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Proposed Forest Reference Emission Level for deforestation in the Colombian Amazon Biome for results–based payments for REDD+ under the UNFCCC

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. Introduction

Colombia presents its first Forest Reference Emission Level (FREL) in adoption of the relevant provisions referred to in paragraph 70 of decision 1/CP.16 (UNFCCC, 2011). It does so with a view to include the FREL in the technical assessment process, in the context of results-based payments for reducing emissions from deforestation and forest degradation and the conservation, sustainable management of forests and the enhancement of forest carbon stocks in developing countries (REDD+) under the United Nations Framework Convention on Climate Change (UNFCCC).

Colombia wishes to highlight that the presentation of this FREL and its technical annexes is voluntary, and is exclusively aimed to generate the baseline for measuring the performance of the implementation of the activities referred to in paragraph 70 of Decision 1/CP.16; in the context of obtaining results-based payments for REDD+ actions under the guidance of the Warsaw Framework for REDD+ in accordance with decisions 9/CP.19, 13/CP.19, 14/CP.19 and others therein cited.

This FREL does not prejudge any nationaly determined contribution that Colombia could propose in the context of a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties, currently under negotiation in the Ad Hoc Working Group on the Durban Platform for Enhanced Action.

Following the guidelines of the Annex to Decision 12/CP.17, paragraphs 10 and 11, Colombia has adopted a "step-wise" approach and a subnational scale to the development of this FREL. This approach allows Parties to improve FRELs by incorporating enhanced information, improved methodologies and, where appropriate, new carbon pools and activities; and to make a transition from subnational to a national FREL.

This FREL submission has been structured considering the following items:

a) Information used in the construction of the FREL;
b) Transparency, completeness, consistency and accuracy, including the methodological information used at the time of the construction of the FREL.
c) Pools, gases and activities included in the FREL; and
d) Definition of forest employed.

Each of these items is discussed in the following sections of the document.

2. Information used in the construction of the FREL

a) Area covered by the FREL

The concept of biome defines large and uniform environments of the geo-biosphere (Walter, 1980) which correspond to a homogeneous area in biophysical terms. In Colombia, five major biomes (Amazon, Andes, Caribbean, Orinoco and Pacific) have been identified (see distribution in Figure 1).

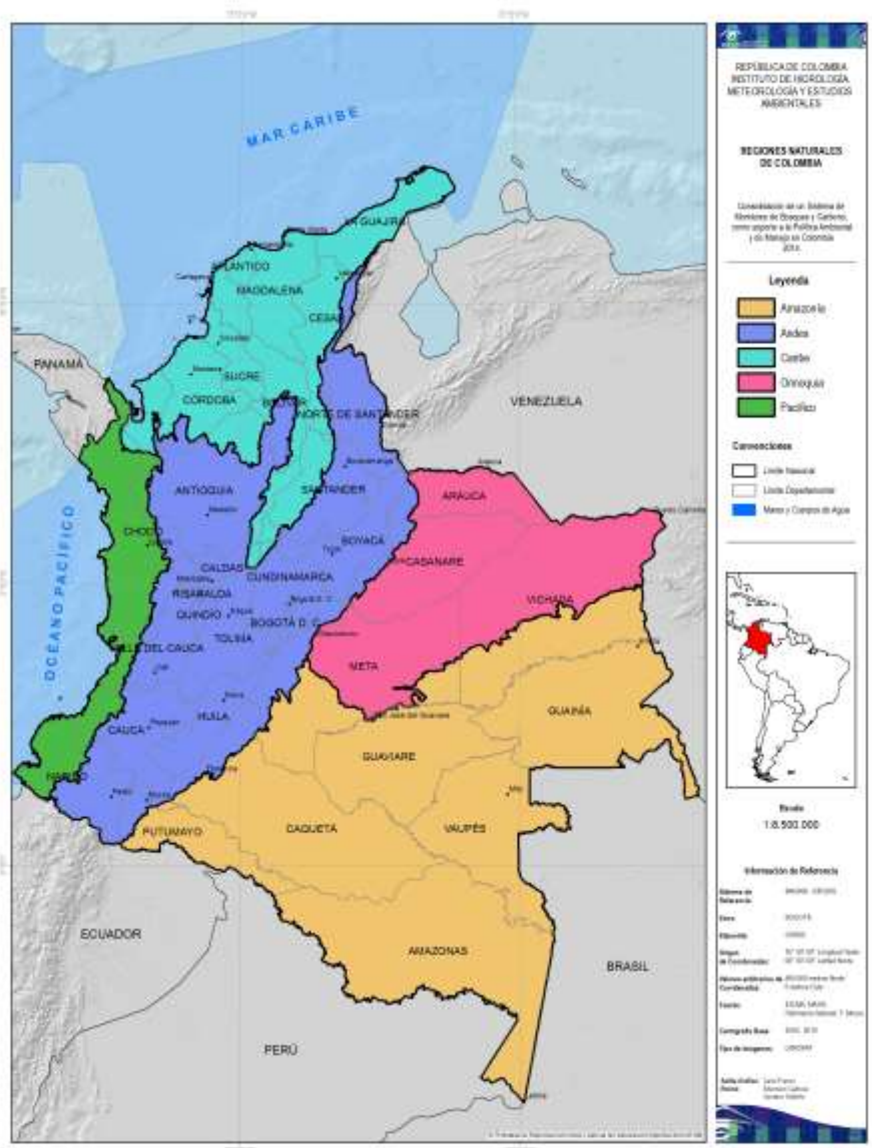

Figure 1 Map of Biomes (Natural Regions) of Colombia

In accordance with decision 12/CP.17 and as an interim measure, a subnational FREL is presented as a first step towards the construction of a national FREL. The area covered by this FREL corresponds to that of the Amazon Biome, delimited on the base of biogeographic criteria which are mainly associated with the presence of Amazon forests, geomorphology and altitudinal ranges (Rodríguez et al., 2006; Narváez & León, 2001).

The northwestern boundary of this area is characterized by the presence of foothills with an altitude ranging between 400-500 meters, where Andean and tropical elements of the Amazon and Orinoco regions converge. The northeastern boundary corresponds with the northern limit of range of the Amazon forest bordering the savannas of the Orinoco; and to the east and south with the international borders of the Bolivarian Republic of Venezuela, the Federal Republic of Brazil, the Republic of Peru and the Republic of Ecuador (see Figure 2).

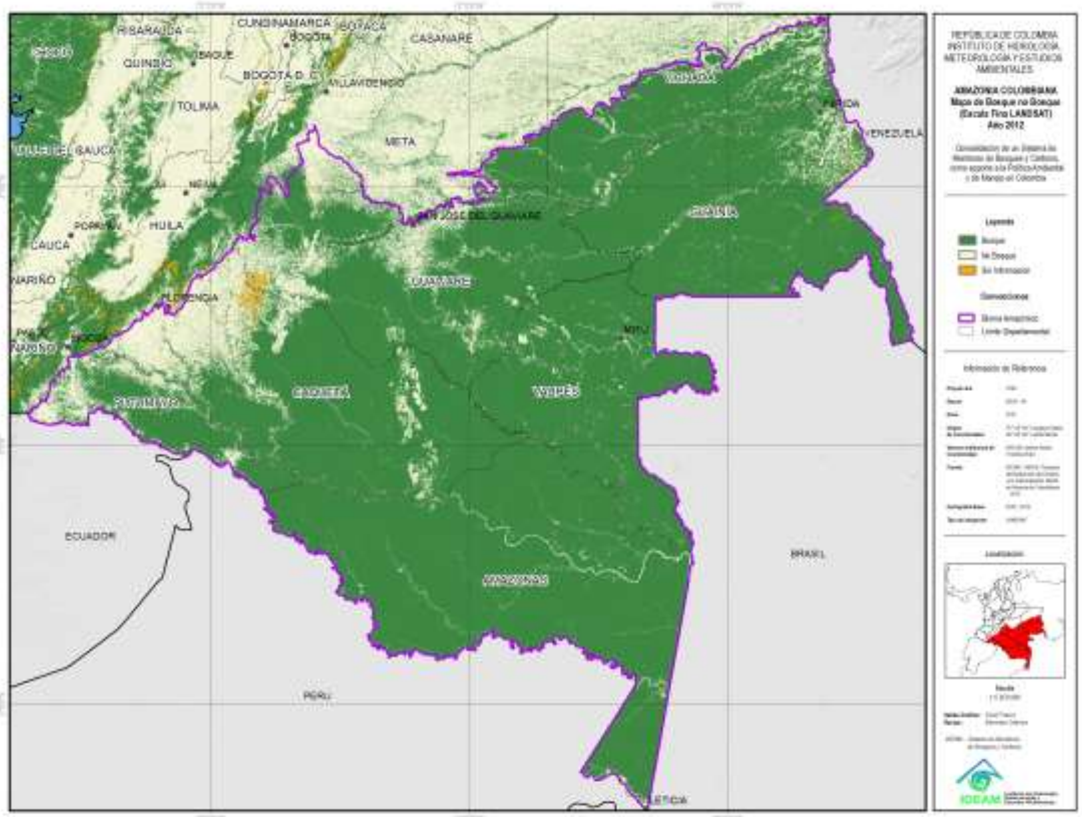

Figure 2 General characteristics of the Colombian Amazon Biome.

Total Area	:	458,961 km^2
Forest area in 2012 (ha)	:	399,737 km^2
Forest Types	:	(4 types). Bs-T(Tropical Dry Forest), Bh-T(Tropical Rain Forest), Bmh-T(Wet Tropical Forest), Bmh-PM (Wet Premontane Forest)
Protected Areas **PNN (National Parks by its acronym in Spanish)** **RNN (Natural Reserve by its acronym in Spanish)**	:	Area in the biome: 89,495 km^2 (19%). Area of natural forest: 85,595 km^2 (21%) PNN Sierra de La Macarena, PNN Tinigua, PNN Cahuinarí,PNN Cordillera de los Picachos, RNN Puinawai, PNN Amacayacu, PNN Río Puré, RNN Nukak, PNN La Paya, PNN Yaigoje Apaporis, PNN Serranía de Chiribiquete (Including its expansion).

Indigenous Territories *(Resguardos)*		Area in the biome: 255,138 km^2 (56%), Area of natural forest: 242,148 km^2 (61%) According to their extension the most representative are: Predio Putumayo, Vaupés, Cuenca media y alta del Río Inírida, Selva de Matavén, Mirití-Paraná, Yaigojé-Río Apaporis, Nukak Maku, Tonina Sejal-San José y otras; Ríos Cuiarí e Isana, Bajo Río Guainía y Rionegro, Morichal Viejo-Santa Rosa-Cedro Cucuy-Santa Cruz-Caño Danta-Otros; y Río Atabapo e Inírida; among others.
Regional Environmental Authorities	:	Corporation for the Sustainable Development of the Northern and Eastern Amazon - CDA; Corporation for the Sustainable Development of the Southern Amazon - CORPOAMAZONIA; Corporation for Sustainable Development and Special Management of La Macarena Area - CORMACARENA; Regional Autonomous Corporation of the Colombian Orinoco – CORPORINOQUIA, and Regional Autonomous Corporation of Cauca - CRC.

This reference level covers an area of 45.9 million hectares, that is, over 40% of the Colombian land surface. In 2012, this subnational area comprised 39.9 million hectares of forests - or 67% of the country's total forest area - in the departments of Putumayo, Caqueta, Amazonas, Guainia, Guaviare, Vaupes, Meta, Vichada and Cauca, and within the jurisdiction of five Regional Environmental Authorities[1] (Corpoamazonia, CDA, Cormacarena, Corporinoquia and CRC). Over the past four decades, this region has experienced the highest rates of deforestation, contributing with a large share of the net carbon dioxide emissions (CO_2) from Land Use, Land Use Change and Forestry (LULUCF) wich, according to the 2004 National Greenhouse Gas Inventory submitted by Colombia to the UNFCCC, constitutes the third largest emitting sector in the country.

b) Activities included

The FREL only includes CO_2 emissions from deforestation. Colombia is currently working on the development of methodologies for the detection and monitoring of forest degradation, yet progress in this area does not allow, from an uncertainty standpoint, for the inclusion of information on emissions from forest degradation in this FREL.

c) Definition of forests and deforestation

For the purposes of the National REDD+ Strategy (ENREDD+), and in particular for the construction of this FREL, forest is defined as:

[1] Regional Environmental Authorities in Colombia are public corporate organizations created by Law 99 of 1993. Integrated by territorial entities whose caractheristics constitutes geographically the same ecosystem, and, in some cases, geopolitical (e.g. departments), biogeographical or hydrogeographical units. Regional Environmental Authorities have administrative and financial independence and are in charge of environmental management and sustainable development in their jurisdictions, in accordance with legal provisions and policies of the Ministry of Environment and Sustainable Development. (Art. 3 Law 99 of 1993)

Land mainly covered by trees which might contain shrubs, palms, *guaduas*, grass and vines, in which tree cover predominates with a minimum canopy density of 30%, a minimum canopy height (in situ) of 5 meters at the time of identification, and a minimum area of 1.0 ha. Tree covers from commercial forest plantations, palm crops and planted trees for agricultural production are excluded.

This definition is in line with the criteria defined by the UNFCCC in decision 11/CP.7, the definition adopted by Colombia under the Kyoto Protocol (MAVDT, 2002), the definition of forest cover used in National Greenhouse Gas Inventory estimations and reports, and the definition included in the Colombian legend adaptation of the CORINE Land Cover (CLC) methodology.

Deforestation is defined as the direct and/or induced conversion of forest cover to another type of land cover in a given timeframe (DeFries et al., 2006; GOFC-GOLD, 2009).

d) Activity data

The 2009 and 2010 Conferences of the Parties to the UNFCCC (COP 15 and 16, respectively), and more recently in Warsaw (COP 19), encouraged developing countries to establish national forest monitoring systems to quantify emissions/removals of greenhouse gases (GHG) and changes in forest area and forest carbon stocks. The use remote of sensing imagery and data are essential to the establishment of such a mechanism (GOFC-GOLD, 2014), as it offers the possibility of obtaining information on the terrestrial surface with large spatial and temporal coverages.

The construction of the FREL for *reducing emissions from deforestation* (gross deforestation) in the Colombian Amazon Biome is based on the information generated by Colombia's Forest and Carbon Monitoring System (SMByC by its acronym in Spanish), operated by the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) with the guidance of the Ministry of Environment and Sustainable Development (MADS), and following the guidelines of the UNFCCC and IPCC orientations. Biennial maps of forest cover change - which resulted from the biennial monitoring of forest cover from 2000 to 2012 – were used to obtain activity data for the construction of this FREL.

The SMByC applies a methodology that integrates tools for the pre-processing and semi-automated processing of satellite imagery to detect and quantify the changes in the extension of forest cover at a national level on a 1:100,000 - scale map, enabling the possibility of identifying the loss of forest cover by deforestation (Galindo *et al.*, in press).

This monitoring methodology comprises four phases:

1. Digital pre-processing of satellite images: Includes band stacking, geometric correction, radiometric calibration, clouds and water bodies masking and radiometric normalization.

2. Digital image processing: Involves the automated detection of changes in forest areas using algorithms, the visual verification of detected changes and the execution of a quality control protocol.
3. Data validation: involves the application of a random and stratified sampling design.
4. Activity data report: calculation and report of the natural forests surface and of changes in the natural forest surface.

The generation of activity data was based on the use of images from the Landsat Satellite program (USGS, 2014) as it provides for appropriate historical availability, temporal and spatial resolution to monitor forest cover, data accessibility and continuity. Corrections, calibrations and radiometric normalizations were applied in order to achieve exact co-registering and reduction of atmospheric effects, which allows for image comparability and ensures that detected changes are not related to such factors (Olthof *et al.*, 2005; Potapov *et al.*, 2012).

Phase 2 involves the automated detection of changes in the forest cover area, allowing direct detection of changes in the spectral response that may correspond to a loss or gain of forest cover. Subsequently, this second phase incorporates the work of experts who carry out a direct visual verification of changes on the images, minimizing false detections that may stem from errors in the interpretation of forest cover in previous dates. This step also reduces errors derived from cartographic processes that generate false detections when information is overlapped and cross-analyzed. Finally, a quality control protocol that continuously evaluates intermediate products is executed with the purpose of detecting errors and inconsistencies and verifying their adjustment. The result of this phase is the semi-automated identification of the following classes: Stable Forest, Stable Non-Forest, Deforestation, Regeneration and No Information (corresponding to masked data).

Phase 3 comprises the thematic validation of the activity data for the monitoring period, which is conducted through a statistically robust accuracy assessment that includes the calculation of the uncertainty of estimators. The thematic validation has been carried out by the Agustin Codazzi Geographic Institute (IGAC)[2] for the period 2010 – 2012. This Institute is not involved in the production of the activity data.

Lastly, in order to calculate the area deforested between two dates in phase 4, only those areas in which forest is detected on the first date and non-forest is detected on the second are taken into account, so there is certainty that the event occurred during the analyzed period. Forest losses detected after one or several dates without information are not included in the calculation, in order to prevent overestimations during periods in which areas without information increase due

[2] The Geographic Institute Agustín Codazzi (in Spanish: Instituto Geográfico Agustín Codazzi, IGAC), is the Colombian Government agency in charge of producing the official map and basic cartography of Colombia, preparing the national cadaster of real state property, inventorying soil characteristics, undertaking geographical research to support territorial development, training professionals in geographic information technologies and coordinating the Colombian Spatial Data Infrastructure (ICDE).

to different factors such as high cloudiness periods, or sensor failures in the satellite programs that capture the images.

The implementation of this methodology allowed the identification of changes in forest cover (measured in hectares) for biennial periods between 2000 and 2012: 2000-2002; 2002-2004; 2004 - 2006; 2006 - 2008; 2008 - 2010 and 2010-2012.

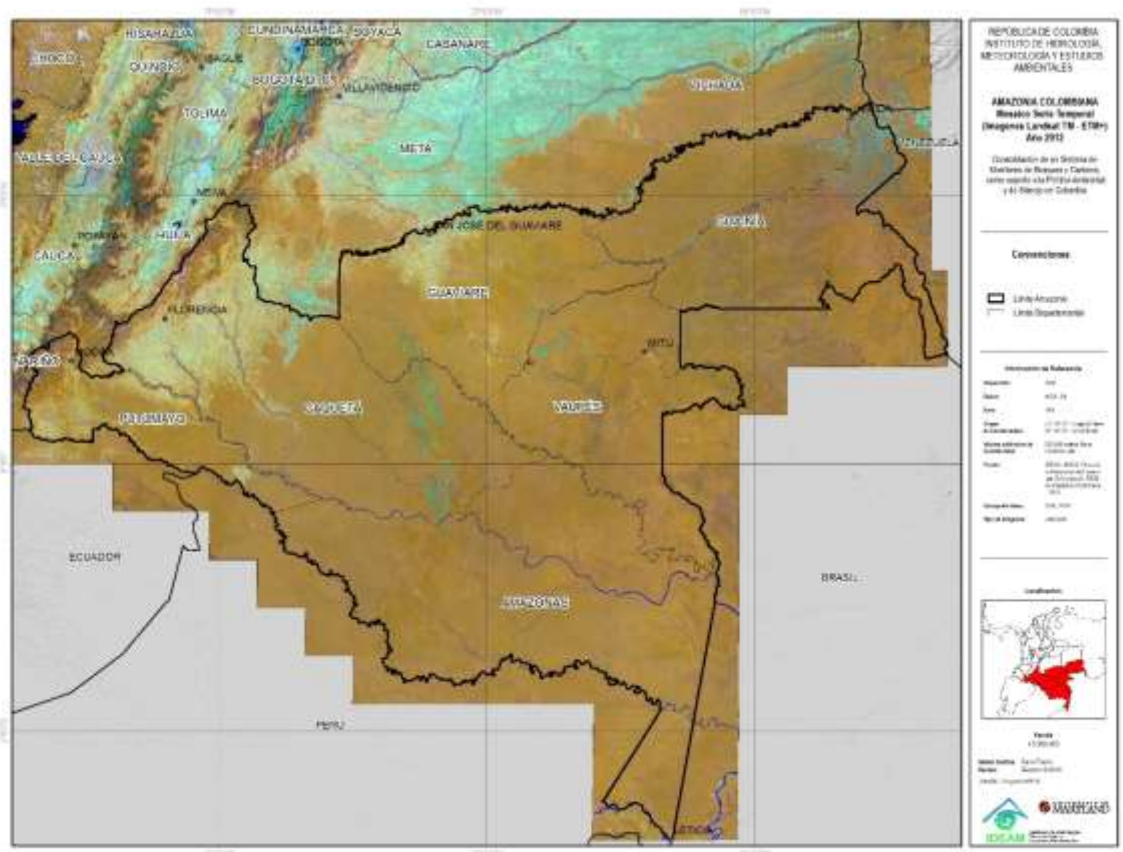

Figure 3 Temporal composite of Landsat images for 2012 (Source: University of Maryland).

The surface covered by forest refers to the area covered by forest observed in a given period from satellite images. Areas without information (due to the presence of clouds and other factors that obstruct interpretation) are excluded from the calculation of this figure.

Change in the surface covered by forest (CSB by its acronym in Spanish): refers to the difference between the surface covered by forest detected in the initial period and the surface covered by forest detected in the final period, divided by the number of years of the period. Only those areas which are common to both periods and can be interpreted are taken into account, excluding from the analysis the areas without information in any of the periods.

Annualized data for changes in the surface covered by forest constitute the *activity data* required for the construction of the FREL (Table 1). Cartographic inputs to obtain deforestation in each period are available on www.ideam.gov.co

Table 1 **Deforestation data used in the construction of the Reference Level.**

Analyzed Period	CSB (ha/year)	Fraction of the Amazon Biome area without information
2000 – 2002	-77.042	0.07
2002 – 2004	-95.846	0.06
2004 – 2006	-82.448	0.10
2006 – 2008	-78.998	0.12
2008 – 2010	-69.355	0.13
2010 – 2012	-93.604	0.27
AVERAGE 2000 -2012	-82.883	

Source: Forest and Carbon Monitoring System, IDEAM (2014)

The lineal trend of the data is neutrally sloped (blue dotted line in Figure 4) and nearly corresponds to the average of annualized deforestation for the analyzed periods. For the reference period of 2000 – 2012, this is 82.883 ha/year in the Amazon biome region (red line in Figure 4). Figure 5 presents the loss of forest cover for the Amazon biome compared to deforestation.

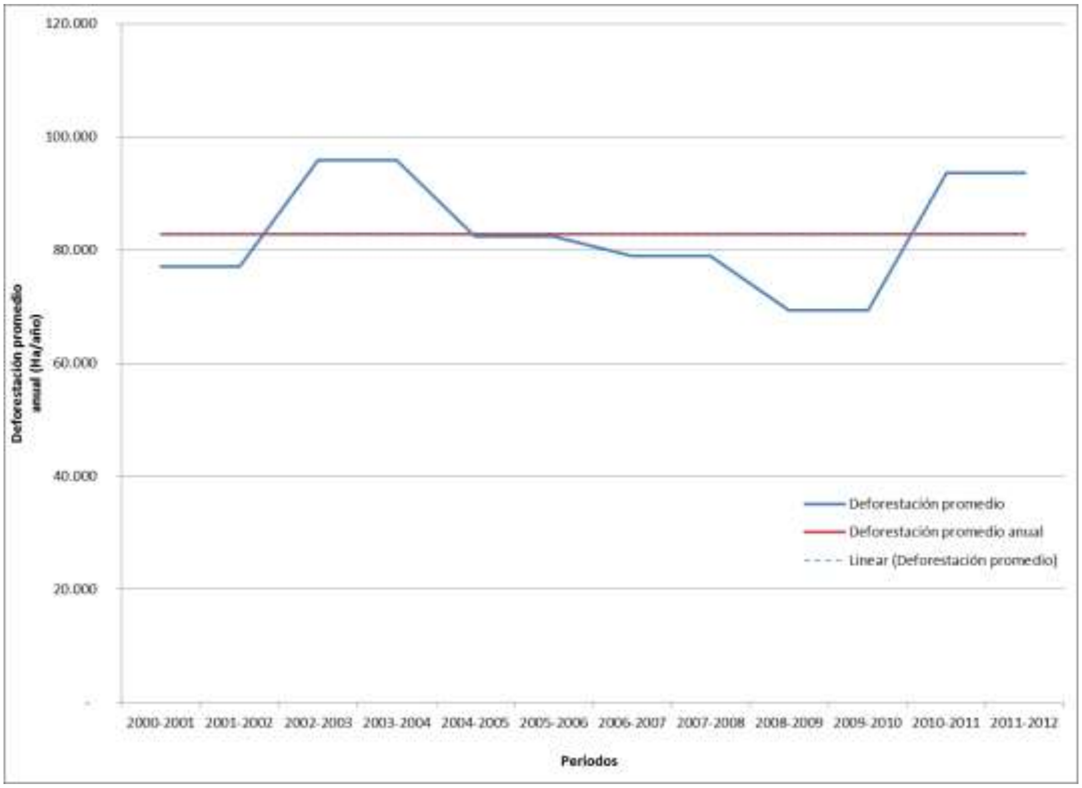

Figure 4 Deforestation trend for the Amazon Biome based on the CSB data.

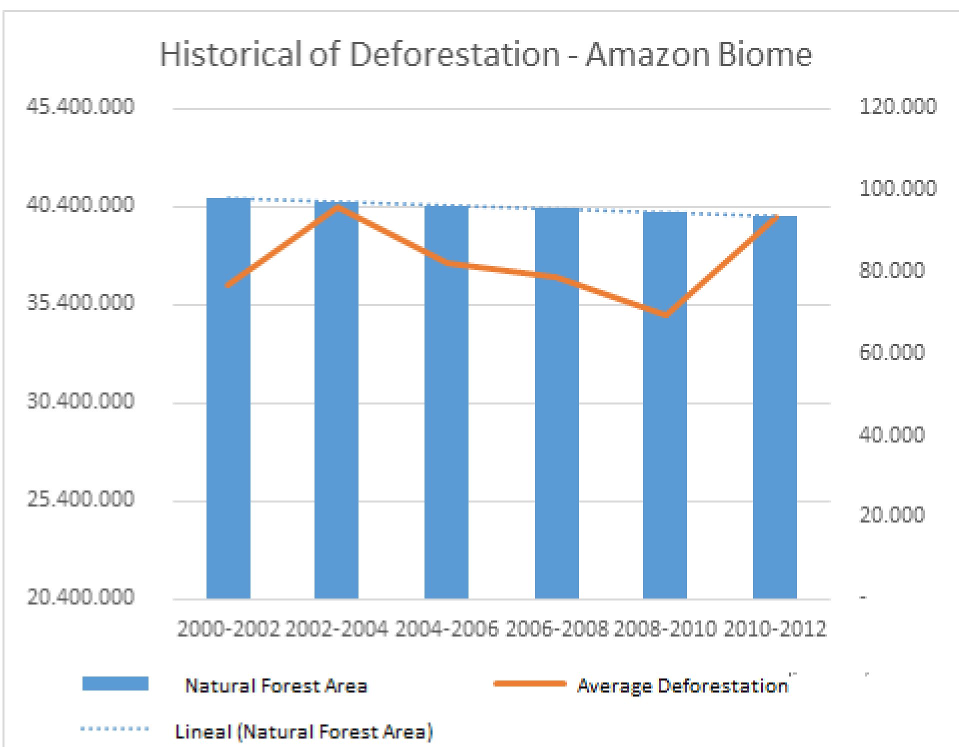

Figure 5 Surface covered by forest versus average deforestation in the Amazon biome (in ha).

e) Emission Factors

i. Pools included

The FREL includes the "Aboveground Biomass - AB" and "Belowground Biomass - SB" pools. "Litter", "Dead wood" and "Carbon in organic soils" pools have not been included, as no information is currently available to allow for their incorporation in this FREL. The *emission factor* for the above and belowground biomass is the carbon content in above and belowground biomass (roots) per hectare, measured in tonnes of carbon (tC ha^{-1}) for the types of forest in the FREL region.

ii. Forest Stratification

To date, one of the forest stratification legends most frequently used to estimate aboveground biomass (AB) in tropical forests employs precipitation as a single diagnostic variable. This legend, proposed by Chave et al., 2005, is based on the number of dry months per year, with a dry month being one in which the total evapotranspiration exceeds precipitation.

Following this classification, the main types of forests are: dry forest, tropical forest and rainforest. However, a considerable number of papers (Grubb et al, 1963; Kitayama, et al, 1994, 2002; LIEBERMAN et al 1996; AIBA et al, 1999; SCHAWE et al, 2007; MOSER et al 2008; GIRARDIN et al., 2010) have examined the distribution of AB and its relationship with meteorological parameters that co-vary with altitude (e.g. temperature, solar radiation, atmospheric pressure, UV-B radiation) and other climatic factors (e.g. humidity, precipitation, seasonality) that respond to regional or local variations (e.g. orography, winds) (KÖRNER, C. 1998, 2006).

These works propose that the reduction in air temperature, combined with changes in nutrient availability and soil chemistry can affect the growth rates of trees and the vegetation structure (KÖRNER, 2006; Coomes et al, 2007), resulting in an AB reduction. For this reason, it is considered that the inclusion of these diagnostic variables, together with rainfall, allows for a more appropriate estimation of biomass and carbon stocks stored in forests.

Considering the above, forests were stratified according to the bioclimatic Holdridge et al. classification (HOLDRIDGE, et al 1971), in which vegetation is classified using the potential evapotranspiration as a diagnostic variable, expressed as a function of the equilibrium between precipitation and annual temperature.

The stratification map was generated using climatological averages from the climatological normal for 1981-2010 reported by IDEAM[3] and the 30m digital elevation model (DEM) from NASA (SRTM mission). The Diaz-Almanza (2013) methodology was applied to the construction of the annual

[3] The climatological average values of the 1981-2010 series can be downloaded from http://institucional.ideam.gov.co/descargas?com=institucional&name=pubFile15803&downloadname=Promedios%2081-10.xlsx. The link was last visited on September 14, 2014.

mean temperature cartographic outputs; while the "Inverse Distance Weighting" method (IDW) was used for annual precipitation, following the spatial-temporal distribution of climate variables in IDEAM, 2005. After applying this stratification, it was found that three types of forests occur in the Colombian Amazon biome, which covered 87% of the total biome area in 2012 (see table 2). Tropical Rain Forest represents over 99% of this forest area; hence this FREL has been constructed with biomass content information for this type of forest.

Table 2 Forest stratification and its extension in the Amazon biome region, following the bioclimatic classification proposed by Holdridge et al. (1971), adapted to Colombia by IDEAM (2005).

Type of Forest	Temperature (°C)	Precipitation (mm/year)	Area (ha) 2012	% Forest in the Biome
Tropical Rain Forest	>24,0	2.001-4.000	39.637.401	99.2
Wet Tropical Forest	>24,0	4.001-8.000	267.024	0.7
Wet Premontane Forest	18,0-24,0	2.001-4.000	44.436	0.1

iii. Compilation of field data

The data used to estimate carbon stocks in the AB have been obtained from the establishment of 721 plots in the tropical rainforest between 1990 and 2014 (Figure 6). The size of the plots ranged from 0.1 ha to 1.5 ha. The total sampled area was of approximately 142 ha. Data were compiled by the SMByC and were subsequently recorded in separate tables, differentiating the attributes of plots and individuals.

The online application *i Plant Collaborative* (Boyle et al., 2013) was employed to standardize the taxonomic nomenclature under the APG III classification system (APG 2009), using reference data from the Missouri Botanical Garden, the *Global Compositae Checklist*, and the catalogue of plants of the United States Department of Agriculture (USDA). The repository includes 92,388 records of individuals with normal diameter greater than or equal to 10 cm, 4,894 morpho-species, 621 genera and 130 families of plants. Each record was assigned with the basic wood density (ρ) of the species to which it belongs, drawn from data in the scientific literature (Chave et al, 2006; Zanne et al., 2009). In cases when this was not applicable, the basic wood density of the genus or family was used. Individuals without botanical identification were grouped under the ρ average of all species recorded in the plot.

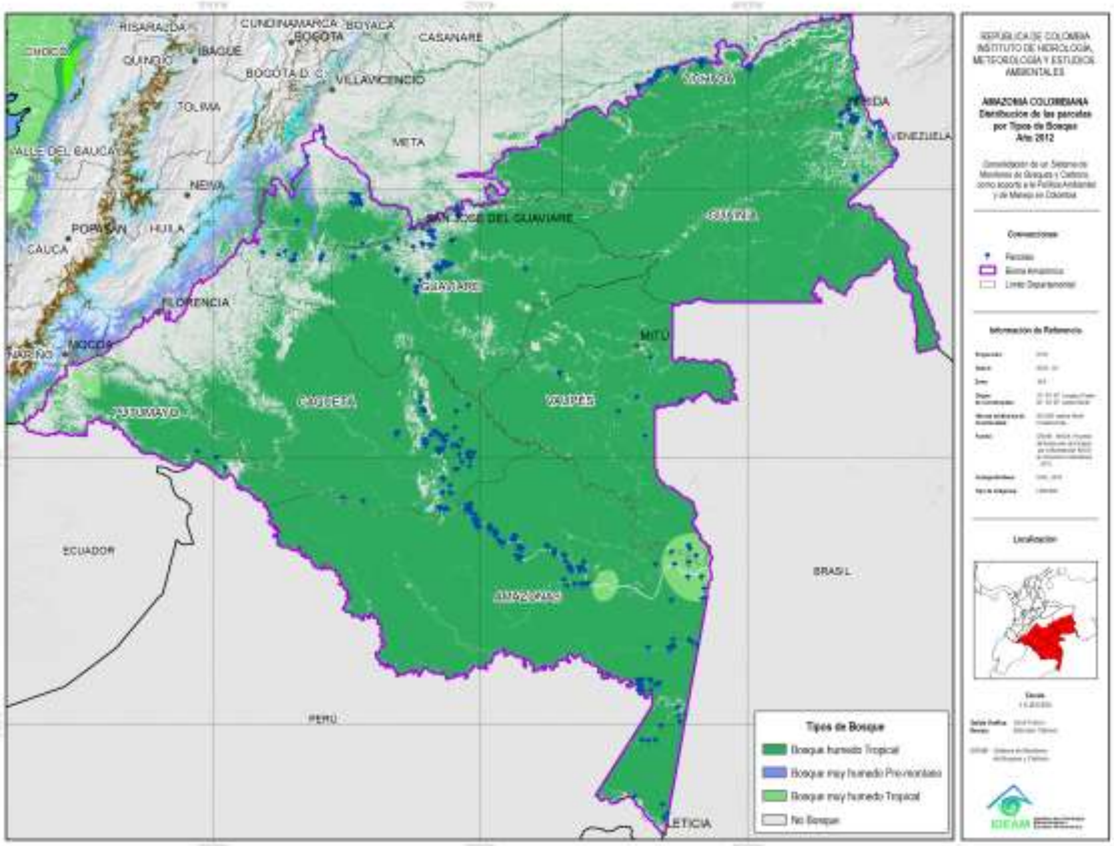

Figure 6 Distribution of forest types and of forest and/or floristic inventory plots available for the Amazon biome.

iv. Data preparation:

The AB of each tree (expressed in kg) was estimated using the allometric equation developed by Alvarez et al. 2012, where AB is expressed as a function of the diameter (D) and density (ρ):

$$BA = exp^{\left(2{,}406-\left(1{,}289\, ln(D)\right)+\left(1{,}169\,(ln(D))^2\right)-\left(0{,}122\,(ln(D))^3\right)+\left(0{,}445\, ln(\rho)\right)\right)}$$

Alvarez *et al*. models were developed from data for 631 trees (D ≥ 10 cm) harvested in Colombia, and allow for a more accurate estimation of the AB of the country's forests compared to the pantropical models that are more widely used in this type of studies (Álvarez *et al.*, 2012). After calculating the AB, the belowground biomass (BS) of each tree was estimated using the following equation proposed by Cairns et al. 1997, where the BS is expressed as a function of AB.

$$BS = exp^{-1,085 + (0,9256 \ln BA)}$$

Subsequently, the total biomass (BT) for each individual was obtained through the summation of its AB and BS. The BT of each plot was obtained from the sum of the TB of the individuals it comprises, excluding palms, vines and ferns (e.g. non-arboreal individuals). This value was then converted to mega grams per hectare (Mg/ha).

By excluding non-arboreal individuals from the estimation, BT in 52 plots (corresponding to ca. 7 ha sampled) decreased significantly (≥ 20%). The diameter distribution of the individuals included in each plot was analyzed, finding that 26 out of the 52 plots (ca. 3 ha) showed anomalous distributions when compared to others located in the same type of forest. In general, no individuals from lower diametric categories (e.g. 10 to 30 cm) were registered in these plots, while other intermediate diametric categories (e.g. 30 to 60 cm) were absent. A continued harvesting of forests may lead to the presence of this type of truncated or discontinuous distributions (Dancé & Kometter, 1984; Lopez & Tamarit, 2005; Vilchez & Rocha, 2006; Ayma-Romay et al 2007; Morales-Salazar et al. 2012).

In addition, it was found that the absolute difference between the reported and the interpolated altitude above sea level in 18 parcels (ca. 3 ha) was greater than or equal to 100 meters, which may be attributed to errors in data collection.

As a precautionary measure, the information from these 70 plots was excluded from the estimation of the BT. Therefore, analyses were performed from a total of 651 plots, representing ca. 133 sampled hectares.

v. Estimation of total biomass by forest type

Variations in plot and sample size might lead to different levels of uncertainty on biomass estimations (Chambers et al., 2001; Chave et al., 2004). Considering the above, BT for each forest type was estimated using a weighting factor by the inverse of the variance (Thomas & Rennie 1987), where TB of the forest h ($\bar{y}_h$) was calculated as follows:

$$\bar{y}_h = \sum \frac{w_i \bar{y}_i}{w_h}$$

where,

$$w_i = {}^{1}/_{var(\bar{y}_i)},\ var(\bar{y}_i) = \frac{\left(\sum y_{ij}^2\right) - n_i \bar{y}_i^2}{n_i(n_i - 1)},$$

and

$$w_h = \sum w_i.$$

The variance associated with $\bar{y}_h$ was obtained as follows:

$$var(\bar{y}_h) = \frac{1}{w_h}\left[1 + \frac{4}{w_h^2}\sum\frac{1}{n_i}(w_i\{w_h - w_i\})\right]$$

Where, n_i is the number of plots of size $\boldsymbol{i}$ established in the forest $\boldsymbol{h}$. In all cases, a minimum of three plots of size $\boldsymbol{i}$ and ten plots by forest type are needed to calculate the variance (WESTFALL, et al, 2011). The confidence interval ($\boldsymbol{IC_{\bar{y}_h}}$) of the weighted average was calculated as follows:

$$IC_{\bar{y}_h} = \bar{y}_h \pm \sqrt{var(\bar{y}_h)}\,t_{0,05,n_h-1}$$

Where, n_h is the number of plots estabished in forest $\boldsymbol{h}$. The Sampling Error (SE_h) was obtained as follows:

$$SE_h = 100\,\frac{\sqrt{var(\bar{y}_h)}}{\bar{y}_h}$$

This weighting factor was used in each forest type h, in order to 'penalize' the mean values associated with a given size plot that showed high uncertainty, regadless of the sample size. Using this approach, it was found that TB of tropical rainforest is **328,2 ± 11,7 Mg/ha (SE_f = 1,8%)**

To calculate forest carbon contents, a 0.47 factor was applied to BT. In estimating the carbon dioxide equivalent (CO_2e) stored in the TB, the amount of carbon was multiplied by a factor of 3.67 (IPCC, 2003, 2006). Therefore, the carbon content is equal to **154.3 Mg C/ha**, representing **566.1 Mg CO_2e/ha**.

vi. Gases included

This FREL only includes CO_2 emissions.

f) National Circumstances

Decision 12/CP.17 invited Parties to provide, when appropriate, details on how national circumstances have been taken into account in the construction of the FREL.

In line with this provision, Colombia considers that in addition to the historical analysis of deforestation in this FREL's subnational area, it is necessary to assess possible future developments regarding the country's economic, social and cultural circumstances, which might modify the dynamics of forest transformation and which are not reflected on historical deforestation data.

In the case of the Colombian Amazon, qualitative analyses of main future investment trends and regional development plans and programs have been carried out, identified by Arenas *et al.* (2001) and Nepstad *et al.* (2013) (cited in González *et al.*, 2014.) as factors that could incentivize deforestation in the future:

- Crops for agricultural production
- Increase in the areas dedicated to cattle ranching
- Increase in mining activities
- Land reform
- Land restitution
- Transport and energy infrastructure projects

a) Initiative for the Integration of the South American Regional Infrastructure – IIRSA (by its acronym in Spanish): the Amazon is the scenario for ten initiatives in four different groups: Access to the waterway of Putumayo 2015-2019, Amazon waterways Network, Colombia-Ecuador Connection II (Bogotá-Mocoa-Tena-Zamora-Palanda-Loja) 2014-2016, and systems of energy infrastructure integration 2006 - 2020.
b) Expansion plan of the national network of roads for 2000-2021, adopted by the CONPES 3085 policy paper of 2000, which establishes the design of 8 roads that change the mobility dynamics of the Colombian Amazon.

- Policies for the development of the mining and energy infrastructure, in particular: i) the National Energy Plan for 2006- 2025[4], which aims at maximizing the contribution of the energy sector to sustainable development in the country and ensuring the availability and supply of energy resources to meet the domestic demand in the upcoming years; and ii) the National Mining Development Plan - Vision for 2019[5], which proposes a long-term vision to increase the competitiveness of the mining sector, investor confidence and the derived benefits that can be captured by the State.
- Peace agreements between the government and armed groups operating outside the law.[6]

i. Qualitative analysis of deforestation drivers and future trends

In order to understand the relationship between deforestation agents and changes detected in land use, IDEAM performed geographical analyses to identify the variables that best explain the changes in Forest cover. Table 3 summarizes the procedure carried out by IDEAM for the characterization of drivers and agents of deforestation. Tables 4 and 5 present the main deforestation agents identified.

Table 3 Summary of inputs, processing methods and results obtained for the analysis of drivers and agents of deforestation. Source: González et al. (2014).

Inputs	*Compilation of available scientific and technical literature on agents and drivers of deforestation at national and regional levels, from several public institutions and other sources.*

[4] http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=39201284
[5] http://www.upme.gov.co/Docs/PNDM_2019_Final.pdf
[6] https://www.mesadeconversaciones.com.co/documentos-y-comunicados

	Compilation of spatial information of proxy variables associated with agents and / or drivers in the study area (González et al. 2014b).
Processing	Based on the literature review, González et al. (2014b) carried out a general description of the main agents and drivers of deforestation. From this description, spatial variables were processed to represent agents and drivers of deforestation. Additionally, adjustments were made dividing the study area in subregions due to different dynamics of deforestation within the Amazon region (González et al. 2014b).
Results	1. Descriptive analysis of agents and drivers of deforestation at the regional level. 2. Identification of geographic variables associated with drivers of deforestation.

Table 4 Agents of deforestation identified historically in the Amazon region. Source: González et al. (2014)

Agent of deforestation	***Description***
Small, medium and large scale farmers	This agent is described by the SINCHI (2013) as recent settlers in the northwest of the Colombian Amazon, mainly located in Forest Reserve Zone of Law 2nd, 1959; and are characterized by subsistence farming, and in some cases coca crops. In some cases they live on small farms with crops or large areas with mosaics of crops, pastures and forests where they are permanently settled. In other cases no settlement occurs in colonization fronts, after the change of land cover. In general, colonization of new areas is driven by the loss of productivity in crops (González et al. IDEAM, 2011).
Cattle ranchers	Agents dedicated to cattle ranching. Two groups are identified, those with productive purposes and those whose interest is to ensure land tenure with the introduction of cattle (González et al. IDEAM 2011). They are located in areas of high intervention and normally occupy large areas (SINCHI, 2013).
Mining and oil and gas companies	They include formal mining and oil exploitation and indirectly influence deforestation since road openings trigger the entry of other agents of transformation (González et al. IDEAM 2011). The impact may be even greater in the case of illegal mining, due to the rudimentary practices used in such activities (MADS, 2013).
Armed groups	They can act as agents of transformation (e.g. exercise agricultural activities, mainly illegal crops, weakening the control of state institutions in legally protected areas) or slowing deforestation (e.g. conflict that leads to the abandonment of land by deforestation agents) (González et al. IDEAM 2011).

Table 5 Drivers of deforestation identified historically in the Amazon region

Driver of deforestation	***Decription***
Expansion of the agricultural frontier	It is defined as the advance of the deforestation front for intensive farming of land. Due to the fragility of the soils, the land ends up becoming unproductive (Nepstad et al. 2013).

Cattle ranching	The conversion to pastures is causing the greatest loss of forest cover in the region. Armenteras et al. (2013), Nepstad et al. (2013)
Illicit crops	Compared to other land uses, their area is not very large. However, they generate isolated and moving pockets of deforestation. (Nepstad et al. 2013).
Migration (e.g. colonization, displacement)	Migration, including displacement associated with the armed conflict, generates colonization of forest areas (Nepstad et al. 2013).
Mining (legal and illegal)	Since 2006 the mining activity has been favored in the region due to national economic growth strategies (Arenas et al. 2011). Compared to other land uses, their area is not very large. However, it generates foci of deforestation by the construction of access roads. (Nepstad et al. 2013).
Oil and gas exploitation	In recent years, knowledge of the geological potential of the region has improved. By 2010, 1% of the Amazon territory was in production, 10% in exploration and 40% in technical evaluation. (Arenas et al. 2011).
Infrastructure development	There is a positive correlation between the location of productive land uses and the presence of access roads (Nepstad et al. 2013).
Forest fires	They can occur because of natural or anthropogenic causes, the latter to manage or to enhance productivity of the land (Nepstad et al. 2013).
Population density	Armenteras *et al.* (2013)

Historically, Colombia has had a lag in transportation infrastructure (Fedesarrollo, 2013). According to the Global Competitiveness Report 2014-2015 of the OECD, the transport infrastructure of Colombia is below that of developed countries, emerging Asian ecountries and several Latin American countries. On average, during the first decade of the century, investment in transport infrastructure was below 1% of GDP. The document outlining the basis of the National Development Plan - NDP 2014 - 2018[7] (DNP, 2014), points out in its diagnostic that delays in the provision of logistics and transportation infrastructure is one of the main obstacles to economic development and peace in Colombia. The NDP 2014-2018 has a regionalized approach and supports the integration and transformation of territories, particularly those which have been most affected by armed conflict, are lagging institutionally or have not managed to connect with regional and national economic development. Therefore, special efforts are required to improve governance and good government, as well and infrastructure and connectivity of these territories; by giving adequate maintenance to local roads, reducing the deficit in electrification and water provision, and improving connectivity in communications, among others.

The National Government is committed to the goal of bringing the levels of investment in transport infrastructure to 3% of GDP before the end of the decade, to achieve the great purpose

[7] https://colaboracion.dnp.gov.co/CDT/Prensa/Bases%20Plan%20Nacional%20de%20Desarrollo%202014-2018.pdf

of closing the infrastructure gap. In the four-year period of the government, investment in road concessions will increase from 1,2 billion dollars to 3.5 billion dollars a year. The NDP 2014- 2018 also provides for an increase in investment in tertiary roads that are considered the big bet for infrastructure and peacebuilding in rural areas, given that they are built in the most vulnerable areas and can have greater impact on the generation of local economies.

With regards to mining and energy development, the sector will continue to be one of the engines of development of the country through its contribution to economic growth, rural employment, private investment and the generation of resources for public social investment. Within the mining and energy sector, the oil and gas subsector is the main driver of GDP, with a share of 52.3% of the total contribution of the mining and energy sector in the years 2010-2013. In this regard, during the next four years the government seeks to promote maximum utilization of natural resources.

The NDP 2014-2018 determines that the welfare of rural communities is one of the fundamental approaches to public policy of these four years, which must be ensured through strategies that seek to reduce regional disparities, and promote, through integrated rural development, higher levels of equity in the country, with emphasis on those areas with high risk of social and economic unrest.

Consequently, the NDP 2014-2018 includes strategies and goals to achieve the purposes of territorial integration, welfare of rural communities and improved competitiveness, including among others: the development of modern infrastructure and competitive services, particularly rural infrastructure that is required to close the regional gaps; increase of the participation of the mining and energy sector in sustained and inclusive economic development, ensuring that the economy has competitive energy sources to allow it to grow, create jobs and generate significant resources to finance investments required for peace building, education and social policies in the fight against inequality.

For the first time, the country has framed its development strategy within a green growth long term vision, also contained in the NDP 2014-2018. Thus, the objectives of welfare and economic development opportunities will be reconciled with conservation and restoration objectives for environmentally sensitive and strategic ecosystems that are part of the national agenda on climate change.

As can be seen from the above summary, a qualitative analysis of future trends of these drivers of deforestation, based on projected investments and government plans, allow us to assume that increased extractive activities in the Colombian Amazon, investment associated with infrastructure and related public goods; as well as migration and colonization, may trigger increases in the historical trends of deforestation in the region.

ii. Qualitative analysis of a post-conflict scenario

Colombia considers essential to include national circumstances in the Forest Reference Emission Level for the sub region of the Amazon biome. This is especially relevant as the country finds itself close to the possibility of ending the armed conflict and beginning the construction of a stable and lasting peace. This condition will generate new dynamics of occupation and land use, where deforestation patterns may be altered and differ from historical averages observed so far.

The first consideration is related to the time period during which the effects of the end of armed conflict manifest themselves on the use of the land. The analyses suggest that initially, a *transitional period* would occur which basically covers the time frame between the signing of a peace agreement and the start of implementation of policies and measures included under the agreement. Subsequently, a *period of stability* would ensue, which could generate a process planned present deforestation.

During the *transitional period*, an increase in infrastructure development processes, the return of internally displaced people to rural areas and the growth of extractive industries are expected. These would occur as a consequence of there being new possibilities to explore areas that were formerly inaccessible due to the armed conflict, as well as the need for suitable productive lands for the internally displaced people that would be returning and for the population that would be deposing arms.

It is important to note that although the development processes that stimulate deforestation could occur without the eventual signing of a peace agreement, it is clear that a sociopolitical scenario of the end of the armed conflict can stimulate accelerated deforestation as it creates greater investor confidence and allows entry to areas formerly inaccessible by the conflict. Consequently, one might expect that after a successful peace agreement, an increase in deforestation would occur during a transition period.

Although Colombia has had a long history around the armed conflict, there is no adequate information to relate variables related to conflict with patterns of deforestation. Consequently, the discussion is grounded on literature review and other post-conflict scenarios to establish the arguments and situate the Colombian case after a peace agreement as a factor that may lead to increased deforestation.

Globally, it has been observed that half of the conflicts in the Twentieth century developed in forested regions, showing a strong correlation between armed conflict and forests (Thomson et al. 2007). Since the Cold War ended nearly 40 countries have experienced armed conflict in forest areas (Collier et al. 2005). In Colombia, forests are still a place where armed groups hide from government operations. They also become places for people to flee from war. Several studies indicate that insurgents locate their camps and organize their operations inside the forests. Additionally, they use them for the production of illicit crops: coca and popy seed, and to protect traffickers from military control.

In the case of Central American countries, findings suggest that processes of forest regeneration dominated forest cover change when the armed conflict was most intense. It has been further found that at the end of a civil war, on average, during its last seven years, countries had a 15% lower per capita income and 30% more people living under poverty (Thomson et al. 2007). Under a post-conflict scenario, studies affirm that the presence of government and the strengthening of communities require of a transition process before developing an efficient control of the process of deforestation (Stevens et al. 2011).

Other studies have found that the change in forest cover could be generated by the armed conflict. The conflict could have mixed environmental effects, i.e. it could promote deforestation by armed groups and simultaneously stimulate the abandonment of land devoted to agricultural activities, which would allow forest regeneration (Aide & Grau 2004). Farmers and livestock owners are displaced for fear of being kidnapped; while logging, legal mining and infrastructure projects are not carried out due to fears of human and material losses.

However, in post-conflict settings, it has been shown that deforestation could increase due to the return of displaced communities to their regions of origin, which would trigger the expansion of the agricultural frontier. Additionally, it has been identified that 44% of countries affected by armed conflict may return to war over a period of 5 years of ceasefire, because even though the conflict ends, many of the factors that caused it are still present and could worsen (Collier et al. 2005).

Once the transitional post-conflict period starts, the process of forest conversion develops as a result of increased demand for food from people returning to occupy land formerly uninhabitable before the conflict. This scenario has been evident in emerging economies. The increase in food prices, combined with trade liberalization becomes an incentive for producers to convert forests without armed groups into agricultural landscapes. In the case of Colombia, a significant amount of deforestation could occur due to pressures from the agricultural and mining sectors, infrastructure projects and forest concessions that respond to the growing international demand, not only for food but also for fossil fuels and timber (Koning et al. 2007). However, once this transitional period ends, the use and management of natural resources can be used as a tool for building cooperation around the strengthening of peace and the control of deforestation.

The region of the Amazon biome includes areas affected by armed conflict located in forest areas, in many cases remote and inaccessible, but rich with natural resources such as timber, oil, land and minerals that insurgent groups have exploited. The government has been working on improving forest governance, law enforcement in the region and improvement of security conditions and legalization of property rights. Under the above considerations, in addition to those related to the sectoral green growth and integrated rural development strategies that the national government has proposed in the NDP 2014 - 2018, it is arguable that the transitional period of deforestation in the post conflict is applicable to the Colombian Amazon biome.

The aim of involving national circumstances in projecting the rate of deforestation is to propose an adjustment that allows projecting a difference of the expected deforestation for the period 2013-2017, as compared to the historical average deforestation from 2000 to 2012. This difference is estimated abovethe average historical deforestation.

According to these analyses, Colombia considers a five-year transitional period, which is the time in which the rate of deforestation will continue to increase until the political and social scenario of the country manages to stabilize, during which the present trend in deforestation would increase relative to the historical 2000-2012 average. Once this period is over, the deforestation rate could decrease and then stabilize.

Depending on the evolution of current peace dialogues and the resulting agreement, as well as of the availability of information to define more precisely the causal relationships between post-conflict and deforestation, Colombia will update this FREL.

iii. Adjustment for national circumstances

The reference level incorporates an adjustment for national circumstances described above and according to the guidelines of the UNFCCC. Colombia estimates a conservative adjustment of +10% over the value of the average deforestation 2000-2012, which is within the range of annual deforestation data in the Colombian Amazon biome observed in the reference period. The adjustment is justified by the results of qualitative analysis of the Amazon on the behavior of drivers of deforestation, as well as a possible post-conflict scenario, which suggests an increase from historical deforestation trends.

iv. Spatialization of Deforestation

The projection of deforestation is a needed step towards indentifying potential areas for implementation of a REDD+ mechanism and for calculating reference levels (Achard et al. 2009; González et al. IDEAM 2011). In Colombia, most of the deforestation is located on land owned by the State, and occurs due to unplanned and usually illegal colonization (Etter et al. 2006; Gonzalez et al. IDEAM 2011). Little is known about changes within different ecosystems. Existing studies are mainly descriptive and limited in their ability to predict the future transformations; then, there is the need to develop models with a solid theoretical foundation that can be tested empirically using real data and which have a good predictive ability (Etter et al 2006b; González et al. IDEAM 2011).

Colombia includes the spatialization of deforestation in its FREL as a complementary and independent tool to the quantification of the activity data and emission factors. Therefore, it does not imply changes in the estimated amounts described in sections 2.a; 2.b; 2.c; 2.d and 2.e. This process was carried out on the area of the two Environmental Authorities (CDA and Corpoamazonia) where most forest and deforestation in the Amazon biome is concentrated.

Spatial projection of forest cover loss in a particular area requires the characterization of historical change processes for such covers through the identification of key drivers and agents of deforestation. The application of Land Use and Land Change models (LULC) is needed for representing explicitly changes in land and use in a particular geographical context. (Aguilar *et al.*, 2014; Soares-Filho *et al.*, 2002). The potential occurence of the factors responsible of forest transformation is critical for improving the understanding of drivers and patterns of change. (Several authors cited by Etter et al. 2006a). Monitoring and reporting changes in land cover at a national and regional level is important but doesn´t inform about the spatial and temporal complexity of the dynamics that occur below these levels of analysis (Etter et al. 2006a). Several authors emphasize the importance of improving the explanatory and predictive capacity of LULC models in order to increase their contribution to sustainable land use planning and conservation actions (Kaimowitz D & Angelsen., 1998; Verburg et al, 2002 ; Etter et al 2006a;. Southworth et al, 2011).

The modeling process started from a previous characterization of the historical change dynamics to obtain a more precise approximation to the different dynamics of forest conversion in the study region. This process allowed to differentiate areas of "high" and "low" deforestation using annualized deforestation data from the 2000-2012 period. Complementarily, an analysis of drivers and agents of deforestation was used (Gonzalez et al. IDEAM 2014a), with available socioeconomic information about the pattern of agglomeration and connectivity (roads and rivers), settlements (Riaño y Salazar, 2009), dynamics of livestock (Murcia et al. 2011), and patterns of historical distribution of illicit crops in the region (UNODC & SIMCI 2013), discriminating two main areas in the Amazon: Northwestern sector with a higher degree of urban consolidation and road connectivity were coca production and conversion of land for livestock have been bigger; and the southeastern sector with scattered settlements, reduced or restricted connectivity, low historical density of coca crops and of livestock production.

For each of those areas a set of inputs was structured, from which a database of variables with potential explanatory power of the phenomenon was generated (Annex C).g General methodology of deforestation risk modelling is presented in Figure 7. The spatial distribution of changes was based on the behavior of explanatory variables derived from the analysis of drivers of deforestation. Combinatorial multiple tests were ran to establish the set of variables and periods that best predicted deforestation in the latest known deforestation year; this allowed the evaluation through validation tests of the more precise models. The latter was carried out using two of the most employed tools for simulating spatial cover (IDRISI SELVA and DINAMICA-EGO) in a complementary way; the validation results were above the minimum required by the validation methodologies of the voluntary market (Annex C). Finally, from the best models found for each area, an anual probability map was generated, which shows the risk level and future pattern of expansion of the deforestation phenomenon in the study area to the year 2022 (Figure 8). The map identifies those areas where it is advisable to proceed with the implementation of REDD+ activities.

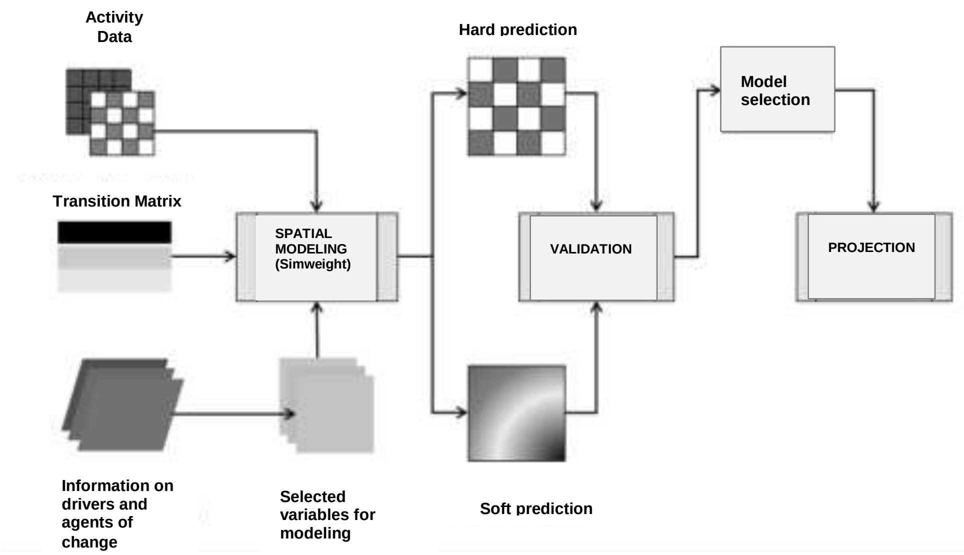

Figure 7. Diagram of the procedure implemented for the spatial modeling of deforestation.

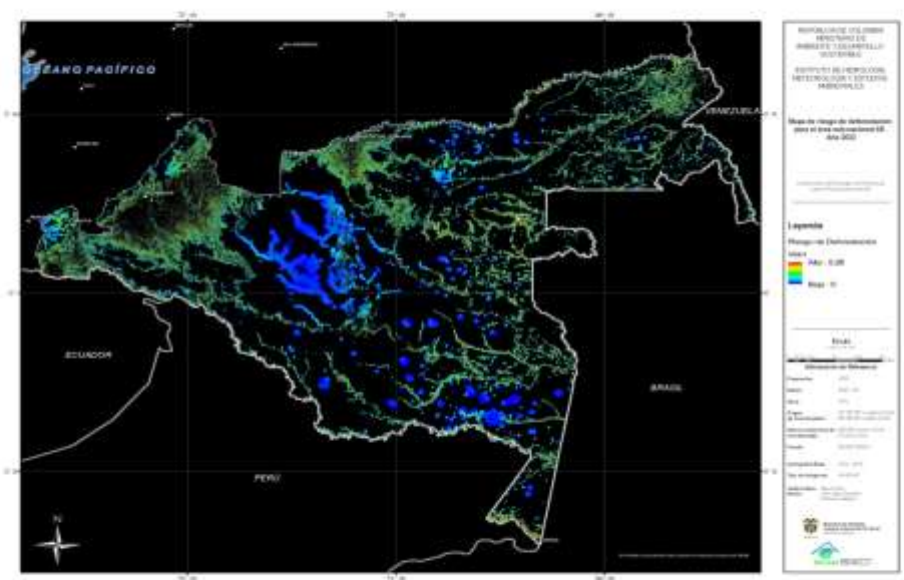

Figure 8. Risk of deforestion in the Amazon for the year 2022

The results of the spatial simulation for the study area are a key input for decision making about the definition and implementation of strategies to slow the progression of deforestation in the área and at the same time can become an important tool to propose transparent benefit distribution schemes and Monitoring, Report and Verification (MRV) measures.

Deficiencies in the information needed for more precise spatial predictions remain a constrain; however, the results from the different methods of validation applied during the modeling process show that the best models obtained far exceed the minimum levels of precision required in defining baselines for REDD+. As part of the "step by step" approach that should guide the construction of reference levels (Mora et al. 2012), Colombia will continue to explore the potential of spatial modeling to define reference levels, as well as for the development and implementation of effective mitigation and compensation strategies.

3. Construction of the Forest Reference Emission Level

Table 6 summarizes the information selected for the components of the FREL: activity data, emission factors and drivers of deforestation. The construction of the FREL involved three steps:

i. Determination of the activity data (According to section 2.d of this document).
ii. Determination of emission factors (According to section 2.e of this document).
iii. Multiplication of the average emission factor by the average deforestation plus 10% from national circumstances (According to section 2.f of this document).

Table 6 Summary of selected inputs for the deforestation simulation

Component	***Input***	***Source***
Activity data	Forest, -Non forest cover layers. Minimal mapping unit: 1ha.	IDEAM (2014) Based on the methodology proposed by (Cabrera *et al.* IDEAM 2011: Galindo *et al.*, in press)
Emission factors	Biomass (t ha^{-1}) and gross emissions (t CO_2 ha^{-1}) by type of forest.	Based on Phillips *et al.* IDEAM (2011); Phillips *et al.* IDEAM, in press.
National circumstances	Conservative estimate of future investment trends, as well as development plans and programs.	Based on secondary information reported in section 2.d of this document.

a) FREL Calculation

The total forest biomass per hectare (BT) is the sum of above ground forest biomass per hectare (BA), and the belowground forest biomass per hectare (BS). The BA of Tropical Rain Forest is **273.14 ± 9.8 Mg/ha (SE_f = 1,8%)** ; and the BS is **55.02 ± 1.83 Mg/ha (SE_f = 1,7%).**

So then, using this proxy, it was found that BT of Tropical Rain Forest is **328,2 ± 11,7 Mg/ha** (SE_f = **1,8%).(**section 2.e.v),

Carbon contained in the total forest biomass (CBF) per hectare is the product of the total biomass (BT) and carbon fraction (0.47 according to IPCC, 2003, 2006), using the following equation :

$$CBF = BT \cdot 0.47$$

$$CBF = 328.2 \cdot 0.47 = 154.3\ TonC/ha$$

The content of equivalent carbon dioxide in the total biomass per hectare (CBFeq) is the product of the carbon in the total biomass per hectare (CBF) and the constant of the molecular ratio between carbon (C) and carbon dioxide (CO_2) equal to 44/12 , using the following equation:

$$CBFeq = CBF \cdot (3.67)$$

$$CBFeq = 154.3 \cdot 3.67 = 566.1\ TonCO_2eq/ha$$

The emissions of every year (EA) used by the FREL during the period 2013-2017 are the product between the 2000-2012 average anual deforestation (CSB), (Average annualized change in natural forest cover, section 2.d), the equivalent carbon dioxide content in total forest biomass per hectare (*CBFeq*) and the national circumstances (CN), (Section 2.f), according to following equation:

$$EA = CBFeq \cdot CSB \cdot CN$$

$$EA = 566{,}1 \cdot 82.863 \cdot 1{,}1 = 51.599.618{,}7\ TonCO_2eq/year$$

The FREL for the Colombian Amazon Biome will have a projection period of 5 years, i.e. 2013-2018, after this period, the FREL will be updated.

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5. Annexes

a. Digital imagery Protocol to quantify deforestation in Colombia v.2 (Document in Spanish).
b. Technical contributions of the Forest and Carbon Monitoring System to the REDD+ Preparation Proposal by Colombia: Activity data and emission factors included (Document in Spanish).
c. Results of the adjustment of the forest referencie emission level of deforestation in the subnational area A8. (Document in Spanish)

6. GLOSSARY

CDA: Corporation for the Sustainable Development of Northern Eastern Amazon (for its translation from Spanish: Corporación para el Desarrollo Sostenible del Norte y Oriente Amazónico).

CLC: CORINE Land Cover.

CONPES : National Council for Economic and Social Policy. (for its translation from Spanish:Consejo Nacional de Política Económica y Social).

COP: Conference of the Parties.

CORMACARENA: Corporation for the Sustainable Development and Special Management of La Macarena Area

CORPOAMAZONIA: Corporation for the Sustainable Development of the Southern Amazon (for its translation from Spanish: Corporación para el Desarrollo Sostenible del Sur de la Amazonía).

CORPORINOQUIA: Regional Autonomous Corporation of the Colombian Orinoco

CRC: Regional Autonomous Corporation of Cauca -.

ENREDD + : National REDD + Strategy.

FREL : Forest Reference Emission Level .

IDEAM : Institute of Hydrology, Meteorology and Environmental Studies. (for its translation from Spanish: Instituto de Hidrología, Meteorología y Estudios Ambientales).

IIRSA. Initiative for the Integration of the South American Regional Infrastructure

IPCC : Intergovernmental Panel on Climate Change.

LULC : Land use and Land Change .

LULUCF : Land Use, Land Use Change and Forestry.

MADS : Ministry of Environment and Sustainable Development (For its translation from Spanish: Ministerio de Ambiente y Desarrollo Sostenible)

MAVDT : Ministry of Environment, Housing and Territorial Development.(For its translation from Spanish: Ministerio de Ambiente, Vivienda y Desarrollo Territorial)

REDD+ : Reducing Emissions from Deforestation and forest Degradation and conservation, sustainable forest management and enhancement of forest carbon stocks in developing countries .

RPP: Readiness Preparation Proposal

SINCHI : Amazon Institute of Scientific Research. (For its translation from Spanish: Instituto Amazónico de Investigaciones Científicas.)

SMByC: Forest and Carbon Monitoring System (For its translation from Spanish: Sistema de Monitoreo de Bosques y Carbono)

UNFCCC : United Nations Framework Convention on Climate Change.