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Modified REDD+ Forest reference emission level/forest reference level (FREL/FRL)

COSTA RICA

SUBMISSION TO THE UNFCCC SECRETARIAT FOR TECHNICAL REVIEW
ACCORDING TO DECISION 13/CP.19

MINISTRY OF ENVIRONMENT AND ENERGY
COSTA RICA

Contents

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Note on the modified submission

This modified submission was presented on May 23rd to the UNFCCC Secretariat to address several comments by the Assessment Team, according to the procedures set out in the annex to decision 13/CP.19 for the review of REDD+ reference levels. Costa Rica would like to thank the Assessment Team and the Secretariat for their input.

This modified submission presents *different* FREL/FRL values compared to the original submission, specifically due to the exclusion of Harvested Wood Products (HWP). Based on comments from the Assessment Team, and considering the ongoing work on forest degradation and management, Costa Rica decided to exclude HWP from this FREL/FRL submission, in order to improve methods and obtain more accurate data for future submissions.

Other, non-quantitative changes were incorporated in the FREL/FRL submission to increase transparency. For example, three new sub-sections were included in Section 2 to provide more information on Costa Rica's approach to managed and non-managed lands, forest lands in transition and drivers of deforestation and forest regeneration. Finally, other minor edits were conducted to further clarify the ideas in the text.

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Acronyms

AAAA	A year of the historical reference period analyzed
AD	Activity data
AFOLU	Agriculture, Forestry and Other Land Uses
AGB.n	Above-ground biomass in non-trees
AGB.t	Above-ground biomass in trees
BAU	Business-as-usual
BGB.n	Below-ground biomass in non-trees
BGB.t	Below-ground biomass in trees
BUR	Biennial Update Report
C	Carbon
CDM	Clean Development Mechanism
CENIGA	National Center for Geo-Environmental Information (*Centro Nacional de Información Geoambiental*)
CoP	Conference of the Parties to the UNFCCC
dbh	Diameter at breast height
DOM	Dead organic matter
DW	Dead wood
DW.b	Below-ground dead wood
DW.l	Lying dead wood
DW.s	Standing dead wood
EF	Emission factor
ER-PIN	Emission Reduction Program Idea Note
ER-Program	Emission Reduction Program
FAO	Food and Agriculture Organization
FBS	Sustainable Biodiversity Fund (*Fondo de Biodiversidad Sostenible*)
FCPF	Forest Carbon Partnership Facility
FONAFIFO	National Forest Financing Fund (*Fondo Nacional de Financiamiento Forestal*)
FRA	Forest Resources Assessment
FREL/FRL	Forest Reference Emission Level and/or Forest Reference Level
GHG	Greenhouse Gas(ses)
HWP	Harvested wood products
ICAFE	Costa Rican Coffee Institute (*Instituto del café de Costa Rica*)
IMN	National Meteorological Institute (*Instituto Meteorológico Nacional*)
INDC	Intended Nationally Determined Contribution

IR-MAD	Iteratively Reweighted Multivariate Alteration Detection
L	Litter
LULUCF	Land Use, Land use-Change and Forestry
MAG	Ministry of Agriculture (*Ministerio de Agricultura*)
MCS	Land-cover map (*mapa de cobertura del suelo*)
MINAE	Ministry of the Environment and Energy (*Ministerio de Ambiente y Energía*)
MRV	Measurement, reporting and verification
MTB-S	Forest types map of the National Forest Inventory
NAMA	Nationally Appropriate Mitigation Action
NFI	National Forest Inventory (*Inventario Nacional Forestal*)
NFMS	National Forest Monitoring System
PSA	Payments for Environmental Services
REDD+	Reducing Emissions from Deforestation and Forest Degradation, Sustainable Management of Forests, Conservation and Enhancement of Forest Carbon Stocks
RF	Random Forest
R-PP	Readiness Preparation Proposal (to FCPF´s Carbon Fund)
SINAC	National System of Conservation Areas (*Sistema Nacional de Áreas de Conservación*)
SOC	Soil organic carbon
TAGB	Total above-ground biomass
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars

1. Introduction

In response to Decision 1/CP.16, paragraphs 70 and 71, Costa Rica aims to provide a positive contribution to mitigation actions in the forest sector by reducing emissions from deforestation and enhancing forest carbon (C) stocks, in accordance with its national circumstances and respective capabilities. Costa Rica welcomes the opportunity to submit our proposed national Forest Reference Emission Level and Forest Reference Level (FREL/FRL) to the United Nations Framework Convention on Climate Change (UNFCCC) for technical assessment, according to decision 13/CP.19 and its annex.

The submission of this FREL/FRL, and of the subsequent Technical Annexes to the Biennial Update Reports (BUR), is voluntary and exclusively for the purpose of obtaining results-based payments for REDD+ activities, according to decisions 1/CP.16, paragraph 71, 13/CP.19, paragraph 2, and 14/CP.19, paragraphs 7 and 8.

Since 2009, Costa Rica has worked on developing the four elements referred to in paragraph 71 of decision 1/CP.16. In addition to the National Climate Change Strategy, and existing NAMAs, a comprehensive National REDD+ Strategy was completed and is in its final consultation phase (*cf*. section 1.1. for more details).

Regarding the development of a National Forest Monitoring System (NFMS), Costa Rica has developed a protocol for measuring changes and mapping land use (Agresta *et al.*, 2015.a)[1] that has been applied to generate the activity data (AD) reported below. This protocol or a demonstrably equivalent set of methodologies[2] will be applied in future measurement periods in order to keep consistency with the proposed FREL/FRL. Hence, the protocol may be improved, as appropriate, in order to enable the collection of more accurate AD, which may also allow including additional REDD+ activities in future revisions of Costa Rica's FREL/FRL. Although Costa Rica included all REDD+ activities in its national REDD+ strategy, only emission reductions from deforestation and enhancement of forest carbon stocks were included in the FREL/FRL, as accurate information on forest degradation and sustainable management of forests is not yet available. Conservation of forest carbon stocks is not included in the FREL/FRL, although Costa Rica will measure and report forest C stocks biannually.

In terms of national arrangements for estimating emissions by sources and removals by sinks, the process for developing a robust and transparent NFMS is led by the Ministry of the Environment and Energy (MINAE). The National Meteorological Institute (IMN) is responsible for the National Greenhouse Gas (GHG) Inventory. The National System of Conservation Areas (SINAC) recently completed the first National Forest Inventory (NFI). The National Forest Financing Fund (FONAFIFO) is responsible for coordinating the development of the National REDD+ Strategy. Finally, through a Ministerial Guideline, MINAE assigned the coordination of the development of the NFMS to the National Center for Geo-Environmental Information (CENIGA) that is MINAE's depositary of all official environmental information. These arrangements are consistent with Costa Rica's Intended Nationally Determined Contribution (INDC).

1.1. Relevant policies and programs (para. 2d, annex to 13/CP.19)

Costa Rica's FREL/FRL is largely influenced by the country's forest policies and programs. The most relevant piece of policy is the current Forest Law, passed in 1996. This law established the program of Payments for Environmental Services (PSA), a landmark in Costa Rica's ambitious environmental

1 Agresta, Dimap, Universidad de Costa Rica, Universidad Politécnica de Madrid, 2015.a. Informe Final: Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level: Protocolo metodológico. Informe preparado para el Gobierno de Costa Rica bajo el Fondo de Carbono del Fondo Cooperativo para el Carbono de los Bosques (FCPF). 44 p.

2 As explained in Section 5, important investments are being made by Costa Rica to improve current data and methods for measuring and reporting emissions by sources and removals by sinks.

policy framework. Additionally, the Forest Law banned forest conversion, making deforestation illegal.

Although pre-1996, REDD-like incentives existed in Costa Rica, the PSA program greatly increased Costa Rica's investment around forest conservation. Since 1996, the PSA program allows forest owners to receive payments for protecting their forests and growing new forests, as well as managing standing forests for timber and non-timber products. As the PSA program targets private forests, it was the perfect complement to the long-standing Protected Area System, mostly comprised of state-owned forests since the 1970s. Jointly, they comprise 32% of Costa Rica's continental territory in 2013.

In 2009, Costa Rica developed its first National Climate Change Strategy. It includes specific climate change mitigation and adaptation objectives, as well as a national-level Carbon Neutrality goal. In this context, a domestic carbon market was created in order to catalyze emission reductions. Presently, over 80 private entities have been granted the "C-neutral" brand. Further, Costa Rica's Carbon Neutrality goal was ratified in its INDC to the UNFCCC. Costa Rica's INDC draws a path for reducing emissions to a level consistent with the ultimate goal of the UNFCCC to avoid surpassing the 2ºC temperature limit.

All sectors have been proactive in seeking a low-carbon economy and in securing international finance to promote green development. Several Nationally Appropriate Mitigation Actions (NAMA) are being developed and the Coffee NAMA is already operational. Plans and project documents exist for NAMAs in the energy and agriculture sectors. For the Land Use, Land use-Change and Forestry sector (LULUCF), a comprehensive National REDD+ Strategy was completed and is in its final consultation phase.

Costa Rica's National REDD+ Strategy builds on years of experience in forest conservation. It includes six new forest policies designed to complement the current National Forestry Development Plan and its 12 forest policies. Together, Costa Rica proposes to achieve emission reductions while increasing resiliency and fostering economic growth in rural areas. This proposal is also reflected in Costa Rica's draft Emission Reduction Program (ER-Program) before the FCPF Carbon Fund.

A list of relevant documents/sites is shown below to facilitate the review of policies and programs related to the FREL:

- Emission Reduction Program
- National REDD+ Strategy
- Climate Change Strategy
- List of private entities granted the C-neutral brand
- National Forestry Development Plan
- Coffee NAMA
- National Forestry Fund (FONAFIFO) and gateway to the PSA program documentation
- National System for Conservation Areas (SINAC) and gateway to information on National Parks, Biological Reserves and other conservation areas
- Costa Rica INDC

2. Scope and boundaries

2.1. Geographical boundaries

Figure 1. shows the accounting area of the FREL/FRL, which includes the country’s continental territory (5,133,939.50 ha), but excludes the Coco Island (238,500 ha)[3], a World Heritage site at 532

3 https://es.wikipedia.org/wiki/Isla_del_Coco

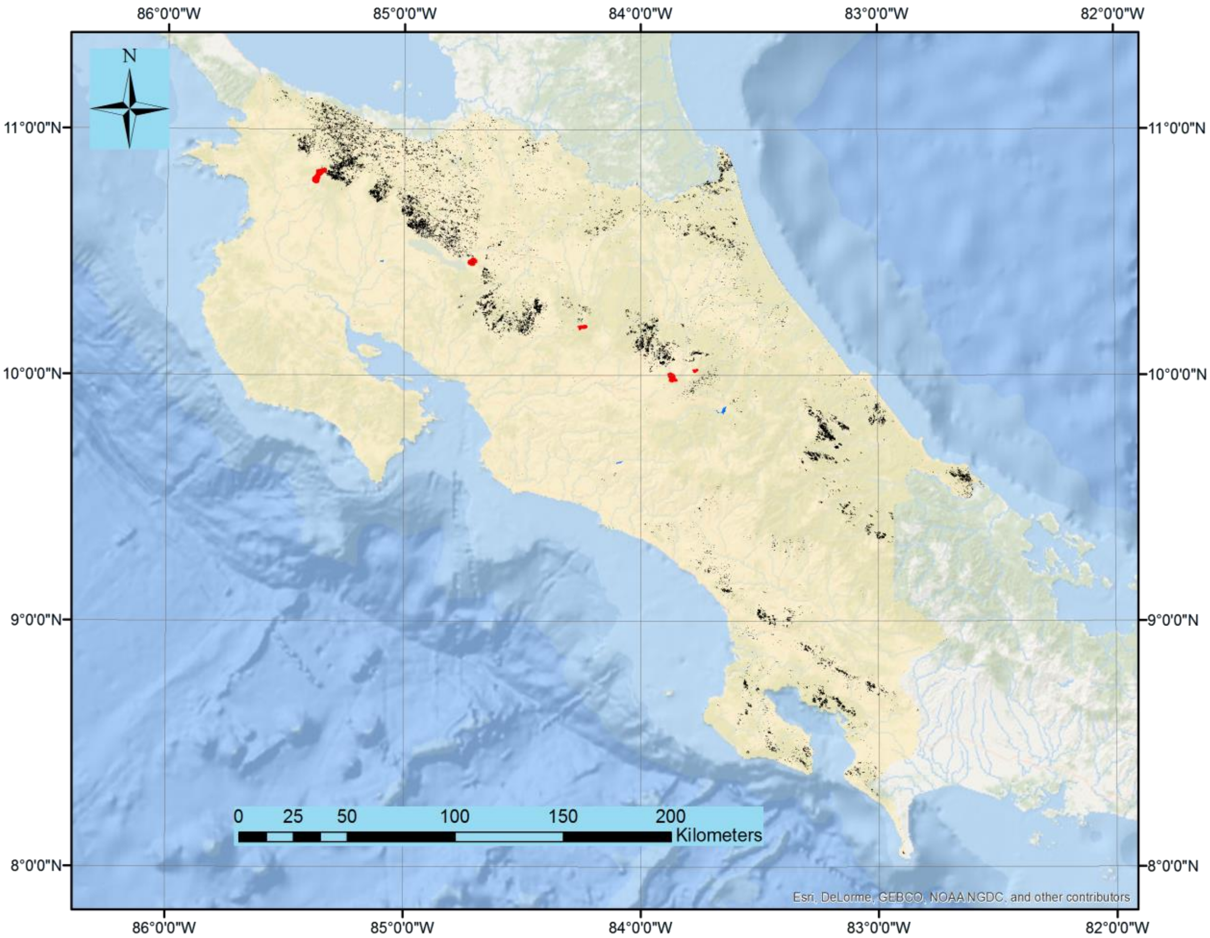
km from the Pacific coast. The Coco Island is inhabited solely by park rangers and is not subject to anthropogenic intervention. The island is also too distant from Costa Rica's continental territory and is therefore not prone to displacements that may be caused by Costa Rica´s REDD+ activities. The exclusion of the Coco Island is consistent with the estimation of emissions by sources and removals by sinks in the national GHG inventory.

Figure 1. Geographical boundary of the proposed FREL.

Source: https://wiki.hattrick.org/w/images/0/09/Location_of_Costa_Rica.PNG

Within the accounting area, special considerations were made for two types of areas: those without land use information due to clouds and shadows, and those where forest losses are associated to natural disturbances (see Figure 2).

Figure 2. Areas with special considerations within the accounting area of the proposed FREL/FRL.



Color	Type of area	FREL	ha	%
	Areas associated to volcanic activity	excluded	1,580.67	0.03%
	Areas associated to river-meandering	excluded	16,693.29	0.33%
	Areas covered by clouds and shadows	excluded	115,364.16	2.26%
	Area with land-cover information	included	4,980,301.3	97.39%
	Total area considered		**5,113,939.5**	**100.00%**

- **Areas without land use information.** This is due to the tropical moist to rainy climate in Costa Rica and the presence of three major mountain ranges, causing high cover by clouds and cloud shadows. Because of this, it is almost impossible to create cloud-free mosaics of satellite images without combining images acquired at different points in time

  For estimating AD, several maps[4] were generated for the accounting area representing land-use on December 31st/January 1st of the years 1985/86, 1991/92, 1997/98, 2000/01, 2007/08, 2011/12 and 2013/14[5]. These maps were created using Landsat images acquired within a 14-months' time window. This resulted in 0.49%-1.83% of the total accounting area covered by clouds and shadows for each map (Agresta *et al*., 2015.a, p. 8). For 1986-2013, a total of 2.26% of the accounting area lacked land use information.

4 These maps are presented in Annex 1.

5 A notation with two years is used to indicate that the land use maps represent simultaneously the ground situation on December 31st of the first year of the notation and on January 1st of the second year of the notation.

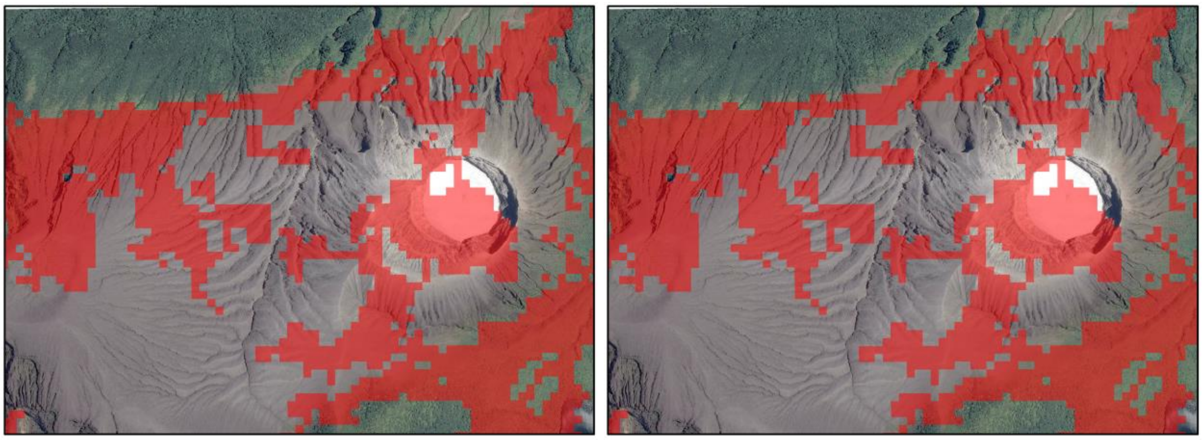
The low percentage of area without land use information was obtained by filling cloud and shadow areas with global data published by Hansen *et al.* (2013)[6]. This method will also be used in future measurement and reporting. Due to increasing availability of global forest cover data, it is likely that no additional areas will have to be excluded due to gaps in land use information in future periods.

- **Areas impacted by natural disturbances**. Losses of forest cover associated to natural disturbances, such as volcanic activities and river-meandering, are not anthropogenic and cannot be avoided through REDD+ activities. Although they are quantified and transparently reported in this submission, Costa Rica deems more appropriate to exclude such losses in the context of results-based payments.

  Costa Rica has a mountain range composed exclusively by volcanoes (*Cordillera Volcánica Central*), six of which are active (*Arenal, Miravalle, Rincón de la Vieja, Poás, Irazú* and *Turrialba*). During 1986-2013, volcanic activity impacted 6,105.42 hectares of land (0.12% of the total accounting area), destroying 1,580.67 hectares of forests (63.6% of which were old-growth forests). Considering that areas impacted by volcanic activity can easily be identified in satellite images (Figure 3) and that volcanoes can inflict significant non-anthropogenic damage to forests, Costa Rica decided to exclude forest losses associated to volcanic activity from its proposed FREL/FRL and proposes to do the same in future measurement and reporting.

  Similarly, flooding and river meandering may cause non-anthropogenic forest loss that could actually increase in the future as a consequence of more extreme weather events related to climate change. During 1986-2013, 16,693.29 hectares of forests (55.4% of which were old-growth forests) were lost to river meandering. As in the case of volcanic activity, forest-related emissions caused by flooding and river meandering are measured and reported, but excluded from the FREL/FRL.

Figure 3. Examples of non-anthropogenic losses of forest cover associated to volcanic eruptions (red colored areas) and river-meandering (purple-colored areas).



6 Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, J. R. G. Townshend, 2013. High-resolution global maps of 21st-Century forest cover change. Science: 342 (6160):850-853. Available at: https://earthenginepartners.appspot.com/science-2013-global-forest

(Figure 3 continued).

2.2. Historical reference period

Costa Rica has demonstrated strong political commitment for REDD+. Together with Papua New Guinea, Costa Rica proposed REDD+ under the UNFCCC in 2005 and has actively participated in subsequent negotiations ever since. REDD+ is included in the country's INDC, evidencing a continued interest in considering forests as part of a global solution to climate change and under the Paris Agreement.

In Costa Rica, political commitment has been coupled with on-the-ground early actions for reducing emissions. Effective forest policies and programs have been installed well before 1996. For example, since 1995, Costa Rica has invested over 200 million[7] United States Dollars (USD) of public funds and a total of over 320 million USD[8] considering all funding sources for PSA. This has enabled payments for over 1 million hectares (20% of Costa Rica's territory).

National parks and other forms of conservation areas cover approximately 26% of Costa Rica's territory. The establishment of national parks and conservation areas came with a very high cost, both financially and economically. The cost of managing the current Protected Area System ranges from 39-134 million USD[9]. Economically, Costa Rica compromised agricultural production in a quarter of its territory; as well as jobs, rural economic growth, and coastal development. Still, many people originally relocated outside current protected areas have not been appropriately compensated. Costa Rica's National REDD+ Strategy has developed specific measures to deal with this.

This context is relevant for distinguishing two periods of enhanced mitigation actions in Costa: **1997-2009** and **2010-2025.** The first period was defined to reflect the adoption of relevant policies and regulations to reduce deforestation and enhance forest coverage while the second period is marked by the adoption of enhanced commitments by the government of Costa Rica and additional public spending on mitigation actions.

- The historical reference period of the first period (1997-2009) is **1986-1996**.
- The historical reference period of the second period (2010-2025) is **1997-2009.**

The first period started with the adoption of the current Forestry Law, passed in 1996, which includes various innovative policy instruments such as the PSA program. This Law entered into force

7 Exact amount is 109.685.936.083 Colones (data Available here).
8 Exact amount is 172.049.699.033 Colones (data Available here).
9 According to REDD+'s financial projections for 2010-2025 (data Available here).

with the publication of its regulation on January 23, 1997[10]. Starting the first historical reference period in 1986 up to December 1996 would allow for the measurement, reporting and verification of emissions and removals additional to a business-as-usual (BAU) performance, considering policies and programs implemented since 1997.

The second period is characterized by the adoption of new commitments and additional investments in mitigation actions. According to Costa Rica's R-PP and ER-PIN[11], the country's National REDD+ Strategy under the FCPF Carbon Fund began in 2010. Close to this date (July 03, 2008[12]), the Law 8640 was passed. This law increased PSA financial resources in USD 30 million and directed USD 10 million to creating a heritage fund for the protection of biodiversity (FBS). Hence, an important step was taken to increase ambition in compensating environmental services, including GHG mitigation, as well as co-benefits. Additionally, during 2009-2010, following a mandate from the General Comptroller Office of the Republic, the National Forestry Development Plan was updated for the period 2011-2020, which included specific REDD+ and GHG mitigation objectives and actions. It is also very important to note that the ongoing information, pre-consultation and consultation processes with stakeholders are based on the start of REDD+ implementation in 2010, with the goal of increasing ambition over time.

Use of historical information (para. 2b, annex to 13/CP.19)

For the construction of the proposed FREL/FRL, a 1986-2013 time series of land use maps was developed. This time series was specifically designed for REDD+ with the goal to ensure consistent methodologies, data and assumptions when estimating AD. Satellite imagery was collected and analyzed starting for 1985/86, 1991/92, 1997/98, 2000/01, 2007/08, 2011/12 and 2013/14. This time series was developed at the national level and is the product of a 2-year process lead by the Government of Costa Rica with participation of multiple institutions, national and international experts.

Emission factors (EF) were mostly obtained from the first (and only) field collection campaign (2013-2014) of the National Forest Inventory (NFI), but were complemented by data collected from nationally derived scientific literature dating back to 2005.

2.3. REDD+ activities included in the FREL

According to Decision 1/CP.16, paragraph 70, the following activities were included in the FREL/FRL: **emission reductions from deforestation,** and **enhancement of forest C stocks**. At the moment, sufficient quality data are lacking to include the remaining REDD+ activities.

2.4. Greenhouse gases and C pools

The proposed FREL/FRL includes carbon dioxide (**CO_2**) emissions and removals associated to changes in C stocks in the following pools: **above-ground biomass** (AGB), **below-ground biomass** (BGB), **dead wood** (DW), and **litter** (L). Soil organic carbon (SOC) and Harvested Wood Products (HWP) were not

[10] Available at: http://www.cne.go.cr/cedo_dvd5/files/flash_content/pdf/spa/doc386/doc386-contenido.pdf

[11] Approved by the Carbon Fund in its resolution CFM/5/2012/1, which acknowledged the high quality of the ER-PIN (para. 1) and granted additional financing to move towards the ER-P (para. 2 and 3). In addition, the annex of the resolution identified key issues, these do not include an objection to the start of the National REDD+ Strategy or the ER-P in 2010.

[12] Year 2010 is also defined as the start year of the second period considering that between the Law approval by the Legislative Assembly in 2008 and its full implementation in 2010 it was necessary to complete operational and financial procedures to execute disbursements by the World Bank. Administrative measures also took additional time, for example, the incorporation of financial resources into the annual budget and the implementation of adjustments to the Procedural Manual of the PSA, which is reviewed on an annually basis.

included considering the limited availability of data. Costa Rica will consider these C pools in light of the potential inclusion of additional REDD+ activities, such as forest degradation and forest management, in future revisions of its FREL/FRL.

Before 1997, slash-and-burn was the common practice for land use change in Costa Rica, as this was the easiest way to convert forests to grasslands and croplands (Sader and Joyce, 1988)[13].In 1997, conversion of forest became illegal with the current Forest Law; hence, slash-and-burn dramatically decreases after 1996. For this reason, biomass burning and related emissions of methane (**CH_4**) and nitrous oxide (**N_2O**) were included in conversions of forests to cropland and grassland that occurred in the period 1986-1996, and excluded in the post-1996 period.

Data on C stocks were obtained from recent (2005-2015) scientific literature and the NFI. As shown in Table 1, the tree below-ground biomass was estimated following Cairns *et al.* (1997)[14], while non-tree below-ground biomass was obtained from IPCC default values.

Above-ground biomass, dead wood and litter were entirely estimated from direct measurements carried out in Costa Rica and are therefore considered Tier 2 level data, while below-ground tree biomass, harvested wood products and biomass burning were estimated by combining national data with IPCC default factors, and are thus considered a mix between Tier 1 and Tier 2.

Table 1. Greenhouse gasses and carbon pools included in the FREL.

GHG	Carbon pool		Symbol	FREL	Tier level	Comment
CO_2	Above-ground biomass	Trees	ABG.t	included	Tier 2	Data from direct measurements
		Non-trees	ABG.n	included	Tier 2	Data from direct measurements
	Below-ground biomass	Trees	BGB.t	included	Tier 1/2	Cairns *et al.* (1997).
		Non-trees	BGB.n	included	Tier 1	IPCC default values
	Dead wood	Above-ground (standing and lying)	DW.s DW.l	included	Tier 2	Data from direct measurements
		Below-ground	DW.b	excluded		
	Litter		L	included	Tier 2	Data from direct measurements
	Soil organic carbon		SOC	excluded		
	Harvested Wood Products		HWP	excluded		
Non-CO_2	Biomass burning	Methane	CH_4	included	Tier 1/2	IPCC default factors
		Nitrous oxide	N_2O	included	Tier 1/2	IPCC default factors

The detailed list of data and references used to estimate carbon stocks are available in a Microsoft Excel file BaseDeDatos_v5 and are further referenced in the sheet "C-STOCKS" of the spreadsheet tool developed for the calculation of the proposed FREL/FRL (FREL TOOL CR).

2.5. Exclusion of non-anthropogenic emissions

As mentioned in section 2.1, Costa Rica deems more appropriate, in the context of results-based payments, to measure and report forest-related emissions associated to natural disturbances separately from anthropogenic emissions and to exclude non-anthropogenic sources of GHG

13 Sader, S. y A. Joyce, 1988. Deforestation rates and trends in Costa Rica, 1940 to 1983. Biotropica 20:11-19.

14 Cairns, M. A., Brown S., Helmer E. H., and Baumgardner G. A., 1997. Root biomass allocation in the world's upland forests. Oecologia 111: pp. 1-11.

emissions from its FREL/FRL as well as from REDD+ results. This proposal takes into account Costa Rica's national circumstances, especially in relation to its vulnerability to various types of extreme natural disturbances, such as volcanic activity, earthquakes, flooding, changes in river courses, etc. These losses are not anthropogenic and should not be included in the estimation of emission reductions for result-based payments.

Please note that the enhancement of forest C stocks through natural regeneration included in the proposed FREL is anthropogenic. Natural regeneration is vegetation that grows on lands previously used for agriculture, grazing or other purposes, and occurs after a conscious decision by the landowner to let the forest re-grow. Some lands where natural regeneration is fostered may continue to be Forest land remaining Forest land permanently, while in other cases, natural regeneration is removed after a period of time to revert to agricultural practices. As explained in Section 4, if at any point in time this natural regeneration complies with the definition of forest and is later removed, it is considered as deforestation in the FREL. Emissions from deforestation, but also absorptions due to natural regeneration are included in the FREL.

2.6. Managed and non-managed lands

Managed lands are all lands included in *Cropland*, *Grassland*, *Wetlands*, *Settlements* and *Other lands* categories (Section 4.3.1). *Forest land* include managed and non-managed lands. Non-managed lands are comprised of primary forests[15]. All primary *Forest land* converted to other land use categories are considered to be managed immediately after conversion. This means that emissions and absorptions in primary *Forest land remaining Forest land* are not included in the FREL/FRL. All lands that transitioned to *Forest land* during the historical reference period are considered "secondary". Some lands were considered to be "secondary" at the beginning of the historical reference period (please see Section 4.3.1 for more information).

2.7. Forest lands in transition

Considering the *good practices* recommended in the 2006 IPCC Guidelines, Costa Rica defines two periods for lands transitioning to *Forest land*. Four- and eight-year thresholds were used to define when land transitions to *Forest land remaining Forest land*, for wet and dry forests, respectively. These values are directed related to parameters defined for determining when a forest meets the minimum threshold values of the definition of "forest" and is "visible" using LANDSAT images. These parameters are based on Expert Judgment (for more information please see Section 4.1). All CO_2 absorptions included in Costa Rica's FREL/FRL occur in *Forest land remaining Forest land* (except for primary forests which are considered non-managed).

2.8. Drivers of deforestation and forest regeneration

Deforestation and forest regeneration were assessed for 1987-2013 at the national and sub-national level[16]. This assessment was based on the same land use maps used for the construction of the FREL. This data was combined with ancillary information from national agricultural censuses to determine key drivers of deforestation and forest regeneration. It is important to note that deforestation

[15] A very small fraction of Costa Rica's primary forests are managed for timber or other purposes. According to information from the National Forest Resources System (SIREFOR[15]), in 2013 a total of 362.1 ha were managed for 6,583 m^3 of timber at the national level. This represents less than 0.02% of the total area of primary forests in 2012/2013 and 1.37% of total timber production. Costa Rica acknowledges that this is a small source of emissions that is not included in the FREL/FRL. For more information please go here.

[16] CDI, 2015.d. Patterns and factors of change in the natural forest cover of Costa Rica, 1987-2013. Report prepared for the Government of Costa Rica under the Carbon Fund of the Forest Carbon Facility (FCPF). 57 p (available here).

reflects current conditions and decision-making by land-owners, while forest regeneration results from longer-term land use planning considerations.

According to regional validation of the findings at the national level, the following were identified as key drivers (in order of importance; in parenthesis the relative contribution to land use change decision making by land-owners):

- Prices of key agricultural crops (24%)
- Tourism (employment, land value) (9%)
- Urban markets growth and increase of urban demand for derived products (8%)
- Proximity and access to the central valley (control, land price) (8%)
- Changes in employment structure (to urban and tourism) (7%)
- Productive transformation towards agribusiness systems (productive intensification) (7%)
- Demand increase of cattle products (6%)
- Rural-urban migration (5%)
- Foreign labor force, rural labor force availability (4%)
- Appropriate ecological context for cattle (4%)
- Fall of livestock density capacity (3%)
- Fall of livestock density capacity in regions neighboring traditional livestock areas (3%)
- Indigenous productive systems (3%)
- Foreign labor force availability in services sector (2%)
- Land cost increase in neighboring regions (2%)
- Forest moratorium (2%)
- Land cost increase (in other economic activities) (1%)

Key additional information on drivers

Besides these key drivers, during the assessment other key findings were identified:

Net forest gain: for 1987-2013, changes in primary *Forest land* were small. Due to a fall in gross deforestation and an increase in forest regeneration, a net gain in forest cover was observed.

Direct factors: during 1987-2013, 70% of *Forest lands* are converted to *Grasslands*, a little over 20% are converted to *Croplands* and almost 10% to tree plantations. Land converted to *Forest land* was previously *Grassland* (65%), *Cropland* (20%) and tree plantations (20%).

Effect of land tenure regime: higher deforestation rates were observed in private lands. Higher forest regeneration rates were found in State-owned National Parks. There seems to be a gradient of deforestation by land tenure regime (a deforestation rate of 1.4% was observed in Private Lands, 0.9% in mixed-tenure Wilderness Areas, 0.3% in indigenous territories and 0.1% in Protected Areas.

Effect of forest age: forest age is an important factor driving deforestation in all land tenure regimes; the deforestation rate in forests <15 years was 4.5%, 2.0% in 15-25-year forests and <1.0% in forests >25 years; arguably, deforestation is more likely in younger forests.

Deforestation concentration: higher concentration of deforestation was found in the North Pacific coast and foothills (34% of total deforestation in 1987-2001 and 19% in 2001-2013), the North Caribbean plateau and coast (28% and 31% of total deforestation for 1987-2001 and 2001-2013, respectively), and the South Range (with 6% and 14%, respectively). For forest regeneration, these are the most important regions as well. For the same periods, North Pacific coast and foothills 35% and 29%, the North Caribbean plateau and coast 20% and 20%, and South Range 8% and 5%.

More information is included in a technical report, available here.

3. Transparent, consistent, complete and accurate information

3.1. Consistency with the national GHG inventory

Important efforts have been conducted to harmonize GHG reporting under the UNFCCC, including National GHG inventories and REDD+. Namely, the historical data mentioned in section 2.2 and further described in section 4.3 were used to recalculate the years 2005, 2010 and 2012 of the 2012 GHG inventory, included in Costa Rica's first BUR (2015)[17]. Due to time and resources constraints, only these inventory years were considered in the recalculations. The years 1990, 1995 and 2000 will be recalculated as well and reported in the country's next National Communication to the UNFCCC.

For the AFOLU sector and in relation to REDD+, the current GHG inventory included the following sources and sinks:

- GHG emissions and CO_2 absorptions from carbon stock changes in biomass, dead organic matter and mineral soils, for managed lands;
- CO_2 and non-CO_2 emissions from biomass burning, in managed lands;

The following sections provide a description of the latest National GHG Inventory.

Forest land remaining Forest land

C stock changes were estimated for tree plantations. AD were derived from the 2014 National Agriculture Census, *i.e.* Tier 2. Emission factors (EF) were identified for the 8 most important tree species planted in Costa Rica, while all other species were grouped in "others" and were assigned a generic EF. All EF are IPCC Tier 1, according to Tables 4.11A and 4.13, p. 4.61 and 4.64 of Chapter 4, Vol. 4, IPCC 2006. The carbon fraction employed was 0.47 and the root-to-shoot ratio 0.25. CO_2 emissions from HWP were estimated according to national statistics. In 2012, -1,451 Gg CO_2 were absorbed in 74,625 ha of tree plantations, CO_2 emissions from HWP were 575 Gg and carbon losses due to other disturbances were 608 Gg. Overall, a net removal of -267 Gg of CO_2 was estimated for tree plantations.

Lands converted to Forest land

Forest regeneration in Cropland and Grassland was included in the GHG inventory. AD were derived from the 1986-2013 land use change analysis developed for REDD+ (Sections 2.2. and 3.4.). For estimating EF, IPCC default factors were used (Table 10, p.4.59, Chapter 4, Vol. 4, IPCC 2006). In 2012, removals of -9,062 Gg of CO_2 were estimated for five forest types in 794,729 ha. C losses due to disturbances were 1,891 Gg. Overall, removals of -7,170 Gg of CO_2 were estimated for forests that re-grew in non-Forest lands.

Forest lands converted to other land use categories

For Forest lands converted to Cropland and Forest lands converted to Grassland, AD were derived from the 1986-2013 land use change analysis. In 2012, total CO_2 emissions were 2,238 Gg and 3,053 Gg, respectively. Overall, these emissions occurred from the conversion of 33,840 hectares of forest.

[17] Ministerio de Ambiente y Energía (MINAE), Instituto Meteorológico Nacional (IMN), 2015. Costa Rica: informe bienal de actualización ante la Convención Marco de las naciones Unidas sobre el Cambio Climático. San José (Costa Rica), 106 p. Available here.

Non-CO_2 emissions

CH_4 and N_2O emissions were estimated from biomass burning in Forest lands. AD were obtained from the National Fire Management Program. In 2012, a total of 9,998 ha were burned, resulting in 3.00 Gg of CH_4 and <0.00 Gg of N_2O.

3.2. Consistency with the Annex to Decision 12/CP.17

The information presented here is meant to be consistent with COP decisions 1/CP.16, 12/CP.17 and 13/CP.19. The document was drafted in a way to facilitate its review by the UNFCCC Secretariat. If additional information is required, it can be obtained through Costa Rica's REDD+ website at www.reddcr.go.cr or through Costa Rica's REDD+ Secretariat at asaenz@fonafifo.go.cr or via telephone at +(506) 2545-3501. The FREL/FRL was estimated following the 2006 IPCC guidelines.

(a) Information that was used by Parties in constructing a forest reference emission level and/or forest reference level, including historical data, in a comprehensive and transparent way: for an explanation of how historical data was employed, see section 2.2. For increasing transparency of the information used to estimate the FREL, the REDD+ Secretariat compiled a list of technical documents and data. These are available here. If further information is required, please email asaenz@fonafifo.go.cr or jfernandez@fonafifo.go.cr.

(b) Transparent, complete, consistent and accurate information, including methodological information, used at the time of construction of forest reference emission levels and/or forest reference levels, including, inter alia, as appropriate, a description of data sets, approaches, methods, models, if applicable and assumptions used, descriptions of relevant policies and plans, and descriptions of changes from previously submitted information: the description of how information used to construct the FREL/FRL is transparent, complete, consistent and accurate is explained in detail in section 4. Throughout the document, a description of data sets, approaches, methods and models is provided.

(c) Pools and gases, and activities listed in Decision 1/CP.16, paragraph 70, which have been included in forest reference emission levels and/or forest reference levels and the reasons for omitting a pool and/or activity from the construction of forest reference emission levels and/or forest reference levels, noting that significant pools and/or activities should not be excluded: an explanation of included and excluded activities and carbon pools is presented in sections 2.3. and 2.4., respectively.

(d) The definition of forest used in the construction of forest reference emission levels and/or forest reference levels and, if appropriate, in case there is a difference with the definition of forest used in the national greenhouse gas inventory or in reporting to other international organizations, an explanation of why and how the definition used in the construction of forest reference emission levels and/or forest reference levels was chosen: the definition of "forest" used in the construction of the FREL/FRL is:

- **Minimum area: 1.00 ha;**
- **Minimum forest canopy cover: 30%;**
- **Minimum height of trees: 5.00 m.**

This definition is consistent with the definition of "forest" that Costa Rica reported under the Clean Development Mechanism (CDM) and is also consistent with the definition of "forest" used in the context of the national GHG inventory. However, this definition is different from Costa Rica's reports to FAO's Forest Resources Assessment (FRA). Under FAO-FRA, Costa Rica defines "forest" as:

- Minimum area: 0.50 ha;

- Minimum forest canopy cover: 10%;
- Minimum height of trees: 5.00 m.

Costa Rica deemed more appropriate to maintain consistency in all its GHG-related reports and therefore decided that using the definition already applied in the context of the National GHG inventory and the CDM.

Additionally, article 3 of Costa Rica's Forestry Law 7575 defines "forest" as a "Native or indigenous ecosystem, intervened or not, regenerated by natural succession or other forestry techniques that occupies a surface of two or more hectares, characterized by the presence of mature trees of different ages, species and appearance, with one or more canopies covering over seventy percent (70%) of the area and with more than sixty trees per hectare with a diameter at breast height (dbh) of more than fifteen centimeters". This definition translates to:

- Minimum area: 2.00 ha;
- Minimum forest canopy cover: 70%;
- Minimum height of trees: N.A.;
- Minimum number of trees: 60 per hectare (with a diameter of at least 15 cm at breast height).

Although these definitions are not entirely consistent, the definition of "forest" used in the context of REDD+ is broader and largely includes the definition of forest in the law (*i.e.* the 1-ha threshold defined for REDD+ includes the 2-ha requirement by law).

4. Information on the proposed FREL

4.1. Proposed FREL/FRL

The proposed FREL/FRL has been constructed using the data and methodological approaches summarized in this section and further described in the technical reports and related databases and spreadsheets referred to in this submission. To access these reports and databases please go here.

The FREL/FRL has been estimated as the sum of the **annual average emissions** from deforestation and the annual **average removals**[18] from enhancements of forest C stocks in the following two historical reference periods:

- **1986-1996** for the first period of enhanced mitigation actions (1997-2009);
- **1997-2009** for the second period of enhanced mitigation actions (2010-2025).

The proposed FREL/FRL, expressed in tons of carbon dioxide equivalent per year (t CO_2e yr^{-1}), was estimated as follows (all emissions and removals are annual averages):

- For the period **1997-2009** (with the historical reference period 1986-1996):

Emissions from deforestation:	**17,064,070**	100.0%
- Deforestation of primary forests:	14,903,561	87.3%
- Deforestation of secondary forests:	2,160,509	12.7%
Removals through C-stock enhancements:	**-2,152,603**	100.0%

- For the period **2010-2025** (with the historical reference period 1997-2009):

Emissions from deforestation:	**8,590,840**	100.0%
- Deforestation of primary forests:	6,477,346	75.4%

18 Removals are expressed as negative numbers, as CO_2 is directly removed from the atmosphere.

- Deforestation of secondary forests:	2,133,494	24.6%
Removals through C-stock enhancements:	**-4,225,681**	100.0%

Figure 4 shows forest-related emissions and removals in Costa Rica between 1985/86 and 2012/13. Figure 5 shows the proposed FRELs and an estimation of emission reductions based on current measurements. Table 2 shows **annual emissions from deforestation** and **removals from forest C stock enhancement** for 1986-2009 and the estimation of total and annual average emissions and removals for two historical periods: 1986-1996 and 1997-2009.

The proposed FREL/FRLs are:

For the REDD+ implementation period 1997-2009:**14,911,467** t CO_2e yr^{-1}
For the REDD+ implementation period 2010-2025: **4,365,160** t CO_2e yr^{-1}

Figure 4. Forest-related emissions and removals in Costa Rica between 1986 and 2013 (tCO_2-e yr^{-1}).

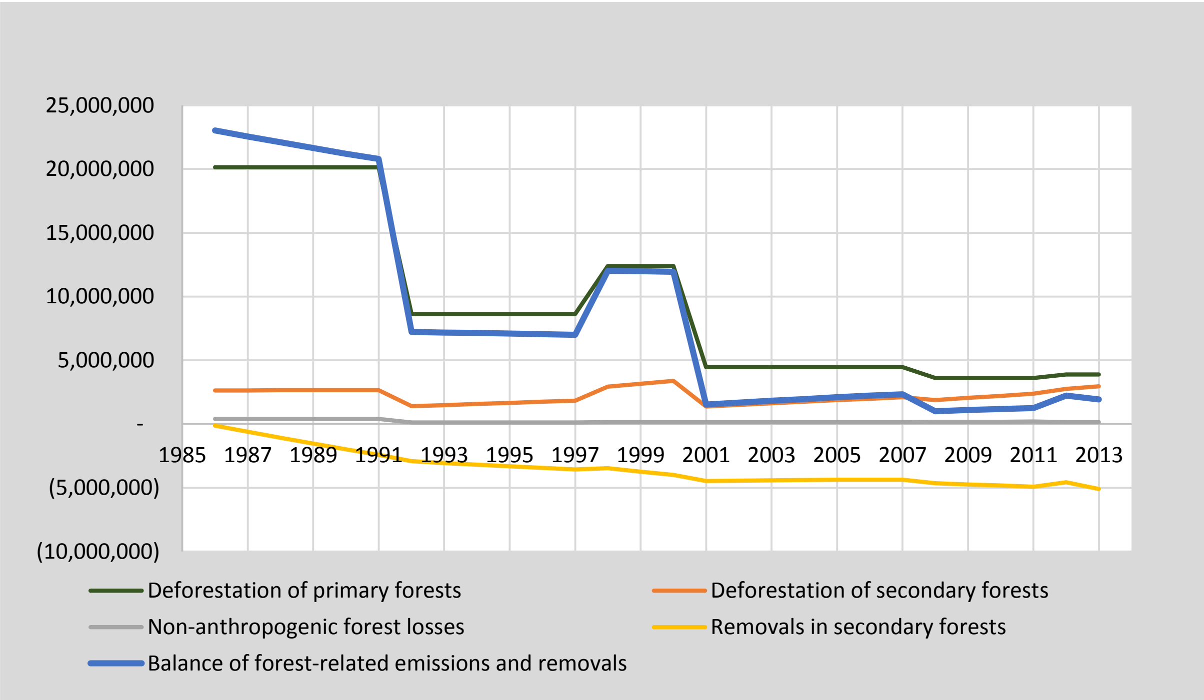


Figure 12 illustrates the estimated FREL/FRL for the two periods of enhanced mitigation actions (1997-2009 and 2010-2025, respectively) and the net emissions from the included REDD+ activities.

The difference between net emissions and the FREL/FRL for the period 1997-2009 is an emission reduction of -137,101,994 tCO_2-e (-10,546,307 tCO_2-e yr^{-1} on average) while for the period 2010-2014 the estimated emission reduction is -11,556,284 tCO_2-e (-2,889,071 tCO_2-e yr^{-1} on average).

Figure 5. FREL/FRL and actual forest-related net emissions included in the FREL/FRL ($tCO_2e\ yr^{-1}$).

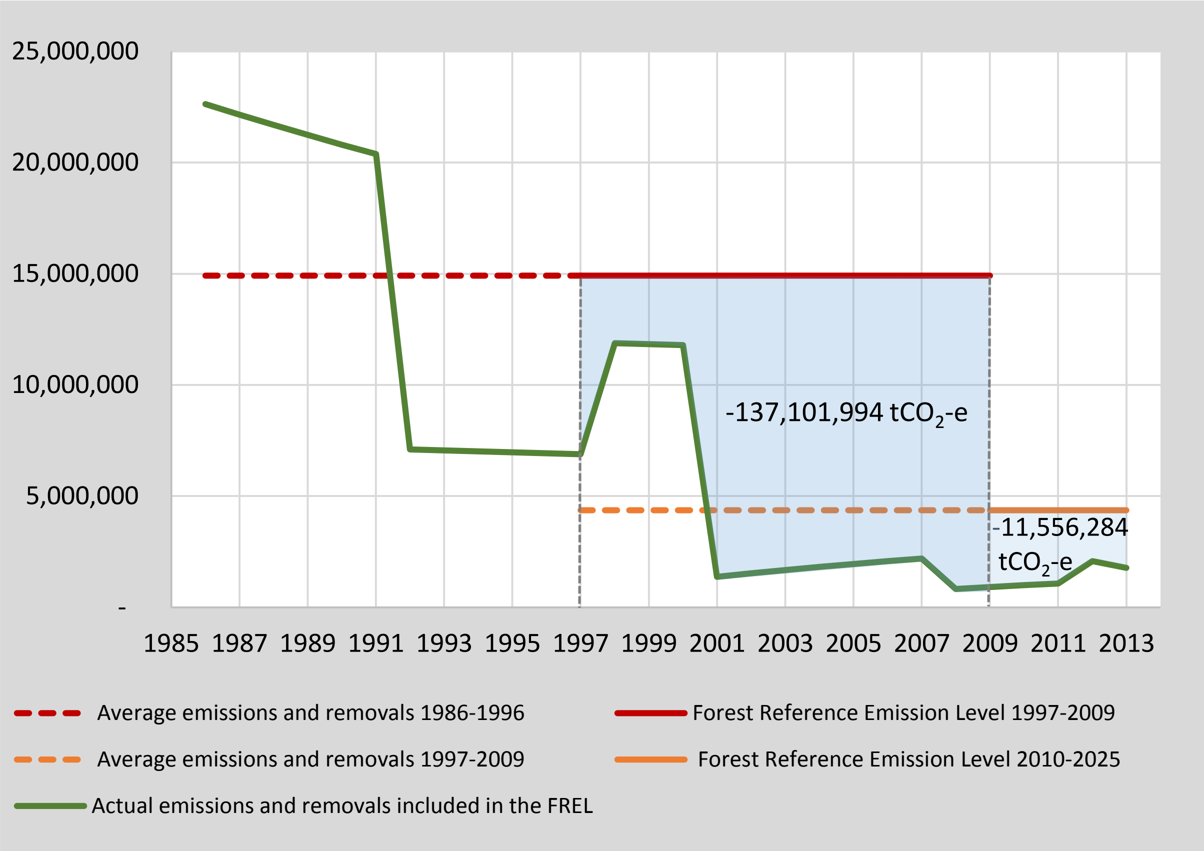


Table 2. Forest reference emission level/forest reference level proposed by Costa Rica.

PF = non-managed primary forest; SF = managed secondary forest

Year	Emissions from deforestation			Removals through enhancement of C stocks			Net emissions		
	PF	SF	Total	PF	SF	Total	PF	SF	Total
	tCO_2-e yr^{-1}	tCO_2-e yr^{-1}	tCO_2-e yr^{-1}	tCO_2-e yr^{-1}	tCO_2-e yr^{-1}	tCO_2-e yr^{-1}	tCO_2-e yr^{-1}	tCO_2-e yr^{-1}	tCO_2-e yr^{-1}
1986	20,137,007	2,631,044	22,768,051		(133,643)	(133,643)	20,137,007	2,497,401	22,634,408
1987	20,137,007	2,638,486	22,775,493		(615,380)	(615,380)	20,137,007	2,023,106	22,160,113
1988	20,137,007	2,645,724	22,782,731		(1,084,191)	(1,084,191)	20,137,007	1,561,533	21,698,540
1989	20,137,007	2,652,766	22,789,773		(1,540,369)	(1,540,369)	20,137,007	1,112,397	21,249,404
1990	20,137,007	2,659,616	22,796,623		(1,984,169)	(1,984,169)	20,137,007	675,447	20,812,454
1991	20,137,007	2,666,281	22,803,288		(2,415,773)	(2,415,773)	20,137,007	250,508	20,387,515
1992	8,623,426	1,397,098	10,020,524		(2,918,659)	(2,918,659)	8,623,426	-1,521,561	7,101,865
1993	8,623,426	1,488,297	10,111,723		(3,050,859)	(3,050,859)	8,623,426	-1,562,562	7,060,864
1994	8,623,426	1,576,882	10,200,308		(3,182,205)	(3,182,205)	8,623,426	-1,605,323	7,018,103
1995	8,623,426	1,662,922	10,286,348		(3,312,517)	(3,312,517)	8,623,426	-1,649,595	6,973,831
1996	8,623,426	1,746,481	10,369,907		(3,440,872)	(3,440,872)	8,623,426	-1,694,391	6,929,035
1997	8,623,426	1,827,616	10,451,041		(3,567,221)	(3,567,221)	8,623,426	-1,739,605	6,883,821
1998	12,396,451	2,936,065	15,332,515		(3,457,118)	(3,457,118)	12,396,451	-521,053	11,875,398
1999	12,396,451	3,168,688	15,565,139		(3,728,836)	(3,728,836)	12,396,451	-560,148	11,836,303
2000	12,396,451	3,394,316	15,790,766		(4,002,603)	(4,002,603)	12,396,451	-608,287	11,788,164
2001	4,455,983	1,381,703	5,837,686		(4,458,316)	(4,458,316)	4,455,983	-3,076,613	1,379,370
2002	4,455,983	1,509,820	5,965,803		(4,431,811)	(4,431,811)	4,455,983	-2,921,991	1,533,992
2003	4,455,983	1,633,999	6,089,982		(4,410,160)	(4,410,160)	4,455,983	-2,776,161	1,679,822
2004	4,455,983	1,754,367	6,210,350		(4,393,061)	(4,393,061)	4,455,983	-2,638,694	1,817,289
2005	4,455,983	1,871,041	6,327,024		(4,378,745)	(4,378,745)	4,455,983	-2,507,704	1,948,279
2006	4,455,983	1,984,133	6,440,116		(4,367,188)	(4,367,188)	4,455,983	-2,383,055	2,072,928
2007	4,455,983	2,093,750	6,549,732		(4,358,413)	(4,358,413)	4,455,983	-2,264,663	2,191,320
2008	3,600,417	1,874,696	5,475,113		(4,648,116)	(4,648,116)	3,600,417	-2,773,420	826,997
2009	3,600,417	2,045,235	5,645,652		(4,732,261)	(4,732,261)	3,600,417	-2,687,026	913,391
Total 1986-1996	**158,132,962**	**22,779,114**	**180,912,076**	**-**	**(23,678,638)**	**(23,678,638)**	**163,939,172**	**86,960**	**164,026,132**
Average 1986-1996	14,375,724	2,070,829	16,446,552	-	(2,152,603)	(2,152,603)	**14,903,561**	**7,905**	**14,911,467**
Total 1997-2009	**81,171,061**	**26,089,558**	**107,260,619**	**-**	**(54,933,848)**	**(54,933,848)**	**84,205,494**	**-27,458,420**	**56,747,074**
Average 1997-2009	6,243,928	2,006,889	8,250,817	-	(4,225,681)	(4,225,681)	**6,477,346**	**-2,112,186**	**4,365,160**

4.2. General estimation approach by REDD+ activity

4.2.1. Deforestation

According to the National GHG inventory and for purposes of the FREL/FRL, deforestation was defined as *Forest land converted to other land use* categories in the year of conversion. If deforestation occurs in primary forests (non-managed), such land is immediately considered as managed. AD for deforestation was obtained from a multi-year land use change time series. It is important to note that tree plantations are part of the sub-category "secondary forests", which are included in the *Forest land* category. Changes from secondary forests to other land uses are thus regarded as deforestation. If the land is allowed to regenerate back to a secondary forest or is planted again as part of a timber production regime, the event is recorded as conversion to *Forest land* at year 4 or 8, as appropriate. In Costa Rica, all forest conversion is illegal, so "legal" clear cutting does not exist. Hence, forest management does not incur in forest loss at any point of the silvicultural regime. Emissions from deforestation were estimated assuming constant C stocks over time in primary *Forest land* and variable C stocks according to forest age in secondary *Forest land*.

4.2.2. Enhancement of Forest C Stocks

It was assumed that *Forest land* in transition complies with the definition of forest at years 4 and 8, for wet and dry forests, respectively (see Section 4.1. for more details on land classification). C stock enhancement in secondary[19] *Forest land remaining Forest land* was estimated using growth models developed in Costa Rica (Cifuentes, 2008)[20]. These models estimate C stocks as a function of age. Cifuentes' equations were applied by determining the age of the forest in the year of the conversion and tracking forest age along the AD time series (more details are presented in Section 4.4).

Once a secondary forest is lost, this land is no longer considered under *Forest land remaining Forest land,* but under the land use category it converted to (*e.g.* Grassland). During this conversion, all *forest* C stocks were assumed to oxidize. However, post-deforestation, non-forest C stocks were considered. If later on in the time series, secondary forests were observed, this land was considered under *Forest land remaining Forest land.* Subsequent *forest* C stocks accumulation was considered under this category.

4.2.3. Excluded REDD+ activities

According to Costa Rica's National REDD+ Strategy, several policies and measures have been defined to implement all five REDD+ activities. However, due to data limitations, forest degradation and management were not included in the current FREL. In 2012, Costa Rica conducted its first National Forest Inventory (NFI), which provided important data on forest C stocks; nonetheless, the NFI is yet to provide gains and losses to estimate activity data and emissions factors for potential forest degradation. Besides the NFI, national-level information is lacking for the period 1985/86-2012/13 to accurately estimate potential forest degradation. In relation to forest management, information on timber harvesting in managed *Forest land* is available at the National Forest Resources System, but only for years 2011, 2012 and 2013. Also, as explained above, the managed forest area is very small in Costa Rica, hence this activity is likely to be not significant.

19 The term "secondary" refers to forests that regenerated from previously disturbed land. Secondary forests were completely cleared for agricultural production or due to natural disturbance events. The term "secondary" is helpful to distinguish these Forest lands from primary Forest lands, which are non-managed.

20 Cifuentes, M. 2008. Aboveground Biomass and Ecosystem Carbon Pools in Tropical Secondary Forests Growing in Six Life Zones of Costa Rica. Oregon State University. School of Environmental Sciences. 2008. 195 p.

4.3. Activity data

4.3.1. Consistent representation of lands

Land classification for deriving AD from the 1985/86-2012/13 land use change time series is consistent with the National GHG inventory (except for tree plantations, as explained below). The classes defined were:

1. Forest land:
   - 1.1 Wet and Rain Forests (*Bosques muy húmedos y pluviales*)
     - 1.1.1 Primary Forest
     - 1.1.2 Secondary forests
   - 1.2 Moist Forests (*Bosques húmedos*)
     - 1.2.1 Primary forest
     - 1.2.2 Secondary forest
   - 1.3 Dry Forests (*Bosques secos*)
     - 1.3.1 Primary forest
     - 1.3.2 Secondary forest
   - 1.4 Mangroves (*Manglares*)
     - 1.4.1 Primary forest
     - 1.4.2 Secondary forest
   - 1.5 Palm Forests (*Bosques de palma – Yolillales)*
     - 1.5.1 Primary forest
     - 1.5.2 Secondary forest
2. Cropland:
   - 2.1 Annual crops
   - 2.2 Perennial crops
3. Grassland
4. Settlements
5. Wetlands:
   - 5.1 Natural wetlands
   - 5.2 Artificial wetlands
6. Other lands:
   - 6.1 Paramo
   - 6.2 Bare soil
     - 6.2.1 Natural bare soil
     - 6.2.2 Artificial bare soil

A 1978/80 ancillary map was used to determine the area of primary and secondary *Forest land* at the beginning of the land use change time series. More information on this map is included in Annex 2. "**Primary forests"** are assumed to maintain constant C stocks per hectare over time, given that growth usually equals mortality and that these lands are not managed. However, Costa Rica acknowledges that due to forest management, natural disturbances and other factors, C stocks in primary forests are subject to fluctuations over time, resulting in emissions and removals of CO_2 and emissions of non-CO_2 gases. These emissions and removals may be considered at a later stage of development of Costa Rica´s FREL/FRL, by including "forest management" and "forest degradation" as additional REDD+ activities. Costa Rica currently does not have sufficient quality information for 1986-2013 to include these activities.

"**Secondary forests**" are forests that regenerated on non-forest land. They also include forests that were classified as "secondary" in 1985/86 according to the 1978/80 ancillary map. Secondary forests in 1985/86 are assumed to be representative of all possible age classes, up to 400 years old, with equal proportions of areas. To estimate C accumulation in these forests (identified with the notation "… - 1985" in Tables 3 and 4) it was assumed that all age classes grow old one year each year, as shown in Table 3. Since C stocks are stable in age classes ≥400 years (Cifuentes, 2008), the same C stock was assumed for all age classes ≥400 years".

Table 3. Age classes assumed to exist in different years of the historical period analyzed in secondary forests established before 1985/86.

Cohort	**Years of the historical period analyzed**						
	1986	1987	1988	…	2007	2008	2009
… - 1985	5	6	7	…	26	27	28
	6	7	8	…	27	28	29
	7	8	9	…	28	29	30
	8	9	10	…	29	30	31
	9	10	11	…	30	31	32
	…	…	…	…	…	…	…
	396	397	398	…	**418**	**419**	**420**
	397	398	399	…	**419**	**420**	**421**
	398	399	**400**	…	**420**	**421**	**422**
	399	**400**	**401**	…	**421**	**422**	**423**
	400	**401**	**402**	…	**422**	**423**	**424**

Note: This distribution of age classes per historical year applies to all types of secondary forests, except dry forests. For dry forest, 4 years should be added to the numbers shown in the table, as dry forests surpass the minimum threshold values of the parameters used to define "forest" at an age of 8 years (4 years in other forest types).

Secondary forests established after 1985/86 were assumed to have a number of age-classes equal to the number of years in the measurement period, *i.e*. 6 age classes for 1986-1991 and 1992-1997; 3 age classes for 1998-2000; 7 age classes for 2001-2007; 4 age classes for 2008-2011 and 2 ages classes for 2012-13. It was also assumed that, within a monitoring period, the same amount of area was established each year (*e.g.* for each hectare established between 1986 and 1991 it was assumed that 1/6 hectares were established annually). Table 4 shows how age classes were assumed to exist in different years of the historical reference period for the case of dry forests.

Table 4. Age classes assumed to exist in different years of the period analyzed in secondary forests (dry forests).

Cohort	**Years of the historical period analyzed**							
	1986	1987	1988	1989	1990	1991	1992	1993
… - 1985	9-401	10-402	11-403	12-404	13-405	14-406	15-407	16-408
1986-91	8	8-9	8-10	8-11	8-12	8-13	9-14	10-15
1992-97							8	8-9
1998-00								
2001-07								
2008-11								

Cohort	**Years of the historical period analyzed**							
	1994	1995	1996	1997	1998	1999	2000	2001
… - 1985	17-409	18-410	19-411	20-412	21-413	22-414	23-415	24-416
1986-91	11-16	12-17	13-18	14-19	15-20	16-21	17-22	18-23

1992-97	8-10	8-11	8-12	8-13	9-14	10-15	11-16	12-17
1998-00					8	8-9	8-10	9-11
2001-07								8
2008-11								

Cohort	Years of the historical period analyzed							
	2002	2003	2004	2005	2006	2007	2008	2009
... - 1985	25-417	26-418	27-419	28-420	29-421	30-422	31-423	32-424
1986-91	19-24	20-25	21-26	22-27	23-28	24-29	25-30	26-31
1992-97	13-18	14-19	15-20	16-21	17-22	18-23	19-24	20-25
1998-00	10-12	11-13	14-20	15-21	16-22	17-23	18-24	19-25
2001-07	8-9	8-10	8-11	8-12	8-13	8-14	9-15	10-16
2008-11							8	8-9

Note: This distribution of age classes per age cohort and year applies to secondary dry forests. For all other types of secondary forests, 4 year should be subtracted to the numbers shown in this table.

Despite all efforts, it was not possible to distinguish tree plantations as an additional sub-category in *Forest land*. The quality of the satellite imagery employed was not sufficient to overcome the spectral confusion of tree plantations with secondary forests and agro-forestry systems. As other sources of national information on forest plantation are neither spatially explicit nor complete for 1985/86-2012/13, forest plantations could not be considered in the FREL/FRL.

For these same reasons, some areas classified as “secondary forest” and as “permanent crop” may actually be tree plantations. Given this situation, the emission factor (EF) applied to secondary *Forest land remaining Forest land* does not differentiate between tree plantations and secondary forests. This is less accurate but avoids the over-estimation of removals in the historical reference period, considering that tree plantations generally grow faster than secondary forests.

It is important to note that the National GHG inventory reports emissions and removals in tree plantations based on the following AD:

- 115,157.00 hectares in year 2000. This is equivalent to 15.65% of the area of secondary forests estimated for 2000 (735,866 ha);
- 123,894.00 hectares in year 2005. This is equivalent to 16.29% of the area of secondary forests estimated for 2005 (760,530 ha);
- 74,627.00 hectares in year 2012. This is equivalent to 8.57% of the area of secondary forests estimated for 2012 (871,290 ha).

This information was derived from the 2014 National Agriculture Census and from non-spatial national statistics.

4.3.2. Data sources for estimating activity data

The construction of the AD time series required the following sources of data:

- Remotely sensed data from four generations of the Landsat family (Landsat 4 TM, Landsat 5 TM, Landsat 7 ETM and Landsat 8 OLI/TIRS).
- A “Life Zones” map according to the classification system of Holdridge (1966)[21]. This map was used to stratify “Forests” into the three sub-categories: “Wet and Rain Forests”, “Moist Forests” and “Dry Forests” (see Figure 6).

[21] Holdridge, L.R., 1966. The Life Zone System, *Adansonia VI: 2*: 199-203.

- Ancillary data (*i.e*. the various maps mentioned in the next section) to edit the results of the spectral classification of remotely sensed data and to further stratify the five forest categories “Wet and Rain Forests”, “Moist Forests”, “Dry Forests”, “Mangroves” and “Palm Forests” into the sub-categories “primary forests” and “secondary forest.

Figure 6. Grouping of life zones used for forest stratification and equations applied to estimate carbon stocks in secondary forests.

Forest strata	**Wet and rain forests**	**Moist forests**	**Dry forests**	**Mangroves**	**Palm forests**
Equation applied (see section 4.4.2.)	**Eq.04**	**Eq.05**	**Eq.06**	**Eq.07** **Eq.08**	**Eq.07** **Eq.08**
LIFE ZONES ACCORDING TO HOLDRIDGE (1966)				Spectral classification with posterior editions (see text).	
BOSQUE MUY HUMEDO MONTANO					
BOSQUE MUY HUMEDO MONTANO BAJO					
BOSQUE MUY HUMEDO MONTANO BAJO TRANSICION A HUMEDO					
BOSQUE PLUVIAL MONTANO					
BOSQUE PLUVIAL MONTANO BAJO					
BOSQUE PLUVIAL MONTANO TRANSICION A MONTANO BAJO					
BOSQUE PLUVIAL PREMONTANO					
BOSQUE PLUVIAL PREMONTANO TRANSICION A BASAL					
BOSQUE MUY HUMEDO PREMONTANO-ATLANTICO					
BOSQUE MUY HUMEDO PREMONTANO TRANSICION A PLUVIAL-ATLANTICO					
BOSQUE MUY HUMEDO TROPICAL					
BOSQUE MUY HUMEDO TROPICAL TRANSICION A PREMONTANO					
BOSQUE MUY HUMEDO PREMONTANO TRANSICION A BASAL-PACIFICO					
BOSQUE MUY HUMEDO PREMONTANO TRANSICION A BASAL-ATLANTICO					
BOSQUE MUY HUMEDO PREMONTANO-PACIFICO					
BOSQUE MUY HUMEDO PREMONTANO TRANSICION A PLUVIAL-PACIFICO					
BOSQUE HUMEDO MONTANO BAJO					
BOSQUE HUMEDO PREMONTANO					
BOSQUE HUMEDO PREMONTANO TRANSICION A BASAL					
BOSQUE HUMEDO TROPICAL					
BOSQUE HUMEDO TROPICAL TRANSICION A PERHUMEDO					
BOSQUE HUMEDO TROPICAL TRANSICION A PREMONTANO					
BOSQUE HUMEDO TROPICAL TRANSICION A SECO					
BOSQUE SECO TROPICAL					
BOSQUE SECO TROPICAL TRANSICION A HUMEDO					

4.3.3. Methods for mapping land use

The land use maps presented in Annex 1 were created using the methodology summarized here; further information may be found in a separate report[22] available at the Costa Rica REDD+ Documentation Center.

Pre-processing:

- **Selection of satellite images**. To minimize the area covered by clouds and cloud shadows, low cloud-coverage Landsat images were combined. In most cases, the scenes were selected from the same year and season but, in some cases it was necessary to select scenes from different years within a 14-month timeframe.

- **Registration**. All images were registered to a common system of coordinates (CRTM05). Mean quadratic error in control points was less than one pixel (30 m). Maximum registration error was estimated at 2 pixels (60 m). Ground control points were obtained from ortho-photographs from year 2005.

- **Radiometric normalization**. To reduce radiometric differences between images due to atmospheric conditions and in the calibration of the sensors at the image acquisition dates, all images were radiometrically normalized, by applying the "Iteratively Reweighted Multivariate Alteration Detection" (IR-MAD), as described by Canty and Nielsen (2008)[23].

Classification:

- **Methodology**. "Random Forest" (RF) by Breiman (2001)[24] was employed. This was implemented in two phases: (1) training or adjustment of the RF classifier, and (2) image classification using the RF classifier.

- **Training of the RF classifier**. Training sites were created by digitalizing homogeneous areas that corresponded to the land use categories of interest for 2001 and 2014. The following sources of data were used to create these training sites: (1) systematic plot grid (n = 10,000) from the national Forest Inventory, (2) high-resolution Rapideye images for 2013; and (3) GoogleEarth imagery. Using these datasets, ground-control points for training were generated randomly.

  Variables of the RF classifier: 20 variables were used to adjust the RF classifier using information from the spectral bands, vegetation indexes, variables related to the image texture and variables derived from a digital elevation model.

Post-processing:

- **Minimum mapping unit**. To avoid the "salt and pepper" effect and comply with the minimum area parameter of the definition of "forest: (1.00 ha), the products of the digital classification were filtered in order to represent the land use categories with a minimum mapping unit of 0.99 ha[25].

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22 Agresta, Dimap, Universidad de Costa Rica, Universidad Politécnica de Madrid, 2015.a. Informe Final: Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level: Protocolo metodológico. Informe preparado para el Gobierno de Costa Rica bajo el Fondo de Carbono del Fondo Cooperativo para el Carbono de los Bosques (FCPF). 44 p.

23 Canty, M. J. y A. A. Nielsen, 2008. Automatic radiometric normalization of multitemporal satellite imagery with the iteratively re-weighted MAD transformation. Remote Sensing of Environment 112 (2008):1025-1036.

24 Breiman, L., 2001. Random Forests. Machine Learning, 45:5-3. Available at: http://link.springer.com/article/10.1023/A%3A1010933404324

25 Due to the dimensions of the pixels in the Landsat images (30.00 m x 30.00 m) the minimum mapping area is 99 ha, which is equivalent to 11 pixels (11 x 30.00 m x 30.00 m).

- **Manual editions**. In order to improve land use mapping, several editions were made, largely aimed at decreasing high classification errors:

  (1) "*Forest Plantations*" were merged with the "*Forest land*" category (see Section 4.3.1.). This means that although initially classified as a separate class, @Forest Plantations@ presented a very high classification error and, for purpose of GHG estimation, it was treated as Forest land".

  (2) For estimating the area of "*Coffee Plantations*", several ancillary maps were used from the Ministry of Agriculture (MAG), the Costa Rican Coffee Institute (ICAFE) and the Costa Rican Meteorological Institute (IMN). These maps were used to correct the classified areas for the years 2000/01, 2007/08, 2011/12 and 2013/14. For previous maps, a mask representing potential "*Coffee Plantation*" areas was created using the location and elevation of all areas mapped as "Coffee Plantations" considering all available sources of information (MAG, ICAFE and IMN).

  (3) "*Mangroves*" and "*Palm Forests*" are forest ecosystems that exist in very specific soil conditions (e.g. high water table and, in the case of Mangroves, high salinity and influence of tides). This makes conversions of Mangroves and Palm Forests to other forest types, and vice versa, highly unlikely. For this reason, masks were created to represent all potential areas of "*Mangroves*" and "*Palm Forests*". Within these masks, all pixels originally classified as "*Forest*" were reclassified either as "*Mangroves*" or as "*Palm Forests*"; all pixels classified as "*Mangroves*" or "*Palm Forests*" outside the two masks were reclassified as "*Forest*".

  The "*Mangroves*" mask was created by adding all areas classified as "*Mangroves*" for 1986-2913 to the area classified as "*Mangroves*" according to the National Forest Inventory. Further, all areas <0 and > 20 m.a.s.l classified as "*Mangroves*" were reclassified as "Forest". The reclassification was then edited manually by visually comparing the areas classified as "*Mangroves*" with 2013 high-resolution Rapideye images.

  The "*Palm Forests*" mask was created using a similar approach. First all areas classified as "*Palm Forests*" for 1986-2013 were added to the area classified as "*Palm Forest*" according to the national Forest Inventory. The result was then manually edited by visually comparing the areas classified as "*Palm Forest*" with 2013 high resolution Rapideye images.

  (4) A mask was also created for "*Paramo*". "*Paramo*" is an ecosystem composed of shrubs and grasses that only occurs at high elevations, above the forest line. The area classified as "*Paramo*" in the National Forest Inventory was manually edited through visual interpretation using 2013 high resolution RapidEye images. Inside the mask, all pixels classified as "*Forest*" were reclassified as "*Paramo*"; conversely, all pixels classified as "*Paramo*" outside the mask were reclassified as "*Forest*".

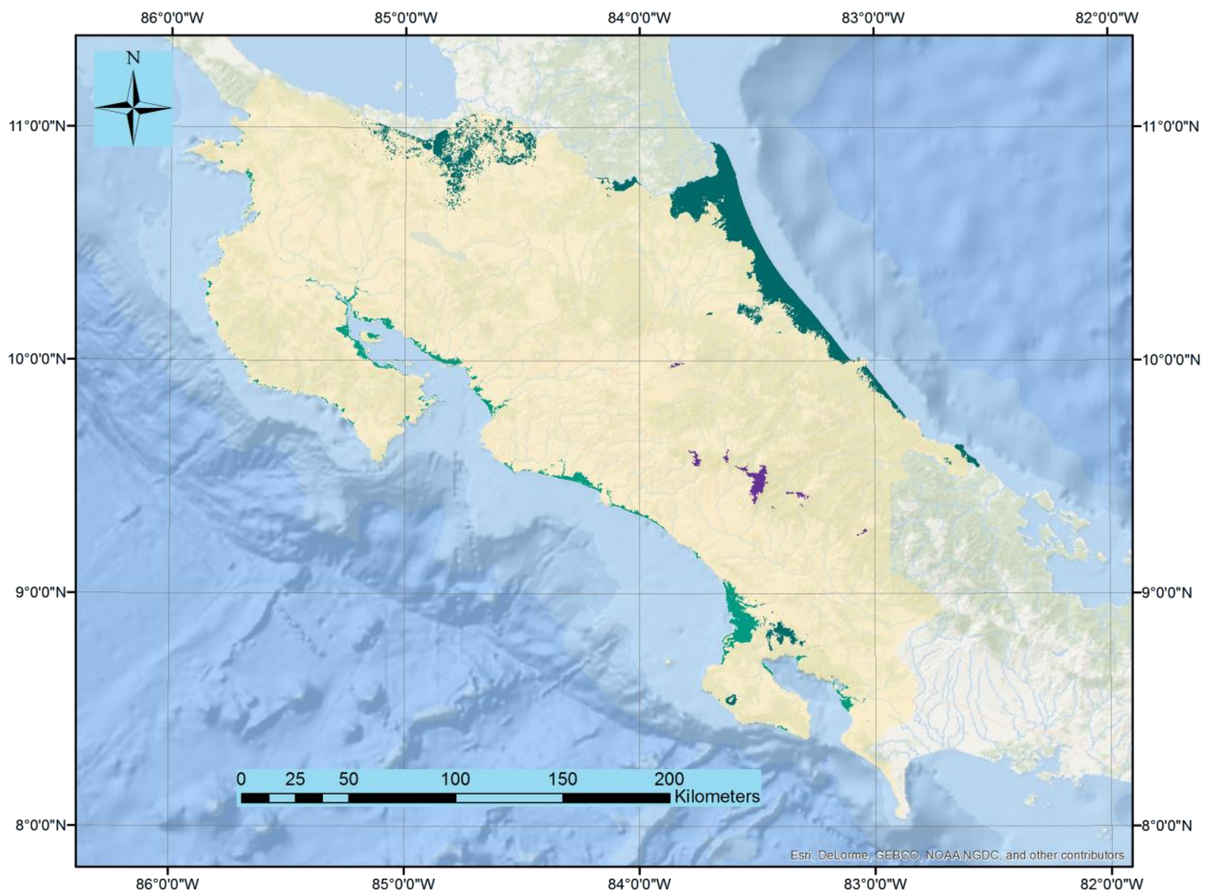
  (5) All masks representing "*Mangroves*", "*Palm Forests*" and "*Paramo*" have been compiled in a map of masks that will be kept in order to enable consistent map editions in future measurement and reporting (Figure 7).

  (6) Areas classified as "*Urban Areas*" in 2013/14 were manually edited through visual interpretation of 2013 high resolution RapidEye images and creation of a mask representing "*Urban Areas*" in 2013/14. Pixels originally classified as "*Urban Areas*" outside the mask were reclassified as "*Bare Soil*" and conversely, pixels classified as "*Bare Soil*" inside this mask were reclassified as "*Urban Areas*". Additionally, under the assumption that "*Urban Areas*" never convert to other land use categories, all pixels

within the 2013/14 "*Urban Areas*" mask that were classified as "*Urban Areas*" at some date between 1986 and 2013 were forced to remain "*Urban Areas*" in all posterior dates.

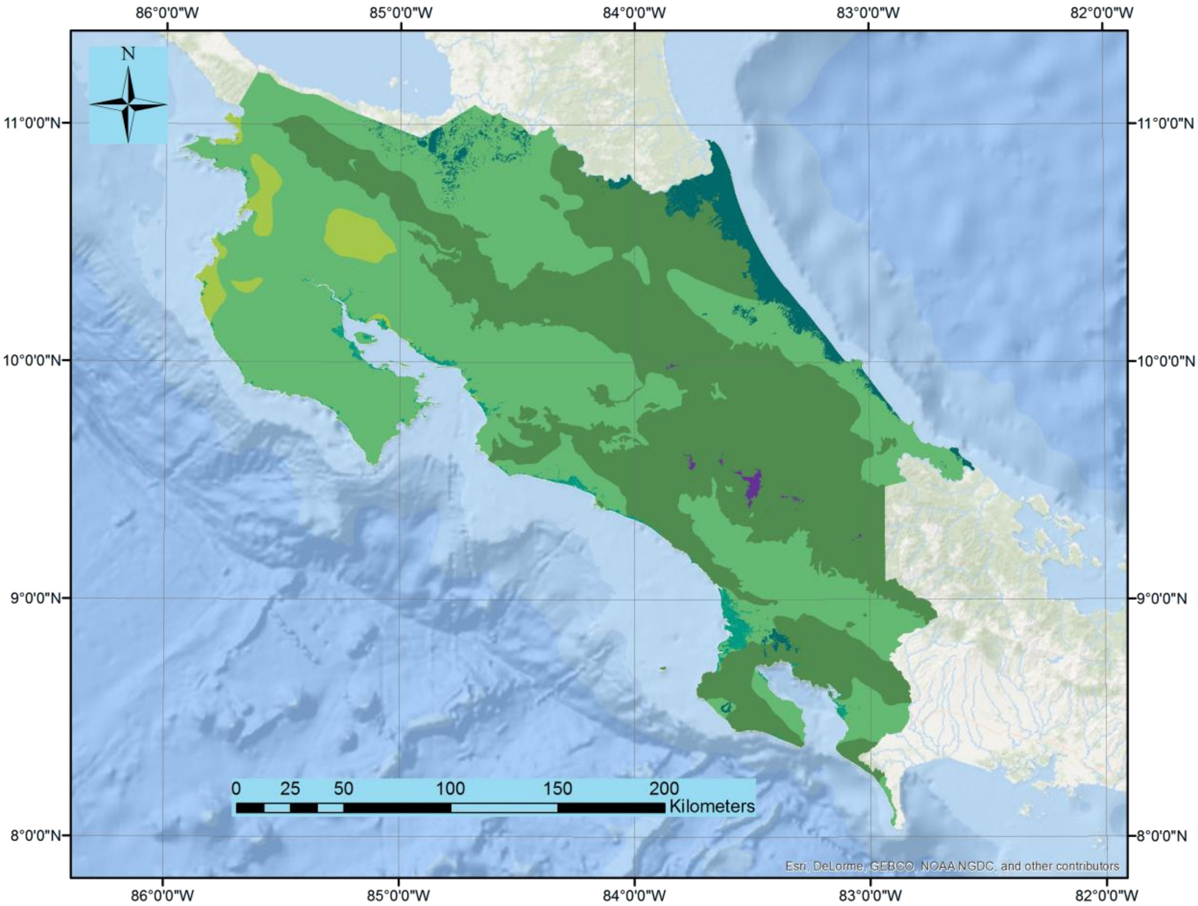
(7) In order to assign secondary forests to a forest type (Wet and Rain Forests, Moist Forests, Dry Forests, Mangroves, Palm Forests) a map of potential forest types was created. This map will also be used in future measurements for determining the forest type of secondary forests. The map of potential forest types (Figure 8) was created by combining the life-zones as shown in Figure 5 and then overlapping the map of the masks of potential areas of "*Mangroves*", "*Palm Forests*" and "*Paramo*" shown in Figure 6.

Figure 7. Map of the masks of potential areas of Mangroves, Palm Forests and Paramo.



Mask		Area
Color	Description	ha
	Mask of potential areas of Mangroves	53,894.61
	Mask of potential areas of Palm Forests	182,903.31
	Mask of potential areas of Paramo	10,430.19
	Other areas	4,866,711.39
	Total area	**5,113,939.50**

Figure 8. Map of potential forest types.



Potential Forest Type		Area
Color	Name	ha
	Wet and Rain Forests (*Bosques muy húmedos y*	2,138,674.32
	Moist Forests (*Bosques húmedos*)	2,593,615.41
	Dry Forests (*Bosques secos*)	134,421.66
	Mangroves (*Manglares*)	53,894.61
	Palm Forests (*Bosques de palma -Yolillales*)	182,903.31
	Paramo (*Páramo*)	10,430.19
	Total area	**5,113,939.50**

4.3.4. Methods for estimating AD

AD were estimated by combining all land use maps created for 1985/86-2012/13 in a Geographical Information System (GIS) and then extracting the values of the areas that remained in the same category or converted to other land use categories from the combined set of multi-temporal data. The results of this operation are reported in land use change matrices prepared for each measurement period in the sheets "LCM 1986-91", "LCM 1992-97", "LCM 1998-00", "LCM 2001-07", "LCM 2008-11", and "LCM 2012-13" of the spreadsheets in FREL TOOL CR.

To obtain annual AD, the land use change matrices were interpolated as follows:

- For all cells of the land use change matrices (except for the cells in the top/left – bottom/right diagonal):

  $AD_t = AD_p/T$ **(Eq.01)**

  Where:

  AD_t Interpolated annual AD applicable to year *t* within the monitoring period *p*; ha yr^{-1}

  AD_p AD for the period *p*; ha in *p* years

  T Number of years elapsed in the period *p* (e.g. 6 years for period 1986-91); years

- For all cells in the top/left – bottom/right diagonal of the land use change matrices:

  $AD_t = A_{(t-1)} - \Sigma(ADleft_t) - \Sigma(ADright_t)$ **(Eq.02)**

  Where:

  AD_t Interpolated annual AD applicable to year *t* within the period *p*; ha yr^{-1}

  $A_{(t-1)}$ Area of the initial land use category at the end of the previous year (*t-1*); ha

  $\Sigma(ADleft_t)$ Sum of all annual AD of year *t* in the cells of the same line of the matrix at the left of the cell for which AD is calculated; ha

  $\Sigma(ADright_t)$ Sum of all annual AD of year *t* in the cells of the same line of the matrix at the right of the cell for which AD is calculated; ha

The estimated annual AD are reported in the sheets "AD AAAA" of the FREL TOOL CR ("AAAA" indicates the year).

4.3.5. Results for activity data

Figure 9 shows forest cover in Costa Rica for 1985/86-2012/13. Figure 10 shows forest losses in the same period. Annual areas of forest loss estimated for primary forests are shown in Table 5 and those for secondary forests in Table 6. Table 7 shows the areas of new forests at the end/beginning of each period (*i.e.* 1985/86, 1991/92, 1997/98, 2000/01, 2007/08, 2011/12, and 2013/14). The results shown in Table 6 and Table 7 are reported at an aggregate level, more information is available in the spreadsheets in FREL TOOL CR.

Figure 9. Forest cover in Costa Rica between 1985/86 and 2012/13 (in hectares).

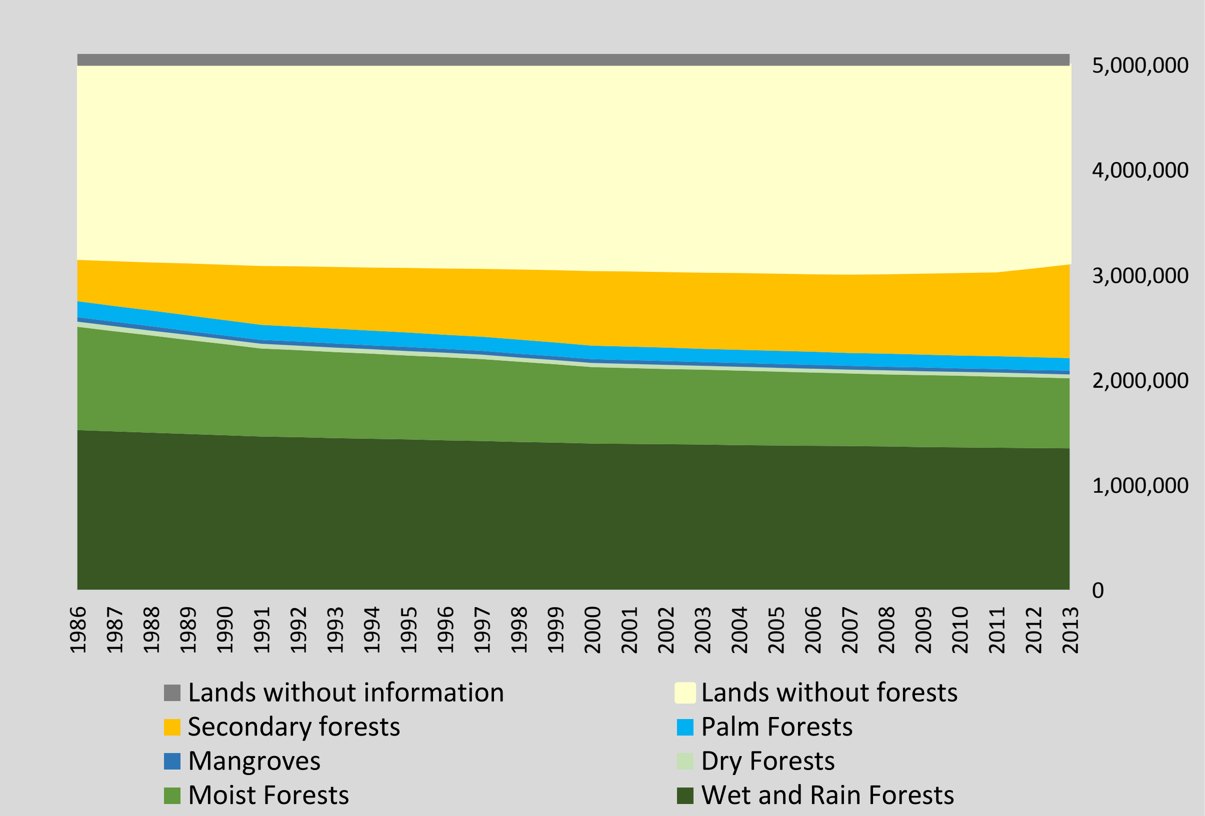


Figure 10. Forest loss in Costa Rica between 1985/86 and 2012/13 (hectares).

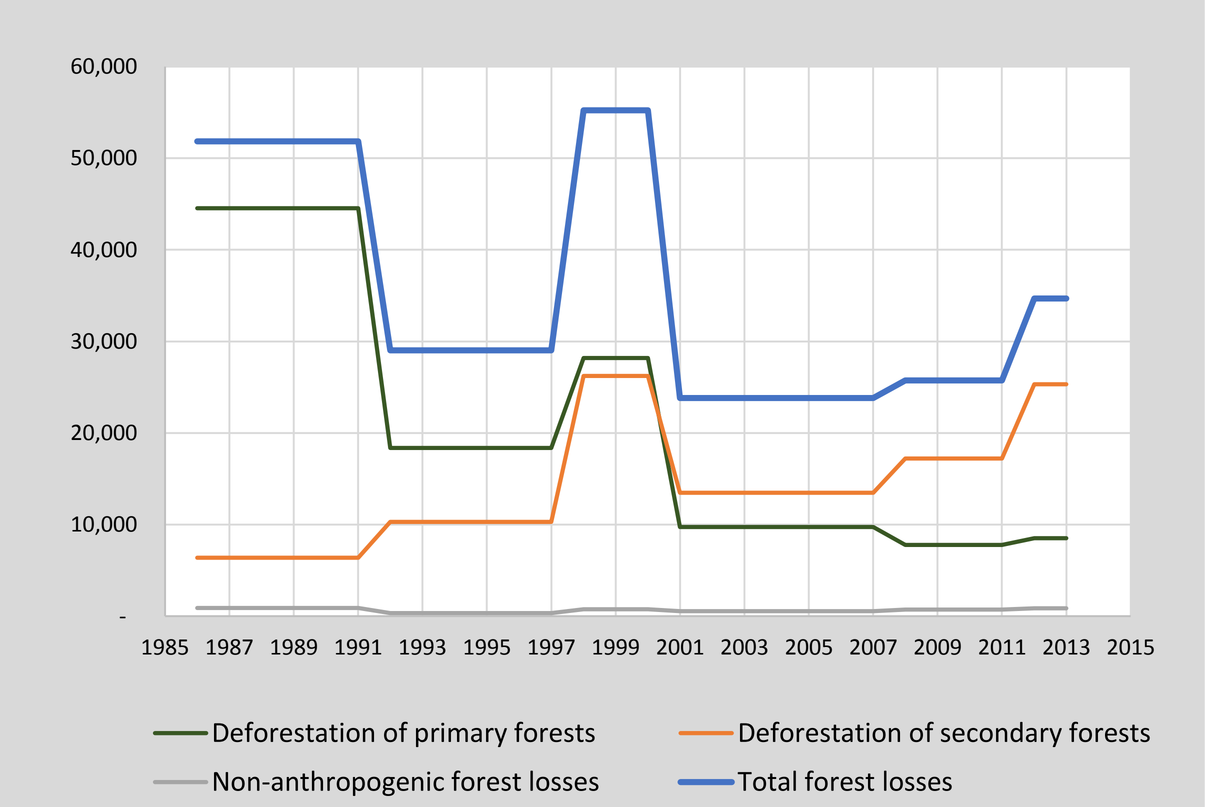


Table 5. Annual loss of primary forests.

	Primary Forests	1986-91	1992-97	1998-00	2001-07	2008-11	2012-13
	Forest category	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}
DF	Wet and Rain Forests	12,058.12	6,951.17	8,142.45	3,555.36	3,337.83	2,836.40
DF	Moist Forests	28,712.62	9,684.13	17,202.96	5,358.57	3,598.18	4,982.94
DF	Dry Forests	1,197.44	386.80	836.79	130.68	75.22	267.98
DF	Mangroves	366.25	116.04	225.18	77.88	62.15	54.23
DF	Palm Forests	2,215.37	1,224.44	1,786.35	638.27	713.25	368.24
DF	**Total primary forests**	**44,549.80**	**18,362.58**	**28,193.73**	**9,760.76**	**7,786.62**	**8,509.77**
NL	Wet and Rain Forests	214.52	93.45	66.63	66.56	111.22	51.35
NL	Moist Forests	116.88	27.63	38.73	52.60	48.04	54.68
NL	Dry Forests	0.51	0.57	0.75	0.08	-	2.93
NL	Mangroves	272.46	38.25	61.56	86.55	56.21	48.02
NL	Palm Forests	142.14	76.41	95.13	58.45	75.69	121.10
NL	**Total primary forests**	**746.50**	**236.31**	**262.80**	**264.24**	**291.15**	**278.06**
TL	Wet and Rain Forests	12,272.64	7,044.62	8,209.08	3,621.92	3,449.05	2,887.74
TL	Moist Forests	28,829.50	9,711.76	17,241.69	5,411.17	3,646.22	5,037.62
TL	Dry Forests	1,197.95	387.37	837.54	130.76	75.22	270.90
TL	Mangroves	638.71	154.29	286.74	164.43	118.35	102.24
TL	Palm Forests	2,357.51	1,300.85	1,881.48	696.72	788.94	489.33
TL	**Total primary forests**	**45,296.31**	**18,598.89**	**28,456.53**	**10,025.00**	**8,077.77**	**8,787.83**

DF = Deforestation; **NL** = Non-anthropogenic loss; **TL** = Total Loss.

Table 6. Annual loss of secondary forests (includes tree plantations).

	New Forests	1986-91	1992-97	1998-00	2001-07	2008-11	2012-13
	Forest category	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}
DF	Wet and Rain Forests	1,926.02	3,511.47	6,842.97	3,350.26	5,143.64	5,984.73
DF	Moist Forests	4,342.31	6,170.09	17,245.50	9,403.29	10,906.81	17,860.41
DF	Dry Forests	61.43	165.42	539.22	146.02	383.69	609.62
DF	Mangroves	49.26	136.34	360.06	138.79	219.56	260.51
DF	Palm Forests	18.30	320.28	1,260.78	455.82	568.76	617.09
DF	**Total new forests**	**6,397.31**	**10,303.59**	**26,248.53**	**13,494.19**	**17,222.45**	**25,332.35**
NL	Wet and Rain Forests	75.76	35.30	138.51	66.57	137.21	107.28
NL	Moist Forests	61.68	37.10	97.02	92.60	109.62	147.92
NL	Dry Forests	0.02	1.22	0.39	0.14	0.27	3.24
NL	Mangroves	9.59	28.05	178.32	71.60	92.00	177.30
NL	Palm Forests	0.08	12.77	98.43	58.36	89.93	149.27
NL	**Total new forests**	**147.12**	**114.42**	**512.67**	**289.27**	**429.03**	**585.00**
TL	Wet and Rain Forests	2,001.78	3,546.77	6,981.48	3,416.84	5,280.84	6,092.01
TL	Moist Forests	4,403.99	6,207.18	17,342.52	9,495.89	11,016.43	18,008.33
TL	Dry Forests	61.44	166.64	539.61	146.16	383.96	612.86
TL	Mangroves	58.85	164.39	538.38	210.39	311.56	437.81
TL	Palm Forests	18.38	333.05	1,359.21	514.18	658.69	766.35
TL	**Total new forests**	**6,544.43**	**10,418.01**	**26,761.20**	**13,783.46**	**17,651.48**	**25,917.35**

DF = Deforestation; **NL** = Non-anthropogenic loss; **TL** = Total Loss.

Table 7. Secondary forests existing at the end/start of each period.

	New Forest		1985/86	1991/92	1997/98	2000/01	2007/08	2011/12	2013/14
		Cohort	ha	ha	ha	ha	ha	ha	ha
AE	Wet and Rain Forests	...-1985	155,736.63	143,725.95	136,417.86	132,867.36	128,482.38	126,376.83	125,269.65
		1986-91	0.00	72,110.52	58,138.02	47,139.30	41,460.12	38,342.52	37,202.85
		1992-97	0.00	0.00	34,012.71	27,617.49	20,833.38	18,387.81	17,642.25
		1998-00	0.00	0.00	0.00	36,330.75	29,261.16	23,815.08	21,976.92
		2001-07	0.00	0.00	0.00	0.00	47,171.34	39,162.78	35,067.78
		2008-11	0.00	0.00	0.00	0.00	0.00	31,148.91	27,890.46
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	43,937.19
AE	Moist Forests	...-1985	218,226.69	191,802.78	182,115.36	173,450.79	165,067.65	162,410.76	160,325.73
		1986-91	0.00	149,696.28	122,140.62	97,306.29	83,812.68	78,632.91	75,798.27
		1992-97	0.00	0.00	98,490.87	79,962.21	57,203.46	50,783.04	48,241.62
		1998-00	0.00	0.00	0.00	95,699.70	73,863.99	57,683.07	50,013.36
		2001-07	0.00	0.00	0.00	0.00	74,943.36	61,315.65	51,689.43
		2008-11	0.00	0.00	0.00	0.00	0.00	84,833.46	73,573.83
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	89,883.27
AE	Dry Forests	...-1985	5,926.41	5,557.77	5,350.68	5,104.71	5,051.52	5,031.18	5,000.22
		1986-91	0.00	6,750.81	5,958.09	4,979.79	4,745.70	4,639.77	4,517.91
		1992-97	0.00	0.00	5,242.23	4,847.67	4,510.62	4,338.63	4,214.70
		1998-00	0.00	0.00	0.00	6,739.11	6,340.32	5,428.26	5,216.04
		2001-07	0.00	0.00	0.00	0.00	2,882.70	2,557.17	2,167.92
		2008-11	0.00	0.00	0.00	0.00	0.00	2,152.89	1,805.40
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	1,853.19
AE	Mangroves	...-1985	2,683.17	2,330.10	2,183.40	2,088.36	1,982.34	1,938.24	1,928.52
		1986-91	0.00	4,665.33	3,825.72	3,262.14	2,895.21	2,727.63	2,647.62
		1992-97	0.00	0.00	2,816.82	1,860.30	1,327.95	1,148.76	1,074.87
		1998-00	0.00	0.00	0.00	1,394.64	927.18	710.73	635.58
		2001-07	0.00	0.00	0.00	0.00	1,858.50	1,219.59	1,024.02
		2008-11	0.00	0.00	0.00	0.00	0.00	1,862.55	1,421.28
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	2,126.43
AE	Palm Forests	...-1985	795.51	685.26	605.70	594.00	564.39	551.52	550.17
		1986-91	0.00	9,213.30	7,294.59	4,767.93	4,074.39	3,752.73	3,609.72
		1992-97	0.00	0.00	5,513.58	3,974.31	2,640.33	2,248.02	2,123.01
		1998-00	0.00	0.00	0.00	5,878.98	4,336.83	3,492.36	3,350.25
		2001-07	0.00	0.00	0.00	0.00	4,157.55	3,094.11	2,730.78
		2008-11	0.00	0.00	0.00	0.00	0.00	4,309.65	3,551.76
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	8,421.39
AE	Wet and Rain Forests		155,736.63	215,836.47	228,568.59	243,954.90	267,208.38	277,233.93	308,987.10
AE	Moist Forests		218,226.69	341,499.06	402,746.85	446,418.99	454,891.14	495,658.89	549,525.51
AE	Dry Forests		5,926.41	12,308.58	16,551.00	21,671.28	23,530.86	24,147.90	24,775.38
AE	Mangroves		2,683.17	6,995.43	8,825.94	8,605.44	8,991.18	9,607.50	10,858.32
AE	Palm Forests		795.51	9,898.56	13,413.87	15,215.22	15,773.49	17,448.39	24,337.08
AE	**Total**		**383,368.41**	**586,538.10**	**670,106.25**	**735,865.83**	**770,395.05**	**824,096.61**	**918,483.39**

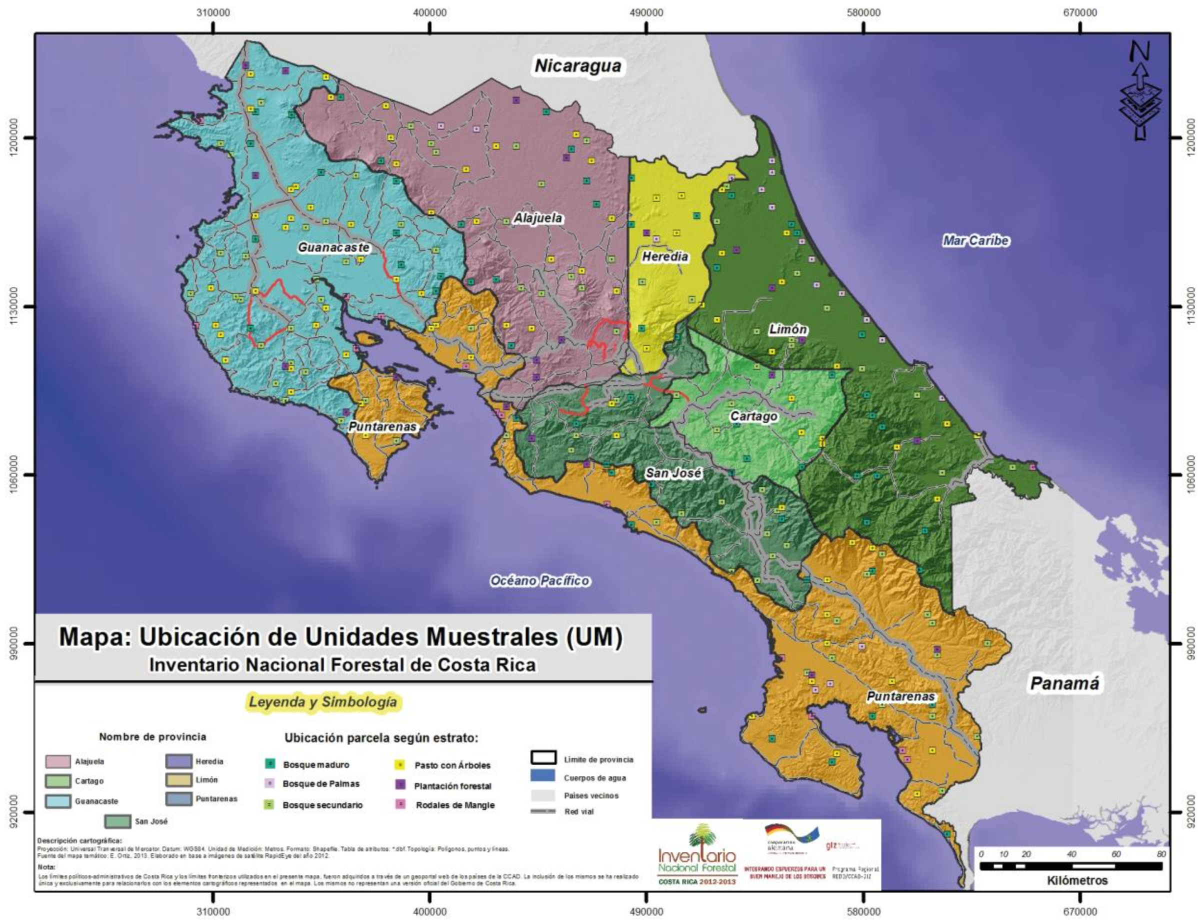
AE = Areas with enhancement of forest C stocks.

4.4. Emission factors

4.4.1. Data sources for estimating EF

While working on the current FREL/FRL submission, the National Forest Inventory (NFI) was undergoing. Therefore, the final results of the NFI were unavailable. However, data from a 289-plot representative sample was used for the estimation of forest C stocks. The location of these plots is shown in Figure 11. Plot distribution was based on fixed sample intensities by forest class. Please go here for more information. NFI plot locations were not biased by excluding disturbed forest areas or managed areas, if occurring. Therefore, this data is considered to be representative of all possible conditions and succession stages of *Forest land* at the national-level.

Figure 11. Plots of the National Forest Inventory measured 2014-15
(Source: REDD/CCAD-GIZ - SINAC. 2015)[26]



NFI data were complemented with additional information given that:

- The NFI did not measure C stocks for some of the land use categories considered in the National GHG inventory and in the FREL/FRL, such as non-Forest land use categories and

[26] See page 58 in: Programa REDD/CCAD-GIZ - SINAC. 2015. Inventario Nacional Forestal de Costa Rica 2014-2015. Resultados y Caracterización de los Recursos Forestales. Preparado por: Emanuelli, P., Milla, F., Duarte, E., Emanuelli, J., Jiménez, A. y Chavarría, M.I. Programa Reducción de Emisiones por Deforestación y Degradación Forestal en Centroamérica y la República Dominicana (REDD/CCAD/GIZ) y Sistema Nacional de Áreas de Conservación (SINAC) Costa Rica. San José, Costa Rica. 380 p. Availabble at: http://www.sirefor.go.cr/?p=1170

categories of age classes of secondary forests. As the FREL/FRL should be consistent with the National GHG inventory, additional information was required.

- The NFI and the national GHG inventory differ in their forest classifications. However, using the location of the 289 NFI plots, it was possible to allocate each plot to the five *Forest land* strata in order to estimate average C stocks per hectare per stratum.

To collect additional C stock data, a meta-analysis that involved the revision of 110 publications[27] was carried out. To consider a publication, the following criteria must have been met:

- The publication reported data from direct measurements carried out in Costa Rica.
- Measurements were carried out after the year 2005.
- Data were sufficiently disaggregated in order to obtain information on C stocks for relevant land use categories and C pools listed in the previous sections.
- The publications included information on uncertainties related to the C stock estimates.

All data collected were compiled in an Excel database (*cf.* BaseDeDatos_v5).

4.4.2. Methods for estimating C stocks

Average C stocks by C pool and strata were estimated from the consulted sources of information (NFI and selected studies from the meta-data analysis). All C stock estimates from the consulted sources were compiled in the sheet "2.BaseDeDatos" BaseDeDatos_v5 in tons of carbon per hectare (t C ha^{-1}), using IPCC's default carbon fraction (0.47) when the values were reported in tons of dry matter (t d.m. ha^{-1}). All information related to C stock estimates, such as information on land use, number of sampling units, plot size, allometric equation used, etc. were also recorded in the sheet "2.BaseDeDatos".

As information on the uncertainty of the estimates was reported in different ways, it was necessary to standardize the reporting of uncertainties associated to the average C stock values by applying the following equation that assumes normal distribution of the data:

$$E_{90\%,i} = 1.645 \times \frac{SD_i}{\sqrt{n_i}} = 1.645 \times SE_i \quad \textbf{(Eq.03)}$$

Where:

$E_{90\%,i}$	Error estimate at a 90% confidence level of the reference *i*; tC ha^{-1}
SD_i	Reported standard deviation of the simple given for the reference *i*; tC ha^{-1}
n_i	Sample size for reference *i*; number
$SE_{i.}$	Standard error of the sample mean given for reference *i*; tC ha^{-1}

Data collected were analyzed in order to obtain mean tCO_2-e values and associated uncertainties for all pools and land use categories. A total of 184 values for forest C pools and 194 for non-forest C pools were found. The analysis considered:

Forest-related C stocks:

- **Above-ground tree biomass (AGB.t)**:

[27] The full list of consulted sources may be found in the sheet "1.Referencias" of the Excel file "BaseDeDatos_v5.

Primary forests: C stocks per hectare were estimated as the area-weighted average C stock value from the selected sources, using the sampled area as weighting criterion. For Mangroves and Palm Forests, a simple arithmetic mean was calculated.

Secondary forests: C stocks in total *net*[28] above-ground biomass (TAGB) of Wet and Rain Forests, Moist Forests and Dry Forests were estimated using the equations developed by Cifuentes (2008)[29] for Costa Rican secondary forests based on direct measurements in 54 plots located in age classes between 0 and 82 years (see also Figure 6 to see the application of these equations per Life Zone). For Mangroves and Palm Forests, a linear function was assumed for estimating C stocks as a function of age. The following equations were applied:

- Wet and Rain Forests (Cifuentes, 2008, Table 2.5, p. 42, equation for "*Tropical Wet*"):

$$TAGB_t = B_{max} * \left[1 - e^{(-0.0186*t)}\right]^1 \quad \textbf{(Eq.04)}$$

- Moist Forests (Cifuentes, 2008, Table 2.5, p. 42, equation for "*Tropical Permontane Wet Transition to Basal-Atlantic*"):

$$TAGB_t = B_{max} * \left[1 - e^{(-0.0348*t)}\right]^1 \quad \textbf{(Eq.05)}$$

- Dry Forests (Cifuentes, 2008, Table 2.5, p. 42, equation for "*Tropical Dry*"):

$$TAGB_t = B_{max} * \left[1 - e^{(-0.113*t)}\right]^{5.1411} \quad \textbf{(Eq.06)}$$

- Mangroves and Palm Forest the following linear equation was applied:

$$TAGB_t = \frac{B_{max}}{100} * t \qquad \text{when } t <= 100 \quad \textbf{(Eq.07)}$$

$$TAGB_t = B_{max} \qquad \text{when } t > 100 \quad \textbf{(Eq.08)}$$

It was assumed that the maximum biomass in secondary forests (B_{max}) equals the biomass estimated for primary forests.

- **Below-ground tree biomass (BGB.t)**: The values reported in the selected sources were calculated using either allometric equations or root-to-shoot factors. To standardize the method it was decided to recalculate all below-ground biomass values using Cairns *et al.* (1997)[30].

$$BGB.t = e^{-1.085+0.9256*\mathrm{LN}(AGB.t)} \quad \textbf{(Eq.09)}$$

Where:

$BGB.t$ Below-ground tree biomass; t d.m. ha^{-1}

$AGB.t$ Above-ground tree biomass; t d.m. ha^{-1}

This equation was applied to both, primary and secondary forests.

- **Dead wood (DW)**:

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28 Net TAGB implies that forests considered by Cifuentes included disturbed forest areas. As explained in a previous section, logging is rare in Costa Rica, especially in secondary forests. Hence their exclusión by Cifuentes does not represent an important bias.

29 Cifuentes, M. 2008. Aboveground Biomass and Ecosystem Carbon Pools in Tropical Secondary Forests Growing in Six Life Zones of Costa Rica. Oregon State University. School of Environmental Sciences. 2008. 195 p.

30 Cairns M.A., Brown S., Helmer E.H., and Baumgardner G.A. (1997). Root biomass allocation in the world's upland forests. Oecologia 111: pp. 1-11.

Primary forests: Many studies did not report the dead wood carbon pool separately for standing dead wood (DW.s), lying dead wood (DW.l) and below-ground dead wood (DW.b). For this reason, all selected values are reported as DW (in the column DW.s in the sheet "C-STOCKS" of theFREL TOOL CR). As for AGB.t, the values were estimated as the area-weighted average of selected studies (except for Mangroves and Palm Forests, where the a simple arithmetic mean was calculated).

Secondary forests: It was assumed that the DW/AGB.t ratio in primary forests also applies to secondary forests. This assumption may be considered conservative as young secondary forests usually present higher ratios of dead wood due to the succession of vegetation communities and the dead wood originated from the woody vegetation of the previous land use.

- **Litter (L)**: As in the case of dead wood, the C stocks per hectare per stratum of primary forests were estimated as the area-weighted average of the values reported in the selected studies (except for Mangroves and Palm Forests, where a simple arithmetic mean was calculated). For secondary forests, C stocks were estimated assuming the same L/AGB.t ratio found in primary forests.

C stocks in non-Forest land uses:

C stocks in these land use categories were estimated as the average values reported by the selected studies.

- **Cropland**: C stock values reported in selected studies showed high variability, depending on crop type (sugar cane, coffee, banana, cocoa, etc.). For this reason, and area-weighted average C stock was calculated.
- **Grassland:** C stocks were estimated as the average values reported in different C pools in the selected studies.
- **Settlements and Wetlands:** no studies could be found reporting biomass values for these categories. It was assumed that their C stock is zero.
- **Other Land:** studies were found reporting C stocks for *Paramo.* In the case of *Bare Soil* it was assumed that the biomass C stocks are zero.

Results in full detail are presented in the sheet "3.DensidadesCarbono" *cf.* BaseDeDatos_v5 and reported in the sheet "C-STOCKS" in FREL TOOL CR.

Table 8 presents the estimated average C stock values per C pool and land use category and their corresponding 90% confidence intervals. Note that in the case of secondary forests, only the estimated C stock values at selected ages are shown. For the complete list of C stock values calculated for each age class (from 1 to 400 years), please see "C-STOCKS" in FREL TOOL CR.

Table 8. Estimated average C stocks per hectare and related 90% confidence intervals.

					CO_2							Non-CO_2	
					Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (L_{fire})	
					$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	CH_4	N_2O
					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}
FL	Wet and Rain Forest	PF		**AVG**	**481.10**		**106.92**	**-**	**49.50**	**10.05**	**647.57**	**11.10**	**4.82**
FL	Wet and Rain Forest	PF		90%CI	443.65	-	98.60	-	40.75	9.11	608.21	4.50	1.96
FL	Wet and Rain Forest	PF		90%CI	518.56	-	115.24	-	58.25	11.00	686.94	17.71	7.69
FL	Wet and Rain Forest	SF	4 yr	**AVG**	**34.50**		**9.33**	**-**	**3.74**	**0.36**	**47.92**	**0.97**	**0.42**
FL	Wet and Rain Forest	SF	4 yr	90%CI	31.59	-	8.54	-	3.43	0.27	44.89	0.48	0.21
FL	Wet and Rain Forest	SF	4 yr	90%CI	37.40	-	10.11	-	4.06	0.44	50.95	1.46	0.64
FL	Wet and Rain Forest	SF	15 yr	**AVG**	**117.13**		**28.92**	**-**	**12.71**	**1.21**	**159.96**	**3.30**	**1.43**
FL	Wet and Rain Forest	SF	15 yr	90%CI	107.34	-	26.50	-	11.65	0.92	149.82	1.64	0.71
FL	Wet and Rain Forest	SF	15 yr	90%CI	126.92	-	31.33	-	13.77	1.50	170.11	4.97	2.16
FL	Wet and Rain Forest	SF	30 yr	**AVG**	**205.74**		**48.71**	**-**	**22.33**	**2.12**	**278.90**	**5.80**	**2.52**
FL	Wet and Rain Forest	SF	30 yr	90%CI	188.72	-	44.68	-	20.48	1.62	261.30	2.88	1.25
FL	Wet and Rain Forest	SF	30 yr	90%CI	222.77	-	52.74	-	24.18	2.63	296.50	8.73	3.79
FL	Moist Forest	PF		**AVG**	**339.71**		**77.48**	**-**	**48.27**	**8.01**	**473.46**	**8.27**	**3.59**
FL	Moist Forest	PF		90%CI	311.51	-	71.04	-	25.02	6.96	436.33	3.31	1.44
FL	Moist Forest	PF		90%CI	367.91	-	83.91	-	71.52	9.05	510.58	13.23	5.74
FL	Moist Forest	SF	4 yr	**AVG**	**44.14**		**11.72**	**-**	**5.10**	**0.85**	**61.81**	**1.28**	**0.55**
FL	Moist Forest	SF	4 yr	90%CI	40.80	-	10.83	-	2.67	0.72	57.58	0.63	0.27
FL	Moist Forest	SF	4 yr	90%CI	47.49	-	12.61	-	7.53	0.98	66.05	1.93	0.84
FL	Moist Forest	SF	15 yr	**AVG**	**138.15**		**33.69**	**-**	**15.96**	**2.67**	**190.47**	**4.00**	**1.74**
FL	Moist Forest	SF	15 yr	90%CI	127.50	-	31.09	-	8.37	2.25	177.13	1.96	0.85
FL	Moist Forest	SF	15 yr	90%CI	148.79	-	36.28	-	23.56	3.08	203.81	6.04	2.62
FL	Moist Forest	SF	30 yr	**AVG**	**220.12**		**51.85**	**-**	**25.43**	**4.25**	**301.65**	**6.37**	**2.77**
FL	Moist Forest	SF	30 yr	90%CI	202.84	-	47.78	-	13.32	3.58	280.15	3.12	1.35
FL	Moist Forest	SF	30 yr	90%CI	237.39	-	55.92	-	37.54	4.91	323.14	9.62	4.18

(Table 8 continued)

					CO2						Non-CO2	
					Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (L_{fire})	
					$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	CH_4	N_2O
					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}
FL	Dry Forest	PF		AVG	**225.58**		**53.04**	**-**	**56.47**	**22.73**	**357.82**	**6.74**	**2.92**
				90%CI	207.62	-	48.82	-	34.54	22.12	329.16	2.69	1.17
					243.54	-	57.26	-	78.39	23.35	386.48	10.78	4.68
		SF	8 yr	AVG	**15.64**		**4.49**	**-**	**1.88**	**1.51**	**23.51**	**0.51**	**0.22**
				90%CI	14.40	-	4.13	-	1.34	1.38	22.10	0.25	0.11
					16.89	-	4.84	-	2.41	1.64	24.92	0.77	0.33
			15 yr	AVG	**79.50**		**20.20**	**-**	**9.54**	**7.68**	**116.92**	**2.60**	**1.13**
				90%CI	73.17	-	18.59	-	6.81	7.02	109.81	1.29	0.56
					85.83	-	21.81	-	12.26	8.33	124.03	3.91	1.70
			30 yr	AVG	**189.12**		**45.05**	**-**	**22.68**	**18.26**	**275.12**	**6.18**	**2.68**
				90%CI	174.07	-	41.47	-	16.19	16.71	258.27	3.06	1.33
					204.18	-	48.64	-	29.17	19.82	291.98	9.29	4.03
	Mangroves	PF		AVG	**264.78**		**61.52**	**-**	**6.95**	**0.97**	**334.22**		
				90%CI	233.57	-	54.27	-	4.90	0.73	302.11	-	-
					296.00	-	68.77	-	8.99	1.22	366.33	-	-
		SF	4 yr	AVG	**10.59**		**3.13**	**-**	**0.27**	**0.03**	**14.02**		
				90%CI	9.34	-	2.76	-	0.17	(0.00)	12.71	-	-
					11.84	-	3.50	-	0.37	0.06	15.32	-	-
			15 yr	AVG	**39.72**		**10.63**	**-**	**1.02**	**0.11**	**51.47**		
				90%CI	35.04	-	9.37	-	0.64	(0.00)	46.60	-	-
					44.40	-	11.88	-	1.39	0.21	56.33	-	-
			30 yr	AVG	**79.43**		**20.18**	**-**	**2.03**	**0.21**	**101.86**		
				90%CI	70.07	-	17.81	-	1.28	(0.00)	92.17	-	-
					88.80	-	22.56	-	2.78	0.43	111.56	-	-

(Table 8 continued)

					CO_2							Non-CO_2	
					Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (L_{fire})	
					$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	CH_4	N_2O
					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}
FL	Palm Forests	PF		**AVG**	**189.57**		**45.15**	**-**	**5.97**	**0.96**	**241.66**		
				90%CI	148.68	-	35.41	-	(1.05)	(0.17)	199.03	-	-
					230.47	-	54.89	-	12.98	2.10	284.29	-	-
		SF	4 yr	**AVG**	**7.58**		**2.29**	**-**	**0.24**	**0.04**	**10.16**		
				90%CI	5.95	-	1.80	-	(0.10)	(0.01)	8.41	-	-
					9.22	-	2.79	-	0.57	0.08	11.90	-	-
			15 yr	**AVG**	**28.44**		**7.80**	**-**	**0.89**	**0.14**	**37.28**		
				90%CI	22.30	-	6.12	-	(0.37)	(0.03)	30.79	-	-
					34.57	-	9.48	-	2.15	0.32	43.76	-	-
			30 yr	**AVG**	**56.87**		**14.82**	**-**	**1.79**	**0.29**	**73.77**		
				90%CI	44.60	-	11.62	-	(0.73)	(0.05)	60.84	-	-
					69.14	-	18.01	-	4.31	0.63	86.70	-	-
CL	Annual			**AVG**	**-**	**83.57**	**-**	**21.16**	**-**	**-**	**104.72**		
				90%CI	-	73.88	-	18.70	-	-	94.73	-	-
					-	93.26	-	23.61	-	-	114.72	-	-
	Permanent		4 yr	**AVG**	**38.54**	**17.35**	**10.33**	**4.94**	**0.81**	**5.06**	**77.04**		
				90%CI	11.34	5.54	3.04	1.58	0.53	2.65	46.22	-	-
					65.74	29.17	17.63	8.30	1.10	7.47	107.87	-	-
			5 yr	**AVG**	**48.18**	**21.69**	**12.71**	**6.07**	**1.02**	**6.33**	**95.99**		
				90%CI	14.17	6.92	3.74	1.94	0.66	3.32	57.51	-	-
					82.18	36.46	21.67	10.20	1.38	9.34	134.47	-	-
			6 yr	**AVG**	**57.81**	**26.03**	**15.04**	**7.19**	**1.22**	**7.59**	**114.89**		
				90%CI	17.01	8.31	4.43	2.29	0.79	3.98	68.75	-	-
					98.61	43.76	25.66	12.08	1.65	11.20	161.03	-	-

(Table 8 continued)

				CO_2							Non-CO_2	
				Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (L_{fire})	
				$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	CH_4	N_2O
				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}
GL			**AVG**	**28.48**	**14.23**	**7.81**	**4.11**	**8.28**	**-**	**62.92**		
			90%CI	28.48	14.23	7.81	4.11	1.99	-	56.62	-	-
				28.48	14.23	7.81	4.11	14.58	-	69.21	-	-
SL			**AVG**	-	-	-	-	-	-	-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-
WL		Natural	**AVG**	-	-	-	-	-	-	-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-
		Artificial	**AVG**	-	-	-	-	-	-	-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-
OL		Paramo	**AVG**	-	**126.87**	**-**	**31.13**	**-**	**-**	**158.00**		
			90%CI	-	124.70	-	30.60	-	-	155.77	-	-
				-	129.03	-	31.67	-	-	160.23	-	-
	Bare Soil	Natural	**AVG**	-		-	-			-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-
		Artificial	**AVG**	-		-	-			-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-

FL = Forest land; **CL** = Cropland; **GL** = Grassland; **SL** = Settlements; **WL** = Wetlands; **OL** = Other Land; **PF** = Primary Forest; **SF** = Secondary Forest; **AVG** = Average values: **90%CI** = 90% Confidence Interval.

4.4.3. Methodology for estimating EF

EF were estimated considering CO_2 emissions and removals associated to C stock changes in *Forest land remaining Forest land* and conversions from Forest land, as well as non-CO_2 emissions (CH_4 and N_2O) associated to biomass burning in *Forest land converted to other land* use categories (*i.e.* deforestation). EF were estimated as follows:

$$EF_{i,t} = \Delta C_{i,t} + L_{fire_{i,t}} \quad \textbf{(Ec.11)}$$

Where:

$EF_{i,t}$ EF factor applicable to the land use transition *i* in year *t*; tCO_2-e ha^{-1}
Note: each cell of the land use change matrices for which AD were estimated ($AD_{i,t}$) represents a land use transition *i*.

$\Delta C_{i,t}$ C stock change associated to the land use transition *i* in year *t*; tCO_2-e ha^{-1}

L_{fire} CH_4 or N_2O emissions (depending on the EF [G_{ef}] factor applied, see Eq.15) from biomass burning associated to the land use transition *i* in year *t*; t CO_2-e

CO_2 emissions and removals associated to C stock changes ($\Delta C_{i,t}$):

C stock changes (ΔC) were estimated using the *Stock-Difference Method* by applying IPCC (2006) equation 2.5 (*cf.* Volume 2, Chapter 2, Section 2.2.1.). All results were multiplied by the stoichiometric ratio 44/12, as follows:

$$\Delta C = \frac{(C_{t2} - C_{t1})}{(t2 - t1)} * 44/12 \quad \textbf{(Eq.12)}$$

Where:

ΔC C stock changes associated to the land use transition *i* in year *t*; tCO_2-e ha^{-1}
(for simplicity the notations *i* and *t* used in Ec.11 are omitted here)

C_{t1} C stock at time *t1*, t CO_2 ha^{-1}
t1 in all cases was the 1st of January of each year *t*, *i.e.* C_{t1} is the C stock per hectare existing at the beginning of the year, before the conversion occurs. The estimated values are reported in the column K of the sheets "ER AAAA" (where "AAAA" stands for the year *t*) in the FREL TOOL CR.

C_{t2} C stock at time *t2*, t CO_2 ha^{-1}
t2 in all cases was the 31st of December of each year *t*, *i.e.* C_{t2} is the C stock per hectare existing at the end of the year, after the conversion occurred. The estimated values are reported in the lines 19[31] and 20[32] of the sheets "ER AAAA" (where "AAAA" stands for the year *t*) in the FREL TOOL CR.

t2-t1 In all cases the C stock changes were estimated annually, *i.e.* *t2-t1* = 1 year.

[31] The C stock values reported in line 19 represent total C stocks existing in new forests at the end of the first year at which they meet the definition of "Forest", *i.e.* 4 years for all forest strata and 8 years for dry forests. These values are used to estimate ΔC in conversions of non-Forest land use categories to Forest land (new forests) and conversions of other land use categories to permanent crops.

[32] The C stock values reported in line 20 represent total C stocks existing in the land use categories at the end of the year. They are used to estimate ΔC in all land use transitions, except conversions of non-Forest land use categories to Forest land (new forests) and conversion of other land use categories to permanent crops.

When soil organic C (SOC) is not included in the estimations, Eq.12 can be applied to all C pools individually or, as done in this case, by first adding the C stocks in all pools and then substituting the C_{t1} in Eq.12 with $Ctot_{t1}$ and C_{t2} with $Ctot_{t2}$:

$$C_{tot} = C_{AGB} + C_{BGB} + C_{DW} + C_{L} \qquad \textbf{(Eq.13)}$$

Where:

C_{tot} Total C stock for the land use category LU; tCO_2-e ha^{-1}

C_{AGB} C stock in the above-ground biomass for land use category LU; tCO_2-e ha^{-1}

C_{BGB} C stock in the below-ground biomass for land use category LU; tCO_2-e ha^{-1}

C_{DW} C stock in dead wood for land use category LU; tCO_2-e ha^{-1}

C_{L} C stock in the litter for land use category LU; tCO_2-e ha^{-1}

Non-CO_2 emissions from biomass burning:

These were estimated using equation 2.27 of IPCC (2006) (*cf.* Volume 4, Chapter 2, Section 2.4.):

$$L_{fire} = A \cdot M_B \cdot C_f \cdot G_{ef} \cdot 10^{-3} \qquad \textbf{(Eq.14)}$$

Where:

L_{fire} CH_4 or N_2O emissions (depending on the G_{ef} factor applied) from biomass burning; t CO_2-e

A Area burnt; ha
Note: in this case A is equivalent to AD_t (AD of Forest land converted to other land use categories).

M_B Mass of fuel available for combustion; t ha^{-1}.
Note: this includes above-ground biomass, dead wood and litter:

$$M_B = C_{AGB\,t1} + C_{ADW\,t1} + C_{L\,t1} \qquad \textbf{(Eq.15)}$$

C_f Combustion factor; dimensionless
Note: 2006 IPCC default values of 0.36 for primary forests and 0.55 for secondary forests were used (*cf.* Table 2.6, Volume 4, Chapter 2, Section 2.4.).

G_{ef} EF; g kg^{-1} dry matter burnt
Note: 2006 IPCC default values of 6.8 for CH_4 and 0.2 for N_2O were used (*cf.* Table 2, Volume 4, Chapter 2, Section 2.4.).

Biomass burning was considered only in conversions of Wet and Rain Forests, Moist Forests and Dry Forests to other land use categories. Due to inherent humidity, it was assumed that Mangroves and Palm Forests do not suffer biomass burning.

According to the National Meteorological Institute (IMN), biomass burning for converting forests to other land use categories was a common practice before the current Forest Lay in 1997, but disappeared thereafter. Emissions from biomass burning were thus assumed to be zero for 1998-2013.

Non-CO_2 EF are fully reported in Table 8 (*cf.* also “C-STOCKS” column H in the sheets “ER AAAA” of FREL TOOL CR).

4.4. Method used to estimate the FREL

The proposed FREL/FRL was defined as the **annual average emissions from deforestation** and **annual average removals from enhancements of forest C stocks** during the historical reference periods considered: 1986-1996 for the first period of enhanced mitigation actions (1997-2009) and 1997-2009 for the second period of enhanced mitigation actions (2010-2025). The results of these calculations are shown in Table 2 (see also the sheet "FREL&FRL" in FREL TOOL CR).

Annual emissions or removals were calculated by determining emissions or removals for all land transitions *i* by REDD+ activity, and then adding the results for all selected REDD+ activities for each year:

$$ER_{RA_t} = \sum_{i=1}^{I}\left(AD_{RA_{i,t}} * EF_{RA_{i,t}}\right) * \qquad \textbf{(Eq.16)}$$

<u>Where:</u>

ER_{RA_t} Emissions or removals associated to REDD+ activity *RA* in year *t*; tCO_2-e yr^{-1}

$AD_{RA_{i,t}}$ AD associated to REDD+ activity *RA* for the land use transition *i* in year *t*; ha yr^{-1}

$EF_{RA_{i,t}}$ EF associated to REDD+ activity *RA* applicable to the land use transition *i* in year *t*; tCO_2-e ha^{-1}

i A land use transition represented in a cell of the land use change matrix; dimensionless

I Total number of land use transitions related to REDD+ activity *RA*; dimensionless

t A year of the historical period analyzed; dimensionless

In the FREL TOOL CR, this calculation is performed in the sheets "ER AAAA" ("AAAA" = *t*). The allocation of each cell of the land use change matrices to a REDD+ activity.

5. Planned improvements

Costa Rica made considerable efforts to improve data and methods for estimating historical emissions and removals. Much of this work has been possible thanks to the support from the FCPF. When Costa Rica presented a draft of its reference level to the FCPF Carbon Fund in 2012, several key issues were raised in relation to the estimation of emissions and removals. Because of this, an important investment was made to develop a 27-year land use change analysis (Section 2.2.). This analysis included information for 1985/86-2012/13, including seven land use maps, following the same (pre-) processing and classification methodology. This methodology is the base for the current protocol for estimating AD. Simultaneously, Costa Rica implemented its first NFI, thanks to support by GIZ. The NFI was finished in 2015 and collected information on four C pools in all forest types across the country. These data sources were central to the FREL/FRL proposed here. The land use analysis was used to determine *Forest land remaining Forest land* and *Forest land converted to other land* use categories. However, it was not possible to provide estimates for additional activities within the *Forest land remaining Forest land* category, *e.g.* potential forest degradation or management.

Despite these developments, there is still ample room for improvement. For example, part of the emissions time series in the National GHG inventory has not been fully updated and certain parameters still need to be made consistent with the REDD+ FREL/FRL. To ensure consistency and accuracy, Costa Rica initiated a process for designing a new forest monitoring system compatible with the National MRV framework. For this, Costa Rica has received important support from the US Forest Service, GIZ and FAO. It is expected that during the technical review of the FREL/FRL, a final design of the system may be shared with the reviewers, as well as be made public. This system will be compatible with the FREL/FRL, although increased accuracy is expected, *e.g.* for determining C stock gains and losses in primary *Forest land remaining Forest land*, as well as developing a better land use and cover categorization. Besides the USFS, GIZ and FAO, additional funding sources are being identified, however, adequate and predictable support is still required.

The new monitoring system will be part of Costa Rica's National System for Environmental Information (SINIA). This platform will enable close coordination between REDD+ MRV and reporting of other environmental indicators, such as information on how the country is addressing and respecting REDD+ safeguards. This is also expected to increase consistency with MRV provisions under the Domestic Carbon Market (MDC) and the upcoming National Climate Change Metric System (SINAMECC), Costa Rica's proposed mechanism to demonstrate progress in achieving commitments under the UNFCCC. In parallel to this work, the Climate Change Office will conclude work on C registries, in order to ensure the environmental integrity of emission reductions for all sectors, including AFOLU and REDD+.

For these efforts to bear fruit, financial support and capacity building are needed. In its first BUR, Costa Rica stated some of the most pressing needs in terms of capacity building. In relation to MRV, as outlined in the Ministerial Guideline DM-417-2015, the National Center for Geospatial Information (CENIGA) requires technical and administrative personnel to efficiently coordinate all monitoring responsibilities in the environment sector and within the SINIA.

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Annex 1. Land use maps created for the construction of the FREL

The land use maps presented in this annex were created by analyzing mosaics of satellite images acquired within a time-window of up to 14 months. For this reason, a rule had to be adopted to define the date of the land use maps. The rule adopted is the following:

(a) The acquisition date of the central image of the country (Path 15, Row 53 - Landsat WRS-2), which is the image that covers the largest percentage of the national territory, was taken as the reference date.

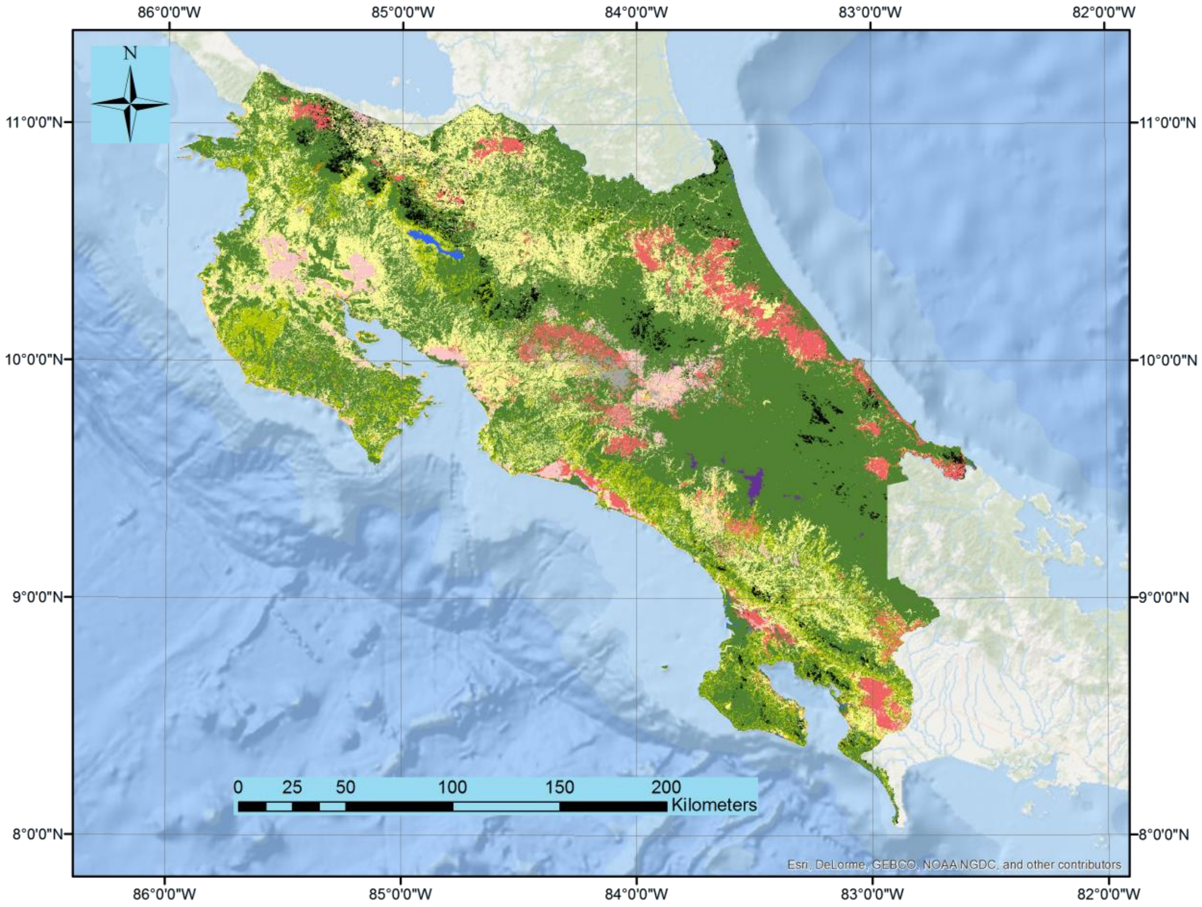
(b) If the central image was acquired between January 1st and June 30th, it was assumed that the land use map represents the land uses existing in Costa Rica on January 1st of the image acquisition date and on December 31st of the previous year.

(c) If the central image was acquired between July 1st and December 31st, it was assumed that the land use map represents the land uses existing in Costa Rica on December 31st of the image acquisition year and January 1st of the following year.

This rule was adopted to calculate the number of years between each map and thus the average annual emissions and removals associated to the selected REDD+ activities during the different historical periods analyzed.

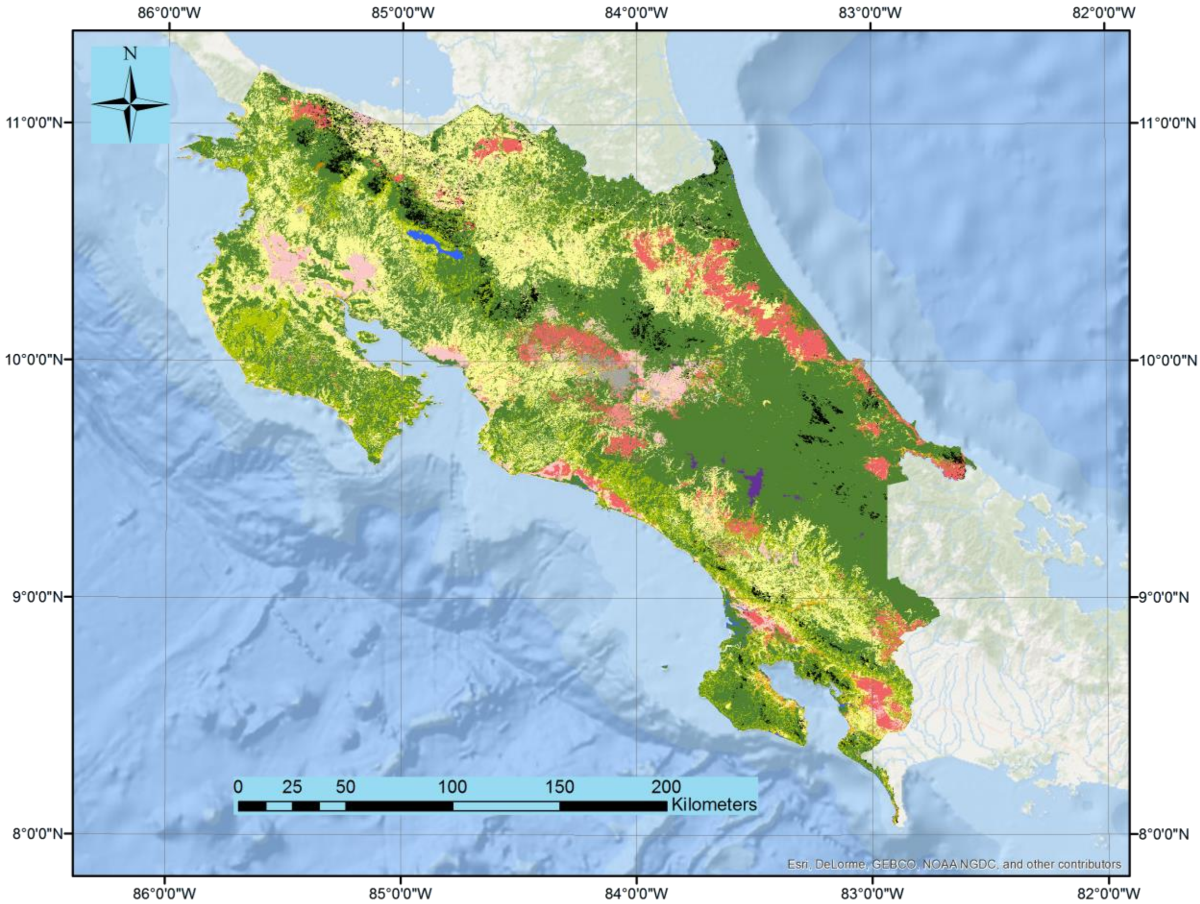
To facilitate the visual interpretation of the maps presented in this annex, the number of land use categories has been reduced, *i.e.* the area classified as "Forest" is not stratified in the five sub-categories "Wet and rain Forests", "Moist Forests", "Dry Forests", "Mangroves" and "Palm Forests".

Land Use Map 1985/86



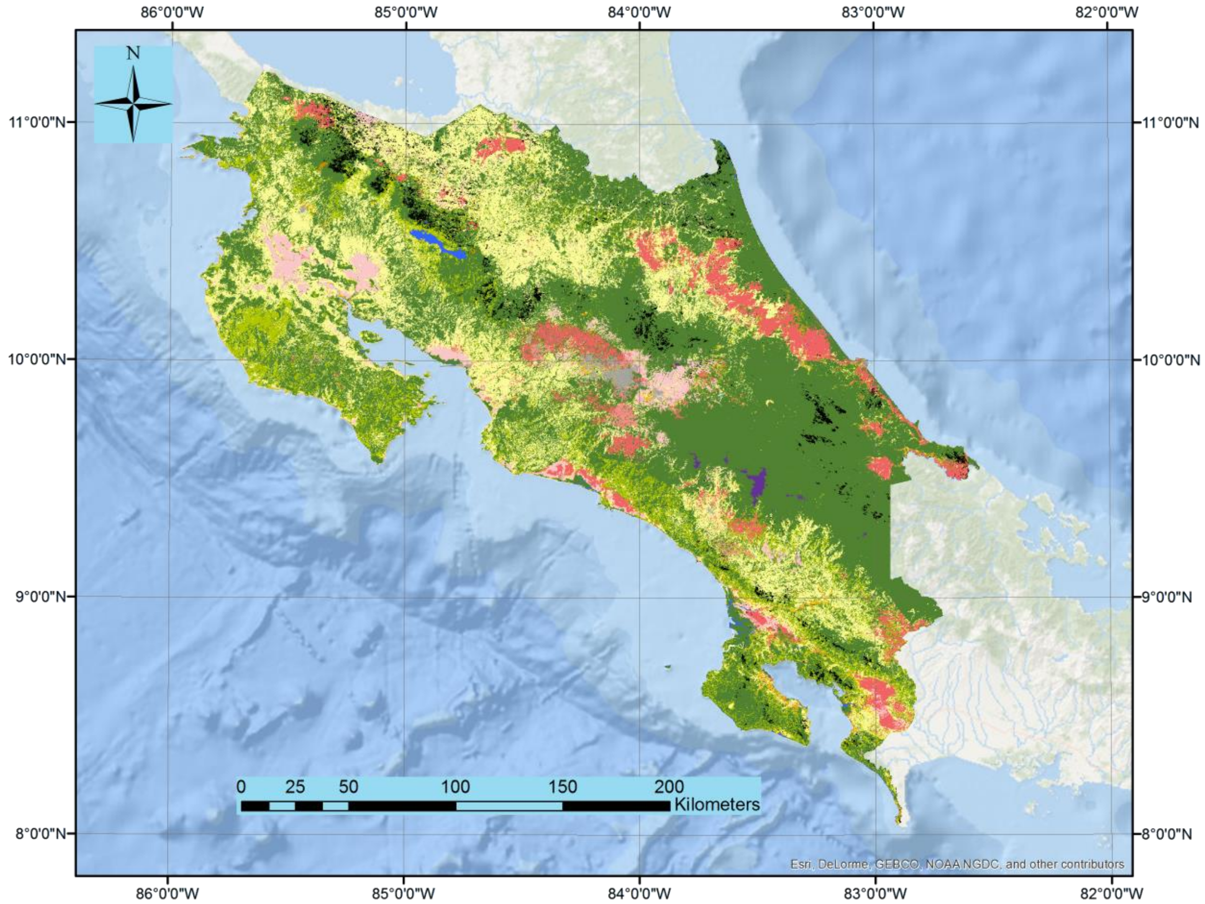
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,807,028.90
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	380,685.24
	CROPLAND – permanent	336,664.35
	CROPLAND – annual	197,797.23
	GRASSLAND	1,190,245.23
	SETTLEMENTS	22,876.92
	WETLANDS – natural	12,993.03
	WETLADNS – artificial	89.55
	OTHER LAND – Paramo	10,412.37
	OTHER LAND – Bare Soil - natural	1,479.33
	OTHER LAND –Bare Soil- artificial	38,303.19
	WITHOUT INFORMATION – clouds and shadows	115,364.16
	Total area	**5,113,939.50**

Land Use Map 1991/92



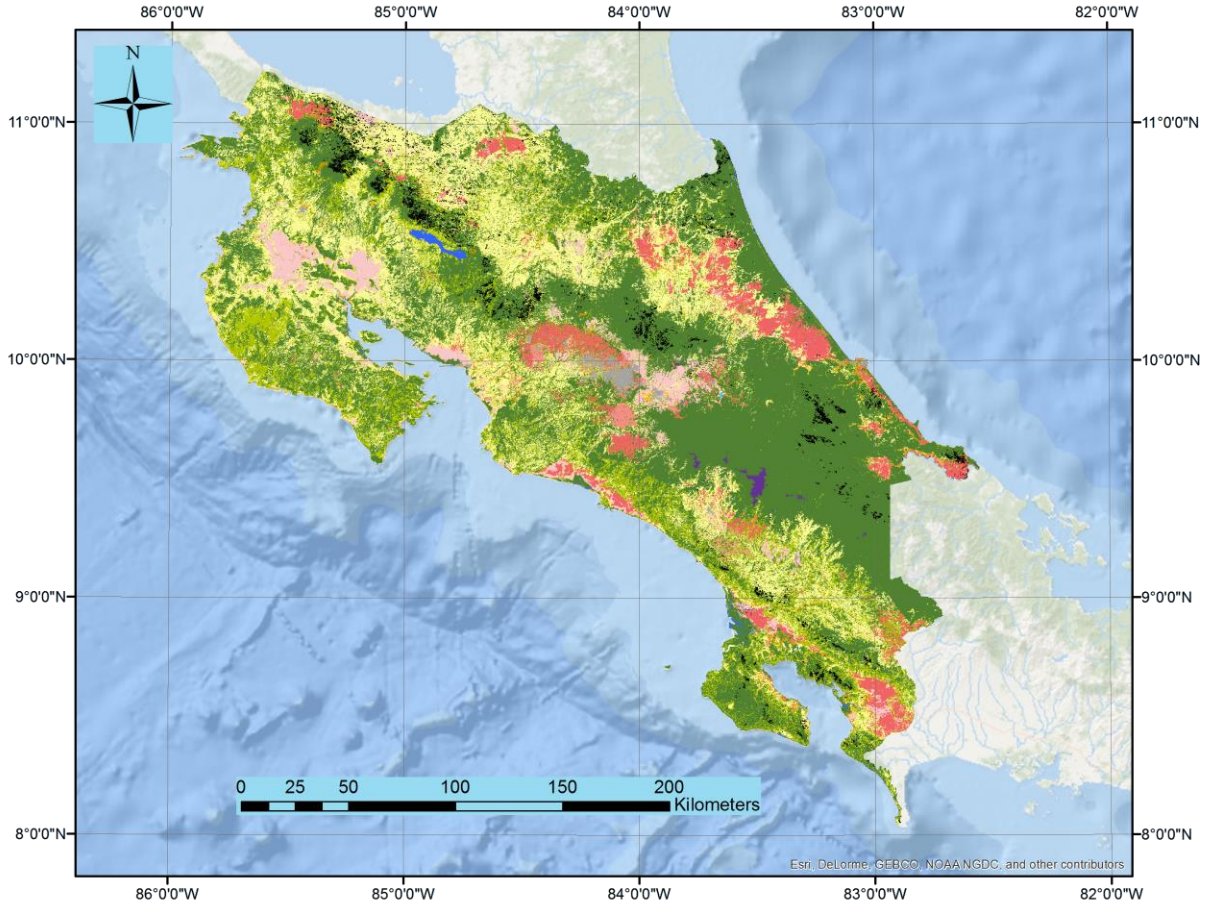
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,532,567.87
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	586,538.10
	CROPLAND – permanent	331,386.39
	CROPLAND – annual	203,960.88
	GRASSLAND	1,239,471.36
	SETTLEMENTS	30,210.12
	WETLANDS – natural	17,814.33
	WETLADNS – artificial	659.88
	OTHER LAND – Paramo	10,411.92
	OTHER LAND – Bare Soil - natural	1,392.21
	OTHER LAND –Bare Soil- artificial	44,162.28
	WITHOUT INFORMATION – clouds and shadows	115,364.16
	Total area	**5,113,939.50**

Land Use Map 1997-98



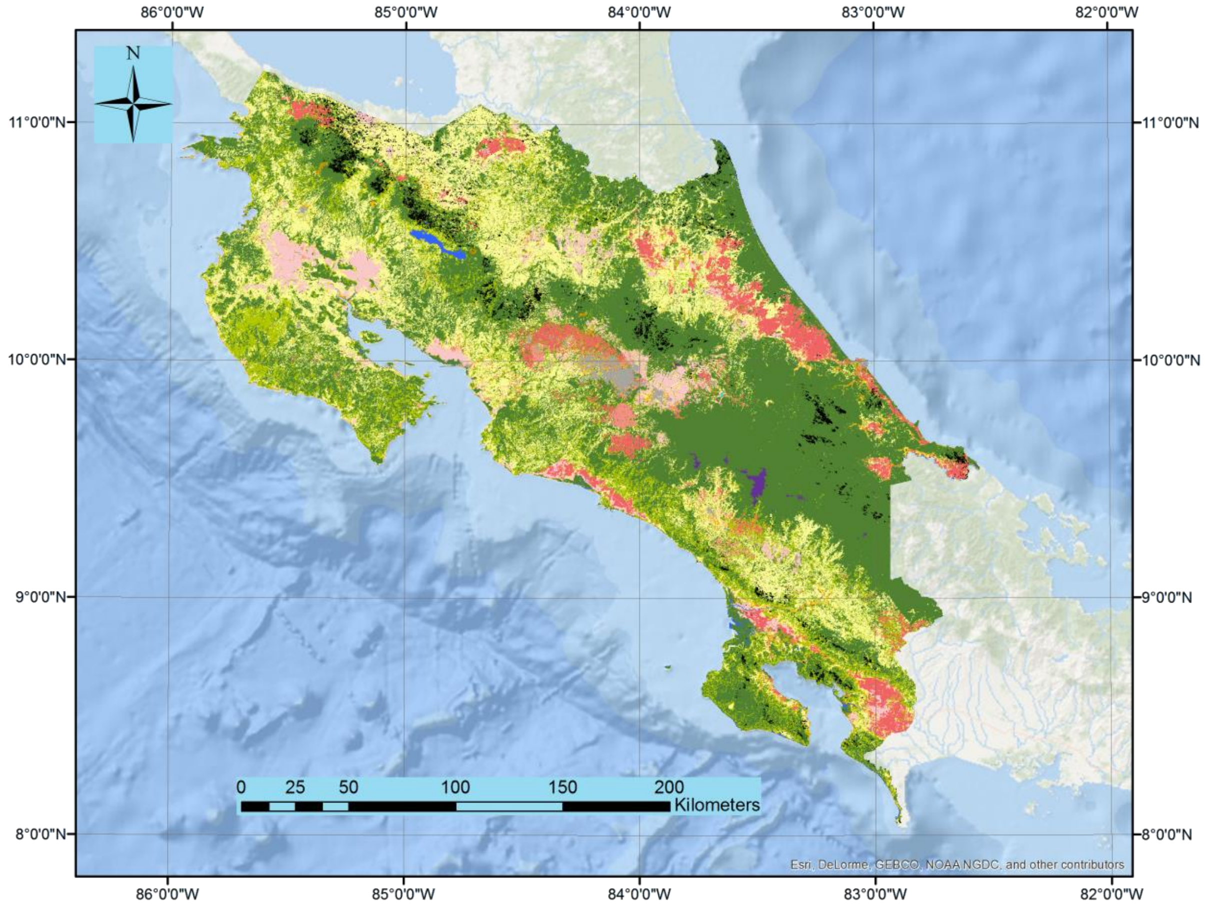
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,420,974.53
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	670,106.25
	CROPLAND – permanent	345,113.28
	CROPLAND – annual	211,800.60
	GRASSLAND	1,239,510.42
	SETTLEMENTS	35,203.86
	WETLANDS – natural	17,126.55
	WETLADNS – artificial	190.08
	OTHER LAND – Paramo	10,416.96
	OTHER LAND – Bare Soil - natural	2,009.43
	OTHER LAND –Bare Soil- artificial	46,123.38
	WITHOUT INFORMATION – clouds and shadows	115,364.16
	Total area	**5,113,939.50**

Land Use Map 2000/01



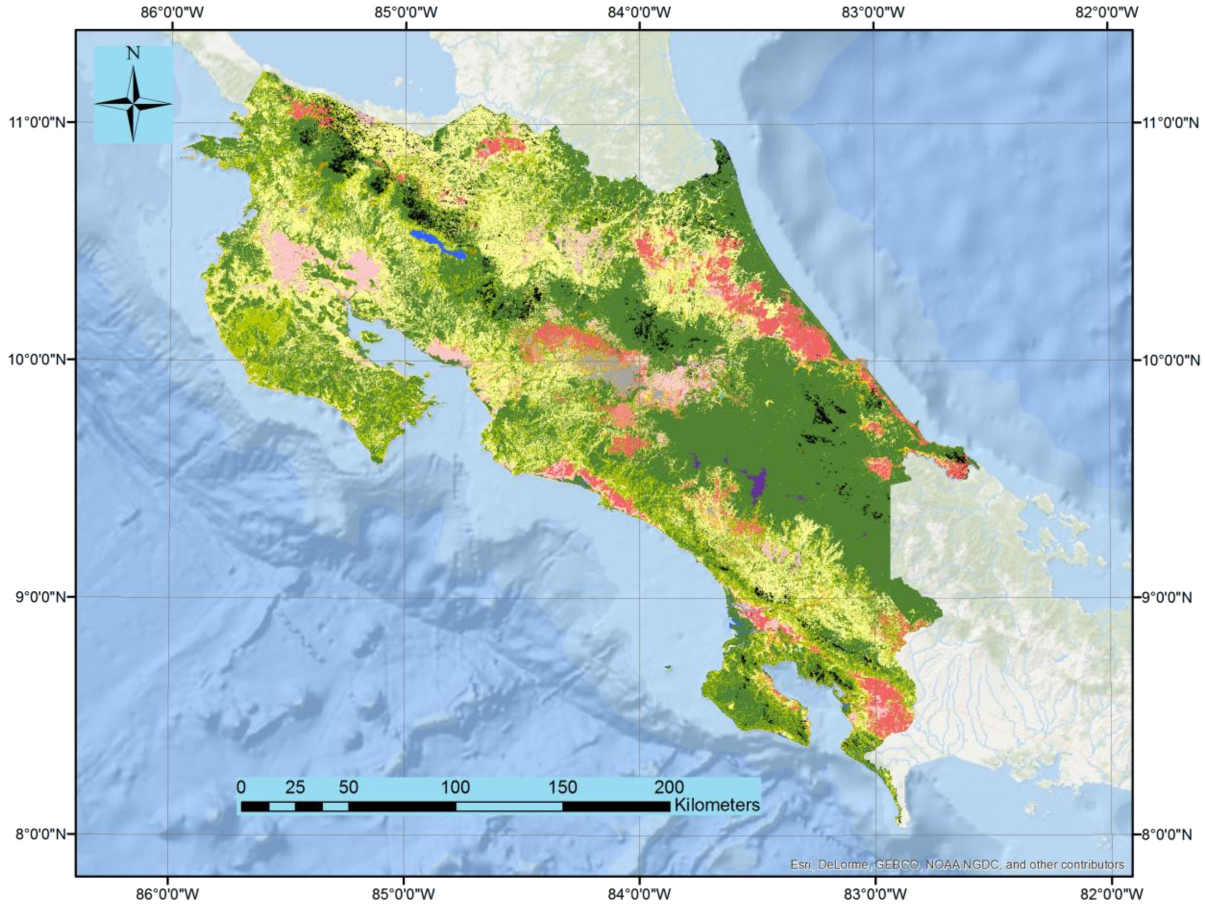
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,335,604.94
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	735,865.83
	CROPLAND – permanent	351,353.43
	CROPLAND – annual	218,656.71
	GRASSLAND	1,242,871.56
	SETTLEMENTS	38,819.97
	WETLANDS – natural	18,742.95
	WETLADNS – artificial	324.36
	OTHER LAND – Paramo	10,416.33
	OTHER LAND – Bare Soil - natural	1,662.48
	OTHER LAND –Bare Soil- artificial	44,256.78
	WITHOUT INFORMATION – clouds and shadows	115,364.16
	Total area	**5,113,939.50**

Land Use Map 2007/08



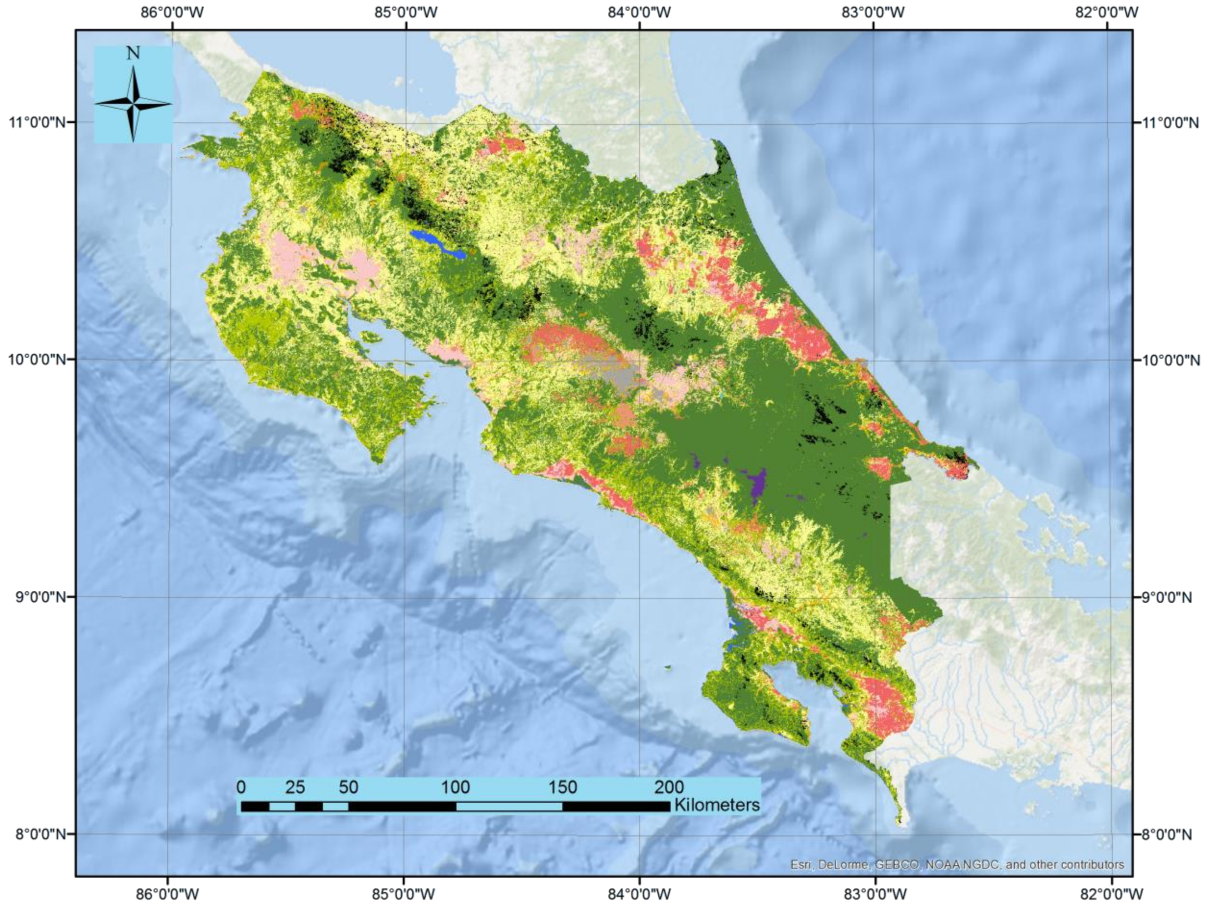
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,265,429.96
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	770,395.05
	CROPLAND – permanent	323,930.52
	CROPLAND – annual	242,276.76
	GRASSLAND	1,260,219.24
	SETTLEMENTS	43,086.69
	WETLANDS – natural	21,875.85
	WETLADNS – artificial	294.12
	OTHER LAND – Paramo	10,422.45
	OTHER LAND – Bare Soil - natural	1,948.32
	OTHER LAND –Bare Soil- artificial	58,696.38
	WITHOUT INFORMATION – clouds and shadows	115,364.16
	Total area	**5,113,939.50**

Land Use Map2011/12



Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,233,118.88
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	824,096.61
	CROPLAND – permanent	311,794.20
	CROPLAND – annual	244,122.84
	GRASSLAND	1,247,688.99
	SETTLEMENTS	45,039.24
	WETLANDS – natural	22,350.60
	WETLADNS – artificial	336.69
	OTHER LAND – Paramo	10,420.38
	OTHER LAND – Bare Soil - natural	1,973.43
	OTHER LAND –Bare Soil- artificial	57,633.48
	WITHOUT INFORMATION – clouds and shadows	115,364.16
	Total area	**5,113,939.50**

Land Use Map 2013/14



Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,215,543.23
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	918,483.39
	CROPLAND – permanent	277,262.82
	CROPLAND – annual	251,873.55
	GRASSLAND	1,190,834.73
	SETTLEMENTS	46,998.90
	WETLANDS – natural	24,484.86
	WETLADNS – artificial	382.32
	OTHER LAND – Paramo	10,423.71
	OTHER LAND – Bare Soil - natural	1,897.29
	OTHER LAND –Bare Soil- artificial	60,390.54
	WITHOUT INFORMATION – clouds and shadows	115,364.16
	Total area	**5,113,939.50**

Annex 2. Ancillary information used to determine secondary forest area and age distribution

An ancillary forest map was used to determine the proportion of secondary forest existing at the start of the 1985/86 - 2012/13 time series, especially to avoid assuming that all *Forest land* in 1985/86 was “primary". Hence, the main intent in using this map is to obtain the proportion of prmimary:secondary *Forest land*; it was further assumed that this proportion was the same for 1985/86. It was also assumed that all secondary forest age classes were equally distributed, *i.e.* the probability of occurrence of every possible forest age was the same.

The map is composed of 5 LANDSAT images spanning from March 1975 to December 1979. It is estimated that the map has a 10% error. More details may be obtained upon request by emailing jfernandez@fonafifo.go.cr or archacon@imn.ac.cr. This map was developed by the National Meteorology Institute in 2013 (www.imn.ac.cr).