	Wooded Steppe Savannah	
Td	Forested Steppe Savannah	

Step 3: Allometric equation used to estimate aboveground fresh mass from DBH.

The allometric equation used in the construction of the carbon map (Higuchi et al., 1994)[14] is applied according with the diameter at breast height (DBH)[15] of the sampled trees, as indicated in ***Equation 4*** and ***Equation 5*** below:

For 5 cm $\leq$ DBH < 20 cm

$$\ln P = -1.754 + 2.665 \times \ln DBH \qquad \textbf{\textit{Equation 4}}$$

For DBH $\geq$ 20 cm

[14] Higuchi, N.; dos Santos, J.; Ribeiro, R.J.; Minette, L.; Biot, Y. (1998) Biomassa da Parte Aérea da Vegetação da Floresta Tropical Úmida de Terra-Firme da Amazônia Brasileira - Niro Higuchi, Joaquim dos Santos, Ralfh João Ribeiro, Luciano Minette, Yvan Biot. Acta Amazonica 28(2):153-166.

[15] For the conversion of CBH to DBH, the CBH was divided by 3.1416.

$$\ln P = -0.151 + 2.170 \times \ln DBH \qquad \textbf{\textit{Equation 5}}$$

where:

P = aboveground fresh biomass of a sampled tree; kilogram (kg of fresh biomass);

DBH = diameter at breast height of the sampled tree; centimeters (cm).

Step 4: Conversion of aboveground fresh mass to dry mass and then to carbon in dry mass.

For each sampled tree, the associated carbon density in the aboveground dry biomass was calculated from the aboveground fresh biomass of the tree using either **Equation 4** or **Equation 5** above, applying **Equation 6**:

$$C_{(CBH > 100\ cm)} = 0.2859 \times P \qquad \textbf{\textit{Equation 6}}$$

where:

P = aboveground fresh biomass of a sampled tree; (kg of fresh biomass);

$C_{(CBH > 100\ cm)}$ = carbon in the aboveground dry biomass of a tree with CBH>100cm; kilogram of carbon (kg of C).

> **Important remarks:** the value 0.2859 is applied to convert the aboveground fresh biomass to aboveground dry biomass; and from aboveground dry biomass to carbon. Silva (2007) updated Higuchi *et al.*(1994) values for the average water content in aboveground fresh biomass and the average carbon fraction of dry matter, but the values are still very similar. Silva's (2007) values are 0,416 (± 2.8 per cent) and 0,485 (±0.9 per cent), respectively. Hence, in 100 kg of aboveground fresh biomass there is 58.4 kg of aboveground dry matter and 28.32 kg of carbon in aboveground dry biomass. The IPCC default values are 0.5 tonne dry matter/ tonne fresh biomass (IPCC 2003); and 0.47 tonne carbon/ tonne dry matter (IPCC 2006, Table 4.3), respectively.

The carbon density of all trees in a sample unit was summed up and then divided by the area of the sample unit (either 1 hectare or half hectare, depending on the type of forest) to provide an estimate of the average carbon stock in aboveground biomass for that sample, $AC_{(CBH>100cm)}$.

Step 5: Inclusion of the carbon density of trees with CBH less than 100 cm.

Due to the fact that the RADAMBRASIL only sampled trees with circumference at breast height (CBH) above 100 cm (corresponding to diameter at breast height of 31.83 cm), an extrapolation factor was applied to the average carbon stock of each sampled unit to include the carbon of trees with CBH smaller than 100 cm. This was based on the extrapolation of the histogram containing the range of CBH values observed in all sample units and the associated total number of trees (in intervals of 10 cm).

Figure 12 show the histograms used and the observed data (CBH and associated total number of trees), as well as the curves that best fit the observed data (shown in green). The extrapolation factor was applied to the average carbon stock in each sample plot, $AC_{(CBH > 100\ cm)}$, as indicated by **Equation 7**.

$$C_{(total)} = 1.315698 \times AC_{(CBH > 100\ cm)} \qquad \textbf{\textit{Equation 7}}$$

where*:*

$C_{(total)}$ = total carbon stock of all trees in a sample unit; tC/ha;

$AC_{(CBH > 100\ cm)}$ = average carbon stock in a sample unit from trees with CBH > 100 cm; tC/ha.

Important remarks: the adequacy of this extrapolation was verified comparing data (biomass of trees in experimental areas in Amazonia) in a study by Higuchi (2004). In this study, the relationship between the aboveground biomass of all trees with DBH < 20 cm and those with DBH > 20 cm varied between 3 and 23 per cent, depending on the area. The average value was 10.1 per cent. On the other hand, applying the methodology presented here (developed by Meira Filho (2001), available in BRASIL, 2010) for DBH=20 cm (instead of CBH equals to 100 cm), the value 9.4 per cent is obtained, consistent with the value found by Higuchi (2004).

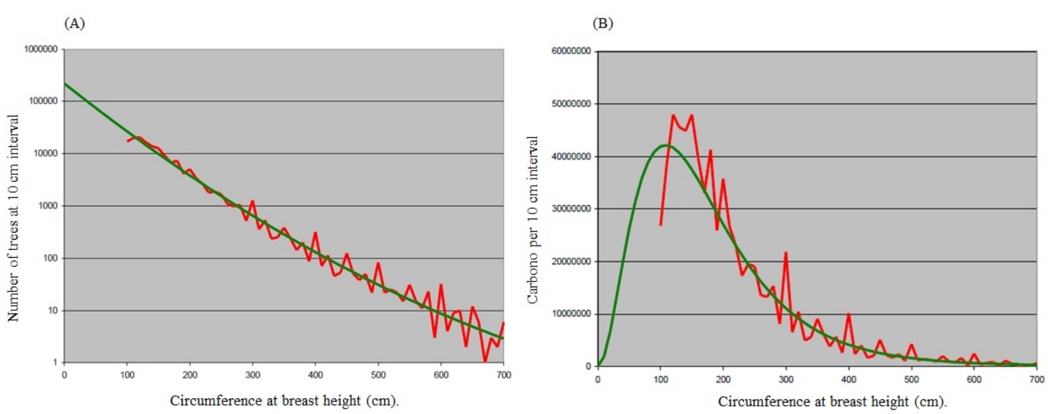

Figure 12. Histogram and observed data and histogram with carbon values in the aboveground biomass in Amazonia biome, per CBH. ***Source:*** BRASIL, 2010, from BRASIL 2004 (developed by Meira Filho and Higuchi) **Note:** The red line represents observed data and the green line the adjusted information.

Step 6: Inclusion of carbon in palms and vines.

In addition to the biomass from trees in the sampled units (regardless of their DBH value), the biomass from palms and lianas, normally found in the Amazonia biome, have also been included. This inclusion, in fact, was a response to the public consultation conducted for the First National Inventory, part of the Initial National

Communication of Brazil to the UNFCCC. Silva (2007) has estimated that the biomass of palms and lianas represent 2.31 and 1.77 per cent of the total aboveground biomass.

Hence, these values have been applied to $C_{(total)}$ to obtain the total aboveground carbon in the sample as shown in **Equation 8**:

$$C_{aboveground} = 1.3717 \times AC_{(CBH > 100\ cm)} \qquad \textbf{\textit{Equation 8}}$$

where:

> $C_{aboveground}$ = the carbon stock in aboveground biomass in a sample unit (from all trees, lianas, palms), tC ha^{-1};
>
> $AC_{(CBH > 100\ cm)}$ = average carbon stock in a sample unit from trees with CBH > 100 cm; tC ha^{-1}.

Step 7: Inclusion of carbon in belowground biomass and litter.

In addition, Silva (2007) estimated that the contribution of thick roots and litter in the fresh weight of living vegetation was 27.1 per cent (or 37.2 of the aboveground weight) and 3.0 per cent, respectively. When the carbon from these pools is considered, **Equation 9** provides the total carbon stock in the sample unit:

$$C_{total,\ SU} = 1.9384 \times AC_{(CBH > 100\ cm)} \qquad \textbf{\textit{Equation 9}}$$

where*:*

> $C_{total,\ SU}$ = total carbon stock in living biomass (above and below-ground) for all trees, lianas and palms in the sample unit; tC ha^{-1};
>
> $AC_{(CBH > 100\ cm)}$ = average carbon stock in a sample unit from trees with CBH > 100 cm; tC ha^{-1}.

Step 8: Application of extrapolation rules to estimate the carbon density associated with forest physiognomies in each volume of RADAMBRASIL.

The application of ***Steps 3 to 7*** produces estimates of carbon density in living biomass (including palms and vines) and litter mass for the data collected by RADAMBRASIL. These sample estimates, gathered from different forest physiognomies in different locations, did not necessarily cover every vegetation physiognomies in each RADAMBRASIL volume (see ***Figure 10***).

Hence, a set of rules were created to allow for the estimation of carbon densities for each vegetation physiognomy considered. This set is as follows:

- **Rule 1.** For a given forest type in a specific RADAMBRASIL volume, if there were corresponding sample plots (where Steps 3 to 7 are applied to each tree to estimate the associated carbon density), the carbon density for that forest type was calculated as the average of the average carbon density associated with sample plots. For instance, suppose that volume v has 2 sample plots (sample plot 1, with 60 trees, and sample plot 2, with 100 trees) associated with forest type Aa. For sample plot 1, the average of the 60 carbon densities was calculated, say ASP1; for sample plot 2, the average of the 100 trees was also calculated, say ASP2. The carbon density for forest type Aa in volume 1 was then calculated as (ASP1+ ASP2)/2 (in green on ***Table 4***).

- **Rule 2.** For a given forest type in a specific RADAMBRASIL volume, if there were no corresponding sample plots in that volume, then the carbon density for that forest type was calculated as the weighted average (by number of samples per sample plot) of the average carbon density for each sample plot in the neighboring volume(s) (using a minimum of one and maximum of eight volumes).For instance, suppose that volume v has neighboring volumes v1, v2 and v3 with 2, 5 and 3 sample plots associated with forest type Aa. For each sample plot, an average carbon density, say ASP1, ASP2 and ASP3, was calculated as in Rule 1 above. The carbon density for forest type As in volume v, was then calculated as follows: (2* ASP1 + 5*ASP2 + 3* ASP3)/10 (in blue on ***Table 4***).
- **Rule 3.** For a given forest type in a specific RADAMBRASIL volume, if there were no corresponding sample plots in that volume nor in the neighboring volumes, but there are samples plots in the neighbors to the neighboring volumes (second order neighbors), then the average carbon stock for that forest type in the specific volume is the average of the average carbon density calculated from the second order neighbors. For instance, assume that there are no sample plots associated with forest type Aa in volume v and its neighboring volumes v1, v2 and v3, and that volumes v4, v5, v6 , v7 and v8 (second order neighbors) have 2, 4, 6, 3 and 5 sample plots associated with forest type Aa. Then, the carbon density for forest type in volume v was calculated applying Rule 2 to the second order neighbors (in pink on ***Table 4***).

This set of rules originated the carbon densities for the forest types identified as RADAMBRASIL in ***Table 4***.

Table 4: Carbon densities in living biomass (aboveground and belowground, including palms and vines; and litter mass) for the Amazonia biome, following the set of rules in ***Step 8***. ***Note:*** Rule one: green, Rule 2: blue, Rule 3: pink. ***Source:*** BRASIL, 2010

RADAMBRASIL Volume	Forest Fisionomy								
	Aa	Ab	As	Da	Db	Dm	Ds	La	Ld
2	98.24	154.55	110.06	182.98	176.10	139.03	169.35	183.00	
3	98.24	154.55	129.28	137.85	161.01	139.03	275.37	183.00	
4	94.88	154.55	129.28	119.67	154.59	139.03	148.30	183.00	
5	108.33	154.55	146.82	213.85	185.15	109.69	230.13	183.00	
6	123.75	154.55	133.99	131.82	222.39	109.69	213.55	183.00	
7	159.51	160.29	180.66	142.58	153.42	139.03	175.71	262.99	
8	146.97	197.91	73.64	270.89	163.92	149.50	138.56	183.00	183.00
9	127.61	213.37	112.13	262.68	157.38	109.69	184.64	262.99	
10	141.81	169.49	146.45	174.03	149.54	147.77	171.21	262.99	262.99
11	154.71	197.91	158.20	166.72	168.13	83.74	144.81	114.31	114.31
12	144.32	150.69	116.14	164.35	157.42	139.03	161.84	183.00	
13	144.76	144.62	139.24	168.64	153.25	104.05	121.02	160.43	160.43
14	154.71	177.28	173.89	157.86	174.17	104.05	142.46	160.43	160.43
15	172.81	164.36	156.03	171.77	154.38	104.05	155.40	228.80	
16	165.70	136.14	156.76	175.73	188.14	139.03	175.02	183.00	
17	136.09	159.17	157.15	175.64	165.53	104.05	159.63	228.80	
18	162.92	213.37	150.61	174.79	158.01	139.03	140.48	262.99	262.99
19	150.22	147.92	135.72	170.56	159.40	139.03	154.78	183.00	
20	150.61	151.80	117.97	169.39	163.05	139.03	123.29	183.00	183.00
22	148.74	154.55	97.40	137.67	153.42	139.03	145.55	183.00	
25	155.84	154.55	113.12	172.77	162.51	139.03	127.87	183.00	
26	165.70	136.14	130.49	175.73	188.14	139.03	153.93	183.00	

__***Step 9:*** Literature review to estimate the carbon in forest physiognomies not sampled by RADAMBRASIL to fill in gaps from RADAMBRASIL__

A literature review was conducted to fill in the gaps for which RADAMBRASIL had not estimated the associated carbon density. ***Table 5*** presents the carbon density estimated from the literature and makes reference to the literature used.

The weighted average carbon stock is 151.6 tC ha-1. Eighty-four per cent of the carbon density of the forest types defined for the Amazonia biome was estimated using sample data from RADAMBRASIL. The remaining 16 per cent were derived from literature review.

Table 5: Carbon density for the vegetation typologies in the Amazonia biome estimated from the literature and the indication of the references used

Description (IBGE Vegetation Typologies)		**tC ha^{-1}**	**Reference***
Cb	Lowland Deciduos Seasonal Forest	116.27	1
Cs	Submontane Deciduous Seasonal Forest	116.27	1
Fa	Alluvial Semi deciduous Seasonal Forest	140.09	2
Fb	Lowland Semi-deciduous Seasonal Forest	140.09	2
Fm	Montane Semi-deciduous Seasonal Forest	140.09	2
Fs	Submontane Semi deciduous Seasonal Forest	140.09	2
Pa	Vegetation with fluvial influence and/or lake	105,64	2
Pf	Forest Vegetation Fluviomarine influenced	98,16	2
Pm	Pioneer influenced Marine influenced	94,48	2
Sa	Wooded Savannah	47,1	3
Sd	Forested Savannah	77,8	3
Ta	Wooded Steppe Savannah	14,41	4
Td	Forested Steppe Savannah	30,1	4

Note*:

1 Britez, R.M. et al. (2006)

2 Barbosa, R.I. and Ferreira, C.A.C (2004)
Barbosa, R.I. and Fearnside, P.M. (1999)

3 Abdala, G. C. et. Al.., 1998
Andrade, L. A.; Felfili, J. M.; Violati, L., 2002
Araújo. L. S., 2010
Araújo, L. S. et al., 2001
Barbosa, R. I. & Fearnside, P. M., 2005
Batalha, M.A., Mantovani, W & Mesquita Junior, 2001
Bustamante, M. M. da C. & Oliveira, E. L. de, 2008
Castro, E. A., 1996
Castro, E. A., & Kauffman, J. B., 1998
Costa, A. A. & Araújo, G. M., 2001
Delitti, W. B. C. & MEGURO, M., 2001
Delitti, W. B. C.. Pausas, J. & Burger, D. M. 2001
Delitti, W. B. C., Meguro, M. & Pausas, J. G., 2006
Durigan, G., 2004
Fearnside, P. M. et al., 2009
Fernandes, A. H. B. M., 2008
Gomes, B. Z., Martines, F. R. & Tamashiro, J. Y., 2004
Grace, J. et al., 2006
Kauffman, J. B., Cummings & D. L. & Whard, D. E., 1994

Kunstchik, G., 2004
Meira Neto, J. A. A. & Saporeti-Junior, A. W., 2002
Martins, O. S., 2005
Ottmar, R. D. et al., 2001
Paiva, A. O. & Faria, G. E., 2007
Pinheiro, E. da S., Durigan, G. & Adami, M., 2009
Resende, D., Merlin, S. & Santos, M. T., 2001
Ronquim, C. C., 2007
Salis, S. M., 2004
Santos, J. R., 1988
Santos, J. R. et al., 2002
Schaefer, C. E. G. et al., 2008
Silva, F. C., 1990
Silva, R. P., 2007
Vale, A. T. do & Felfili, J. M., 2005
Valeriano, D. M. & Biterncourt-Pereira, M. D., 1988

4 Fearnside, P.M. et al., 2009
Barbosa, R.I. and Fearnside, P.M., 2005
Graça, P.M.L.A. (1997) apud Fernside (2009)

All the data used to construct the forest reference emission level made available with this submission should allow for the reconstruction of the deforestation increments for years 1998-2000 and annually thereafter; and the map with the carbon densities associated with the forest physiognomies aggregated for the Amazonia biome for each RADAMBRASIL volume in the biome.

Hence, Brazil considers the information provided in this submission to be complete and transparent.

b.3. Consistency

Paragraph 8 in Decision 12/CP.17 requires that the forest reference emission levels shall maintain consistency with anthropogenic forest related greenhouse gas emissions by sources and removals by sinks as contained in the country's national greenhouse gas inventory. Brazil applied the IPCC definition of consistency (IPCC, 2006)[16], meaning that the same methodologies and consistent data sets are used to estimate emissions from deforestation in the reference level construction and in the national inventory.

At the onset, Brazil clarifies that the estimation of emissions by sources and removals by sinks in the Second National Inventory followed the methodological guidance in the IPCC Good Practice Guidance for Land Use, Land-use Change and Forestry (IPCC, 2003). Moreover, Brazil adopted approach 3 for land representation, meaning that all the land conversions and lands remaining in a same land category between inventories are spatially explicit. The basis for all activity data in the Second National Inventory as well as the assessment of deforestation for the purposes of this submission rely on the use of remotely sensed data of same spatial resolution (Landsat-class, up to 30 meters).

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[16] Consistency means that an inventory should be internally consistent in all its elements over a period of years. An inventory is consistent if the same methodologies are used for the base year and all subsequent years and if consistent data sets are used to estimate emissions or removals from sources or sinks. An inventory using different methodologies for different years can be considered to be consistent if it has been estimated in a transparent manner taking into account the guidance in Volume 1 on good practice in time series consistency (IPCC Glossary, 2006).

Also, the same national institutions and the same team engaged in the development of the LUCF estimates in the First National Inventory and LULUCF estimates in the Second National Inventory are in charge of the PRODES area estimates, ensuring an even greater consistency between the estimates for the national inventory and those used for the generation of the PRODES data, which are the basis for estimating the gross emissions from deforestation for the Amazonia biome reported here. Furthermore, the experts from the institutions responsible for the development of the National GHG Inventory and the PRODES data are also part of the technical team that supported the development of this FREL submission and its quality control.

It is to be noted that the reporting of LULUCF under Brazil's Second National Inventory covered the period 1994 to 2002 and incorporated some improvements relative to the Initial Inventory (1990-1994). The Second Inventory includes land-use transition areas and net CO_2 emissions for each individual biome from 1994 to 2002. Hence, the figures provided in the inventory[17] for the area deforested in both managed and unmanaged forest land represent the area converted or maintained in the same land category for the 8-years between the 1994 and 2002.

In addition, the figures provided in the Second National Inventory took into account both the emissions from the conversion to a new land-use category as well as removals from this new category. The Amazonia biome data presented in this submission refers only to gross data. The emissions associated with forestland converted to other land uses in the National Inventory and for deforestation in this submission are based on the same carbon map as introduced in ***section b.2*** (***Steps 1 to 6***).

Hence, Brazil considers that consistency is fully maintained between the emissions reported in the Second National Inventory and those used to construct the proposed forest reference emission level.

b.4. Accuracy

b.4.1. Activity Data

The definition of deforestation adopted for PRODES, i.e., clear cut, in conjunction with wall-to-wall annual assessment of deforestation based on satellite imagery of high spatial resolution (up to 30 meters) allows deforestation increments to be mapped with very high accuracy. No ground truth is required due to the unequivocal identification of the clear cut patches characteristic of deforestation in the Landsat imagery. Only new increments of deforestation are added since these are mapped on the aggregated deforestation map containing all deforestation up to the previous year.

In addition, with the advent of new processing tools and greater availability of satellite data at lower cost, the observed observation gaps from Landsat imagery due to the presence of clouds are replaced by imagery from similar spatial resolution satellites (Resourcesat, DMC, CBERS), so as to have a coverage of the Amazonia biome that is as comprehensive as possible every year.

Note that all the land defined as forest land, regardless of being managed or unmanaged according to the managed land definition by the IPCC 2006 Guidelines is included in the assessment. Hence, even if a clear cut on unmanaged land is identified, it

[17] Table 3.97 (Land-use transition areas identified in the Amazon biome from 1994 to 2002) and Table 3.98 (Net CO_2 emissions in the Amazon biome from 1994 to 2002).

automatically becomes part of the managed forest land database, adding to the total area deforested. Regardless of the fate of the clear cut patches on unmanaged land (converted or not converted to other land-use categories), the area is added to the total area deforested in the year that clear cut occurs.

Finally, the fact that PRODES is conducted by a consistent team of technicians every year and is subject to rigorous quality control and quality assurance by INPE´s researchers adds to the accuracy of the activity data, estimated by expert judgement to be around 5 per cent.

b.4.2. Emission Factors

The emission factors used in the construction of the forest reference emissions level are the carbon stocks in the living biomass (including palms and lianas) and litter mass, as contained in the carbon map used by Brazil on its Second National Inventory (refer to ***section b.1*** and the carbon map for the Amazonia biome).

Brazil does not yet have a nationally wide forest inventory in place. However, some States have already implemented their forest inventory following the National Forest Inventory (NFI) design developed jointly by the Brazilian Forest Service (SFB, Serviço Florestal Brasileiro) of the Ministry of the Environment of Brazil (MMA) and the Food and Agriculture Organization of the United Nations (FAO)[18].

Hence, the carbon map, as already mentioned, uses an extensive set of ground data collected in the mid-70s in the Amazonia biome and an allometric equation developed by Higuchi *et al*. (1998) to relate aboveground fresh biomass with carbon densities using updated values (da Silva, 2007) for the average water content in fresh aboveground biomass and the average carbon content in dry aboveground biomass).

The uncertainties associated with the water and carbon content in fresh and dry biomass have been estimated by Silva (2007).

(1) The average water content of 41.6 percent represents the weighted average of water in the following components from trees: (1) trunk (water content of 38.8 per cent and contribution to total biomass of 58.02 per cent); (2) thick branch (water content of 40.6 per cent and contribution to total biomass of 12.48 per cent); (3) thin branch (water content of 44.9 per cent and contribution to total biomass of 12.78 per cent); (4) leaves (water content of 59.7 per cent and contribution to total biomass of 2.69 per cent); (5) thick roots (water content of 48.9 per cent and contribution to total biomass of 3.06 per cent); (6) thin roots (water content of 44.5 per cent and contribution to total biomass of 11.59 per cent). The 95 per cent confidence interval for the average percent water content is 41.6 ± 2.8.

(2) The average carbon content of 48.5 per cent represents the weighted average of the following components from trees (dry mass): (1) trunk (carbon content of 48.5 per cent and contribution to total dry biomass of 85.98 per cent); (2) thick roots (carbon content of 47.0 per cent and contribution to total biomass of 11.59 per cent); (6) thin roots (carbon content of 45.7 per cent and contribution to total biomass of 3.06 perr cent). The 95 per cent confidence interval for the average percent carbon content is 48.5 ± 0.9.

[18] For more information see: http://www.fao.org/forestry/17847/en/bra/, last accessed on April 4th, 2014.

(3) Regarding the uncertainties related to the biomass of palms and lianas, Silva (2007) estimated that these are high (73.0 and 57.0 per cent, respectively). However, their contribution to the average total aboveground biomass is only 4.0 per cent, the largest contribution being from the trees themselves (94.0 per cent). Hence, the contribution of the biomass of palms and vines to the biomass uncertainty is low.

Other uncertainties associated with the carbon map may arise from other sources, including the following:

(1) data collection, sampling design;
(2) allometric equation;
(3) aggregated forest type;
(4) rules used to estimate the carbon density of the forest types per RADAMBRASIL volume.

It is difficult to associate uncertainties to most of these elements. An approach that can provide an estimate of the uncertainty associated with the carbon map used by Brazil on its Second National Inventory is to assess the differences in estimates of emissions from deforestation by comparing it to emissions associated with other carbon maps available in the literature. Work is underway to assess and to minimize this uncertainties and this process will contribute for improving the data for future submissions.

c) Pools, gases and activities included in the construction of the forest reference emission level

c.1. Activities included

The forest reference emission level proposed by Brazil in this submission includes only the activity "*Reducing Emissions from Deforestation*" in the Amazonia biome, using as a basis the PRODES data. In addition to the systematic assessment of deforestation in the Brazilian Amazonia, Brazil has developed other systems to track forest degradation and forest management in the Amazonia biome (refer to ***Table 6***).

Table 6: Brazil´s forest monitoring systems for the Amazonia biome

	Satelite and Resolution	**Data update**	**Minimum area mapped**	**Type of activity mapped**	**Objective and History**
PRODES	LANDSAT TM, CBERS CCD (30 m)	Annually	6.25 ha	Clear cut	Annual deforestation rates (since 1988)
DEGRAD	LANDSAT TM, CBERS CCD (30 m)	Annually	6.25 ha	Degradation	Monitor areas in the process of degradation (since 2008)

Brazil has, through INPE, implemented since 2008 a system to assess the areas affected by degradation in the Amazon biome, through the use of satellite imagery of the same spatial resolution as that used to assess deforestation increments (Landsat, up to 30 meters). This system, referred to as DEGRAD, provides detailed maps of areas under a degradation process (refer to ***Figure 13***).

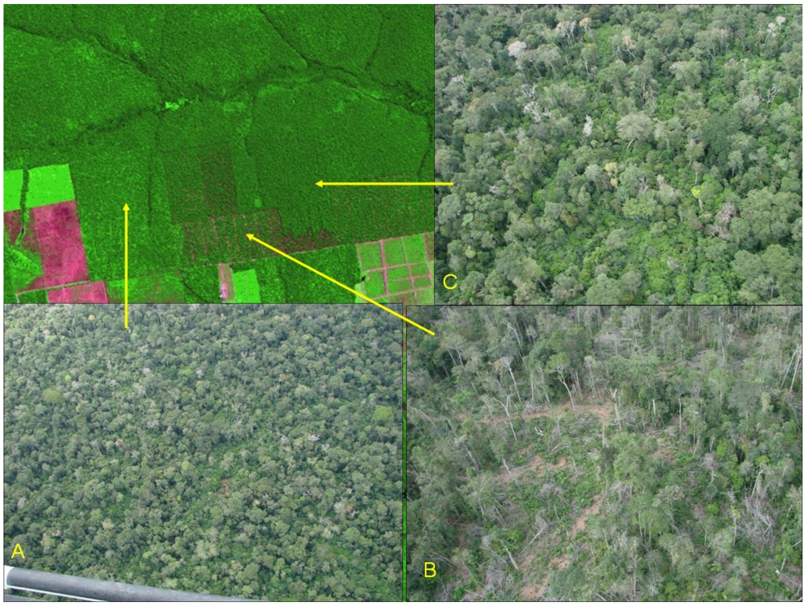

Figure 13. Representation of forest degradation in a portion of a Landsat image: A) degradation of moderate intensity, regeneration after logging patios still evident; B) degradation of high-intensity, large proportion of exposed soil; C) degradation of light intensity, evidence of opening of acess roads. ***Source.*** DEGRAD, INPE, 2014

These areas have not been subject to clear cut and hence have not been included in PRODES figures. Brazil provides some information regarding DEGRAD in ***Annex 2***. The time series is still too short to allow a better understanding of the degradation process. It is expected that this understanding improves with time, as new data becomes available, allowing for the future submission of a FREL for degradation.

c.2. Pools included

The pools included in this forest reference emission level are those used in the construction of the carbon map, i.e, spatial distribution of added living biomass (above and below-ground) and litter. This carbon map is the same as the one used to estimate emissions from forestland converted to other land uses in Brazil's Second National Inventory.

There are several publications in Brazil regarding changes in carbon stock in the soil organic carbon from conversion of forest to pasture or agriculture in Amazonia. As already mentioned, Brazil does not have data on the dynamics of forest conversion for all years in the period considered in the construction of the forest reference emission level. However, there are two sources of information that may be used as proxies to estimate the fate of the forest converted to other uses.

The first of these is the Second National Inventory (BRASIL, 2010) that has a spatially explicit database for the conversions of forest (managed and unmanaged) to other land-use categories from 1994 to 2002, per biome. The land cover/use for these two years was mapped using Landsat as the main source of data. The data in Tables 3.97 (Land-use transition areas identified in the Amazon biome from 1994 to 2002 (hectares)) (BRASIL, 2010) can provide an estimate of the forestland converted to grassland and cropland, the two major forest land conversions in Amazonia. Considering the total area of Forest Land converted to Grassland - Ap; Cropland – Ac; Settements – S; Wetlands - Res; and Other land (other land) in Table 3.97 (BRASIL, 2010), which totals 16,500,461 hectares, the area converted to Grassland and Cropland is 14,610,248 hectares and 1,846,220 hectares, respectively, corresponding to 88.5 per cent and 11.2 per cent, respectively.

The second source of information on transition of forest is the TerraClass[19], a more recent project carried out by INPE, which has estimated forest transitions for years 2008 and 2010. For these two years, 80.3 per cent and 80.0 per cent, respectively, have been converted to grassland (exposed soil grassland; clean grassland; dirty grassland; regeneration with pasture). Hence, the two sources consistently indicate that the major Forest Land conversion is to Grassland, including cattle ranching, abandoned grassland etc.).

With this assumption in mind, a literature review was carried out to assess the impact of the conversion of native forest to pasture on the soil organic carbon. It is important to bear in mind that the literature review cited here is limited, and may not be representative of all the situations that may be occur in Amazonia. Brazil will intensify efforts to improve the understanding of the changes in carbon stock in the soil organic carbon, including by expanding the review and by stimulating new research. One of the issues that make soil carbon change assessments difficult relates to the timing of the changes, which may not occur immediately after the conversion. Normally the process may take years before a change can be detected.

A large area of the Amazonia biome (approximately 75 per cent) is covered by Latossolos (Oxisols) and Podzólicos (Ultisoils and Alfisols) (Cerri *et al.* (1999), following Jacomine and Camargo (1996)). The remainder falls in 7 soil divisions (refer to ***Figure 14***).

[19] More information on TerraClass can be found in www.inpe.br/cra/projetos_pesquisas

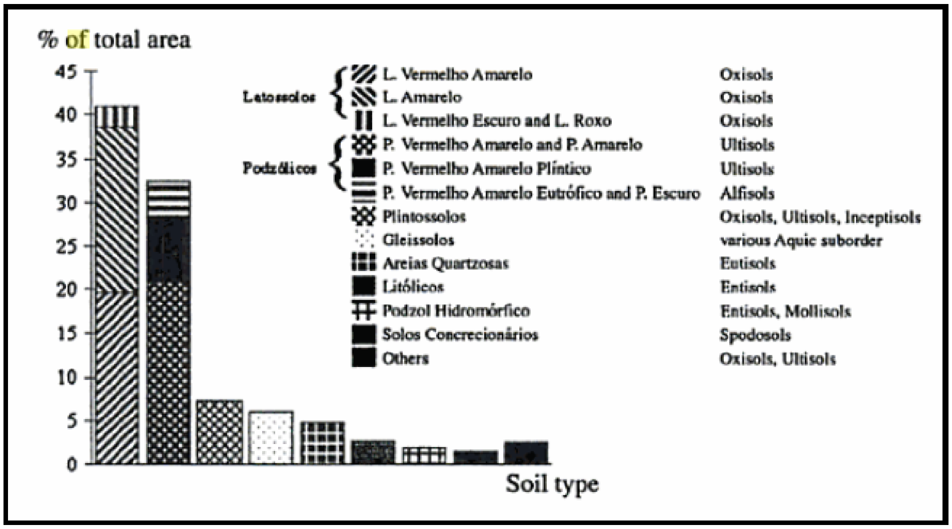

Figure 14: Percent distribution of the main soil types in the Amazonia basin. ***Source:*** Cerri *et al.*, 1999.

Regarding the changes in carbon organic soil from conversion of forest to grassland (pasture), part of the literature indicates that there is a loss of carbon in the first years of conversion, generally followed by full recovery of the carbon in organic soil as if under native forest. In some cases, an increase in soil carbon can occur, particularly in the superficial soil layer. A summary of some of the literature consulted in described below.

Fearnside and Barbosa (1998) showed that trends in soil carbon were strongly influenced by pasture management. Sites that were judged to have been under poor management generally lost soil carbon, whereas sites under ideal management gained carbon. Salimon et al. (2007) concluded that the soils under pasture present larger carbon stocks in the superficial soil layer where approximately 40 to 50 per cent of the carbon originated from grasses at depth 0 to 5 cm. In deeper layers, the contribution of the remaining carbon from the primary forest is larger, notably in those soils with greater clay content.

Cerri *et al*. (2006) carried out a literature review on this issue and concluded that approximately two thirds of the pasture in Amazonia exhibited an increase in carbon stock in soil relative to the native vegetation. It estimated equilibrium organic matter levels by running the models for a period of 10,000 years. Then, the models were run for 100 years under pasture. Century and Roth predicted that forest clearance and conversion to well managed pasture would cause an initial decline in soil carbon stocks, followed by a slow rise to levels exceeding those under native forest. The only exception to this pattern was found for the chronosequence called Suia-Missu, where the pasture is degraded rather than well managed like the other chronosequences.

Costa et al., (2009) concluded that there was no significant difference in the soil carbon stocks under vegetation, degraded pasture and productive pasture, at different land use time and different depth. The authors also conclude that after 28 years of use with well managed pasture, approximately 62 per cent of the carbon organic soil still derives from the original forest until 30 cm depth.

Fernandes et al. (2007) concluded that the incorporation of carbon by the pasture occurs gradually in increasing depth through time, and that the layer 0 – 10 cm apparently reached an equilibrium state after 10 years (around 9.8 tonnes per hectare). For the other layers, differences can still be observed in the stocks in areas of 10 and 20 years, this difference being largest at 40 cm depth. In the layer 0 – 20 cm the carbon stock in 10.8 tonnes per hectare in the soil with native vegetation; 15.1 and 17.3 tonnes per hectare for pastures of 10 and 20 years, respectively. These values represent an increase of 40 and 60 per cent in relation to the soil under native vegetation, respectively.

Trumbore et al. (1995) reported soil carbon losses in overgrazed pasture but soil carbon gains from fertilized pasture in the Amazon region. Neil et al. (1997) suggested that degraded pastures with littlegrass cover are less likely to accumulate soil carbon because inputs to soil organic carbon from pasture roots will be diminished, but that might not be true in more vigorous re-growth of secondary forest. Greater grazing intensity and soil damage from poor management would, in all likelihood, cause soil carbon losses.

Finally, Neill et al. (1997) when examining carbon and nitrogen stocks in seven chronosequences, each consisting of an intact forest and pastures of different ages created directly from cleared forest (7 forests, 18 pastures), along a 700-km transect in the southwestern Amazon basis indicated that when site history was controlled by considering only pastures formed directly from cleared forest, carbon and nitrogen accumulation was the dominant trend in pasture soils.

Ideally, more studies are needed to determine with more certainty how significant the changes in the soil organic carbon pool are following conversion of Forest Land. Considering the above information, the soil organic carbon has not been included in the construction of the forest reference emission level proposed by Brazil in this submission.

c.3. Gases included

This forest reference emission level only includes CO_2 emissions. Non-CO_2 emissions in the Amazonia biome are normally associated with the recurrent burning of tree residues left on the ground after the deforestation activity; or with wild fires, which are not very common.

Emissions resulting from the burning of tree residues and other organic matter present on the ground are directly related to the deforestation activity. Hence, the decrease of deforestation, *per se*, will lead to a decrease not only in CO_2 emissions but also in non-CO_2 emissions associated with fire (during the forest conversion and post-conversion).

The most common conversion of forest in Amazonia is to pasture for cattle ranching (IBGE, 2009). Pasture burning is the prevalent type of fire in Amazonia on an area basis. The majority (80 to 90 per cent) of the fire emissions derive from deforestation in Amazonia and Cerrado (***Box 2***).

Box 2: Estimates of CO_2 and non-CO_2 emissions of greenhouse gases
Bustamante *et al.* (2012) have provided estimates of CO_2 and non-CO_2 emissions of greenhouse gases (including CO_2, CH_4, N_2O, CO, NO_x) associated with deforestation, burning for pasture establishment, and pasture maintenance in the period from 2003 to 2008 (inclusive). ***Figure 15*** bellow shows the area of fire for pasture establishment and maintenance in all Brazilian biomes from 2003 to 2008 inclusive, and the associated

CO_2, CH_4, N_2O and CO emissions (in Mt $CO_{2\text{-eq}}$) for the Amazonia biome.

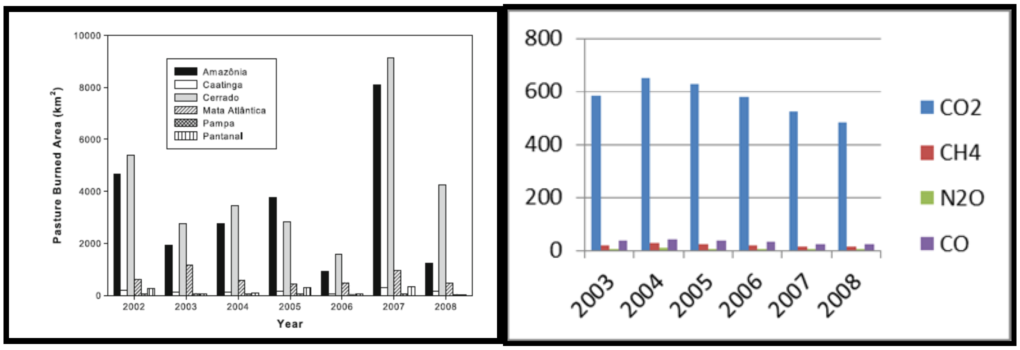

Figure 15. (A) Extension of burned pastures (2002 – 2008) in the Brazilian biomes; (B) CO_2, CH_4, N_2O and CO emissions (in Mt $CO_{2\text{-eq}}$) for the Amazonia biome in the same period.

For the conversion of CH_4, N_2O and CO to $CO_{2\text{-eq}}$, the global warming potential values used were 21, 310 and 2, respectively. Relative to the average CO_2 emissions in the period, the average CH_4; N_2O and CO emissions represented 3.4 per cent; 1.0 per cent; and 5.9 per cent, respectively (IPCC, 2001).

c) Forest definition

Brazil is a country of continental dimensions and with a large diversity of forest types. The forest definition broadly applicable in Brazil is that reported to the Food and Agriculture Organization of the United Nations (FAO) for the Global Forest Resources Assessments (FRA), reproduced below:

> *"Forest is defined as land spanning more than 0.5 hectare with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. Land not classified as "Forest", spanning more than 0.5 hectare; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent are classified as "Other Wooded Land"*.

These two categories (*Forest* and *Other Wooded Land*) do not include land that is predominantly under agricultural or urban land use.

The classification of vegetation typologies into the categories of "Forest" and "Other Wooded Land" used by FAO was defined by Brazilian experts involved in the preparation of the FRA 2010.

Table 7. FRA 2010 vegetation typologies included in this FREL (in grey)

Da	Alluvial Dense Humid Forest
Db	Lowland Dense Humid Forest
Ds	Submontane Dense Humid Forest
Dm	Montane Dense Humid Forest
Dl	High montane Dense Humid Forest
Aa	Alluvial Open Humid Forest
Ab	Lowland Open Humid Forest
As	Submontane Open Humid Forest
Am	Montane Open Humid Forest
M	Mixed Humid Forest:
Ma	Alluvial Mixed Humid Forest
Mm	Montane Mixed Humid Forest
Ml	Montane Mixed High Humid Forest
Ms	Submontane Mixed High Humid Forest
Fa	Alluvial Semi deciduous Seasonal Forest
Fb	Lowland Semi deciduous Seasonal Forest
Fs	Submontane Semi deciduous Seasonal Forest
Fm	Montane Semi deciduous Seasonal Forest
Ca	Alluvial Deciduous Seasonal Forest
Cb	Lowland Deciduous Seasonal Forest
Cs	Submontane Deciduous Seasonal Forest
Cm	Montane Deciduous Seasonal Forest
Ld	Forested Campinarana
La	Wooded Campinarana
Sd	Forested Savannah
Sa	Wooded Savannah
Td	Forested Steppe Savannah
Ta	Ta - Wooded Steppe Savannah
Ea	Tree Steppe
Pma	Forest Vegetation Marine Influenced
Pfm	Forest Vegetation Fluviomarine influenced
OM	Transition Humid Forest / Mixed Humid Forest
ON	Transition Humid Forest / Seasonal Humid Forest
NM	Transition Seasonal Forest / Mixed Humid Forest
NP	Transition Seasonal Forest / Pioneer Formations
LO	Transition Campinarana / Humid Forest
SO	Transition Savannah / Humid Forest
SM	Transition Savannah / Mixed Humid Forest
SN	Transition Savannah / Seasonal Forest
ST	Transition Savannah / Steppe Savannah
SP	Transition Savannah / Pioneer Formations (Restinga)
TN	Transition Steppe Savannah / Seasonal Forest
EM	Transition Steppe / Mixed Humid Forest
EM	Transition Steppe / Seasonal Forest
STN	Transition Savannah / Steppe Savannah / Seasonal Forest
	Secondary Vegetation in Forestry areas
	Forest Plantations

It is to be noted that the number of vegetation typologies under "Forest" for the purposes of FRA is much larger than the aggregated forest types defined for the purposes of this submission, the reason being the need to have a basis for estimating the carbon density in the forest types defined. Since the basis for the estimation of the carbon densities in the different forest types was the RADAMBRASIL sample plots and vegetation map, it would not be logical to disaggregate the estimates to accommodate a larger set of forest types.

For the Amazonia biome, the historical time-series available for deforestation has been constructed assuming a clear cut pattern (exposed soil) and does not follow strictly the definition used for the FRA. However, the boundaries of forest/non-forest were based on the definition applied in the FRA report.

Hence, deforestation for the Amazonia biome is not associated with thresholds, but simply with canopy cover equals to zero. Any situation in which forest falls below the thresholds of the FAO definition but still does not have canopy cover equals to zero is characterized as forest degradation and treated as such (DEGRAD/INPE).

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Annex 1: Additional information about the forest reference emission level for reducing emissions from deforestation in the Amazonia biome

I. Gross Deforestation Monitoring Program in Amazonia - PRODES

PRODES is part of a larger program (Amazonia Program) developed at the National Institute for Space Research (INPE) that provides annual rates of gross deforestation in the Legal Amazonia[20] (***Figure a.1***) since 1988.

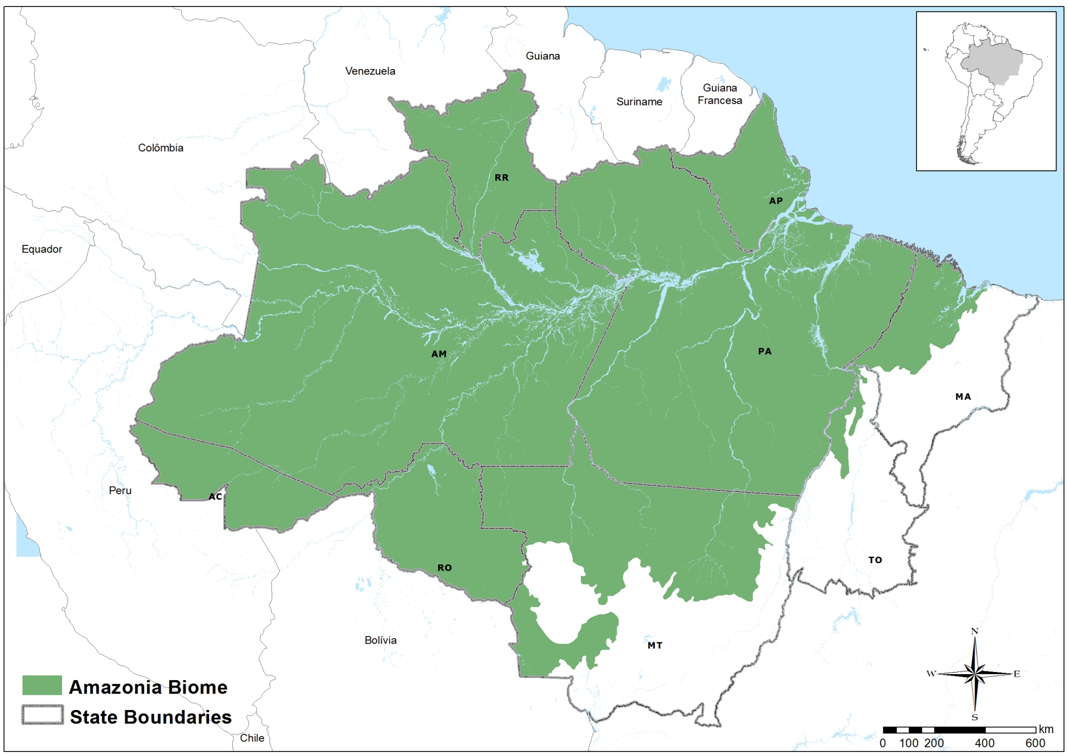


Figure a.1: State boundaries, boundaries of the Amazonia biome and of the Legal Amazonia. ***Source*:** MMA, 2014 based on IBGE, 2010.

It uses satellite imagery to identify new deforestation increments every year. Deforestation is associated with clear-cut activities, normally associated with the

[20] The Legal Amazonia covers the totality of the following states: Acre (AC), Amapá (AP), Amazonas (AM), Pará (PA), Rondônia (RO), Roraima (RR) and Tocantins (TO), and part of the states of Mato Grosso (MT) and Maranhão (MA), totalizing approximately 5.217.423 km² (521.742.300 ha).

conversion of forest land to other land-use categories. Only areas of ***primary forest***[21] are assessed for deforestation. ***Figure a.2*** below shows the time series with the annual rates of gross deforestation (in km^2) from 1988 until 2013[22].

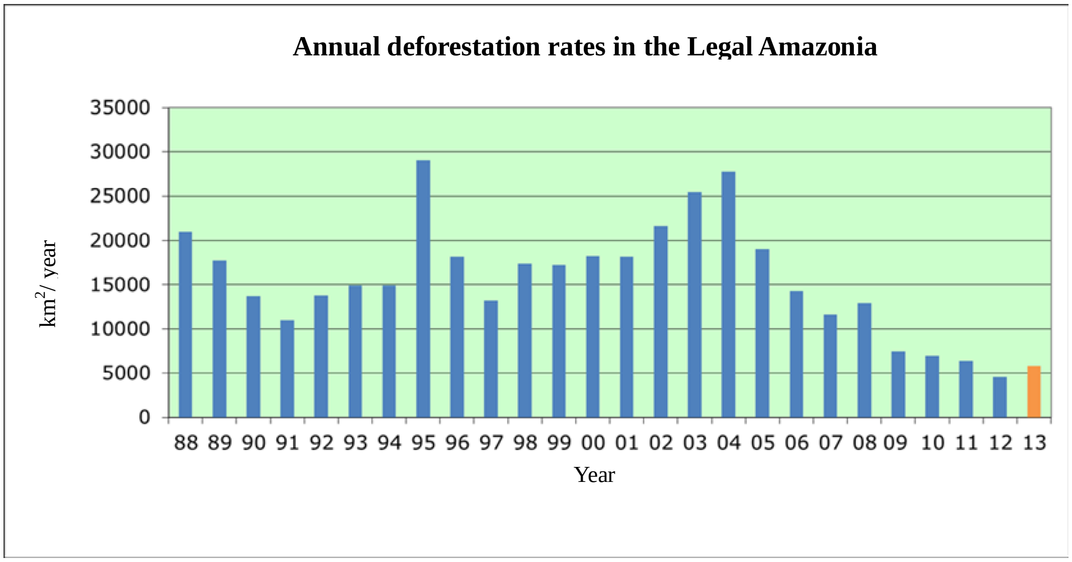


Figure a.2: Annual deforestation rate in the Legal Amazonia area. ***Source***: PRODES, INPE, 2014 (http://www.obt.inpe.br/prodes/prodes_1988_2013.htm).

The gross deforestation is assessed annually on a wall-to-wall basis, encompassing the analysis of approximately 230 Landsat images. The minimum mapping unit is 6.25 hectares. INPE ensures that a consistent approach is used to identify new deforestation increments every year. This includes maintaining the same definition, minimum assessed area, similar spatial resolution, same forest/non-forest boundaries, and similar methodological approach.

Forest areas affected by forest degradation that do not have a clear-cut pattern in the satellite imagery are not included in PRODES. A separate project, named DEGRAD (refer to ***Annex 2*** for more information), is carried out at INPE to address forest degradation. This ensures the consistency of the PRODES deforestation time series over time.

At the start of PRODES, deforestation increments were identified by visual interpretation on false color composites of Landsat imagery at the scale of 1:250,000 and mapped on overlays that contained the aggregated deforestation up to the previous year. Subsequently these polygons were manually digitized in a Geographic Information System (GIS) developed by INPE. This analogical approach to assess deforestation (Prodes Analog) was employed from 1988 until 2002.

[21] Forests in which human action did not cause significant alterations in its original structure and species.

[22] The deforestation rate for 2013 is a pre-estimate based on a large set of satellite imagery that covers Legal Amazonia but not all. Hence, the number presented here is preliminary and may be modified after the wall-to-wall assessment is finalized.

Due to the increased computing facility, INPE transitioned to a digital assessment of deforestation (PRODES Digital) in 2002. PRODES Digital maintains full consistency with the PRODES Analog data. This includes consistency with the forest boundaries in Prodes Analog and the aggregated deforestation increments. Despite the evolution to a digital assessment, the identification of the deforestation increments continued to be carried out through visual interpretation in the screen and not through digital classification methods[23]. This ensured even greater consistency between the analogical and digital PRODES.

Due to the large volume of analogical data at the time digital PRODES started, INPE decided to map the deforestation increments from years 1998 to 2000 on an aggregated deforestation map until 1997 (base map). Hence, the deforestation increments for these years are lumped into a single digital database, with no discrimination of the specific year when deforestation occurred. From year 2000 onwards, the deforestation increments were annually assessed and dded to the PRODES digital database. The digital PRODES allowed for the visualization of the deforestation increments year after year, in a single file. Thus, the geographical expansion of deforestation, as well as its pattern (size) could be monitored. Digital PRODES was also instrumental to help identify drivers of deforestation in the different States and Municipalities (counties)

In summary, the **digital database** does not have individual deforestation information for years prior to 1997, inclusive; have information for years 1998 to 2000 in an aggregated format; and information (deforestation increments) for all years after 2000 on an annual basis.

PRODES digital data allowed INPE to make available through the web the deforestation maps in vector format, as well as all the satellite images used, thus ensuring full transparency to the public in general. Since 2003, INPE began to publish the annual deforestation rate on the Institute´s website, together with all the satellite imagery used to generate the information, and the maps with the identification of deforested polygons. Annually INPE provides for the download of approximately 210 Landsat satellite images of 5/7/8 (or similar). Each image is accompanied by the associated map with all past deforestation.

INPE continuously improves its tools to better manage large-scale projects such as PRODES. Its latest development, the TerraAmazon, is a system that manages the entire workflow of PRODES, annually storing approximately 600 images (e.g., Landsat, CBERS, DMC, Resourcesat). It performs geo-referencing, pre-processing and enhancement of images for subsequent analysis in a multi-task, multi-processing environment. The database stores and manages approximately 4 million polygons.

The methodology for generating the gross deforestation rates in the Legal Amazonia area is based on the following assumptions:

- The deforestation increments are only those associated with clear-cut (complete removal of forest cover) in areas larger than 6.25 ha.

[23] INPE has developed alternative methodologies to identify deforestation increments in satellite imagery (e.g., linear mixture model, Shimabukuro *et al*., (2004). However, the visual assessment demonstrated to be simpler and more efficient).

- The satellite images used are of similar spatial and spectral resolutions (approximately 30 meters, 3 or more spectral bands). The most common satellite images used are those from Landsat 5, 7 or 8 NASA/USGS (USA), CBERS 2B INPE /CRESDA (Brazil /China), UK2-DMC's DMC International Imaging (UK) and Resourcesat ISRO (India), the last two basically to cover gaps data gaps from Landsat due to the presence of clouds.

There are some steps that are followed until the deforestation increments are identified in the satellite imagery (refer to ***Figure a.3***). These are now detailed:

Images selection

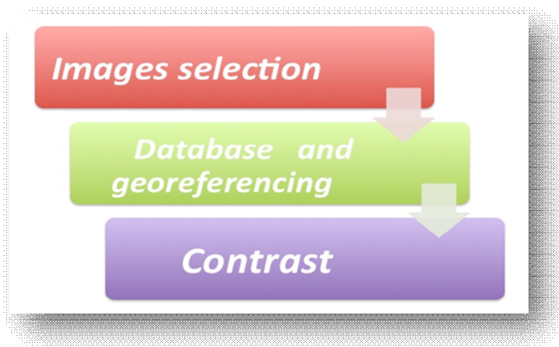


Figure a.3: Steps prior to identification of the deforested polygons.

The first step consists of selecting the images to be used. For this, a query is conducted directly from the site of INPE´s Image Generation Division (DGI) (http://www.dgi.inpe.br/siteDgi_EN/index_EN.php) to identify preferably Landsat 5 images (or similar) for the year of interest (usually corresponding to the months of July, August and September), with minimal cloud cover, better visibility and a suitable radiometric quality.

Satellite imagery available in the DGI are usually pre-processed for geometric correction and made available in UTM projection. ***Figure a.4*** shows an image from Landsat 5 selected in the DGI library.

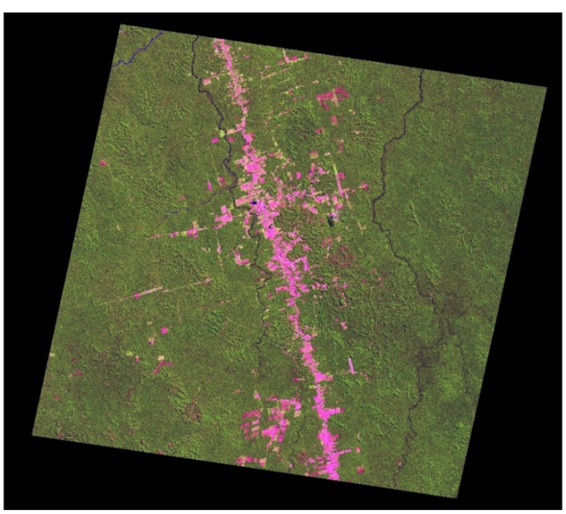


Figure a.4: Landsat 5 (pathrow 227/65) of 01/07/2002 - Color composite Red, Green, Blue 5,4,3, available on the DGI catalog .

Database and georeferencing

The next step consists of image georeferencing, which is carried out through visual collection of at least nine control points evenly distributed in coherent features (rivers, roads intersection) between the reference images, Landsat satellite images ortoretificadas 5 for the year 2000 produced by Geocover NASA project (https:// zulu.ssc.nasa.gov / MrSID) and image adjustment, which were previously selected in the digital catalog of the DPI website at INPE.

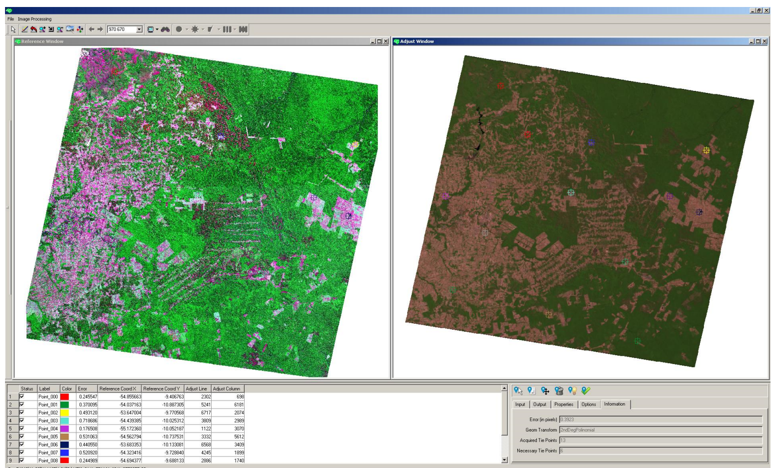


Figure a.5: An example of control points collection.

Contrast enhancement

Finally, the technique of contrast enhancement may be applied to improve the quality of the images under the subjective criteria of the human eye. The contrast between two objects may be defined as the ratio between their average gray levels.

The goal of this step is to increase the contrast to facilitate the visual discrimination of objects in the image.

PRODES has generated a time-series of 25 years of gross deforestation for the Legal Amazonia area, from 1988 to 2013. All data are available at: http://www.obt.inpe.br/prodes/prodes_1988_2013.htm.

II. PPCDAm: Action Plan for the Prevention and Control of Deforestation in the Legal Amazonia

The process of deforestation in Legal Amazonia is not homogeneous, presenting distinct spatial and temporal features. It is estimated that by 1980 accumulated deforestation will reach approximately 300,000 km^2, corresponding to 6% of the total forest area in Legal Amazonia. During the 80's and 90's, about 280 km^2 were added to the total deforested area. In the early years of the past decade, the pace of deforestation changed, and the accumulated deforestation totaled approximately 670,000 km^2 in 2004, corresponding to approximately 16 per cent of the total forest area in Legal Amazonia.

This changed deforestation trend led the Federal Government to establish, in 2003, a Permanent Interministerial Working Group (GPTI – Grupo Permanente de Trabalho Interministerial) through Decree s/n, July 3rd, to identify and promote coordinated actions aimed at reducing deforestation rates in Legal Amazonia. The GPTI was coordinated by the Chief of Staff of the Presidency until 2013 and is currently being coordinated by the Ministry of the Environment (MMA).

The GPTI was responsible for the development of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazonia – PPCDAm, in 2004, which identified a number of measures, policies and actions to reverse the deforestation trend.

Since 2004, the Federal Government has been working in coordination with the various stakeholders, including state and municipal governments as well as the civil society, to promote a sustainable model of forest resource use and agricultural practices. PPCDAm is structured in three thematic axis that direct government actions towards reducing deforestation: i) Land Tenure and Territorial Planning; ii) Environmental Monitoring and Control, and iii) Fostering Sustainable Production Activities.

Since 2004, deforestation in Legal Amazonia has significantly decreased, reaching 6,418 km^2 for the period 2010-2011. In 2012, gross deforestation reached its lowest historical value of 4,656 km^2. In 2013, a pre-estimate based on a set of Landsat images indicates that deforestation has increased to 5,843 km^2. Despite this increase, this value was the second lowest in the PRODES time-series.

The Brazilian government is developing and implementing a modular system (SMMARE, Sistema Modular de Monitoramento e Acompanhamento das Reduções das Emissões de Gases de Efeito Estufa) to monitor actions and GHG emission reductions to be achieved through the Brazilian Climate Change Mitigation Plans. This system also aims at supporting the analysis and management of the mitigation actions implemented by Brazil. It is presently under development by the Ministry of the Environment.

During the period from 2004 until 2011, the decrease in gross deforestation is mostly attributable to Environmental Monitoring and Control, due to the implementation of the Deforestation Detection Almost in Real Time (DETER – Detecção em Tempo Real[24])

[24] In 2004 INPE launched DETER, a quick monthly survey that maps both clear cut areas as well as areas undergoing deforestation by forest degradation. DETER uses the MODIS sensor of the Terra / Aqua satellite and the WFI Sensor of the satellite CBERS, with spatial resolution of 250 m. It only detects deforestation in areas bigger than 25 ha. DETER was designed as an early warning system to support surveillance and control of deforestation for the Legal Amazonia. To facilitate and streamline surveillance operations by different entities, the information is presented stratified by municipality,

integrated with planning and supervision. Land Tenure and Territorial Planning were also key areas for achieving results during this period, through the establishment of Conservation Units and demarcation of Indigenous Lands.

The change in the pattern of deforestation (from large to small annual increments) increased the cost of the monitoring initiatives, limited by both human resources and budget. The occurrence of deforestation increments smaller than 6,25 hectares increased the need for investments on Land Tenure and Territorial Planning and on Development for Sustainable Production Activities. It is under this context that the Action Plan for the Prevention and Control of Deforestation in the Legal Amazonia (MMA, 2013), a key operational plan for the implementation of Brazil's National REDD+ Strategy (2014-2020), initiated its third phase of implementation (2012-2015).

state, IBAMA's operative basis and protected areas. This system can only be used as an indicator of trends in annual deforestation, not as a means for calculating annual deforestation rates. For more information see: http://www.obt.inpe.br/deter/

Annex 2: The development of forest reference emission levels for other REDD+ activities in the Amazonia biome

I. Degradation in the Amazon biome: available historical data and forest monitoring systems and related uncertainties

INPE has developed a system, referred to as DEGRAD, to map the occurrence and monitor the fate of degraded areas in the Legal Amazonia using satellite imagery (Landsat-class, up to 30 meters spatial resolution).

DEGRAD maps mostly forest fire scars that occur predominately in previously logged sites and areas under logging activities characterized by widespread damage to the forest canopy and that most likely is transitioning to a clear cut state that characterizes deforestation. However, part of the selectively logged areas are abandoned and left to regenerate.

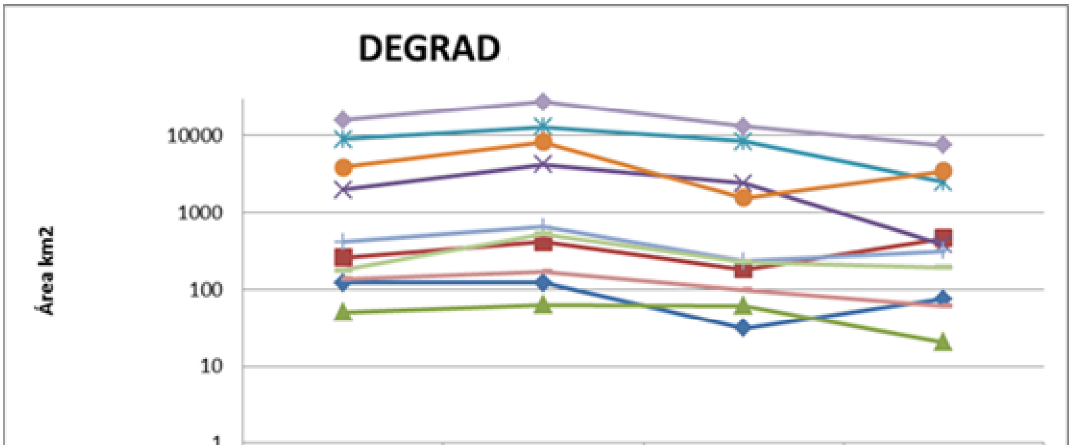
For DEGRAD, a time series with annual data for the period 2007 to 2010 is available, based on the same set of images used for the PRODES assessment for these years. INPE plans to maintain this system as part of the Amazonia Program to create a long enough time series to allow the dynamics and fate of degraded forests to be better understood.

The maps generated by DEGRAD, with evidence of forest degradation, are also publicly available as part of INPE´s policy of open data distribution (http://www.obt.inpe.br/degrad/).

The identification of degraded forest areas is carried out through visual interpretation of color composites of Landsat-class data (multispectral with resolution up to 30 m) where the conspicuous damage to the forest canopy by forest fire and rampant traditional forest exploitation is clear.

Analysis of DEGRAD for this period indicates the following:

- There is a close relationship between the increase in the forest area mapped as degraded and the increase of fire occurrences. Hence, for particularly dry years (drought), it is expected that the forest area mapped as degraded will increase, due to the vulnerability of the forest areas in areas of dry, easily combustible material (dry litter). It is also possible that there is a lagged effect from extreme events (e.g., an extremely dry year may lead to increased fire occurrences in subsequent year or years).
- The increase in the area mapped as degraded is not uniformly distributed in the Legal Amazonia. Despite the significant reduction in the area mapped as degraded (43.5 per cent), there was a significant increase in the area mapped in Pará State (124.4 per cent).
- The causal relationship between the reduction in deforestation in some areas and the increase in forest degradation in others is difficult, if not impossible, to be established. DEGRAD shows that the degradation process is associated to climatic conditions in a given year, such as warmer years (as in 2007 and 2010).



	2007	2008	2009	2010
Acre	122	121	31	76
Amazonas	257	412	181	459
Amapá	50	63	61	20
Maranhão	1976	4230	2423	383
Mato Grosso	8951	12987	8486	2502
Pará	3899	8264	1559	3499
Rondônia	412	643	232	315
Roraima	137	171	99	61
Tocantins	179	522	229	194
Amazonia Legal	15983	27413	13301	7508

Figure b.1: Distribution of degraded areas per state in the Legal Amazonia (in km^2). ***Source***: INPE, DEGRAD, 2014 (http://www.obt.inpe.br/degrad/)

On the top of the already mentioned limitations of addressing forest degradation adequately (in particular in relation to the anthropogenic contribution to the associated emissions), another difficulty lies in the ability to accurately assess the changes of carbon stock in the areas affected by degradation, particularly aboveground biomass. Degradation may have different intensities, from very low (where few trees are removed) to very high (where most likely the land will be eventually deforested).However, forest degradation has not been included in the construction of this FREL[25].

The time series is not long enough for the development of a forest reference emission level for the activity “Reducing Emissions from Degradation”. The time series is still too short to allow a better understanding of the degradation process. It is expected that this understanding improves with time, as new data becomes available.

The data provided ***Figure b.1*** indicates that the emissions associated with forest degradation in the Amazonia biome from 2007 to 2010, inclusive, correspond to approximately 14.6 per cent of the emissions from deforestation (refer to ***Figure b.2***). It is to be noted that the pattern of emissions from deforestation and forest degradation

[25] The significance of the emissions from other activities (in particular forest degradation) has been assessed in relation to the potential decrease in deforestation leading to an increase in forest degradation, in which case both would have to be included in the FREL.

show some correspondence in the time series from 2007 to 2010 (a decrease in one is followed by a decrease in the other, and vice versa), as can be seen from ***Figure b.2***.

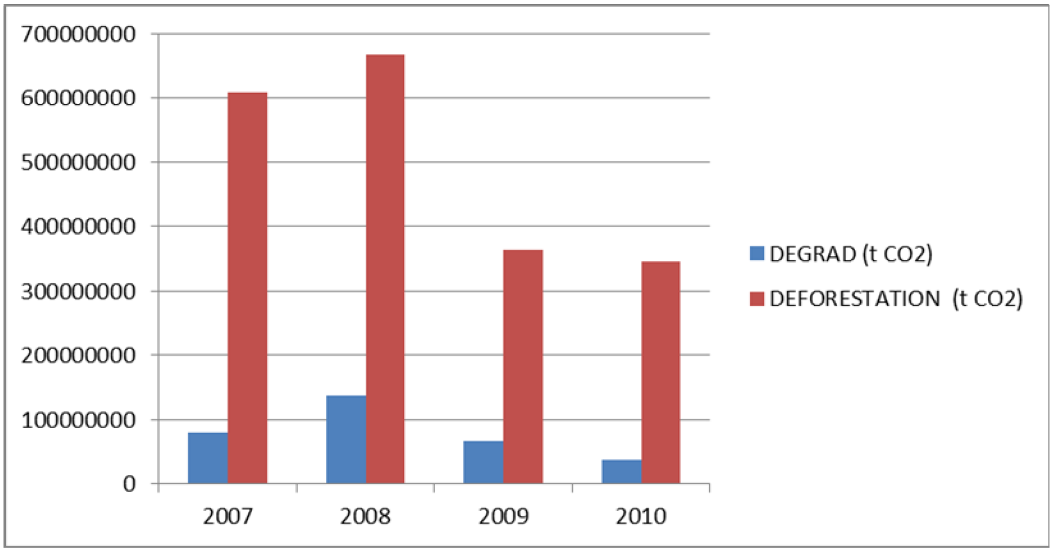


Figure b.2: Emissions (in tCO_2) from deforestation and from forest degradation in the Amazonia biome for years 2007 to 2010, inclusive.

Refer to ***Important Remark*** below for information on how emissions from forest degradation have been estimated.

IMPORTANT REMARK: The emissions from forest degradation have been estimated using the area of forest degradation identified in DEGRAD (refer to ***Figure b.1***); the mean carbon density in forest physiognomies in the biome Amazonia, as per the carbon map to estimate emissions from deforestation; and an estimate of the average carbon density loss from forest degradation of 33 per cent, after Asner *et al.*, 2005. An expert judgement from the Ministry of the Environment (Brazilian Forest Service) was similar to this percentage (30 per cent). For the Second National Inventory, the estimated loss was 33 per cent (BRASIL, 2010; Chapter 3, page 228).

It is worth noting that some forest degradation activities may be followed by abandonment and subsequent regrowth of the vegetation, whereas others may lead to deforestation (clear cut) after removal of the most valuable merchantable wood. In this case, the loss of carbon density in the area subject to forest degradation may be gradual and may take some years.

Annex 3: The development of forest reference emission levels for other biomes

I. From subnational to national (all biomes)

As an interim measure, Brazil presents in this submission only a forest reference emission level for reducing emissions from deforestation in the Amazonia biome. Currently, Brazil only has a historical time-series for deforestation that is consistent, credible, accurate, transparent, and verifiable for the Legal Amazonia area (and hence, the Amazonia biome).

Investments have already started to be made to expand the forest monitoring system developed for Legal Amazonia to other biomes. Currently the work is focused on the analysis of deforestation that occurred in years 2009, 2010 and 2011. After that, between 2014 and 2015, data will be drawn up for year 2013. So from 2015 onwards Brazil will be systematically monitoring all biomes annually.

The idea is to advance in the development of forest reference emission level submissions to the other biomes in order of emissions importance, the Cerrado biome being the second in this respect (refer to section II of this Annex). ***Table c.1*** presents the relative importance of the Brazilian biomes to the average annual CO_2 emissions from deforestation, estimated from the Second National Inventory.

Table c.1*:** Average annual gross CO_2 emissions from forest (managed + unmanaged) converted to other land uses. ***Source: Adapted from Tables 3.98, 3.100, 3.102, 3.104, 3.106, 3.108, Second National Inventory, BRASIL, 2010

Biomes	Annual Average Gross CO_2 Emissions from Deforestation (Gg) (1994 - 2002)	Relative importance (%)
Amazonia	1,021,875	70.2
Cerrado	287,728	19.8
Caatinga	42,193	2.9
Mata Atlantica	87,377	6.0
Pantanal	16,363	1.1
Pampa	41	0
TOTAL	1,455,539	100.0

II. Deforestation and degradation in the Cerrado biome

The Cerrado biome is considered to be the richest savanna in the world in terms of biodiversity. This biome provides fundamental local and global environmental services, and since the 1970s faces high pressure from deforestation due to mechanized agriculture, livestock and charcoal production to meet the demand of the steel industry.

Cerrado is a strategic biome both for economic and environmental reasons and also for food security.

The Cerrado landscape is a mosaic of different vegetation types, ranging from grasslands to forestlands, corresponding to a gradient of woody cover (Eiten 1972, Castro & Kauffman 1998). The structural diversity of vegetation types in the Cerrado involves a wide spectrum of total biomass amounts (Miranda et al. 2014). Available data highlight the importance of woodland savannas as carbon sinks particularly the belowground compartments (soil and root system) (Miranda et al. 2014, Abdala 1993).

a. Available historical data, forest monitoring systems and related uncertainties

Only recently forest monitoring systems beyond that for Legal Amazonia have started to be developed in Brazil. In 2002, the project *Monitoring Deforestation in Brazilian Biomes by Satellite* was created and had as a starting point the vegetation map generated for the PROBIO/MMA project ("time zero map") containing the historical natural vegetation changes that occurred up to 2002 based on the use of satellite imagery. New changes from 2002 to 2008 were also identified through visual interpretation of satellites images (CBERS and Landsat).

Available data for the loss of natural vegetation in the Cerrado biome consists of the loss that occurred between 2002 and 2008, and annual rates from 2009 and 2010. Considering the average loss from 2002 and 2008, and the individual data after 2008, a downward trend in the loss of natural vegetation in this biome is noted. The accuracy of the estimates of natural vegetation loss in the Cerrado is nevertheless still being assessed.

The mapping of the loss of natural vegetation from 2002 to 2008 mentioned above was contracted, and presented some distortions that were not readily identified. For years 2008, 2009 and 2010, the analysis of satellite imagery to identify new deforestation was carried out by the technical team at Brazilian Institute of Environment and Renewable Natural Resources (IBAMA, Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis) of the MMA which, to a great extent, was able to correct the distortions. For example, some deforestation that occurred prior to 2008 was mapped in either one of years 2008, 2009 or 2010, thus overestimating the deforestation associated with these years.

Recognizing this problem, the Brazilian government is now working to rebuild the time series for this biome, having as a reference the methods used for PRODES for the Legal Amazonia. One of the initiatives to produce environmental information for the Cerrado biome is funded by the Forest Investment Program, FIP.[26]

Up to now, data analysis does not indicate a relationship between the reduction of deforestation in the Amazonia biome with an increase in natural vegetation loss in the Cerrado biome. This risk is mitigated by policies in place to tackle deforestation in the Cerrado biome (see ***Box 1*** below).

[26] The Brazil Investment Plan comprises coordinated actions by three Ministries (Environment; Science, Technology & Innovation; and Agriculture and Livestock and Food Supply) focused on building synergies in order to maximize the impact of a larger set of policies aimed at reducing deforestation in the Cerrado biome through (1) improving environmental management in areas previously impacted by Human actions; and (2) producing and disseminating environmental information at the biome scale.

***Box 1.* Action Plan for Prevention and Control of Deforestation in the Cerrado and Burning – PPCerrado**

The overall goal of PPCerrado is to promote the continuous reduction of deforestation and forest degradation, as well as the incidence of unwanted forest fires in the Cerrado biome, through joint actions and partnerships between federal, state and municipal governments, civil society, business sector and universities. PPCerrado actions include the promotion of sustainable activities and the monitoring of private rural properties through the Rural Environmental Registry - CAR, considered one of the main instruments for environmental management of the Forest Code.

In the Cerrado, deforestation drivers are related to agriculture, cattle ranching and the demand for charcoal, mainly for the steel industry. Reconciling the binomial production/environmental protection is the great challenge for the Cerrado biome, considering its legal regime of (legal reserve of 20%, as defined by the Forest Code) and the high demand for the occupation of lands, particularly for agriculture production.

The positive results already achieved reducing deforestation in the Cerrado biome are viewed with caution by the Federal Government, because there is no systematic monitoring of deforestation in the biome as there is for the Amazonia (PRODES). In order to bridge this gap in deforestation data for the Cerrado, a system for annual monitoring and for early warnings are being developed under the PPCerrado.

The loss of natural vegetation of the Cerrado biome is often associated with the use of fire. According to the National Information System about Fires (Sisfogo, Sistema Nacional de Informações sobre Fogo)[27], about 90 per cent of the fires are human related. In 2010 alone, 74,120 hot spots were detected, of which 70 per cent were located in areas of native vegetation[28]. Data on degradation in Cerrado has a high degree of variability and uncertainty[29].

Despite its relevance to the profile of emissions in Brazil, estimation of degradation by fire still depends on the development of land cover monitoring tools. Historical data series of burned areas in the Cerrado biome are not yet available.

Initiatives in coordination between INPE and the MMA seek to provide the means for the development of automated tools so that these data become regularly available. Brazil is also working on the historical time series of burned areas between 2000 and 2013, which will allow for the development of the forest reference emission level for degradation by fire for the Cerrado biome.

[27] Sisfogo is an online automated tool available for the management of early warnings and records of forest fires and controlled biomass burning. It is powered by various institutions working in the control of fires, prevention and combating forest fires. Available for public access on: http://siscom.ibama.gov.br/sisfogo/

[28] INPE´s site for Monitoring Fires and Biomass Burning and includes operational monitoring of fire outbreaks and forest fires detected by satellite, and the calculation of the risk of fire. Data for Central and South America, Africa and Europe, are updated every three hours, every day of the year. Access to this information is free for users, available online on: http://www.inpe.br/queimadas/.

[29] More information about actions in other Brazilian biomes are presented in Annex II.

Another source of uncertainty for estimating emissions in this biome is the carbon density for different regions and vegetation types. The Second National GHG Inventory uses distinct biomass content for different types of Cerrado vegetation for which data in the national scientific literature could be found. For example, for determining the biomass content of the typology Savanna Woodland, eleven different sources were consulted. To obtain the total biomass, expansion factors were applied to consider dead organic matter and belowground biomass (root-to-shoot ratio), having as a basis the GPG-LULUCF (IPCC, 2003). Despite the existence of national data for carbon pools, as in Miranda (2012), there is great variability in the literature depending on the methods used and the areas under investigation.

Brazil is continuously working to improve its database and aims to provide forest reference emission levels for deforestation and forest degradation for the Cerrado biome on tits next submission. For now, this information is provided here only to demonstrate the ongoing efforts by Brazil to expand its coverage of REDD to the national level.

III. Enhancement of forest carbon stocks in the Atlantic Forest biome

The Atlantic Forest is the most threatened biome in Brazil: there are only 7.9 per cent of remaining forest fragments over 100 hectares. Considering all the small fragments of natural forest over 3 acres, this rate reaches 13.32%[30]. Data from 2005 to 2008 show that the level of deforestation for that period was a total of 1,030 km^2, an average of 340 km^2 per year. In the period between 2008 and 2010, about 208 km^2 of native forest were cleared, representing a drop in deforestation from the previous period (SOS/INPE, 2010). Although deforestation has dropped in recent years, deforestation is still of concern for this biome.

After habitat loss, the second major threat to Atlantic Forest is its high degree of fragmentation. This leads to high vulnerability to disturbance (by fire, edge effects, etc.) and high degree of isolation of natural populations of the biome.

This has motivated investments from governmental and non-governmental entities in initiatives to promote the restoration of this biome.

The estimation of CO_2 removals from restoration is of paramount importance to monitor mitigation efforts that occur in this biome. However, unlike what is observed with clear-cut logging (or even forest degradation), the identification of growing stocks through remotely sensed data is still questionable and lies as a research theme.

Brazil is investing on the development of monitoring tools and protocols in the field of restoration, which so far occurs only at the project level.

[30] For more information see: http://www.inpe.br/noticias/noticia.php?Cod_Noticia=2923, last accessed on May 23rd, 2014.