Ministerio del Ambiente

Submission of the Republic of Ecuador
to the United Nations Framework Convention on Climate Change

Ecuador's Forest Reference Emission Level for Deforestation

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Acronyms

ABG	Aboveground biomass
ABG.NT	Aboveground biomass, non-trees
ABG.T	Aboveground biomass, trees
AD.AAAA-AAAA	Activity data for the period AAAA-AAAA
BGB	Belowground biomass
BGB.NT	Belowground biomass, non-trees
BGB.T	Belowground biomass, trees
BUR	Biennial Update Report
Cl	Cropland
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DBH	Diameter at breast height
DW	Dead wood
DW.L	Lying dead wood
DW.R	Dead coarse roots
DW.S	Standing dead wood
EF	Emission Factors
ENF	National Forest Inventory (*Evaluación Nacional Forestal*)
FN	Forest Land (natural forest)
FP	Forest Land (planted forest)
FREL	Forest reference emission level
FREL/FRL	Forest reference emission level and/or forest reference level
G	Grassland
GHG	Greenhouse gas
GIS	Geographical information system
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
GPG	Good Practice Guidance
HWP	Harvested wood products
IPCC	Intergovernmental Panel on Climate Change
L	Litter
LUC	Land-use Category
LULUCF	Land-use, Land-use change and Forestry

LUX	Land-use change
MAE	Ministry of Environment of the Republic of Ecuador (*Ministerio del Ambiente del Ecuador*)
MLUC AAAA/AA	Map of land-use categories for year AAAA/AA with information added from the maps MPFT
MLUCa AAAA	Map of land-use categories for year AAAA as constructed by MAE
MLUX AAAA-AAAA	Map of land-use change for the period AAAA-AAAA
MPFT	Map of potential forest types
O	Other lands
REDD+	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
S	Settlements
SOC	Soil organic carbon
UNFCCC	United Nations Framework Convention on Climate Change
Wa	Wetland (anthropogenic)
Wn	Wetland (natural)

1 Introduction

Ecuador welcomes the opportunity to submit its Forest Reference Emissions Level (FREL) for a technical assessment as per Decisions 12/CP.17 and 13/CP.19 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 for Climate Change.

Ecuador's new Constitution (2008) is a meaningful milestone for sustainable development in the country, since policies and programs derived from it have contributed to significant progress in improving the control and sustainable management of its forests while promoting actions for climate change mitigation in the land-use and forestry sectors. As part of these efforts, a consistent time-series of forest cover data has been generated and a national forest inventory has been completed, and they are now the basis for the development of this proposed FREL, in the context of broader national policies for sustainable development and actions currently being undertaken by Ecuador pursuant to the Bali Action Plan and the implementation of the Warsaw Framework for REDD+.

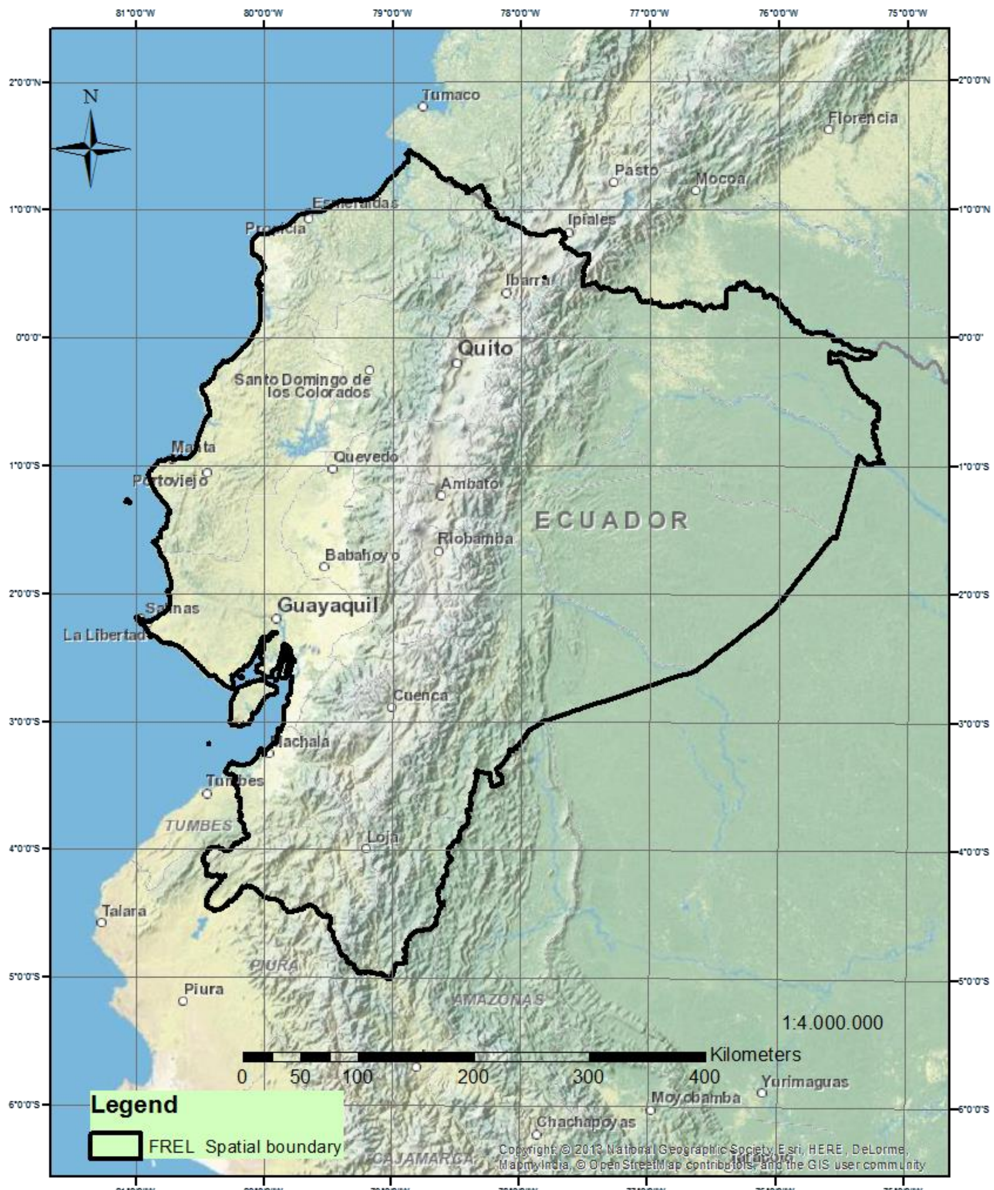
Ecuador underlines that the submission of this proposed FREL, and the subsequent Technical Annex in the Biennial Update Report on the results of emission reductions from the implementation of REDD+ results-based actions, are voluntary and exclusively for the purpose of obtaining and receiving results-based payments, as per Decisions 9/CP.19, 13/CP.19 and 14/CP.19.

This submission therefore does not prejudge any nationally appropriate mitigation action in the land and forestry sectors undertaken by Ecuador pursuant to the Bali Action Plan, nor does it prejudge any nationally determined contribution by Ecuador in the context of the protocol, another legal instrument or an agreed outcome with legal force under the Convention currently being negotiated under the Ad Hoc Working Group on the Durban Platform for Enhanced Action.

2 Area covered in Ecuador's FREL

The area covered in Ecuador's FREL consists of 100% of its continental territory (approximately 24,898,059.90 hectares) and excludes the Galapagos Islands, and other smaller islands. The official jurisdictional demarcation is presented in **Figure 1** as per geographical coverage of *forest coverage and forest change* monitoring being undertaken by the MAE.

Figure 1. *Area covered in Ecuador's FREL.*



3 Information on the FREL

Ecuador has followed the guidelines for the submission of information on reference levels as per the Annex to Decision 12/CP.17, therefore the present submission has been developed and is structured accordingly, as follows:

a) *Information used in constructing the FREL* (section 3.1);

b) *Transparent, complete, consistent and accurate information, including methodological information, used at the time of construction of the FREL* (section 3.2);

c) *Pools and gases, and activities listed in decision 1/CP.16, paragraph 70, which have been included in the FREL and the reasons for omitting a pool and/or activity from the construction of the FREL, noting that significant pools and/or activities should not be excluded* (section 3.3);

d) *The definition of forest used in the construction of the FREL* (section 3.4).

3.1 Information used in constructing the FREL

3.1.1 Activity data

Activity data used for the construction of Ecuador's FREL was extracted from an historical time series of land-use maps developed by the Ministry of Environment (MAE) for the years 1990, 2000 and 2008 (see MAE, 2014b). Activity data for the construction of Ecuador's FREL has been estimated following approach 3 as described in the IPCC's Good Practice Guidance for LULUCF (IPCC, 2003). This approach takes into account geographically explicit land-use and land-use change data for the estimation of activity data. Following this approach, three wall-to-wall maps were generated for the entire country by analyzing remotely sensed data to represent land-use categories in Ecuador for the reference years 1990, 2000 and 2008.

For the purpose of this submission, maps of land-use categories used in the estimation of activity data have been named with the notations 1990/91, 2000/01, and 2008/09. This notation referring to two years is used to indicate that each land-cover map was produced by analyzing Landsat and Aster images acquired over a period of several months (up to ± 24 months). This was necessary to generate land-use information in areas obscured by clouds and shadows in the satellite images, as well as to address imperfections (such as stripes) that exist in the Landsat images since 2003.

It was further assumed that each land-use map represents the ground situation by December 31st each year. In this way, calculations of the average annual activity data were based on the assumption that the first historical reference period (1990-2000) encompassed exactly 10 years, while the second historical period (2000-2008) exactly 8 years.

The methods used to produce these maps have been summarized in section 3.2.5 of this submission and are further described in the document "*Actualización del protocolo metodológico para la generación del Mapa Histórico de Deforestación del Ecuador Continental*" (MAE, 2014b), which is available for download through the website http://suia.ambiente.gob.ec/en/anexos-nivel-referencia.

Information on the accuracy of the land-use maps has been summarized in section 3.2.4 of this document and is further described in the documents "*Informe Final de la Evaluación de la Precisión del Mapa Histórico de Deforestación del Ecuador Continental 1990, 2000 y 2008*" (MAE, 2013a) and *Review of the historical change and classification of forest areas of Ecuador*

(Forest Carbon International, 2013), which are also available for download through the website http://suia.ambiente.gob.ec/en/anexos-nivel-referencia.

Activity data was quantified for each land-use change transition by combining the three maps of land-use available, a map of potential forest types (MPFT) in a geographical information system (GIS), following the methods further described in Annex 1.

To ensure a consistent time-series of activity data, the same source of multispectral data (Landsat and Aster), minimum mapping unit (1.00 ha), classification method and forest definition were used to construct land-use maps for the years 1990/91, 2000/01 and 2008/09 and the same method of map comparison was used to obtain activity data per land-use change category for the periods 1990-2000 and 2000-2008.

Table 1 shows the estimated activity data per forest type estimated for the two historical periods. On average, 129,943.10 hectares per year were deforested between 1990 and 2000 and 108,650.13 hectares per year between 2000 and 2008.

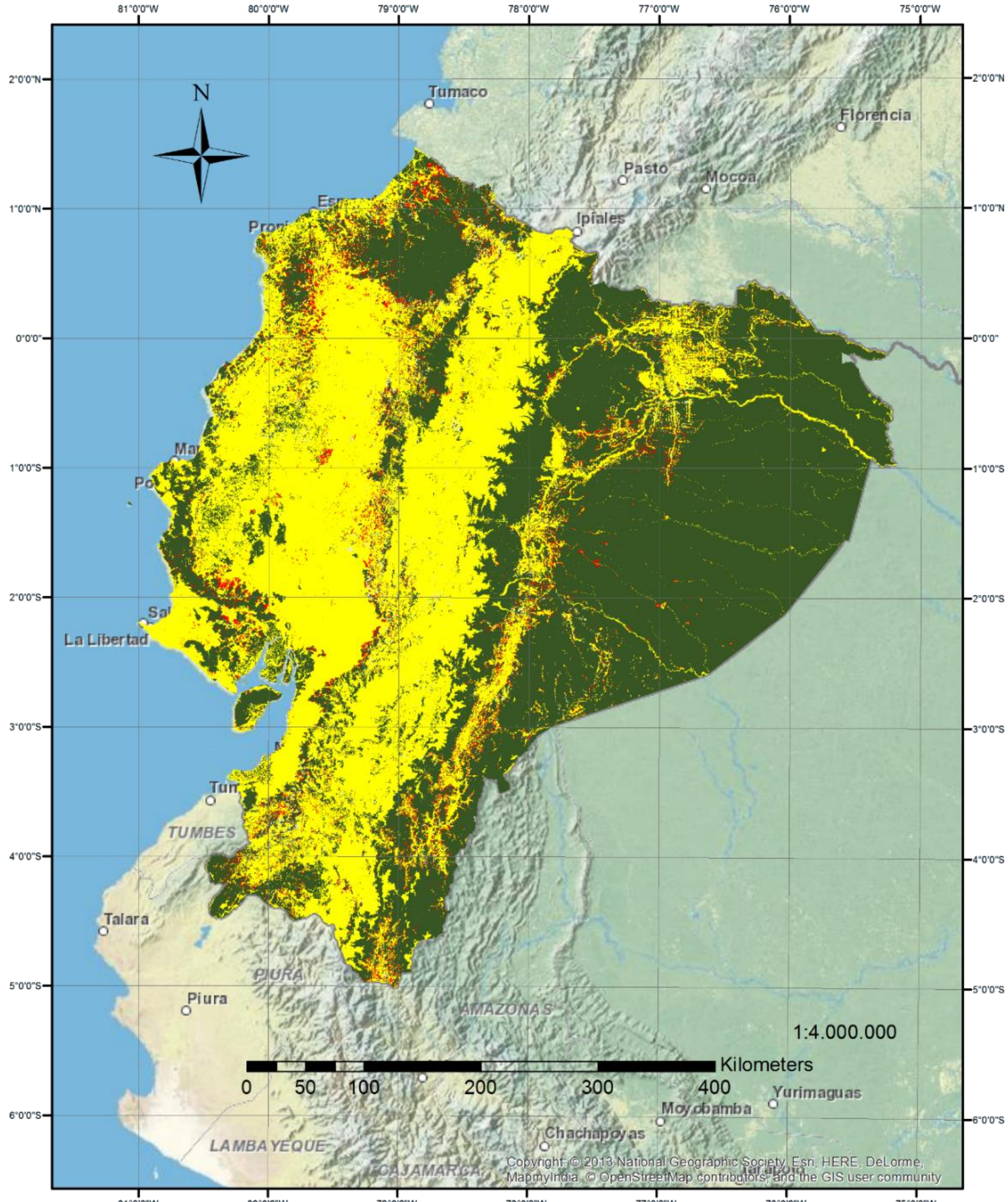
Table 1. *Historic gross deforestation in Ecuador per forest type.*

Categories of Forest Land converted to other land categories	1990-2000		2000-2008	
	ha	ha yr^{-1}	ha	ha yr^{-1}
Dry Andean Forest	19,154.97	1,915.50	17,135.01	2,141.88
Pluviseasonal Dry Forest	152,989.83	15,298.98	106,680.06	13,335.01
Andean Montane Evergreen Forest	183,291.39	18,329.14	138,404.52	17,300.57
Andean Foothills Evergreen Forest	250,064.10	25,006.41	185,587.65	23,198.46
Andean High Mountain Evergreen Forest	31,681.98	3,168.20	20,431.62	2,553.95
Amazon Lowland Evergreen Forest	318,742.02	31,874.20	179,981.73	22,497.72
Choco Lowland Evergreen Forest	324,627.21	32,462.72	208,887.57	26,110.95
Mangrove	12,569.85	1,256.99	10,095.21	1,261.90
Morete Palms Forest	6,309.63	630.96	1,997.64	249.71
Total gross deforestation	**1,299,430.98**	**129,943.10**	**869.201.01**	**108,650.13**

Note: The numbers in **Table 1** do not include the conversion of forest plantations to other land-use categories, the conversion of natural forest to natural wetlands and the conversion of forest to other land-use categories. More detailed information on activity data is provided in Annex 1. All information used in the FREL calculation is available for download through the website http://suia.ambiente.gob.ec/en/anexos-nivel-referencia.

Figure 2 shows geographically explicit information on land-use change for the period 2000-2008 (MLUX2001_2008), while **Table 2** presents its attributes.

Figure 2. *Map of land-use change for the period 2000-2008 (MLUX2000_2008).*



Note: The map of land-use change for the period 2000-2008 (MLUX2000_2008) has many more land-use change transitions than shown here. For space reasons only the most relevant land-use conversions are illustrated in this figure. The map that has been made available for download through the website (*http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*) contains data on all land-use transitions and the corresponding activity data, which can be downloaded from the same website.

__Table 2.__ Attributes table of MLUX2000_2008.

Legend	Land-use change category	Area
	Description	ha
(red)	Deforestation as defined for Ecuador's FREL*	869,201.01
(light blue)	Forest Land converted to natural Wetland (not included in the FREL)	127.17
(dark green)	Forest Land remaining Forest Land	12,821,892.66
(light green)	Forest Plantations converted to Natural Forests	0.00
(pale yellow)	Forest Plantations converted to Non Forest Land	39,283.02
(light grey)	No Information converted to Forest Land (Forest Plantations)	0.00
(grey)	No Information converted to Non-Forest Land	0.00
(pale green)	Non-Forest land converted to Forest Land	276,549.30
(yellow)	Non-Forest land remaining Non-Forest Land	10,891,006.74
	Total area of Ecuador	24,898,059.90

* Includes conversion of natural forests to forest plantations[1]

Detailed description of the methods used to extract information on activity data from the three land-use maps referred to above, and other sources of information, is provided in Annex 1.

Ecuador has worked on acquiring its own data by applying a methodology that includes field measurements. Considering that such methodology improves the precision of the generated maps, the country's own data were used for the construction of the proposed FREL. Due to differences in the approach and methodologies applied in some deforestation models, like the one carried out at global scale by Matt Hansen[2], no direct comparison with such deforestation estimates has been developed nor considered for the construction of the proposed FREL.

3.1.2 Emission factors

To estimate historical emissions, Ecuador proposes to multiply gross deforestation per forest type with forest type specific emission factors. It should be noted that the forest type stratification for the activity data and emission factors is consistent with the stratification used in the national greenhouse gas inventory. Emission factors were calculated following IPCC's 2003 Good Practice Guidance (GPG) on Land Use, Land Use-Change and Forestry (LULUCF), as further described in section 3.2.5 and Annex 2.

Emission factors for Ecuador's FREL consist of the carbon stock associated with the forest type. It is assumed that the biomass immediately after deforestation is zero. Furthermore, 100% oxidation of the carbon stocked in dead wood and litter is assumed at the time of conversion. This assumption is made since available information on the carbon contents of land-use following deforestation is not sufficiently accurate.

Data on forest carbon stocks for 9 natural forest types were obtained from the results of Ecuador's national forest inventory (*Evaluación Nacional Forestal*, ENF), which is about to be officially

[1] Deforestation due to the conversion of forest plantations represent less than 1% of the total deforested area.
[2] See Hansen et al. (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change Science15 November 2013:Vol. 342 no. 6160 pp. 850 – 853 DOI:10.1126/science.1244693

approved and published (MAE, 2014a); details on the methods used to collect field measurements and estimate carbon stocks are described in the mentioned report, which can be downloaded from the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*.

The ENF has reported carbon stock estimates on four forest carbon pools: Aboveground biomass (AGB); Belowground biomass (BGB); Litter (L); Deadwood (DW) - including the following components: standing dead wood (DW.S); lying dead wood (DW.L); and dead coarse roots (DW.R). The underlying field measurements were made between 2011 and 2014 and are therefore recent enough to be used for estimating emission factors in the construction of Ecuador´s proposed FREL for deforestation in the context of REDD+ results-based payments.

The information collected by the ENF was structured in the Collect module of the OpenForis software; in order to carry out the calculations the information was divided in five data sets:

- Individual tree level data set
- Plot level data set
- Litter information data set
- Lying dead wood data set
- Understory data set

The clusters were designed in an L form, and the information is extracted from three plots of each cluster (**Figure 3**). Within each plot, there are nested plots that are used for collecting information and measurements of the different carbon pools as established by the IPCC (1996 revised version): lying deadwood, litter, understory, above-ground biomass and soil organic matter (**Figure 4**). The variables considered for each pool are:

- Dead wood: Lying dead wood with a DBH $\geq$ 10 cm.
- Litter: Organic matter lying in the soil with a diameter less than 10 cm and higher than 2 mm.
- Regenerating trees: Young tress with a height greater than 30 cm and a DBH less than 5 cm (saplings and seedlings).
- Living Biomass with a DBH less than 5cm: Understory; shrubs and woody fruit trees; grass, crops and cultivated and natural pastures in the 2m x 2m plot, by the destructive method.
- Living trees, standing deadwood and stumps: Location, tree identification, DBH, total height (HT), commercial height (HC), plant health, crown cover, phenology and; use, diameter and state of stumps. Subjects with a DBH greater than 20 cm were considered in the main plot (60m x 60m), 10-20 cm DBH in the nested plot of 20m x 20m. In the Andean High Mountain Evergreen Forest type, where the stem are mainly small, subjects were measured in the range of 5-20cm DBH.
- Soil: Color, texture, structure, stoniness, carbon content, bulk density and organic horizon depth.

Figure 3. *Cluster design of Ecuador's National Forest Inventory*

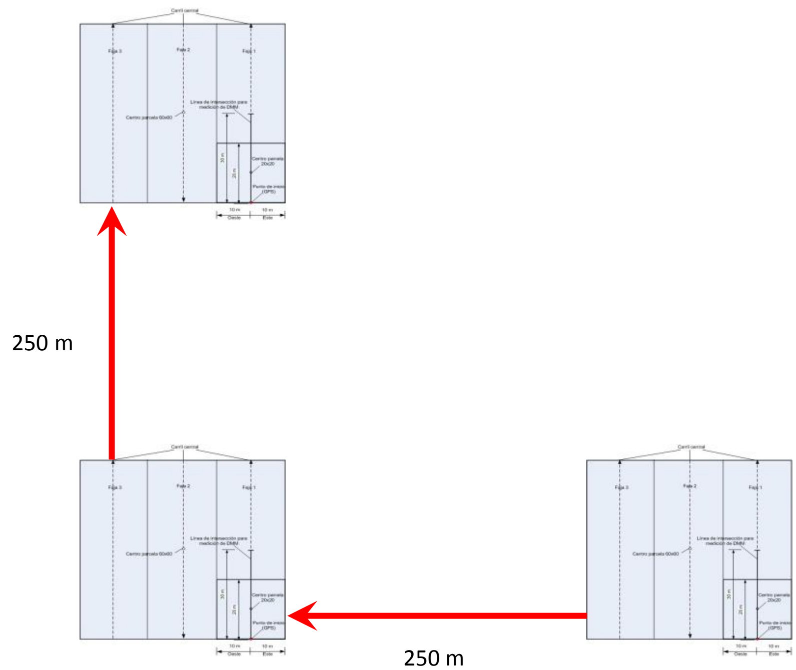
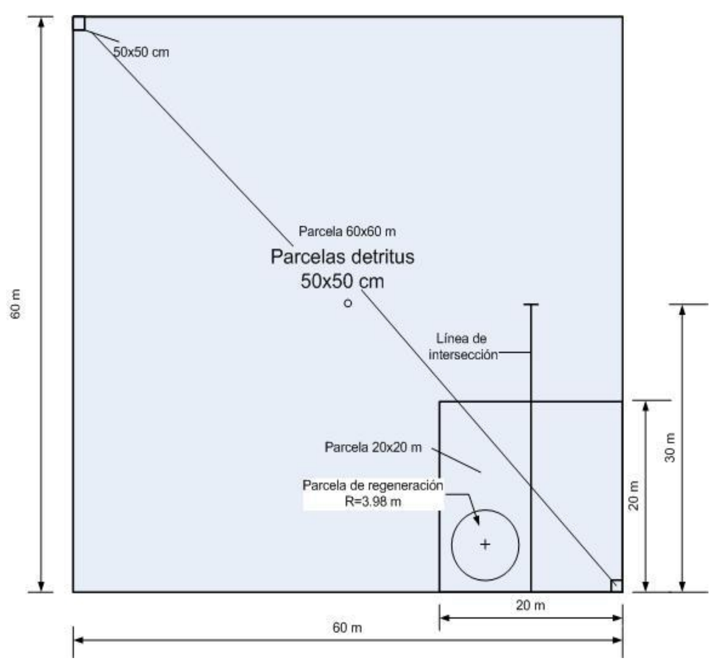


Figure 4*. Design, layout and sizes of the nested plots where the different measurements were performed.*



Detailed information regarding the methodology for estimating biomass and emission factors may be found in the file MAE 2014a Evaluación Nacional Forestal (ENF), page 57, available at *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*

So far Ecuador´s ENF has not reported the results of carbon stock measurements for the Soil Organic Carbon (SOC) pool, although measurements have been taken and are currently being analyzed. Carbon stock estimates in the SOC pool may therefore be considered in future improvements of Ecuador's proposed FREL.

The estimated average carbon stocks (table 3), expressed in tons of carbon dioxide equivalent per hectare (CO_2-e ha^{-1}).

As the data presented in the report of the ENF is expressed in tons of carbon per hectare (tC ha^{-1}) it was necessary to convert them to tons of carbon dioxide equivalent per hectare (tCO_2-e ha^{-1}) for the construction of the proposed FREL. This conversion consists of a multiplication by 44/12, as suggested by IPCC.

Table 3. *Estimated average carbon stocks used in the calculation of emission factors.*

Land-use category	Aboveground biomass		Belowground biomass		Dead wood			Litter	Total
	AGB.T	AGB.NT*	BGB.T	BGB.NT**	DW.S	DW.L	DW.R	L	SUM
Description (English translation)	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}
Dry Andean Forest	105.60	5.83	25.34	1.40	2.13	20.35	0.95	15.47	**177.07**
Pluviseasonal Dry Forest	91.67	5.46	22.00	1.31	1.50	7.59	0.77	6.82	**137.12**
Andean Montane Evergreen Forest	296.60	15.25	71.17	3.66	21.27	28.12	10.12	8.87	**455.06**
Andean Foothills Evergreen Forest	267.45	11.92	64.20	2.86	15.44	76.01	7.22	7.92	**453.02**
Andean High Mountain Evergreen Forest	224.47	28.20	53.86	6.77	14.78	47.23	6.97	9.86	**392.13**
Amazon Lowland Evergreen Forest	396.44	13.68	95.15	3.28	15.40	48.84	7.41	11.26	**591.45**
Choco Lowland Evergreen Forest	192.17	11.26	46.13	2.70	8.36	34.32	4.84	8.51	**308.28**
Mangrove	183.77	70.33	44.11	-***	3.41	14.52	1.50	-	**317.64**
Morete Palms Forest	181.28	9.46	43.52	2.27	4.55	24.27	2.16	12.72	**280.24**

F = Forest Land;

* Carbon sink in palm trees and understory.

** Below ground carbon sink based on a root expansion factor for understory and palm trees.

*** The root expansion factor was not applied in the mangrove strata since root weight was measured in the field.

Note: More detailed information on how the average carbon stock values were determined can be found in:

- MAE, 2014a. *Evaluación Nacional Forestal – Resultados*. Available for download through the website http://suia.ambiente.gob.ec/en/anexos-nivel-referencia
- Annex 2.

3.1.3 The construction of Ecuador's forest reference emission level for deforestation

Enabling policies and actions for REDD+ activities implementation

Ecuador started to implement new policies and programs to reinforce forest governance, reduce deforestation, and improve forest control and forest management since 2009 in accordance to provisions established by Ecuador's new Constitution from 2008.

Ecuador's National Constitution recognizes, among others:

- 'The right of people to live in healthy and ecologically balanced environment to ensure sustainability and good living, sumak kawsay. It is of public interest environmental preservation, conservation ecosystems, biodiversity and integrity of genetic heritage the country, the prevention of environmental damage and recovery degraded natural areas' (Art. 14)
- 'The nature or Pacha Mama, where life happens, has the right to be fully respected and to the maintenance and regeneration of its vital cycles, structure, functions and evolutionary processes' (Art. 71)
- 'The nature is entitled to restoration' (Art. 72)

The recognition of rights detailed above under the Constitution, as the main legal and policy instrument for public administration, led to a wide range of cross-cutting and multi-level policy instruments, guided by the National Development Plan (Plan Nacional del Buen Vivir). Ecuador's National Development Plan 2009-2013 aimed to 'Guarantee nature rights and promote a healthy and sustainable environment'. This development objective established as a policy the need to 'protect and give a sustainable management to its natural patrimony', while 'Enhancing climate change adaptation and mitigation', and established a national targets: 'Increasing in 5% territory under conservation or environmental management schemes' and the 'reduction in 30% deforestation rates by 2013'.

Those clear and strong objectives, policies and targets were mainstreamed in a broad range of sectorial policies and planning tools at different government levels including:(i) Ministerial Agreement (139) made official, which established administrative rules and procedures for authorizing the use and timber harvesting (2010), which also reinforced the forestry regulation and control; (ii) establishment of the Socio Bosque Program, as a domestic policy of positive incentives for forest conservation; iii) establishment of a Forest Governance Policy as the guiding tool for forest management nation-wide technical reference in DNF; iv) implementation of the Forest Administration System (SAF) which aims to improve forestry control and ensure transparency of information; among others including restoration and reforestation efforts.

Ecuador's National Development Plan 2013-2017 also recognizes at objective level the need to 'Guarantee nature rights and promote environmental national and global sustainability'. With this, Ecuador aims to confirm its commitment to an eco-efficient production transformation under a model with greater economic, social and environmental value. With this regard, Ecuador recognizes as priorities the conservation and sustainable use of natural resources. Therefore, Ecuador's environmental public policy promotes conservation, valuation and sustainable use of heritage natural, ecosystem services and biodiversity. This requires the establishment guarantees, regulations, standards and procedures for protection and effective sanction to compliance with the rights of nature. They should also strengthen environmental management interventions in the territories, increasing efficiency and effectiveness in the management and administration the National System of Protected Areas (SNAP) and ecosystem restoration.

That said, our Development Plan 2013-2017 established as a targets the need to: 'Increase continental territory under conservation or environmental management in 35.9%' and 'Increase forest restoration in 500,000 hectares', among others relevant for reducing deforestation and sustainable forest management under a broader policy 'Changing the Production Model in the Amazon', which aims to intensify production in current productive areas while avoiding the expansion of the agricultural frontier.

Thus, it is important to highlight that currently there are not official studies on the contribution of specific policies to reducing deforestation; however, independent studies have reported that policies and efforts related to intensification of certain agricultural activities, since 2009, have had an impact on limiting the expansion of the agricultural frontier.

Therefore Ecuador considers that national efforts, including policies and actions, derived from our 2008 Constitution and National Development Plans have contributed so far to reducing rates of deforestation while complying with national targets and thus, contributing to the reduction of forest-related GHG emissions at national level, where national performance on reducing deforestation, and associated emission reductions, may not be linked to any specific policy or action.

Therefore the year 2009 is considered the base year for Ecuador's REDD+ results-based activities implementation, where the historical reference period chosen for the FREL is 2000-2008.

Methods applied in the construction of the FREL

Estimation methods used in the construction of the FREL are described below and further developed in Annexes to this submission. Ecuador's FREL does not include assumptions on potential changes or impacts of domestic policies, however it has been constructed in the basis of available historic data that will enable to reflect the effects on emissions associated to gross deforestation of policies and plans implemented at national level since 2009.

It has not been decided yet if this proposed FREL will be revisited and improved pursuant a stepwise approach as per paragraph II.10 of Decision 12/CP.17. However, Ecuador wants to emphasize that this proposed FREL may be revisited and improved at any time in the context of available data, methodologies and adequate and predictable support, as per Decisions 12/CP.17 and 9-13-14/CP.19.

a) Calculation of emission factors (EFlc)

Recognizing that forest reference emission levels and/or forest reference levels should be established by developing country parties in accordance to national circumstances, as per paragraph 7 in Decision 4/CP.15, and; in consistency with anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks as contained in each country's greenhouse gas inventories as per paragraph 8 in Decision 12/CP.17, Ecuador has taken into consideration existing literature from IPCC for assisting countries in the compilation of national greenhouse gas inventories for the estimation of emission factors in the context of the construction of this proposed FREL. Ecuador therefore describes below the chosen method, as deemed the more appropriate in the context of the construction of Ecuador's FREL.

Applied method for the calculation of emission factors in the construction of Ecuador's FREL:

Immediate oxidation of 100% of the forest carbon stocks in all carbon pools and assumption of zero carbon stocks in the post-deforestation vegetation

This is the most conservative and simplest method to calculate emission factors. It assumes that emission factors are equal to 100% of the pre-deforestation forest carbon stocks:

$$EF_{lc} = \sum_{cp}^{CP} FC_{l,cp} \tag{1}$$

<u>Where</u>:

EF_{lc}	Average emission factor as estimated for the land-use change category *lc* for the period 2000-2008; ha yr^{-1}
$FC_{l,cp}$	Forest carbon stock in the carbon pool *cp* of the forest land-use category *l*; tCO_2-e ha^{-1}
CP	Number of carbon pools included in the estimation of emission factors; dimensionless

b) Calculation of average annual activity data (ADlc)

The average annual activity data estimated for each land-use change category (*lc*) is calculated by dividing the periodic (2000-2008) activity data of each land-use change category by the number of years elapsed during the historical reference period:

$$AD_{lc} = \frac{ADHP_{lc}}{THP} \tag{2}$$

<u>Where</u>:

AD_{lc}	Average annual activity data as estimated for the land-use change category *lc* in the period 2000-2008; ha yr^{-1}
$ADHP_{lc}$	Activity data as estimated for the land-use change category *lc* in the period 2000-2008; ha
THP	Duration of the historical reference period 2000-2008 (8 years); yrs

c) Calculation of the forest reference emission level (FREL)

Ecuador's FREL has been estimated as the average annual GHG emissions from deforestation of the historical reference period 2000-2008. This is the most recent period for which national activity data have been generated; data and methodological approaches have been summarized in this section of the submission and further described in Annex 1 (methods used for estimating activity data) and Annex 2 (methods used for estimating emission factors). The 2000-2008 period also represents a period in which broad policy changes that took place and influenced national circumstances in Ecuador since 2009, were not yet in place.

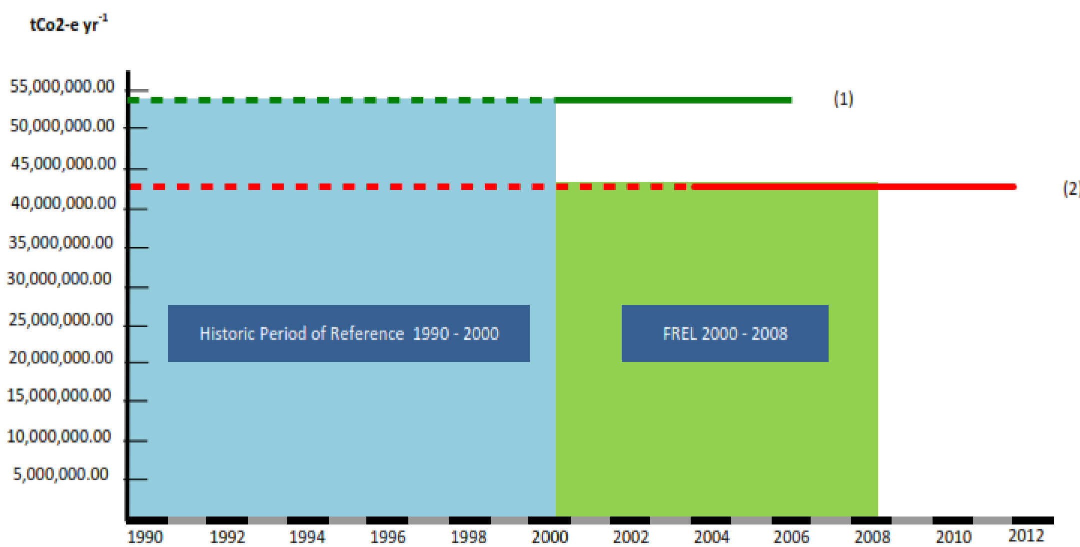
Historical activity data have also been estimated for the period 1990-2000 (129,943 ha yr^{-1}), showing that gross deforestation was approximately 119% of the average annual gross deforestation estimated for the period 2000-2008 (108,650 ha yr^{-1}). Activity data of the 1990-2000 period were conservatively excluded in the construction of Ecuador's FREL as they no longer reflect current national circumstances for Ecuador.

Ecuador has decided to use the average annual GHG emissions from deforestation estimated for the 2000-2008 period in the context of the proposed forest reference emission level, for REDD+ results-based payments in the period up to 2020. However, both historic data are described below:

Table 4. *Historical deforestation activity data and associated GHG emissions.*

Period	Historical activity data		Estimated historical GHG emissions	
	ha	ha yr^{-1}	tCO_2-e yr^{-1}	tCO_2-e yr^{-1} ha^{-1}
1990-2000	1,299,431	129,943	52,784,480	406
2000-2008	869,201	108,650	43,418,126	400

Figure 5. *Ecuador's reference level and average annual emissions for the 1990-2000 period (historical reference period) and 2000-2008 period, associated with the mean annual gross deforestation*



(1) Mean emission (1990-2000) (2) Mean emission (2000-2008)

The method used to calculate average annual GHG emissions from deforestation (as defined by Ecuador in section 3.1.3 of the submission) follows the generic guidance given in IPCC GPG on LULUCF (2003), in terms of multiplying the "activity data" by a carbon stock coefficient or "emission factor" to provide the source/or sink estimates, considering all relevant carbon pools and changes of land-use from one type to another. This principle, as presented in equation 3, below, follows the approach of equation 3.1.1 in IPCC GPG (IPCC 2003, page 3.16), where EF_{lc} represents the sum of gains and losses occurred during the temporal boundary of the FREL assessment for each land-use change category.

$$FREL = \sum_{lc=1}^{LC} (AD_{lc} * EF_{lc}) \qquad (3)$$

<u>Where</u>:

$FREL_t$ Forest Reference Emission Level; tCO_2-e yr^{-1}

lc A land-use change category; dimensionless

LC Total number of land-use change categories, as listed in the sheet <AD.2000-2008> >; dimensionless

AD_{lc} Average annual activity data as estimated for the land-use change category *lc* in the period 2000-2008; ha yr^{-1}

EF_{lc} Emission factor as estimated for the land-use change category *lc* for the period 2000-2008; ha yr^{-1}

Table 5. *Estimated FREL including main assumptions.*

GHG emissions from pre-2000 activities	Forest carbon pools	Post-deforestation carbon pools	Estimated FREL		
			Period	tCO_2-e yr^{-1}	tCO_2-e ha^{-1} yr^{-1}
Excluded	Included-IO	Excluded	1990-2000	52,784,480	406[(1)]
			2000-2008	43,418,126	400[(2)]

Notes: IO = Assumption of immediate oxidation of 100% of the carbon stocks in all forest carbon pools in the year of land-use change;

(1) The average emission factor is calculated by dividing the average annual emissions by the average annual activity data of the period 1990-2000 ($AD_{1990-2000}$);

(2) The average emission factor is calculated by dividing the average annual emissions by the average annual activity data of the period 2000-2008 ($AD_{2000-2008}$);

The results shown in **Table 5** can be reproduced with the information provided in the FREL calculation.xlsx *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*.

3.2 Transparent, complete, consistent and accurate information

3.2.1 Transparent information

All the process followed and methodologies used for the estimation of activity data, emission factors and the construction of the FREL is transparently documented in this document, its annexes and external sources cited in this document, which have all been made available for download through the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*.

All maps used for estimating activity data per land-use category, as cited in Annex 1 to this submission, have been also uploaded to the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia* and are available for download.

3.2.2 Complete information

According to the definition of *complete* information provided in Annex I in Decision 12/CP.17 meaning the provision of information that allows for the reconstruction of forest reference emission levels and/or forest reference levels, Ecuador highlights that all information used in the context of the construction of this proposed FREL has been developed by Ecuador, allows for the reconstruction of the FREL and is publicly available.

All information used for the construction of Ecuador's FREL has been uploaded to the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia* and is available for download. Available information includes the following:

(a) Maps used to estimate activity data, as described in Annex 1 to this submission, in geotiff format and in their full original spatial resolution:

MLUCa_1990:	Map of Land-use Categories 1990, as generated by the MAE through analysis of remotely sensed data.
MLUCa_2000:	Map of Land-use Categories 2000, as generated by the MAE through analysis of remotely sensed data.
MLUCa_2008:	Map of Land-use Categories 2008, as generated by the MAE through analysis of remotely sensed data.
MPFT:	Map or Potential Forest Types Map, containing the 9 forest strata that were defined by the ENF, used to stratify natural forests according to their average carbon content.

(b) Tools developed for the construction of Ecuador's FREL:

< FREL calculation.xlsx>	Spreadsheet showing the calculation procedure of Ecuador's FREL
<MAPS.xlsx>	Spreadsheet showing the relationship between categories of all maps listed above.

(c) All the literature sources consulted, as listed in section "References cited", except IPCC documents, which can be obtained through IPCC´s official website (*http://www.ipcc.ch/*).

3.2.3 Consistent information

Consistency with the national greenhouse gas inventory

Paragraph 8 in Decision 12/CP.17 establishes that FREL and/or FRL *shall maintain consistency with anthropogenic forest related greenhouse gas emissions by sources and removals by sinks as contained in the country's national greenhouse gas inventory*.

Ecuador applied the IPCC definition of consistency (IPCC, 2006), meaning that the same methodologies and consistent data sets are used to estimate emissions from deforestation in the construction of the forest reference level and in the national GHG inventory.

When compared to the most recent National GHG Inventory submitted by Ecuador in its Second National Communication, no consistency should be expected since the available activity data have undergone a significant improvement – geographically explicit information was not available back then-, and the methodological guidance has been updated from the Revised 1996 IPCC Guidelines to the 2003 Good Practice Guidance on LULUCF.

Therefore, all data and methods used in the construction of Ecuador's FREL, including activity data, assumptions, default values, geographical boundaries, etc. will be taken into account to attain consistency with the most recent calculation of the national greenhouse gas inventory which is currently under preparation and will be presented in Ecuador's First Biennial Update Report (BUR).

As such, the methodological guidance given in IPCC's 2003 Good Practice Guidance (GPG) on Land Use, Land Use-Change and Forestry has been followed, consistent with Ecuador´s approach for the compilation and reporting of the national GHG inventory.

3.2.4 Accurate information

Accuracy of the estimated activity data

The maps of land-use categories for the years 1990, 2000 and 2008 were generated by the Ministry of Environment (MAE) through analysis of remotely sensed data following the methodological approaches described in the report "*Actualización del protocolo metodológico para la generación del Mapa Histórico de Deforestación del Ecuador Continental*" (MAE, 2014b).

The assessment of the accuracy of these maps was implemented separately for each of the three land-use maps, and the methods used and results obtained are reported in detail in the report "*Informe Final de la Evaluación de la Precisión del Mapa Histórico de Deforestación del Ecuador Continental 1990, 2000 y 2008*" (MAE, 2013a).

A stratified random sampling protocol was followed to select samples for the accuracy assessment. The entire continental portion of the country was divided in a 20x20 km grid and the total number of grids were divided into three different strata, representing low, medium and high historic deforestation, according to the deforestation rates of the two historical periods 1990-2000 and 2000-2008.

A random sample representing 30% of Ecuador´s continental area was selected, and the classification accuracy assessed for each of these grids. The overall accuracy of the maps was estimated at 69% for the 1990 land-use map, 73% for the 2000 land-use map and 76% for the 2008 land-use map.

Forest Carbon International (2013) did an independent accuracy assessment of the 2000 and 2008 land-use maps after collapsing all non-forest categories into the one single category "non-forest". The overall accuracy was then estimated at 95.5 % (Kappa coefficient: 88.1%) for the 2000 map, and 94.0% (Kappa coefficient: 87.0%) for the 2008 map. These results show that for the purpose of establishing a national FREL, Ecuador's land-use maps are of adequate accuracy.

Nonetheless, the estimated accuracy of Ecuador´s land-use maps reflects the country´s first effort for producing spatial information on forest coverage, developed as part of the country´s ongoing processes for forest coverage and forest loss monitoring, but also in the context of its national readiness process for REDD+.

Ecuador is already working on the improvement of its forest monitoring capabilities and aims to produce more frequent and accurate data for future periods, as methods and national capacities will continue to improve as part of national priorities under forest and land-use policies, and pursuant the stepwise approach referred to in paragraph 10 of Decision 12/CP.17.

A methodology to assess the land cover change accuracy –especially deforestation- is among the future improvements that Ecuador is looking forward to incorporate in future versions of the FREL.

Uncertainty of the estimated emission factor

The estimation of emission factors is associated to many sources of uncertainty, such as default biomass stock values, default parameters, sample errors and unavoidable bias from field measurements, uncertainty from conservatively assumed parameters, uncertainty values not reported by IPCC, and inter-annual variability affecting biomass-stock changes.

In case of ENF-produced carbon stock values for the 9 different natural forest types, uncertainties of errors associated with the estimates were calculated for the different carbon pools measured per forest type. Highest uncertainty was associated with the measurements in the dead wood pool. For plantation forests, IPCC default reported uncertainty values were applied.

The total carbon stocks in the inventoried forest strata (9 native forest subcategories, **Table 6**) have an average uncertainty value of 10.25%.

Considering that most of the deforestation is happening in natural forest categories and that conversions of forest plantations to non-forest land-uses represent less than 3% of the overall deforestation estimated between 2000-2008; it can be assumed that the data, including default values, used for estimating emission factors are of adequate accuracy and lead to conservative estimations of emission factors for the construction of a FREL in the context of REDD+ results-based payments.

Table 6. *Uncertainty percentages per carbon sink for each forest stratum*

Stratum	Uncertainty (%)				
	C in Above ground biomass	C in Roots	C in Understory	C in Lying Wood	C in Litter
Dry Andean Forest	18.04	18.04	57.59	67.20	14.33
Pluviseasonal Dry Forest	14.99	15.00	27.11	79.09	9.86
Andean Montane Evergreen Forest	9.87	10.17	32.23	23.86	9.12
Andean Foothills Evergreen Forest	10.61	10.60	27.58	84.96	11.53
Andean High Mountain Evergreen Forest	24.36	26.18	34.32	45.20	11.80
Amazon Lowland Evergreen Forest	6.06	6.09	19.61	34.94	7.36
Choco Lowland Evergreen Forest	8.97	8.99	22.43	24.13	6.89
Mangrove	17.92	17.92	24.74	55.04	--*
Morete Palms Forest	20.79	21.07	44.26	67.52	14.33

*-- The estimation for C in Litter does not apply for the mangrove stratum

3.2.5 Methodological information

Methodological information related to activity data

Activity data used for the construction of Ecuador´s FREL was estimated following approach 3 as described in the IPCC’s 2003 GPG on LULUCF. This approach takes into account geographically explicit land-use data for the estimation of historical activity data. Accordingly, wall-to-wall maps have been produced for the entire country by analyzing remotely sensed data acquired for the reference dates 1990, 2000 and 2008. The data sources used were optical remote sensing data acquired through Landsat TM, Landsat ETM+ and Aster.

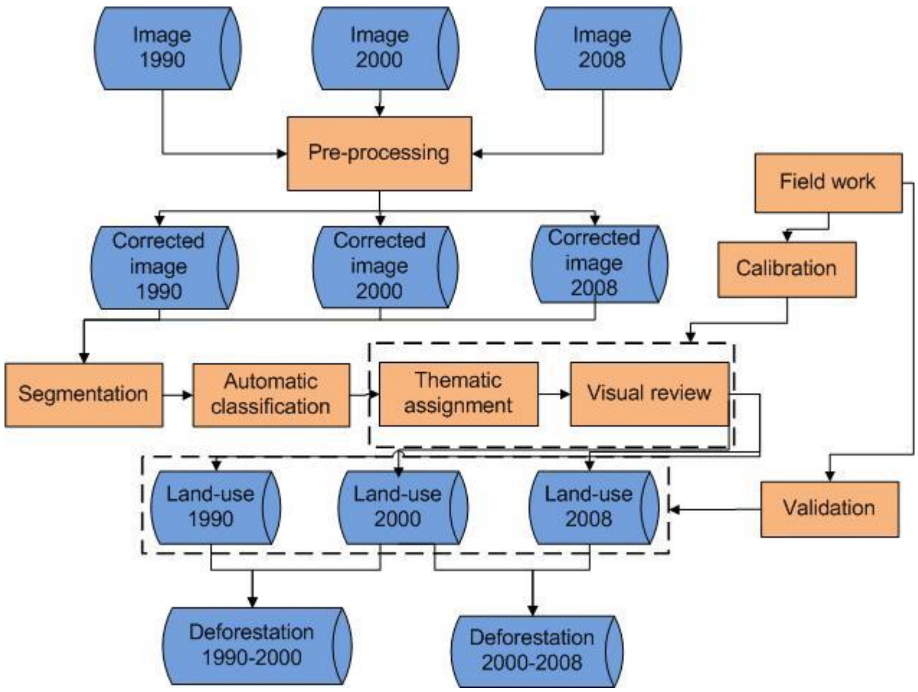
The satellites images for the classification were selected within a time window of up to ±2 years with respect to the 31st of December of the selected reference year[3]. This interval of time was necessary to ensure a minimum cloud cover in the final maps. Areas with persistent cloud cover were visually interpreted and removed as much as possible. In this way it was possible to remove all clouds and shadows obscured areas in the maps created for the reference years 2000/01 and 2008/09 and to reduce at a minimum the area without information in the 1990/91 map.

A hierarchical legend was used to classify the land-use categories: the superior level of the legend corresponds to the 6 land-use categories defined by IPCC (2003): forest land (F), cropland (Cl), grassland (G), wetlands (W), settlements (S) and other lands (O). The lower levels of the legend, were defined considering the feasibility of detecting the different sub-categories through medium spatial resolution remote sensing imagery, and stratification using ancillary data (MPFT)

Figure 6 shows the general process proposed to obtain land coverage maps and calculate deforestation.

[3] Due to the permanent cloudiness in some zones of the country, particularly in the western slope of the Andes and the Choco region (Esmeraldas province), more than 4 images have been used in order to fill information gaps by cloud coverage. Because of the same reason, and since the standardization of images at more detailed scales gets hampered, no normalization process was carried out.

Figure 6. *Methodological scheme for characterizing land cover change maps*



Blue colored objects represent spatial data. Orange colored objects represent methodological processes.

Pre-Processing

Pre-processing of the remotely sensed data included the ortho-rectification of the images. In the period 1990 – 2000 no radiometric correction process was carried out because of the following reasons:

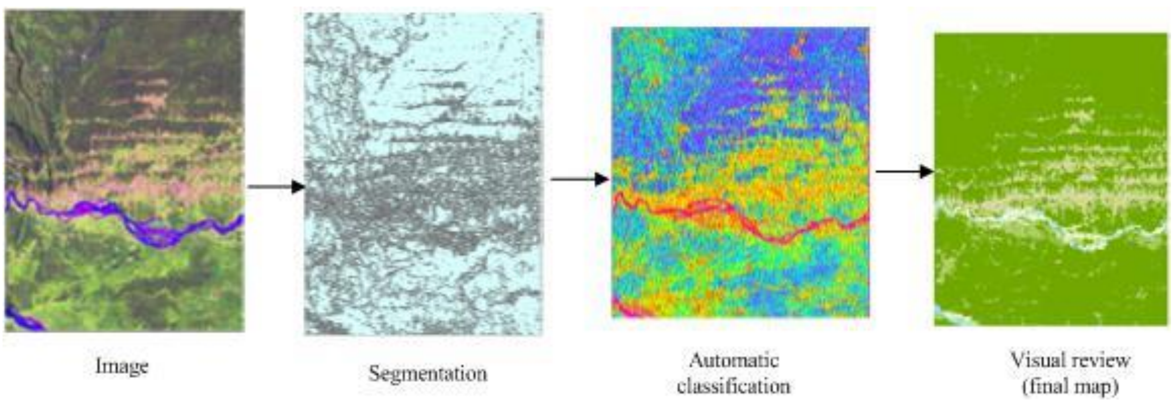
- A post-classification method for land cover change detection is being applied. In this method, the images for each year are individually classified and the land cover change in forest areas is determined by comparing the resulting land use change and cover maps. This change detection process does not require the absolute nor the relative correction of the images since the atmosphere effect is incorporated within the classification procedure of each satellite image.
- The absolute or relative correction of the images requires a complex set of procedures. Some alternatives require a subjective estimation of certain parameters (eg. definition of dark objects), hardly available information or data with a high degree of uncertainty (eg. atmospheric parameters).

The radiometric correction process is implemented for the 2008 period in order to cover areas with information gaps. The relative radiometric normalization process was developed with the purpose of generating Landsat 7 SLC-OFF mosaics. A relative calibration strategy of two images, which is based in a linear transformation between bands that maximizes the change and minimizes correlation, was implemented.

Land use and cover change detection and classification process

The classification in land-use categories was independently made for each of the selected years and the detection of land-use changes was made by comparing the results of the land-use maps generated through classification of remotely sensed data. **Figure 7** shows the image classification process followed in order to obtain the map for each reference year.

Figure 7. *Image classification process scheme*



The classification was carried out as an iterative process where the first step consists on generating a preliminary classification. Simultaneously, field information is gathered and is subsequently used as a reference in order to fine-tune the preliminary classification and allow the interpreter to become familiar with the landscape.

The classification of the satellite images included manual and automatic procedures. Images were individually segmented, this procedure was used to define spectrally homogenous regions (polygons) inside the images and these groups of polygons were then classified according to their spectral classes using a non-supervised classification algorithm.

The spectral classes were assigned to the thematic categories of the map-legend, except for the forest categories, which were classified in IPCC categories and then further divided in sub-categories by combining the map of land-use categories with a map of potential forest types (MPFT).

The final edition of the land-use maps involved a visual review and manual corrections to solve problems related with the mixture of spectral classes among the thematic categories. Finally, a mosaic of the segmentation was developed and the consistency of categories was controlled for the whole map.

The independently developed maps were combined in order to obtain change patterns. The methodology for developing a spatially explicit characterization of the land use and cover change patterns is called post-classification change detection. Minimizing the requirements for absolute and/or relative calibration of the images is among the advantages of this methodology. On the other hand, overestimating the changes is a potential risk when applying this methodology; for such reason a visual quality control of the generated transitions was carried out in order to remove potential inconsistencies among different coverages and reduce errors caused by the methodology.

A more detailed description of the methods used to classify the remotely sensed data can be found in the report "*Actualización del protocolo metodológico para la generación del Mapa Histórico de Deforestación del Ecuador Continental*" (MAE, 2014b).

Annex 1 contains figures and attributes table of all maps referred to above.

Conversion of natural forest to forest plantations only happened occasionally in the historical reference period (1% of total natural forest conversion was converted to forest plantations). However, in order to avoid the creation of incentives for the conversion of natural forest to forest plantations, the associated historical emissions have been calculated

Map of Potential Forest Types Generation Process

The Map of Potential Forest Types was developed by applying a methodology that integrates a variety of cartographic inputs in order to generate a Forest Type classification based on its environmental conditions. This methodology is summarized in the following steps:

- Definition and standardization of biotic and abiotic variables in order to define the environmental conditions of the forest types in areas with and without disturbance.
- An analysis unit system was used in order to draw the information generated in the previous step.
- Development of decision trees based on a group of samples gathered from the actual forest types remains in order to predict the potential distributions.
- Integration of the preliminary results.
- Map of Potential Forest Types' review and final edition.

Since the applied methodology depends on the quality of its inputs, as well as on the uncertainty level from the samples gathered to predict the distributions, it is worth mentioning that the accuracy of the results depends on the Map of Forest Types (MAE (a) 2013) which is the main input for the process.

Finally, the results were discussed with the technical team of the Vegetation Map Project from the Ministry of Environment in order to ensure the validity of the results and be able to keep using the tools generated in R language (Ihaka and Gentleman 2013).

Methodological information related to emission factors

Following the GPG on LULUCF of IPCC (2003), where available national data as reported in the national GHG inventory was used.

Biomass carbon stocks in natural forest categories were estimated by using the information produced by the ENF, MAE (2014a).

GHG emissions and removals due to land-use changes are accounted for the year of the land-use transition, assuming immediate oxidation of all biomass, dead wood and litter.

The changes in carbon stocks in the biomass, dead wood and litter pools due to land-use conversions were estimated as the existing carbon stocks.

3.3 Pools, gases and activities included in the FREL

3.3.1 Pools and gases included in the FREL

The following carbon pools and GHG gases are included in Ecuador's proposed FREL:

Carbon pools:

- Aboveground biomass (AGB) of trees (AGB.T) and non-trees[4] (AGN.NT);
- Belowground biomass (BGB) of trees (BGB.T) and non-trees (BGN.NT);
- Dead wood (DW), standing (DW.S), lying (DW.L) and in dead coarse roots (DW.R);
- Litter (L);

Greenhouse gases:

- Carbon dioxide (CO_2);

Only Carbon dioxide (CO_2) has been included in this proposed FREL. The process of slash-and-burn is the most common deforestation practice in Ecuador (Ramsey and Oxley, 2001; ITTO, 2004; Beck *et al*., 2008; UNDOC, 2010). Biomass burning through slash-and-burn results in the emission of the non-CO_2 gases Methane (CH_4) and Nitrous oxide (N_2O). However, insufficient data has been collected on emissions of non-CO_2 gases for inclusion of accurate non-CO_2 emissions in previous reporting in greenhouse gas inventories. To maintain consistency with the scope of reporting in the national GHG inventory and in attendance of more accurate data to be collected, this FREL only includes CO_2 emissions. In order not to omit significant gases, the potential contribution to annual GHG emissions from non-CO_2 gases has been calculated assuming all deforestation to be associated with fire (as a result of slash-and-burn).

This calculation, which can be considered an estimate of the maximum contribution from non-CO_2 gases, resulted in <5% of total annual GHG emissions in tCO_2 eq. However, since fire is associated with deforestation, it is expected that a reduction in deforestation will result in a reduction of fire and thus a reduction in non-CO_2 emissions. For this reason, the exclusion of non-CO_2 gases can be considered conservative.

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4 Incudes trees with a DBH < 10.00 cm and palms.

Box 1. Estimates of non- CO_2 emissions of greenhouse gases

The emission of the non-CO_2 gases Methane (CH_4) and Nitrous oxide (N_2O) has been calculated assuming that all deforestation processes in Ecuador are accompanied by slash-and-burn. The emissions were estimated by applying the equation described in the IPCC Good Practice Guidance for LULUCF (p. 3.49, 2003).

Estimation of GHGs directly released in fires : $L_{fire} = A \times B \times C \times D \times 10^{-6}$

Where:

L_{fire}: quantity of GHG released due to fire, tones of GHG

A: area burnt, ha

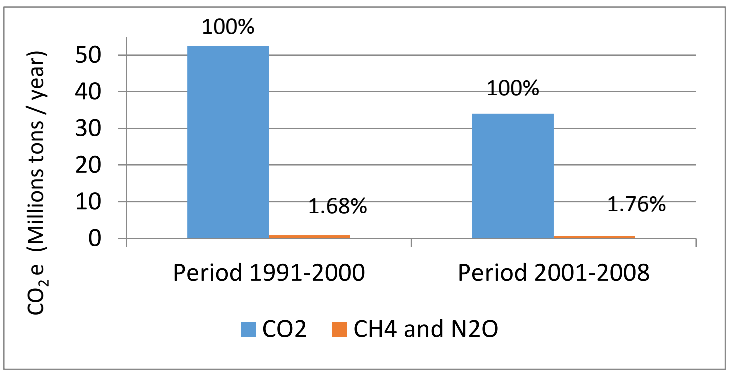
B: mass of available fuel, kg d.m.ha^{-1}

C:combustion efficiency, dimensionless

D: emission factor, g (kg d.m.)$^{-1}$

The values applied for combustion efficiency and emission factors were obtained from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories since they are the most updated available ones. For the conversion of CH_4 and N_2O to CO_2-e, the global warming potential values of 21 and 310 were used.

Figure 8. *Comparison of CO_2 and non CO_2 emissions per year for each period*



As shown in **Figure 8**, the emissions of non CO_2 gases from biomass burning is less than 5% of the CO_2 emissions from deforestation.

Considering that the IPCC Good Practice Guidance for LULUCF indicates that the evidence on the effects of forest types, management practices and other disturbances on soil organic carbon remains largely site and study specific; soil organic carbon (SOC) has been excluded from Ecuador's proposed FREL not due to lack of significance but due to the lack of accurate data for estimating carbon stocks in this pool. Additionally, a step-wise approach has been considered in the construction of Ecuador's proposed forest reference emission level, as per Decision 12/CP.17 paragraph 10. Ecuador recognizes that the inclusion of the SOC pool might be a future improvement for the current FREL and for such reason; country-specific data is currently under development and when available, might be considered for future FREL's submissions. Instead of affecting the completeness of the FREL, the exclusion of the SOC pool results, in Ecuador's view, is a conservative estimation of the FREL since it is reasonable to assume that SOC will behave in the same way as the biomass pool in natural forests.

Regarding organic soil/peatlands in Ecuador, peatlands under Ecuador's forest definition, they are mainly found in the Amazon region under the classification 'Moretales'. However, according to historic deforestation data, these areas are not under pressure of deforestation.

3.3.2 REDD+ activities included in the FREL

Considering the significant contribution of land-use change to national CO_2 anthropogenic emissions, as well as the availability and accuracy of the data for estimating national GHG emissions in the LULUCF sector, Ecuador decided to construct its FREL for *Reducing emissions from Deforestation* only, considering historical average deforestation for the period 2000-2008 in the context of seeking and obtaining REDD+ results-based payments. Other activities referred to in Decision 1/CP.16, including *reducing emissions from forest degradation*[5], *conservation of forest carbon stocks*, *sustainable forest management* and *enhancement of forest carbon stocks* have not been included at this time due to the current lack of available information in Ecuador[6], however they may be included in the future when information becomes available, under a stepwise approach, pursuant paragraph II.10 of Decision 12/CP.17.

In the context of this FREL, and national forest loss monitoring, deforestation is defined as the conversion of forest land to non-forest land with the exception of conversions of natural forests to natural wetlands (Wn). Conversions of natural forest to natural wetlands has been excluded from the FREL, since in Ecuador's case, this type of transition is due to natural movements of the riverbeds in naturally forested area (mostly in the Amazon region) and are not anthropogenic.

Conversions of natural forests (FN) to forest plantations (FP) are monitored by the MAE; if this happens, the full carbon contents in the converted natural forest would be deducted from the estimation of emission reductions in the context of REDD+ results-based payments, in accordance to Appendix I to Decision 1/CP.16.

The choice to include or exclude certain types of categories of land-use change in the FREL may change in future submissions of a FREL, in accordance to national circumstances as deemed appropriate. However, in order to ensure consistency as per paragraph 8 in Decision 12/CP.17, Ecuador will ensure methodological consistency of emission reductions in the context of this FREL – or future FRELs – with reports on national GHG emission reductions.

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[5] Currently, Ecuador does not have a definition for forest degradation. For such reason, the information gathering and quantification processes for forest degradation have not yet started.

[6] Data regarding reduced canopy cover areas in Ecuador are available at FAO. Data comes from a global level estimation and have not been assessed by Ecuador, for such reason these data is not included in the present document.

3.4 Definition of forest used in the construction of the FREL

A national forest definition was adopted (http://cdm.unfccc.int/DNA/index.html) in the context of identifying forest land in Ecuador's land-use maps. According to this definition all land units bearing "a single minimum tree crown cover value of 30%; a single minimum land area value of 1.00 hectare; and, a single minimum tree height value of 5.00 meters" are considered as forest.

This definition is consistent with ministerial agreement number 033 of April the 5th, 2013 (MAE, 2013b) and with the definition of forest land used in the national greenhouse gas inventory.

This definition differs from the definition applied by FAO's Global Forest Resources Assessment (FRA 2010) which applies a minimum tree cover of 10%. The 10% cover threshold is considered very low for Ecuador's natural vegetation and would include vegetation types which according to Ecuadorian standards would be considered other wooded land.

3.5 Areas for future improvements

Forest Cover Monitoring

The methodology has specific procedures for documentation and information management in order to ease the external validation process. Additionally, a robust strategy for generating quantitative uncertainty estimates is under consideration. However; this methodological proposal should be seen as an on-going process which allows for continuous improvements. In this context, the following potential improvements have been identified:

- To assess the applicability of relative radiometric calibration procedures between images from different years, in order to improve the thematic coherence of the land use and cover change maps
- To assess different options in order to improve the results obtained by satellite image automatic classification procedures. The current methodology considers only average spectral values for each segment in the clustering process. However; segmentation would allow including other variables (eg. dispersion of spectral values, texture) which could potentially improve the discrimination process among the different classes of the thematic legend.
- It has been suggested that the direct classification of changes in multi-temporal composite images allows for a better representation of deforestation patterns (GOFC-GOLD 2009). Preliminary tests suggest that this methodology has major challenges, especially in areas with land cover complex mosaics. However; this methodology could work in areas with homogeneous environmental conditions (eg. Amazon). The identified alternative is to carry out tests in different regions of the country in order to determine whether the direct classification of changes is suitable for the country conditions or not.
- It is necessary to assess strategies in order to improve spatial and temporal coverage of the data used to characterize deforestation and, potentially, degradation. The coverage problems are especially acute in areas with continuous presence of clouds (eg. Northwest region of the country) or in ecosystems with considerable phonological variations (eg. Manabí and Loja).
- Regarding the accuracy assessment, a methodology that does not only evaluate the maps in an independent manner, but also the land cover change accuracy –especially deforestation- should be implemented. An alternative might be to apply the methodology presented in the

study Good practices for estimating area and assessing accuracy and land change (P Olofsson, et al.).

- Ecuador is currently analyzing the definition of degradation in order to start with the methodological design for its detection and monitoring; so the estimations could be included in the constructions of future FREL submissions, once the uncertainty levels suggested by the IPCC have been reached, in the context of results based payments for *Reducing Emissions from forest Degradation*.

National Forest Inventory

- The National Forest Inventory will start its second phase by gathering additional information in new plot clusters in order to improve the uncertainty levels in the different pools.
- The estimates for the soil pool will be incorporated once the analysis procedure and estimation of the associated errors have been completed.

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Annex 1: Methods used for estimating activity data

In the following a detailed description of the methods used to extract information on activity data from the three land-use maps referred to above and other sources of information is provided.

1.1 Construction of maps of land-use change

Activity data for the construction of Ecuador's FREL were extracted from land-use change maps created for the period 1990-2000 and 2000-2008 (named and MLUX2000_2008 respectively, in Ecuador's geodatabase).

For the construction of land-use change maps the following maps were used:

MLUCa_1990:	Map of land-use categories as produced by the Ministry of Environment of Ecuador (MAE) for year 1990 (see **Figure 9** and **Table 7**);
MLUCa_2000:	Map of land-use categories as produced by the MAE for year 2000 (see **Figure 10** and **Table 8**);
MLUCa_2008:	Map of land-use categories as produced by the MAE for year 2008 (see **Figure 11** and **Table 9**);
MPFT:	Map of potential forest types as produced by MAE (see **Figure 12** and **Table 10**);

These maps were used with the WGS 1984 UTM Zone 17S spatial reference and spatially aligned as presented below:

Top	10,163,536.35
Left	490,613.41
Right	1,147,853.41
Bottom	9,445,216.35

All the maps have a spatial resolution of 30.00 x 30.00 meters and were combined in raster format to create maps with more information on the different land-use categories.

The addition of information on forest type from the MFT map to the land-use category "natural forest" (= forest land) in the MLUCa maps was necessary because the national forest inventory (ENF) used the MPFT map to stratify the forest and estimate carbon stocks for each of the forest strata.

The maps with added information on land-use categories (MLUC1990_91, MLUC2000_01, and MLUC2008_09) were then further combined to generate the land-use change maps (MLUX1990_2000 and MLUX2000_2008) from which information on activity data, where the estimated activity data are combined with emission factors to calculate Ecuador's FREL.

It is worth noting that the only map that presented areas obscured by clouds and shadows (= areas without information) was the 1990 map (MLUCa_1990).

The maps of land-use categories containing the information added from the map of potential forest types (MPFT),

The maps of land-use change for the periods 1990-2000 (MLUX1990_2000) and 2000-2008 (MLUX2000_2008) are shown in **Figure 13** and **Figure 2** and their attributes in **Table 11** and **Table 2** respectively.

A spreadsheet called <MAPS.xlsx> showing the relationship between the categories of all maps used and created for the estimation of activity data has been available for download through the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*.

1.2 Figures and attributes tables of the maps used to estimate activity data

Maps used and constructed for the estimation of activity data, with their corresponding attribute tables, are given. All these maps are available for download through the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*.

Figure 9. *Map of land-use categories as produced by the MAE for year 1990 (MLUCa_1990).*

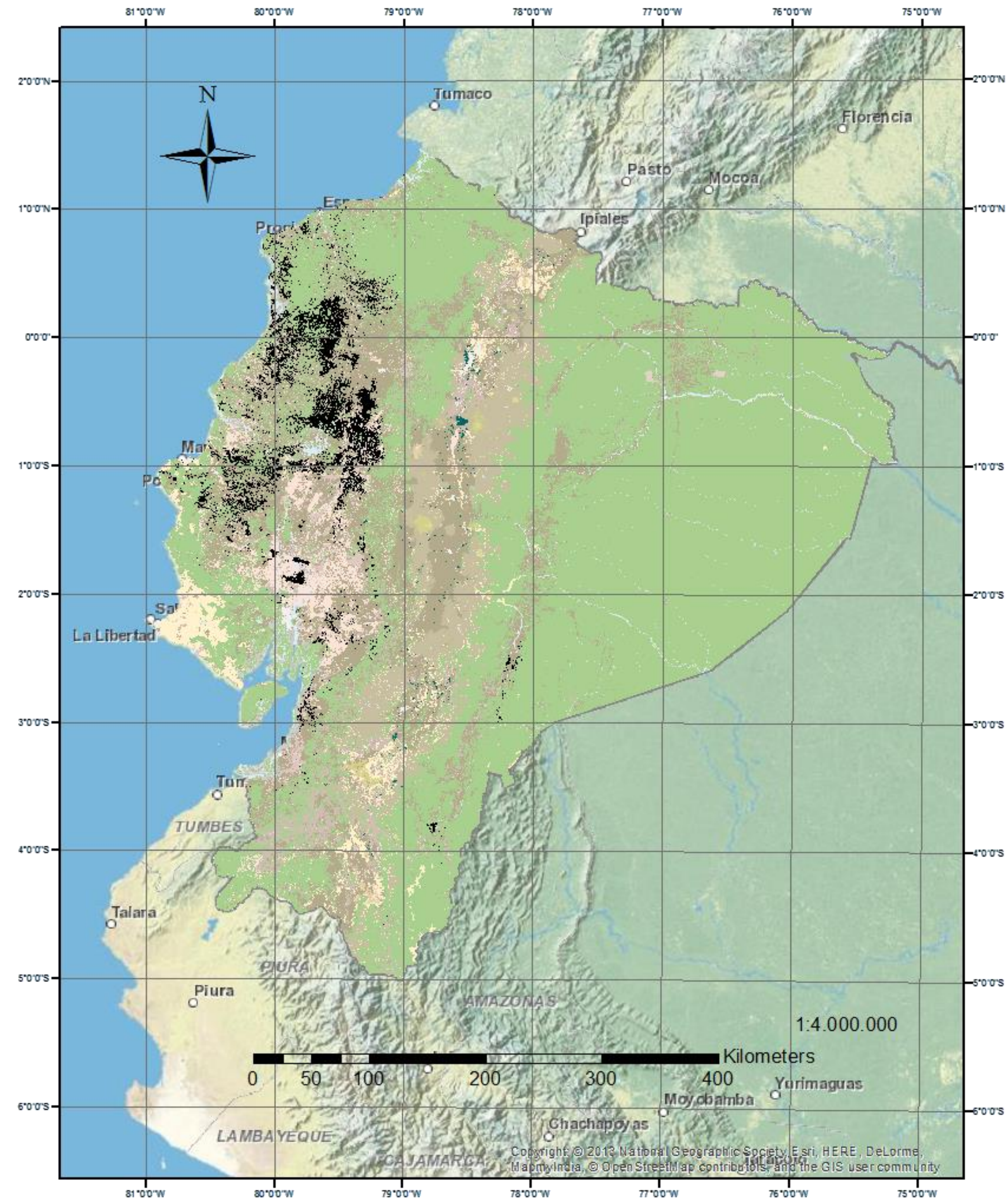


Table 7. *Attributes table of MLUCa_1990.*

Legend	MLUCa_1990 Categories	Corresponding IPCC Tier1 Categories		Area
		ID	Description	ha
	Annual crop	2	Cropland	718,899.03
	Artificial wetland	4	Wetland	138,041.19
	Bare soil	6	Other Land	99,338.94
	Farming mosaic	2	Cropland	4,398,854.76
	Glacier	6	Other Land	11,430.81
	Infrastructure	5	Settlements	1,209.42
	Natural Forest	1	Forest Land	14,587,770.60
	Natural grassland	3	Grassland	108,028.35
	Natural wetland	4	Wetland	350,879.76
	No Information	7	No Information (Clouds and shadows)	797,971.50
	Paramo	3	Grassland	1,566,273.06
	Pasture	2	Cropland	1,092,681.81
	Permanent crop	2	Cropland	35,592.21
	Semi-permanent crop	2	Cropland	151,648.74
	Shrubland	3	Grassland	732,028.59
	Forest plantation	1	Forest Land	44,443.08
	Urban area	5	Settlements	62,968.05
			Total area of Ecuador	24,898,059.90

Figure 10. *Map of land-use categories as produced by the MAE for year 2000 (MLUCa_2000).*

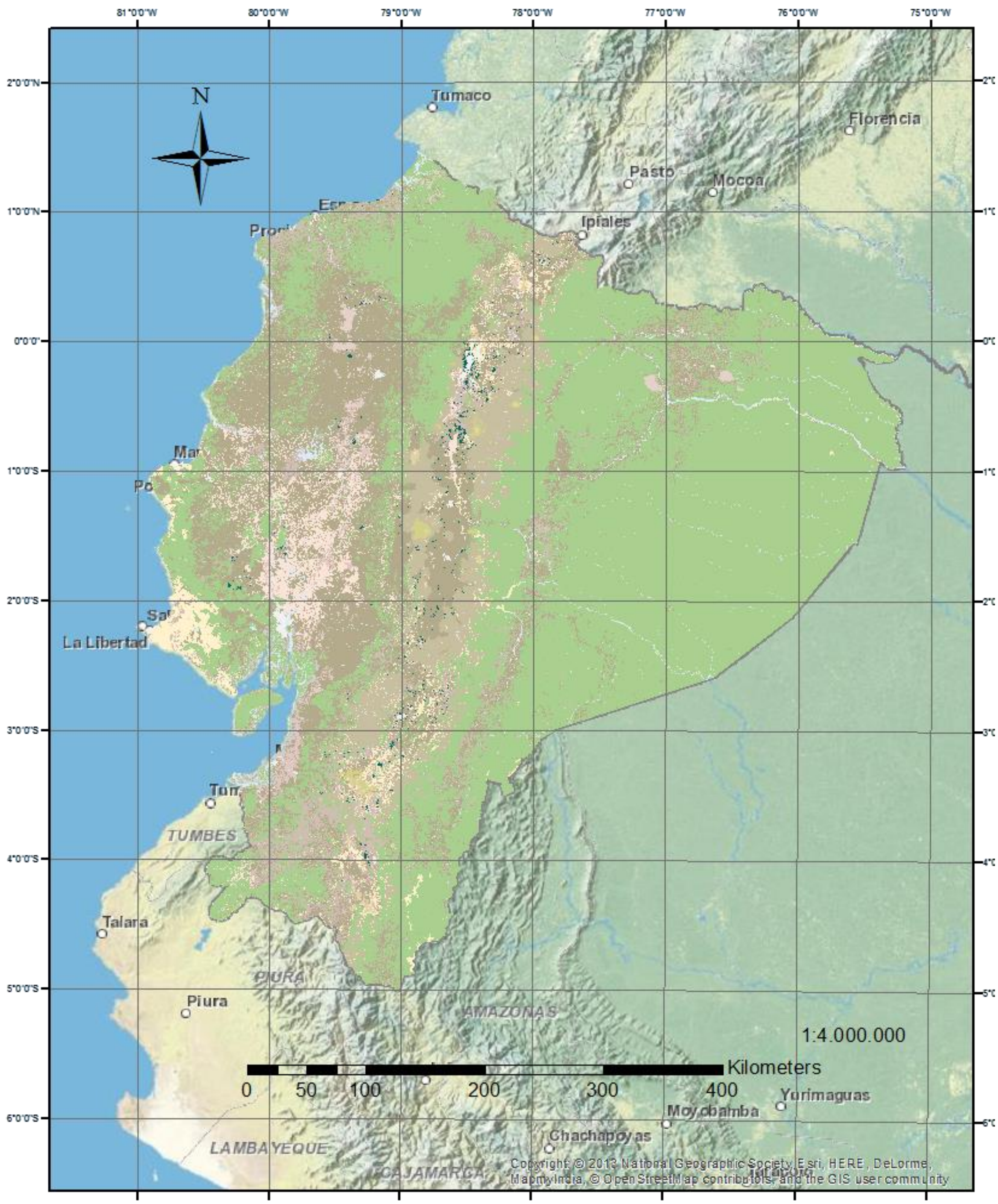


Table 8. *Attributes table of MLUCa_2000.*

Legend	MLUCa_2000 Categories	Corresponding IPCC Tier1 Categories		Area
		ID	Description	ha
	Annual crop	2	Cropland	703,538.73
	Artificial wetland	4	Wetland	124,602.57
	Bare soil	6	Other Land	112,681.71
	Farming mosaic	2	Cropland	5,844,287.97
	Glacier	6	Other Land	7,972.65
	Infrastructure	5	Settlements	5,524.20
	Natural Forest	1	Forest Land	13,660,353.63
	Natural grassland	3	Grassland	126,308.25
	Natural wetland	4	Wetland	351,094.59
	No Information	7	No Information (Clouds and shadows)	0.00
	Paramo	3	Grassland	1,535,575.23
	Pasture	2	Cropland	1,279,028.52
	Permanent crop	2	Cropland	114,303.24
	Semi-permanent crop	2	Cropland	218,204.19
	Shrubland	3	Grassland	634,572.81
	Forest plantation	1	Forest Land	70,150.23
	Urban area	5	Settlements	109,861.38
			Total area of Ecuador	24,898,059.90

Figure 11. *Map of land-use categories as produced by the MAE for year 2008 (MLUCa_2008).*

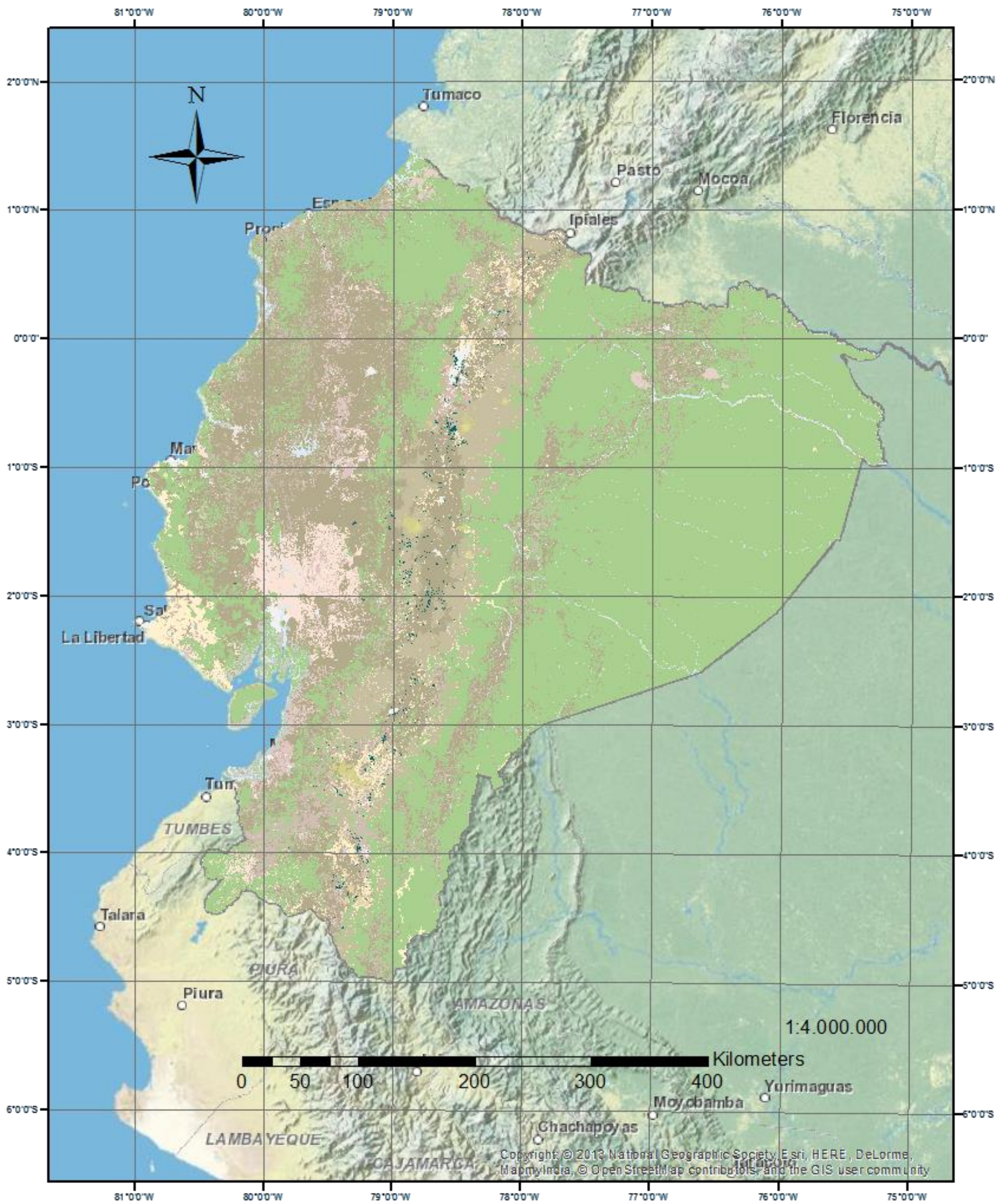


Table 9. *Attributes table of MLUCa_2008.*

Legend	MLUCa_2008 Categories	Corresponding IPCC Tier1 Categories		Area
		ID	Description	ha
	Annual crop	2	Cropland	611,941.95
	Artificial wetland	4	Wetland	157,677.57
	Bare soil	6	Other Land	109,686.69
	Farming mosaic	2	Cropland	6,337,045.35
	Glacier	6	Other Land	9,968.49
	Infrastructure	5	Settlements	11,615.85
	Natural Forest	1	Forest Land	13,038,367.32
	Natural grassland	3	Grassland	109,528.02
	Natural wetland	4	Wetland	348,472.62
	No Information	7	No Information (Clouds and shadows)	0.00
	Paramo	3	Grassland	1,465,935.84
	Pasture	2	Cropland	1,454,890.32
	Permanent crop	2	Cropland	167,305.59
	Semi-permanent crop	2	Cropland	260,389.08
	Shrubland	3	Grassland	587,499.84
	Forest plantation	1	Forest Land	62,196.93
	Urban area	5	Settlements	165,538.44
			Total area of Ecuador	24,898,059.90

Figure 12. *Map of potential forest types as produced by the MAE (MPFT).*

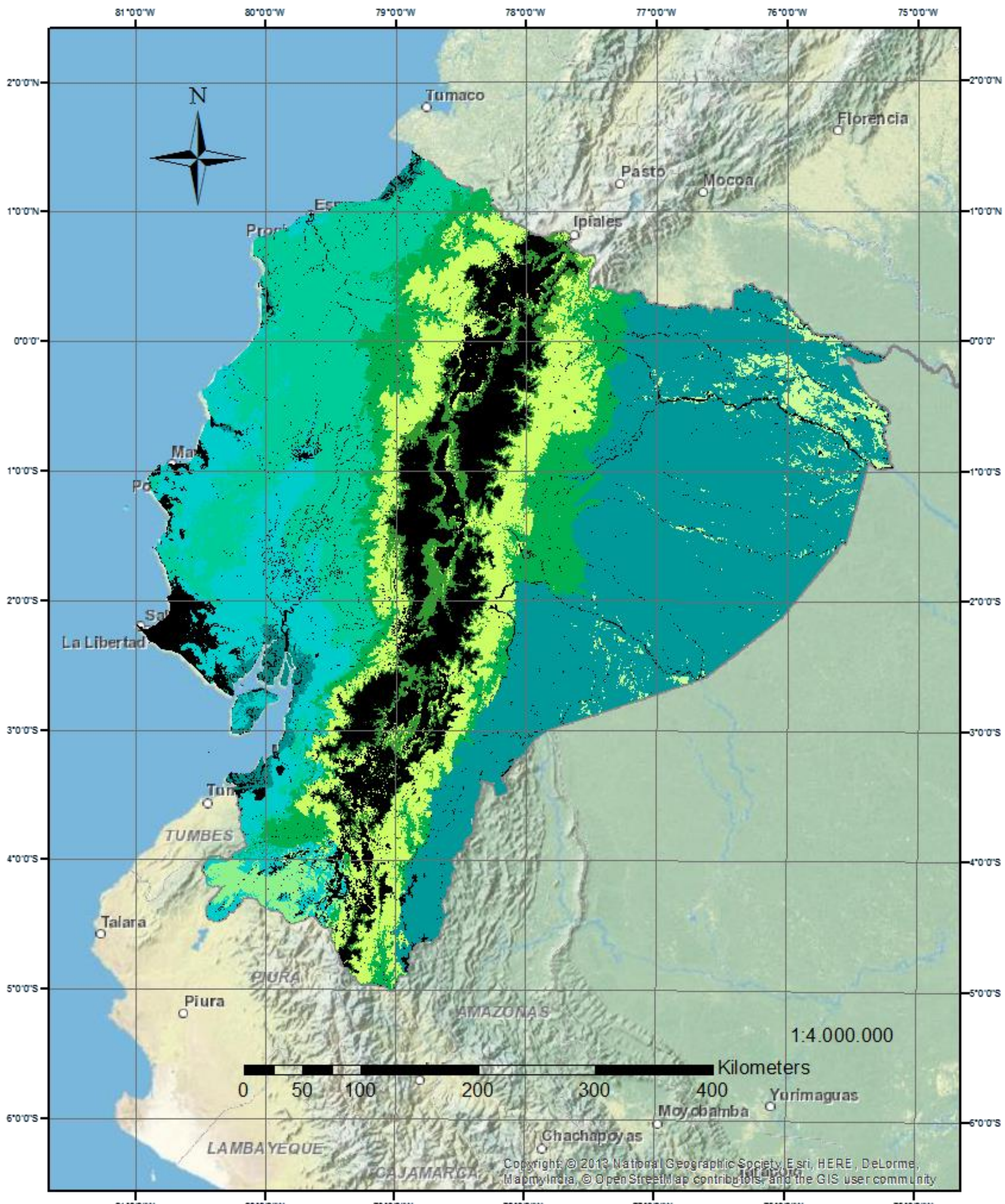
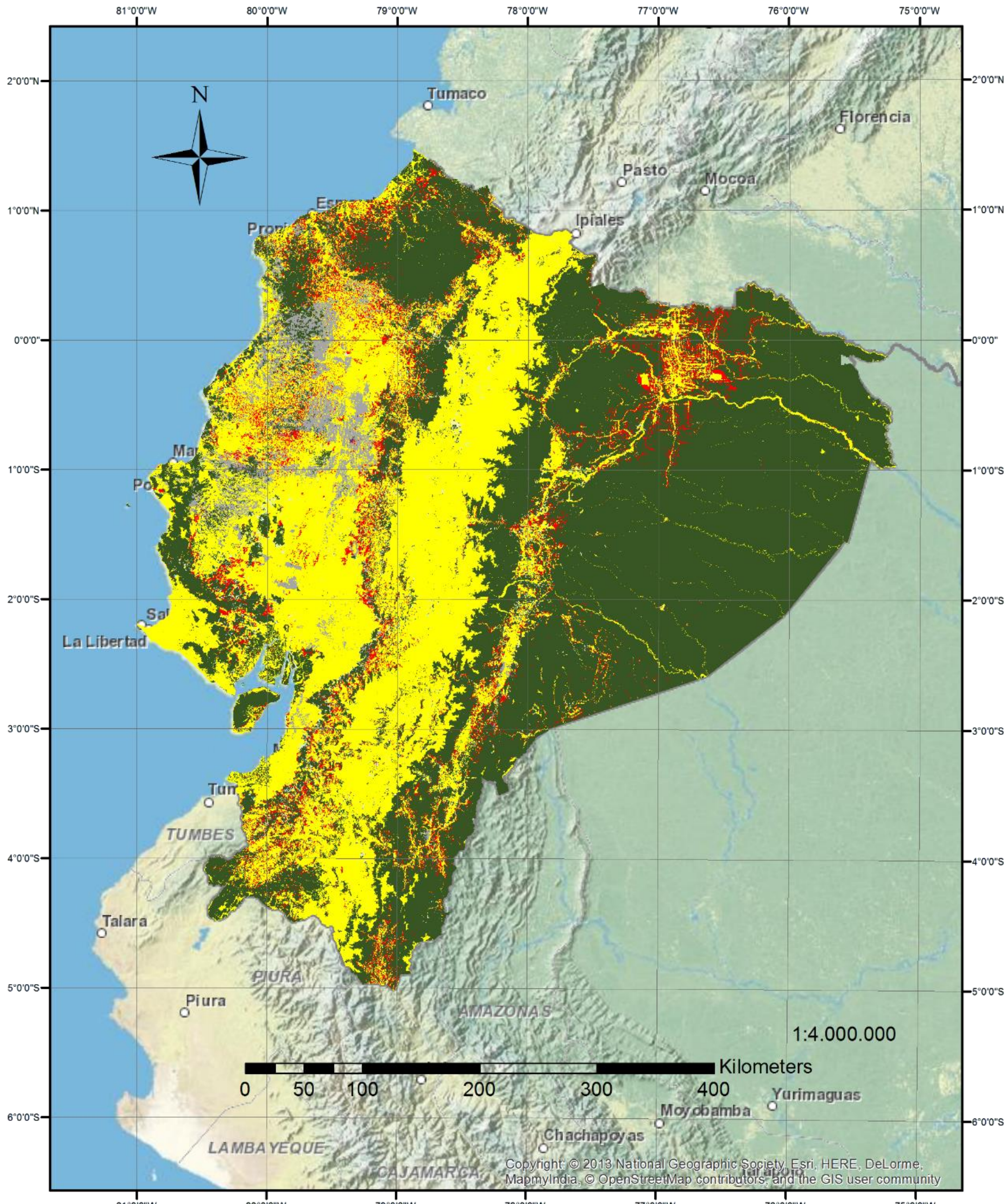


Table 10. *Attributes table of MPFT.*

Legend	Description	Area (ha)
	Dry Andean Forest	294,231.78
	Pluviseasonal Dry Forest	2,333,894.22
	Andean Montane Evergreen Forest	3,037,782.15
	Andean Foothills Evergreen Forest	1,143,827.01
	Andean High Mountain Evergreen Forest	2,385,082.89
	Amazon Lowland Evergreen Forest	7,557,112.62
	Choco Lowland Evergreen Forest	3,672,836.55
	Mangrove	325,821.06
	Morete Palms Forest	445,750.38
	Dry Andean Forest	3,701,721.24
	Total area of Ecuador	24,898,059.90

Figure 13. *Map of land-use change for the period 1990-2000 (MLUX1990_2000).*



Note: The map of land-use change for the period 1990-2000 (MLUX1990_2000) has many more land-use change transitions than shown here. For space reasons only the most relevant land-use conversions are illustrated in this figure. The map that has been made available for download through the website *http://suia.ambiente.gob.ec/en/web/suia/anexos-nivel-de-referencia* contains data on all land-use transitions, and the corresponding activity, which can be downloaded from the same website.

Table 11. *Attributes table of MLUX1990_2000.*

Legend	Land-use change category	Area
	Description	ha
	Deforestation as defined for Ecuador's FREL*	1,299,430.98
	Forest Land converted to natural Wetland (not included in the FREL)	0.00
	Forest Land remaining Forest Land	13,313,190.24
	Forest Plantations converted to Natural Forests	0.00
	Forest Plantations converted to Non Forest Land	19,592.46
	No Information converted to Forest Land (Forest Plantations)	1,395.36
	No Information converted to Non-Forest Land	796,576.14
	Non-Forest land converted to Forest Land	412,460.28
	Non-Forest land remaining Non-Forest Land	9,055,414.44
	Total area of Ecuador	24,898,059.90

* Includes conversion of natural forests to forest plantations.

Annex 2. Methods used to estimate emission factors

2.1 Definitions

2.1.1 Emission factors

With conversion of forest to other land use a 100% loss of carbon in biomass, deadwood and litter is assumed as suggested by IPCC

2.1.2 Deforestation

For the purpose of the construction of Ecuador's FREL for the national level, deforestation is defined as the anthropogenic conversion of natural forests to other land-use categories, and excluding the conversion of natural forests to natural wetlands (because these conversions are not anthropogenic).

2.1.3 Conservativeness in the context of the construction of a FREL

Immediate oxidation of all organic matter is considered as a default conservative assumption according to the approach followed in the calculation of the Greenhouse Gas Inventory.

2.2 Methodological choices

2.2.1 Biomass gains and losses

Pre-deforestation carbon stocks

An important portion of the total carbon stocks will be emitted in the year of the deforestation event, as a result of the slash-and-burn activities that affect part of the total aboveground living biomass (trees and non-trees), total deadwood (standing, lying and belowground), and litter existing in the forest strata.

In the case of Ecuador, an immediate oxidation approach has been used whereas the information used for the construction of this FREL, is what has been obtained through the *Proyecto Evaluación Nacional Forestal*, *Mapa Histórico de Deforestación* and *Mapa de Vegetación* and taking into account that this information and it has not been used is will incorporate a future in a stepwise approach, and to improve the information provided.

2.2.2 Linkage with the national forest inventory

The definition of emission factors was based on the results reported by the national forest inventory of Ecuador -ENF- (MAE, 2014a). The results in terms of average carbon content per hectare for each carbon pool in each category, as reported by ENF, are referred to a combination of mature and secondary forest age-classes, and were used in the compilation of Ecuador's FREL, as the basis for the estimation of average carbon contents in early successional stages of each category, which were not reported by ENF.

2.3 Estimation of carbon stocks

Average carbon stocks were estimated for each land-use category as to determine emission factors correspondent to each land-use change. For that purpose the different age-classes found in each forest category were analyzed to determine the respective conservative average carbon stock values.

2.3.1 Biomass and Carbon estimation procedures in the different forest components.

Biomass for living standing trees was calculated by applying different methods, the obtained results were compared and the most suitable method was selected. The volumetric method uses a specific density for each species, an average for the genus, an average for the family and, a weighted average for the subjects that were not identified.

Moreover, Chave et al. (2005) classification of forests was used in order to assign the equations to data per stratum. The allometric equations were selected by matching them with the climatic charecteristics of each forest type (stratum) as considered by the ENF (**Table 12**).

Table 12. *Allometric equations used to estimate above-ground biomass in living trees per stratum.*

Stratum INF	Environmental Characteristics (height/ precipitation)	Forest type Chave et al. 2005	Equation*
Dry Andean Forest	800-2600 msnm / < 1500 mm	Dry Forest (1200-1700 mm precipitation and more than 5 dry months)	Biomass=(ρ*exp(-0.667+(1,784*ln(dbh))+(0.207*(ln(dbh))^2)-0.0281*(ln(dbh))^3))
Pluviseasonal Dry Forest	0-700 msnm / < 1600 mm	Dry Forest (1200-1700 mm precipitation and more than 5 dry months)	Biomass=(ρ*exp(-0.667+(1.784*ln(dbh))+(0.207*(ln(dbh))^2)-0.0281*(ln(dbh))^3))
Andean Montane Evergreen Forest	1300-1800 msnm / promedio 2450 mm	Moist Forest (1800-6000 mm precipitation with 1 to 5 dry months)	Biomass=(ρ*exp(-1.499+(2.148*ln(dbh))+(0.207*(ln(dbh))^2)-0.0281*(ln(dbh))^3))
Andean Foothills Evergreen Forest	300–1500 msnm / promedio 3406 mm	Wet Forest (2335 - 3936 mm precipitation and no dry months	Biomass=(ρ*exp(-1.239+(1.98*ln(dbh))+(0.207*(ln(dbh)) ^2)-0.0281*(ln(dbh))^3))
Andean High Mountain Evergreen Forest	1500–4000 msnm / > 2500 mm	Moist Forest (1800-6000 mm precipitation with 1 to 5 dry months)	Biomass=(ρ*exp(-1.499+(2.148*ln(dbh))+(0.207*(ln(dbh))^2)-0.0281*(ln(dbh))^3))
Amazon Lowland Evergreen Forest	150-1300 msnm / promedio 2835 mm	Moist Forest (1800-6000 mm precipitation with 1 to 5 dry months)	Biomass=(ρ*exp(-1.499+(2.148*ln(dbh))+(0.207*(ln(dbh))^2)-0.0281*(ln(dbh))^3))
Choco Lowland Evergreen Forest	0-300 msnm / >3500 mm	Moist Forest (1800-6000 mm precipitation with 1 to 5 dry months)	Biomass=(ρ*exp(-1.499+(2.148*ln(dbh))+(0.207*(ln(dbh))^2)-0.0281*(ln(dbh))^3))
Mangrove	0-20 msnm	Mangrove Forest (1800 – 3200 mm precipitation)	Biomass=(ρ*exp(-1.349+(1.98*ln(dbh))+(0.207*(ln(dbh))^2)-0.0281*(ln(dbh))^3))
Morete Palms Forest	40-300 msnm / >3500 mm	Wet Forest (2335 - 3936 mm precipitation and no dry months)	Biomass=(ρ*exp(-1.239+(1.98*ln(dbh))+(0.207*(ln(dbh))^2)-0.0281*(ln(dbh))^3))

For more information, please refer to the file MAE, 2014a. *Evaluación Nacional Forestal – Resultados*. Available for download through the website http://suia.ambiente.gob.ec/en/anexos-nivel-referencia

Carbon estimation in biomass of living tres with a DBH greater than 10 cm, required the variables DBH (in cm) and wood specific density (**ρ**, en g cm^{-3}).

Wood density (**ρ**) was obtained from the FAO wood density global database (Zanne et al. 2009). The density value was assigned to each individual according to its species. For subjects whose species was not found in FAO database, the average genus or family **ρ** value was applied. For subjects whose species, genus or family were not found in the database, the weighted average (0.52 g cm^{-3}) of all the species in the INF was used.

For the above ground biomass estimation in palms , Goodman et al. (2013) equations were applied, one equation for the family and six genus specific equations (**Table 13**).

Table 13. *Above ground biomass equations in palms per genus*

Genus	Equation
Astrocaryum	AGB= 21.302*Hc
Attalea	Ln(AGB)= 3.2579+1.1249*Ln(Hc+1)
Euterpe	AGB= -108.81+13.598*Hc
Iriartea	Ln(AGB)= -3.483+0.94371*Ln(dap2*Hc)
Mauritia	Ln(AGB)= 2.4647+1.3777*Ln(Hc)
Mauritiella	AGB= 2.8662*Hc
Oenocarpus	Ln(AGB)=4.5496+0.1387*Hc

Above ground biomass for the Arecaceae Family (palms):

Ln (AGB)= -3.3488+2.7483*Ln(dbh)

Biomass in palm roots:

Ln (BGB)= -0.3688+2.0106*Ln(Hc)

For the dry biomass estimation in standing dead trees, Chave et al. (2005) allometric equations were applied according to stratum and assuming that all of the standing dead trees were in a decomposition state. Because of this assumption, a discount was applied by dividing the dead trees in: dead with branches without leaves and dead without branches. According to Brown et al. (1992) and Saldarriaga et al. (1988) (as cited in Sarmiento et al., 2005) the biomass percentage in branches and leaves ranges from the 25% to the 50% of the total in Amazon forests; for this reason a 25 % discount was applied to the dead trees with branches and a 50% discount was applied to the dead trees without branches. The average wood density value is 0.52 g cm^{-3} (average value for no identified species).

Lying dead wood refers to remains of stem or branches on the soil with a DBH ≥ 10 cm. The sampling design uses the line intersection scheme (Böhl and Brändli, 2000 cited by MAE, 2012). For the biomass carbon estimation; diameter, length of lying trees and location within the sampling plot were taken into account (MAE, 2012). With those values, and by applying Brown and Roussopoulos (1974) equation, volume was calculated. Biomass values were obtained by multiplying the volume with the average value for wood density (0.52 g cm^{-3}); finally the obtained values were expanded to a hectare.

It was assumed that all of the lying wood was in a decomposition state; for such reason a 0.9 discount factor was applied to solid wood, 0.5 to wood in an advanced decomposition state and 0.15 to easily broken wood (MAE, 2012); according to what is stated in the methodologies for CDM projects (MDL AR-TOOL12) based on Harmon and Sexton (1996).

Stumps are remains of logging that were also accounted for within the plots. Diameter and height were measured in field (MAE, 2012); whereas the stump biomass was calculated by applying a volumetric equation since Chave et al. equations are not designed for estimating stump biomass. To the volumetric equation, a form factor of 1 was applied, assuming that the stump was a perfect cylinder.

Litter and detritus refers to all of the organic matter lying on the soil with a diameter less than 10 cm and greater than 2 mm (leaves, stems, flowers, fruits, dead grass, bark); including organic matter in the soil organic horizon which is found above the mineral horizon (greater than 2 mm) (MAE, 2012). Fresh weight was measured in field, and 0.5 kg samples were taken from each plot and were later sent to the lab in order to estimate the dry weight of biomass.

The understory biomass that was considered as natural regeneration from all of the young trees with a height greater than 30 cm and a DBH < 10 cm (MAE 2012), was estimated from the total amount of the nested plot biomass, whose fresh weight was measured in field; whereas the dry weight was estimated from 1 kg samples that were taken from each plot and were later sent to the lab.

Biomass from roots of living and dead subjects and of stumps (which are considered as living trees in this study) were estimated by multiplying the above ground biomass (obtained by applying the equations from Chave et al., 2005) with a factor of 0.24 (Cairns et al. 1997) for tropical forests. Detailed information may be found in the file MAE, 2014a. *Evaluación Nacional Forestal – Resultados*. Available for download through the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*

The mathematical formulas that were used for the lying wood, dead wood, stumps, litter, understory and roots volume and biomass calculation may be seen in **BOX 2**.

Box 2. Uncertainty in dead wood and expected improvements

Dead fallen wood are remains or pieces of wood on the forest floor with DBH ≥ 10 cm. To collect information on dead fallen wood, a sampling design was used of intersecting lines as proposed by Bohl and Brändli 2000 (MAE 2012). For the National Forest Inventory (ENF), measurements were collected in the first 30 m strip of the 60 m x 60m measurement plot. To estimate the carbon in the biomass, in field measurements were taken of diameter and length of the fallen log within the sample plots (MAE, 2012). Volume was estimated applying the equation proposed by Brown and Roussopoulos (1974) to the parameters measured for each log. Biomass was calculated by multiplying with the average value of wood density for all species (0.52 g cm^{-3}). Dead wood biomass was obtained with the equation for calculating the volume of dead wood *(Formulas may be seen below)**. Values were expanded to per hectare estimates.

Formulas applied to calculate volume and biomass in the different components of the ecosistem:

Lying Wood Volume: $V = \frac{\pi^2 \sum_d 2}{8l}$

Where:

V: volume (m^3 m^{-2})

d: diameter (m)

l: horizontal length of the sample plot (m)

Lying Dead Wood Biomass: $B = V * frd * p$

Where:

B: biomass (kg)

V: lying dead wood volume

frd: wood density reduction factor

p: wood density

Biomass from stumps: $B = \left(\frac{\pi}{4}\right) * ([dap] * 0.001)^2 * [H] * p * Fft$

Where:

B: biomass (kg)

dap: stump diameter (m)

H: stump height (m)

Fft: total height form factor (1)

p: densidad de madera (0,52 gm cm^{-3})

Litter Biomass: $$B = ps * \left(\frac{pf}{psl}\right)$$

Where:

B: biomass (kg)

ps: dry matter weight of the sub-sample (kg)

pf: wet matter weight total of the sample (kg)

psl: wet matter weight of the sub-sample

Roots Biomass: $$Braices = Ba * (fer)$$

Where:

Braices: roots biomass (kg)

Ba: aboveground dry biomass per tree according to Chave *et al* (2005) allometric equation (kg)

fer: aboveground biomass - roots biomass relation factor (0.24 for all species)

It was assumed that all the fallen wood is decaying, so that a discount factor (or density reduction factor) of 0.9 is applied to all wood in solid state, a factor of 0.5 is applied to non-solid wood, i.e. wood at an advanced stage of decomposition, and a factor of 0.15 is applied for decomposed material of which the wood was easily taken apart (MAE 2012). Discussions with local experts were held to apply the above factors to the correct state of decomposition, guided by the methodological tool for CDM (CDM AR-TOOL12) based on work by Harmon and Sexton (1996).

Above information explains the high uncertainty; on one hand because the methodological part only considers the first thirty meters at the intersection line to calculate this sink, on the other hand, there was no record in about 60% of the plots measured in dead wood. The second stage of the inventory will complete the measurements in the omitted plots and provide an increased sample size which is expected to reduce uncertainty in the future.

***Equations taken from Evaluación Nacional Forestal* (MAE 2012)**

Carbon Estimations

Carbon content calculations were carried out by using the IPCC 2006 suggested coefficients: 0.44 for litter, 0.9 for lying wood under no decomposition state, 0.5 for wood with a medium decomposition state and 0.15 for decomposed wood. Stratum estimates were independently developed per sink; firstly calculating the total carbon content at plot level and then expanding the value per hectare. Due to the fact that the clusters had a different amount of plots **(Table 14),** the average values per hectare and per cluster were first calculated and were later used for deriving the values per stratum as well as confidence intervals and uncertainties.

The biomass estimations per sink were carried out with a different sampling effort. In the case of living trees, dead trees without leaves, dead trees without branches, roots and stumps; the complete information of the plots was gathered. For the other sinks, only some plots have complete information (**Table 14**. Number of plots or nested plots per carbon sink for each forest stratum). In general, the procedure at plot level, consisted on estimating the total biomass dry weight for each forest component (living trees, standing dead trees, lying wood, litter and detritus, stumps, understory, living and dead roots). The biomass amount was estimated in carbon tons or mega grams and the values were expanded to a hectare.

Strata 3 Andean Montane Evergreen Forest and 6 Amazon Lowland Evergreen Forest have more information for understory, lying wood and detritus. There is no registered data for litter in the Mangrove stratum. More information may be found in the file archivo MAE, 2014a. *Evaluación Nacional Forestal – Resultados*. Available for download through the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*

Table 14. *Number of plots or nested plots per carbon sink for each forest stratum*

Land-use category	Living trees	Dead without leaves	Dead without branches	Stumps	Understory	Litter	Lying wood
Dry Andean Forest	105	105	105	105	31	80	7
Pluviseasonal Dry Forest	151	151	151	151	108	108	13
Andean Montane Evergreen Forest	312	312	312	312	274	249	129
Andean Foothills Evergreen Forest	175	175	175	175	142	114	60
Andean High Mountain Evergreen Forest	118	118	118	118	106	106	36
Amazon Lowland Evergreen Forest	432	432	432	432	285	270	217
Choco Lowland Evergreen Forest	207	207	207	207	147	151	87
Mangrove	87	87	87	87	55	0	11
Morete Palms Forest	52	52	52	52	45	4	17

2.3.2 Forest sub-categories

Forest strata reported by the National Forest Inventory (ENF): Mature forests

The reported data is the result of a process of data acquisition and processing by means of surrogate measures and the application of allometric equations to determine the carbon contents for AGB, DW.S, BGB and DW.R, as well as direct measurements for L and DW.L.

Nine different strata were assessed by the ENF. For those strata, the results of the ENF were used as the basis for the emission factors in the same terms as they are reported in the report issued by the Ministry of Environment (MAE, 2014a). Since the carbon contents in Belowground Non-Tree biomass (BGB.NT) were not reported, the respective values for mature forests were derived from the aboveground Non-Tree biomass (AGB.NT), applying the same Root-to-Shoot coefficient as applied for the BGB.T (tree) compartment.

For each of the carbon pools reported in any given stratum, the uncertainty of the estimate as a percentage of the mean was reported as part of the ENF results.

Carbon stock per forest type

The results of the ENF show a carbon stock gradient in Ecuador's forests. Dry forests store less carbon whereas forests in the Amazon region store more carbon (Mg ha^{-1}, **Table 15**). Uncertainties were estimated per sink (**Table 6**), detailed information regarding the considerations and results of the calculations may be found in the ENF file.

Total carbon stock in Ecuadorian forests is in the range of 47.91 Mg ha^{-1} (for Dry Andean Forest) and 108.12 Mg ha^{-1} (for Amazon Lowland Evergreen Forest), these values include living and dead biomass above and below ground. The carbon contents in Pluviseasonal Dry Forest, Evergreen Andean Forest, Choco Lowland Evergreen Forest, Mangrove and Morete Palm Forest range in between the before mentioned values. More information may be found in the file MAE, 2014a. *Evaluación Nacional Forestal – Resultados*. Available for download through the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*

Table 15. *Carbon Stocks (Mg ha^{-1}) in biomass per forest type and component.*

Forest Type	Living trees	Palms	Standing dead trees with branches and without leaves	Standing dead trees without branches and leaves	Stumps	Roots in living trees	Roots in dead trees and stumps	Understory	Lying wood	Litter	Relative C. (ton/ha) Total
Dry Andean Forest	28.80	0.00	0.22	0.35	0.01	6.91	0.26	1.59	5.55	4.22	47.91
Pluviseasonal Dry Forest	25.00	0.00	0.08	0.32	0.01	6.00	0.21	1.49	2.07	1.86	37.04
Andean Montane Evergreen Forest	80.89	0.10	0.68	5.10	0.02	19.41	2.76	4.06	7.67	2.42	123.11
Andean Foothills Evergreen Forest	72.94	0.01	0.54	3.66	0.01	17.51	1.97	3.24	20.73	2.16	122.77
Andean High Mountain Evergreen Forest	61.22	0.07	0.46	3.56	0.01	14.69	1.90	7.62	12.88	2.69	105.10
Amazon Lowland Evergreen Forest	108.12	0.49	0.39	3.79	0.02	25.95	2.02	3.24	13.32	3.07	160.41
Choco Lowland Evergreen Forest	52.41	0.05	0.39	1.77	0.12	12.58	1.32	3.02	9.36	2.32	83.34
Mangrove	50.12	0.00	0.23	0.70	0.00	12.03	0.41	19.18	3.96	N/A	86.63
Morete Palms Forest	49.44	1.42	0.15	1.01	0.08	11.87	0.59	1.16	6.62	3.47	75.81

More information is available in the file MAE, 2014a. *Evaluación Nacional Forestal – Resultados*. Available for download through the website *http://suia.ambiente.gob.ec/en/anexos-nivel-referencia*

Forest strata not reported by the National Forest Inventory (ENF):

a. Plantation forests

The ENF did not gathered information regarding forest plantations. Moreover, the Land Use and Cover Map does not distinguish all of the forest plantations in the country, since the identification process is quite complex.

Currently, the country promotes reforestation projects for commercial purposes (through the Ministry of Agriculture, Livestock, Aquaculture and Fishery (MAGAP for its name in Spanish)) as well as reforestation and forest restoration (through the MAE). For such reasons, these areas are under a continuous georeferencing process and may be included in future analysis.

2.4 Fate of the living biomass and dead organic matter existing in the forest strata during and after the deforestation event

2.4.1 Biomass oxidation

Following GPG's Tier1 approach, all biomass and dead organic matter are assumed to be oxidized in the year of conversion.

2.4.2 Biomass burning – Non CO_2 GHG emissions

Anthropogenic biomass burning for the purpose of clearing land to allow for new land-uses are analyzed and non-CO_2 emissions are quantified (i.e. naturally occurring fires are not accounted for in the FREL). Although biomass burning normally occurs sometime after the forest slashing process, typically during the dry season that follows the deforestation event, which can occur in the subsequent year, for the purpose of this FREL estimation, biomass burning is assumed to occur within the same year in which the deforestation event is detected.

Following the prescriptions of GPG, a fraction of the existing aboveground biomass and dead organic matter in the forest strata is assumed to be burned at the time of the land-use conversion. Default values for the since belowground biomass is not affected by the burning process, it was not accounted in the mass of available fuel Calculations were performed applying LULUCF-GPG equations and default assumptions (emission factors and GWP of N_2O and CH_4, for the emissions of N_20 and CH_4.