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Forest reference emission level/forest reference level

COSTA RICA

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

MINISTRY OF ENVIRONMENT AND ENERGY
COSTA RICA

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National REDD+ Focal Point

Jorge Mario Rodríguez
Director
National Forestry Fund (FONAFIFO)
jrodriguez@fonafifo.go.cr

Alexandra Sáenz
National REDD+ Director
National Forestry Fund (FONAFIFO)
asaenz@fonafifo.go.cr

Technical team

Lucio Pedroni, *Carbon Decisions International*
Javier Fernandez, *Costa Rica REDD+ Secretariat*

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AAAA	A year of the historical reference period analyzed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(es)
HWP	Harvested wood products
HWP.F1	Fraction 1 in HWP: paper products
HWP.F2	Fraction 2 in HWP: non-structural panels
HWP.F3	Fraction 3 in HWP: veneer, plywood and structural panels

HWP.F4	Fraction 4 in HWP: saw wood
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 therefore welcomes the opportunity to submit its proposed national Forest Reference Emission Level and Forest Reference Level (FREL/FRL) to the United Nations Framework Convention on Climate Change (UNFCCC) for a technical assessment, in accordance with Decision 13/CP.19 and its Annex.

The submission of this FREL/FRL, and of the subsequent Technical Annexes to the Biennial Update Report (BUR) in which the emission reductions of results-based actions may be reported, are voluntary and exclusively for the purpose of obtaining results-based payments for REDD+ actions, as per Decisions 1/CP.16, paragraph 71, 13/CP.19, paragraph 2, and 14/CP.19, paragraphs 7 and 8.

This submission therefore does not prejudge any Nationally Appropriate Mitigation Actions (NAMA) currently being considered or undertaken by Costa Rica pursuant to the Bali Action Plan, neither prejudges Costa Rica's Intended Nationally Determined Contribution (INDC) in the context of the Paris Agreement.

Costa Rica worked on developing the four elements referred to in paragraph 71 of Decision 1/CP.16 since 2009. In addition to the National Climate Change Strategy, and 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 in forest cover and mapping forest cover (Agresta *et al.*, 2015.a)[1] that has been applied to generate the activity data (AD) that are 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. 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.

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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.

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 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 Climate Change National 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 Intended Nationally Determined Contribution (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 and management. 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:

- ER-Program: http://reddcr.go.cr/sites/default/files/centro-de-documentacion/programa_de_reduccion_de_emisiones_01.11.15.pdf
- National REDD+ Strategy: http://reddcr.go.cr/sites/default/files/centro-de-documentacion/estrategia_reddcr_0.pdf
- Climate Change Strategy: http://cambioclimaticocr.com/2012-05-22-19-42-06/estrategia-nacional-de-cambio-climatico
- List of private entities granted the C-neutral brand: http://cambioclimaticocr.com/2012-05-22-19-47-24/empresas-y-organizaciones-hacia-la-carbono-neutralidad-2021
- National Forestry Development Plan: http://www.sirefor.go.cr/images/stories/pdf/plannacionafinalweb.pdf
- Coffee NAMA: http://www.nama-facility.org/projects/costa-rica.html

- National Forestry Fund (FONAFIFO) and gateway to the PSA program documentation: www.fonafifo.go.cr
- National System for Conservation Areas (SINAC) and gateway to information on National Parks, Biological Reserves and other conservation areas: www.sinac.go.cr
- Costa Rica's INDC: http://www4.unfccc.int/submissions/INDC/Published%20Documents/Costa%20Rica/1/INDC%20Costa%20Rica%20Version%202%200%20final%20ENG.pdf

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 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.

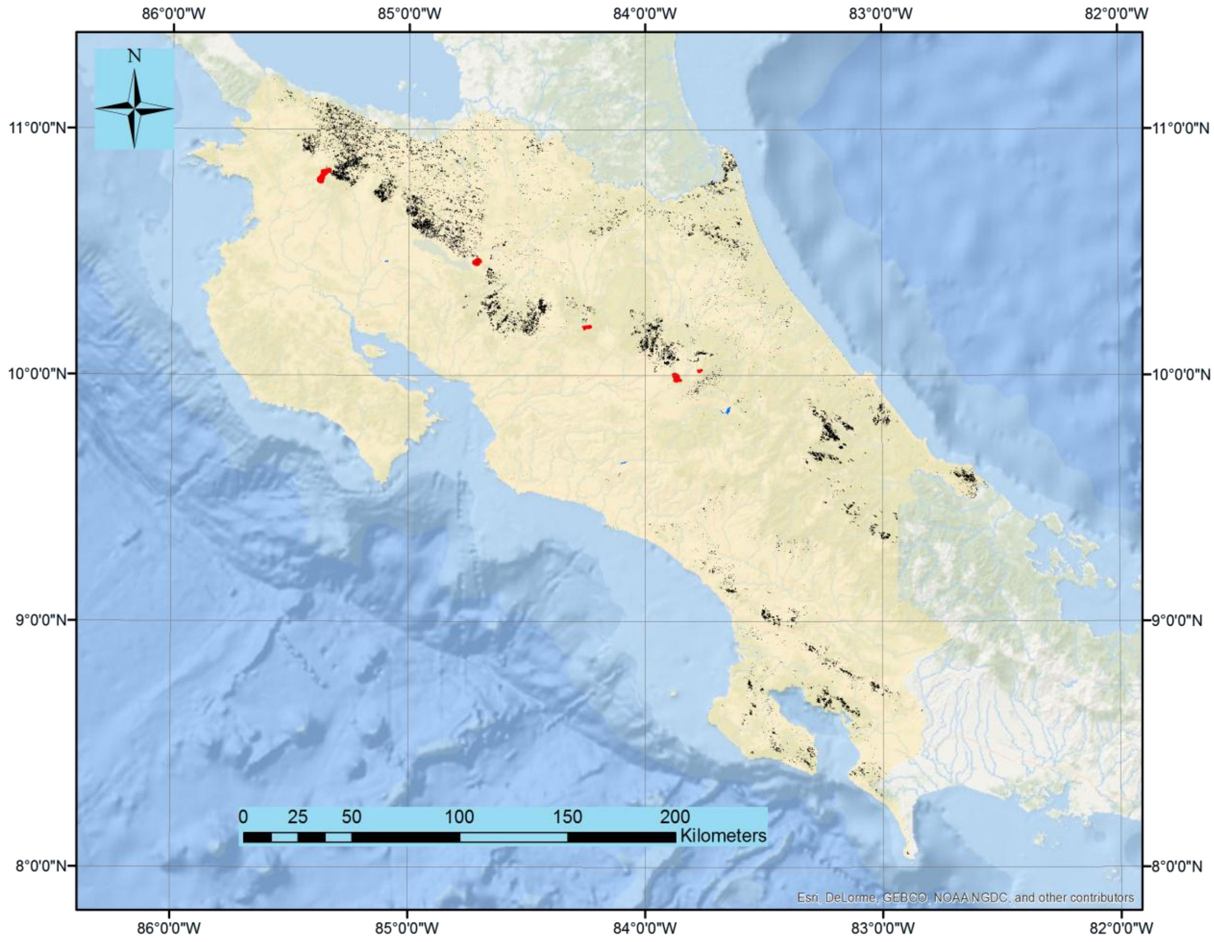
Figure 1. Geographical boundary of the proposed FREL.

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).

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

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 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

[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.

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.

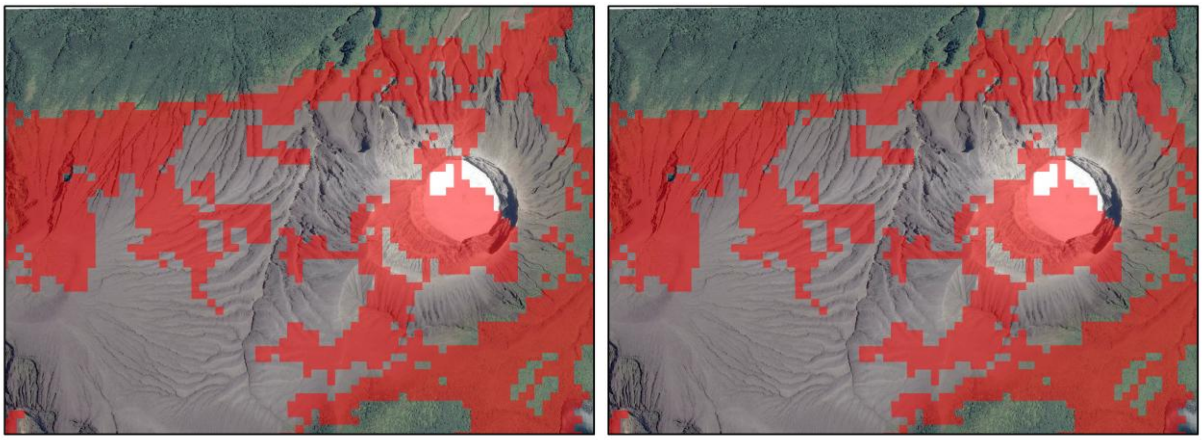
The low percentage of area without land use information was obtained by filling cloud and shadow areas with global data published by Hansen *et al.* (2013)[6]. This method will also be used in future measurement and reporting. Due to increasing availability of global forest cover data, it is likely that 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.

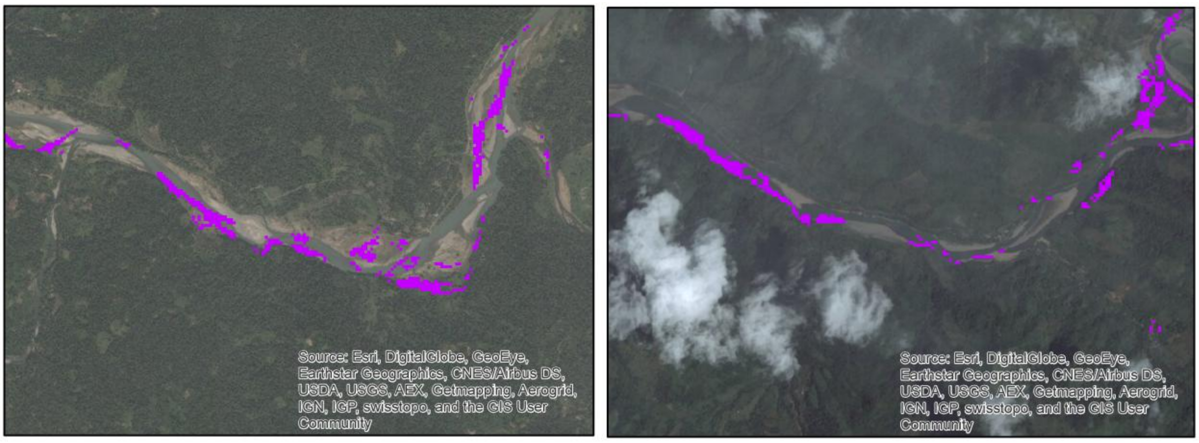
  Similarly, flooding and river meandering may cause non-anthropogenic forest loss that could actually increase in the future as a consequence of more extreme weather events related to climate change. During 1986-2013, 16,693.29 hectares of forests (55.4% of which were old-growth forests) were lost to 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**.

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7 Exact amount is 109.685.936.083 Colones. Available at: http://www.fonafifo.go.cr/psa/estadisticas/gePSA-MontoPresupuestarios.pdf

8 Exact amount is 172.049.699.033 Colones.

9 According to REDD+'s financial projections for 2010-2025. Data available at: http://reddcr.go.cr/sites/default/files/centro-de-documentacion/programa_de_reduccion_de_emisiones_01.11.15.pdf

- 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 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**.

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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.

At the moment, sufficient quality data are lacking to include the remaining REDD+ activities, which is a goal of the National REDD+ Strategy.

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). **Harvested wood products** (HWP) are also included. Soil organic carbon (SOC) was not included considering the limited availability of Tier 2 data to estimate emission factors.

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	Fraction 1	HWP.F1	included	Tier 1/2	National data (FONAFIFO, 2015) combined with IPCC default factors
		Fraction 2	HWP.F2	included	Tier 1/2	
		Fraction 3	HWP.F3	included	Tier 1/2	
		Fraction 4	HWP.F4	included	Tier 1/2	
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

[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.

Note: Fraction 1 = paper products; Fraction 2 = non-structural panels; Fraction 3 = Structural panels, veneer and plywood; Fraction 4 = Saw wood.

The detailed list of data and references used to estimate carbon stocks are available in a Microsoft Excel file ("**BaseDeDatos_v5 (28.12.2015).**")[15] 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 (28.12.2015).xlsx**")[16]

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 emissions from its FREL/FRL as well as from REDD+ results. This proposal takes into account that 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 accounting of emission reductions for result-based payments. Natural disturbances may affect managed and non-managed lands; however, all lands are considered managed in Costa Rica.

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+ accounting. 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;
- CO_2 emissions from harvested wood products (HWP).

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

[15] Available at: https://www.dropbox.com/s/66dwjnaotlbphen/BaseDeDatos_v5%20%2828.12.2015%29.xlsx?dl=0

[16] Available at: https://www.dropbox.com/s/od6kf1bd23whwg6/FREL%20TOOL%20CR%20%2828.12.2015%29.xlsx?dl=0

[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 at: http://unfccc.int/resource/docs/natc/crinir2.pdf

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.

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 which is available at http://reddcr.go.cr/es/centro-de-documentacion/datos-y-metodos-para-la-reconstruccion-del-nivel-de-referencia. If further information is required, please email asaenz@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 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 proposed FREL 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 not consistent with 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 would be more appropriate in the context of the REDD+ FREL than using the definition applied in FAO´s FRA.

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 totally consistent, the definition of "forest" used in the context of REDD+ is broader and largely includes the definition in the law. In the context of the National REDD+ Strategy and the relevant national legislation, the definition of "forest" in the law is applicable for domestic purposes. In terms of GHG accounting, it is still difficult to compare "deforestation" and "enhancement of forest C stocks" as measured with current methods, with activities sanctioned under the Forest Law. For example, the loss of younger forests that may be observed through Landsat imagery may not be considered "deforestation" according to the law, if the previous tree vegetation did not comply with the definition of "forest"; which is the case for many areas that are periodically cleared for cattle grazing. In this case, both emissions from forest loss and gains from forest regeneration are accounted for.

Regardless, for all forest definitions, only the minimum area parameter can be measured using Landsat imagery. Tree height and the percent of canopy cover cannot be measured directly with Landsat imagery, although it is often assumed that lands classified as "forest" actually surpass the threshold values of the three parameters used for defining "forest". For this reason, a test was carried out to determine how well the analysis of remotely sensed data performed in classifying "forests" according to its definition.

The test involved comparing areas classified as "forest" and "non-forest" with two canopy density maps prepared by an independent study[18] for the years 2001 and 2012. The result of this assessment revealed that 92.36% of the area classified as "primary forests" (*i.e*. old-growth forest) and 79.03% of the area classified as "new forest" (*i.e.* secondary forests and forest plantations) in 2001 presented ≥30% of canopy cover, while for 2012 the percentage was 93.45% and 79.33%, respectively. Results for "non-forest" areas showed that only 53.31% of the areas classified as "non-forest" in 2001 presented <30% of canopy cover, while for 2012 the percentage was 56.61%. This could be explained by the presence of wooded pastures and agroforestry systems in Costa Rica, and also by inherent error of the canopy-density maps.

4. Information on the proposed FREL

4.1. Description of the proposed FREL

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 refer to http://reddcr.go.cr/es/centro-de-documentacion/datos-y-metodos-para-la-reconstruccion-del-nivel-de-referencia.

The FREL/FRL has been estimated as the **annual average emissions** from deforestation and the annual **average removals** from enhancements of forest C stocks in the following two 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).

According to the national GHG inventory and for purposes of the FRELF/FRL, deforestation was defined as Forest land converted to non-Forest land in the year of conversion. For enhancement of forest C stocks, it was assumed, based on expert judgment, that secondary vegetation in all forest strata, except dry forests, surpasses the minimum thresholds of the parameters used for defining "forest" at an age of 4 years after land abandonment (8 years for dry forests). Thus, the conversion of non-Forest land to Forest Land can occur relatively rapidly in Costa Rica.

[18] Agresta, Dimap, University of Costa Rica, Universidad Politécnica de Madrid, 2015. b. Index of cover as base for the estimate of degradation and increase of carbon stocks: Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level. Consultancy report prepared for the Government of Costa Rica under the Carbon Fund of Forest Carbon Partnership (FCPF). 18 p.

C-stock enhancement in lands converted to Forest land was estimated using growth models developed in Costa Rica (Cifuentes, 2008)[19]; these models estimate C stocks as a function of age. Knowing the age of the forest in the year of the conversion and tracking forest age over time made it possible to apply these equations (more details are presented in section 4.4.). Emissions from deforestation were estimated assuming constant C stocks over time in primary forests and variable C stocks according to forest age in secondary forests.

Thus, the proposed FREL/FRL, expressed in tons of CO_2-e per year, was estimated as follows (all emissions and removals are annual averages):

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

Emissions from deforestation:	**16,446,552**	100.0%	
- Deforestation of primary forests:	14,375,724	82.0%	
- Deforestation of new forests:	2,070,829	18.0%	
Removals through C-stock enhancements:	**-2,152,603**	100.0%	growth of new forests

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

Emissions from deforestation:	**8,250,817**	100.0%	
- Deforestation of primary forests:	6,243,928	65.9%	
- Deforestation of new forests:	2,006,889	34.1%	
Removals through C-stock enhancements:	**-4,225,681**	100.0%	growth of new forests

Table 2 shows the annual emissions from deforestation and removals through forest C stock enhancement estimated for 1986-2009 and the calculation of total and annual average emissions and removals for two historical periods: 1986-1996 and 1997-2009.

[19] 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.

Table 2. GHG emissions from deforestation and removals from forest C stock enhancement.
(PF = Primary Forests; NF = New Forests, which include secondary forests and forest plantations).

Year	Emissions from deforestation			Removals through enhancement of C stocks			Net emissions		
	PF	NF	Total	PF	NF	Total	PF	NF	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	19,421,983	2,529,055	21,951,039		(133,643)	(133,643)	19,421,983	2,395,412	21,817,395
1987	19,421,983	2,536,253	21,958,236		(615,380)	(615,380)	19,421,983	1,920,873	21,342,856
1988	19,421,983	2,543,254	21,965,237		(1,084,191)	(1,084,191)	19,421,983	1,459,063	20,881,047
1989	19,421,983	2,550,065	21,972,048		(1,540,369)	(1,540,369)	19,421,983	1,009,695	20,431,679
1990	19,421,983	2,556,691	21,978,674		(1,984,169)	(1,984,169)	19,421,983	572,522	19,994,505
1991	19,421,983	2,563,138	21,985,121		(2,415,773)	(2,415,773)	19,421,983	147,365	19,569,348
1992	8,320,212	1,328,609	9,648,822		(2,918,659)	(2,918,659)	8,320,212	(1,590,050)	6,730,162
1993	8,320,212	1,416,871	9,737,083		(3,050,859)	(3,050,859)	8,320,212	(1,633,989)	6,686,224
1994	8,320,212	1,502,598	9,822,811		(3,182,205)	(3,182,205)	8,320,212	(1,679,607)	6,640,606
1995	8,320,212	1,585,861	9,906,073		(3,312,517)	(3,312,517)	8,320,212	(1,726,656)	6,593,556
1996	8,320,212	1,666,720	9,986,932		(3,440,872)	(3,440,872)	8,320,212	(1,774,152)	6,546,060
1997	8,320,212	1,745,231	10,065,443		(3,567,221)	(3,567,221)	8,320,212	(1,821,990)	6,498,223
1998	11,946,941	2,780,358	14,727,298		(3,457,118)	(3,457,118)	11,946,941	(676,760)	11,270,180
1999	11,946,941	3,005,277	14,952,218		(3,728,836)	(3,728,836)	11,946,941	(723,559)	11,223,382
2000	11,946,941	3,223,428	15,170,368		(4,002,603)	(4,002,603)	11,946,941	(779,175)	11,167,766
2001	4,295,172	1,306,939	5,602,111		(4,458,316)	(4,458,316)	4,295,172	(3,151,377)	1,143,796
2002	4,295,172	1,430,799	5,725,971		(4,431,811)	(4,431,811)	4,295,172	(3,001,012)	1,294,160
2003	4,295,172	1,550,846	5,846,018		(4,410,160)	(4,410,160)	4,295,172	(2,859,314)	1,435,858
2004	4,295,172	1,667,206	5,962,378		(4,393,061)	(4,393,061)	4,295,172	(2,725,855)	1,569,317
2005	4,295,172	1,779,992	6,075,164		(4,378,745)	(4,378,745)	4,295,172	(2,598,754)	1,696,419
2006	4,295,172	1,889,313	6,184,485		(4,367,188)	(4,367,188)	4,295,172	(2,477,876)	1,817,297
2007	4,295,172	1,995,272	6,290,444		(4,358,413)	(4,358,413)	4,295,172	(2,363,141)	1,932,031
2008	3,471,910	1,775,020	5,246,930		(4,648,116)	(4,648,116)	3,471,910	(2,873,096)	598,815
2009	3,471,910	1,939,879	5,411,789		(4,732,261)	(4,732,261)	3,471,910	(2,792,383)	679,528
Total 1986-1996	**158,132,962**	**22,779,114**	**180,912,076**	**-**	**(23,678,638)**	**(23,678,638)**	**158,132,962**	**(899,524)**	**157,233,438**
Average 1986-1996	14,375,724	2,070,829	16,446,552	-	(2,152,603)	(2,152,603)	14,375,724	(81,775)	14,293,949
Total 1997-2009	**81,171,061**	**26,089,558**	**107,260,619**	**-**	**(54,933,848)**	**(54,933,848)**	**81,171,061**	**(28,844,290)**	**52,326,771**
Average 1997-2009	6,243,928	2,006,889	8,250,817	-	(4,225,681)	(4,225,681)	6,243,928	(2,218,792)	4,025,136

4.2. Accounting approach: spatially explicit gross AD with net EF

According to frequently cited REDD+ literature (*e.g.* Angelsen *et al.*, 2009[20]; GOFC-GOLD, 2014[21]), IPCC Approach 3 should be used to collect AS and a Tier 2-methods should be employed by countries to measure and report emissions and removals, especially in the context of REDD+ result-based payments. Such reported emissions and removals should be estimated based on gross AD and net EF.

- **Gross AD** requires accounting as "deforestation" only the area of forest lost in a particular period of time (DF.1 and DF.2 in figure 4), without considering the area afforested/reforested or naturally regenerated during the same period (*i.e.* "gross deforestation"); and accounting as "enhancement of forest C stocks" the gains in forest area occurred during the same period of time (EC.1 in figure 4), as well as the gains in forest areas occurred in previous periods (EC.2 and EC.3), as these areas continue to enhance their forest C stocks as long as the standing forest is growing.

  A method that facilitates a transparent implementation of this approach is to develop spatially explicit land use data sets to represent all land use transitions in land use change matrices. By assigning one REDD+ activity to each cell of the matrices, it is also easy to show REDD+ activities are defined. This also avoids the risk of omitting or double counting emissions and removals (see Figure 4)[22].

Figure 4. Simplified land use change matrix illustrating how REDD+ activities were defined.

	FL	LCFL	CL	GL	SL	WL	OL
FL	CO	NA	DF.1	DF.1	DF.1	DF.1	DF.1
LCFL	EC.3	EC.2	DF.2	DF.2	DF.2	DF.2	DF.2
CL	NA	EC.1	NA	NA	NA	NA	NA
GL	NA	EC.1	NA	NA	NA	NA	NA
SL	NA	EC.1	NA	NA	NA	NA	NA
WL	NA	EC.1	NA	NA	NA	NA	NA
OL	NA	EC.1	NA	NA	NA	NA	NA

FL = Forest land; **LCFL** = Land Converted to Forest land; **CL** = Cropland; **GL** = Grassland; **SL** = Settlements; **WL** = Wetlands; **OL** = Other Land; **CO** = Conservation of Forest C Stocks; **EC** =Enhancement of Forest C Stocks (EC.1 EC in conversions of non-Forest land to Forest land; EC.2 EC in LCFL remaining LCFL; EC.3 = EC in LCFL converting to FL after a country-defined period) ; **DF** = Deforestation (DF.1 = Deforestation of old-growth forests; DF.1 = Deforestation of secondary forests); **NA** = Not Applicable in the context of REDD+.

20 Angelsen, A., S. Brown, C. Loisel, L. Peskett, C. Streck, & D. Zarin, 2009. Reducing Emissions from Deforestation and Forest Degradation (REDD); An Options Assessment Report, Meridian Institute Report, Prepared for the Government of Norway; 21 p.

21 GOFC-GOLD (Global Observation of Forest and Land Cover Dynamics) 2014. A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals associated with deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. GOFC-GOLD Report version COP20-1, (GOFC-GOLD Land Cover Project Office, Wageningen University, The Netherlands). Available at: http://www.gofcgold.wur.nl/redd/sourcebook/GOFC-GOLD_Sourcebook.pdf.

22 In the spreadsheets "FREL TOOL CR (28.12.2014).xlsx" this approach has been implemented in the sheet "REDD+ ACT".

- **Net EF** requires the estimation of the difference in C stocks of the two land use categories participating in each land use change transition. In the case of "deforestation" this means that C stocks must be estimated for the forest being cleared and for the replacing land use. In the case of "enhancement of forest C stocks", net EF requires the estimation of the difference in C stocks of the land use category being replaced by the new forest and the C stock of the new forest (EC.1 in figure 4) or, in case of growing forests, the C stocks of the growing forest at year *t* and the C stocks of the growing forest at year *t+n* (EC.2 and EC.3 in figure 4). Therefore, accounting for net emissions requires higher Tier C stock estimates for all forest and non-forest categories involved in the conversions of "forest" to "non-forest", and vice versa.

Accounting for spatially explicit gross AD has been possible because a land use change time series is available for Costa Rica. This time series includes maps for 1985/86, 1991/92, 1997/98, 2000/01, 2007/08, 2010/11 and 2013/14. As these maps depicts IPCC's land use categories, it was possible to create land use change matrices for six periods (1986-1991, 1992-1997, 1998-2000, 2001-2007, 2008-2011 and 2012-2013), thus enabling the tracking of land use conversions. This also allows for the application of net EF for exclusive land use change conversions, as exemplified in Figure 4 and shown in the sheet "REDD+ ACT" of the tool "FREL TOOL CR (28.12.2015).xlsx".

4.3. Activity data

4.3.1. Consistent representation of lands

Land classification for deriving AD from the 1986-2013 land use change time series is consistent with the national GHG inventory (except for forest plantations, as explained below). The classes defined were:

1. Forest land and land converted to 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

Forest land remaining Forest land since 1985/86 that was not classified as “secondary forest” in this year[23] was assumed to be old-growth forest or “**primary forest**”. Primary forests are assumed to maintain the constant C stocks per hectare over time, given that growth usually equals mortality. 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 new forests on lands previously classified as “non-forest”. They also include forests that were classified as “secondary forest” already in 1985/86. 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 Table 3 and 4) it was assumed that all age classes growth 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

[23] To determine whether a forest was “primary” or “secondary” in 1985/1986, a map of the IMN depicting areas of secondary forests for 1978/1980 was employed.

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 include forest plantation as an additional sub-category in the land use change time series. The quality of the satellite imagery employed was not sufficient to overcome the spectral confusion of forest plantation with secondary forests and certain agro-forestry systems. As other sources of national information on forest plantation are neither spatially explicit nor complete for 1986-2013, 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 forest plantations. Hence, the terminology “new forest” is considered more appropriate than “secondary forests”. Given this situation, the EF applied to “new forests” does not differentiate between tree plantations and secondary forests. This is less accurate but more conservative, 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 forest 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 AD

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)[24]. This map was used to stratify “Forests” into the three sub-categories: “Wet and Rain Forests”, “Moist Forests” and “Dry Forests” (see Figure 5).
- 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.

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

Figure 5. 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[25] available at http://reddcr.go.cr/es/centro-de-documentacion/datos-y-metodos-para-la-reconstruccion-del-nivel-de-referencia.

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)[26].

Classification:

- **Methodology**. "Random Forest" (RF) by Breiman (2001)[27] 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

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25 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.

26 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.

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

classification were filtered in order to represent the land use categories with a minimum mapping unit of 0.99 ha[28].

- **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*".

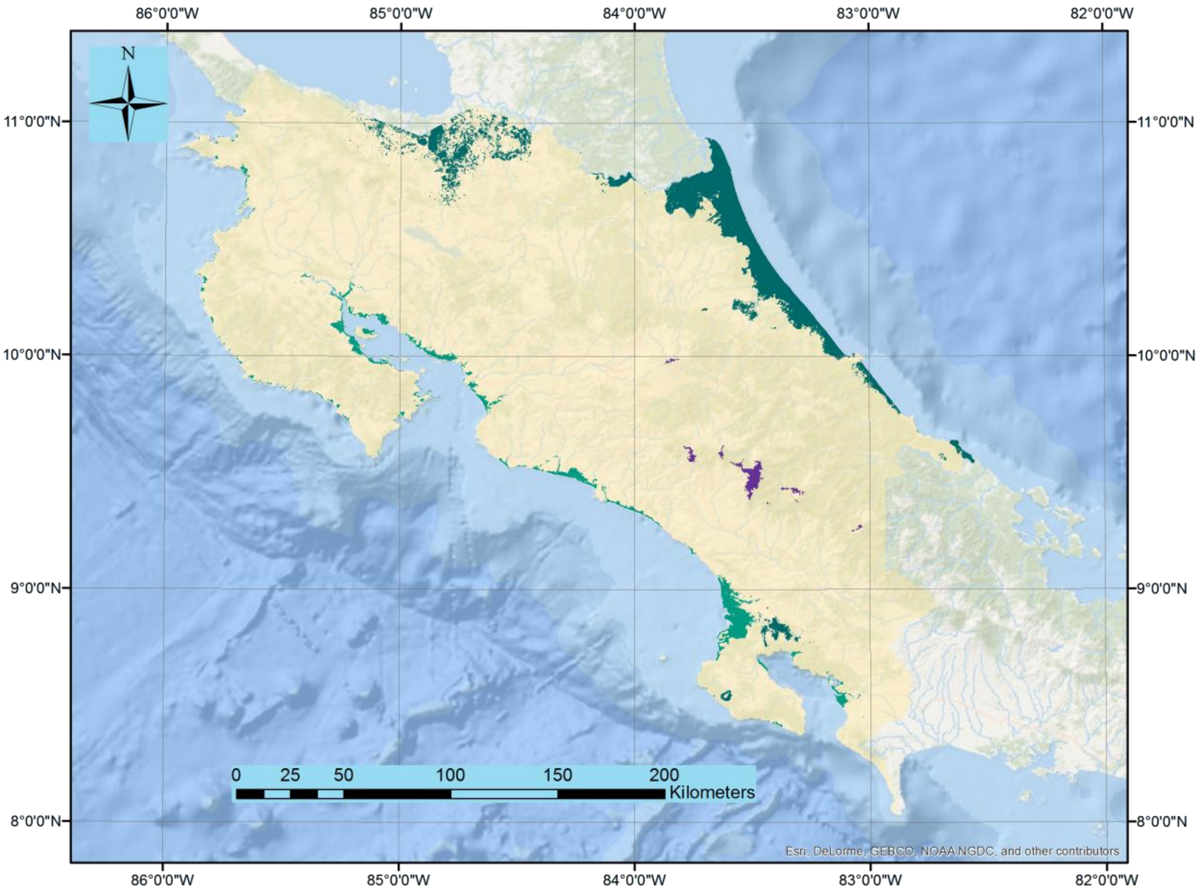
  (5) All masks representing "*Mangroves*", "*Palm Forests*" and "*Paramo*" have been compiled in a map of masks that will be kept in order to enable consistent map editions in future measurement and reporting (Figure 6).

[28] 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).

(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 7) 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.

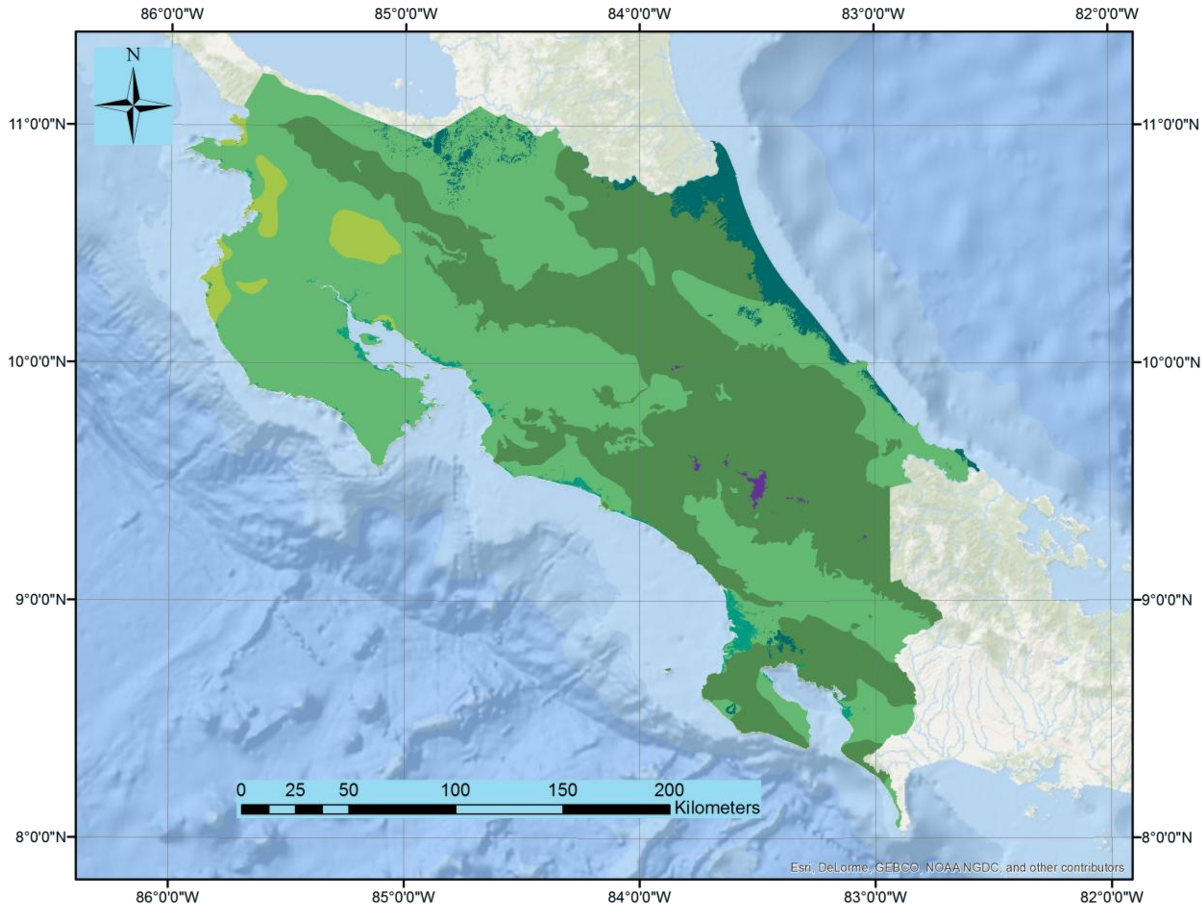
Figure 6. Map of the masks of potential areas of Mangroves, Palm Forests and Paramo.



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 7. 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 1986-2013 in a Geographical Information System (GIS) and then extracting from the combined set of multi-temporal data the values of the areas that remained in the same category or converted to other land use categories. 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 tool “FREL TOOL CR (28.12.2015).xlsx”. The tool can be downloaded here: https://www.dropbox.com/s/od6kf1bd23whwg6/FREL%20TOOL%20CR%20%2828.12.2015%29.xlsx?dl=0

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):

  $$AD_t = AD_p / T \quad \textbf{(Eq.01)}$$

  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:

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

  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 “FREL TOOL CR (28.12.2015).xlsx” (“AAAA” indicates the year).

4.3.5. Results for activity data

Figure 8 shows forest cover in Costa Rica for 1986-2013. Figure 9 shows forest losses in the same period. Annual areas of forest loss estimated for primary forests are shown in Table 5 and those for new 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/FRL TOOL CR (24.12.2015).xlsx”.

Figure 8. Forest cover in Costa Rica between 1986 and 2013 (in hectares).

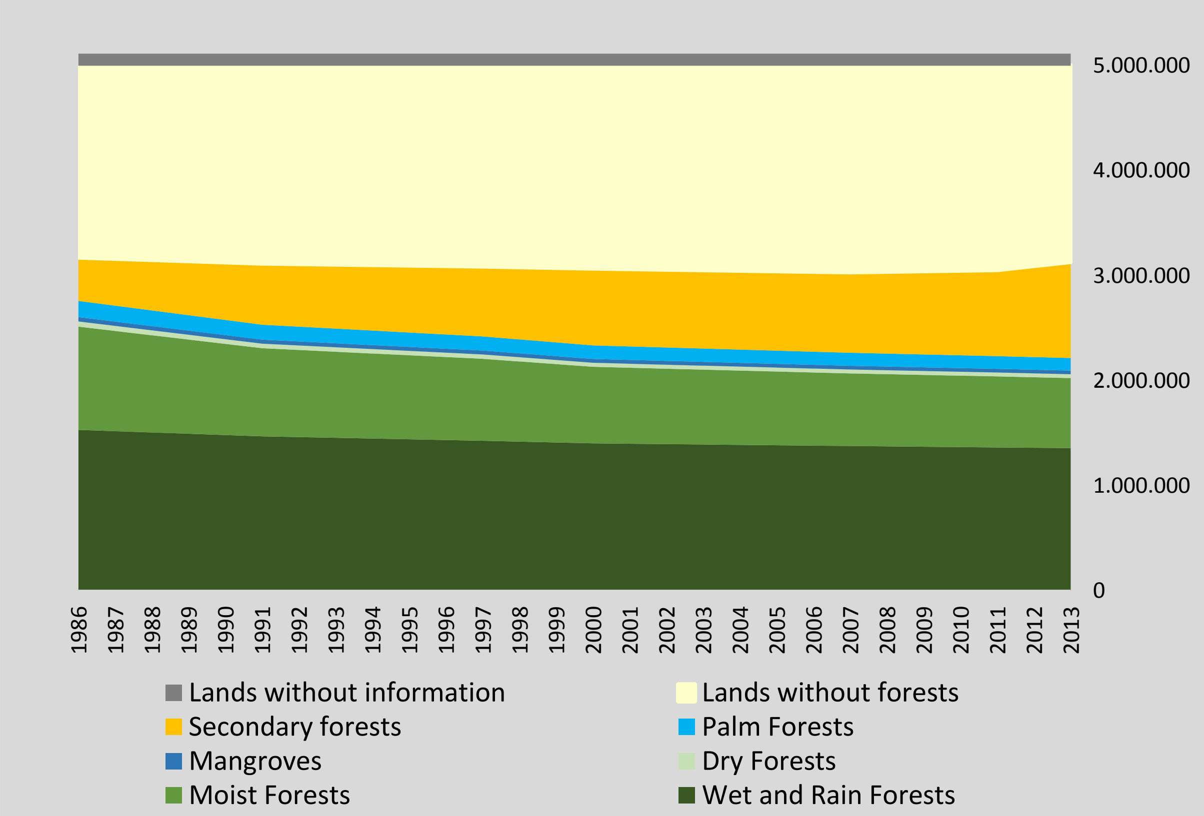


Figure 9. Forest loss in Costa Rica between 1986 and 2013 (hectares).

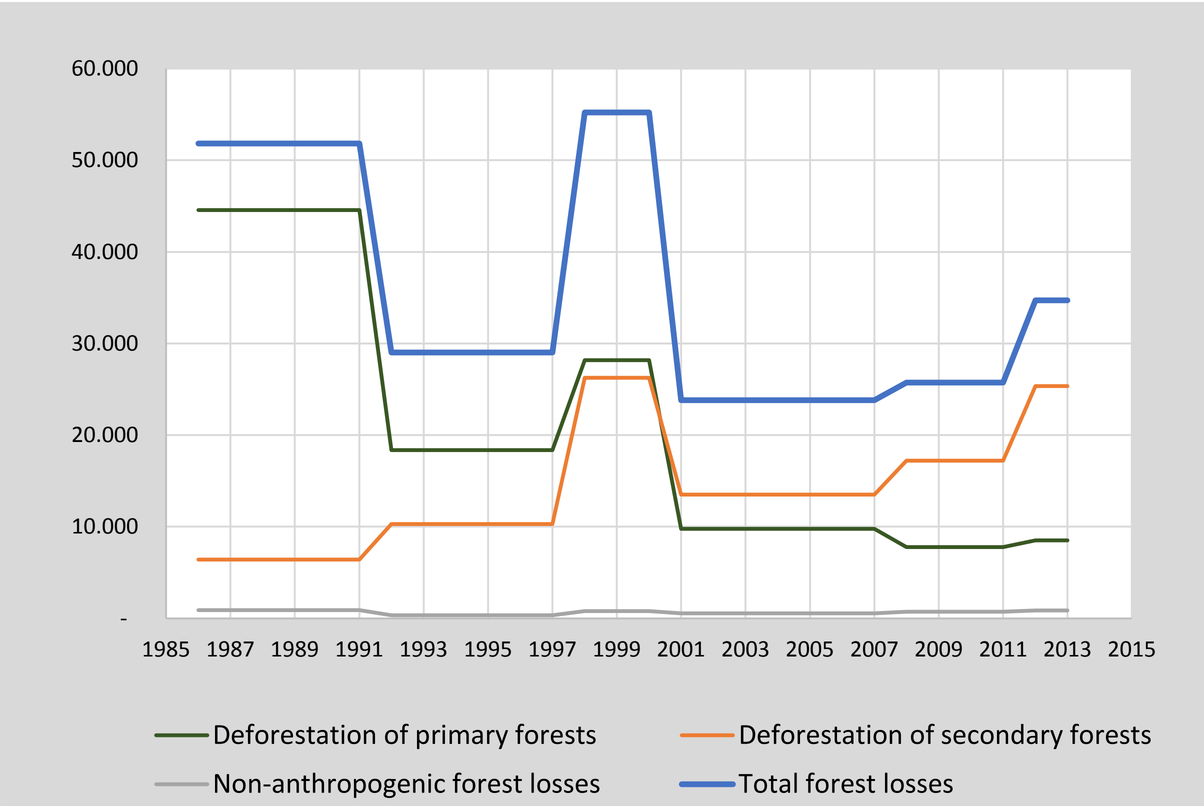


Table 5. Annual loss of primary forests.

	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 new forests.

	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. New 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 new forest**		**383,368.41**	**586,538.10**	**670,106.25**	**735,865.83**	**770,395.05**	**824,096.61**	**918,483.39**

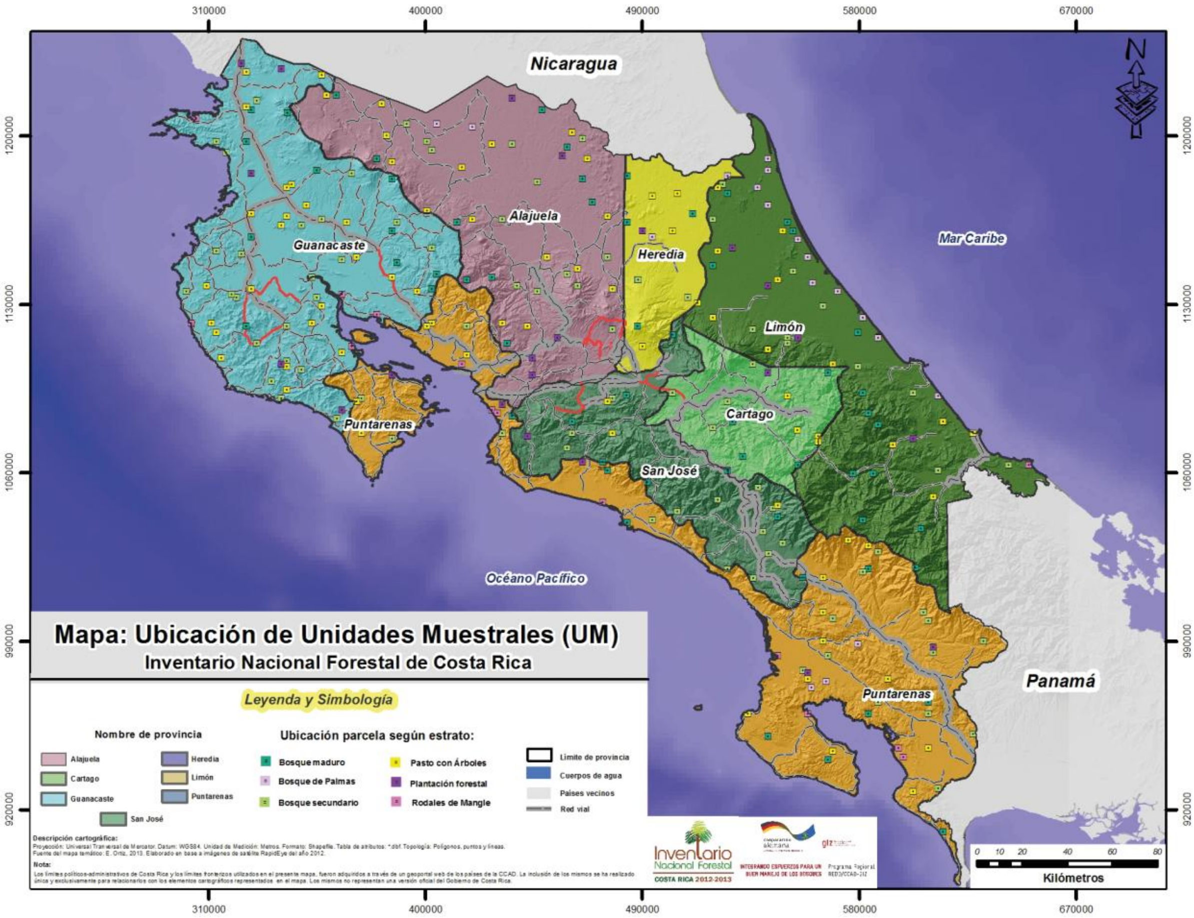
AE = Areas with enhancement of forest C stocks.

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 sample was used for the estimation of forest C stocks. The location of these plots is shown in Figure 10. Plot distribution was based on fixed sample intensities by forest class. Please visit http://www.sirefor.go.cr/?p=801 for more information.

Figure 10. Plots of the National Forest Inventory measured 2014-15
(Source: Programa REDD/CCAD-GIZ - SINAC. 2015)[29]



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

29 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

- The NFI and the national GHG inventory differ in their forest stratifications. However, using the location of the 289 NFI plots, it was possible to allocate each plot to the five forest strata considered for Forest land 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[30] was carried out. To consider a publication, the following criteria must be 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 (28.12.2015).xlsx").

4.4.2. Methods for estimating C stocks

Average C stocks by C pool and land use category 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" (*cf.* "BaseDeDatos_v5 (28.12.2015).xlsx") in tons of carbon per hectare (tC 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 lan -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:

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

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)**:

30 The full list of consulted sources may be found in the sheet "1.Referencias" of the Excel file "BaseDeDatos_v5 (28.12.2015).xlsx".

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 above-ground biomass (TAGB) of Wet and Rain Forests, Moist Forests and Dry Forests were estimated using the equations developed by Cifuentes (2008)[31] for Costa Rican secondary forests based on direct measurements in 54 plots located in age classes between 0 and 82 years (see also Figure 5 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)[32].

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

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)**:

31 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.

32 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 "FREL TOOL CR (28.12.20145).xlsx"). 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.
- **Harvested wood products (HWP.F4)**: for Forest land converted to other land use categories, it was assumed that, in all cases, high-value timber is harvested before the conversion. The saw wood fraction of HWP (Fraction 4) was assumed not to oxidize in order to estimate conservative EF.

To estimate C stocks extracted in HWP.F4, it was assumed that 35% of total biomass in primary forests is concentrated in trees ≥60 cm dbh and that these trees are harvested. This assumption is supported by Eguiguren-Velepucha (2013)[33] for a tropical wet forest; further, 60 cm is the minimum diameter for harvestable timber in Costa Rica. For secondary forests, it was assumed that 50% of total biomass is in trees with ≥40 cm dbh are harvested. These assumptions were made for all strata, except Palm Forest were high-value timber was assumed to be absent and no harvesting occurs.

The following equation was used to calculate C stock in HWP:

$$C_{HWP.Fx} = C_{AGB.t} * HWP\% * BCEF^{-1} * SAW\% * FX\% \qquad \textbf{(Eq.10)}$$

Where:

$C_{HWP.Fx}$ C stock in harvested wood products, fraction *X*; tCO_2-e ha^{-1}

$C_{AGB.t}$ Carbon stock in above-ground tree biomass; tCO_2-e ha^{-1}

$HWP\%$ Percentage of tree biomass extracted as HWP prior to the conversion to non-forest (35% in primary forests and 50% in secondary forests); %

$BCEF$ Biomass conversion and expansion factor to convert biomass in merchantable timber to total biomass (2.0, which is the lowest value given by IPCC, 2003, LULUCF, Table 3A.1.10); dimensionless

33 Eguiguren-Velepucha, P. A. 2013. Los efectos de intervenciones forestales y la variabilidad climática sobre la dinámica a largo plazo de bosques tropicales en el noreste de Costa Rica. Turrialba (Costa Rica): CATIE , 2013.

SAW% Sawmill efficiency in converting log volume to timber products (0.7 for primary forests and 0.5 for secondary forest according to FONAFIFO, 2015[34] and expert judgment); %

FX% Proportion of Fraction X in total HWP;%
For the saw wood fraction (Fraction 4) the value 36.7% is used (source: FONAFIFO, 2015).

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 (28.12.2015).xlsx") and reported in the sheet "C-STOCKS" in "FREL TOOL CR (28.12.20145).xlsx".

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 (28.12.20145).xlsx" available here: https://www.dropbox.com/s/od6kf1bd23whwg6/FREL%20TOOL%20CR%20%2828.12.2015%29.xlsx?dl=0

34 FONAFIFO (2015) - Informe Final - Aumentando los acervos de carbono en productos de madera y derivados en Costa Rica.

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

					CO₂							Non-CO_2	
				Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Harvested wood products	Biomass burning (L_{fire})	
				$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	$C_{HWP.F4}$	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}	tCO_2-e ha^{-1}
FL & ->FL	Wet and Rain Forest	PF	AVG	**481.10**		**106.92**	**-**	**49.50**	**10.05**	**647.57**	**21.61**	**11.10**	**4.82**
			90%CI	443.65	-	98.60	-	40.75	9.11	608.21	19.04	4.50	1.96
				518.56	-	115.24	-	58.25	11.00	686.94	24.17	17.71	7.69
		SF 4 yr	AVG	**34.50**		**9.33**	**-**	**3.74**	**0.36**	**47.92**	**1.58**	**0.97**	**0.42**
			90%CI	31.59	-	8.54	-	3.43	0.27	44.89	1.37	0.48	0.21
				37.40	-	10.11	-	4.06	0.44	50.95	1.79	1.46	0.64
		SF 15 yr	AVG	**117.13**		**28.92**	**-**	**12.71**	**1.21**	**159.96**	**5.37**	**3.30**	**1.43**
			90%CI	107.34	-	26.50	-	11.65	0.92	149.82	4.67	1.64	0.71
				126.92	-	31.33	-	13.77	1.50	170.11	6.07	4.97	2.16
		SF 30 yr	AVG	**205.74**		**48.71**	**-**	**22.33**	**2.12**	**278.90**	**9.43**	**5.80**	**2.52**
			90%CI	188.72	-	44.68	-	20.48	1.62	261.30	8.20	2.88	1.25
				222.77	-	52.74	-	24.18	2.63	296.50	10.66	8.73	3.79
	Moist Forest	PF	AVG	**339.71**		**77.48**	**-**	**48.27**	**8.01**	**473.46**	**15.26**	**8.27**	**3.59**
			90%CI	311.51	-	71.04	-	25.02	6.96	436.33	13.39	3.31	1.44
				367.91	-	83.91	-	71.52	9.05	510.58	17.12	13.23	5.74
		SF 4 yr	AVG	**44.14**		**11.72**	**-**	**5.10**	**0.85**	**61.81**	**2.02**	**1.28**	**0.55**
			90%CI	40.80	-	10.83	-	2.67	0.72	57.58	1.76	0.63	0.27
				47.49	-	12.61	-	7.53	0.98	66.05	2.28	1.93	0.84
		SF 15 yr	AVG	**138.15**		**33.69**	**-**	**15.96**	**2.67**	**190.47**	**6.33**	**4.00**	**1.74**
			90%CI	127.50	-	31.09	-	8.37	2.25	177.13	5.52	1.96	0.85
				148.79	-	36.28	-	23.56	3.08	203.81	7.15	6.04	2.62
		SF 30 yr	AVG	**220.12**		**51.85**	**-**	**25.43**	**4.25**	**301.65**	**10.09**	**6.37**	**2.77**
			90%CI	202.84	-	47.78	-	13.32	3.58	280.15	8.78	3.12	1.35
				237.39	-	55.92	-	37.54	4.91	323.14	11.39	9.62	4.18

(Table 8 continued)

					CO_2								Non-CO_2	
					Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Harvested wood products	Biomass burning (L_{fire})	
					$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	$C_{HWP.F4}$	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}	tCO_2-e ha^{-1}
FL & LCFL	Dry Forest	PF		**AVG**	**225.58**		**53.04**	**-**	**56.47**	**22.73**	**357.82**	**10.13**	**6.74**	**2.92**
				90%CI	207.62	-	48.82	-	34.54	22.12	329.16	8.92	2.69	1.17
					243.54	-	57.26	-	78.39	23.35	386.48	11.34	10.78	4.68
		SF	8 yr	**AVG**	**15.64**		**4.49**	**-**	**1.88**	**1.51**	**23.51**	**0.72**	**0.51**	**0.22**
				90%CI	14.40	-	4.13	-	1.34	1.38	22.10	0.62	0.25	0.11
					16.89	-	4.84	-	2.41	1.64	24.92	0.81	0.77	0.33
			15 yr	**AVG**	**79.50**		**20.20**	**-**	**9.54**	**7.68**	**116.92**	**3.64**	**2.60**	**1.13**
				90%CI	73.17	-	18.59	-	6.81	7.02	109.81	3.17	1.29	0.56
					85.83	-	21.81	-	12.26	8.33	124.03	4.11	3.91	1.70
			30 yr	**AVG**	**189.12**		**45.05**	**-**	**22.68**	**18.26**	**275.12**	**8.67**	**6.18**	**2.68**
				90%CI	174.07	-	41.47	-	16.19	16.71	258.27	7.54	3.06	1.33
					204.18	-	48.64	-	29.17	19.82	291.98	9.79	9.29	4.03
	Mangroves	PF		**AVG**	**264.78**		**61.52**	**-**	**6.95**	**0.97**	**334.22**	**11.89**		
				90%CI	233.57	-	54.27	-	4.90	0.73	302.11	10.13	-	-
					296.00	-	68.77	-	8.99	1.22	366.33	13.65	-	-
		SF	4 yr	**AVG**	**10.59**		**3.13**	**-**	**0.27**	**0.03**	**14.02**	**0.49**		
				90%CI	9.34	-	2.76	-	0.17	(0.00)	12.71	0.42	-	-
					11.84	-	3.50	-	0.37	0.06	15.32	0.55	-	-
			15 yr	**AVG**	**39.72**		**10.63**	**-**	**1.02**	**0.11**	**51.47**	**1.82**		
				90%CI	35.04	-	9.37	-	0.64	(0.00)	46.60	1.56	-	-
					44.40	-	11.88	-	1.39	0.21	56.33	2.08	-	-
			30 yr	**AVG**	**79.43**		**20.18**	**-**	**2.03**	**0.21**	**101.86**	**3.64**		
				90%CI	70.07	-	17.81	-	1.28	(0.00)	92.17	3.12	-	-
					88.80	-	22.56	-	2.78	0.43	111.56	4.16	-	-

(Table 8 continued)

					CO_2								Non-CO_2	
					Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Harvested wood products	Biomass burning (L_{fire})	
					$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	$C_{HWP.F4}$	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}	tCO_2-e ha^{-1}
FL & LCFL	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	Harvested wood products	Biomass burning (L_{fire})	
				$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	$C_{HWP.F4}$	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}	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 & ->FL = Forest land and land converted to Forest land; **CL** = Cropland; **GL** = Grassland; **SL** = Settlements; **WL** = Wetlands; **OL** = Other Land; **PF** = Primary Forest; **SF** = Secondary Forest (*i.e.* New 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 to and 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). Thus, EF were estimated as follows:

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

<u>Where:</u>

$EF_{i,t}$ EF factor applicable to the land use transition *i* in year *t*; tCO_2-e ha^{-1}
<u>Note:</u> 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:

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

<u>Where:</u>

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 (28.12.2015).xlsx").

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[35] and 20[36] of the sheets "ER AAAA" (where "AAAA" stands for the year *t*) in the "FREL TOOL CR (28.12.2015).xlsx").

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

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[35] 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.

[36] 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 (except HWP) and then substituting the C_{t1} in Eq.12 with $Ctot_{t1}$ and C_{t2} with $Ctot_{t2}$:

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

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}

It is important to note that for conversions of Forest land to other land use, C_{AGB} in in $Ctot_{t1}$ is estimated as follows:

$$C_{AGB_{t1}} = C_{AGB_{t1-1}} - C_{HWP.F4} \quad \textbf{(Eq.14)}$$

Where:

$C_{AGB_{t1}}$ C stock in above-ground biomass after harvest, but before conversion; tCO_2-e ha^{-1}

$C_{AGB_{t1-1}}$ C stock in the above-ground biomass before harvest; tCO_2-e ha^{-1}

$C_{HWP.F4}$ C stock in HWP, fraction 4 (saw wood) as estimated with Eq.10.
Note: It is assumed that C stock in HWP.F4 is not oxidized.

In conversions of permanent crops to secondary forests it was assumed, consistently with the National GHG Inventory, that only the non-tree component of the biomass ($C_{AGB.n}$) of the permanent crop oxidizes. The tree component of the biomass ($C_{AGB.t}$) is assumed to continue as part of the secondary forest and is not oxidized.

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.):

$$L_{fire} = A \cdot M_B \cdot C_f \cdot G_{ef} \cdot 10^{-3} \quad \textbf{(Eq.15)}$$

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 (except for HWP.F4), dead wood and litter:

$$M_B = C_{AGB_{t1}} - C_{HWP.F1} - C_{HWP.F2} - C_{HWP.F3} - C_{HWP.F4} + C_{ADW_{t1}} + C_{L_{t1}} \quad \textbf{(Eq.16)}$$

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 (28.12.2015).xlsx").

4.4. Method used to construct the FREL/FRL

The proposed FREL was defined as the annual average emissions from deforestation and annual average removals from enhancements of forest carbon 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 (28.12.2015).xlsx").

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:

$$ER_{RA_t} = \sum_{i=1}^{I}\left(AD_{RA_{i,t}} * EF_{RA_{i,t}}\right) * \quad \textbf{(Eq.17)}$$

Where:

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 file "FREL TOOL CR (28.12.2015).xlsx", 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 is shown in the sheet "REDD+ ACT" (as exemplified in Figure 4).

4.5. Estimated FREL/FRL

The methods described in the previous sections resulted in the forest-related emissions and removals sown in Figure 11.

Figure 11. Forest-related emissions and removals in Costa Rica between 1986 and 2013 (tCO_2-e yr^{-1}).

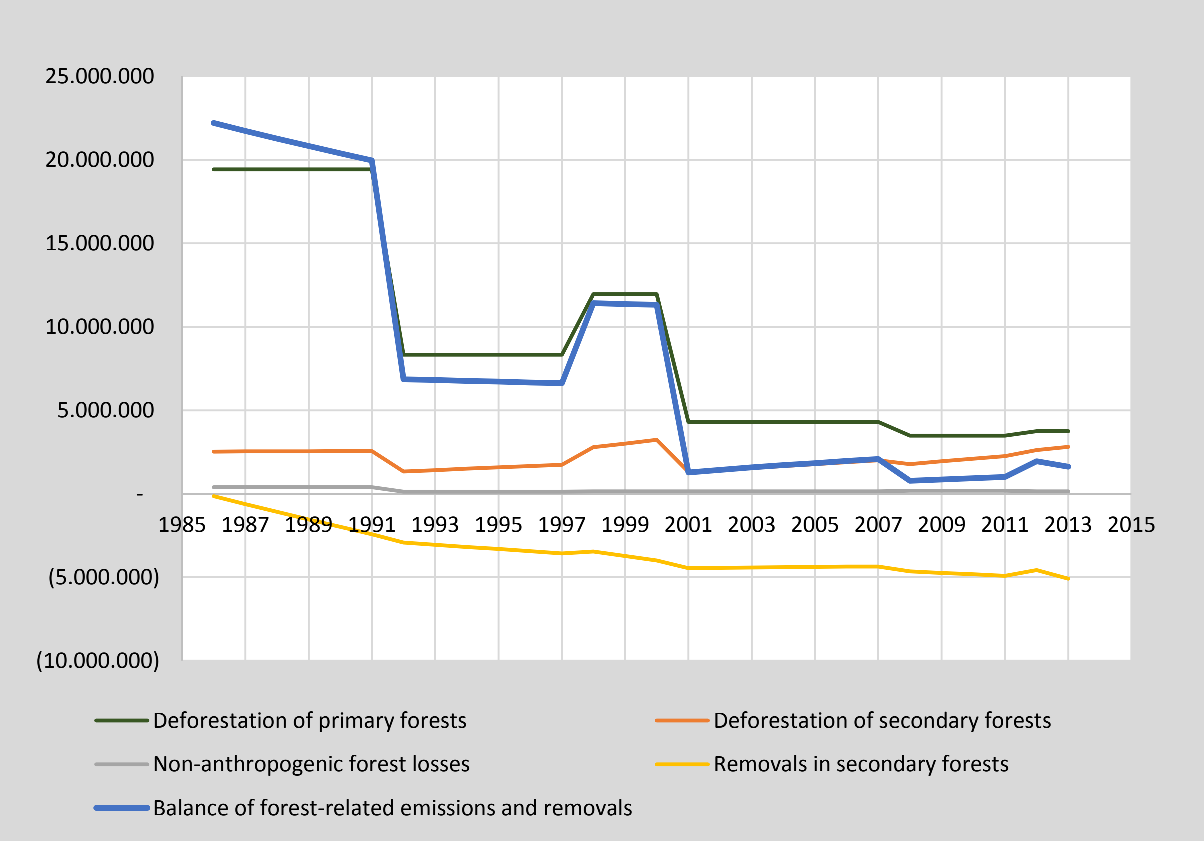
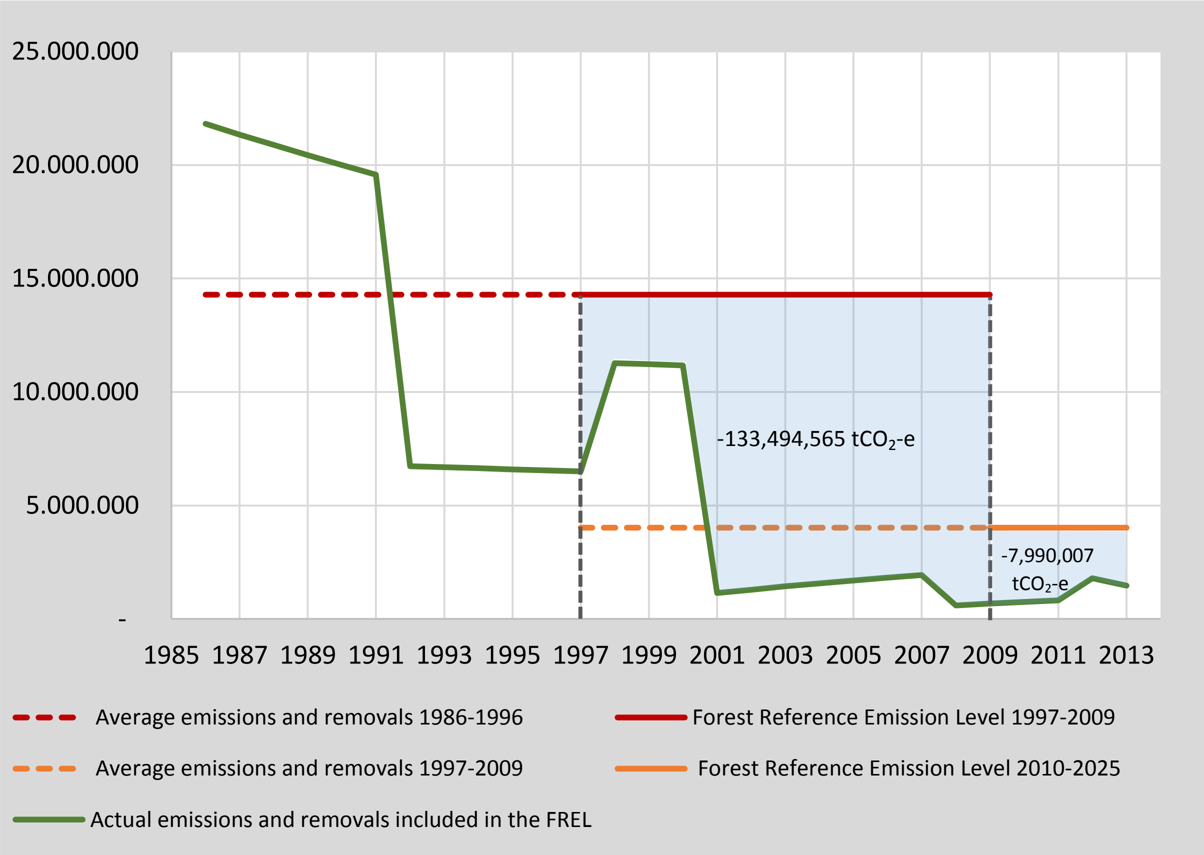


Figure 12 illustrates the estimated FREL/FRL for the two periods of enhanced mitigation actions (1997-2009 and 2010-2025, respectively) and the net emissions from the included REDD+ activities.

The difference between net emissions and the FREL/FRL for the period 1997-2009 is an emission reduction of -133,494,565 tCO_2-e (-10,268,813 tCO_2-e yr^{-1} on average) while for the period 2010-2014 the estimated emission reduction is -7,990,007 tCO_2-e (-1,997,502 tCO_2-e yr^{-1} on average).

Figure 12. FREL/FRL and actual forest-related net emissions included in the FREL/FRL (tCO_2-e yr^{-1}).



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 carbon accounting. 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 1986-2013, considering 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 are central to the FREL/FRL proposed here. The land use analysis was used to determine Forest land remaining Forest land, Land converted to Forest land and Forest lands converted to other land use categories. However, it was not possible to determine specific activities within the Forest land remaining Forest land category, e.g. forest degradation or enhancement. At the moment, this remains an important area for improvement. The sustainable management of forests was not included either, however this was due to lack of data on management plans which are mainly kept in paper copies in regional offices. As part of the on-going readiness actions, Costa Rica plans to compile this information and create mechanisms for documenting and digitally archiving new management plans.

Despite these developments, there is still ample room for improvement. For example, part of the emissions time series in the GHG inventory has not been fully updated and certain parameters still need to be made consistent with the REDD+ FREL. 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 and GIZ. 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, although increased accuracy is expected, e.g. for determining C stock gains and losses in Forest land remaining Forest land, as well as developing a better land use and cover categorization. Besides the USFS and GIZ, 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+. This is key to avoiding double counting with the Coffee NAMA and other upcoming NAMAs, e.g. the Livestock NAMA.

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.

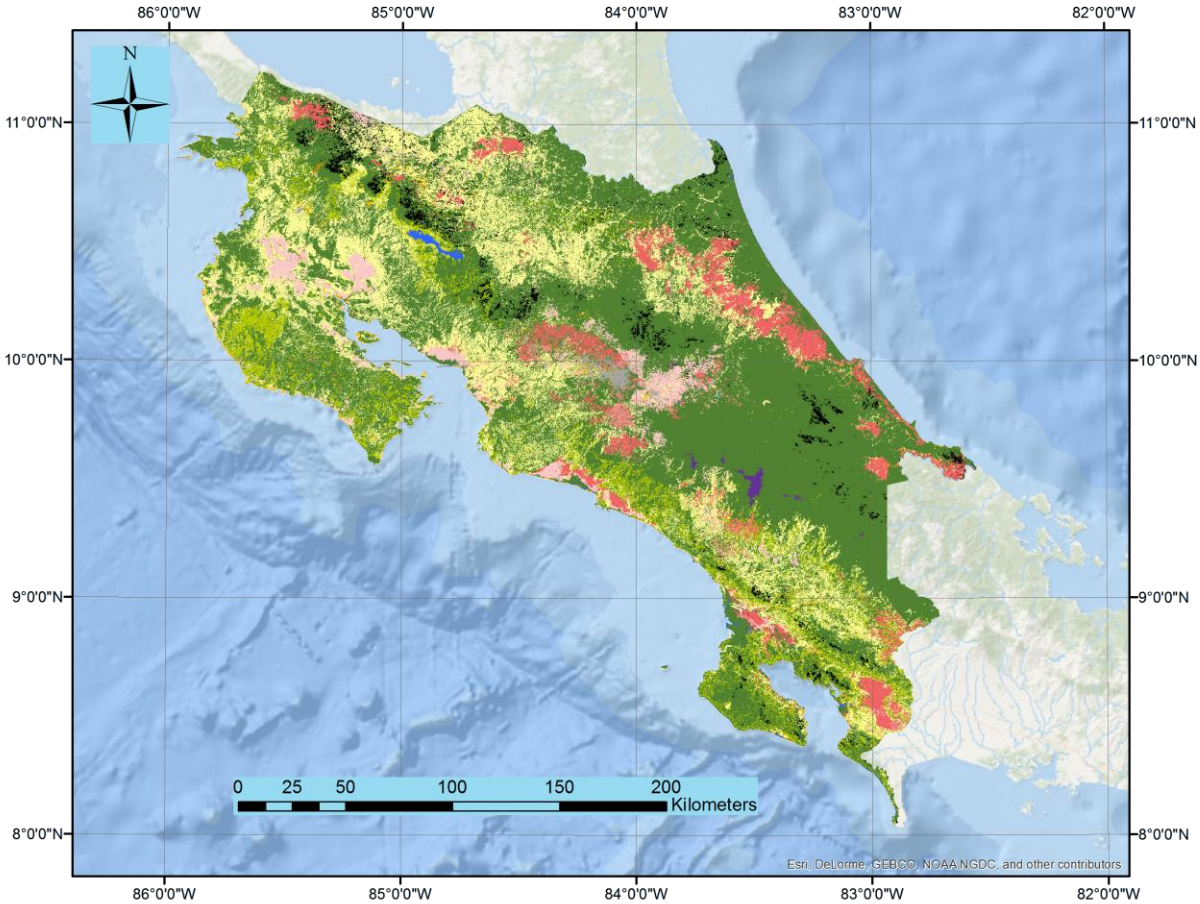
(b) If the central image was acquired between January 1st and June 30th, it was assumed that the land use map represents the land uses existing in Costa Rica on January 1st of the image acquisition date and on December 31st of the previous year.

(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.

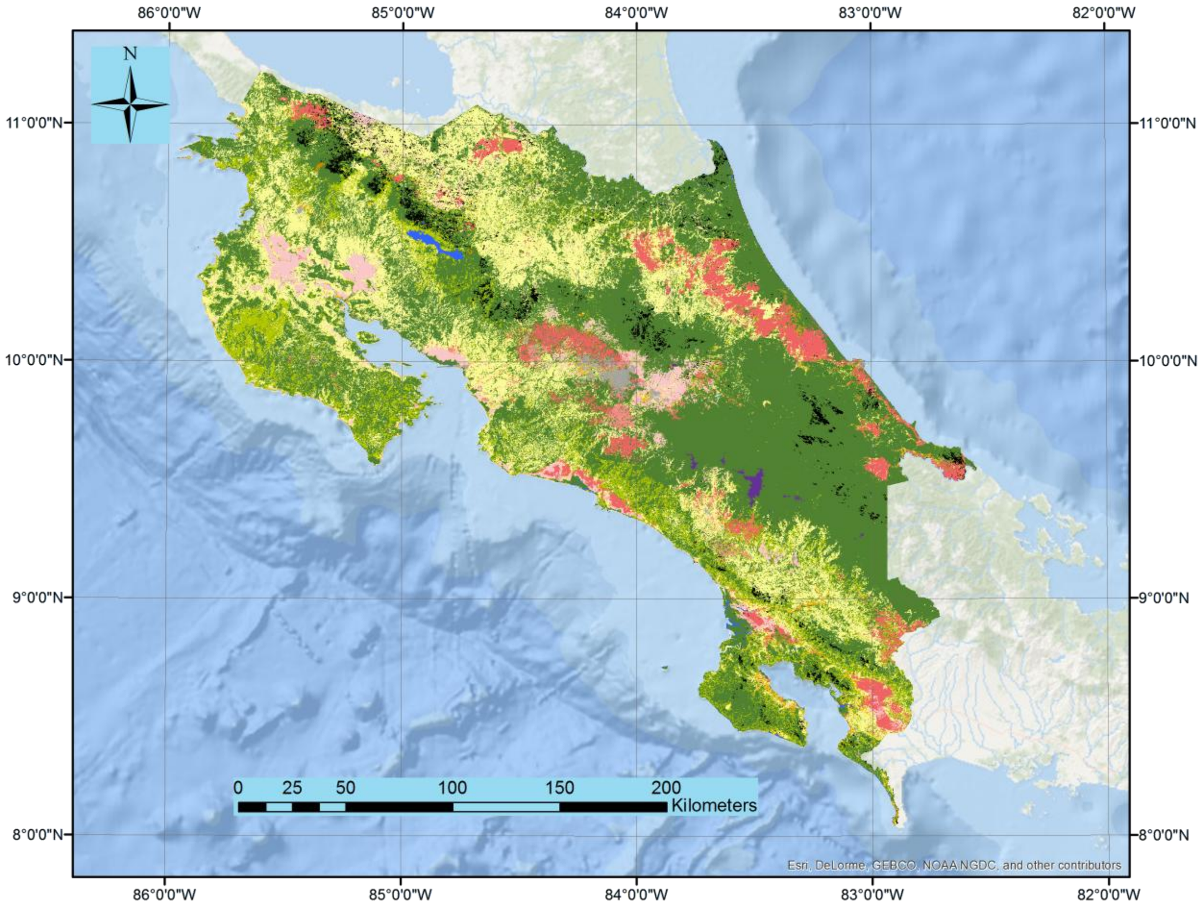
To facilitate the visual interpretation of the maps presented in this annex, the number of land use categories has been reduced, *i.e.* the area classified as “Forest” is not stratified in the five sub-categories “Wet and rain Forests”, “Moist Forests”, “Dry Forests”, “Mangroves” and “Palm Forests”.

Land Use Map 1985/86



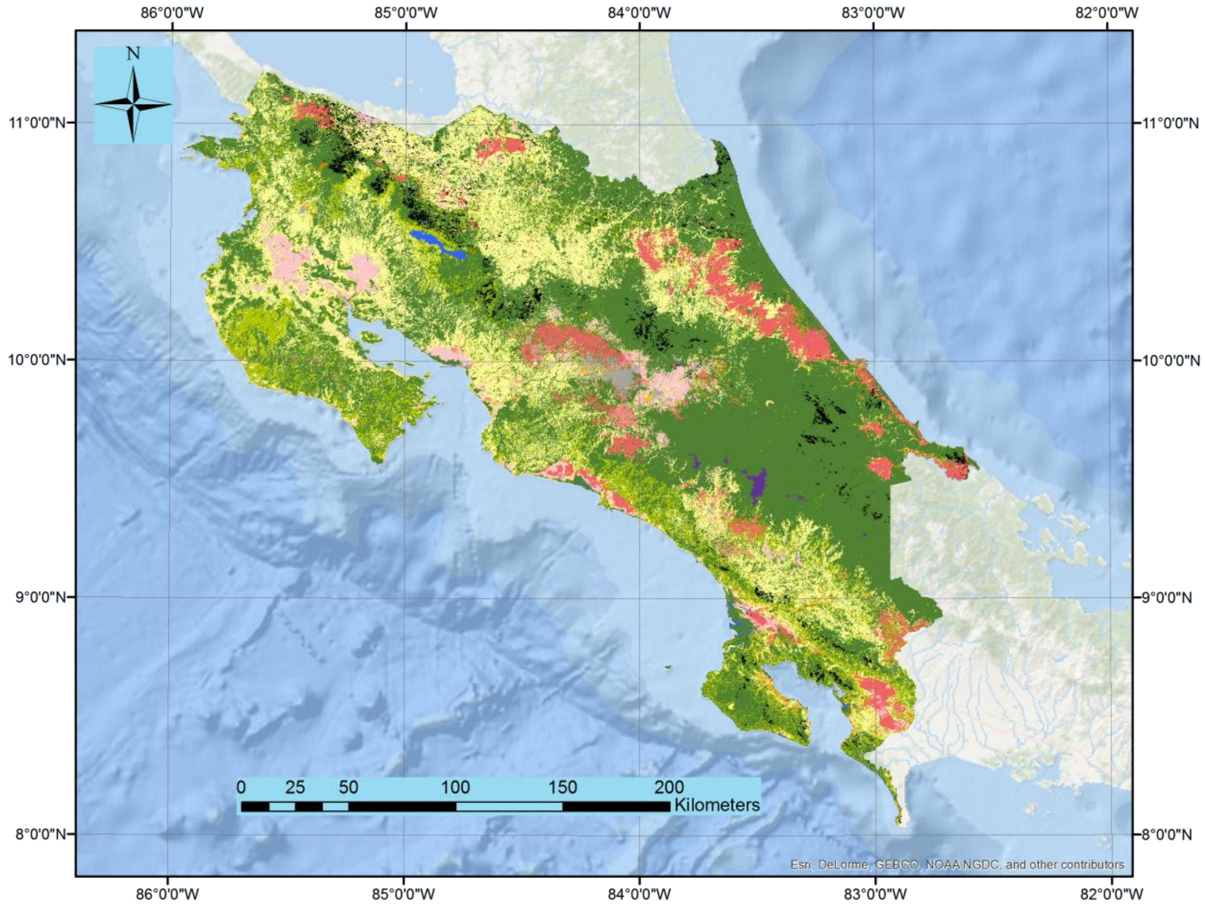
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,807,028.90
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	380,685.24
	CROPLAND – permanent	336,664.35
	CROPLAND – annual	197,797.23
	GRASSLAND	1,190,245.23
	SETTLEMENTS	22,876.92
	WETLANDS – natural	12,993.03
	WETLADNS – 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



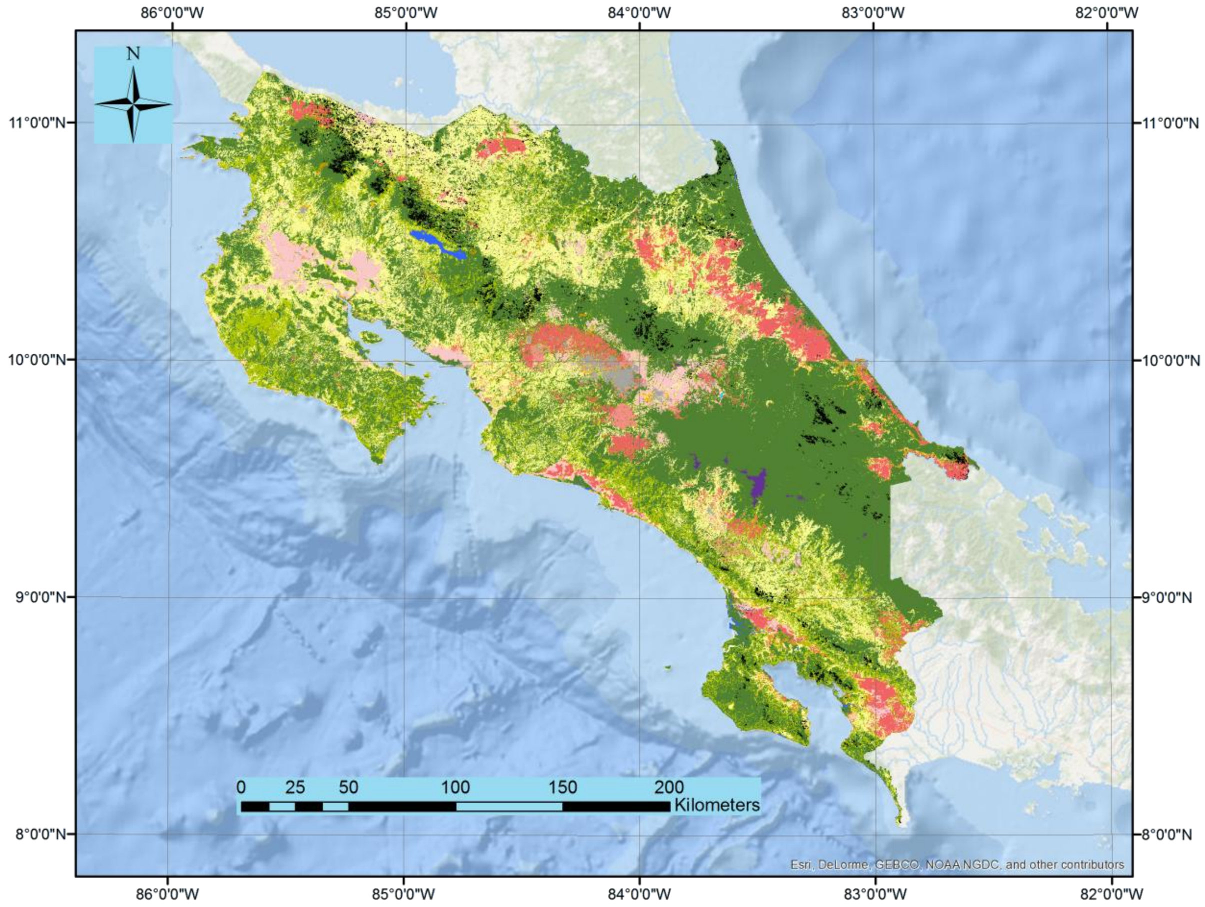
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,532,567.87
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	586,538.10
	CROPLAND – permanent	331,386.39
	CROPLAND – annual	203,960.88
	GRASSLAND	1,239,471.36
	SETTLEMENTS	30,210.12
	WETLANDS – natural	17,814.33
	WETLADNS – 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



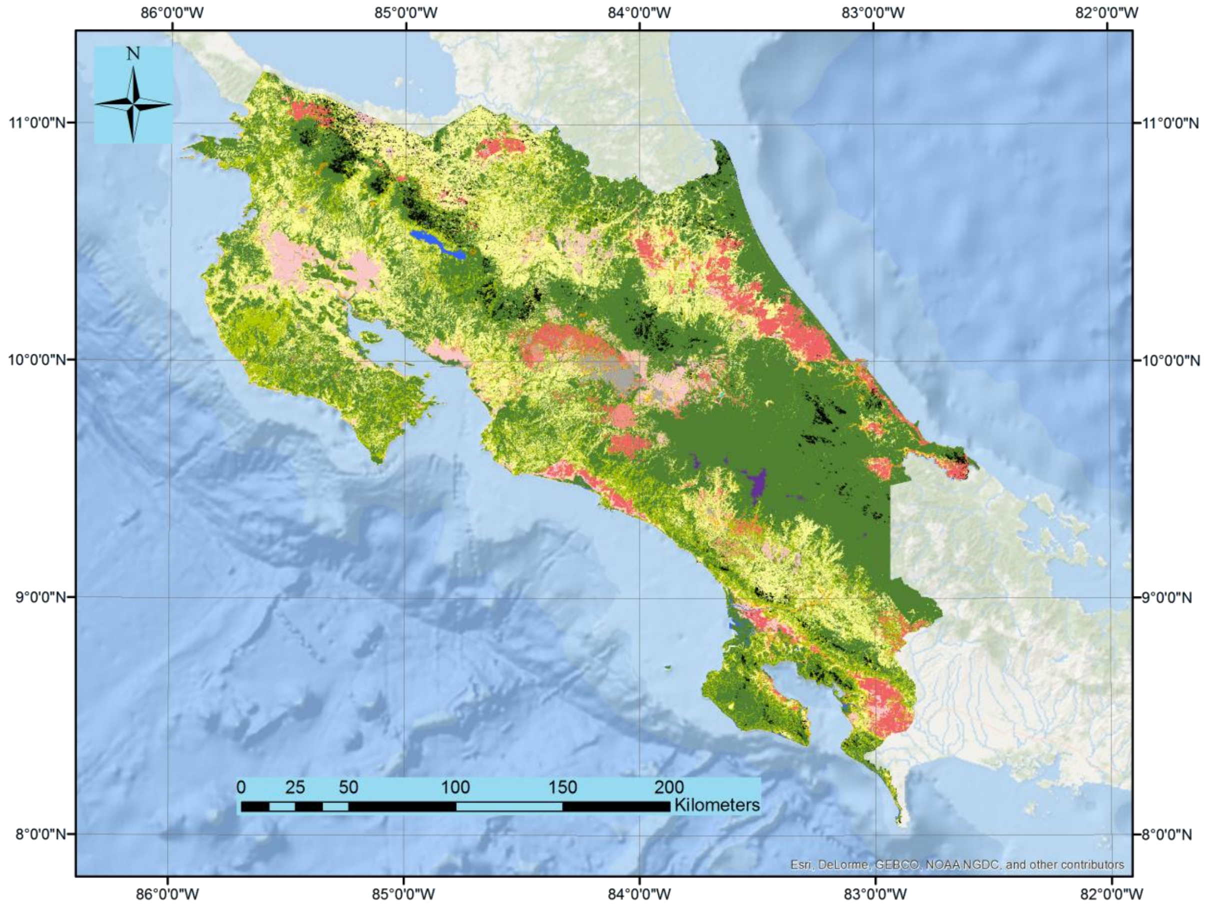
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,420,974.53
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	670,106.25
	CROPLAND – permanent	345,113.28
	CROPLAND – annual	211,800.60
	GRASSLAND	1,239,510.42
	SETTLEMENTS	35,203.86
	WETLANDS – natural	17,126.55
	WETLADNS – 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



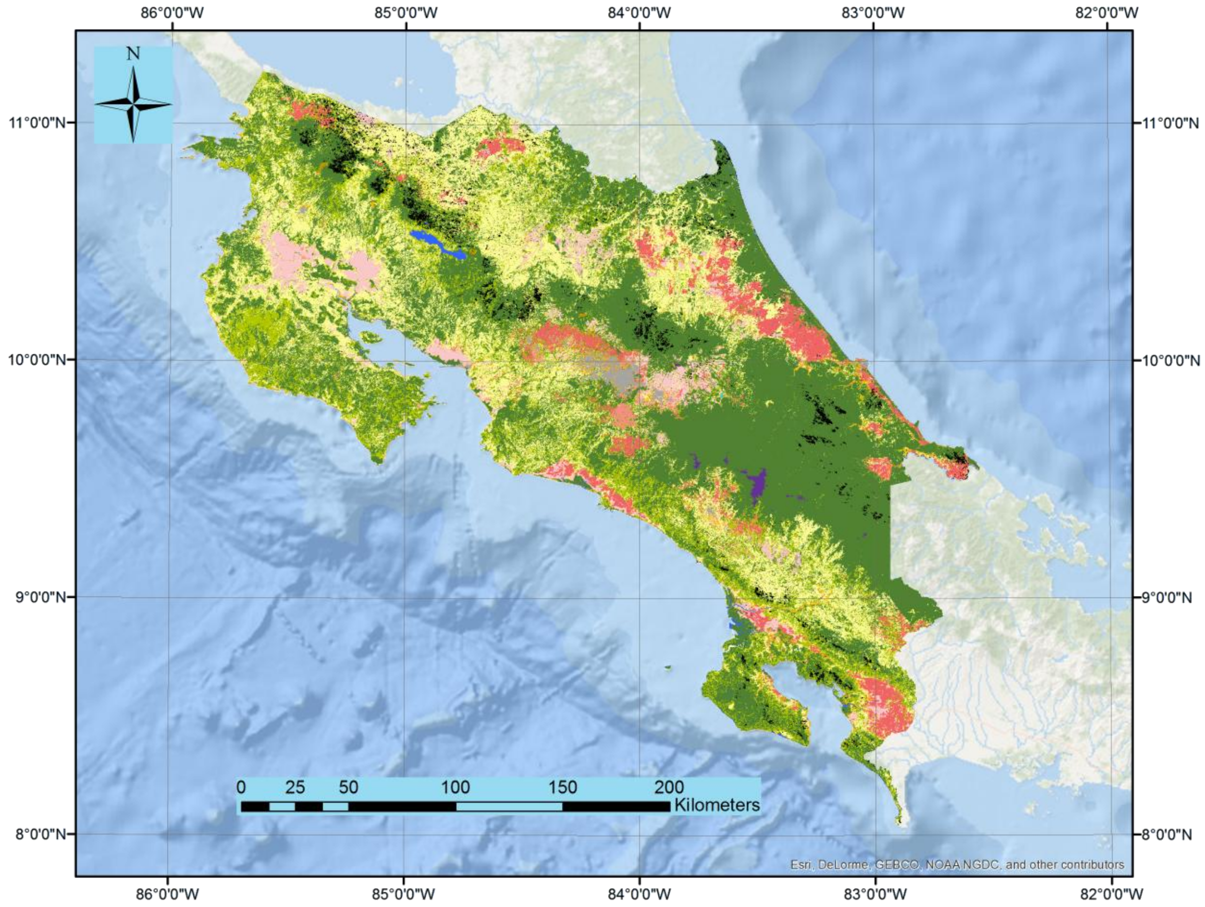
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,335,604.94
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	735,865.83
	CROPLAND – permanent	351,353.43
	CROPLAND – annual	218,656.71
	GRASSLAND	1,242,871.56
	SETTLEMENTS	38,819.97
	WETLANDS – natural	18,742.95
	WETLADNS – 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



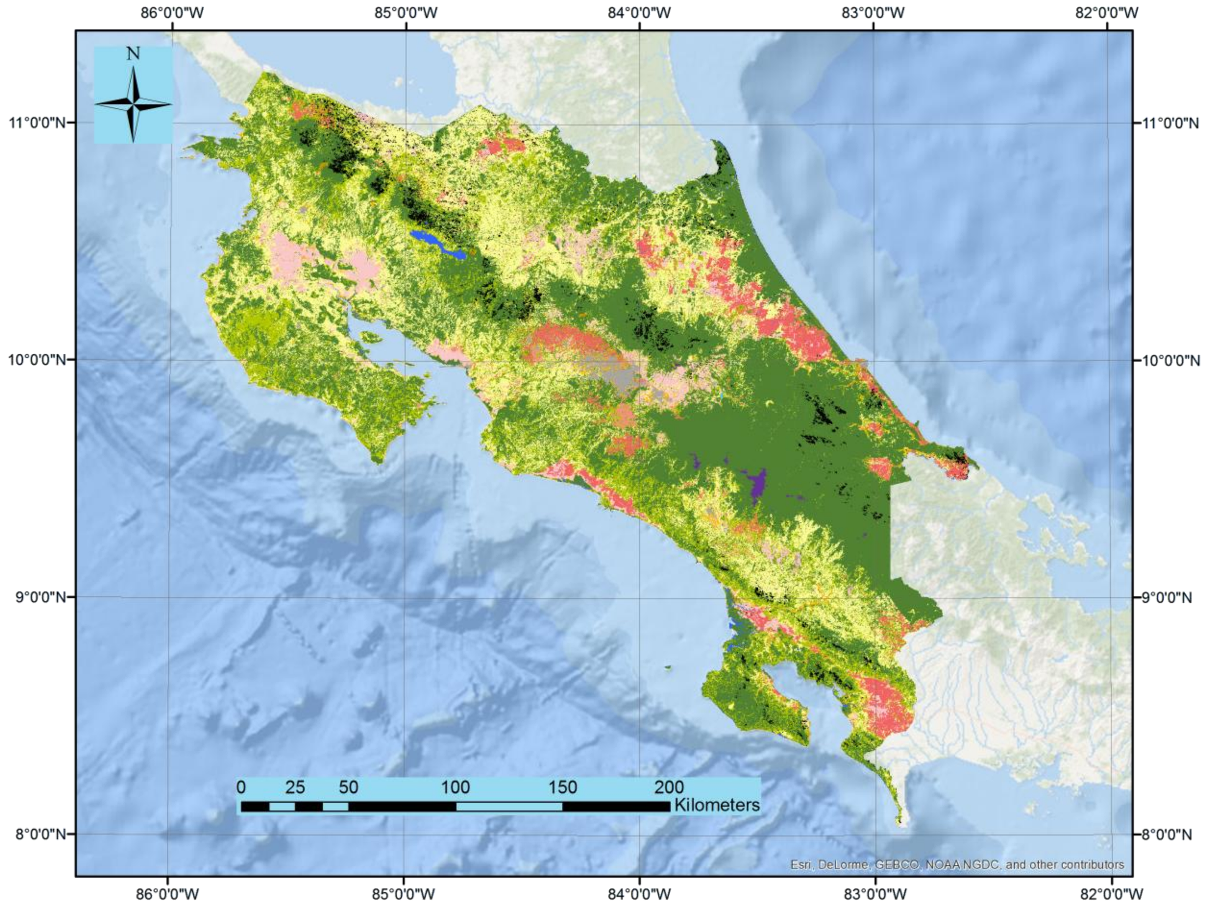
Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,265,429.96
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	770,395.05
	CROPLAND – permanent	323,930.52
	CROPLAND – annual	242,276.76
	GRASSLAND	1,260,219.24
	SETTLEMENTS	43,086.69
	WETLANDS – natural	21,875.85
	WETLADNS – 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**