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

Ecuador's Forest Reference Emission Level for Deforestation

Quito

December, 2014

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117 **Acronyms**
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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 and MMAP
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
MMAP	Map of mean annual precipitation
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)

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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+.

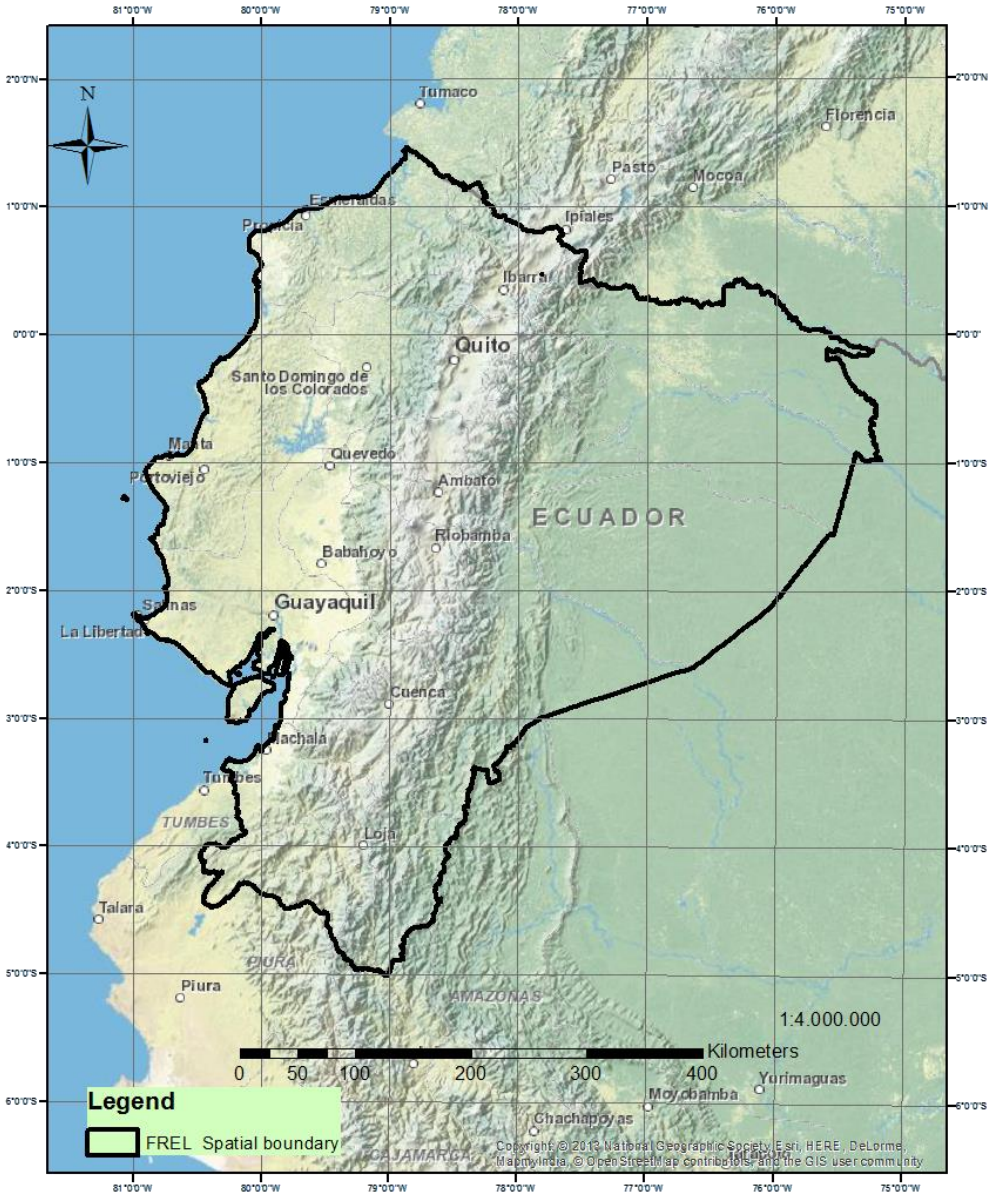
Ecuador underlines that the submission of this proposed FREL, and the subsequent Technical Annex in the Biennial Update Report on the results of emission reductions from the implementation of REDD+ results-based actions, are voluntary and exclusively for the purpose of obtaining and receiving results-based 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, the Puná 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(a) 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/web/suia/anexos-nivel-de-referencia*.

Information on the accuracy of the land-use maps has been summarized in section 3.2.4(a) 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/web/suia/anexos-nivel-de-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) and a map of mean annual rainfall (MMAP) 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 2 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 1991 and 2000 and 89,492.73 hectares per year between 2000 and 2008.

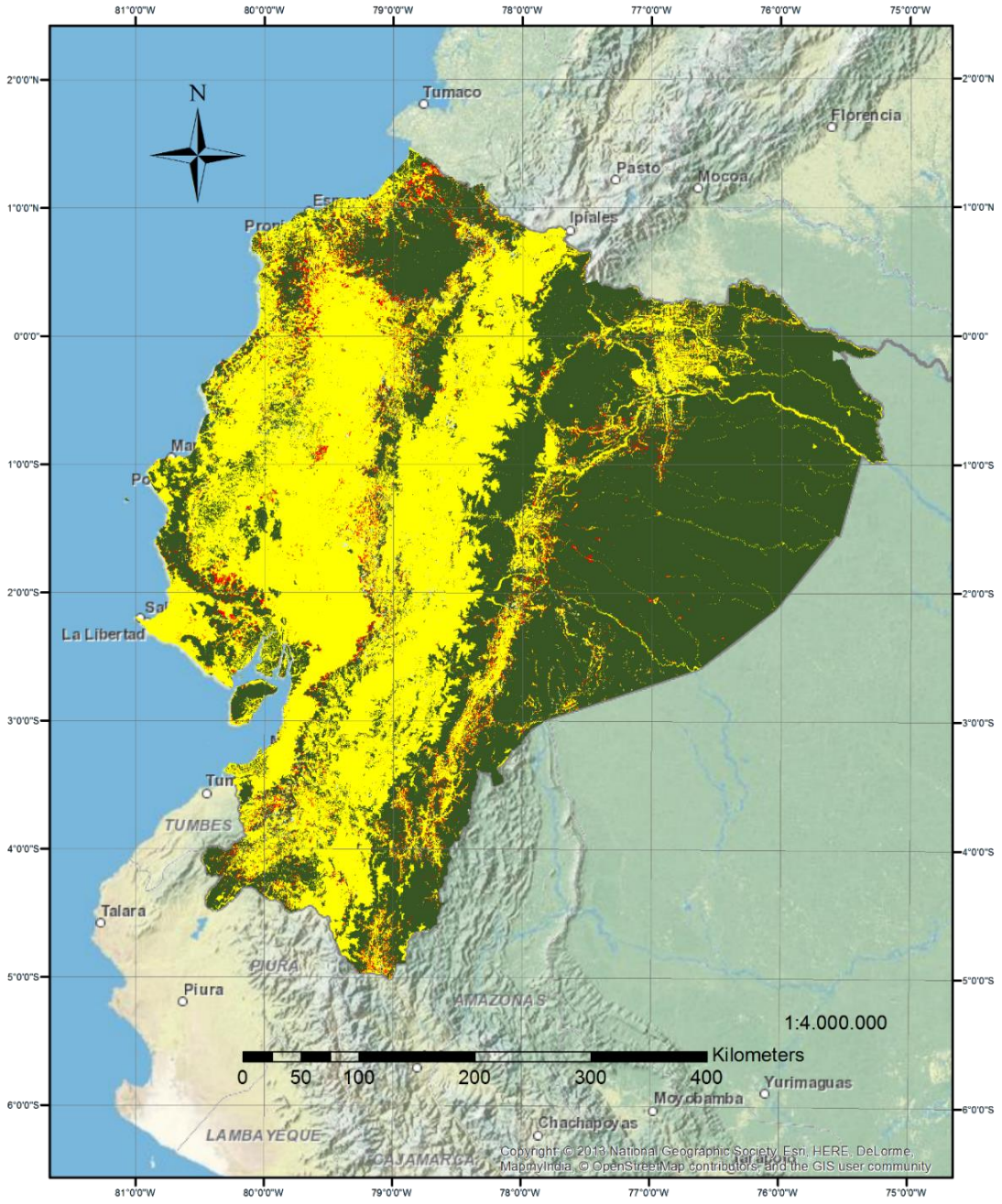
Table 1. Historic gross deforestation in Ecuador per forest type.

Categories of Forest Land converted to other land categories	1990-2000		2000-2008	
	ha	ha yr^{-1}	ha	ha yr^{-1}
Andean dry forest	19,154.97	1,915.50	16,345.53	2,043.19
Dry Forests with Seasonal Rains	152,989.83	15,298.98	83,810.07	10,476.26
Evergreen Andean forest	183,291.39	18,329.14	109,117.26	13,639.66
Evergreen lowland-Andean forest	250,064.10	25,006.41	142,140.42	17,767.55
Evergreen highland-Andean forest	31,681.98	3,168.20	15,704.64	1,963.08
Lowland evergreen Amazon forest	318,742.02	31,874.20	157,151.52	19,643.94
Lowland evergreen Chocó forest	324,627.21	32,462.72	181,005.84	22,625.73
Mangrove	12,569.85	1,256.99	8,874.45	1,109.31
Moretal (palm forest)	6,309.63	630.96	1,792.08	224.01
Total gross deforestation	**1,299,430.98**	**129,943.10**	**715,941.81**	**89,492.73**

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 with less than 10 years of age 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/web/suia/anexos-nivel-de-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 2001-2008 (MLUX2001_2008).



Note: The map of land-use change for the period 2001-2008 (MLUX2001_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/web/suia/anexos-nivel-de-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 MLUX2001_2008.

Legend	Land-use change category	Area
	Description	ha
	Deforestation as defined for Ecuador's FREL*	715,941.81
	Forest Land <10 yrs. converted to Non-Forest Land (not included in the FREL)	179,238.15
	Forest Land converted to natural Wetland (not included in the FREL)	127.17
	Forest Land remaining Forest Land	12,821,892.66
	Natural Forest < 10 years converted to Forest Plantations	181.26
	Forest Plantations converted to Natural Forests	0.00
	Forest Plantations converted to Non Forest Land	13,122.81
	No Information converted to Forest Land (Forest Plantations)	0.00
	No Information converted to Non-Forest Land	0.00
	Non-Forest land converted to Forest Land	276,549.30
	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.

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.

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 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/web/suia/anexos-nivel-de-referencia*. Insufficient national data was available for the estimation of carbon stock in forest plantations therefore carbon stock for forest plantations uses an IPCC default factor. The default factor was chosen in order to reflect that a higher percentage of plantations are located in wet regions of the country.

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 equivalents per hectare (tCO_2-e ha^{-1}) for

the construction of the FREL. This conversion consists of a multiplication by 44/12, as suggested by IPCC.

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.

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, expressed in tons of carbon dioxide equivalent per hectare (CO_2-e ha^{-1}), are shown in Table 4 below.

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

Land-use category	Aboveground biomass		Belowground biomass		Dead wood			Litter	Total
	ABG.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}
Andean dry forest	105.60	5.83	25.34	1.40	2.13	20.35	0.95	15.47	177.07
Dry Forests with Seasonal Rains	91.67	5.46	22.00	1.31	1.50	7.59	0.77	6.82	137.12
Evergreen Andean forest	296.60	11.92	64.20	2.86	15.44	76.01	7.22	7.92	482.17
Evergreen lowland-Andean forest	267.45	28.20	53.86	6.77	14.78	47.23	6.97	9.86	435.11
Evergreen highland-Andean forest	224.47	15.25	71.17	3.66	21.27	28.12	10.12	8.87	382.94
Lowland evergreen Amazon forest	396.44	13.68	95.15	3.28	15.40	48.84	7.41	11.26	591.45
Lowland evergreen Chocó 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	16.88	3.41	14.52	1.50	-	334.52
Moretal (palm forest)	181.28	9.46	43.52	2.27	4.55	24.27	2.16	12.72	280.24
Broadleaved plantation forest - Rainfall >2000 mm/year	258.5	-	62.04	-	-	12.93	-	4.52	337.99

F = Forest Land;

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/web/suia/anexos-nivel-de-referencia*
- Annex 2.

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

Ecuador started to implement new policies and programs to reinforce forest governance, reduce deforestation, and improve forest control and forest management since 2009. All these policies and actions were expected to contribute to the reduction of forest-related GHG emissions and therefore the year 2009 is considered the base year for Ecuador's REDD+ results-based activities implementation. For these reasons, the historical reference period chosen for the FREL is 2000-2008.

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:

$$EF_{lc} = \sum_{cp}^{CP} FC_{l,cp} \qquad (1)$$

Where:

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

306 $FC_{l,cp}$ Forest carbon stock in the carbon pool *cp* of the forest land-use category *l*; tCO_2-e
307 ha^{-1}

308 *CP* Number of carbon pools included in the estimation of emission factors;
309 dimensionless

310
311 **b) Calculation of average annual activity data (ADlc)**

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

$$AD_{lc} = \frac{ADHP_{lc}}{THP} \quad (2)$$

315 Where:

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

318 $ADHP_{lc}$ Activity data as estimated for the land-use change category *lc* in the period 2000-
319 2008; ha

320 *THP* Duration of the historical reference period 2000-2008 (8 years); yrs
321

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

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

330 Historical activity data have also been estimated for the period 1990-2000 (129,943 ha yr^{-1}),
331 showing that gross deforestation was approximately 145% of the average annual gross deforestation
332 estimated for the period 2000-2008 (89,493 ha yr^{-1}). Activity data of the 1990-2000 period were
333 conservatively excluded in the construction of Ecuador's FREL as they no longer reflect current
334 national circumstances for Ecuador.

335 Ecuador has decided to use the average annual GHG emissions from deforestation estimated for the
336 2000-2008 period in the context of the proposed forest reference emission level, for REDD+
337 results-based payments in the period up to 2020. However, both historic data are described below:

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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	52,385,615	403
2000-2008	715,942	89,493	34,044,101	380

The method used to calculate average annual GHG emissions from deforestation (as defined by Ecuador in section 3.3.2 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 1, 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.

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

Where:

$FREL_t$ 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	52,385,615	403[(1)]
			2000-2008	34,044,101	380[(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/web/suia/anexos-nivel-de-referencia.*

3.2 Transparent, complete, consistent and accurate information

3.2.1 Transparent information

All the process followed 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/web/suia/anexos-nivel-de-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/web/suia/anexos-nivel-de-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/web/suia/anexos-nivel-de-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.
MMAP:	Map of Mean Annual Precipitation, used to stratify forest plantations and other non-forest land-use categories.
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 the 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.

According to GOFC-GOLD (2014), an overall accuracy estimate between 30% and 80% can be considered as a medium accuracy. However, it is worth emphasizing that the abovementioned overall accuracy estimates are for land-use maps with the six IPCC land-use categories.

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.

Accuracy of the estimated emission factors

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. The reason for this higher uncertainty is explained in Box 1 and uncertainty is expected to decrease in future estimations and/or future FRELs. For plantation forests, IPCC default reported uncertainty values were applied.

The estimated uncertainty of carbon stock values for each carbon pool in each land-use sub-category are reported in the FREL calculation.xlsx

The total carbon stocks in the inventoried forest strata (9 native forest subcategories,) 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.

Box 1. 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 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:

Laying 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)

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

Where:

B: biomass (kg)

V: laying 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)**

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.

Pre-processing of the remotely sensed data included the ortho-rectification of the images. No radiometric corrections were performed.

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. 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.

In the 2000/01 map, areas that were covered by clouds and shadows in 1990/91 were assumed not to have changed since 2001. This only affects the assumption about the age of the land-use categories in the 2000/01 map. Information on age classes has not been used for this proposed FREL submission. As in the 1990/01 map, it was assumed that all land-use categories observed for the first time in the oldest land-use map had more than 17 years of age at that time. This assumption does not have any impact on Ecuador's proposed FREL, as no natural forests existed in 2000/01 in areas that were obscured by clouds and shadows in 1990/91.

The classification in land-use categories was made independently 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.

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 and MMAP)

The classification of the satellite images included manual and automatic procedures. A segmentation 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), a map of mean annual precipitation (MMAP) and through multi-temporal analysis for detecting areas corresponding to different age classes.

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.

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 (3% 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 and deducted from the FREL.

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).

Biomass carbon stocks in forest plantations were estimated using default Tier1 IPCC data and parameters. The data, parameters and assumptions used in estimating carbon stocks are transparently documented in the FREL calculation.xlsx. Available: *http://suia.ambiente.gob.ec/en/web/suia/anexos-nivel-de-referencia*.

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[1] (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 (CO2) 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 (CH4) and Nitrous oxide (N2O). However, insufficient data has been collected on emissions of non-CO2 gases for inclusion of accurate non-CO2 emissions in

[1] Incudes trees with a DBH < 10.00 cm and palms.

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 CO2 emissions. In order not to omit significant gases, the potential contribution to annual GHG emissions from non-CO2 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-CO2 gases, resulted in <5% of total annual GHG emissions in tCO2 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-CO2 emissions. For this reason, the exclusion of non-CO2 gases can be considered conservative.

Box 2. Estimates of non- CO2 emissions of greenhouse gases

The emission of the non-CO_2 gases Methane (CH4) and Nitrous oxide (N2O) 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

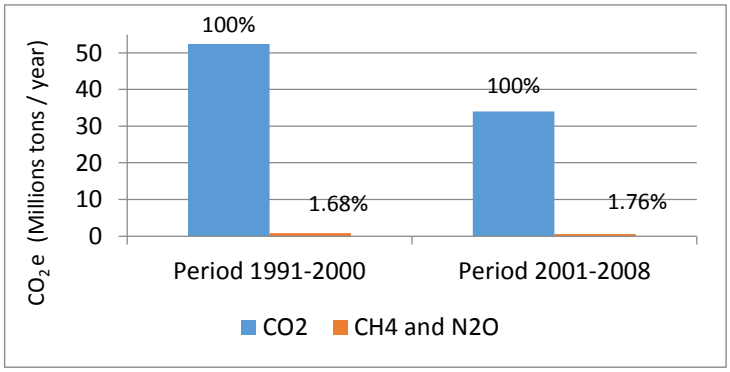
B: mass of available fuel, kg d.m.ha^{-1}

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 3. Comparison of CO2 and non CO2 emissions per year for each period



As shown in figure 3, the emissions of non CO_2 gases from biomass burning is less than 5% of the CO_2 emissions from deforestation.

Soil organic carbon (SOC) is excluded from this FREL due to the current lack of accurate data for estimating carbon stocks in this pool at the national level. SOC may be included in the future, considering that data relevant for calculating carbon stocks in this pool is currently under analysis.

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*, *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, 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.

Only gross deforestation of natural forests (FN) with more than 10 years of age has been included in the FREL[2]. Conversions of young natural forests with less than 10 years of age (FN<10) to other land-use categories have not been included in the FREL because areas subject to this type of conversions are considered temporarily stocked and will most likely be maintained in other land-use categories in the long-term.

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.

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

[2] The age classes of the forests have been determined by comparing lands classifieds as "forest land" in the land-use maps created by the Ministry of Environment of Ecuador (MAE) for the years 1990/91, 2000/2001 and 2008/09.

very low for Ecuador's natural vegetation and would include vegetation types which according to Ecuadorian standards would be considered other wooded land.

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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 4 and Table 6);
- MLUCa_2000: Map of land-use categories as produced by the MAE for year 2000 (see Figure 5 and Table 7);
- MLUCa_2008: Map of land-use categories as produced by the MAE for year 2008 (see Figure 6 and Table 8);
- MMAP: Map of mean annual precipitation as produced by MAE (see Figure 8);
- MPFT: Map of potential forest types as produced by MAE (see Figure 7 and Table 9);

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 addition of information on annual mean precipitation from the MMAP to the land-use category "timber forest" (= forest plantation) and other non-forest land-use categories (such as permanent crops, pastures and shrubland) in the MLUCa maps was necessary because carbon stock values for these land-use categories were estimated using default values presented in IPCC tables. IPCC assigns these default carbon stock values according to three ranges of mean annual precipitation: <1,000 mm yr^{-1}, 1000-2000 mm yr^{-1} and >2,000 mmm yr^{-1}.

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). As carbon stocks depend on the age of the forest and, depending on the methods used to calculate emission factors, also on the age of all other land-use categories, some assumptions were made regarding the age class of the forest land-use categories in each land-use map:

- All land-use categories present in the 1990 MLUCa map were assumed to have existed for a long time (i.e. >17 years);
- All land-use categories present in the 2000 MLUCa map that were obscured by clouds and shadows in 1990 were assumed to have >17 years in 2000/2001. It was found that only forest plantations and non-forest land-use categories existed in these areas, so that it was unnecessary to do this assumption for natural forest land-use categories.

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

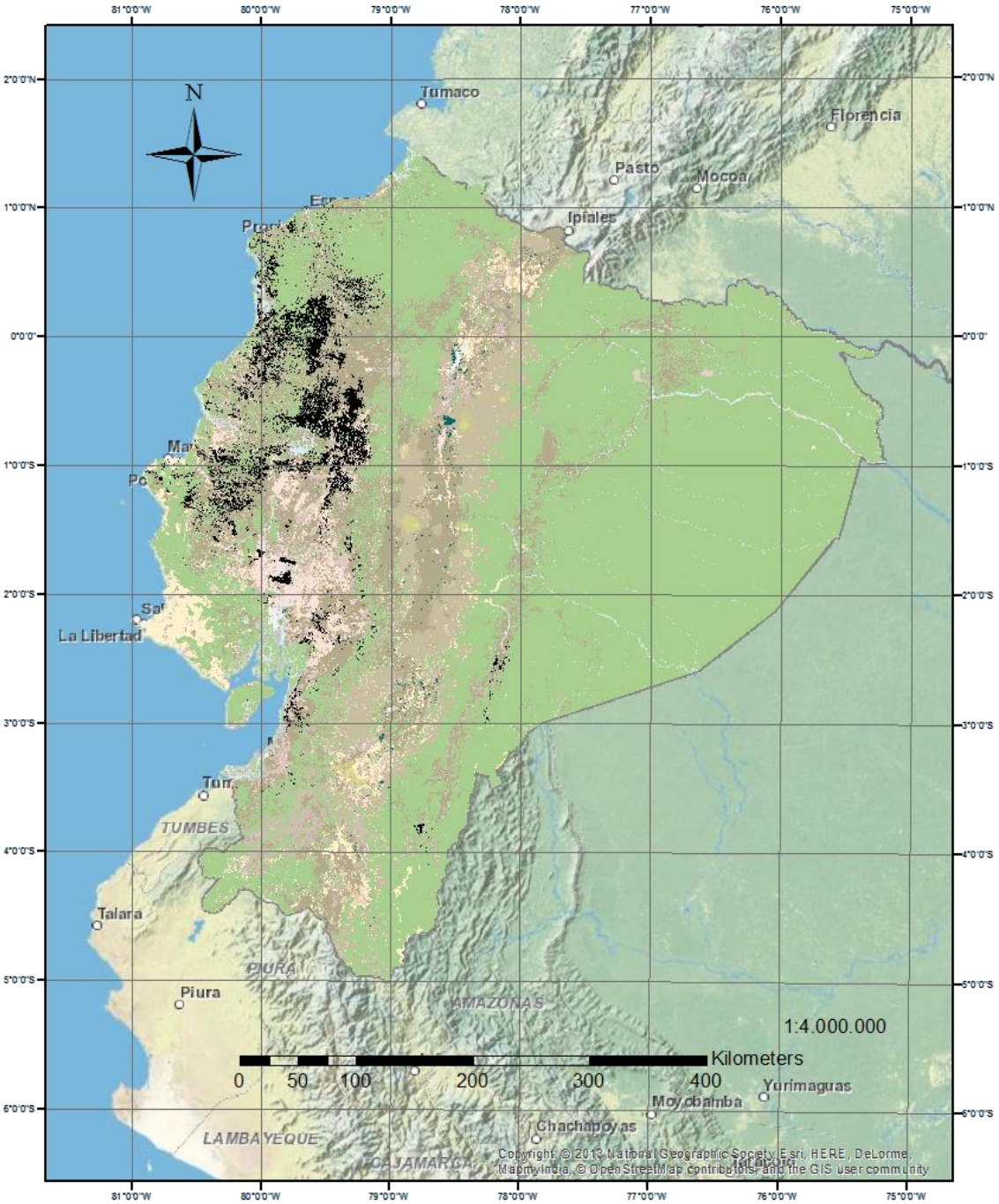
The maps of land-use change for the periods 1990-2000 (MLUX1990_2000) and 2000-2008 (MLUX2000_2008) are shown in Figure 9 and Figure 2 and their attributes in Table 10 and Table 2 respectively.

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/web/suia/anexos-nivel-de-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/web/suia/anexos-nivel-de-referencia*.

760 *Figure 4. Map of land-use categories as produced by the MAE for year 1990 (MLUCa_1990).*



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764 *Table 6. 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

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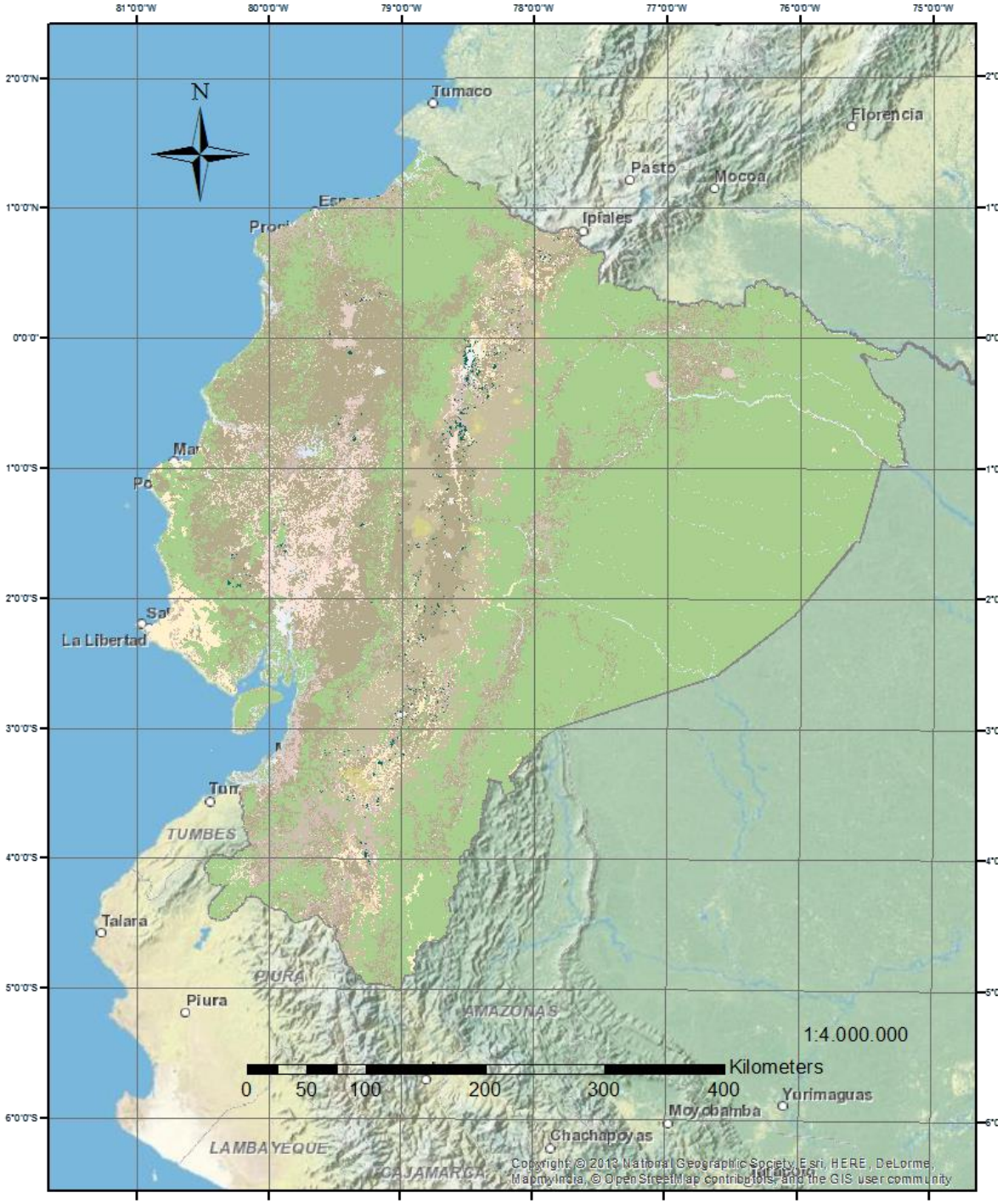
766 *Figure 5. Map of land-use categories as produced by the MAE for year 2000 (MLUCa_2000).*



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770 *Table 7. 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

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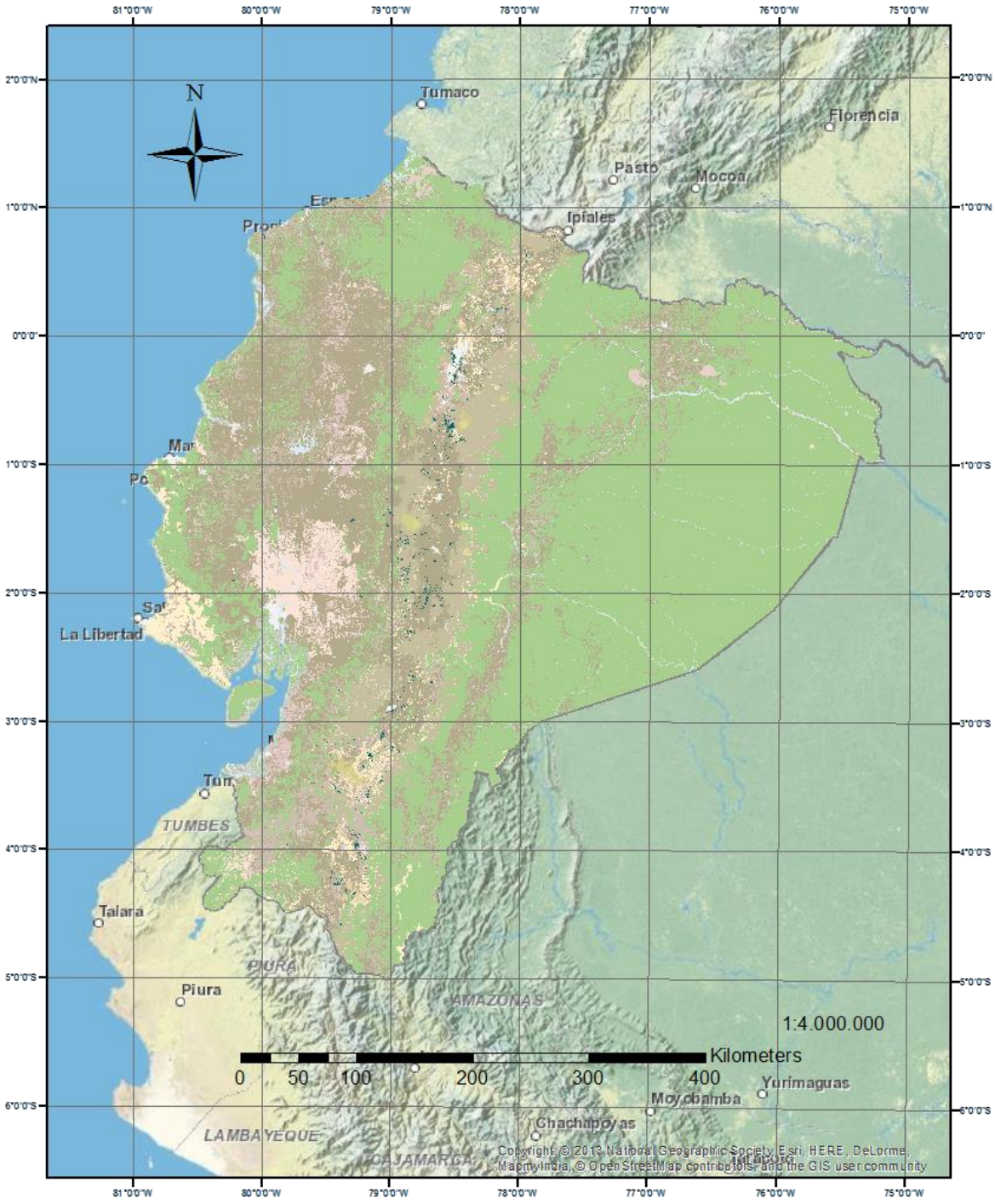
772 *Figure 6. Map of land-use categories as produced by the MAE for year 2008 (MLUCa_2008).*



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775 *Table 8. 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

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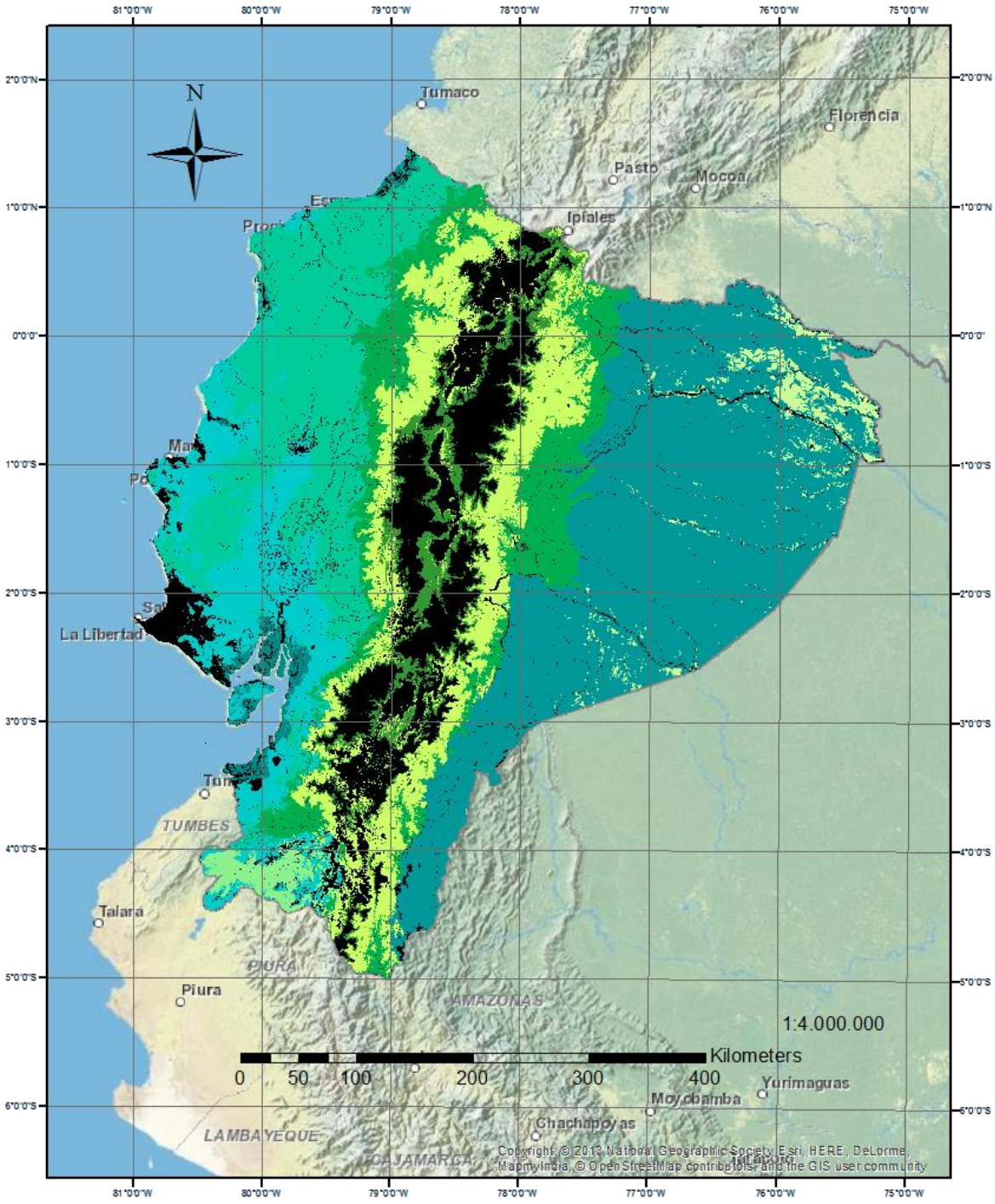
778 *Figure 7. Map of potential forest types as produced by the MAE (MPFT).*



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781 *Table 9. Attributes table of MPFT.*

Legend	Description	Area (ha)
	Andean dry forest	294,231.78
	Dry Forests with Seasonal Rains	2,333,894.22
	Evergreen Andean forest	3,037,782.15
	Evergreen highland-Andean forest	1,143,827.01
	Evergreen lowland-Andean forest	2,385,082.89
	Lowland evergreen Amazon forest	7,557,112.62
	Lowland evergreen Chocó forest	3,672,836.55
	Mangrove	325,821.06
	Moretal (Palm forest)	445,750.38
	No Information	3,701,721.24
	Total area of Ecuador	24,898,059.90

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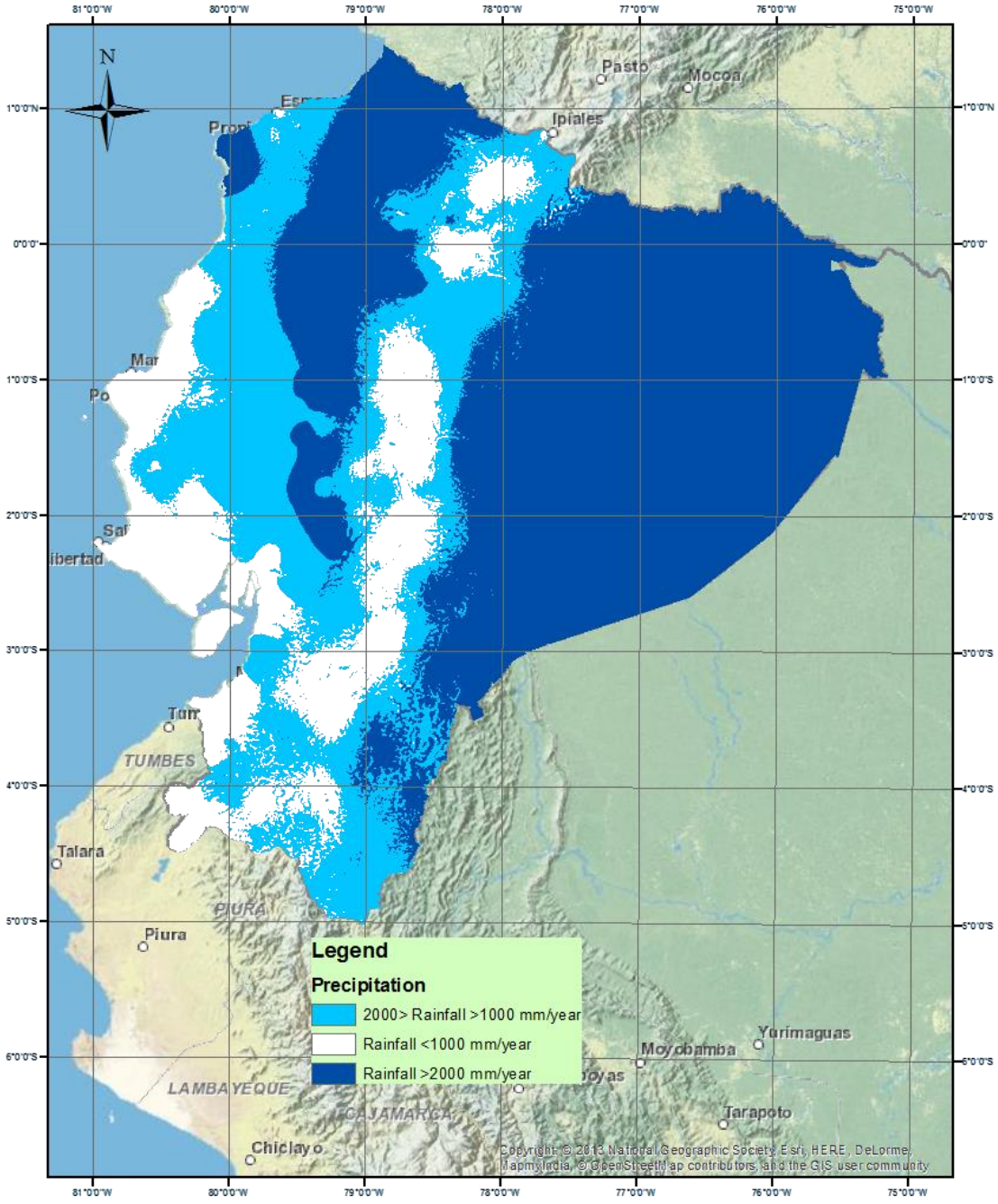
784 *Figure 8. Map of mean annual precipitation as produced by the MAE (MMAP).*



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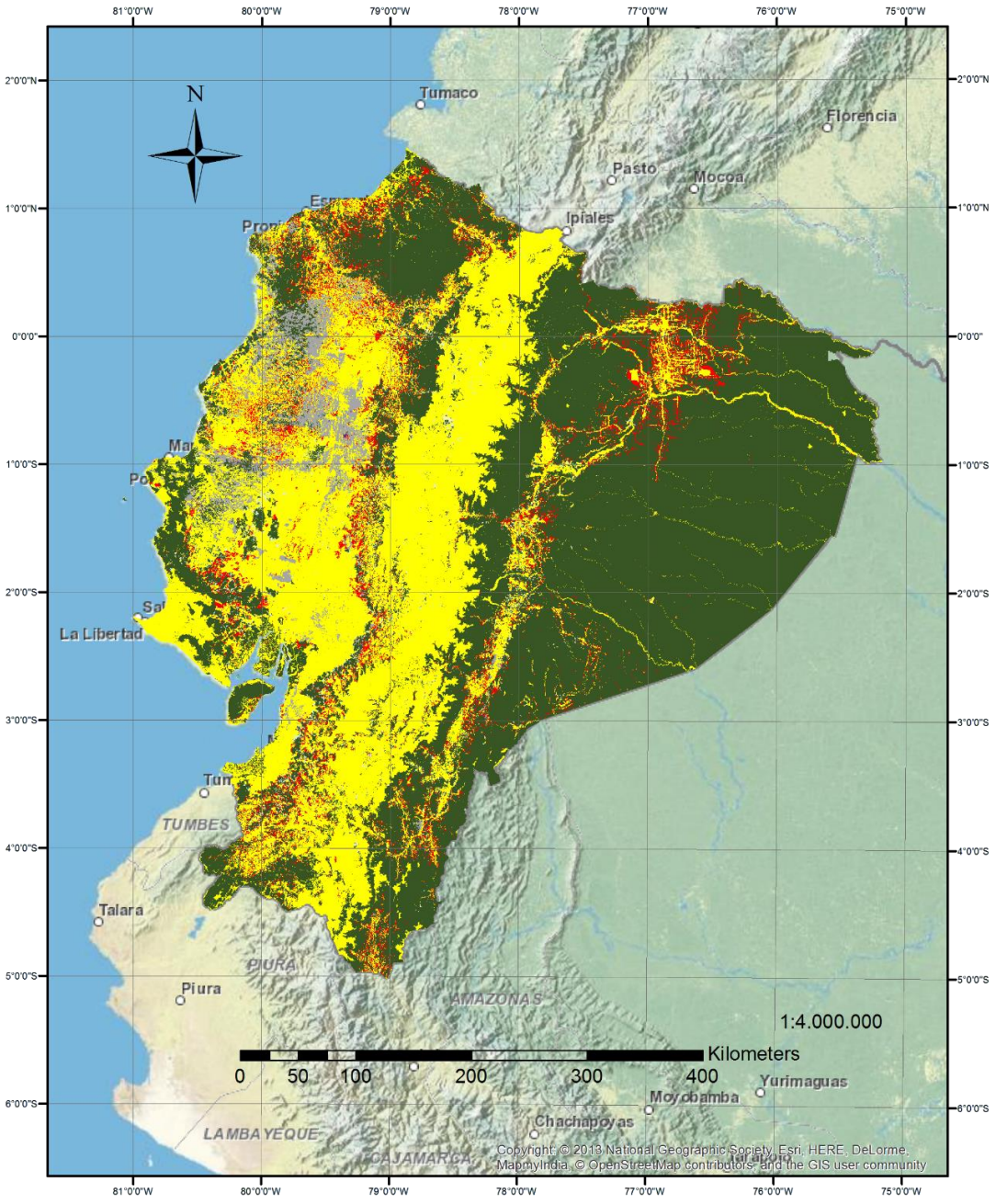
787 *Figure 9. Map of land-use change for the period 1990-2000 (MLUX1990_2000).*



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

794 *Table 10. 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 <10 yrs. converted to Non-Forest Land (not included in the FREL)	0.00
	Forest Land converted to natural Wetland (not included in the FREL)	0.00
	Forest Land remaining Forest Land	13,313,190.24
	Natural Forest < 10 years converted to Forest Plantations	0.00
	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

795 * Includes conversion of natural forests to forest plantations.

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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.

Post-deforestation carbon stocks

Biomass accumulation processes in the land-uses that occur following the deforestation events are considered and linear accumulation patterns are assumed following LULUCF-GPG prescriptions for Tier2. The length of the transition to a new steady-state depends on the kind of post-deforestation land-use (i.e. transition periods will vary between annual crops, perennial crops in wet conditions or perennial crops in dry conditions).

Depending on the post-deforestation land-use categories the biomass stocks are accounted for differently in the respective carbon pools within the scope of this FREL.

A detailed description of the assumptions and steps followed to assign carbon stock values for the different post-deforestation land-uses is included further in this annex.

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. The same procedure was followed regarding the post-deforestation land-use categories.

2.3.1 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.

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

a. Plantation forests

The ENF does not offer information on plantation forests; therefore, a decision had to be made as to choose appropriate sources of information for the plantation forests found in the land-use classification.

Since three sub-categories of plantation forests were found, being differentiated by the climatic region of occurrence, , the decision was to pick the most representative default biomass value as they are reported by LULUCF-GPG (IPCC, 2003).

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.