7. Technical Annex pursuant to decision 14/CP.19

Results achieved by Brazil from Reducing Emissions
from Deforestation in the Amazon biome
for REDD+ results-based payments

Coordination:

Ministry of Environment (MMA)

Ministry of Science, Technology and Innovation (MCTI)

Working Group of Technical Experts on REDD+:

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Ministry of Science, Technology and Innovation, National Institute of Amazon Research (MCTI/INPA)

Foundation for Space Science, Applications and Technology (FUNCATE)

University of São Paulo (USP)

Ministry of Environment, Brazilian Institute for the Environment and Renewable Natural Resources (MMA/IBAMA)

Ministry of Environment, Brazilian Forest Service (MMA/SFB)

Federal University of Goiás (UFG)

Ministry of Agriculture, Livestock and Supply, Brazilian Enterprise for Agricultural Research (MAPA/EMBRAPA)

University of Brasilia (UnB)

Brazilian Research Network on Global Climate Change (Rede CLIMA)

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1. Introduction

Brazil welcomes the opportunity to submit a Technical Annex to its Biennial Update Report (BUR) 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 this Technical Annex with REDD+ results is 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[9].

This submission, therefore, does not modify, revise or adjust in any way the Nationally Appropriate Mitigation Actions (NAMAs) currently being undertaken by Brazil pursuant to the Bali Action Plan (FCCC/AWGLCA/2011/INF.1), neither prejudges any nationally determined contribution (NDC) 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.

This submission was developed by the Brazilian government with the support of the Working Group of Technical Experts on REDD+, created in February 2014 by the Ministry of Environment (MMA) through the Ministerial Ordinance No. 41.

This Technical Annex presents the results from reducing emissions from deforestation in the Amazon biome, measured against the forest reference emission level (FREL) presented by Brazil to the UNFCCC in June 2014[10]. Brazil´s FREL submission went through a technical assessment from July to November of 2014 by two LULUCF experts appointed by the UNFCCC Secretariat. Brazil´s final FREL and the report of the technical assessment can be found at the UNFCCC REDD web platform (http://unfccc.int/methods/redd/items/8414.php).

This Technical Annex for REDD+ was developed following the guidelines of Decision14/ CP. 19 and contains the following elements:

1. Summary of information from the final report containing each corresponding assessed forest reference emission level;
2. Results in tonnes of CO_2eq per year, consistent with the assessed FREL;
3. Demonstration that the methodologies used to produce the results are consistent with those used to establish the assessed FREL;

9 Decision 14/ CP 19, paragraph 7, "requests developing country Parties seeking to obtain and receive payments for results-based actions, when submitting the data and information referred to in paragraph 3 above, through the biennial update reports, to supply a technical annex as per decision 2/CP.17, annex III, paragraph 19". Paragraph 8, "underlines that the submission of the technical annex referred to in paragraph 7 above is voluntary and in the context of results-based payments".

10 For more information see: http://www.mma.gov.br/redd/index.php/en/forest-reference-emission-levels-frel/spatial-information, last accessed on November 19th, 2014.

4. A description of national forest monitoring systems and the institutional roles and responsibilities for measuring, reporting and verifying the results;

5. Necessary information that allows for the reconstruction of results;

6. A description of how the elements contained in Decision 4/ CP.15, paragraph 1(c) and (d), have been taken into account[11].

The elements of Brazil´s Technical Annex for REDD+ are presented below.

2. Summary of information from the FREL for reducing emissions from deforestation in the Amazon biome

Brazil´s FREL, submitted on a voluntary basis for a technical assessment in the context of results based payments, covers the activity ‘reducing emissions from deforestation” in the Amazon biome[12], the most significant of the five activities included in paragraph 70 of Decision 1/CP.16.

Brazil applied a step-wise approach to the development of its FREL, in accordance with Decision 12/CP.17, paragraph 10, and has presented a subnational FREL with the aim of transitioning to a national FREL in the future, by incorporating other biomes and activities. The step-wise approach enables Parties to improve the FREL by incorporating better data, improved methodologies and, where appropriate, additional pools.

Brazil used the 2003 Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance for Land Use, Land-use Change and Forestry as a basis for estimating changes in carbon stocks from forest land converted to other land-use categories.

11 Decision 4/ CP.15, paragraph 1, "requests developing country Parties, on the basis of work conducted on the methodological issues set out in decision 2/CP.13, paragraphs 7 and 11, to take the following guidance into account for activities relating to decision 2/CP.13, and without prejudging any further relevant decisions of the Conference of the Parties, in particular those relating to measurement and reporting: (c) To use the most recent Intergovernmental Panel on Climate Change guidance and guidelines, as adopted or encouraged by the Conference of the Parties, as appropriate, as a basis for estimating anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes; (d) To establish, according to national circumstances and capabilities, robust and transparent national forest monitoring systems and, if appropriate, sub-national systems as part of national monitoring systems that: (i) Use a combination of remote sensing and ground-based forest carbon inventory approaches for estimating, as appropriate, anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes; (ii) Provide estimates that are transparent, consistent, as far as possible accurate, and that reduce uncertainties, taking into account national capabilities and capacities; (iii) Are transparent and their results are available and suitable for review as agreed by the Conference of the Parties."

12 The Amazon biome covers 4,197,000 km^2, corresponding to almost half (49.29 per cent) of the territory, and is responsible for 50.8 percent of the national net CO_2 emissions of Brazil in 2000 (Second National Communication, BRASIL, 2010).

Accordingly, the gross emissions from deforestation were estimated from 1996 onwards by combining activity data (i.e. the area of annual gross deforestation per forest type considered) with the appropriate emission factor (i.e. carbon densities associated with the forest types considered). Regarding the pools, the submission considers aboveground biomass, belowground biomass and litter. Dead wood and soil organic carbon (for mineral and organic soils) were not considered to be significant sources. Regarding greenhouse gases, the submission includes gross CO_2 emissions.

The basis for the activity data used in the construction of the FREL for the Amazon biome was the historical time series from the National Institute for Space Research (INPE), Ministry of Science, Technology and Innovation (MCTI). INPE, through the Amazon Gross Deforestation Monitoring Project – PRODES, has been assessing annual gross deforestation in the Legal Amazon since 1988 using Landsat-class satellite data on a wall-to-wall basis, with a minimum mapping unit of 6.25 hectares. The areas from the Cerrado and Pantanal biome in the Legal Amazon were excluded from the construction of the FREL. Data on deforestation are available in analogue format until 1997 and in digital format from 1998 onwards.

With regard to the emission factors, the carbon density associated with the different forest types in the Amazon biome were estimated by combining sample-plot information from RADAMBRASIL, with various equations to convert circumference at breast height (CBH) into total carbon stock in living biomass (above and below-ground) and litter. Based on this information, and complemented by data from the literature, a carbon density map including 22 different forest types was constructed. Brazil assumed that the biomass immediately after the forest conversion to other land uses is zero and does not consider any subsequent CO_2 removal after deforestation.

To estimate annual emissions from deforestation, the following procedure was applied: the area of each deforested polygon under a certain forest type was multiplied by the emission factor (i.e. carbon density in tonnes C/ha) of the corresponding forest type and by 44/12 (to convert carbon into CO_2). Then, for each year, the emissions from all the areas deforested were summed up.

Brazil´s FREL is a dynamic mean of the CO_2 emissions associated with gross deforestation since 1996, 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 base year was chosen by the Working Group of Technical Experts on REDD+ so as to leave out the high deforestation peak in 1995 and also to maintain consistency with other initiatives in Brazil, including the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm)[13], the National Climate Change Policy[14] and the Amazon Fund[15].

13 For details regarding relevant policies and plans for the Amazon biome see: http://www.mma.gov.br/redd/index.php/en/environmental-policies-related-to-redd/deforestation-reduction, last accessed on November 19th, 2014.

14 For more information on the Presidential Decree no. 7390 of December 9, 2010 see: http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2010/Decreto/D7390.htm, last accessed on September 18th, 2014.

15 For more information on the Amazon Fund see: www.amazonfund.gov.br, last accessed on November 4th, 2014.

The dynamic nature of Brazil´s FREL is meant to reflect the effects of policies and plans implemented in the Amazon biome, as well as improvements in data quality and availability.

Brazil's FREL does not include assumptions on potential future changes to domestic policies.

In summary, for results based payments the following applies:

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

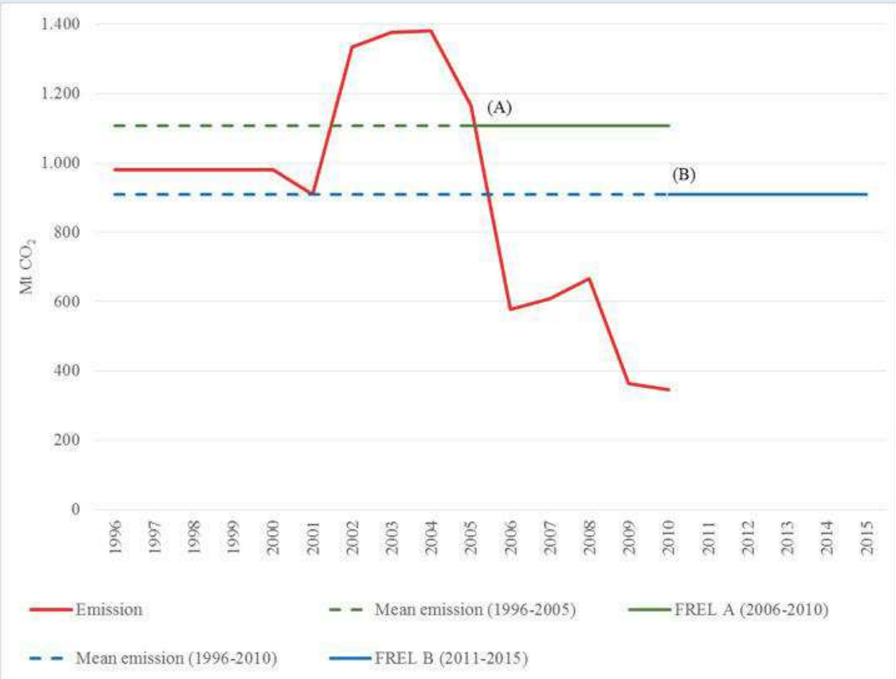

Figure 1: Pictorial representation of Brazil's FREL, where (A) refers to the mean annual CO_2 emissions from the period 1996 to 2005 (1,106,027,616.63 tCO_2); (B) refers to the mean annual CO_2 emissions from the period 1996 to 2010 (907,959,466.33 tCO_2).

Table 1: Adjusted deforestation increments and associated emissions (in tC and t CO_2) from gross deforestation in the Amazon biome, from 1996 to 2010[16].

YEAR	ADJUSTED DEFORESTATION INCREMENT (ha)	EMISSIONS FROM GROSS DEFORESTATION (tC)	CO_2 EMISSIONS FROM GROSS DEFORESTATION (tCO_2)
1996	1,874,013.00	267,142,749.24	979,523,413.88
1997	1,874,013.00	267,142,749.24	979,523,413.88
1998	1,874,013.00	267,142,749.24	979,523,413.88
1999	1,874,013.00	267,142,749.24	979,523,413.88
2000	1,874,013.00	267,142,749.24	979,523,413.88
2001	1,949,331.35	247,899,310.88	908,964,139.89
2002	2,466,603.88	363,942,942.80	1,334,457,456.93
2003	2,558,846.30	375,060,876.74	1,375,223,214.70
2004	2,479,429.81	376,402,076.09	1,380,140,945.68
2005	2,176,226.17	317,420,001.73	1,163,873,339.68
2006	1,033,634.15	157,117,398.10	576,097,126.38
2007	1,087,468.65	165,890,835.62	608,266,397.26
2008	1,233,037.68	181,637,813.29	666,005,315.39
2009	596,373.64	99,365,584.69	364,340,477.19
2010	583,147.53	93,929,048.84	344,406,512.43
1996 - 2005			1,106,027,616.63
1996 - 2010			907,959,466.33

The areas presented in ***Table 1*** are the ***adjusted deforestation increments*** of gross deforestation estimated for the Amazon biome. Note that those from PRODES correspond to the ***rate*** of gross deforestation estimated for the Legal Amazon. See ***Box 2*** for detailed explanation of the differences between these two approaches.

16 The grey lines in ***Table 1*** correspond to years for which data are only available in analogic format. For any year in the period from 1996 to 2010, gross CO_2 emissions from deforestation have been calculated following ***Steps 1-4*** in ***Figures 6*** to ***8***, and ***Step 5*** presented in Brazil´s FREL available through the UNFCCC REDD web platform (http://unfccc.int/methods/redd/redd_web_platform/items/4531.php). Brazil is investing considerable human and financial resources to improve its historical data sets. INPE has a project to expand Digital PRODES to years before 2001 which will allow for the spatial analysis of deforestation and lead to more precise estimates for years before 2000. With the improved data, Brazil will submit a revised FREL to the UNFCCC. REDD+ decisions under the UNFCCC value the constant improvement of data sets and information over time. It is not expected that countries will submit their information to the UNFCCC only when and if they have the most accurate data available for all significant pools. Brazil understands that the most important element before accuracy is to ascertain consistency and transparency of the data submitted.

3. Results in tonnes of CO_2eq per year, consistent with the assessed FREL for the Amazon biome

Decision 14/ CP. 19 paragraph 3, "*decides* that the data and information used by Parties in the estimation of anthropogenic forest-related emissions by sources and removals by sinks, forest carbon stocks, and forest carbon stock and forest-area changes, as appropriate to the activities referred to in decision 1/CP.16, paragraph 70, undertaken by Parties, should be transparent, **and consistent over time and with the established forest reference emission levels and/or forest reference levels** in accordance with decision 1/CP.16, paragraph 71(b) and (c) and chapter II of decision 12/CP.17".

CO_2 emissions from gross deforestation in the Amazon biome from 1996 to 2010 were calculated for Brazil´s FREL using the methodology presented in the previous section. For this Technical Annex, the results for years 2006 to 2010 were calculated simply by subtracting the reference value for that period of 1,106,027,616.63 tCO_2 from the emissions for each year from 2006 to 2010. So for year *t*, the reduced emissions from deforestation were as follows:

REDD+ (*t*) = FREL (1996-2005) – Gross emissions from deforestation at year *t*; (tCO_2)

As an example, the emission reductions in 2006 correspond to:

1,106,027,616.63 tCO_2 - 576.097.126,38 tCO_2 = 529.930.490,25 tCO_2

The total result achieved by Brazil in reducing emissions from gross deforestation in the Amazon biome from 2006 to 2010, was the sum of the results achieved for each year of the period, i.e. ***2,971.02 $MtCO_2$ (Figure 2)***.

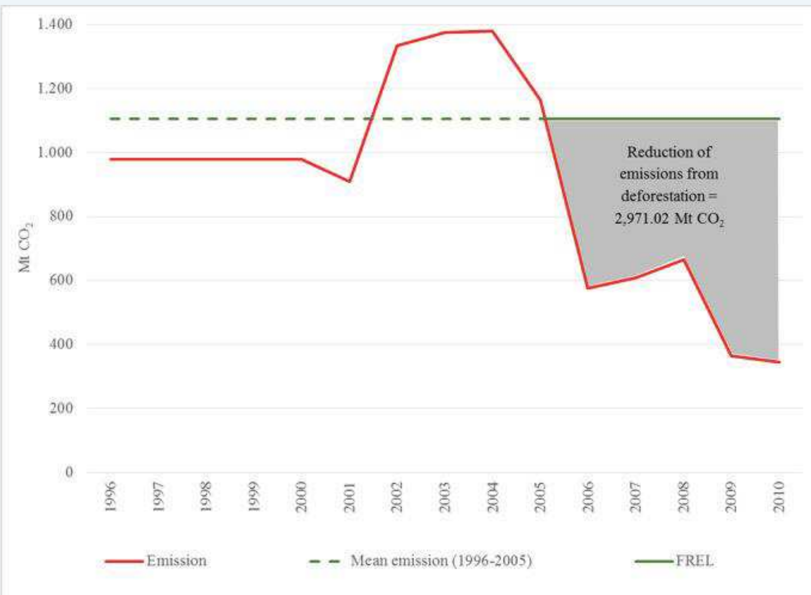

Figure 2: REDD+ results from 2006 to 2010 calculated based on the FREL submitted to the UNFCCC in June 2014

Table 2: Annual REDD+ results in tonnes of CO_2 from 2006 to 2010

Year	EMISSIONS FROM GROSS DEFORESTATION (tCO_2)	FREL (1996-2005, tCO_2)	REDD+ RESULTS(2006 -2010, tCO_2)
1996	979,523,413.88	1,106,027,616.63	
1997	979,523,413.88	1,106,027,616.63	
1998	979,523,413.88	1,106,027,616.63	
1999	979,523,413.88	1,106,027,616.63	
2000	979,523,413.88	1,106,027,616.63	
2001	908,964,139.89	1,106,027,616.63	
2002	1,334,457,456.93	1,106,027,616.63	
2003	1,375,223,214.70	1,106,027,616.63	
2004	1,380,140,945.68	1,106,027,616.63	
2005	1,163,873,339.68	1,106,027,616.63	
2006	576,097,126.38		529,930,490.25
2007	608,266,397.26		497,761,219.37
2008	666,005,315.39		440,022,301.24
2009	364,340,477.19		741,687,139.44
2010	344,406,512.43		761,621,104.20
TOTAL			**2,971,022,254.49**

4. Demonstration that the methodologies used to produce the results are consistent with those used to establish the assessed FREL

The calculation of the REDD+ results presented in this Technical Annex uses the same methodology, the same data set and the same information used for Brazil´s FREL for the Amazon biome.

Accordingly, **the emissions from gross deforestation in the Amazon biome between 2006 and 2010 had already been presented by Brazil on its FREL that was subjected to a technical assessment.**

As presented in the previous section, the results between 2006 and 2010 were measured as emissions at year *t*, minus the average annual CO_2 emissions from gross deforestation in the Amazon biome between 1996 and 2005, i.e. ***1,106,027,616.63 tCO_2***.

5. A description of national forest monitoring systems and the institutional roles and responsibilities for measuring, reporting and verifying the results

5.1. The Amazon Gross Deforestation Monitoring Project – PRODES

Brazil has a consistent, credible, accurate, transparent, and verifiable time-series for gross deforestation for the Legal Amazon (and hence, for the Amazon biome). PRODES is part of a larger program (Amazon Program) developed at INPE to monitors gross deforestation in the Legal Amazon[17]. It uses satellite imagery to identify new deforestation polygons every year in areas of ***primary forest***. Deforestation is associated with clear-cut activities, normally associated with the conversion of forest land to other land-use categories. Gross deforestation is assessed annually, on a wall-to-wall basis, encompassing the analysis of approximately 215 Landsat images, aided by additional Landsat class data (CBERS/CCD, REsourcSat/LISS3 and DMC) to reduce the incidence of cloud cover, with the minimum mapping area of 6.25 hectares (***Box 1***).

Box 1: PRODES minimum mapping area

PRODES was set in 1988 to map deforestation over hardcopy prints of Landsat images at the 1:250,000 scale. Consistent data for gross deforestation are available on an annual basis since 1988. Minimum mapping unit was defined as 1 mm^2, which is equivalent to 6.25 ha in the surface.

Since 2008, deforestation polygons with area larger than 1 ha and under are retrieved in a separate dataset and registered as PRODES deforestation as they coalesce to a size larger than 6.25 ha.

The first three years of this dataset are inflated by past deforestations. However, for all years since 2011 the total area (in km^2) of small deforestation polygons stabilizes at values around 500 km^2 yr^{-1}, (642 km^2 in 2011, 390 km^2 in 2012 and 479 km^2 in 2013).

The consistency of the PRODES time series is ensured by using the same deforestation definition, same minimum mapping area, similar satellite spatial resolution[18], same Forest/Non-Forest vegetation boundaries, and same methodological approach to analyze the remotely sensed data at every new assessment.

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

18 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.

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 is carried out by INPE to address forest degradation. This ensures the consistency of the PRODES deforestation time series over time.

At the start of PRODES, deforestation polygons 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 deforestation polygons were manually digitized in a Geographic Information System (GIS) developed by INPE. This analogical approach to assess deforestation (*Analog PRODES*) was employed from 1988 until 2002.

Due to the increased computing capability built at INPE, it was possible to transition from an ***analogical*** approach to ***digital*** annual assessments of deforestation (*Digital PRODES*) after 2000, which was preceded by a 1997 ***digital base map***, and an aggregated deforestation assessment for years 1998-2000.

Digital PRODES maintains full consistency with the Analog PRODES data. This includes consistency with the forest/non-forest boundaries in Analog PRODES and the aggregated deforestation polygons. Despite the evolution to a digital assessment, the identification of the deforestation polygons continued to be carried out through visual interpretation in the screen and not through digital classification methods[19]. This ensured even greater consistency between the *Analog and Digital PRODES*.

Due to the large volume of analogic data when *Digital PRODES* started, INPE decided to map the deforestation polygons from years 1998 to 2000 on an aggregated deforestation map until 1997 (***digital base map***). Hence, the deforestation polygons for these years were lumped into a single digital database, with no discrimination of the specific year when deforestation occurred. From year 2000 onwards, the deforestation polygons have been annually assessed and included in the *Digital PRODES* database. The *Digital PRODES* allows for the visualization of the deforestation polygons every year, in a single file. Thus, the geographical expansion of deforestation, as well as its spatial pattern, can be assessed and monitored.

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

Digital PRODES 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 in the web, together with all the satellite imagery used to generate the information, and the maps with the identification of deforestation polygons (http://www.obt.inpe.br/prodes/index.php). Annually INPE provides for the download of approximately 215

19 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).

Landsat satellite images of Landsat5/7/8 (or similar data as CBERS/CCD, REsourceSat/LISS3 and DMC). Each image is accompanied by the associated map containing 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.

There are some steps that are followed until the deforestation increments are identified in the satellite imagery. These are now detailed:

Images selection

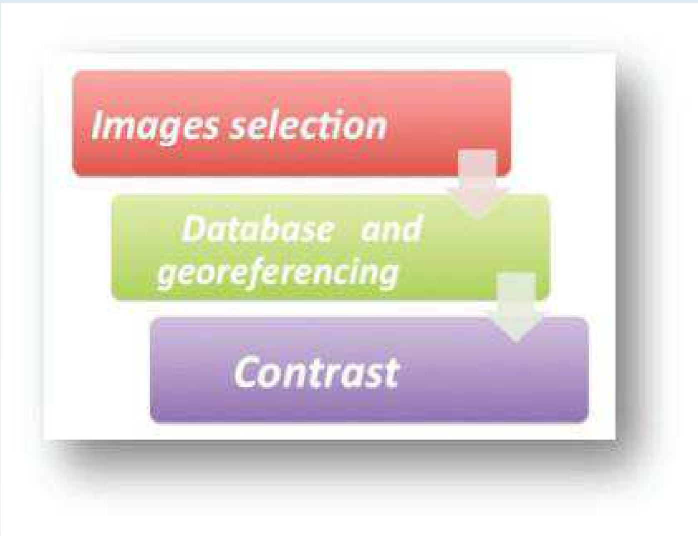

Figure 3: Steps prior to identification of the deforested polygons.

The first step consists of selecting the images to be used. For this, a query is conducted directly from INPE´s Image Generation Division (DGI) site (http://www.dgi.inpe.br/siteDgi_EN/index_EN.php) to identify (preferably) Landsat images (or similar) for the year of interest (usually corresponding to the months of July and August), 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.2 shows an image from Landsat 5 selected in the DGI library.

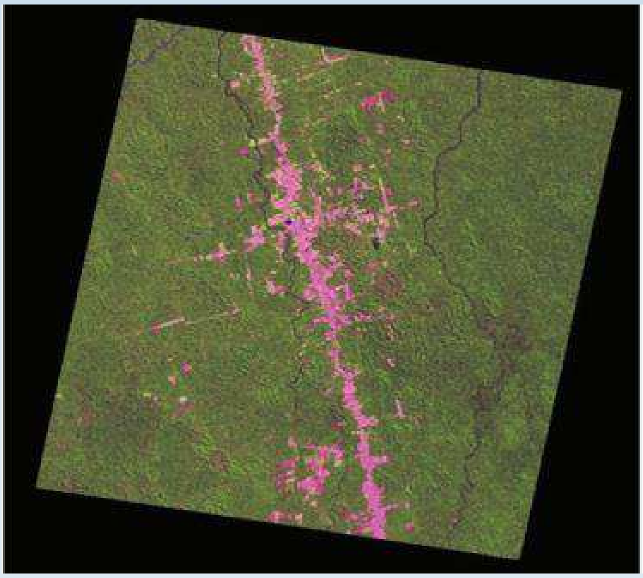

Figure 4: Landsat 5 (pathrow 227/65) of 01/07/2002 Note: Color composite Red, Green, Blue for bands 5, 4, 3, respectively, available on the DGI catalog.

Database and geo-referencing

The next step consists of image geo-referencing, which is carried out through visual collection of at least nine control points evenly distributed in coherent features (rivers, roads intersection) in the image to be geo-referenced. INPE uses as reference data the orthorectified Landsat mosaic for the year 2000, produced by Geocover NASA project (https://zulu.ssc.nasa.gov/MrSID). The geo-referencing is carried out by linear matrix transformation of first or second order, depending on the image quality, with transformation parameters obtained by least-square method applied to the set of control points.

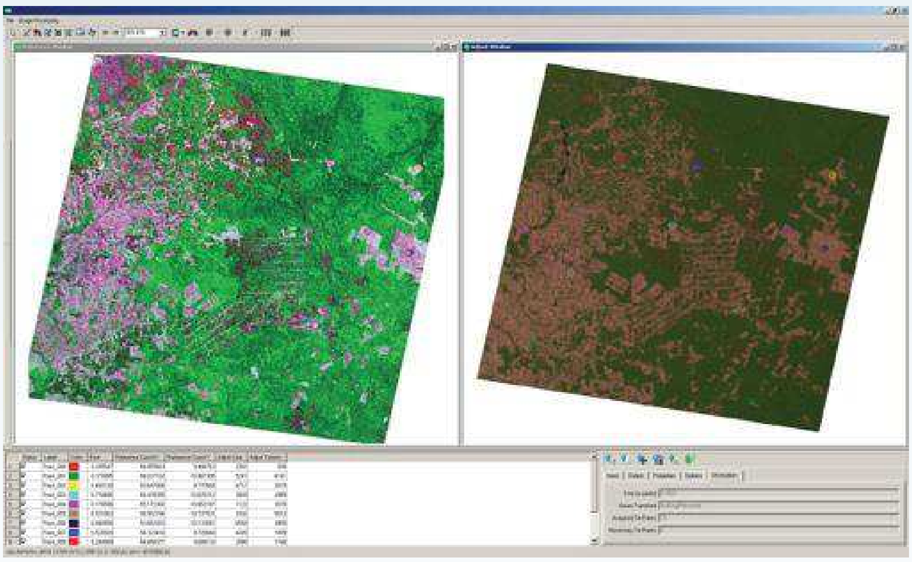

Figure 5: An example of control points collection.

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

Activity data for Brazil´s Technical Annex and FREL

The area of the deforestation polygon by forest type (in km^2 or hectares) is the ***activity data*** necessary for the application of the first order approximation to estimate emissions[20] 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 time series data (modified to consider only deforestation in the Amazon biome) and the vegetation map from the Brazilian Institute for Geography and Statistics (IBGE).

The fact that satellite data from optical systems (e.g., Landsat) are the basic source of information to identify new deforestation events every year, and considering that the presence of clouds may impair the observation of deforestation events under clouds, requires the application of an approach to deal with the estimation of the areas of primary forest under clouds that may have been deforested so as not to underestimate the total deforestation at any year (refer to ***Box 2*** for alternative approaches to estimate the area of gross deforestation in the Amazon biome). This is in line with good practice as defined in GPG LULUCF (IPCC, 2003).

20 "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).

Box 2: Approaches to estimate the area of gross deforestation in the Amazon biome

There are several approaches to estimate the area deforested and each may lead to different results. The total deforested area may be different if calculated as deforestation increment, or deforestation rate, or adjusted deforestation increment. To further clarify the above, the text that follows explains the different approaches and terminologies used throughout this submission.

1. **Deforestation Polygons** (at year *t*): refer to new deforestation events identified from the analysis of remotely sensed data (satellite images) at year t as compared to the accumulated deforestation mapped up to year *t-1*. Each deforestation polygon is spatially identified (geocoded), has accurate shape and area representations, and has an associated date of detection (the date of the satellite image from which it was mapped). For each year, a map containing all deforestation polygons (deforestation map) is made available in shapefile format for PRODES (and hence, for the Amazon biome, after exclusion of the areas associated with the Cerrado and Pantanal biomes) at (http://www.obt.inpe.br/prodesdigital/cadastro.php). This map does not include deforestation polygons under cloud covered areas. However, the deforestation map also renders spatially explicit distribution of the cloud covered areas.
2. **Deforestation Increment** (at year *t*): refers to the sum of the areas of all observed deforestation polygons within a given geographical extent. This geographical extent may be defined as the boundaries of a satellite scene which has the same date as the deforestation polygons mapped on that scene; or the entire Amazon biome, for which the deforestation increment is calculated as the sum of the individual deforestation increment calculated for each scene that covers the biome. The deforestation increment **may underestimate** the total area deforested (and associated emissions), since it does not account for the area of deforestation polygons under clouds.
3. **Adjusted Deforestation Increment** (at year *t*): this adjustment is made to the deforestation increment at year *t-1* (or years *t-1* and *t-2*, etc., as applicable) to account for deforestation polygons in areas affected by cloud cover and that are observable at time *t*. It is calculated according with ***Equation 1***:

$$Inc_{adj(t)} = Inc_{(t)} - \sum_{\Delta=1} A_{CC(t-\Delta),(t)} + \sum_{\Delta=1} \frac{A_{CC(t-\Delta),(t)}}{\Delta+1} + \sum_{\Omega-1} \frac{A_{CC(t+\Omega),(t)}}{\Omega+1} \quad \textit{Equation 1}$$

where:

$Inc_{adj(t)}$ = adjusted deforestation increment at year *t*; km^2

$Inc_{(t)}$ = deforestation increment at year *t*; km^2

$A_{CC(t-\Delta),(t)}$ = area of the deforestation polygons observed (cloud-free) at year *t* over cloud-covered areas at year *t*-; km^2. Note that when $\Delta=1$, $A_{CC(t-1),(t)}$ equals the area of the deforestation polygons observed at year *t* over cloud-covered areas at year *t*-1 (but which were under cloud-free at year *t*-2); for $\Delta=2$, $A_{CC(t-2),(t)}$ equals the area of the deforestation polygons observed at year *t* over an area that was cloud-covered at both years *t*-1 **and** *t*-2.

$A_{CC(t+\Omega),(t)}$ = area of the deforestation polygons observed at year t+ over cloud-covered areas at year *t*; km^2. Note that when $\Omega=1$, the term $A_{CC(t+1),(t)}$ provides the area of the deforestation polygons observed at year *t*+1 over the area that was cloud-covered at year *t*; when $\Omega=2$, the term $A_{CC(t+2),(t)}$ provides the area of the deforestation polygons observed at year *t*+2 over the area that was cloud-covered at years *t* **and** *t*+1.

Δ = number of years that a given area was persistently affected by cloud cover prior to year *t* but was observed at year *t*; Δ =1, 2, ...

Ω = number of years until a given area affected by cloud cover at year t is observed in subsequent years (i.e., is free of clouds); Ω = 1,2, ...

As an example, suppose that the area of the deforestation increment observed at year *t*, $Inc_{(t)}$, is 200 km^2 and that 20 km^2 of this occurred over primary forest areas that were cloud covered at year *t*-1 (but are cloud-free at year *t*). Since these 20 km^2 may accumulate the area of the deforestation polygons under clouds at year *t*-1 and the area of the deforestation polygons that occurred at year *t*, the deforestation increment **may overestimate** the total area deforested area (and associated emissions) at year *t*.

The adjusted deforestation increment $Inc_{adj(t)}$ at year *t* evenly distributes the total area of the deforestation polygons observed at year t under the cloud-covered area at year *t*-1 (or before, if the same area was also cloud covered at year *t*-2, for instance) among years *t*-1 and *t*. Hence, the adjusted deforestation increment at year t is 190 km^2 (200 – 20/2) and not 200 km^2, assuming that there were no cloud-covered areas at year t (in which case the adjusted deforestation increment at year t would be adjusted by where = area of the deforestation polygons observed at year *t*+ over cloud-covered areas at year *t*; and Ω is the number of years that a given area affected by cloud cover at year *t* is observed (i.e., is free of clouds).

The rationale behind Equation 1 is to remove from the deforestation increment the area to be distributed among the years (-) and then add back the portion allocated to year *t* . The last term of the equation refers to the area distributed from subsequent years (or year) over cloud covered areas at year *t*.

4. **Deforestation Rate** (at year *t*): was introduced in PRODES to sequentially address the effect of cloud cover; and, if necessary, the effect of time lapse between consecutive images. The deforestation rate aims at reducing the potential under or over-estimation of the deforested area at year t. The presence of cloud-covered areas in an image at year t impairs the observation of deforestation polygons under clouds, and may lead to an underestimation of the area deforested; while the presence of clouds in previous years (e.g., at year t-1) may lead to an overestimation of the area deforested if all deforestation under clouds at year t-1 is attributed to year t.

   This **over** or **under-estimation** may also occur if the dates of the satellite images used in subsequent years are not adjusted. To normalize for a one year period (365 days) the time lapse between the images used at years t and t+1, the rate considers a reference date of August 1st and projects the cloud corrected increment to that date, based on a model that assumes that the deforestation pace is constant during the dry season and zero during the wet season. Refer to Annex I, Part I for more information on PRODES methodology for calculating the deforestation rate.

   As an example of cloud correction, suppose that the primary forest area in an image is 20,000 km^2 and that 2,000 km^2 of this occurred over primary forest areas that were cloud covered. Suppose also that the observed **deforestation increment** is 180 km^2. As part of the calculation of the rate, it is assumed that the proportion of deforestation measured in the cloud-free forest area (18,000 km^2) is the same as that in the area of forest under cloud (2,000 km^2). Therefore the proportion 180/18,000 = 0.01 is applied to the 2,000 km^2, generating an extra 20 km^2 that is added to the observed deforestation increment. In this case, the **cloud corrected** increment is 200 km^2.

   IMPORTANT REMARKS:

1. Note that at any one year, an estimate based on the adjusted deforestation increment may be higher or lower than the rate of gross deforestation.
2. For the sake of verifiability, this submission introduces a slight change in the methodology used in PRODES to estimate the annual area deforested. PRODES methodology to annualize observed deforestation and to take into account unobserved areas due to cloud cover is not directly verifiable unless all the estimates are adjusted backwards.
3. The approach applied in this submission relies on a verifiable deforestation map and does not annualize the time lapse between consecutive scenes. It deals with the effect of cloud cover by equally distributing the area of the deforestation polygons observed at year t over cloud-covered areas at year t-1 (or to years where that area was persistently cloud covered) among years t and t-1.
4. The use of the adjusted deforestation increment to estimate the area deforested and associated gross emissions is deemed to be more appropriate for REDD+, due to the verifiability.

Calculating deforestation rates based on deforestation increments

Deforestation rate calculations are elaborate, and have as a basis the information on deforestation increments. The simple sum of the mapped, observed deforestation polygons is the deforestation increment.

Table 3: Deforestation increments vs deforestation rates Source: INPE, 2014

Deforestation Increments	Deforestation Rates
Value measured by image interpretation Calculated for each pair of LANDSAT image Indicating the date of image acquisition	Value is estimated Interpolated to a reference date (August 1st) Takes into account the area covered by clouds

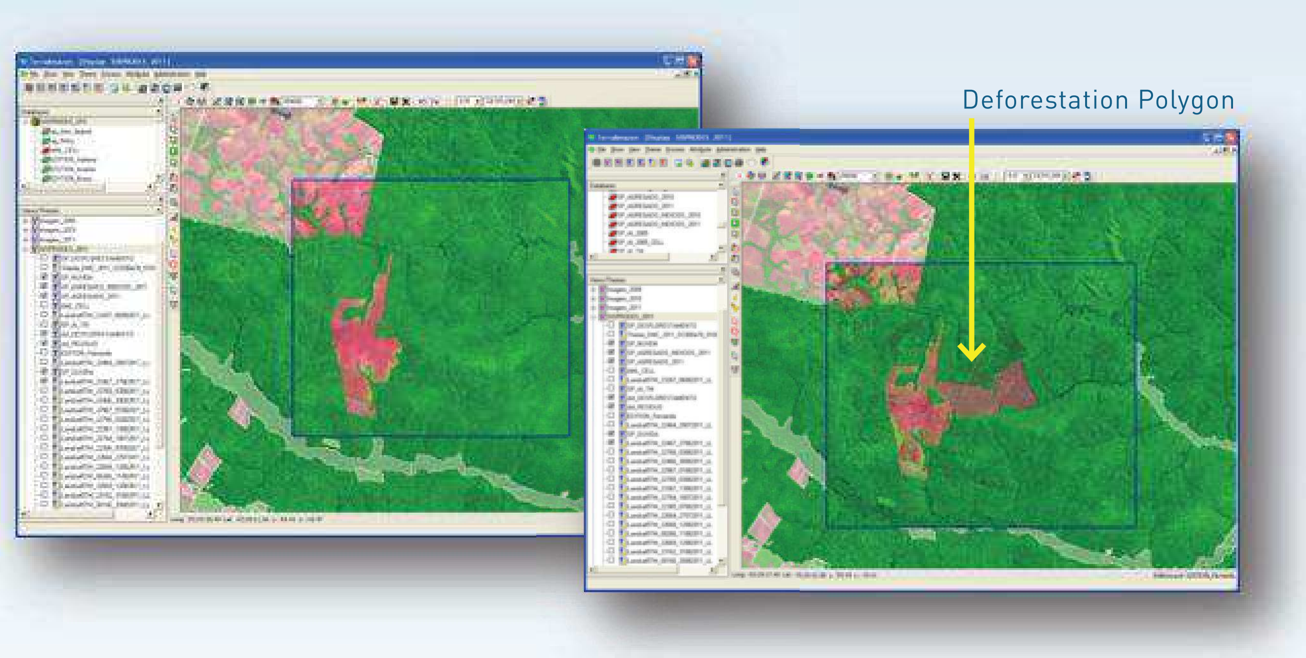

Figure 6: Deforestation polygon as shown by PRODES Source: INPE, 2014

It should be noted that up to 2000, the Landsat TM scenes 222/61 and 222/62 were never considered by PRODES since they were persistently covered by clouds. In 2001, it was possible to observe these scenes. It was then verified that a large area was cleared in these scenes, leading to a high deforestation increment at that year (2001). This implies that there will be a substantial difference between increments and rates in years before 2001.

In early 2000s, there was a predilection for scenes without clouds, even when they were taken many days before the date of reference (August 1st). A limit to the number of days for the analysis of scenes was only later defined as a measure to avoid the discrepancy between deforestation rates and deforestation increment. In 2004, INPE decided to select only the images with dates as close as possible to the next reference date, so that after 2005/2006, the discrepancies between deforestation rates and deforestation increment became very small.

Comparing the emissions estimates: deforestation rates vs. adjusted increments

Deforestation rates were not the basis for the FREL calculations. The FREL was calculated based on adjusted deforestation increments and these are two different approaches. Brazil´s FREL is conservative because it uses only historical data and is dynamics through time (which is not required in any REDD+ decision).

PRODES maps up to 2001 were analogic and constrained the integration with the carbon map adopted in this FREL. As an exercise, the annual CO_2 emissions per year were calculated taking as a basis the deforestation rates from PRODES and applying the average carbon stock per unit area (tC ha^{-1}). This was done to assess the average difference in CO_2 emissions using the annual rates of gross deforestation from PRODES and the emission estimates presented in this submission for years 1996 – 2005 based on the adjusted increments. The formula used was:

Deforestation rate (ha)/year * 151.6 tC/ha * 44/12

Table 4: Emission estimates from deforestation rate vs emission estimates from the FREL

Year	Deforestation (km^2)	Deforestation (ha)	Emission PRODES (tCO_2) (Mean = 151,6 tC/ha)	Emission FREL (tCO_2)
1996	18,161	1,816,100	1,009,509,453	979,523,414
1997	13,227	1,322,700	735,244,840	979,523,414
1998	17,383	1,738,300	966,263,027	979,523,414
1999	17,259	1,725,900	959,370,280	979,523,414
2000	18,226	1,822,600	1,013,122,587	979,523,414
2001	18,165	1,816,500	1,009,731,800	979,523,414
2002	21,651	2,165,100	1,203,506,920	1,334,457,457
2003	25,396	2,539,600	1,411,678,987	1,375,223,215
2004	27,772	2,777,200	1,543,752,907	1,380,140,946
2005	19,014	1,901,400	1,056,924,880	1,163,873,340
Mean			1,090,910,568	1,106,027,617
Difference				**1.39%**

The average emissions from 1996 through 2005, using PRODES rates were **1,090,910,568 tCO_2**. The average emissions from 1996 through 2005 presented in the FREL were **1,106,027,617 tCO_2**. Since the FREL uses the average emissions of 10 years, these differences balance out at the end, being only 1.4 per cent.

The use of adjusted increments to estimate emissions from gross deforestation provides a more accurate figure for the deforested area through time.

5.2. Roles and responsibilities for measuring, reporting and verifying (MRVing) the results

Table 5: Roles and responsibilities for REDD+ MRV

MRV	Instrument/ Project	Responsible Institution	Roles	Additional Information
Measuring		Foundation of Science, Application and Space Technologies (FUNCATE)	Calculating emission reductions from deforestation in the Amazon biome based on the adjusted deforestation increments and the carbon map from RADAMBRASIL project.	http://www.funcate.org.br/
	Amazon Program	INPE, MCTI	Verifying the calculations done by FUNCATE	http://www.obt.inpe.br/prodes/index.php
Reporting	Working Group of Technical Experts on REDD+	MMA MCTI	Providing technical inputs for REDD+ submissions to the UNFCCC and ensuring its quality control.	http://www.mma.gov.br/redd/index.php/en/
	Modular System for Monitoring and Tracking Greenhouse Gases Emission Reductions (SMMARE)	MMA	Tracking and reporting on the implementation of PPCDAm actions that lead to emission reductions. A tool to provide information, in particular in relation to the mitigation actions (NAMAs) implemented in each mitigation plan and its associated methodologies and assumptions, the progress made in their implementation and information on domestic measurement, reporting and verification.	www.mma.gov.br
Verifying	International Consultation and Analysis	UNFCCC	Verifying the submissions from Parties, by appointing two LULUCF experts to assess the FREL submissions and the technical annexes.	http://unfccc.int/methods/redd/redd_web_platform/items/4531.php

6. Necessary information that allows for the reconstruction of results

Complete information, for the purposes of REDD+, means the provision of the following information that allows for the reconstruction of the FREL and this Technical Annex.

Below is a description of the information that allows for the reconstruction of the results. Links to the database and information that allows for the reconstruction of results was detailed in ***Section b.1*** of Brazil´s FREL and are available through the website: http://www.mma.gov.br/redd/index.php/pt/forest-reference-emission-levels/the-submission-of-brazilian-forest-reference-emission-levels

1. All the satellite images used to map the deforestation polygons in the Amazon biome from 1996 to 2010.
2. Accumulated deforestation polygons until 1997 (inclusive), presented in a map hereinafter referred to as the ***digital base map*** (see ***Annex I, Part I*** for more details).
3. Accumulated deforestation polygons for years 1998, 1999 and 2000 mapped on the ***digital base map.***
4. Annual deforestation polygons for the period from 2001 to 2010, inclusive (***annual maps***).

IMPORTANT REMARK 1: All maps referred to in (2), (3) and (4) above are available in shapefile format ready to be imported into a Geographical Database for analysis. All satellite images referred to in (1) above are provided in full resolution in geotiff format. Any individual deforestation polygon can be verified against the corresponding satellite image.

IMPORTANT REMARK 2: The maps referred to in (2), (3) and (4) above are a **subset** of those produced by INPE for PRODES (for additional information see http://www.obt.inpe.br/prodes/index.php) and refer only to the Amazon biome, the object of this submission. The information in (2) and (3) above are provided in a single file.

5. The **deforestation polygons by forest type attributes and RADAMBRASIL volume**; For each year, the deforestation polygons are associated with the corresponding forest type and RADAMBRASIL volume. These files are large and are thus presented here only for year 2003[21], the year that has been used to exemplify the calculation of the adjusted deforestation increment (refer to ***Box 2*** and ***Annex II, Part I***). It is worth noting that for all since 2001, the stratification of the deforestation polygons by forest type attributes and RADAMBRASIL volume indicated that deforestation concentrates mostly in the so called *"Arc of Deforestation"* (a belt that crosses over RADAMBRASIL volumes 4, 5, 16, 20, 22 and 26 – refer to ***Figure 11***), and marginally affects forest types in RADAMBRASIL volumes associated with higher carbon densities.

21 For year 2003, a total of 402,176 deforestation polygons have been identified. For each deforestation polygon in the file, the following information is provided: the State of the Federation it belongs (uf); the RADAMBRASIL volume (vol); the associated forest type (veg) and the associated area (in ha).

6. The **information that allows for the calculation of the adjusted deforestation increments for years 2001, 2002, 2003, 2004 and 2005 is** available at: http://mma.gov.br/redd/index.php/pt/forest-reference-emission-levels/spatial-information. ***Annex II, Part I*** provides an example of the calculation of the adjusted deforestation increment for year 2003 (see **"calculo_def_increment_emission_2003"** thought the FTP. file available at: http://mma.gov.br/redd/index.php/pt/forest-reference-emission-levels/spatial-information).

7. A map with the carbon densities of different forest types in the Amazon biome (**carbon map**), consistent with that used in the Second National GHG Inventory, the latest submitted by Brazil to the UNFCCC at the time of construction of the FREL.

8. Samples of the relevant[22] RADAMBRASIL data that have been used as input to the allometric equation by Higuchi *et al.* (1998). They are generated from the original RADAMBRASIL database, which is the basis for the construction of the carbon map. Consultation with the Working Group of Technical Experts on REDD+ led to the understanding that there may be cases of apparent inconsistencies in carbon densities within a forest type due to specific circumstances of the sample unit. This is part of the natural heterogeneity of the biomass density distribution in tropical vegetation.

7. A description of how the elements contained in Decision 4/ CP.15, paragraph 1(c) and (d), have been taken into account

7.1. Use of the most recent IPCC guidance and guidelines

Brazil´s FREL and its respective Technical Annex use 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.

As stated on the previous sections, the area of the deforestation polygon by forest type (in km^2 or hectares) is the activity data necessary for the application of the first order approximation to estimate emissions as suggested in the IPCC Good Practice Guidance for Land Use, Land-use Change and Forestry (GPG LULUCF) (IPCC, 2003).

22 The original RADAMBRASIL data for the volumes where deforestation occurs most frequently (CBH, forest type, RADAMBRASIL volume) are provided at: http://mma.gov.br/redd/index.php/pt/forest-reference-emission-levels/spatial-information, as RADAMBRASIL sample units data.

7.2. Establish, according to national circumstances and capabilities, robust and transparent national forest monitoring systems

The activity data used for the construction of the FREL and as a basis for calculating the results presented in this Technical Annex was the historical time series from PRODES (for details refer to ***Section 5.1*** above).

PRODES forest definition includes all vegetation types of Evergreen Forest Formations in the Legal Amazon and forest facies of other formations such as Savanna and Steppe, which are generally classified as "Other Wooded Land" according to the Food and Agriculture Organization of the United Nations (FAO) classification system. The presence of these facies in the Amazon biome is not significant. However, when deforestation occurs in any of these facies, the associated emissions are calculated using their corresponding carbon density from the RADAMBRASIL carbon map**.**

At the beginning of PRODES in 1988, a map containing the boundary between Forest – Non-Forest was created based on existing vegetation maps and spectral characteristics of forest in Landsat satellite imagery. In 1987, all previously deforested areas were aggregated in a map (including deforestation in forest areas that in 1987 were secondary forests) and classified as ***deforestation***. Thereafter, on a yearly basis, deforestation in the Amazon biome has been assessed on the remaining annually updated Forest.

For the purposes of PRODES, the areas of Non-Forest are not monitored (regardless of being managed or unmanaged following the IPCC definition of managed land[23] (IPCC, 2006). Deforestation occurring in Forest land (managed or unmanaged) is monitored and the associated CO_2 emission calculated assuming instantaneous oxidation at the year deforestation occurs. Hence, the accumulated gross deforestation in the Brazilian Amazon never decreases at each new assessment.

The Brazilian deforestation time series from PRODES relate only to deforestation in primary forests that may or may not have been impacted by human activities or natural events but has not shown a **clear cut** pattern in the satellite imagery. Hence, areas previously logged, whenever identified in the satellite imagery as **clear cut**, are included as deforestation in PRODES. The definition of deforestation adopted for PRODES and maintained in the FREL (i.e., clear cut), in conjunction with the annual wall-to-wall assessment of deforestation based on satellite imagery of high spatial resolution (up to 30 meters) allows deforestation polygons to be identified and mapped with very high accuracy. No ground truth is required for the Amazon biome since there is an unequivocal identification of the clear cut patches in the Landsat imagery from one year to another. Only new polygons of deforestation are mapped each year on the aggregated deforestation map containing deforestation up to the previous year.

23 Managed land is land where human interventions and practices have been applied to perform production, ecological or social functions. (IPCC, 2006)

All deforestation polygons[24] mapped for the Amazon biome (i.e., aggregated until 2007; aggregated for years 1998, 1999 and 2000; and annual from 2001 until 2010) are available at http://www.mma.gov.br/redd/index.php/en/forest-reference-emission-levels-frel/spatial-information.

Note that this information is a subset of that made available since 2003 by INPE for PRODES at www.obt.inpe.br/prodes. At this site, for each satellite image (see (1) above), a vector map in shapefile 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.

The experts appointed by the UNFCCC Secretariat noted on their report of the technical assessment of Brazil´s FREL that the transparency and completeness of information significantly improved in the final submission and commended Brazil for the efforts taken. According to their report, the information provided in the final FREL submission, including through the data made available in websites and the examples of how estimates of deforestation were calculated, increased the reproducibility of FREL numbers. This Technical Annexes uses of the emissions calculated in the FREL for estimating the REDD+ results achieves in the Amazon biome from 2006 to 2010.

24 The information for PRODES is also available for the Legal Amazon are publicly available since 2003 at INPE´s website (www.obt.inpe.br/prodes).

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