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

COSTA RICA

SUBMISSION TO THE UNFCCC SECRETARIAT FOR TECHNICAL REVIEW

MINISTERIO DE AMBIENTE Y ENERGÍA | GOBIERNO DE COSTA RICA

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Acronyms

AAAA	A year of the historical reference period analyzed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

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

1. Introduction

Costa Rica decoupled agricultural production from deforestation by implementing solid legal frameworks, innovative agricultural and environmental policies, and Payment for Environmental Services schemes (REDD+ financial mechanisms), which together generated agricultural and livestock intensification, plus the growing development of Ecotourism. AFOLU emissions have decreased from 10.9 million tCO2-e yr-1 in 1998 to 0.9 million tCO2-e yr-1 in 2019 (see Table 4).

- ***The Investment in REDD financial mechanisms promoted forest use over marginal agriculture***. By addressing drivers of forest loss, Costa Rica has demonstrated that emissions can be reduced effectively, as planned in the ER Program. During 2012-2021, the government of Costa Rica signed 448,407 ha[1] of PES contracts with private forest owners under the activities of Protection, Reforestation, Regeneration, and Forest Management. Deforestation in Costa Rica has historically been driven by **the lack of ecosystem service value** that incentivizes converting forest land to agriculture and pasture. And **Lack of property rights** prevented small landowners and indigenous people from being incorporated into the existing payment for environmental services (PES) programs[2]. There have not been any new deforestation drivers identified and those listed in ER-PD. Deforestation drivers are also being addressed through the recently released (2020) Benefit Sharing Plan in the National REDD+ Strategy[3]. Costa Rica has established, expanded, and improved the financial mechanisms to strengthen natural reforestation and foster forest management. Costa Rica expanded the PES scheme to include indigenous territories, allowing indigenous peoples to influence and benefit from REDD+ activities in the country. Like the action above, there is no risk of leakage as this activity improves financial incentives for all landowners. Stakeholders in these lands were part of a consultative process that led to implementing of a comprehensive government plan on socioeconomic and environmental safeguards[4], and the benefit-sharing mechanisms[5].
- ***The Intensification of agriculture and livestock*** helped to produce a positive balance of mature forests loss and forest regeneration, improving the agriculture sector's added value and exports (see Figure 4). Between 2012 and 2021, the loss of mature forest was 37,285 hectares (61% for grasslands), while 194,914 hectares of forest were regenerated mainly from pasture lands (51%).
- ***Ecotourism facilitated the Internalization of the benefits of biodiversity conservation*****.** Ecotourism in Costa Rica has become an effective forest conservation strategy. An explicit conservation mechanism, a local economic benefit, and strict monitoring and application of environmental regulations have accompanied ecotourism[6].

The Green Climate Fund (GCF) recently adopted a landmark policy on REDD+ results-based payments. The decision was made at the 40th meeting of the GCF Board. The upcoming policy permanently integrates REDD+ results-based payments into GCF's regular project activity cycle, considering a price of USD 8 /tCO2 emission reduction.

Since 2014, Costa Rica has transformed its forest sector into a carbon sink (see Table 4), primarily due to reduced deforestation and the restoration of one million hectares of native forest. Consequently,

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[1] Contratos de PSA por tamaño de proyectos https://www.fonafifo.go.cr/es/servicios/estadisticas-de-psa/
2 Plan de Implementación de la Estrategia Nacional REDD+ Costa Rica. Secretaria Ejecutiva REDD+ Costa Rica. 2017. Available at https://ceniga.go.cr/wp-content/uploads/2020/02/plan_de_implementacion_enreddcr.pdf
3 Benefit Sharing Plan, National REDD+ Strategy. June 2020. Ministry of Environment and Energy (MINAE), Costa Rica. Available at http://documents1.worldbank.org/curated/en/785151594625278269/pdf/Benefit-Sharing-Plan.pdf
4 Resumen del Diseño del Sistema de Información sobre Salvaguardas REDD+ en Costa Rica. 2017. FONAFIFO. 80 pp. http://reddcr.go.cr/sites/default/files/centro-de-documentacion/propuesta_sis-redd_informe_final_-_fonafifo.pdf
5 ibid 3.
[6] Brandt, J. S., & Buckley, R. C. (2018). A global systematic review of empirical evidence of ecotourism impacts on forests in biodiversity hotspots. *Current Opinion in Environmental Sustainability*, *32*, 112–118. https://doi.org/10.1016/j.cosust.2018.04.004

the country is anticipated to lose additional carbon sequestration capacity after 2030. Therefore, the forthcoming two GCF windows for REDD+ result-based payments present the final opportunity for Costa Rica to receive compensation for its emissions reductions.

Considering the recent Green Climate Fund adopted REDD+ results-based payments policy, Costa Rica has chosen to submit a revised Forest Reference Emission Level (FREL) and Forest Reference Level (FRL) to become eligible for payments. This updated submission encompasses emissions resulting from forest degradation and incorporates the aggregated uncertainty.

The proposed FREL/FRL For the REDD+ implementation period 2020-2029 is **-592,127** ± 598,048 $tCO2e*yr^{-1}$. The FREL/FRL has been estimated as the sum of the **annual average emissions** from deforestation and the annual **average removals**[7] from enhancements of forest C stocks in the historical reference period of **2010-2019**.

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

The key policy for the implementation of Costa Rica's NDC for the forest sector is **the National REDD+ Strategy (2017 – 2025)**[8], developed from 2011 to 2015 through a national participatory process that considered all the social, political and environmental risks derived from the Cancun Safeguards.

The National REDD+ Strategy integrates investment actions with international financing through performance-based payments. It aims to enhance climate action benefits globally and promote rural human development. Costa Rica seeks to generate social and environmental benefits by encouraging integrated landscape management and fostering economic, environmental, social, and cultural development. The vision for EN-REDD+ is to implement a national strategy that improves inhabitants' quality of life, aligns with Sustainable Development Goals (SDGs), and boosts forest ecosystem resilience through collaborative efforts. This approach generates immediate results, improves financial flows to the forest sector, and enhances competitiveness by reducing GHG emissions from deforestation, sustainably managing forests, and conserving forest carbon stocks, contributing to global climate action demands.

The Strategy seeks to implement national policies to sustain forest ecosystems and their goods and services. This involves supporting adaptation, enhancing resilience and carbon stocks, clarifying land tenure, defining owners' rights, promoting forest entrepreneurship, and generating social, environmental, and economic co-benefits that elevate the quality of life for inhabitants. EN-REDD+ intends to acknowledge the forestry sector's international role through measurable reductions in greenhouse gas emissions and its contribution to the national economic dynamism and capacity building for the domestic forestry products market.

The EN-REDD+ includes safeguards to ensure forestry measures avoid damage and social conflicts, are climate-effective, and provide multiple benefits for sustainable emission reductions. A key aspect of the National REDD+ Strategy is identifying mechanisms for collaboration among public entities to fulfill complementary objectives in line with the National Development Plan. This approach aims to address climate change and promote a carbon-efficient economy. EN-REDD+ seeks to improve living conditions for communities managing forest resources, ensuring the social value of environmental services becomes a source of income to enhance their quality of life. Costa Rica seeks recognition under REDD+

[7] Removals are expressed as negative numbers, as CO_2 is directly removed from the atmosphere.
[8] Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party=CRI

based on results aligned with its National REDD+ Strategy, measured in terms of carbon, including early results and new efforts related to the five REDD+ activities recognized by the UNFCCC.

The strategy has a long-term application horizon, synchronized with implementing the Sustainable Development Goals (SDGs) and other government policies, aiming for results consistent with REDD+ that merit appropriate compensation. The national REDD+ strategy supports key social and environmental objectives aligned with the SDGs, promoting rural development, enhancing residents' quality of life, and conserving biodiversity.

Costa Rica's National REDD+ Strategy includes five policies, with quantifiable and verifiable measures and actions by 2025 which will contribute to the achievement of REDD+ results:

- **POLICY 1. Promotion of low-carbon production systems.**
  - Goal: 65,522 ha / 5,100 farms implementing agro-silvopastoral systems. This initiative seeks to reduce emissions from agricultural production systems by enhancing forest biomass. This can be accomplished by planting trees in agroforestry or silvopastoral systems or by creating and conserving forest patches within existing systems. These activities will not hinder the economic activity of landowners but will instead boost their profitability. By doing so, they will discourage landowners from deforesting new areas.
- **POLICY 2. Strengthen programs to prevent and control land use change and forest fires.**
  - Goal: Reduce the percentage of illegal wood processed to 15% and intervene to manage at least 90% of anthropogenic fires. The actions aim to decrease deforestation and forest degradation in the Protected Wild Areas and their buffer zones. This will be accomplished by strengthening prevention and control programs for land use changes and fires. The cycle of deforestation and regeneration will be addressed, and steps will be taken to resolve gaps in forest governance that encourage illegal logging. Additionally, comprehensive fire control and management initiatives will be enhanced. The recovery plan agreed upon by SINAC and INDER will support the sanitation of lands in ASP and the Natural Heritage of the State.
- **POLICY 3. Incentives for conservation and sustainable forest management.**
  - Goal: 640,000 hectares under Forest Emissions Reduction Contracts (CREF). This policy encourages private agents to engage in actions that promote the conservation of existing forests and sustainable forest management. It will be accomplished by establishing incentives and appropriate regulations. The policy also aims to create and implement pay-for-results instruments based on generating emission reductions. Furthermore, it seeks to enhance the capacity of institutional actors to control and monitor activities related to forest conservation. The policy supports the conservation and proper use of forest resources by promoting sound silvicultural practices for timber harvesting, strengthening the capabilities of forest institutions and regulators, enhancing income for forest owners through developing producer organizations, and recognizing their carbon sequestration services forests.
- **POLICY 4. Restoration of landscapes and forest ecosystems.**
  - Goal: increase to 6,500 hectares under Payments for Ecosystem Services (Reforestation modality). The objective of this policy is to enhance carbon stocks in forests by restoring lands that were previously degraded due to overuse. This will be achieved through commercial reforestation and the restoration of degraded watersheds under the Convention to Combat Desertification framework.
- **POLICY 5. Participation of indigenous peoples.**

  - Goal: maintain an average of 65,000 hectares per year of Indigenous land under CREF from 2018 to 2024. During the consultation process with Indigenous territories, three phases were developed: information, feedback, and consultation. The Indigenous territories identified five special themes, and the feedback generated was used to create an implementation plan for each theme, which was then validated by the Indigenous peoples. These themes will be executed based on the critical path agreed upon with the Indigenous peoples during the final stage of the consultation process. Different institutions will be responsible for addressing each of the special topics; therefore, each critical path will have different execution plans times.
- **POLICY 6. Enabling conditions.**
  - Goal: meet REDD+ operational requirements to access result-based finance and improve forest monitoring and stakeholder participation, organization, and information to support implementation of the Strategy. This policy aims to facilitate and monitor the REDD+ actions implemented in the country to adhere to the technical-methodological provisions and safeguards of REDD+. It also supports the participation of key actors. The policy covers the entire issue of the Administration of the National REDD+ Strategy, which includes the Safeguards Information System (SIS), the follow-up to the country's national strategy and emission reduction program, the consistency of the National Forest Monitoring System (MRV), the conditions for the participation of diverse groups, and the necessary institutional arrangements.

Legal framework on climate change and the forestry sector in Costa Rica

Climate change and international regulations

Costa Rica has proactively promoted and participated in international conventions and agreements aimed at environmental protection (see table below). Additionally, it is essential to mention that, according to Article 7 of the Costa Rican Political Constitution, international agreements hold higher authority than ordinary national laws. This hierarchy is affirmed in Article of the Public Administration General Law N° 6227 2/5/1978.

Main international conventions and agreements related to climate change and environmental protection ratified by Costa Rica.

Table 1: Main international conventions and agreements related to climate change and environmental protection ratified by Costa Rica.

LAW	CONVENTION NAME	DATE
Law N° 7414	United Nations Framework Convention on Climate Change	La Gaceta N° 126 of 7/4/94
Law N° 7513	Central American Convention on climate changes Guatemala	La Gaceta N° 128 of 7/6/1995
Law N° 5605	Convention on International Trade in Endangered Species of Wild Flora and Fauna	1/28/1975
Law N° 7224	Convention on Wetlands of International Importance especially as Waterfowl Habitat (RAMSAR Convention)	La Gaceta N° 86 de 8/5/1991
Law N° 7226	Central American Convention for Environmental Protection (Constitutes the Central American Committee for Environment and Development)	La Gaceta N° 88 of 5/10/1991

LAW	CONVENTION NAME	DATE
Law N° 7416	Convention on Biological Diversity	La Gaceta N° 143 of 7/28/1994
Law N° 7433	Convention for the conservation of biodiversity and the protection of priority wildlife areas in Central America	La Gaceta N° 193 of 10/11/1994
Law N° 7572	Regional convention for the management and conservation of forest ecosystems and the development of Tree plantations	La Gaceta N° 47 of 3/6/1996
Law N° 7699	United Nations Convention to Combat Desertification and Drought, in particular African countries	La Gaceta of 11/3/1997

National forestry sector

Specific country-level legislation for forest protection starts with the Political Constitution, the highest legal authority. Article 50 grants everyone the right to a healthy, ecologically balanced environment. In line with this principle, various laws and executive decrees exist to ensure environmental conservation below.

- **Forestry Law N° 7575 of 4/14/1996 and its Forestry Regulation, Decree Nº 25721-MINAE of 10/17/1996 as amended**. The Law mandates the State to conserve, protect, and manage natural forests, regulating land use in forested areas and overseeing the industrialization and export of round wood. It introduces forest regents, engages civil society in forest conservation, defines environmental services, and establishes the National Forestry Financing Fund for sustainable management, reforestation, agroforestry, and environmental services. In protected wildlife areas, the State can expropriate private lands and regulates its activities, including protection areas. It also outlines offenses and penalties for violations of State Natural Heritage, unauthorized forest resource use, and environmental damage.
- **Executive Decree N° 38323-MINAE, La Gaceta N° 72 of 2/14/2014**. Regulates the Payment for Environmental Services, complemented by the Manual for Payment of Environmental Services, published in La Gaceta No. 46 on March 6, 2009, as amended, which outlines all procedures for awarding payments for environmental services.
- **Decree N° 27998-MINAE, of 6/22/1999**. Sets the Principles, Criteria, and Indicators for the Sustainable Management of Secondary Forests and the Forestry Certification in Costa Rica.
- **Executive Decree N° 27388-MINAE of 9/18/1998**. On Principles, Criteria and Indicators for the Exploitation and Management of Forests and Certification.
- **Executive Decree N° 34559- MINAE of 1/8/2008**. Sets the Sustainability Standards for Natural Forests Management: Principles, Criteria and Indicators, Code of Practices and Procedural Manual and the Regulations on Forestry Regencies
- **Decree N° 38444-MINAE of 2/20/2014**. Regulates the requirements for the accreditation of forestry regents, develops the duties of both the regents and their Professional Association, and includes all formal procedures for the performance of regencies along with sanctions in case of failure.
- **Executive Decree N° 25700-MINAE of 11/15/1996**. Sets a comprehensive and complete ban on the exploitation of endangered trees.
- **Organic Law of Environment N° 7554 de 10/4/1995**. Establishes the Environmental Impact Assessment to protect the environment and creates the National Environmental Technical Secretariat for its execution. Reiterates the Executive Branch's authority to designate protected wildlife areas, including private lands, and permits expropriation to achieve this, prohibiting area reductions without justifying technical studies. Creates the Environment Comptroller's office under the Minister of the Environment and Energy. Implements administrative sanctions for violating environmental rules and establishes the Environmental Administrative Tribunal as a decentralized MINAE entity, which operates independently and mandates compliance with its rulings. These measures significantly contribute to environmental conservation.
- **Biodiversity Law N° 7788 of 4/30/1998 and its Regulation, Executive Decree N° 34433-MINAE of 3/11/2008**. Article 22 establishes the National System of Conservation Areas, a decentralized Ministry of the Environment and Energy body that manages forestry, wildlife, and protected areas. It coordinates actions and policies for

sustainable natural resource management. The system includes the Directorate General of Wildlife, the State Forestry Administration, and the National Parks Service, which operate together within its administrative structure. It sets rules to encourage incentives and compensation for environmental services aimed at conserving biodiversity, incorporating essential environmental law principles like the precautionary principle and public interest. Furthermore, it discusses payment for environmental services to incentivize biodiversity conservation.

- **National Parks Service Law, Nº 6084 of 8/24/1977**. Establishes prohibited or permitted activities within national parks.
- **Land Use, management, and Conservation Law, N° 7779 of 4/30/1998 and its regulation, Executive Decree N° 29375-MAG of 8/8/2000**. It aims to sustainably manage lands and natural resources. The Ministry of Agriculture will coordinate with the Ministry of the Environment to manage land conservation and related practices.
- **Law for developing, promoting, and enhancing organic agricultural activities, N° 8591 of 6/28/2007**. Defines the environmental benefits of agriculture, which include mitigating greenhouse gas (GHG) emissions through fixing, reducing, capturing, storing, and absorbing; protecting water; and preserving biodiversity within comprehensive organic agricultural systems, focused on conservation and sustainable use, as well as safeguarding organic agro-ecosystems.
- **The Indigenous Law N° 6172 of 11/29/1977 and its Regulation, Executive Decree No. 8487 of April 26, 1978, and Executive Decree No. 13568 of April 30, 1982 (Legal representation of Indigenous Communities by Development Associations as Local Governments).** Establishes the inalienable character of indigenous territories as property of indigenous communities. It states that forest lands must preserve their nature to maintain hydrological balance and conserve wildlife. Additionally, natural resources should be exploited rationally.

Legal framework specific for REDD+ in Costa Rica

- **Executive Decree N° 37352-MINAET of 8/27/2012, published in La Gaceta N° 220 of 11/14/2012, establishes the legal framework for coordinating REDD+.** It implements the Executive Secretariat, supporting the National Fund for Forest Financing in developing the National REDD+ Strategy per the FCPF Readiness Donation agreement TF012692. The Secretariat's duties include creating a consultation plan, executing the Social and Environmental Strategic Assessment, developing a forest reference level, and preparing the National REDD+ Strategy. The National Fund is the Secretariat's headquarters. The decree also established a REDD+ Executive Committee with specific roles.
- **Executive Decree N° 40464-MINAE of 3/4/2017, published in La Gaceta N° 175 of 7/18/2017.** Its objective is to support current climate policies by preventing deforestation, promoting forest conservation, and increasing carbon stocks. It outlines the benefit-sharing plan, governance of the Strategy, and guidelines for carbon market access.

Consistency in the design and implementation of REDD+ actions with the objectives of national forest policies/programs.

REDD+ actions align with national plans. The National REDD+ Strategy aims to promote sustainable rural development, which includes biodiversity conservation, rural development, quality of life improvement, and integrated landscape and economic management. These actions enhance forest ecosystem resilience, reduce GHG emissions, and increase carbon stock. The policies in the REDD+ implementation plan support sustainable development goals such as poverty reduction, climate action, life on land, and partnerships. The Strategy's actions are consistent with the following national forest policies and programs:

- The National Forestry Development Plan 2011-2020 The framework consisted of seven strategic pillars, starting with forest land management. It also included the competitiveness of forestry activities, sustainability in these endeavors, innovation, and the sustainability of financing. The PES program was integrated into these strategic areas, and the influence of REDD+ resources was highlighted in the latter part.
- Costa Rica's National Development Plan (NDP) 2015-2018, Strategic objective 5.15 promotes consolidating conservation in key ecosystems for sustainable use and fair distribution of genetic, natural, and cultural heritage benefits. It aims to maintain 300,000 hectares under PES contracts and mitigate emissions, along with a document addressing emissions from deforestation and degradation protected by REDD+ (SOI, 2019).

- Costa Rica's National Development and Public Investment Plan 2019-2022, which includes, in strategic axis 2, the goal of contributing to carbon neutrality through the involvement of the forestry sector and key sectors such as public transportation and agriculture, as well as promoting the participation of local governments in climate change mitigation. In this context, the PES Program has targets and the National REDD Strategy aimed at reducing CO2 emissions (p 179).
- The National Plan for the Decarbonization of the Economy (2018-2050) includes axis 10, which establishes the management of rural, urban, and coastal territories focused on conservation and sustainable use, enhancing forest resources and ecosystem services through nature-based solutions, which involves implementing the REDD+ Strategy.
- Nationally Determined Contribution (NDC). The REDD+ Strategy supports the achievement of Costa Rica's climate change objectives and adheres to the Paris Agreement. This action plan facilitates the execution and fulfillment of the NDC, as it encompasses various activities associated with action 8, which extends beyond the PES and incorporates the Territorial Forest Environmental Plans (annex B of the environmental and social assessment [ESA, for its acronym in English]).

Monitoring of the implementation of EN-REDD+.

The Department of Environmental Services Management at FONAFIFO and SINAC quantitatively monitors the implementation of actions included in Policies 1, 2, 3, 4, and 5 of EN-REDD+. The REDD+ Monitoring Committee and the Steering Committee oversee the actions in Policy 6. The following table lists the Monitoring Manager and provides links to the reports and statistics that support the implementation level of these actions.
The implementation of safeguards is closely monitored to ensure that the measures adopted in the REDD+ Strategy do not result in any negative social or environmental impacts. Conversely, they are intended to generate positive effects at the climate level. Two Safeguard Reports were submitted to the UNFCCC, which detail the results of applying safeguards during the monitoring period from 2017 to 2019. The reports can be accessed at the following link: https://redd.unfccc.int/info-hub.html. The first report covers the period from January 1997 to December 2017, while the second report pertains to January 2018 to December 2020.

Table 2: Monitoring Manager and connections to the reports and statistics supporting the EN-REDD+ policy implementation level.

REDD ACTION	MONITORING MANAGER	REPORTS
POLICY 1. Promotion of low-carbon production systems. Goal: 65,522 ha / 5,100 farms applying agro-silvopastoral systems.	Department of Environmental Services Management of FONAFIFO	PES Statistics Click on "Distribution of hectares and trees by PES activity"
POLICY 2. Strengthen programs for the prevention and control of land use change and forest fires.	National System of Conservation Areas.	SINAC in numbers. SEMEC Annual Statistics Report. Section 5.2 Prevention, Control and Protection.
POLICY 3. Incentives for conservation and sustainable forest management. Goal: 640,000 ha under Forest Emissions Reduction Contracts – CREF	Department of Environmental Services Management of FONAFIFO.	PES Statistics Click on "Distribution of hectares and trees by PES activity"
POLICY 4. Restoration of landscapes and forest ecosystems. Goal: increase to 6,500 ha under Payments for Ecosystem Services (Reforestation modality).	Department of Environmental Services Management of FONAFIFO.	PES Statistics Click on "Distribution of hectares and trees by PES activity"

REDD ACTION	MONITORING MANAGER	REPORTS
POLICY 5. Participation of indigenous peoples. Goal: maintain an average of 65,000 ha / year of Indigenous land under CREF from 2018 to 2024.	Department of Environmental Services Management of FONAFIFO.	PES Statistics Click on "PES Contracts Formalized in Indigenous Territories".
POLICY 6. Enabling conditions. Goal: meet REDD+ operational requirements to access result-based finance and improve forest monitoring and stakeholder participation, organization, and information to support implementation of the Strategy.	REDD+ Secretariat	The REDD+ Monitoring Committee and the Steering Committee are responsible for monitoring the actions taken to fulfill the operational requirements necessary for gaining access to results-based payments and ensuring stakeholder participation and organizational effectiveness for EN-REDD+ implementation. Their diligent oversight ensures that all necessary steps are taken to achieve the project's goals and objectives.

2. Scope and boundaries

2.1. Geographical boundaries

Figure 1 shows the accounting area of the FREL/FRL, which encompasses the country's continental territory (5,133,939.50 ha) but excludes Coco Island (238,500 ha), a World Heritage site located 532 km from the Pacific coast. Coco Island is inhabited solely by park rangers and is not subject to anthropogenic intervention. Additionally, the island is too far from Costa Rica's continental territory, making it unlikely to be affected by displacements resulting from Costa Rica's REDD+ activities. The exclusion of Coco Island aligns with estimating emissions from sources and removals by sinks in the national GHG inventory.

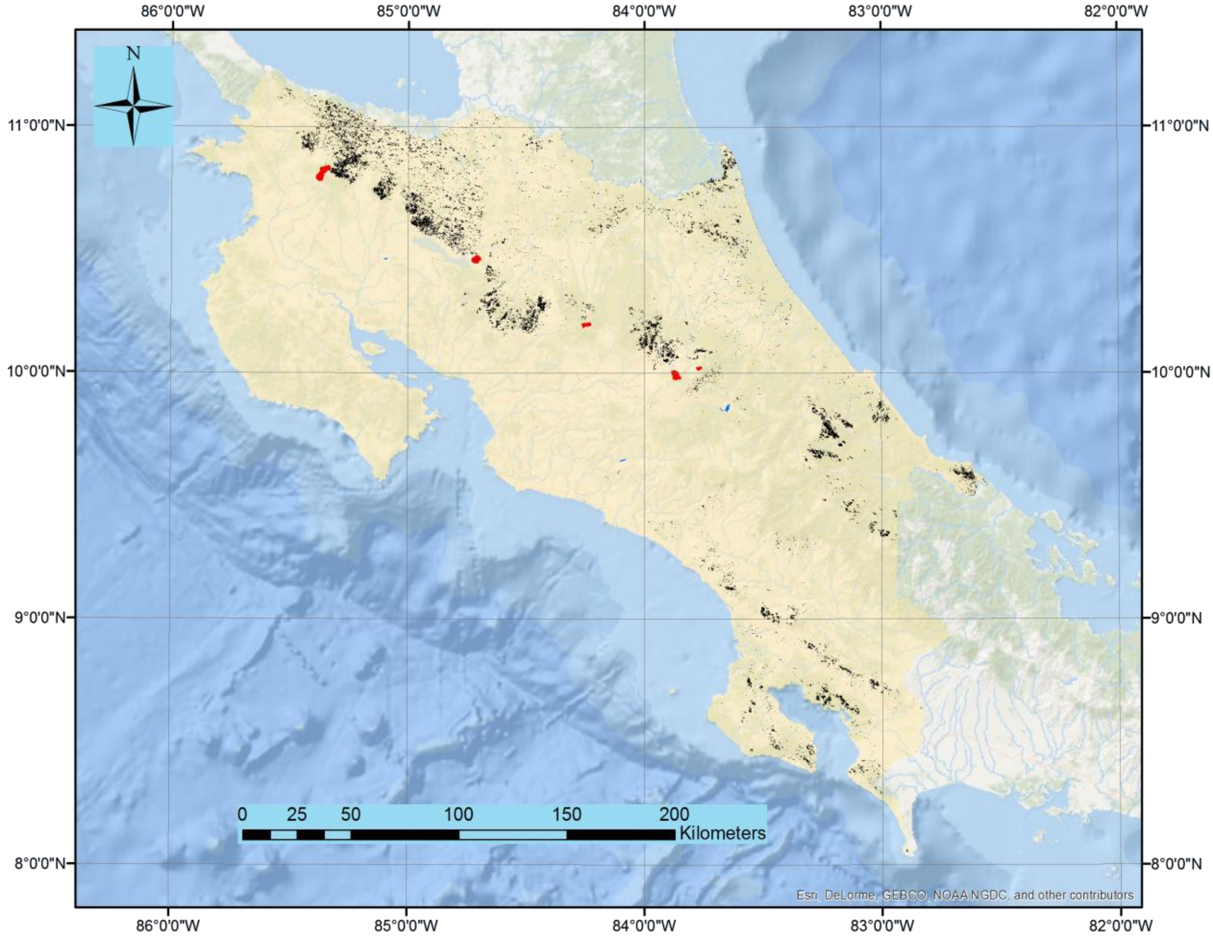
In the accounting area, special considerations were given to two types of regions: those lacking land use information due to clouds and shadows and those where forest losses are linked to natural disturbances (see Figure 2).

Figure 1. Geographical boundary of the proposed FREL.

Figure 1: Geographical boundary of the proposed FREL.

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

Figure 2: Areas with special considerations within the updated FREL/FRL accounting area.



Color	Type of area	FREL	ha	%
(red)	Areas associated to volcanic activity	excluded	1,580.67	0.03%
(blue)	Areas associated to river-meandering	excluded	16,693.29	0.33%
(black)	Areas covered by clouds and shadows	excluded	115,364.16	2.26%
(beige)	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 were generated for the accounting area representing land use on December 31st/January 1st of 1985/86, 1991/92, 1997/98, 2000/01, 2007/08, 2011/12, 2013/14, 2015/16, 2017/18 and 2019/20[9]. These maps were created using Landsat images acquired within a 14-months' time window. This resulted in 0.49%-1.83% of the total accounting area covered by clouds and shadows for each map (Agresta *et al.*, 2015.a, p. 8). For 1986-2013, a total of 2.26% of the accounting area lacked land use information.

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

The low percentage of area without land use information was obtained by filling cloud and shadow areas with global data published by Hansen *et al.* (2013)[10]. This method is also used in subsequent measurement and reporting. Due to increasing availability of global forest cover data, no additional areas were be excluded due to gaps in land use information in after 2013.

- **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.

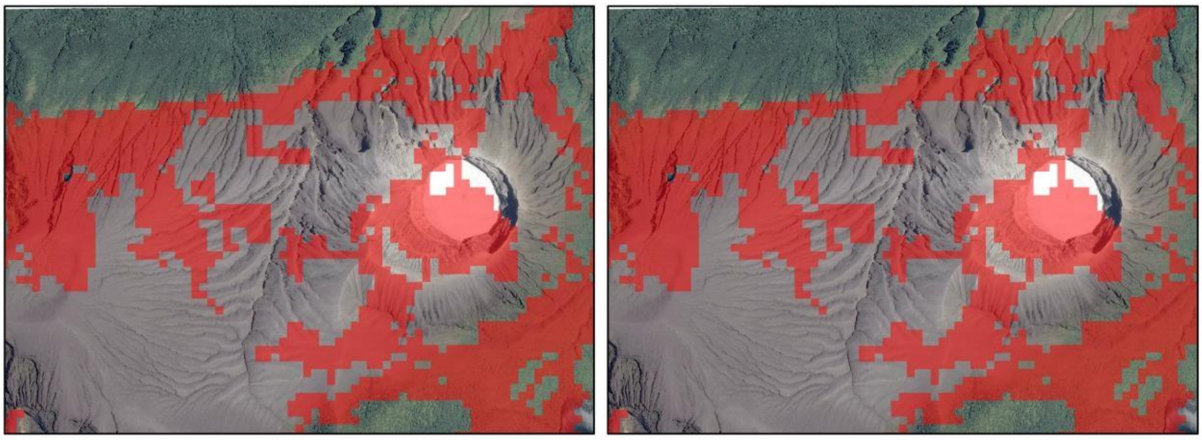


Figure 3: Examples of non-anthropogenic losses of forest cover associated to volcanic eruptions (red colored areas) and river-meandering (purple-colored areas).

[10] 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, from 1997 to 2020, Costa Rica has invested over 524 million[11] United States Dollars (USD) of public funds. This has enabled payments for over 1.3 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 in 2020 was about 86 million USD[12].

This context is significant for distinguishing three periods of enhanced mitigation actions in Costa Rica: **1997-2009, 2010-2019, and 2020-2029**. The first period reflects the adoption of relevant policies and regulations to reduce deforestation and increase forest coverage. The second period is marked by the government's enhanced commitments and greater public spending on mitigation actions. During the third period, the country established the legal and institutional framework for executing REDD+ actions and the benefit-sharing of results-based payments.

- The historical reference period of the first period (1997-2009) is **1986-1996**.
- The historical reference period of the second period (2010-2019) is **1997-2009.**
- The historical reference period of the third period (2020-2029) is **2010-2019.**

[11] https://unfccc.int/climate-action/momentum-for-change/financing-for-climate-friendly-investment/payments-for-environmental-services-program
[12] https://www.sinac.go.cr/ES/transprncia/Informe%20Financiero%202014/Presupuesto%202020.pdf

The first period started with the adoption of the current Forestry Law, passed in 1996, which included various innovative policy instruments such as the PSA program. This Law entered into force with the publication of its regulation on January 23, 1997,[13]. 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 adopting new commitments and additional investments in mitigation actions. According to Costa Rica's R-PP and ER-PIN[14], the country's National REDD+ Strategy under the FCPF Carbon Fund began in 2010. Close to this date (July 03, 2008,[15]), the Law 8640 was passed. This law increased PSA's financial resources by USD 30 million and directed USD 10 million to create 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 and 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 essential to note that the ongoing information, pre-consultation, and consultation processes with stakeholders are based on the start of REDD+ implementation in 2010 to increase ambition over time.

In the third period, the legal, institutional and framework was consolidated. Executive Decree N° 37352-MINAET of 8/27/2012, published in La Gaceta N° 220 of 11/14/2012, establishes the legal framework for coordinating REDD+. It implements the Executive Secretariat, supporting the National Fund for Forest Financing in developing the National REDD+ Strategy per the FCPF Readiness Donation agreement TF012692. The decree also established a REDD+ Executive Committee with specific roles. Explicit institutional arrangements are yet to be defined and included. Executive Decree N° 40464-MINAE of 3/4/2017, published in La Gaceta N° 175 of 7/18/2017. Its objective is to support current climate policies by preventing deforestation, promoting forest conservation, and increasing carbon stocks. It outlines the benefit-sharing plan, strategy governance, and carbon market access guidelines.

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

For the construction of the proposed FREL/FRL, a 1986-2019 time series of land use maps was developed. This time series was designed explicitly for REDD+ 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, 2013/14, 2015/16, 2017/18 and 2019/20. This time series was developed at the national level.

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

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[13] Available at: http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?param1=NRTC&nValor1=1&nValor2=41661&nValor3=131992&param2=1&strTipM=TC&lResultado=2&strSim=simp

[14] 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.

[15] 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.

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: **reducing emission from deforestation, reducing emissions from forest degradation and enhancement of forest C stocks**.

2.4. Greenhouse gases and C pools

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

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)[16].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)[17], while nontree below-ground biomass was obtained from IPCC default values.

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

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

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

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

[17] 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.

Non-CO_2	Biomass burning	Methane	CH_4	included	Tier 1/2	IPCC default factors
		Nitrous oxide	N_2O	included	Tier 1/2	IPCC default factors

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

2.5. Exclusion of non-anthropogenic emissions

As mentioned in section 2.1, Costa Rica deems more appropriate, in the context of results-based payments, to measure and report forest-related emissions associated to natural disturbances separately from anthropogenic emissions and to exclude non-anthropogenic sources of GHG emissions from its FREL/FRL as well as from REDD+ results. This proposal takes into account Costa Rica's national circumstances, especially in relation to its vulnerability to various types of extreme natural disturbances, such as volcanic activity, earthquakes, flooding, changes in river courses, etc. These losses are not anthropogenic and should not be included in the estimation of emission reductions for result-based payments.

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

2.6. Managed and non-managed lands

Managed lands are all lands included in *Cropland*, *Grassland*, *Wetlands*, *Settlements* and *Other lands* categories (Section 4.3.1). *Forest land* include managed and non-managed lands. Non-managed lands are comprised of primary forests[18]. All primary *Forest land* converted to other land use categories are considered to be managed immediately after conversion. This means that emissions and absorptions in primary *Forest land remaining Forest land* are not included in the FREL/FRL. All lands that transitioned to *Forest land* during the historical reference period are considered "secondary". Some lands were considered to be "secondary" at the beginning of the historical reference period (please see Section 4.3.1 for more information).

2.7. Forest lands in transition

Considering the *good practices* recommended in the 2006 IPCC Guidelines, Costa Rica defines two periods for lands transitioning to *Forest land*. Four- and eight-year thresholds were used to define when land transitions to *Forest land remaining Forest land*, for wet and dry forests, respectively. These values are directed related to parameters defined for determining when a forest meets the minimum

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

threshold values of the definition of "forest" and is "visible" using LANDSAT images. These parameters are based on Expert Judgment (for more information please see Section 4.1). All CO_2 absorptions included in Costa Rica's FREL/FRL occur in *Forest land remaining Forest land* (except for primary forests which are considered non-managed).

2.8. Drivers of deforestation and degradation

Deforestation and forest regeneration were assessed for 2012-2021 at the national and sub-national level. This assessment was based on the same land use maps used for the construction of the FREL. At the ***national*** level, the patterns of deforestation and degradation were analyzed.

From 2012 to 2021, the country faced negative deforestation rates. The net deforestation rate in Costa Rica was negative at -0.20%. The gross deforestation rate stood at 0.44%. Costa Rica decreased land allocated for agriculture and cattle ranching during this decade.

Costa Rica decoupled agricultural production from deforestation by implementing solid legal frameworks, innovative agricultural and environmental policies, and Payment for Environmental Services schemes (REDD+ financial mechanisms), which together generated agricultural and livestock intensification, plus the growing development of Ecotourism.

- ***The Investment in REDD financial mechanisms promoted forest use over marginal agriculture***. By addressing drivers of forest loss, Costa Rica has demonstrated that emissions can be reduced effectively, as planned in the ER Program. During 2012-2021, the government of Costa Rica signed 448,407 ha[19] of PES contracts with private forest owners under the activities of Protection, Reforestation, Regeneration, and Forest Management. Deforestation in Costa Rica has historically been driven by **the lack of ecosystem service value** that incentivizes converting forest land to agriculture and pasture. And **Lack of property rights** prevented small landowners and indigenous people from being incorporated into the existing payment for environmental services (PES) programs[20]. Costa Rica has established, expanded, and improved the financial mechanisms to strengthen natural reforestation and foster forest management. Costa Rica expanded the PES scheme to include indigenous territories, allowing indigenous peoples to influence and benefit from REDD+ activities in the country. Stakeholders in these lands were part of a consultative process that led to implementing of a comprehensive government plan on socioeconomic and environmental safeguards[21], and the benefit-sharing mechanisms.

- ***The Intensification of agriculture and livestock*** helped to produce a positive balance of mature forests loss and forest regeneration, improving the agriculture sector's added value and exports (see Figure 1). Between 2012 and 2021, the loss of mature forest was 37,285 hectares (61% for grasslands), while 194,914 hectares of forest were regenerated mainly from pasture lands (51%).

- ***Ecotourism facilitated the Internalization of the benefits of biodiversity conservation.*** Ecotourism in Costa Rica has become an effective forest conservation strategy. An explicit conservation

[19] Contratos de PSA por tamaño de proyectos https://www.fonafifo.go.cr/es/servicios/estadisticas-de-psa/

[20] Plan de Implementación de la Estrategia Nacional REDD+ Costa Rica. Secretaria Ejecutiva REDD+ Costa Rica. 2017. Available at https://ceniga.go.cr/wp-content/uploads/2020/02/plan_de_implementacion_enreddcr.pdf

[21] Resumen del Diseño del Sistema de Información sobre Salvaguardas REDD+ en Costa Rica. 2017. FONAFIFO. 80 pp. http://reddcr.go.cr/sites/default/files/centro-de-documentacion/propuesta_sis-redd_informe_final_-_fonafifo.pdf

mechanism, a local economic benefit, and strict monitoring and application of environmental regulations have accompanied ecotourism[22].

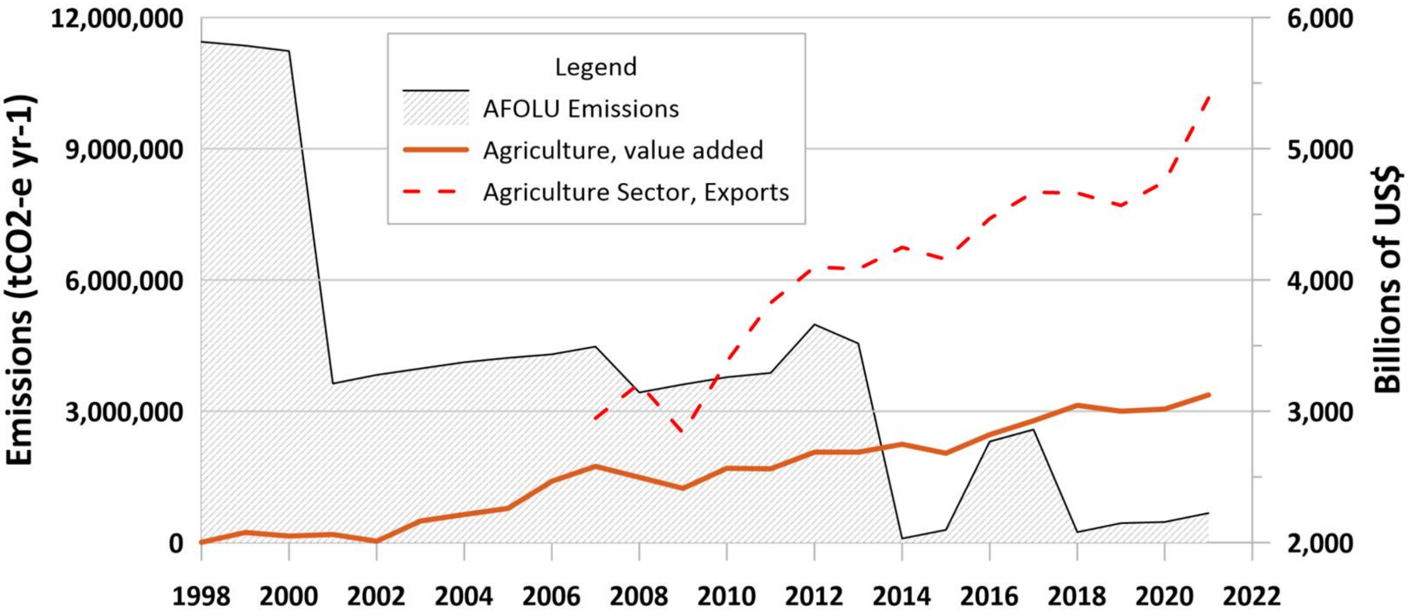

Figure 4: AFOLU emissions are decreasing while the agricultural sector's value-added and exports during 2012-2021 increased, showing that Costa Rica decouples deforestation from commodities production. Sources: World Bank (https://datos.bancomundial.org/indicador/NV.AGR.TOTL.KD), COMEX (https://www.comex.go.cr/estadísticas-y-estudios/comercio-bienes/exportaciones/), SINAMEC (http://sinamecc.opendata.junar.com/dashboards/21151/inventario-nacional-de-gases-de-efecto-invernadero-ingei/) and National Forest Monitoring System.

Drivers and underlying causes of forest degradation

Privately owned forests in Costa Rica went through an intervention process during the 1970s and 1980s, followed by a forestry sector reform in the 1990s. The current Forest Law 7575 allows for payments to forest owners for environmental services (Art. 22-27) and establishes the National Fund for Forest Financing (FONAFIFO) to provide financial support for small and medium-sized forestry companies (Art. 46-51) (Brockett & Gottfried, 2002)[23] triggered the initial identification of forest degradation drivers in Costa Rica.

In the initial stages of implementation of the Payment for Environmental Services Program (1997-2003), forest degradation was identified as associated with harvesting remnant trees in wooded pastures. This practice is attributed to the excessive regulation of the management of natural forests promoted by the Forest Law. In addition, the elimination of PES for forests subject to natural forest

[22] Brandt, J. S., & Buckley, R. C. (2018). A global systematic review of empirical evidence of ecotourism impacts on forests in biodiversity hotspots. *Current Opinion in Environmental Sustainability*, *32*, 112–118. https://doi.org/10.1016/j.cosust.2018.04.004

[23] Brockett, C. D., & Gottfried, R. R. (2002). State Policies and the Preservation of Forest Cover: Lessons from Contrasting Public-Policy Regimes in Costa Rica. *Latin American Research Review*, *37*(1), 7–40. Retrieved from http://links.jstor.org/sici?sici=0023-8791(2002)37:1%3C7:SPATPO%3E2.0.CO;2-0

management (Contraloría General de la República, 2008)[24]; and by flaws in legislation defining the legality of forestry operations (Navarro et al, 2006)[25].

This restrictive legislation may have been excessive, leading to a decline in the commercial competitiveness of forest management compared to other rural economic activities and increasing bureaucracy and associated costs to achieve the legality of native forest management operations. To be illustrative, the cost of attaining legality of native forest management, considering an average four-month processing time, is 13.9 USD/m^3. If this process were to reach eight months, this cost would be 17.5 USD/m^3. Comparatively, the cost to achieve legality for forestry plantations is around 3.87 USD/m^3, which is still high considering that achieving legality for agricultural activities, with which forestry activities compete, comes at no cost for the landowner. Therefore, the increase in the cost of attaining legality of sustainable forest management has reduced the competitiveness of forestry as land use and leads to the logical consequence of forest owners opting to change land use to agriculture and/or grassland or to harvest trees illegally (Navarro et al., 2006 and Navarro et al., 2008[26]).

Such increased costs led to a significant change in the dynamics of wood supply in Costa Rica. Until the mid-1990s, natural forests were the primary source of wood supply; however, the restrictive policy applied to the management of natural forests (primary and secondary forests) resulted in a rapid increase in the use of trees in agricultural lands, along with forest degradation and deforestation. Beginning in 2002, MINAE formalized the strategy to control illegal logging and toughened the requirements to obtain cutting permits in agricultural lands (SINAC, 2007)[27]; consequently, sources of wood supply changed radically. Approximately 49% of processed wood comes from forest plantations, 5% from natural forests, 12% from agricultural lands, and 34% is imported.

The legitimation of forestry operations is guaranteed in Costa Rica through the request and issuance of permits, a process that, as mentioned previously, has become more costly and bureaucratic with the current Forest Law. The stricter regulations of native forest management are believed to have led to a forest degradation process known as “illegal wood washing” with illegal permits (Navarro et al., 2006). The authors point out that public management has gaps that allow the "legitimization" of irregular use of native forest resources.

The Forest Law posed stricter regulations on forest management but fewer restrictions on timber harvesting in non-forest lands, such as treed grassland or agroforestry lands. This created certain negative incentives, such as increased removal of trees from grasslands and forest understory clearings (“socolas”). With the new Forest Law, many landowners converted managed forests into grasslands and croplands (SINAC, 2002). Notably, landowners would take advantage of these gaps in the legislation and practice *“socolas”* to request a permit to harvest trees in non-forest areas.

[24] Contraloría General de la República. (2008). *INFORME No . DFOE-PGAA-7-2008 DIVISIÓN DE FISCALIZACIÓN OPERATIVA Y EVALUATIVA ÁREA DE SERVICIOS PÚBLICOS GENERALES , AMBIENTALES Y NORMATIVA EN MATERIA DE RECURSOS FORESTALES POR EL MINISTERIO DEL AMBIENTE Y ENERGÍA (MINAE)*. San José, Costa Rica. Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiLzarz2c3YAhWDnlMKHdKcBvQQFggqMAA&url=https%3A%2F%2Fcgrfiles.cgr.go.cr%2Fpublico%2Fdocs_cgr%2F2008%2FSIGYD_D_2008008479.doc&usg=AOvVaw27b3cnnwpxntnKkvzdHOPQ

[25] Navarro, G., Vieto, R., & Bermúdez, G. (2006). *Costos de Acceso a la Legalidad, Cadenas y Actores de Mercado de la Madera legal e ilegal en Costa Rica.* San José, Costa Rica. Retrieved from http://www.fao.org/forestry/12925-0876f8fe8d9a597707a654029b82a818a.pdf

[26] Navarro, G., Obando, G., & Corella, O. (2008). Ambientalismo light y la resaca forestal en Costa Rica. In Organización de Estudios Tropicales (Ed.), *El abastecimiento sostenible de madera en Costa Rica* (p. 120). San J: Organización de Estudios Tropicales. Retrieved from http://onfcr.org/media/uploads/cyclope_old/adjuntos/AbastecimientoSostenible_Madera_CRnu34231.pdf

[27] SINAC. (2007). *ESTRATEGIA PARA EL CONTROL DE LA TALA ILEGAL 2002 - 2007*. San José, Costa Rica. Retrieved from http://www.fao.org/forestry/12914-065eef297f49b39d41d2fc1b6dfcf3cd8.pdf

By cutting the understory and sowing grass seeds, the original forest structure gradually changes to tree-shaded pastureland, making it more convenient for landowners to achieve legality for harvesting trees since it does not require a bureaucratic process like native forest management. Thus, issuing permits to cut trees in non-forest land is more rapid and less costly to landowners. To ensure the legitimacy of the tree-cutting licenses issued, georeferencing technology (GPS devices) in pre-felling inventories, along with the use of the Forest Cover Map for the year 2000, was implemented to avoid misleading the officials of the State Forestry Administration.

Summary information on drivers and their underlying causes

Generalities: for 1986-2019, changes in primary forests were small. Due to a fall in gross deforestation and an increase in forest regeneration, a net gain in forest cover was observed.

Direct factors driving deforestation and forest regeneration: 70% of *Forest lands* are converted to grasslands, a little over 20% are converted to Croplands, and almost 10% to tree plantations. Land converted to *Forest land* was previously grassland (65%), cropland (20%), and tree plantations (20%).

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

Forest age: Forest age is an essential factor driving deforestation in all land tenure regimes; the deforestation rate in forests <15 years was 4.5%, 2.0% in 15-25-year forests, and <1.0% in forests >25 years.

Deforestation concentration: A higher concentration of deforestation was found on the North Pacific coast and foothills (34% of total deforestation from 1987 to 2001 and 19% from 2001 to 2013), the North Caribbean plateau and coast (28% and 31% of total deforestation for 1987 to 2001 and 2001 to 2013, respectively), and the South Range (6% and 14%, respectively). These regions are also the most significant for forest regeneration. During the same periods, the North Pacific coast and foothills accounted for 35% and 29%, the North Caribbean plateau and coast for 20% and 20%, and the South Range for 8% and 5%.

Forest degradation: Forest degradation is mainly caused by stricter regulations imposed by the Forest Law on native forest management, which have increased the operating costs of forest management. This has led to the widespread practice of gradually converting native forestland into silvopastoral or agrosilvicultural systems to lower costs associated with obtaining timber harvesting permits.

3. Transparent, consistent, complete, and accurate information

3.1. Consistency with the national GHG inventory

The methodology for estimating emissions of the FOLU sector in the Biennial Update Report is partially consistent with the methods for estimating REDD + results (see Table 3). The main differences between methodologies are the following:

- FOLU Sector emissions include Harvested Wood Products and methane and nitrous oxide emissions.
- Deadwood and litter carbon pools are excluded.

- C stocks in above-ground biomass (AGB) of Forests Lands were estimated using the asymptotic value of the equations developed by Cifuentes (2008).
- Annual average emissions from deforestation and annual removals from enhancements of forest C stocks were calculated using a spreadsheet developed by the IMN.
- Uncertainty of INGEI, including FOLU sector emissions, is estimated using the Error Propagation Method, following approach 1 of the IPCC guidelines.

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 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. To increase transparency of the information used to estimate the FREL, the REDD+ Secretariat included links to access technical documents and data relevant to the preparation of the FREL/FRL.

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

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

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

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

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

  - Minimum area: 0.50 ha;
  - Minimum forest canopy cover: 10%; Minimum height of trees: 5.00 m.

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

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

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

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

Table 3: Consistency of the methods used to obtain the average annual emissions and removals the reference level of forest emissions and / or forest reference level submitted by Costa Rica to the UNFCCC in December 2024, and FOLU emissions of Costa Rica´s INGEI.

PARAMETERS	FREL FOR 2020 – 2029 SUBMITTED BY COSTA RICA TO THE UNFCCC IN DEC 2024.	INGEI[28] FOLU EMISSIONS
IPCC Guidelines applied	• IPCC 2006	
REDD+ activities	• Emission reductions from deforestation • Enhancement of forest C stocks	• Emission reductions from deforestation • Enhancement of forest C stocks • Harvested Wood Products
Greenhouse gases	• Methane (CH4) and nitrous oxide (N2O) were excluded.	• Methane (CH4) and nitrous oxide (N2O) are included.
C pools included	• Above-ground biomass (AGB) • Below-ground biomass (BGB) estimated following Cairns et al. (1997)[29] • Dead wood (DW) • Litter (L)	• Above-ground biomass (AGB) • Below-ground biomass (BGB) estimated with IPCC default values.
Non anthropogenic emissions	• Excluded	
Activity Data		
Representation of lands	• Forest Lands: Wet and rain forest; Moist forest; Dry forest; Mangroves; Palm Forest • Croplands: Annual crops; Perennial crops • Grassland • Settlements • Wetlands: Natural wetlands; Artificial wetlands • Other lands: Paramo; Natural Bare soil; Artificial Bare soil	
Data sources	Remotely sensed data from four generations of the Landsat family (Landsat 4 TM, Landsat 5 TM, Landsat 7 ETM and Landsat 8 OLI/TIRS).	Remotely sensed data from Landsat 8 OLI/TIRS

[28] Personal communication, Ana Rita Chacón, Coordinator of the National Inventory of Greenhouse Gases - National Meteorological Institute.
[29] 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.

PARAMETERS	FREL FOR 2020 – 2029 SUBMITTED BY COSTA RICA TO THE UNFCCC IN DEC 2024.	INGEI[28] FOLU EMISSIONS
Mapping Land Use	The land use maps were created using the methodology detailed in Agresta et al (2015)[30], and postprocessing procedures described in MINAE (2016)[31], section 4.3.3 (See Annex 1).	
Methods for estimating AD	AD was estimated by combining all land use maps created for 1985/86-2019/20 in a Geographical Information System (GIS) and then extracting the values of the areas that remained in the same category or converted to other land use categories from the combined set of multi-temporal data. The results of this operation are reported in land use change matrices prepared for each measurement period in the sheets "LCM 1986-91", "LCM 1992-97", "LCM 1998-00", "LCM 2001-07", "LCM 2008-11", "LCM 2012-13", "LCM 2014-15", "LCM 2016-17" and "LCM 2018-19" of the spreadsheets in FREL TOOL CR.	AD was estimated by combining land use maps created for REDD+ in a Geographical Information System (GIS) and then extracting the values of the areas that remained in the same category or converted to other land use categories from the combined set of multi-temporal data. The results of this operation are reported in land use change matrices in the sheet "LCM XXXX-XX" of the spreadsheets in FREL TOOL CR (see Annex 3).
Emission Factors		
Data sources for estimating EF	National Forest Inventory (NFI)[32] preliminary results including a 289-plot representative sample was used for the estimation of forest C stocks. Non-Forest lands C stocks were estimated as the average values reported by the selected studies (110 publications) [33].	C stocks in above-ground biomass (AGB) of Forests Lands were estimated using the asymptotic value of the equations developed by Cifuentes (2008) [34]
Primary forest AGB	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	

[30] Agresta, Dimap, Universidad de Costa Rica, Universidad Politécnica de Madrid, 2015. 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.

[31] Ministry of the Environment and Natural Resources of Costa Rica. (2016). Modified REDD+ Forest reference emission level/forest reference level (FREL/FRL). COSTA RICA. SUBMISSION TO THE UNFCCC SECRETARIAT FOR TECHNICAL REVIEW ACCORDING TO DECISION 13/CP.19. Retrieved from https://redd.unfccc.int/files/2016_submission_frel_costa_rica.pdf

[32] 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

[33] Costa Rica Carbon Density Database can be accessed in the following link: https://drive.google.com/file/d/1LJ8pbd0EuiVoS7JuMc8ps_OwlD12MUuH/view?usp=sharing

[34] 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.

PARAMETERS	FREL FOR 2020 – 2029 SUBMITTED BY COSTA RICA TO THE UNFCCC IN DEC 2024.	INGEI[28] FOLU EMISSIONS
	arithmetic mean was calculated. More detail in Ministry of the Environment and Natural Resources of Costa Rica. (2016), section 4.4.2, Table 8.	
Secondary forest AGB	C stocks in total net above-ground biomass (TAGB) of Wet and Rain Forests, Moist Forests and Dry Forests were estimated using the equations developed by Cifuentes (2008) for Costa Rican secondary forests. For Mangroves and Palm Forests, a linear function was assumed for estimating C stocks as a function of age. More detail in Ministry of the Environment and Natural Resources of Costa Rica. (2016), section 4.4.2, page 39.	
Methods for estimating EF	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.). More detail in Ministry of the Environment and Natural Resources of Costa Rica. (2016), section 4.4.3.	
DA and EF integration tool		
DA and EF integration tool	The annual average emissions from deforestation and annual removals from enhancements of forest C stocks were calculated using in FREL TOOL CR[35].	The annual average emissions from deforestation and annual removals from enhancements of forest C stocks were calculated using a spreadsheet developed by the IMN.
Uncertainty		
Uncertainty estimate	Uncertainties associated with activity data (AD) and emission factors (EF) were considered separately. Uncertainty estimate for AD was derived form an accuracy assessment carried out for the land-cover change maps using the guidelines from Olofsson et al (2014)[36]. The uncertainty of the aboveground biomass carbon stock for primary forests used to estimate deforestation emission factors from Costa Rica's first NFI is derived from its sampling error. The uncertainty of the annual average emissions is estimated by combining the uncertainty of activity data and emission factors. Combination of uncertainties has been done through Approach 2 of the IPCC 2006 Guidelines, employing Monte Carlo simulations, and the uncertainties are reported in terms of 90% confidence intervals.	Uncertainty of INGEI, including FOLU sector emissions is estimated using the Error Propagation Method, following approach 1 of the IPCC guidelines.

[35] 2016.07.10 - FREL & MRV TOOL CR MapaIMN15v3.xlsx https://drive.google.com/file/d/1WzEZbNwUmO_x74R7udQSD4YmcO5GiFF4/view?usp=sharing
[36] Olofsson et al. (2014) Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment 148, 42-57.

4. Information on the proposed FREL

4.1. Proposed FREL/FRL

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

The FREL/FRL has been estimated as the sum of the **annual average emissions** from deforestation and the annual **average removals**[37] from enhancements of forest C stocks in the following historical reference period:

- **2010-2019** for the third period of enhanced mitigation actions (2020-2029).

The proposed FREL/FRL, expressed in tons of carbon dioxide equivalent per year (t CO_2e yr^{-1}), was estimated as follows (all emissions and removals are annual averages[38]):

- For the period **2020-2029** (with the historical reference period 2010-2019):

Emissions from deforestation:	**2,787,755**	**100.0%**
- Deforestation of primary forests:	1,482,791	75.4%
- Deforestation of secondary forests:	1,304,964	24.6%
Emission from degradation	**2,371,123**	**100%**
Removals through C-stock enhancements:	**-5,751,005**	**100%**
- Removals in primary forest	-297,793	5%
- Removals in secondary forest	-5,453,212	95%

Figure 5 shows forest-related emissions and removals in Costa Rica between 1998 and 2021. Table 2 shows **annual emissions from deforestation** and **removals from forest C stock enhancement** for 1998-2021.

The proposed FREL/FRL For the REDD+ implementation period 2020-2029: **-592,127** t CO_2e yr^{-1}

[37] Removals are expressed as negative numbers, as CO_2 is directly removed from the atmosphere.
[38] Worksheet with annual emissions and removals for the historical reference period 2010-2019 can be accessed at the following link: https://www.dropbox.com/scl/fi/579lb3fqdycma20fjy3hd/FREL-FRL_2010-2019_CR.xlsx?rlkey=9bezlc8yovdg88aeqp6looepz&dl=0

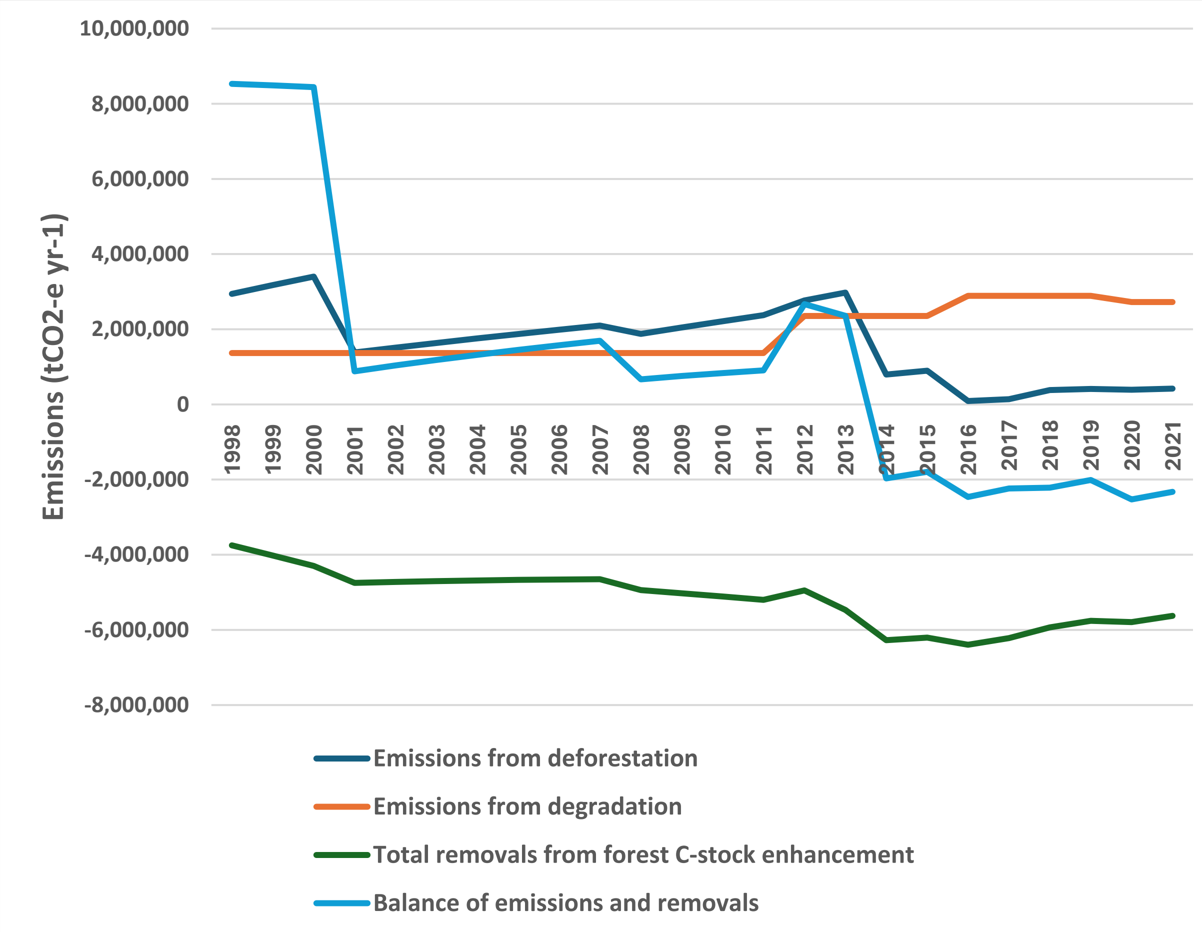

Figure 5: Forest-related emissions and removals in Costa Rica between 1986 and 2013 (tCO2-e yr-1).

Table 4: Emissions estimated for the construction of the Forest Reference Emission Level-Forest Reference Level (tCO2-e yr-1)

Year	Actual emissions from deforestation of primary forests	Actual emissions from deforestation of secondary forests	Total actual emissions from deforestation	Actual emissions from degradation	Removals through C-stock enhancement in permanent forest	Actual removals from forest C-stock enhancement in secondary forest	Total removals from forest C-stock enhancement	Actual emissions included in the FREL/FRL
1998	7,970,125	2,942,267	10,912,392	1,367,747	-283,350	-3,466,027	-3,749,377	8,530,762
1999	7,970,125	3,175,489	11,145,614	1,367,747	-283,350	-3,738,067	-4,021,417	8,491,945
2000	7,970,125	3,401,715	11,371,840	1,367,747	-283,350	-4,012,154	-4,295,504	8,444,083
2001	2,879,088	1,383,656	4,262,744	1,367,747	-283,350	-4,465,800	-4,749,150	881,341
2002	2,879,088	1,511,988	4,391,076	1,367,747	-283,350	-4,439,321	-4,722,671	1,036,152
2003	2,879,088	1,636,381	4,515,469	1,367,747	-283,350	-4,417,697	-4,701,047	1,182,169
2004	2,879,088	1,756,963	4,636,051	1,367,747	-283,350	-4,400,625	-4,683,975	1,319,823
2005	2,879,088	1,873,851	4,752,939	1,367,747	-283,350	-4,386,338	-4,669,688	1,450,998
2006	2,879,088	1,987,156	4,866,244	1,367,747	-283,350	-4,374,810	-4,658,160	1,575,831
2007	2,879,088	2,096,986	4,976,074	1,367,747	-283,350	-4,366,064	-4,649,415	1,694,407
2008	2,363,449	1,878,040	4,241,490	1,367,747	-283,350	-4,656,939	-4,940,289	668,947
2009	2,363,449	2,048,856	4,412,306	1,367,747	-283,350	-4,741,258	-5,024,608	755,445
2010	2,363,449	2,214,597	4,578,047	1,367,747	-283,350	-4,827,948	-5,111,298	834,496
2011	2,363,449	2,375,392	4,738,841	1,367,747	-283,350	-4,917,121	-5,200,471	906,118
2012	2,495,347	2,769,088	5,264,436	2,354,018	-365,601	-4,584,400	-4,950,001	2,668,452
2013	2,495,347	2,974,986	5,470,334	2,354,018	-365,601	-5,102,430	-5,468,031	2,356,321
2014	1,159,752	793,490	1,953,242	2,354,018	-365,601	-5,908,759	-6,274,360	-1,967,100
2015	1,159,752	898,915	2,058,667	2,354,018	-365,601	-5,839,223	-6,204,824	-1,792,139
2016	951,687	90,504	1,042,191	2,889,916	-237,205	-6,157,626	-6,394,832	-2,462,724
2017	951,687	139,772	1,091,459	2,889,916	-237,205	-5,979,878	-6,217,084	-2,235,708
2018	443,720	382,604	826,324	2,889,916	-237,205	-5,695,262	-5,932,467	-2,216,227
2019	443,720	410,289	854,009	2,889,916	-237,205	-5,519,473	-5,756,679	-2,012,753
2020	152,192	390,605	542,797	2,723,518	-509,222	-5,284,270	-5,793,491	-2,527,176
2021	152,192	422,666	574,858	2,723,518	-509,222	-5,115,261	-5,624,483	-2,326,107

4.2. General estimation approach by REDD+ activity

4.2.1. Deforestation

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

4.2.2. Degradation

Emissions from forest degradation were estimated using a visual assessment canopy cover density on high resolution images, which classified primary forest areas as intact, degraded, and very degraded depending on canopy cover in the Forests remaining Forest Land.

4.2.3. Enhancement of Forest C Stocks

Removals were estimated in secondary forest and forest remaining forest as follows:

Secondary Forest: It was assumed that *Forest land* in transition complies with the definition of forest at years 4 and 8, for wet and dry forests, respectively (see Section 4.1. for more details on land classification). C stock enhancement in secondary[39] *Forest land remaining Forest land* was estimated using growth models developed in Costa Rica (Cifuentes, 2008)[40]. These models estimate C stocks as a function of age. Cifuentes’ equations were applied by determining the age of the forest in the year of the conversion and tracking forest age along the AD time series (more details are presented in Section 4.4).

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

Forest remaining forest: Removals from forest enhancements in forest remaining forest is estimated using a visual assessment of canopy cover density on high resolution images (using the same methodology as that used to estimate emissions from forest degradation). As a conservative measurement, when a primary forest was detected to have increased in canopy cover, the increase in C stock was considered to be from secondary forest rather than primary forest regrowth.

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

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

4.2.4. Sustainable management of forest

Emissions/removals associated with the sustainable management of forests (SMF) are excluded. The country estimated the annual emissions due to SFM in about 44,729[41] tCO_2-e yr^{-1} and represent 1% of the yearly emissions from deforestation and degradation observed during the Reference Period (FREL/FRL 5,158,878 tCO_2-e yr^{-1}); therefore, it is considered non-significant source emissions. It is important to note that the total area under forest management in Costa Rica is minimal (<500 ha yr-1). Additionally, silvicultural practices are not stand-replacing but remove partial timber volumes (selective logging) every 15 years.

4.3. Activity data

4.3.1. Consistent representation of lands

Land classification for deriving AD from the 1985/86-2018/19 land use change time series is consistent with the National GHG inventory (except for tree plantations, as explained below). The classes defined were:

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

An ancillary map from 1978/80 was utilized to assess the areas of primary and secondary *Forest land* at the begining of the land use change time series. Detailed information about this map can be found in Annex 2. It is assumed that "**Primary forests**" maintain stable carbon (C) stocks per hectare over time, as growth typically matches mortality and these areas are unmanaged. It's important to note that emissions and removals linked to sustainable forest management (SMF) account for merely 1% of the annual emissions from deforestation and degradation during the Reference Period (FREL/FRL 5,158,878 tCO2-e yr-1). Consequently, Costa Rica views fluctuations in C stocks within primary forests over time due to management practices as insignificant. Additionally, it’s crucial to mention that emissions and removals in primary forests are incorporated into the development of Costa Rica’s FREL/FRL, which includes “forest degradation."

[41] Winrock International. (2018). Sustainable Forest Management Reference Level for Costa Rica. Retrieved from https://drive.google.com/file/d/1yUxQEm3dN6F0jHAfWdPGljqfL_r1R6Cn/view?usp=sharing

"**Secondary forests**" are forests that regenerated on non-forest land. They also include forests that were classified as "secondary" in 1985/86 according to the 1978/80 ancillary map. Secondary forests in 1985/86 are assumed to be representative of all possible age classes, up to 400 years old, with equal proportions of areas. To estimate C accumulation in these forests (identified with the notation "… - 1985" in Tables 5 and 6) it was assumed that all age classes grow old one year each year, as shown in Table 5. 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 5: 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 analyzec						
	1986	1987	1988	…	2017	2018	2019
… - 1985	5	6	7	…	36	37	38
	6	7	8	…	37	38	39
	7	8	9	…	38	39	40
	8	9	10	…	39	40	41
	9	10	11	…	40	41	42
	…	…	…	…	…	…	…
	396	397	398	…	**427**	**428**	**429**
	397	398	399	…	**428**	**429**	**430**
	398	399	**400**	…	**429**	**430**	**431**
	399	**400**	**401**	…	**430**	**431**	**432**
	400	**401**	**402**	…	**431**	**432**	**433**

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;2 ages classes for 2012-13; 2 ages classes for 2014-15; 2 ages classes for 2016-17, and 2 ages classes for 2018-19. 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 6 shows how age classes were assumed to exist in different years of the historical reference period for the case of dry forests.

Table 6: 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**	**9-10**	**10-11**	**11-12**	**12-13**	**13-14**	**14-15**
1992-97							**8**	**8-9**
1998-00								

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	2010
... - 1985	**25-417**	**26-418**	**27-419**	**28-420**	**29-421**	**30-422**	**31-423**	**32-424**	**33-425**
1986-91	**23-24**	**24-25**	**25-26**	**26-27**	**27-28**	**28-29**	**29-30**	**30-31**	**31-32**
1992-97	**17-18**	**18-19**	**19-20**	**20-21**	**21-22**	**22-23**	**23-24**	**24-25**	**25-26**
1998-00	**11-12**	**12-13**	**13-14**	**14-15**	**15-16**	**16-17**	**17-18**	**18-19**	**19-20**
2001-07	**8-9**	**9-10**	**10-11**	**11-12**	**12-13**	**13-14**	**14-15**	**15-16**	**16-17**
2008-11							**8**	**8-9**	**9-10**
2012-13									

Cohort	Years of the historical period analyzed								
	2011	2012	2013	2014	2015	2016	2017	2018	2019
... - 1985	**34-426**	**35-427**	**36-428**	**37-429**	**38-430**	**39-431**	**40-432**	**41-433**	**42-434**
1986-91	**32-33**	**33-34**	**34-35**	**35-36**	**36-37**	**37-38**	**38-39**	**39-40**	**40-41**
1992-97	**26-27**	**27-28**	**28-29**	**29-30**	**30-31**	**31-32**	**32-33**	**33-34**	**34-35**
1998-00	**20-21**	**21-22**	**22-23**	**23-24**	**24-25**	**25-26**	**26-27**	**27-28**	**28-29**
2001-07	**17-18**	**18-19**	**19-20**	**20-21**	**21-22**	**22-23**	**23-24**	**24-25**	**25-26**
2008-11	**10-11**	**11-12**	**12-13**	**13-14**	**14-15**	**15-16**	**16-17**	**17-18**	**18-19**
2012-13		**8**	**8-9**	**9-10**	**10-11**	**11-12**	**12-13**	**13-14**	**14-15**
2014-15				**8**	**8-9**	**9-10**	**10-11**	**11-12**	**12-13**
2016-17						**8**	**8-9**	**9-10**	**10-11**
2018-19								**8**	**8-9**

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

Despite all efforts, it was not possible to distinguish tree plantations as an additional sub-category in *Forest land*. The quality of the satellite imagery employed was not sufficient to overcome the spectral confusion of tree plantations with secondary forests and agroforestry systems. As other sources of national information on forest plantation are neither spatially explicit nor complete for 1985/86-2018/19, forest plantations could not be considered in the FREL/FRL.

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

4.3.2. Data sources for estimating activity data

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

- Remotely sensed data from four generations of the Landsat family (Landsat 4 TM, Landsat 5 TM, Landsat 7 ETM and Landsat 8 OLI/TIRS).
- A "Life Zones" map according to the classification system of Holdridge (1966)[42]. This map was used to stratify "Forests" into the three sub-categories: "Wet and Rain Forests", "Moist Forests" and "Dry Forests" (see Figure 6).
- 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.

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

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

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

4.3.3. Methods for mapping land use

A unique and uniform methodology was used for FREL / FRL to avoid that changes registered in the cartographic comparison of LULC maps were affected by the combination of different techniques and methods. Agresta (2015) prepared the time-series of land use maps for 1985/86-2012/13 in a Geographical Information System (GIS)[43,44]. Córdoba-Peraza, (2017, 2020a;2020b) prepared the LULC Maps 2015, 2017 and 2019 of Costa Rica (MCS 2015/16[45], MCS 2017/18[46] and MCS 2019/20)[47], following the satellite land monitoring protocol (SLMP) developed by AGRESTA (2015) and the protocol for postprocessing developed by Carbon Decisions International (Ministry of the Environment and Natural Resources of Costa Rica, 2016).

The geodatabase's table of uses, types, and ages of the forest was updated for MCS 2015/2016, 2017/18 and MCS 2019/20 considering the last map of the 1987-2013 time-series geodatabase.

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 orthophotographs 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)[48].

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[43] 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. Available at https://www.dropbox.com/s/ygjw6zq00a1qtbm/Informe_tecnico_feb_2015.pdf?dl=0

Córdoba-Peraza, J. (2017). Informe final Elaboración del mapa de cobertura y uso de la tierra en Costa Rica 2015. Retrieved from https://drive.google.com/file/d/15rAwOV9I8jRArkcDnVpkf0tyJyRNu69C/view?usp=sharing

Córdoba-Peraza, J. (2020 a). Informe final Elaboración del mapa de cobertura y uso de la tierra en Costa Rica 2017. Available at https://drive.google.com/file/d/1_p4M48tpPuPrBzm4makYVELb5p6eDSB9/view?usp=sharing

Córdoba-Peraza, J. (2020 b). Informe final Elaboración del mapa de cobertura y uso de la tierra en Costa Rica 2019. Available at https://drive.google.com/file/d/1WPr46RFOu_1Vr5rAYO_QDUIaL090zWd3/view?usp=sharing

[44] The geodatabase with the time series of land use maps created for the reference period 1985/86-2012/13 can be accessed at the following link: https://drive.google.com/drive/folders/1XulVBwfZNam6acIksq-ZMQoK_ISqy0V2?usp=sharing

[45] LULC map 2015 (MCS 2014/15) can be accessed at the following link: https://drive.google.com/open?id=1rvO_NS9M64-bClMt9pOULkg465N36iwC&usp=drive_fs

[46] LULC map 2017 (MCS 2017/18) can be accessed at the following link: https://drive.google.com/drive/folders/1yARo588uxh_KYccBNaVpokPqqu_pMISL?usp=sharing

[47] LULC map 2019 (MCS 2019/20) can be accessed at the following link: https://drive.google.com/drive/folders/1NRxm3yRV6yT1NgLwhp_z00wxyA0fpMdx?usp=sharing

[48] 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.

Classification:

- **Methodology**. "Random Forest" (RF) by Breiman (2001) [49] 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.

It is crucial to clarify that AGRESTA (2015) developed the **REDD tools Costa Rica toolkit** to automate the workflow. This toolbox operates on the geographic information system QGIS for the Microsoft Windows operating system. The programs were compiled within the QGIS Processing framework[50], enabling the execution of geoprocessing algorithms implemented in software libraries external to QGIS. The following libraries are used:

- GRASS GIS (https://grass.osgeo.org/)
- Orfeo Toolbox (https://www.orfeo-toolbox.org/)
- GDAL (https://gdal.org/)

For the preparation of the MCS 2015/2016 onwards, it was necessary to migrate the toolkit to updated versions of QGIS and update the libraries to 64-bit versions to be able to work with recent versions of Windows and QGIS. The updated guide for installing the software tools and the necessary programs to prepare land-use maps can be consulted in Annex 1 of the Córdoba-Peraza (2019) report. It is important to note that none of these updates results in a change in methodology.

Post-processing:

- **Minimum mapping unit**. To avoid the "salt and pepper" effect and comply with the minimum area parameter of the definition of "forest: (1.00 ha), the products of the digital classification were filtered in order to represent the land use categories with a minimum mapping unit of 0.99 ha[51].

- **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

[49] Breiman, L., 2001. Random Forests. Machine Learning, 45:5-3. Available at: http://link.springer.com/article/10.1023/A%3A1010933404324
[50] https://docs.qgis.org/2.8/en/docs/user_manual/processing/
[51] 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).

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

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

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

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

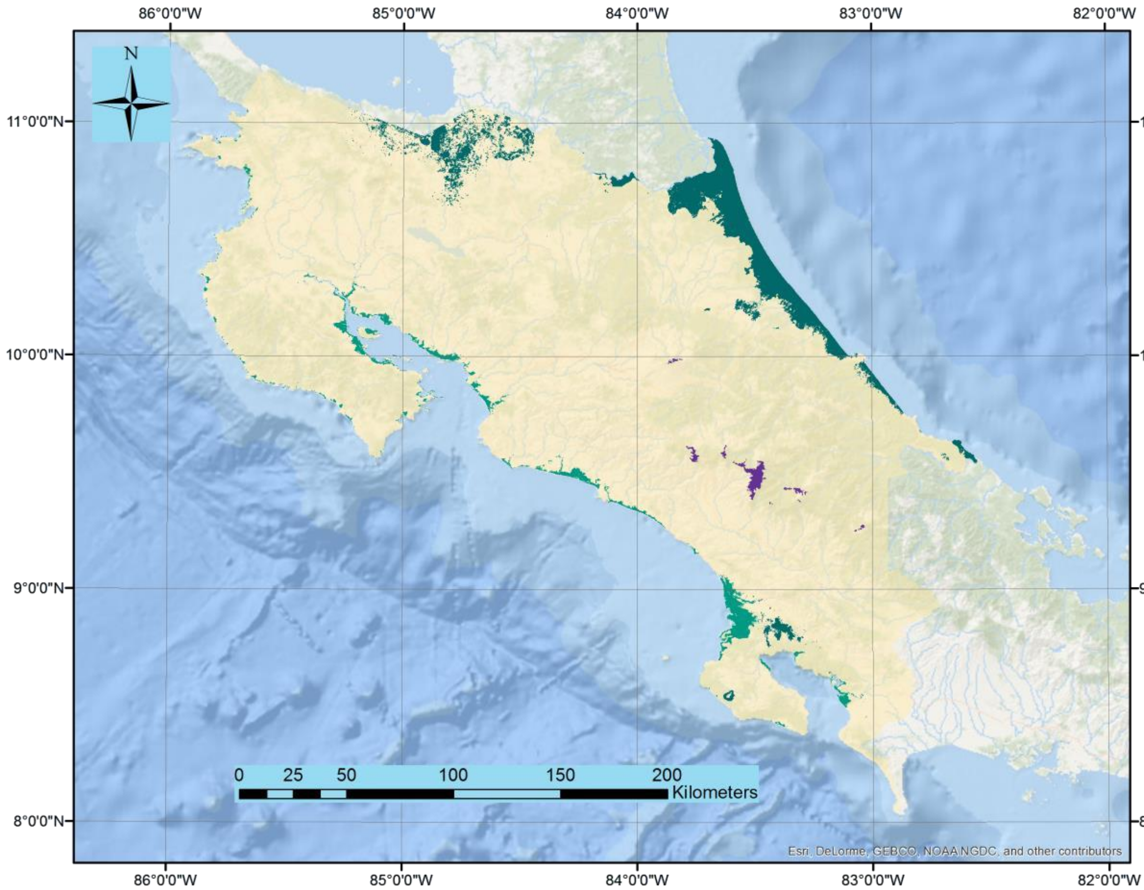
(4) A mask was also created for "*Paramo*". "*Paramo*" is an ecosystem composed of shrubs and grasses that only occurs at high elevations, above the forest line. The area classified as "*Paramo*" in the National Forest Inventory was manually edited through visual interpretation using 2013 high resolution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

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

(6) Areas classified as "*Urban Areas*" in 2013/14 were manually edited through visual interpretation of 2013 high resolution RapidEye images and creation of a mask representing "*Urban Areas*" in 2013/14. Pixels originally classified as "*Urban Areas*" outside the mask were reclassified as "*Bare Soil*" and conversely, pixels classified as "*Bare Soil*" inside this mask were reclassified as "*Urban Areas*". Additionally, under the assumption that "*Urban Areas*" never convert to other land use categories, all pixels within the 2013/14 "*Urban Areas*" mask that were classified as "*Urban Areas*" at some date between 1986 and 2013 were forced to remain "*Urban Areas*" in all posterior dates.

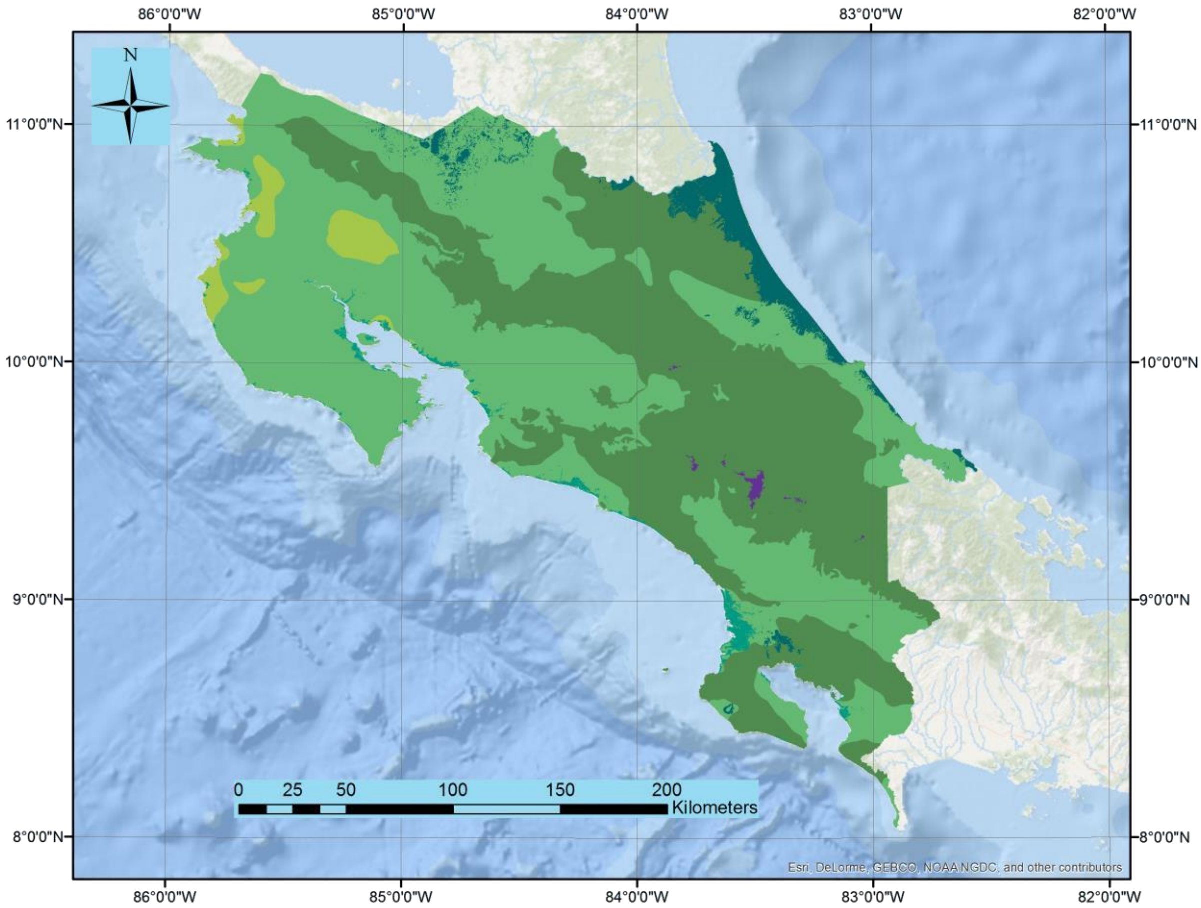
(7) In order to assign secondary forests to a forest type (Wet and Rain Forests, Moist Forests, Dry Forests, Mangroves, Palm Forests) a map of potential forest types was created. This map will also be used in future measurements for determining the forest type of secondary forests. The map of potential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

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



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

Figure 8. Map of potential forest types.



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

4.3.4. Methods for estimating AD

AD was estimated by combining all land use maps created for 1985/86-2019/20 in a Geographical Information System (GIS) and then extracting the values of the areas that remained in the same category or converted to other land use categories from the combined set of multi-temporal data. The results of this operation are reported in land use change matrices prepared for each measurement period in the sheets “LCM 1986-91”, “LCM 1992-97”, “LCM 1998-00”, “LCM 2001-07”, “LCM 2008-11”, “LCM 2012-13”, “LCM 2014-15”, “LCM 2016-17” and “LCM 2018-19”of the spreadsheets in FREL TOOL CR.

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

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

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

  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:

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

  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 the FREL TOOL CR ("AAAA" indicates the year).

4.3.5. Results for activity data

Figure 9 shows forest cover in Costa Rica for 1985/86-2019/20. Figure 10 shows forest losses in the same period. Annual areas of forest loss estimated for primary forests are shown in Table 7 and those for secondary forests in Table 8. Table 9 shows the areas of new forests at the end/beginning of each period (*i.e.* 1986/87, 1991/92, 1997/98, 2000/01, 2007/08, 2011/12 2013/14, 2015/16, 2017/18, 2018/19). The results shown in Table 8 and Table 9 are reported at an aggregate level, more information is available in the spreadsheets in FREL TOOL CR.

Figure 9. Forest cover in Costa Rica between 1985/86 and 2019/20 (in hectares).

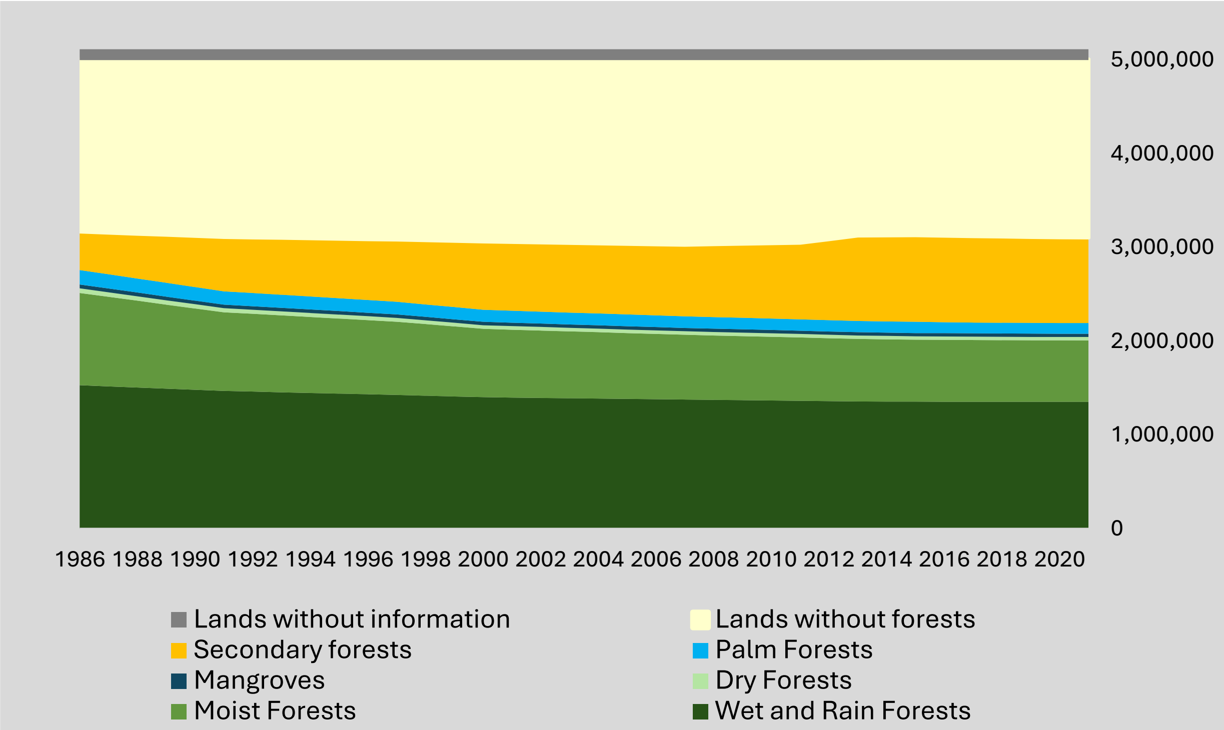


Figure 10. Forest loss in Costa Rica between 1985/86 and 2019/20 (hectares).

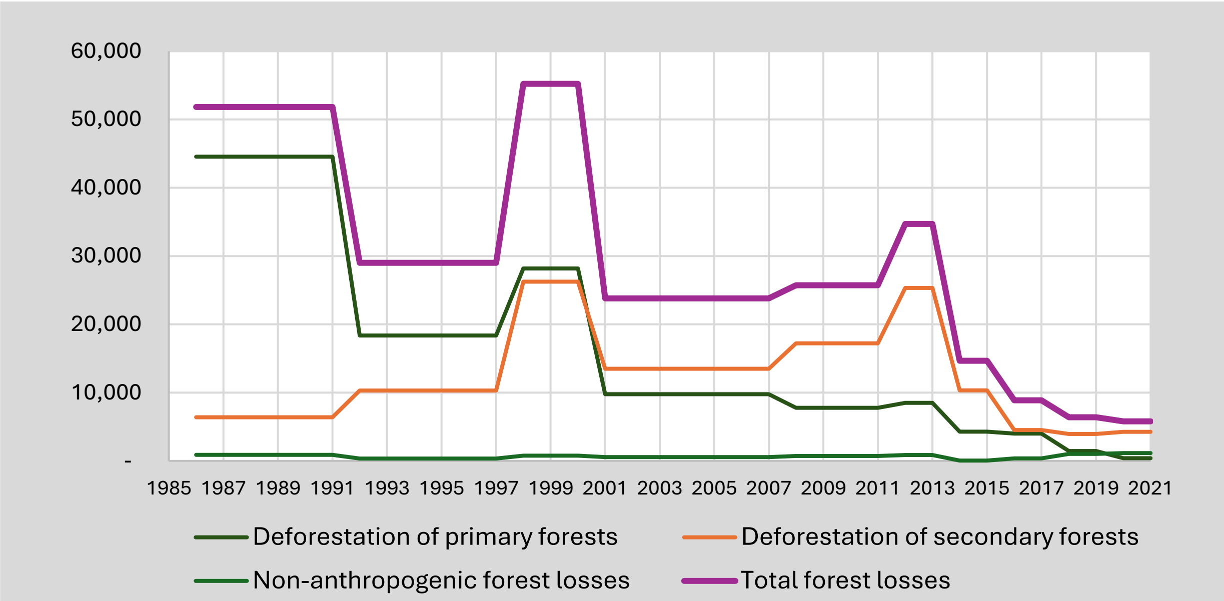


Table 7. Annual loss of primary forests.

	Primary Forests	1986-91	1992-97	1998-00	2001-07	2008-11	2012-13	2014-15	2016-17	2018-19
	Forest category	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}	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	1,295.69	229.54	0.00
DF	Moist Forests	28,712.62	9,684.13	17,202.96	5,358.57	3,598.18	4,982.94	2,942.86	1,001.22	1,403.82
DF	Dry Forests	1,197.44	386.80	836.79	130.68	75.22	267.98	54.40	0.09	0.00
DF	Mangroves	366.25	116.04	225.18	77.88	62.15	54.23	0.00	14.62	32.62
DF	Palm Forests	2,215.37	1,224.44	1,786.35	638.27	713.25	368.24	0.00	2,751.17	7.24
DF	**Total primary forests**	**44,549.80**	**18,362.58**	**28,193.73**	**9,760.76**	**7,786.62**	**8,509.77**	**4,292.95**	**3,996.63**	**1,443.69**
NL	Wet and Rain Forests	214.52	93.45	66.63	66.56	111.22	51.35	0.00	194.26	121.86
NL	Moist Forests	116.88	27.63	38.73	52.60	48.04	54.68	13.00	0.00	250.42
NL	Dry Forests	0.51	0.57	0.75	0.08	-	2.93	0.00	12.06	5.22
NL	Mangroves	272.46	38.25	61.56	86.55	56.21	48.02	0.00	0.00	0.00
NL	Palm Forests	142.14	76.41	95.13	58.45	75.69	121.10	0.00	0.00	0.00
NL	**Total primary forests**	**746.50**	**236.31**	**262.80**	**264.24**	**291.15**	**278.06**	**13.00**	**206.32**	**377.49**
TL	Wet and Rain Forests	12,272.64	7,044.62	8,209.08	3,621.92	3,449.05	2,887.74	1,295.69	423.80	121.86
TL	Moist Forests	28,829.50	9,711.76	17,241.69	5,411.17	3,646.22	5,037.62	2,955.86	1,001.22	1,654.24
TL	Dry Forests	1,197.95	387.37	837.54	130.76	75.22	270.90	54.40	12.15	5.22
TL	Mangroves	638.71	154.29	286.74	164.43	118.35	102.24	0.00	14.62	32.62
TL	Palm Forests	2,357.51	1,300.85	1,881.48	696.72	788.94	489.33	0.00	2,751.17	7.24
TL	**Total primary forests**	**45,296.31**	**18,598.89**	**28,456.53**	**10,025.00**	**8,077.77**	**8,787.83**	**4,305.95**	**4,202.95**	**1,821.18**

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

Table 8. Annual loss of secondary forests (includes tree plantations).

	New Forests	1986-91	1992-97	1998-00	2001-07	2008-11	2012-13	2014-15	2016-17	2018-19
	Forest category	ha yr^{-1}	ha yr^{-1}	ha yr^{-1}	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	2,902.72	505.83	520.72
DF	Moist Forests	4,342.31	6,170.09	17,245.50	9,403.29	10,906.81	17,860.41	7,311.45	3,416.24	2,004.19
DF	Dry Forests	61.43	165.42	539.22	146.02	383.69	609.62	108.18	93.60	98.68
DF	Mangroves	49.26	136.34	360.06	138.79	219.56	260.51	0.00	170.32	191.06
DF	Palm Forests	18.30	320.28	1,260.78	455.82	568.76	617.09	0.00	329.30	1,128.52
DF	**Total new forests**	**6,397.31**	**10,303.59**	**26,248.53**	**13,494.19**	**17,222.45**	**25,332.35**	**10,322.35**	**4,515.29**	**3,943.18**
NL	Wet and Rain Forests	75.76	35.30	138.51	66.57	137.21	107.28	13.68	140.17	94.99
NL	Moist Forests	61.68	37.10	97.02	92.60	109.62	147.92	23.08	1.62	294.20
NL	Dry Forests	0.02	1.22	0.39	0.14	0.27	3.24	0.00	9.40	13.68
NL	Mangroves	9.59	28.05	178.32	71.60	92.00	177.30	0.00	4.09	121.23
NL	Palm Forests	0.08	12.77	98.43	58.36	89.93	149.27	0.00	0.00	116.59
NL	**Total new forests**	**147.12**	**114.42**	**512.67**	**289.27**	**429.03**	**585.00**	**36.76**	**155.29**	**640.69**
TL	Wet and Rain Forests	2,001.78	3,546.77	6,981.48	3,416.84	5,280.84	6,092.01	2,916.40	646.00	615.71
TL	Moist Forests	4,403.99	6,207.18	17,342.52	9,495.89	11,016.43	18,008.33	7,334.54	3,417.86	2,298.39
TL	Dry Forests	61.44	166.64	539.61	146.16	383.96	612.86	108.18	103.00	112.36
TL	Mangroves	58.85	164.39	538.38	210.39	311.56	437.81	0.00	174.41	312.29

TL	Palm Forests	18.38	333.05	1,359.21	514.18	658.69	766.35	0.00	329.30	1,245.11
TL	**Total new forests**	**6,544.43**	**10,418.01**	**26,761.20**	**13,783.46**	**17,651.48**	**25,917.35**	**10,359.11**	**4,670.58**	**4,583.87**

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

Table 9. Secondary forests existing at the end/start of each period.

	New Forest		1986/87	1991/92	1997/98	2000/01	2007/08	2011/12	2013/14	2015/16	2017/18	2018/19
		Cohort	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
AE	Wet and Rain Forests	...-1985	153,734.85	143,725.95	136,417.86	132,867.36	128,482.38	126,376.83	125,269.65	124,759.43	124,759.43	124,646.75
		1986-91	0.00	60,092.10	58,138.02	47,139.30	41,460.12	38,342.52	37,202.85	36,725.19	36,675.43	36,523.60
		1992-97	0.00	0.00	28,343.93	27,617.49	20,833.38	18,387.81	17,642.25	17,399.04	17,292.22	17,182.51
		1998-00	0.00	0.00	0.00	24,220.50	29,261.16	23,815.08	21,976.92	21,589.94	21,429.92	21,388.61
		2001-07	0.00	0.00	0.00	0.00	40,432.58	39,162.78	35,067.78	34,753.90	34,239.75	34,138.23
		2008-11	0.00	0.00	0.00	0.00	0.00	23,361.68	27,890.46	27,144.56	27,003.44	26,973.38
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	21,968.60	40,772.18	40,664.28	40,036.73
		2014-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,273.95	2,335.69	2,288.72
		2016-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	263.15	516.49
		2018-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	501.82
AE	Moist Forests	...-1985	213,822.70	191,802.78	182,115.36	173,450.79	165,067.65	162,410.76	160,325.73	159,196.99	159,196.99	159,196.99
		1986-91	0.00	124,746.90	122,140.62	97,306.29	83,812.68	78,632.91	75,798.27	74,392.57	74,392.39	73,497.82
		1992-97	0.00	0.00	82,075.72	79,962.21	57,203.46	50,783.04	48,241.62	47,129.76	46,644.94	46,470.62
		1998-00	0.00	0.00	0.00	63,799.80	73,863.99	57,683.07	50,013.36	48,745.92	48,213.68	47,743.63
		2001-07	0.00	0.00	0.00	0.00	64,237.17	61,315.65	51,689.43	49,735.89	49,132.73	48,638.11
		2008-11	0.00	0.00	0.00	0.00	0.00	63,625.09	73,573.83	70,605.76	69,628.57	68,514.05
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	44,941.63	85,031.66	84,789.30	83,573.80
		2014-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13,667.99	23,340.20	23,153.10
		2016-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3,032.99	6,019.90
		2018-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,164.56
AE	Dry Forests	...-1985	5,864.97	5,557.77	5,350.68	5,104.71	5,051.52	5,031.18	5,000.22	5,000.06	4,988.27	4,988.27
		1986-91	0.00	5,625.68	5,958.09	4,979.79	4,745.70	4,639.77	4,517.91	4,495.98	4,490.85	4,490.85
		1992-97	0.00	0.00	4,368.53	4,847.67	4,510.62	4,338.63	4,214.70	4,214.56	4,211.32	4,093.97
		1998-00	0.00	0.00	0.00	4,492.74	6,340.32	5,428.26	5,216.04	5,158.99	5,157.73	5,157.73
		2001-07	0.00	0.00	0.00	0.00	2,470.89	2,557.17	2,167.92	2,139.14	2,106.56	2,036.54
		2008-11	0.00	0.00	0.00	0.00	0.00	1,614.67	1,805.40	1,737.30	1,696.80	1,693.65
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	926.59	1,812.18	1,782.48	1,769.97
		2014-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	727.58	1,373.36	1,365.17
		2016-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	386.63	759.76
		2018-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	104.13
AE	Mangroves	...-1985	2,624.33	2,330.10	2,183.40	2,088.36	1,982.34	1,938.24	1,928.52	1,928.46	1,912.44	1,910.19
		1986-91	0.00	3,887.77	3,825.72	3,262.14	2,895.21	2,727.63	2,647.62	2,647.53	2,593.72	2,426.41
		1992-97	0.00	0.00	2,347.35	1,860.30	1,327.95	1,148.76	1,074.87	1,074.84	1,026.96	992.31
		1998-00	0.00	0.00	0.00	929.76	927.18	710.73	635.58	635.56	631.06	583.54
		2001-07	0.00	0.00	0.00	0.00	1,593.00	1,219.59	1,024.02	1,023.99	955.77	833.01
		2008-11	0.00	0.00	0.00	0.00	0.00	1,396.91	1,421.28	1,421.23	1,385.41	1,199.30
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	1,063.21	2,126.36	2,067.14	2,039.42
		2014-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	760.03	1,456.69	1,428.79
		2016-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	158.80	309.23
		2018-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.84
AE		...-1985	777.14	685.26	605.70	594.00	564.39	551.52	550.17	550.15	544.75	539.44

	New Forest		1986/87	1991/92	1997/98	2000/01	2007/08	2011/12	2013/14	2015/16	2017/18	2018/19
		Cohort	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
	Palm Forests	1986-91	0.00	7,677.75	7,294.59	4,767.93	4,074.39	3,752.73	3,609.72	3,609.60	3,501.79	3,461.74
		1992-97	0.00	0.00	4,594.65	3,974.31	2,640.33	2,248.02	2,123.01	2,122.94	2,072.81	2,017.01
		1998-00	0.00	0.00	0.00	3,919.32	4,336.83	3,492.36	3,350.25	3,350.14	3,341.05	3,279.40
		2001-07	0.00	0.00	0.00	0.00	3,563.61	3,094.11	2,730.78	2,730.69	2,694.51	2,324.35
		2008-11	0.00	0.00	0.00	0.00	0.00	3,232.24	3,551.76	3,551.64	3,420.70	2,842.92
		2012-13	0.00	0.00	0.00	0.00	0.00	0.00	4,210.70	8,421.12	8,118.10	6,776.24
		2014-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82.93	149.85	112.23
		2016-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	2.61
		2018-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	278.77
AE	Wet and Rain Forests		153,734.85	203,818.05	222,899.80	231,844.65	260,469.62	269,446.70	287,018.51	304,418.19	304,663.30	304,196.84
AE	Moist Forests		213,822.70	316,549.68	386,331.70	414,519.09	444,184.95	474,450.52	504,583.87	548,506.53	558,371.79	557,972.56
AE	Dry Forests		5,864.97	11,183.45	15,677.30	19,424.91	23,119.05	23,609.68	23,848.79	25,285.80	26,194.01	26,460.04
AE	Mangroves		2,624.33	6,217.87	8,356.47	8,140.56	8,725.68	9,141.86	9,795.10	11,617.99	12,187.99	11,760.05
AE	Palm Forests		777.14	8,363.01	12,494.94	13,255.56	15,179.55	16,370.98	20,126.39	24,419.22	23,844.86	21,634.71
AE	**Total**		**376,823.98**	**546,132.06**	**645,760.21**	**687,184.77**	**751,678.84**	**793,019.74**	**845,372.65**	**914,247.74**	**925,261.94**	**922,024.21**

AE = Areas with an enhancement of forest C stocks.

4.3.5.1 Activity Data Accuracy Assessment.

Uncertainties related to AD arise from how land use maps are produced. The discrepancies in AD for land use change activities, such as deforestation and regeneration, stem from the variations between the pixel count area based on supervised classification of remote sensing imagery and the bias-corrected area estimates derived from high-resolution optical data imagery.

The large number of different transition types, resulting from over 70 distinct land cover classes, along with the fact that most of the land use transitions identified over the time series involve relatively small areas, made determining bias-corrected areas using Olofsson et al.'s (2014) method not only challenging but also impractical. Out of 869 transitions identified, 485 have areas of change less than 100 hectares.

To handle this large number of land-use change transitions, they were grouped into four categories: deforestation (forest to non-forest), new forests (non-forest to forest), stable forest (forest remaining forest), and stable non-forest (non-forest to non-forest). This grouping allowed for calculating the bias-corrected area estimates using a simplified classification scheme. Table 10 below summarizes the aggregated transition categories, area based on pixel count, and number of reference data plots evaluated. We used a sample size of 649 reference points for 2001-2011 and more than 6,000 reference points in the following periods to calculate stratified area estimates. Due to the limited number of reference points for 2001-2011, we could not use more than four main transitions in the stratified area estimate for all the periods. Thus, bias-corrected areas have only been calculated for four aggregated transitions: Deforestation, New Forest, Stable Forest, and Stable non-forest land use.

Table 10: Aggregated transition categories, area based on pixel count, and number of reference data plots evaluated within that transition area.

Monitoring Period 2001-2011

Transition categories	Pixel count ha	Reference Data Plots	Number of transitions in the grouped category	Sampling Error (%)
DF - Deforestation	222,417	44	282	22%
AE.nf - Enhancement of forest carbon stocks on lands converted to forests	208,162	55	103	20%
CO - Conservation of forest carbon stocks + AE.ff - Enhancement of forest carbon stocks in forests remaining forests	2,848,954	318	55	4%
NA - Not Applicable (Non-Forest remaining Non-Forest)	1,718,880	232	161	6%
EXL - Excluded (no-information) + NL - Non-anthropogenic losses of forests	115,364	-	-	-
Total	**5,113,777**	**649**	**601**	

Monitoring Period 2014-2015

Transition categories	Pixel count ha	Reference Data Plots	Number of transitions in the grouped category	Sampling Error (%)
DF - Deforestation	29,231	52	68	23%
AE.nf - Enhancement of forest carbon stocks on lands converted to forests	33,025	36	18	28%
CO - Conservation of forest carbon stocks + AE.ff - Enhancement of forest carbon stocks in forests remaining forests	3,104,594	3326	40	1%
NA - Not Applicable (Non-Forest remaining Non-Forest)	1,831,463	2808	58	2%
EXL - Excluded (no-information) + NL - Non-anthropogenic losses of forests	115,460	-	7	-
Total	**5,113,773**	**6222**	**191**	

Monitoring Period 2016-2017

Transition categories	Pixel count ha	Reference Data Plots	Number of transitions in the grouped category	Sampling Error (%)
DF - Deforestation	17,024	34	85	28%
AE.nf - Enhancement of forest carbon stocks on lands converted to forests	7,686	14	13	44%
CO - Conservation of forest carbon stocks + AE.ff - Enhancement of forest carbon stocks in forests remaining forests	3,119,872	6773	45	1%
NA - Not Applicable (Non-Forest remaining Non-Forest)	1,853,107	3414	78	2%
EXL - Excluded (no-information) + NL - Non-anthropogenic losses of forests	116,084	-	16	-
	5,113,773	**10235**	**237**	

Monitoring Period 2018-2019

Transition categories	Pixel count ha	Reference Data Plots	Number of transitions in the grouped category	Sampling Error (%)
DF - Deforestation	10,774	27	45	32%
AE.nf - Enhancement of forest carbon stocks on lands converted to forests	4,174	9	20	55%
CO - Conservation of forest carbon stocks + AE.ff - Enhancement of forest carbon stocks in forests remaining forests	3,114,748	6794	50	1%
NA - Not Applicable (Non-Forest remaining Non-Forest)	1,866,680	3158	74	2%
EXL - Excluded (no-information) + NL - Non-anthropogenic losses of forests	117,397	-	37	-
	5,113,773	**9988**	**226**	

An accuracy assessment was conducted for all data collection intervals (2001-2011, 2014-2015, 2016-2017, and 2018-2019) except for 2012-2013. Due to cloud cover, high-resolution imagery covering the accounting area for 2012-2013 was infrequent, making reliable reference data for the period impossible. During 2012-2013, high-resolution sensors captured infrequent imagery over the country, with the northern region often covered in clouds. Achieving cloud-free image coverage necessitates frequent high-resolution sensor image capture.

It's important to note that using the same Landsat imagery for bias-corrected areas during 2012-2013 was not an adequate solution. Bias correction involves comparing algorithm-based supervised classifications of Landsat imagery with reference data, such as high-resolution imagery, that is more accurate or representative of the true ground's conditions.

Additionally, it's crucial to clarify that the land-use change maps for 2001-2011 and 2012-2013 are based on Landsat 7 ETM+, while the 2014-2015 land-use change map is based on the sensor Landsat 8 OLI/TIRS. Although both Landsat 7 and Landsat 8 are part of the Landsat program, they significantly differ in their imaging capabilities (see table below). Landsat 8 provides more accurate and detailed satellite imagery than Landsat 7. Considering these differences and the fact that the 2001-2011 and 2012-2013 analyses were based on Landsat 7, the same level of uncertainty is expected for these periods. Therefore, it was assumed that the same level of uncertainty applied to 2001-2011 and 2012-2013.

It is important to note that a stratified random sampling method was employed to estimate bias-corrected areas from 2001 to 2011. In 2015, Costa Rica put SIMOCUTE (Monitoring System for Land Use Change and Ecosystems) into operation. A formal methodology for SAE was created to maintain consistency in land-use change information across government agencies. After implementing SIMOCUTE, the REDD Secretariat utilized systematic sampling (SYS) to estimate bias-corrected areas, using a level 1 systematic grid of 10,325 points for reliable future monitoring periods.

Accuracy Assessment for 2001-2011. The accuracy assessment of the land-use change map 2001/02 – 2011/12 was done by applying Olofsson et al.'s (2014) methods. Due to the large number of land-use change transition types, these were aggregated into four categories for the accuracy assessment of Costa Rica's land use cover maps: Deforestation (forest to non-forest), new forests (non-forest to forest), stable forest (forest remaining forest), and stable non-forest (non-forest to non-forest). The validation of land-use changes during the period 2000/2001 -2010/2011 is based on the photointerpretation of orthophotography from 2005, Rapid eye imagery, and Landsat images since they have higher quality and spatial resolution than the maps and are independent of the sample of land-use data used to produce the maps. Finally, 649 reference data plots were randomly distributed into each four categories/strata: 318 in stable forest areas (areas classified as forest in 2000/2001 remaining forest in 2010/2011), 232 in the non-stable forest (areas classified as non-forest in 2000/2001 remaining non-forest in 2010/2011), 55 in afforestation/reforestation areas (areas classified as non-forest in 2000/2001 classified as forest in 2010/2011) and 44 in deforested areas (areas classified as forest in 2000/2001 classified as non-forest in 2010/2011)[2]. The accuracy assessment analysis is presented in the Excel file "CDI_CostaRicaREL_AnalisisExactitud_MCS2000-2001 vs MCS2010-2011"[52]. The activity data's uncertainty is the bias between the adjusted (reference data) and estimated (land use maps) areas.

Accuracy Assessment for 2014-2015, 2016-2017 and 2018-2019: The accuracy assessment conducted to estimate the uncertainty of the land-cover change maps MCS 2013/14 – MCS 2015/16[53], MCS 2015/16 – MCS 2017/18[54], and MCS 2017/18 – MCS 2019/20 was done following Olofsson et al.'s (2014) guidelines and relied on a comprehensive sample of reference data points. The following is a summary of the sampling design for the collection of reference data plots:
<u>Type of sampling</u>: Systematic sampling (SYS) over the level 1 systematic grid of 10,325 points of the Monitoring System of Land Use Change and Ecosystems (SIMOCUTE). The SIMOCUTE sampling units are permanent, facilitating reinterpretation through time and easy temporal tracking of LULUC.
<u>Sampling Unit (SU)</u>: The SU is a 1-ha square plot for 2014-2015 and 2016-2017 and a 2-ha square plot with a 5x5-point sub-grid (25 points within the sampling plot) for 2018-2019, This plot size allows for a better evaluation of land use if images of lower spatial resolution must be used, as in the case of images from the Planet or Sentinel platforms. A unique land-use dominance class is recorded at the SU level for t1 and t2. The change class is calculated using the dominance class at t1 and t2 at the SU level.
<u>Number of Sampling Units</u>: A total of 6,222 (2014-2015), 10,325 (2016-2017), and 9,988 (2018-2019) reference data plots with land-use information were assessed in the country's territory (excluding Cocos's Island).
<u>Classification scheme</u>: Due to the large number of land-use change transitions, they were aggregated into four categories: deforestation (forest to non-forest), new forests (non-forest to forest), stable forest (forest remaining forest), and stable non-forest (non-forest to non-forest).
<u>Data sources</u>: The reference data for validating land-use changes was collected from the visual interpretation of high-resolution images; during the visual interpretation, priority was given to the high-resolution images available on Google Earth. In the absence of images of less than 4 m resolution, the Planet images available in the NICFI Program were used, and in the second instance, Sentinel-2 or Landsat 8 within the priority dates.

[52] Accuracy Assessment 2001-2011 analysis can be accessed in the following link (CDI_CostaRicaREL_AnalisisExactitud_MCS2000-2001 vs MCS2010-2011.xlsm excel file): https://drive.google.com/file/d/1wUfwkW4E74Y-AZHCesr4coNIs0e_SabC/view?usp=sharing

[53] Reference data (Referencedata1415V3.csv) that was used to estimate the uncertainty of activity data for 2014-2015 and Final Report (II_Informe_Consultoria_EvaluacionMulti-temporalUsodelaTierra.pdf in Spanish) can be accessed at the following link: https://drive.google.com/drive/folders/1qpnJdH-_-0CJD9Eeena7uOQG9_wUtoOu?usp=sharing

[54] Reference data (ReferenceData2016-2018_Umbral30v2) that was used to estimate the uncertainty of activity data for 2016-2017 and Final Report (SegundoInforme_Junio_2019ver2.pdf in Spanish) can be accessed at the following link: https://drive.google.com/drive/folders/10BBeQsPb601Mx53dgh02OaA7GUhpZAQq?usp=sharing

Data analysis: The Stratified sampling tool for area estimation, developed by the FAO Open Foris project and available at https://github.com/openforis/accuracy-assessment, was used to calculate land-use change adjusted areas. The uncertainty of activity data is the bias between the pixel count area and the adjusted area.

The Table 11 summarizes the pixel count, area estimates, and their corresponding confidence intervals (CI) for the different periods where land-use change was monitored in Costa Rica ART-TREES submission. The overall accuracy of Costa Rica's land use cover maps was consistently high, ranging from 80% to 85%. The forest cover class consistently achieved an accuracy rate of over 80%. Also, the pixel count area for deforestation and regeneration generally falls within their confidence interval (CI) for most periods, except for a few selected years. The estimates for deforestation area fall within the bias-corrected area confidence interval (CI) in all periods except for 2014-2015. For the New Forest (reforestation), the area estimates fall within the confidence interval in all periods except for 2001-2011. Pixel count values for Stable Forest and Stable Non-Forest usually fall outside the confidence interval due to the low sampling error rate in these strata, which narrows the CI.

Table 11: Pixel count, bias-corrected area estimates, and corresponding confidence intervals (CI).

Monitoring Period 2001-2011 (Overall accuracy 85%)

Class	Pixel count ha	Adjusted Area (Ha)	Range (ha)	CI 90% (ha)	Does CI contain the estimated area?	Reference Data Plots	Number of transitions in the grouped category	Sampling Error (%)
Deforestación (Forest to Non-Forest)	222,417	280,602	63,086	217516-343688	Yes	44	282	22%
Bosques nuevos (Non-Forest to Forest)	208,162	314,796	64,028	250768-378824	No	55	103	20%
Bosque estable (Forest remaining Forest)	2,848,954	2,661,103	101,885	2559218-2762989	No	318	55	4%
No bosque estable (Non-Forest remaining Non-Forest)	1,718,880	1,741,912	99,201	1642710-1841113	Yes	232	161	6%
	4,998,413	4,998,413				649	601	

Monitoring Period 2014-2015 (Overall accuracy 80%)

Class	Pixel count ha	Adjusted Area (Ha)	Range (ha)	CI 90% (ha)	Does CI contain the estimated area?	Reference Data Plots	Number of transitions in the grouped category	Sampling Error (%)
Deforestación (Forest to Non-Forest)	29,231	40,976	9,359	31617-50335	No	52	68	23%
Bosques nuevos (Non-Forest to Forest)	33,025	28,121	7,738	20383-35859	Yes	36	18	28%
Bosque estable (Forest remaining Forest)	3,104,594	2,805,944	40,520	2765425-2846464	No	3326	40	1%
No bosque estable (Non-Forest remaining Non-Forest)	1,831,463	2,081,829	40,281	2041548-2122110	No	2808	58	2%
	4,998,313	4,956,871				6222	184	

Monitoring Period 2016-2017 (Overall accuracy 81%)

Class	Pixel count ha	Adjusted Area (Ha)	Range (ha)	CI 90% (ha)	Does CI contain the estimated area?	Reference Data Plots	Number of transitions in the grouped category	Sampling Error (%)
Deforestación (Forest to Non-Forest)	17,024	16,967	4,780	12186-21747	Yes	34	85	28%
Bosques nuevos (Non-Forest to Forest)	7,686	6,973	3,064	3909-10037	Yes	14	13	44%
Bosque estable (Forest remaining Forest)	3,119,872	3,383,974	30,579	3353395-3414554	No	6,773	45	1%
No bosque estable (Non-Forest remaining Non-Forest)	1,853,107	1,704,355	30,436	1673919-1734791	No	3,414	78	2%
	4,997,689	5,112,269				10,235	221	

Monitoring Period 2018-2019 (Overall accuracy 81%)

Class	Pixel count ha	Adjusted Area (Ha)	Range (ha)	CI 90% (ha)	Does CI contain the estimated area?	Reference Data Plots	Number of transitions in the grouped category	Sampling Error (%)
Deforestación (Forest to Non-Forest)	10,774	13,498	4,266	9232-17765	Yes	27	45	32%
Bosques nuevos (Non-Forest to Forest)	4,174	4,497	2,464	2033-6961	Yes	9	20	55%
Bosque estable (Forest remaining Forest)	3,114,748	3,401,058	30,075	3370982-3431133	No	6,794	50	1%
No bosque estable (Non-Forest remaining Non-Forest)	1,866,680	1,579,360	30,082	1549278-1609442	No	3,158	74	2%
	4,996,376	4,998,413				9,988	189	

Monitoring Period 2020-2021 (Overall accuracy 81%)

Class	Pixel count ha	Adjusted Area (Ha)	Range (ha)	CI 90% (ha)	Does CI contain the estimated area?	Reference Data Plots	Number of transitions in the grouped category	Sampling Error (%)
Deforestación (Forest to Non-Forest)	9,305	12,489	4,104	8385-16593	Yes	25	657	33%
Bosques nuevos (Non-Forest to Forest)	5,907	5,995	2,845	3149-8840	Yes	12	212	47%
Bosque estable (Forest remaining Forest)	3,107,332	3,211,314	30,256	3181058-3241570	No	6,427	225	1%
No bosque estable (Non-Forest remaining Non-Forest)	1,873,583	1,854,769	30,221	1824548-1884990	Yes	3,716	457	2%
	4,996,127	5,084,567				10,180	1,551	

4.3.6. Methods for estimating Degradation AD.

The forest degradation assessment was made on forest lands that remain as forest lands. The analysis of degradation was only performed on the area of forest remaining forest according to the land-use MCS 2012/13 map to avoid double-counting of baseline emissions between deforestation and forest degradation. This procedure avoided any measurements of degradation that were also accounted for under deforestation. Reference data to estimate Degradation AD were collected by Ortiz-Malavassi, (2017)[55].

A Systematic Sampling (SYS) over the Level 1 Systematic Grid of 10,242 points of the Monitoring system of land-use change and ecosystems (SIMOCUTE) was used. The original systematic grid is in the CRTM05 coordinate system of Costa Rica. However, it was re-projected to geographic coordinates in WGS84 to evaluate the sampling point with the Collect Earth Desktop tool. The SIMOCUTE sampling units are permanent, which facilitates reinterpretation through time and easy temporal tracking of LULC changes.

Sampling unit: The Sampling Unit (SU) is a 90x90 meter plot whose central point coincides with the SIMOCUTE sampling points. The SU corresponds to 3x3 Landsat pixels and covers 0.98 ha. Inside SU, a 7x7 points sub-grid was created to estimate land cover percentage within each sampling unit.

Number of sampling units: The forest degradation assessment was made on forest lands that remain as forest lands during 1998-2019. A total of 4377 points were classified as permanent forest land according to the MCS 2012/13 map. These points are an extract from the Systematic Grid adopted in SIMOCUTE.

Classification scheme: Three classes of canopy cover were considered to estimate degradation/enhancement in permanent forest land: i. Intact forest (85-100% forest cover), ii. Degraded forest (60-85% forest cover), and iii. Very degraded forest (<60% forest cover). The following forest cover change classes were assessed by forest type and type of carbon fluxes (anthropogenic and natural):

Degradation:

a. Intact to Degraded Forest
b. Intact to Very degraded forest
c. Degraded to Very degraded forest

Forest enhancement:

d. Very degraded to intact forest
e. Very degraded to degraded forest
f. Degraded to Intact Forest

No Condition changes

g. Stable intact forest
h. Stable degraded forest

Stable very degraded forest

[55] Ortiz-Malavassi, E. (2017). Evaluación Visual Multitemporal (EVM) del Uso de la tierra, Cambio en el Uso de la Tierra y Cobertura en Costa Rica Zonas A y B Tarea 1: Estimación del área de cambio de uso de la tierra durante el periodo 2014-2015. Accessible at https://drive.google.com/file/d/1GXdN43f-DNKelkM8y7gBLrKou-f7LI-G/view?usp=sharing

Imagery Sources: The range of dates of the images presented in the table below was used. Priority was given to operating with the ortho-rectified photographs of the TERRA 1997 project to evaluate the canopy cover in 1998. Still, since TERRA 1997 covered less than 40% of the national territory, the second priority was to use high-resolution images in Google Earth before 2006. If these did not exist, the next priority was to use the ortho-rectified photos of the project Carta-2005 available on the SNIT server. For the other years, the repository of high-resolution images available in Google Earth and Earth Engine was used as a data source, giving priority to images from the years to be evaluated (2011 to 2019). However, in case of absence, the use was recorded in the year closest to monitoring dates. Data sources and imagery date range used in the canopy cover evaluation are the following:

Monitoring Year	Imagery date range	Data sources
1998	January 1997 – December 2005	• Orthophotos TERRA 1997. • Google Earth imagery repository • Mission CARTA 2005
2011	July 2011 – June 2012	• Google Earth imagery repository
2016	July 2015 – June 2016	• Google Earth imagery repository
2019	July 2019 – June 2020	• Google Earth imagery repository

Interpretation Key: The land cover class keys used to determine canopy cover for the years 1998, 2011, and 2016 are the following:

Code	Land cover class
1100	Trees
1200	Shrubs
1300	Herbaceous
1400	Palm
1500	Bromeliads
1600	Greenhouse
1700	Other vegetation
2000	No vegetation
3000	Water
4000	Clouds and shadows
5000	Not classifiable

Data analysis: The country developed a tool for calculating emissions and removals on permanent forest lands (¨DegradationTool_without_Simulations_DB-Model_Fixed_1998-2019.xlsx¨ [56]). The database for the visual interpretation of canopy cover for the period 1998-2011, 2012-2016 and 2017-2019 are included in the sheet "Base_de_datos". The area of degraded and enhanced forest areas was extrapolated to the forest area in the entire country through proportional representation within the respective degradation classes (intact, degraded and very degraded) and forestry type. Degradation classes were determined based on the reduction of the forest canopy cover, by which intact forests have a cover of 85-100%, degraded forests have a cover of 60-85%, and very degraded forests a cover between 30% and 59%. Forest areas that went from intact to degraded, intact to very degraded, or degraded to very degraded (in terms of their canopy cover) during the assessment period (1998-2019) were classified as degraded. Forest areas that went from very degraded to degraded, very degraded to intact, or degraded to intact were identified as forest enhancement areas. Carbon fluxes were estimated for anthropogenic and natural conditions. Fluxes from sampling

[56] Degradation tool can be accessed in the following link: https://docs.google.com/spreadsheets/d/10LDT-50T8MAxfaGU3slyoqgsQmQLZAab?rtpof=true&usp=drive_fs

points inside protected areas and farther than 500 meters from a road[57] were considered natural fluxes and removed from reference level accounting. The estimation of the areas of change of degradation and canopy enhancement, for both anthropic and natural carbon fluxes, can be found in the sheet ¨Resumen_de_puntos¨ of the Degradation tool, for the reference period 1998-2011 and period 2012-2016.

4.4. Emission factors

4.4.1. Data sources for estimating EF

The emission factor for deforestation of primary forests is derived from data collected during Costa Rica's first National Forest Inventory (INF-CR for its acronym in Spanish) and models or average values of direct measurements reported in the literature. The 289 NFI plot location is shown in Figure 11. Plot distribution was based on fixed sample intensities by forest class. NFI plot locations were not biased by excluding disturbed forest areas or managed areas, if occurring. Therefore, this data represents all possible conditions and succession stages of *Forest land* at the national level.

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. Additional information was required as the FREL/FRL should be consistent with the National GHG inventory.
- The NFI and the national GHG inventory differ in their forest classifications. However, using the location of the 289 NFI plots, each plot was allocated to the five *Forest land* strata, allowing us to estimate the average C stocks per hectare per stratum.

A meta-analysis that involved the revision of 110 publications was carried out to collect additional C stock data[58]. All data collected were compiled in an Excel database (*cf.* BaseDeDatos_v5).

To consider a publication, the following criteria must have been met:

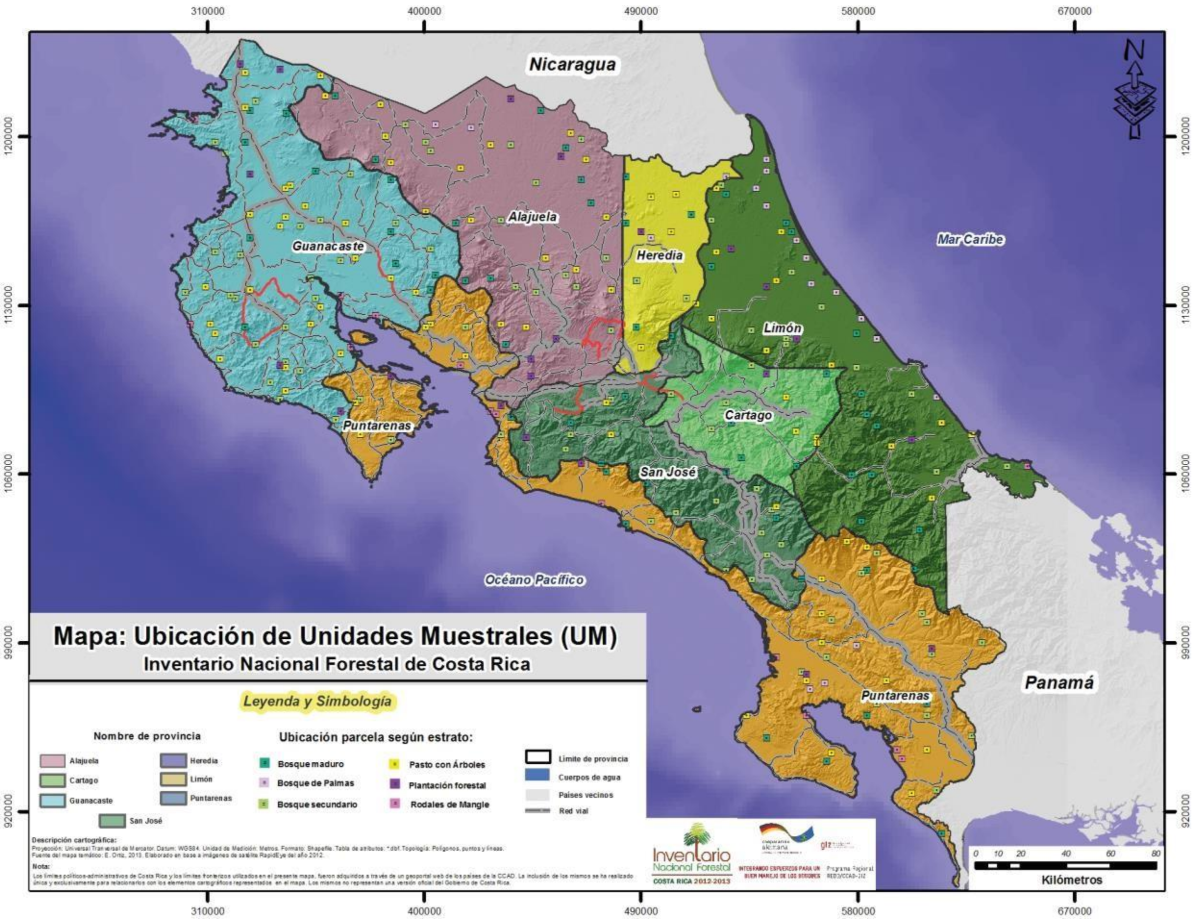
- The publication reported data from direct measurements carried out in Costa Rica.
- Measurements were carried out after the year 2005.
- Data were sufficiently disaggregated to obtain information on C stocks for relevant land use categories and C pools listed in the previous sections.
- The publications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

Figure 11. Plots of the National Forest Inventory measured 2014-15
(Source: REDD/CCAD-GIZ - SINAC. 2015) [59]

[57] The latest and highest-resolution official roads map for Costa Rica was used for this exercise, which was completed in 2007. It is accessible via the National System of Territorial Information (SNIT) website: http://www.snitcr.go.cr/Metadatos/full_metadata?k=Y2FwYW1ldGFkYXRvczo6Y2FwYTo6SUdOXzU6OnZpYXNfNTAwMA

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

[59] 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



4.4.2. Methods for estimating C stocks

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

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

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

Where:

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

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

Forest-related C stocks:

- **Above-ground tree biomass (AGB.t)**:
  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 the weighting criterion. For Mangroves and Palm Forests, a simple arithmetic mean was calculated.

  Secondary forests: C stocks in total *net*[60] above-ground biomass (TAGB) of Wet and Rain Forests, Moist Forests and Dry Forests were estimated using the equations developed by Cifuentes (2008)[61] for Costa Rican secondary forests based on direct measurements in 54 plots located in age classes between 0 and 82 years (see also Figure 6 to see the application of these equations per Life Zone). For Mangroves and Palm Forests, a linear function was assumed for estimating C stocks as a function of age. The following equations were applied:

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

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

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

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

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

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

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

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

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

  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)[62].

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

[61] 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.

[62] 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.

$$BGB.t = e^{-1.085+0.9256*LN(AGB.t)}$$ **(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.

- **Deadwood (DW)**:
  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 column DW.s in the sheet "CSTOCKS" of the FREL TOOL CR). As for AGB.t, the values were estimated as the area-weighted average of selected studies (except for Mangroves and Palm Forests, where the simple arithmetic mean was calculated).

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

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

C stocks in non-forest land uses:

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

- **Cropland**: C stock values reported in selected studies showed high variability, depending on crop type (sugar cane, coffee, banana, cocoa, etc.). For this reason, and area-weighted average C stock was calculated.

- **Grassland:** C stocks were estimated as the average values reported in different C pools in the selected studies.

- **Settlements and Wetlands:** No studies have been 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 were zero.

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

Table 10 presents the estimated average C stock values per C pool and land use category and their corresponding 90% confidence intervals. Note that only the estimated C stock values at selected ages are shown in the case of secondary forests. 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.

4.4.3 Emission Factors for forest degradation estimate.

Costa Rica has updated the forest reference level by recalculating the forest degradation emissions. Additional temporal sampling plots were measured following the methodology used in the NFI to determine aboveground biomass. The number of field observations increased in 100 temporary degradation plots covering all forest types (i.e., wet and rain forests, moist forests, dry forests, mangroves, and palm forests). These new data were integrated into aboveground biomass vs. canopy cover models to develop new degradation emission factors. Degradation categories in the aboveground biomass vs. canopy cover models were updated as follows: intact forests have a cover of 85-100%, degraded forests have a canopy cover of 60-85%, and very degraded forests of 30-59%. Forest areas that went from intact to degraded, intact to very degraded, or degraded to very degraded (in terms of their canopy cover) during the reference period were classified as degraded. In contrast, primary forest areas that went from very degraded to degraded, very degraded to intact, or degraded to intact were identified as forest enhancement areas.

For each forest type, a ratio was estimated of aboveground biomass (in t CO_2e) to percent canopy cover based on direct measurements in 100 permanent forest plots. These ratios were used to estimate degradation and forest regeneration in forests remaining forests.

As Sampling Unit, the Primary Sampling Unit (UMP) of the National Forest Inventory was used to generate complementary and comparable data of Aboveground biomass. The UMP has an area of 1000 m^2 on a rectangular plot of 20 x 50 meters.

Rodriguez (2018)[63] and Coto (2018)[64] selected the points to visit for the assembly of the 100 temporary plots distributed by categories of canopy cover and forest type, using as input the canopy cover assessment over level 1 systematic grid of SIMOCUTE, generated by Ortiz-Malavassi (2017). It was considering that the changes in the canopy cover, can be classified into four types of degradation: 1. Degradation at the edge of the forest, 2. Degradation by elimination of isolated trees, 3. Degradation by elimination of trees in forest blocks, and 4. Degradation by eliminating trees in protection zones; Rodriguez and Coto avoided selecting sample points at sites with degradation at forest edges (types 1 and 4). Likewise, it was requested that the location of the plot reflect the corresponding canopy cover category. The following classes were identified in the first plot distribution exercise without sufficient sampling points: Dry Forest 20-40%, Mangrove 20-49% and 50-80%, and Palm forest 20-49% and 50-80%. Rodriguez and Coto used the level 2 systematic grid of SIMOCUTE to complete the plots' sample in these categories.

In total, 100 temporary plots were measured. Fifteen sampling plots were installed in Palm forests, 36 in Wet and Rain forests, 15 in Moist forests, 19 in Dry forests, and 15 in Mangroves. In total, 4,340 trees greater than 10 cm DBH were measured. The distribution of the 100 plots, according to the type of forest and canopy cover, is as follows:

Forest Type	**Canopy cover class**			**Total of SU – forest type**
	20-49%	50-79%	80-99%	
Wet and Rain Forests	5	5	5	15
Moist Forests	12	14	10	36
Dry Forests	8	6	5	19

[63] Rodríguez, J. (2018). INFORME FINAL DE CONSULTORÍA Estudio de parcelas temporales para estimar el stock de carbono en bosques intactos, degradados y altamente degradados en zona A. (Contrato N°020-2018-REDD). Retrieved from https://drive.google.com/file/d/1dSyL8Dldwym5VN1jXpnAbmPovUW3AiTu/view?usp=sharing

[64] Coto, O. (2018). INFORME FINAL DE CONSULTORÍA. Estudio de parcelas temporales para estimar el stock de carbono en bosques intactos, degradados y altamente degradados en zona B. (Contrato N°019-2018-REDD). Retrieved from https://drive.google.com/file/d/1svYPJGEoBHpLn72sg4ejpf6uZkp6lllM/view?usp=sharing

Mangroves	5	5	5	15
Palm Forests	5	5	5	15
Total SU-canopy cover class	35	35	30	100

The biomass and carbon content were calculated with the equation of Chave et al. (2014) with the variables DBH, total height and Specific Gravity (GE) of each individual. An Excel sheet was prepared with the database and the estimated AGB/canopy cover ratio for forest type (Calculo_FE_041220.xlsx[65]). The AGB / canopy ratio was estimated, excluding outliers. Cook's Distance statistical approach (calculated in R) was used to identify the outliers. Two points out of the total number of observations were eliminated in BMHP and BS, whereas only one outlier was identified in BH, M, and P.

Forest type	**R_c - Ratio Aboveground biomass (t CO_2e ha^{-1})/ % canopy cover**
Wet and Rain Forests	4.94
Moist Forests	3.86
Dry Forests	3.00
Mangroves	3.19
Palm Forests	3.85

[65] Calculo_FE_041220.xlsx can be accessed in the following link: https://docs.google.com/spreadsheets/d/1-xcWSoDXYLIbMU8-iCE8CXE8eSSTBwCa?rtpof=true&usp=drive_fs

Table 12. Estimated average C stocks per hectare and related 90% confidence intervals.

					CO$_2$							Non-CO$_2$	
					Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (*L_{fire}*)	
					$C_{AGB.t}$	*$C_{AGB.n}$*	*$C_{BGB.t}$*	*$C_{BGB.n}$*	*C_{DW}*	*C_L*	*C_{tot}*	CH$_4$	N$_2$O
					tCO$_2$-e ha^{-1}	tCO$_2$-e ha^{-1}	tCO$_2$-e ha^{-1}	tCO$_2$-e ha^{-1}	tCO$_2$-e ha^{-1}	tCO$_2$-e ha^{-1}	tCO$_2$-e ha^{-1}	tCO$_2$-e ha^{-1}	tCO$_2$-e ha^{-1}
FL	Wet and Rain Forest	PF		**AVG**	**313.69**		**71.97**	**-**	**49.50**	**10.05**	**445.21**	**7.86**	**3.41**
				90%CI	250.16	-	57.39	-	40.75	9.11	405.22	3.05	1.32
					377.23	-	86.54	-	58.25	11.00	485.19	12.67	5.50
		SF	4 yr	**AVG**	**34.50**		**9.33**	**-**	**3.74**	**0.36**	**47.92**	**0.97**	**0.42**
				90%CI	31.59	-	8.54	-	3.43	0.27	44.89	0.48	0.21
					37.40	-	10.11	-	4.06	0.44	50.95	1.46	0.64
			15 yr	**AVG**	**117.13**		**28.92**	**-**	**12.71**	**1.21**	**159.96**	**3.30**	**1.43**
				90%CI	107.34	-	26.50	-	11.65	0.92	149.82	1.64	0.71
					126.92	-	31.33	-	13.77	1.50	170.11	4.97	2.16
			30 yr	**AVG**	**205.74**		**48.71**	**-**	**22.33**	**2.12**	**278.90**	**5.80**	**2.52**
				90%CI	188.72	-	44.68	-	20.48	1.62	261.30	2.88	1.25
					222.77	-	52.74	-	24.18	2.63	296.50	8.73	3.79
	Moist Forest	PF		**AVG**	**203.99**		**48.32**	**-**	**48.27**	**8.01**	**308.59**	**5.63**	**2.45**
				90%CI	161.13	-	38.41	-	25.02	6.96	278.85	2.14	0.93
					245.85	-	58.24	-	71.52	9.05	338.32	9.13	3.96
		SF	4 yr	**AVG**	**44.14**		**11.72**	**-**	**5.10**	**0.85**	**61.81**	**1.28**	**0.55**
				90%CI	40.80	-	10.83	-	2.67	0.72	57.58	0.63	0.27
					47.49	-	12.61	-	7.53	0.98	66.05	1.93	0.84
			15 yr	**AVG**	**138.15**		**33.69**	**-**	**15.96**	**2.67**	**190.47**	**4.00**	**1.74**
				90%CI	127.50	-	31.09	-	8.37	2.25	177.13	1.96	0.85
					148.79	-	36.28	-	23.56	3.08	203.81	6.04	2.62

			30 yr	**AVG**	**220.12**		**51.85**	**-**	**25.43**	**4.25**	**301.65**	**6.37**	**2.77**
				90%CI	202.84	-	47.78	-	13.32	3.58	280.15	3.12	1.35
					237.39	-	55.92	-	37.54	4.91	323.14	9.62	4.18

(Table 10 continued)

					CO_2							**Non-CO_2**	
					Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (L_{fire})	
					$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	CH_4	N_2O
					tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}
FL	Dry Forest	PF		**AVG**	**199.19**		**47.27**	**-**	**56.47**	**22.73**	**357.82**	**6.22**	**2.70**
				90%CI	-	-	-	-	34.54	22.12	329.16	2.49	1.08
					-	-	-	-	78.39	23.35	386.48	9.96	4.32
		SF	8 yr	**AVG**	**15.64**		**4.49**	**-**	**1.88**	**1.51**	**23.51**	**0.51**	**0.22**
				90%CI	14.40	-	4.13	-	1.34	1.38	22.10	0.25	0.11
					16.89	-	4.84	-	2.41	1.64	24.92	0.77	0.33
			15 yr	**AVG**	**79.50**		**20.20**	**-**	**9.54**	**7.68**	**116.92**	**2.60**	**1.13**
				90%CI	73.17	-	18.59	-	6.81	7.02	109.81	1.29	0.56
					85.83	-	21.81	-	12.26	8.33	124.03	3.91	1.70
			30 yr	**AVG**	**189.12**		**45.05**	**-**	**22.68**	**18.26**	**275.12**	**6.18**	**2.68**
				90%CI	174.07	-	41.47	-	16.19	16.71	258.27	3.06	1.33
					204.18	-	48.64	-	29.17	19.82	291.98	9.29	4.03
	Mangroves	PF		**AVG**	**253.74**		**59.14**	**-**	**6.95**	**0.97**	**320.80**		
				90%CI	221.91	-	51.72	-	4.90	0.73	300.89	-	-
					285.57	-	66.56	-	8.99	1.22	340.70	-	-

	SF	4 yr	**AVG**	**10.59**		**3.13**	**-**	**0.27**	**0.03**	**14.02**		
			90%CI	9.34	-	2.76	-	0.17	(0.00)	12.71	-	-
				11.84	-	3.50	-	0.37	0.06	15.32	-	-
		15 yr	**AVG**	**39.72**		**10.63**	**-**	**1.02**	**0.11**	**51.47**		
			90%CI	35.04	-	9.37	-	0.64	(0.00)	46.60	-	-
				44.40	-	11.88	-	1.39	0.21	56.33	-	-
		30 yr	**AVG**	**79.43**		**20.18**	**-**	**2.03**	**0.21**	**101.86**		
			90%CI	70.07	-	17.81	-	1.28	(0.00)	92.17	-	-
				88.80	-	22.56	-	2.78	0.43	111.56	-	-

(Table 10 continued)

					CO_2						**Non-CO_2**	
					Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (L_{fire})	
					$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	**CH_4**	**N_2O**
					tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}
FL	Palm Forests	PF		**AVG**	**229.81**		**53.96**	**-**	**5.97**	**0.96**	**290.69**		
				90%CI	204.77	-	48.08	-	(1.05)	(0.17)	274.48	-	-
					254.84	-	59.84	-	12.98	2.10	306.91	-	-
		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 10 continued)

		CO_2							**Non-CO_2**	
		Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (L_{fire})	
		$C_{AGB.t}$	$C_{AGB.n}$	$C_{BGB.t}$	$C_{BGB.n}$	C_{DW}	C_L	C_{tot}	**CH_4**	**N_2O**
		tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}
GL	**AVG**	**28.48**	**14.23**	**7.81**	**4.11**	**8.28**	**-**	**62.92**		
	90%CI	28.48	14.23	7.81	4.11	1.99	-	56.62	-	-
		28.48	14.23	7.81	4.11	14.58	-	69.21	-	-

SL			**AVG**	-	-	-	-	-	-	-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-
WL		Natural	**AVG**	-	-	-	-	-	-	-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-
		Artificial	**AVG**	-	-	-	-	-	-	-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-
OL		Paramo	**AVG**	-	**126.87**	**-**	**31.13**	**-**	**-**	**158.00**		
			90%CI	-	124.70	-	30.60	-	-	155.77	-	-
				-	129.03	-	31.67	-	-	160.23	-	-
	Bare Soil	Natural	**AVG**	-		-	-			-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-
		Artificial	**AVG**	-		-	-			-		
			90%CI	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-

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

4.4.3. Methodology for estimating EF

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

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

<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:

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

<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.

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[66] and 20[67] of the sheets “ER AAAA” (where “AAAA” stands for the year *t*) in the FREL TOOL CR.

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

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[66] 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.

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

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

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

Where:

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

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

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

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

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

Non-CO_2 emissions from biomass burning:

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

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

Where:

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

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

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

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

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

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

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

According to the National Meteorological Institute (IMN), biomass burning for converting forests to other land use categories was a common practice before the current Forest Lay in 1997, but disappeared thereafter. Emissions from biomass burning were thus assumed to be zero for 19982013.

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

4.4. Method used to estimate the FREL

The FREL was defined as the net annual average historical emissions. Annual emissions or absorptions were estimated for all land transitions i by REDD+ activity, and then adding the results for all selected REDD+ activities for each year:

$$\mathrm{RL_{RP}} = \frac{\sum_{t=1}^{RP} \mathrm{ER_{RA_t}}}{\mathrm{RP}} = \frac{\sum_{t=1}^{RP}\sum_{i=1}^{I}\left(\mathrm{AD_{RA_{i,t}}} * \mathrm{EF_{RA_{i,t}}}\right)}{\mathrm{RP}}$$

Equation 16

Where:

$\mathrm{ER_{RA_t}}$	=	Emissions or removals associated to REDD+ activity *RA* in year *t*; tCO_2-e yr^{-1}
$\mathrm{AD_{RA_{i,t}}}$	=	AD associated to REDD+ activity *RA* for the land use transition *i* in year *t*; ha yr^{-1}
$\mathrm{EF_{RA_{i,t}}}$	=	EF associated to REDD+ activity *RA* applicable to the land use transition *i* in year *t*; tCO_2-e ha^{-1}
RP	=	Reference Period in years
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

Deforestation and Reforestation Activity Data (**AD_D** and **AD_R**) are calculated differently from Degradation and Enhancement Activity Data (**AD_{Deg}** and **AD_E**). Deforestation and Reforestation ADs result from the cartographic comparison of land-use maps from the beginning and end of the monitoring period. The Degradation and Enhancement DAs result from the sample-based estimation of canopy change area in permanent forest lands. Below are the equations used to calculate these parameters:

Activity Data of Deforestation (AD_D)	$\boldsymbol{AD_{D_{i,t}} = \lvert D_{i,t}\rvert * 0.81}$, **Equation 16.1**	**Where $\lvert D_{i,t}\rvert$ is the count of pixels of the land-use transition *i* in year *t*, dimensionless; and 0.81 is the pixel size in Hectares (ha).**
Activity Data of Reforestation (AD_R)	$AD_{R_{i,t}} = \lvert R_{i,t}\rvert * 0.81$, **Equation 16.2**	Where $\lvert R_{i,t}\rvert$ is the count of pixels of the land-use transition *i* in year *t*, dimensionless; and 0.81 is the pixel size in Hectares (ha).
Forest remaining forests (AD_{F-F})	$AD_{F-F_{i,t}} = \lvert F-F_{i,t}\rvert * 0.81$, **Equation 16.3**	Where $\lvert F-F_{i,t}\rvert$ is the count of pixels of the land-use transition *i* in year *t*, dimensionless; and 0.81 is the pixel size in Hectares (ha).
Activity Data of Degradation (AD_{Deg})	$AD_{Deg_k} = \frac{\lvert Deg_k\rvert}{N} * AD_{F-F_t}$ **Equation 16.4**	Where $\lvert Deg_{i,t}\rvert$ is the count of sampling points where canopy change decrease (dimensionless) in forest type *k*, *N* is the total of sampling points (dimensionless), and AD_{F-F_t} is the total area of permanent forest (in hectares – ha) in the monitoring period.
Activity Data of Permanent Forest Regeneration (AD_E)	$AD_{E_k} = \frac{\lvert E_k\rvert}{N} * \sum_{i=1}^{I} AD_{F-F_{i,t}}$ **Equation 16.5**	Where $\lvert E_{k,}\rvert$ is the count of sampling points where canopy change increase (dimensionless) in forest type *k*, *N* is the total of sampling points (dimensionless), and AD_{F-F_t} is the total area of permanent forest (in hectares – ha) in the monitoring period.
Emissions & Removals from Deforestation $E_{D\&R(AAAA-AA)}$	$E_{D\&R(AAAA-AA)} = \sum_{k=1}^{I} AD_{D_{i,t}} * EF_{D_i} + \sum_{k=1}^{I} AD_{R_{i,t}} * EF_{R_i}$ **Equation 16.6**	Where *i* is a land-use transition represented in a cell of the land-use change matrix (dimensionless), EF_{D_i} is the deforestation emission factor for land-use transition *i*, EF_{R_i} is the removal factor for land-use transition *i* (when land-use transition *i* is forest loss,

		activity data and emission factor for forest recovery are cero and vice versa).
Emission & Removals from Degradation $E_{Deg(AAAA-AA)}$	$$E_{Deg(AAAA-AA)} = \sum_{i=1}^{I} AD_{Deg_k} * EF_{Deg_k} + \sum_{i=1}^{I} AD_{E_k} * EF_{E_k}$$ **Equation 16.7**	Where *k* is a forest type, EF_{Deg_k} is the degradation emission factor for forest type *k*, EF_{E_k} is the removal factor for forest type *k.*

4.5. Uncertainty of the FREL-FRL calculation.

4.5.1. Identified sources of uncertainty

The table below outlines and evaluates the main sources of uncertainty in qualitative terms, determining if their impact on the total uncertainty of the FREL-FRL is significant (High) or minimal (Low). This assessment pertains to the initial stage of the Monitoring Cycle. Additionally, the discussion of these primary uncertainty sources details the measures taken to mitigate them as part of the Monitoring Cycle.

Sources of uncertainty	Systematic and/or random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
Activity Data					
Measurement	Systematic and random	**Land-use change areas (deforestation, reforestation and forest remaining forest areas)**: A unique and uniform methodology was used both for FREL / FRL and for the forest emission estimate to avoid that changes registered in the cartographic comparison of LULC maps were affected by the combination of different techniques and methods. This error represents the operator error during preparation and interpretation of LULCC maps. This error is reduced by the following QAQC procedures (see table 2 and 6). Quality control was first conducted during the download and image preparation phase by reviewing storage errors that affect the reading of the data, analyzing the image's metadata, and visually previewing the original image. The scenes of the reference period were analyzed by conducting the following image orthorectification procedures: i. Using control points, verify that the average square error never exceeds the pixel size of the image, ii. Visually inspect the image to ensure that there has been no defect in the orthorectification process (i.e., duplicate areas, pixel deformation, or geometry errors caused by errors in the digital terrain model), and iii. Using a regularly distributed grid, take checkpoints in each scene and perform geometric control of rectified images. For the scenes of monitoring period, it was not necessary to rectify the Landsat8 images supplied by the USGS. These images have a 1T processing level (Terrain corrected), a systematic geometric correction using ground control points for image registration with a WGS84 map projection. These also include correction of relief changes A radiometric normalization was applied to reduce the differences between the time-series images. The cloud and shadow masks in all images were then checked by visually comparing them with the original image in RGB or false color. These masks were then validated in a sample of 18 images by visual verification of a systematic grid of checkpoints. Further quality control measures were taken through an iterative process of land use classification, verification of classification, error detection, and review of areas and training points. Errors from the Random Forest classifier were reviewed, classes and training points that needed to be improved were identified, and classifications were visually checked against high resolution images. The final maps were prepared after mosaiced images	Low	Yes	No

Sources of uncertainty	Systematic and/or random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
		were visually checked and information gaps and sensor failures on each of the dates in the series were identified. The final maps were subject to a quality assurance (QA) process that was provided by institutions of the country not used in the classification phase. These reviewers validated the final maps on three of the dates in the time series.			
Measurement	Systematic and random	**Permanent forest degradation and regeneration**: The same methodology was used to estimate degradation and regeneration in permanent forest lands. A Systematic Sampling (SYS) over the Level 1 Systematic Grid of 10,242 points of the Monitoring system of land-use change and ecosystems (SIMOCUTE) was used. The analysis of degradation was only performed on the area of forest remaining forest according to the land-use MCS 2017/18 map to avoid double-counting of baseline emissions between deforestation and forest degradation. This procedure avoided any measurements of degradation that were also accounted for under deforestation. In the assessment of degradation level in forests remaining forests, it was assumed that there was no uncertainty associated with the visual interpretation of sample areas because this procedure employed visual classification of canopy cover using high resolution imagery, as described above in tables 3 and 7. The following QA/QC procedures were applied during the interpretation of high-resolution imagery: i. **Consideration of spatial and temporal context**: The protocol includes a procedure for canopy cover change interpretation considering the spatial and temporal context (see section 1.6 in Aguilar, 2020). ii. **Reference order of the repositories of images**: The analyst gave priority to high-resolution images in Google Earth. In the second instance, on the Planet images available for the monitoring period. In case there are no high-resolution images for any sampling points, lower-resolution images available in the Collect Earth Desktop tool were used, as long as the monitoring period images are equal or better quality than the 2017 assessment. iii. **Data registry forms**: The canopy cover change information was recorded in standard Collect Earth Desktop forms (see section 1.7 in Aguilar, 2020). iv. **Training**: The supervisor trained the interpreters before starting the interpretation of plots to calibrate and leave clear procedures to collect the most accurate information possible. v. **Supervision of interpreters ("Hot Checks"):** The supervisor opened remote sessions between the coordinator and the interpreter (due to the Covid); to oversee the evaluation process without intervening. The coordinator presented the results in periodic sessions with all interpreters to improve the group of interpreters' criteria. The supervisor resolved the consultations of the interpreters online. vi. **Checking of interpretations by the supervisor, without interpreters' presence ("Cold Checks"):** The supervisor reviewed at least 5% of the parcels evaluated. The points that do not coincide were reviewed together by the supervisor and all the interpreters. vii. **Checking of interpreters' consistency ("Blind Checks"):** The analysts performed this procedure at the end of interpreting all the sampling plots. Each analyst evaluated at least 5% of the assessed plots by other interpreters, e.g., Interpreter 1 reviewed interpreters 2 and 3. The minimum level of consistency between evaluators was 90%. If not complying with the standard, the interpreter team should review the work until reaching the 90% threshold. viii. **Consistency between reference and monitoring period data**: The analyst reviewed the consistency of consecutive canopy cover data.. ix. **Treatment of plots with forest cover less than 30%:** The analyst made the degradation analysis over the systematic grid points	Low	Yes	No

Sources of uncertainty	Systematic and/or random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
		that falls on permanent forest lands during 1998-2011 in REDD time series maps. Thus, the 4,377 points of the original sampling implemented by Ortiz-Malavassi (2017) were re-visited in 2016, 2018, and 2020 evaluations. During the review of these points, some of them passed to non-forest conditions due to the loss of coverage and non-compliance with the minimum forest definition area (30% of canopy cover). Some of these points may have been declared deforestation or being part of the omission error in the land-use change's permanent forests for the periods 2012-13, 2014-15, 2016-17, 2018-19. Finally, uncertainty of changes in canopy cover to identify areas of degradation and forest enhancement from reference and monitoring periods vary depending on the forest type and the conversion class. It is based on the sampling error.			
Representativeness	Systematic	**Land-use change areas (deforestation, reforestation and forest remaining forest areas)**: Land-use change areas (deforestation, reforestation and forest remaining forest areas): To prepare the LULCC maps for reference and monitoring periods, four generations of LANDSAT satellites were used: Landsat 4 TM, Landsat 5 TM, Landsat 7 ETM +, Landsat 8 OLI / TIRS. Scenes were selected from June (Year 1) to June (Year 2) for the period under monitoring. Monitoring occurs every two years, and the territorial forest area covered includes the country's continental territory but excludes the Coco Island due to its exclusion from anthropogenic intervention. To ensure the representativeness of the LULCC maps, the Random Forest methodology is used for the reference and monitoring periods to train a forest classifier and then classify imagery. To train the forest classifier, regions of different land cover classes were digitized using (1) a systematic grid of 10,000 points from Rapideye images developed by SINAC, (2) high-resolution images from Rapideye, and (3) current and historical Google Earth images. This base data was then combined with 20 predictor variables to adjust the forest classifier models. To minimize the error (i.e. uncertainty) in these classifier models, the Random Forest R package generates an error and confusion matrix which allows for an initial quality control check based on a subset of checkpoints. To further minimize uncertainty, the random forest classifier was iteratively improved by analysts using the error and confusion matrix generated by the classifier, which identifies classes that need improved training data or predictor variables. Once the classifiers were trained, they were applied to all images to assess land use land cover for the given two-year period. The resulting land use land cover maps then underwent post processing to further reduce uncertainty in classification, through visual comparison of classified maps and high-resolution imagery, analysts performed manual edition of the time- series classification aimed at decreasing high classification errors. Analysts also performed visual verification of the country's main deforestation and reforestation areas to detect any classification errors to ensure an accurate assessment of land use-change. **Permanent forest degradation and regeneration**: High-resolution imagery used to estimate degradation and regeneration were selected from June to June for the year under monitoring.	Low	Yes	No
Sampling	Random	**Land-use change areas (deforestation, reforestation and forest remaining forest areas)**: Uncertainties associated to AD are due to the production process of land use maps. The uncertainties of the AD for land use change activities (deforestation and reforestation) and forest remaining forest activities (degradation and enhancements in forest lands) come from the uncertainties associated with the process creating land use change maps from which the activity data are obtained. The accuracy assessment of the land-use changes map MCS 2001/02, MCS 2011/12, MCS 2017/18, and MCS 2019/20 was done following Olofsson et al.'s (2014)[68] guidelines. Due	Low	Yes	Yes

[68] Olofsson et al. (2014) Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment 148, 42-57.

Sources of uncertainty	Systematic and/or random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
		to a large number of land-use change transitions, they were aggregated into four categories: Deforestation (forest to non-forest), new forests (non-forest to forest), stable forest (forest remaining forest), and stable non-forest (non-forest to non-forest). For further detail of the accuracy assessment for the reference and monitoring periods please see the uncertainty section in tables 3 and 6.			
	Random	**Permanent forest degradation and regeneration**: The same methodology was used to estimate degradation and regeneration in permanent forest lands for reference and monitoring period. A Systematic Sampling (SYS) over the Level 1 Systematic Grid of 10,242 points of the Monitoring system of land-use change and ecosystems (SIMOCUTE) was used. Uncertainty of changes in canopy cover to identify areas of degradation and forest enhancement for reference and monitoring vary depending on the forest type and the conversion class. It is based on the sampling error.	Low	No	No
Extrapolation	NA	This source of uncertainty is not applicable. Costa Rica generates estimates of deforestation, regeneration, and permanent forest lands per forest type, where the total annual areas are the sum of each forest type for a given year.	NA	NA	NA
Approach 3	NA	This source of uncertainty is not applicable. Activity data were estimated conducting tracking of lands or IPCC Approach 3 for reference and monitoring periods.	NA	NA	NA
Emission Factors					
DBH measurement H measurement Plot delineation	Systematic and Random	Extensive quality control procedures were implemented prior to the start of field work during estimation of AGB in the National Forest Inventory and Canopy cover and biomass relationship with additional temporal sampling plots. Field crews were organized by region. Each field crew was trained and provided with manuals to assist with identification, collection, transport, and processing of botanical samples. A terms of reference document was also provided which explained specific roles and responsibilities of each crew member. Finally, an Excel template was created to control the quality of data collection. Quality assurance measures were then taken as supervisors visited field sites to oversee the field crews and take photographic records of each field plot (please see tables 4 and 5). The quality of forest inventory data then underwent an evaluation by an independent crew that visits and remeasures 10% of the plots established in the NFI and 5% of the 100 additional plots. Thanks to these QA/QC procedures implemented before, during, and after the field campaigns the potential biases in the measurement of DBH, H, and plot delineation have been minimized. The random error associated with the measurement of these parameters has therefore been considered to be low, and thus this source of error will not be propagated.	Low	Yes	No
Wood density estimation	Systematic and Random	The wood density values were obtained directly from specialized publications (Biomass estimation tool developed by SINAC, IPCC 2003[69]; Myers 2013[70]; Tree Functional Attributes and Ecological Database, 2018[71]). High-skilled specialists conducted the tree identification following specific protocols to mitigate the error when the wood density value was assigned to each tree.	Low	Yes	No
Biomass allometric model	Systematic and Random	The biomass was calculated using Chave et al. (2005) for NFI inventory data, and Chave et al. (2014) for the 100 additional AGB plots. The propagation of error through MC simulation did not include this source of uncertainty due to the complexity of calculation, the lack of bias (given errors from	Low	No	No

[69] IPCC. 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Intergovernmental Panel on Climate Change (IPCC). Edited by Jim Penman, J.; Gytarsky, M.; Hiraishi, T.; Krug, T.; Kruger, D.; Pipatti, R.; Buendia, L.; Miwa, K.; Ngara, T.; Tanabe K.; Wagner, F. IPCC National Greenhouse Gas Inventories Programme. Published by the Institute for Global Environmental Strategies (IGES) for the IPCC. 583 p.
[70] Myers, R. 2013. Fenología y crecimiento de Raphia taedigera (Arecaceae) en humedales del noreste de Costa Rica. En:Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 61 (Suppl. 1): 35-45
[71] Tree Functional Attributes and Ecological Database. (2018). Wood Density. Recuperado el 10 de 12 de 2018, de http://db.worldagroforestry.org/.

Sources of uncertainty	Systematic and/or random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
		allometric equations are not systematic), and the agreement of experts in the fields and of standards (cf. ART) that it is reasonable to exclude this form of error (Winrock International, personal communication, 2021).			
Sampling	Random	Sampling error is the statistical variance of the estimate of aboveground biomass, dead wood or litter. This source of error is random and is considered to be high and it has been propagated. In Costa Rica, sampling error was identified for aboveground biomass values in primary forests in its National Forest Inventory. In secondary forests and in other carbon pools, sampling error of biomass values was estimated from scientific literature. Sampling error was also identified when estimating the ratio between canopy cover and aboveground biomass based on plot data.	High	No	Yes
Other parameters (e.g. Carbon Fraction, root-to-shoot ratios)	Systematic and Random	Below ground biomass (BGB) is derived directly from Cairns et al., (1997)[72]. The carbon fraction employed was PCC's default value (0.47). The propagation of error through MC simulation did not include either the uncertainty of the root-shoots rations or carbon fraction.	Low	No	No
Representativeness	NA	This source of uncertainty is not applicable. Costa Rica generates estimates of carbon stocks per forest type.	NA	NA	NA
Integration					
Model	Systematic	Manuals have been prepared for the correct use of FREL and Degradation tools[73], to avoid errors during the process of data preparation.	Low	Yes	No
Integration	Systematic	The Emission factors were calculated for each forest type according to AGB sampling plots' location to assure the comparability between transition classes of the Activity Data and those of the Emission Factors. This source of uncertainty is considered in the sampling error of the AGB inventory.	Low	No	No

4.5.2. Parameters and assumptions used in the Monte Carlo method

The country applied Monte Carlo methods (IPCC Approach 2) to quantify the uncertainty of the FREL-FRL. The sources of uncertainty propagated are provided in the Table below, including the parameters subject to the Monte Carlo simulation, the Probability Distribution Function (PDF) type, and the assumptions made.

Parameter included in the model	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Area (hectares) of deforestation	Difference between pixel count and bias-corrected area values.	Truncated normal	Minimum value assumed to be 0
Area (hectares) of forests remaining forests	Difference between pixel count and bias-corrected area values.	Truncated normal	Minimum value assumed to be 0
Area (hectares) of new forests	Difference between pixel count and bias-corrected area values.	Truncated normal	Minimum value assumed to be 0
Change in percent canopy cover in degraded and regenerated forests	Sampling error	Truncated normal	Minimum value assumed to be 0

[72] Cairns M.A., Brown S., Helmer E.H., and Baumgardner G.A. (1997). Root biomass allocation in the world's upland forests. Oecologia 111:1-11.
[73] The manual of FREL Tool can be accessed in the following link: https://drive.google.com/file/d/1INuL5Jld7nlKVsAf7mRsEepm2n8WRVpT/view?usp=sharing

Parameter included in the model	**Error sources quantified in the model (e.g. measurement error, model error, etc.)**	**Probability distribution function**	**Assumptions**
Aboveground biomass for very moist and rain forests – primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for moist forests - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for dry forests – primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for mangroves – primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for palm forest - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for secondary forests	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for annual cropland	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for permanent cropland	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for paramos	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for very moist and rain forests – primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for moist forests - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for dry forests – primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for mangroves - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for secondary forests	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for annual cropland	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for permanent cropland	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for paramos	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for very moist and rain forests – primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for moist forests - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for dry forests – primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for mangroves - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for palm forest - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for secondary forests	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for grassland	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for very moist and rain forests – primary	Sampling error	Truncated normal	Minimum value assumed to be 0

Parameter included in the model	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Litter for moist forests - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for dry forests – primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for mangroves - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for palm forest - primary	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for secondary forests	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for permanent cropland	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in very moist and rain forests	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in moist forests	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in dry forests	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in mangroves	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in palm forests	Sampling error	Truncated normal	Minimum value assumed to be 0

4.5.3. Quantification of the uncertainty of the FREL-FRL

The country estimated the aggregated uncertainty of the FREL-FRL to be 101% (592,127 ± 598,048 $tCO2e*yr^{-1}$), based on a Monte Carlo analysis involving 10,000 iterations of emissions during the reference period[74] (see below table). It's essential to understand that the impact of error sources on the overall uncertainty of the FREL-FRL does not directly lead to emission reductions. Since emission factors remain constant during the establishment of the FREL and the tracking of greenhouse gases (GHGs), emission reductions can be calculated as the difference in activity data between the reference period and the monitoring period multiplied by the emission factor. Furthermore, the extent of the aggregated uncertainty's relative margin primarily stems from the low FREL-FRL, as each component of the FREL—deforestation, degradation, and carbon enhancement—has relative margins below 26%.

		FREL-FRL	Deforestation	Degradation	C-stock enhancement Permanent Forest	C-stock enhancement Secondary Forest
A	**Median**	-666,904	1,484,351	2,537,515	-543,777	-5,451,942
B	**Upper bound 90% CI** (Percentile 0.95)	55,072	1,555,011	3,239,089	-480,556	-5,344,903
C	**Lower bound 90% CI** (Percentile 0.05)	-1,286,579	1,412,168	1,943,581	-608,171	-5,560,697
D	**Half Width Confidence Interval at 90% (B – C / 2)**	670,825	71,422	647,754	63,807	107,897
E	**Relative margin (D / A)**	-101%	5%	26%	-12%	-2%

[74] MC propagation analyses to estimate the uncertainty of FREL-FRL can be found in the following link: https://www.dropbox.com/scl/fi/579lb3fqdycma20fiy3hd/FREL-FRL_2010-2019_CR.xlsx?rlkey=9bezlc8yovdg88aeqp6looepz&dl=0

5. Planned improvements

The country will evaluate the following elements to improve its estimate of forest emissions:

- Re-estimate Activity Data using a sample-based approach for the time series.
- Differentiate between forest plantations and secondary forests, ensuring traceability of harvested plantation areas.
- Estimate removals through new growth models in Palm Forests and Mangroves.
- Estimate Soil Organic Carbon emissions.

It is important to note that the country has established a sample-based time series of Activity Data with assistance from the World Bank. This calculation of sample-based Activity Data was necessary because distinguishing natural secondary forests from forest plantations using pixel-count techniques is challenging. Furthermore, this new estimate of Activity Data has enabled the incorporation of data from both the agriculture and forest sectors. This integration is crucial for the successful implementation of a cohesive Measurement, Reporting, and Verification (MRV) system for the Agriculture, Forestry, and Other Land Use (AFOLU) sector. You can find the relevant files regarding this work at the link below: https://fonafifo-my.sharepoint.com/:f:/g/personal/redd_fonafifo_go_cr/EqPBhdxoIy1AhTlwhNqpSkUBbjrnzMW43_nL0ZHSwBT3Hw?e=1lEmk3

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Rodríguez, J. (2018). INFORME FINAL DE CONSULTORÍA Estudio de parcelas temporales para estimar el stock de carbono en bosques intactos, degradados y altamente degradados en zona A. (Contrato N°020-2018-REDD). Available at https://drive.google.com/file/d/1dSyL8Dldwym5VN1jXpnAbmPovUW3AiTu/view?usp=sharing

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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.

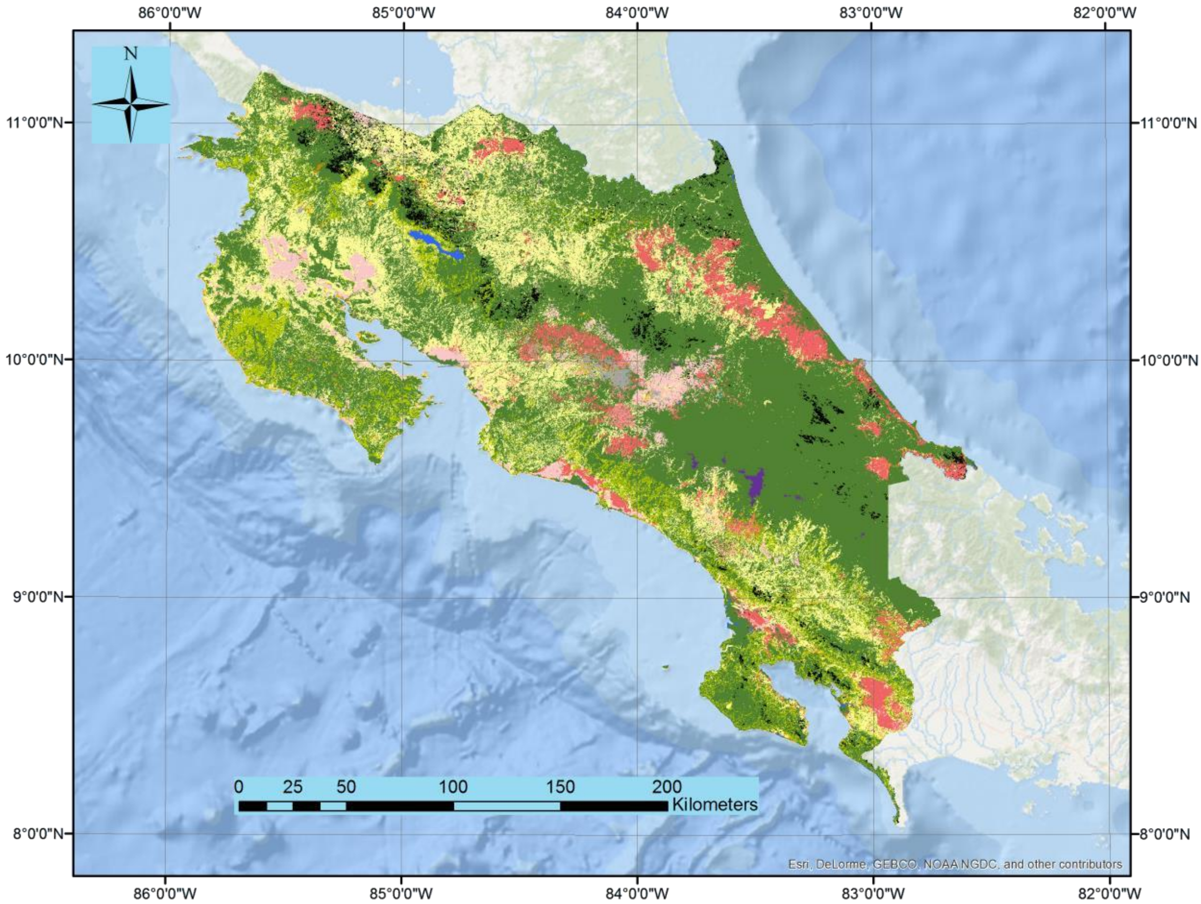
(b) If the central image was acquired between January 1st and June 30th, it was assumed that the land use map represents the land uses existing in Costa Rica on January 1st of the image acquisition date and on December 31st of the previous year.

(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 subcategories “Wet and rain Forests”, “Moist Forests”, “Dry Forests”, “Mangroves” and “Palm Forests”.

Land Use Map
1985/86

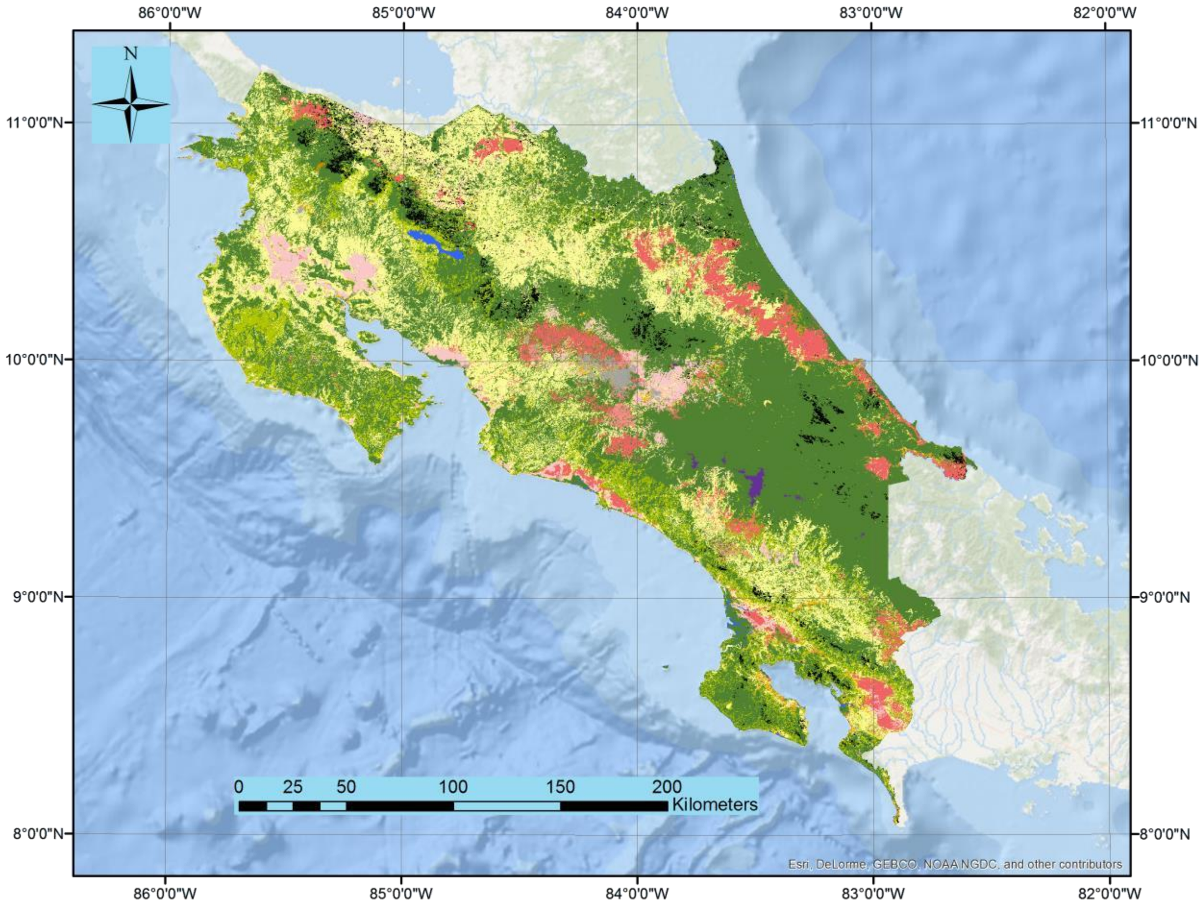


Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,807,028.90
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	380,685.24
	CROPLAND – permanent	336,664.35
	CROPLAND – annual	197,797.23
	GRASSLAND	1,190,245.23
	SETTLEMENTS	22,876.92
	WETLANDS – natural	12,993.03
	WETLADNS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

Land Use Map

	Total area	**5,113,939.50**

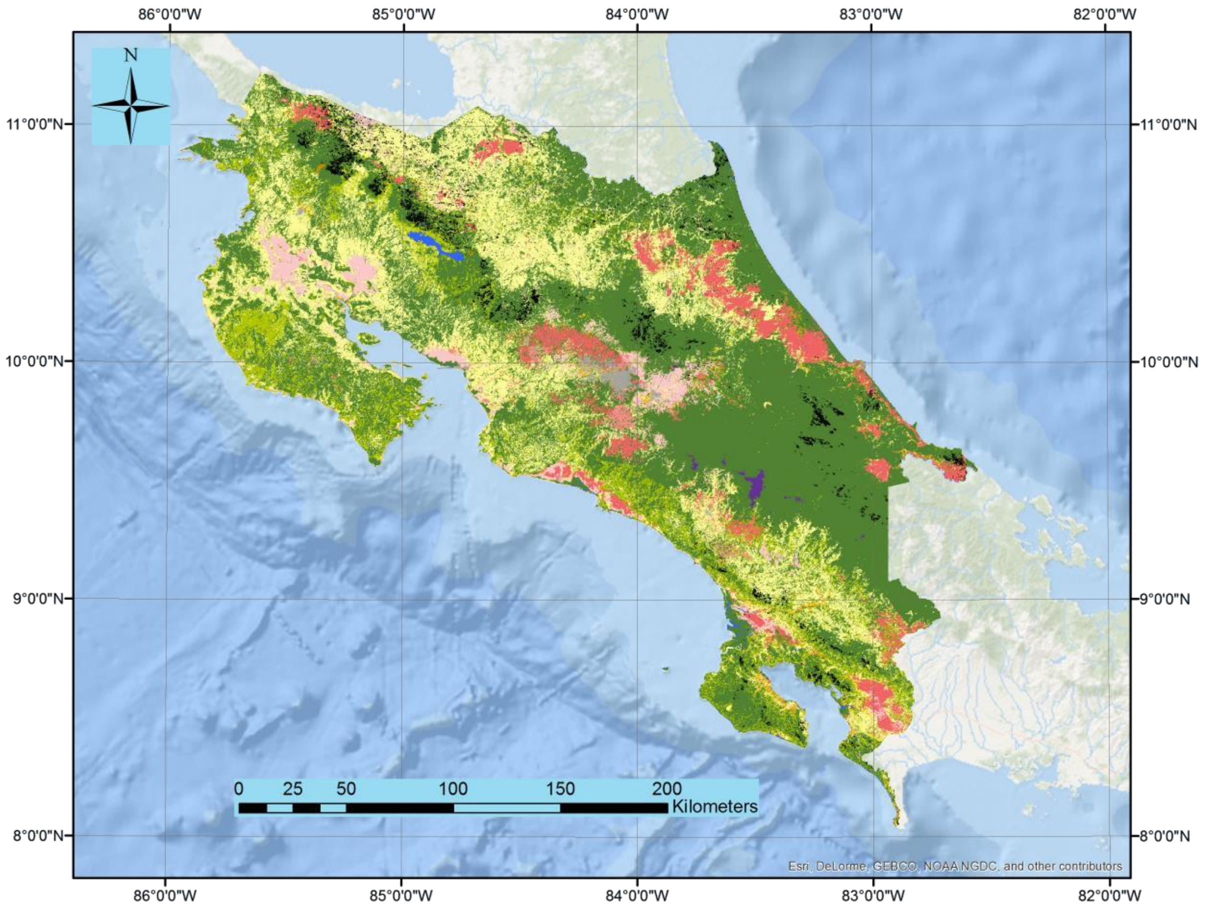
Land Use Map 1991/92



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**

1997-98

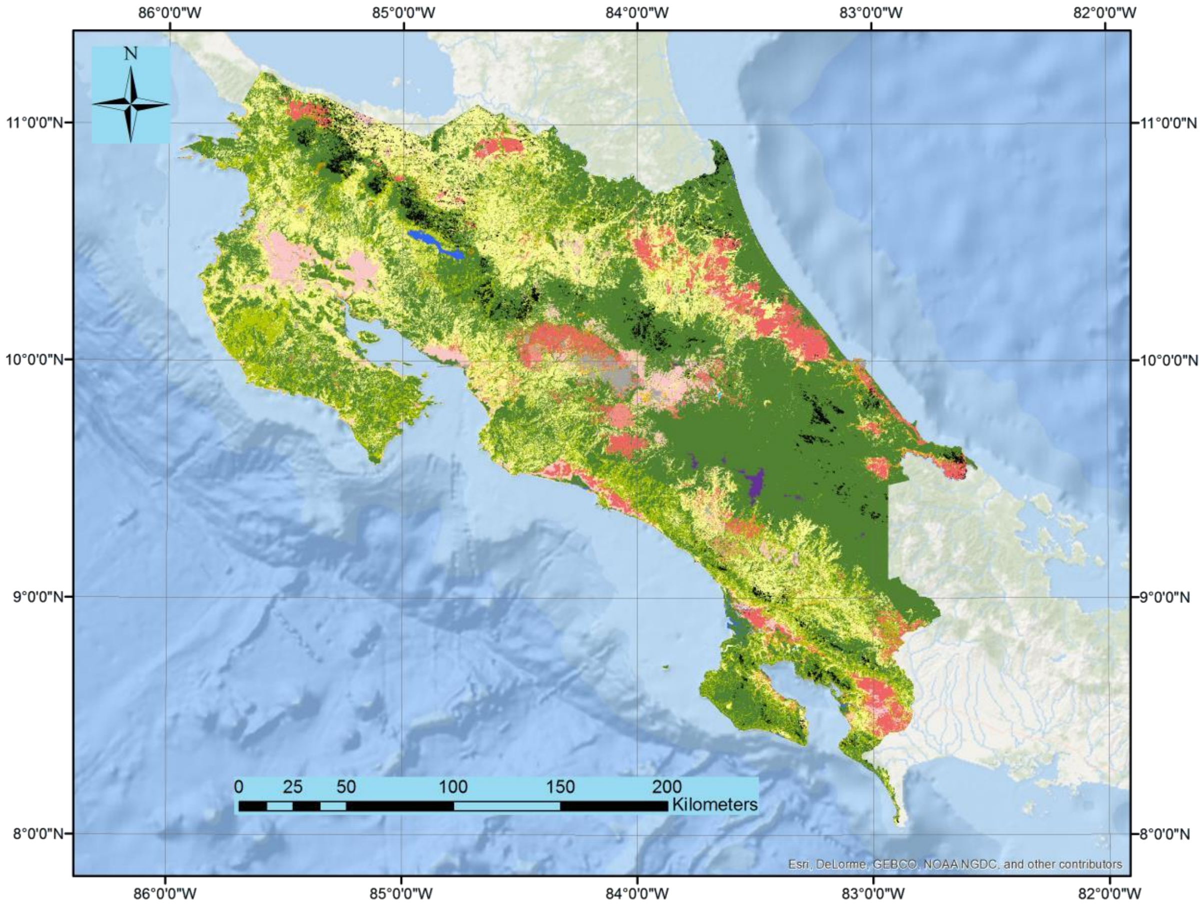


Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,420,974.53
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	670,106.25
	CROPLAND – permanent	345,113.28
	CROPLAND – annual	211,800.60
	GRASSLAND	

Land Use Map

	SETTLEMENTS	1,239,510.42
	WETLANDS – natural	35,203.86
	WETLADNS – artificial	17,126.55
	OTHER LAND – Paramo	190.08
	OTHER LAND – Bare Soil - natural	10,416.96
	OTHER LAND –Bare Soil- artificial	2,009.43
	WITHOUT INFORMATION – clouds and shadows	46,123.38
		115,364.16
	Total area	**5,113,939.50**

Land Use Map
2000/01

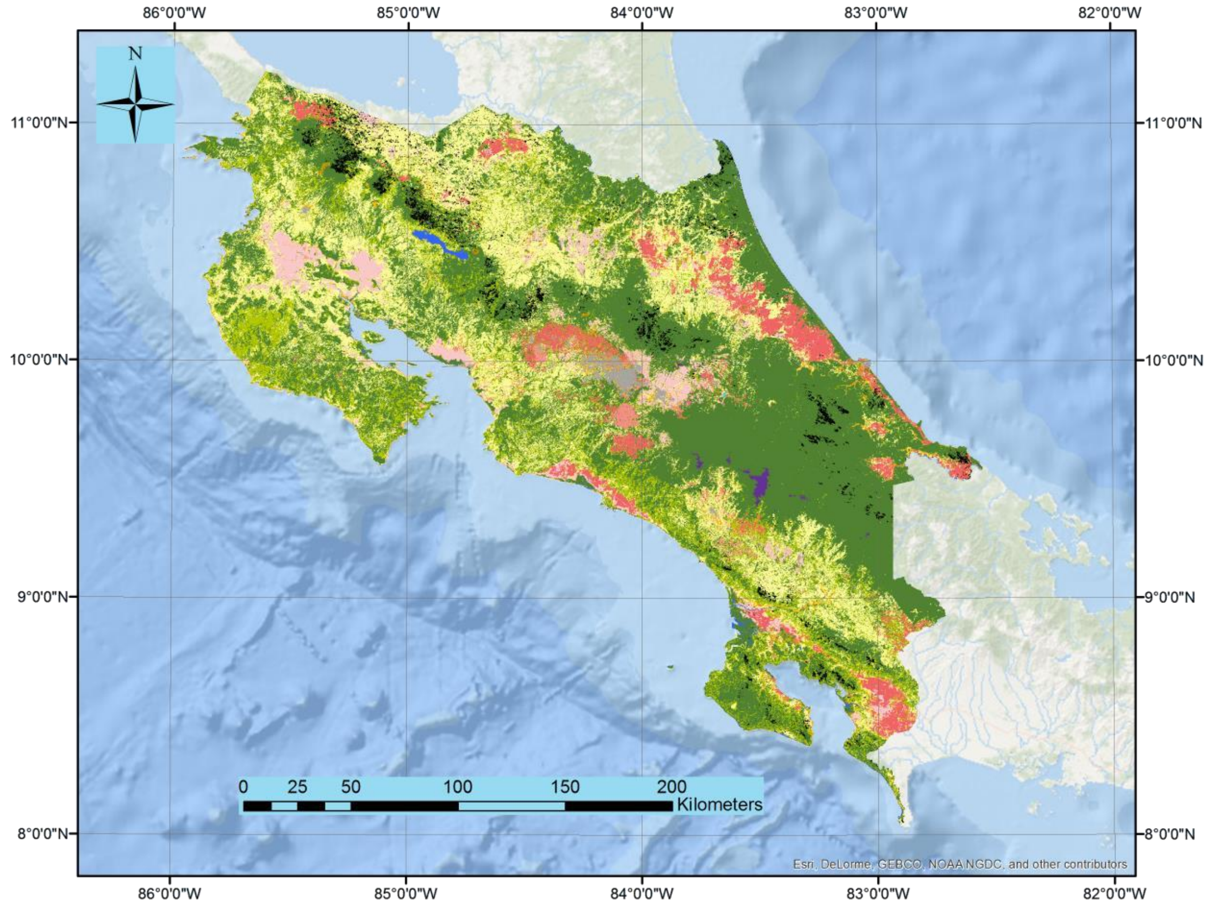


Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,335,604.94
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	735,865.83
	CROPLAND – permanent	351,353.43
	CROPLAND – annual	218,656.71
	GRASSLAND	1,242,871.56
	SETTLEMENTS	38,819.97
	WETLANDS – natural	18,742.95
	WETLADNS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

Land Use Map

	WITHOUT INFORMATION – clouds and shadows	115,364.16
	Total area	**5,113,939.50**

2007/08

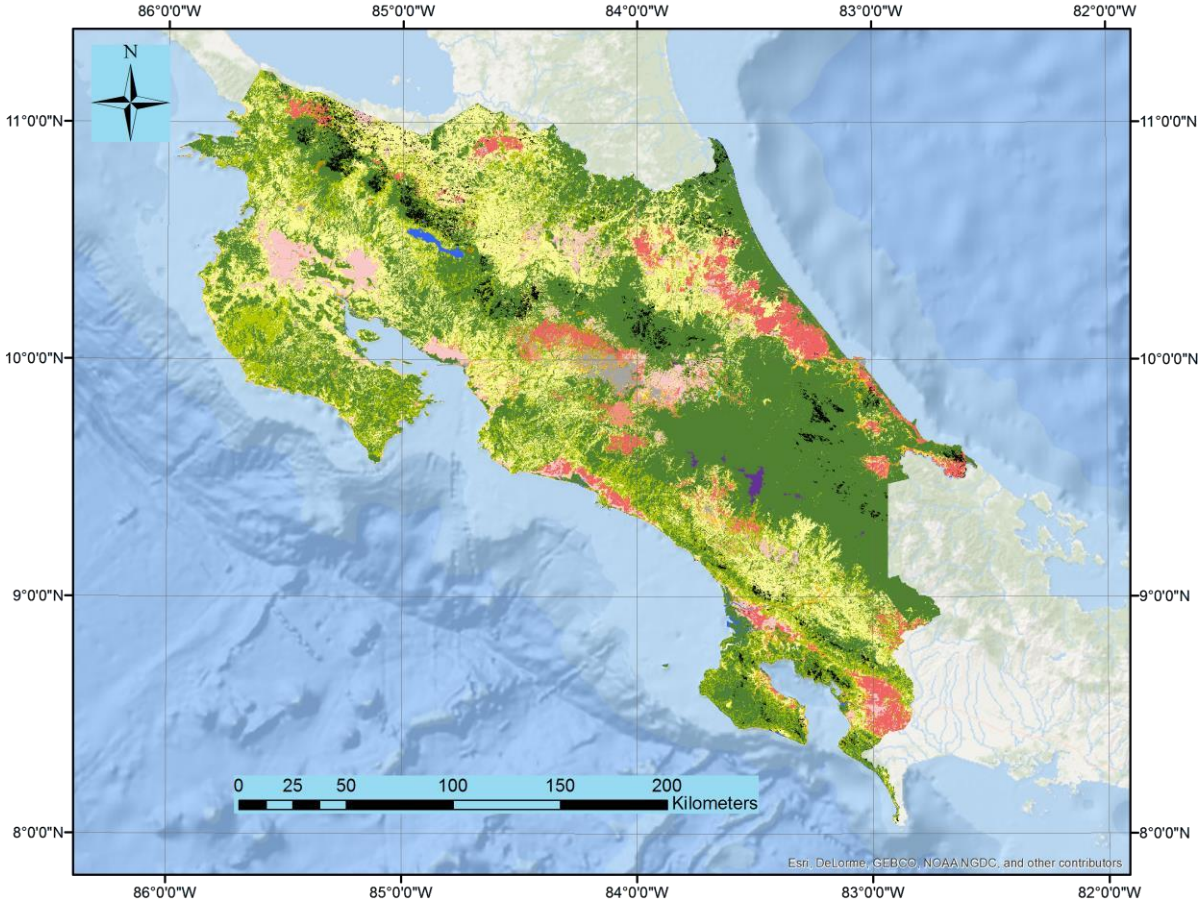


	Land use category	**Area**
Color	Description	ha
	FORESTLAND–primary forest	2,265,429.96
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	770,395.05
	CROPLAND – permanent	323,930.52
	CROPLAND – annual	242,276.76
	GRASSLAND	1,260,219.24
	SETTLEMENTS	43,086.69
	WETLANDS – natural	21,875.85

Land Use

	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**

Map2011/12

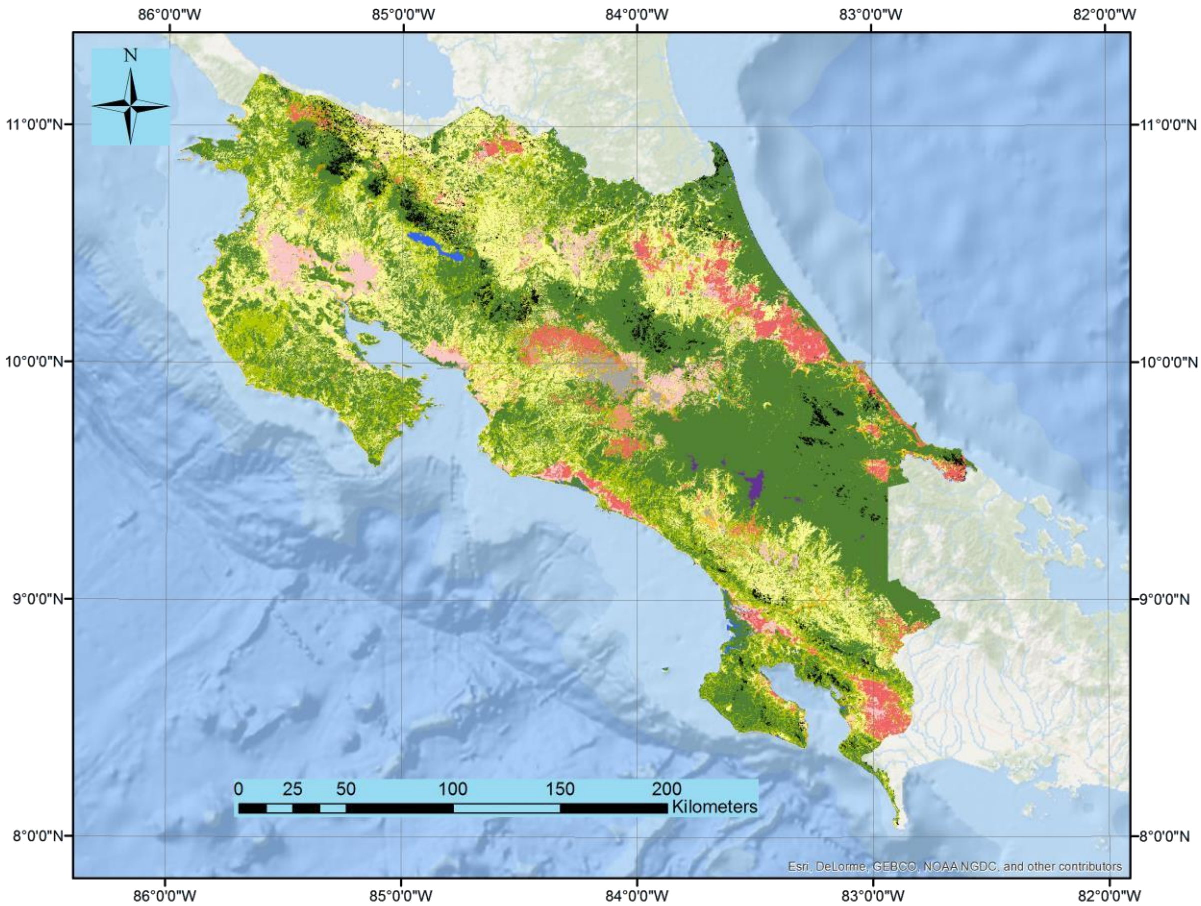


Land use category		Area
Color	Description	ha
	FORESTLAND–primary forest	2,233,118.88
	FOREST LAND / LAND CONVERTED TO FOREST LAND – new forest	824,096.61
	CROPLAND – permanent	311,794.20

Land Use Map

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**

2013/14



Land use category	Area

Land Use

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

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

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

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