Forest Carbon Partnership Facility (FCPF)
Carbon Fund

ER Monitoring Report (ER-MR)

ER Program Name and Country:	Costa Rica
Reporting Period covered in this report:	January 1, 2018 – December 31, 2019
Number of FCPF ERs:	8,305,141 t CO_2e
Quantity of ERs allocated to the Uncertainty Buffer:	1,258,355 t CO_2e
Quantity of ERs to allocated to the Reversal Buffer:	922,793 t CO_2e
Quantity of ERs to allocated to the Reversal Pooled Reversal buffer:	2,181,148 t CO_2e
Date of Submission:	14 May 2021

Notice

This ER Monitoring Report is made public for validation and verification purposes. Annex 1, 2, and 3 are not included in this version since they are being completed by the Program Entity. The full Report will be made available as soon as Annex 1, 2, and 3 are completed and the validation/verification are concluded as outlined in the FCPF Process Guidelines.

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1 IMPLEMENTATION AND OPERATION OF THE ER PROGRAM DURING THE REPORTING PERIOD

1.1 Implementation status of the ER Program and changes compared to the ER-PD

Progress on the actions and interventions under the ER Program: This section refers to FONAFIFO and SINAC's REDD+ actions implemented during the 2018-2019 period[1].

Promote the generation and implementation of campaigns to prevent forest fires (REDD+ Strategy action 2.1.1): During 2018 -2019, SINAC implemented a yearly campaign of forest fire management at national, regional, and local levels and engaging the relevant actors such as brigades, private companies, local organizations, NGOs, and civil society. These campaigns focused on promoting the Guanacaste area, one of the most vulnerable regions to forest fires. The campaigns included a communication plan, negotiations with private companies, educational activities for students, informational events for the communities, and agricultural and livestock producers.

Monitoring and promotion of volunteer forest firefighters' brigades (REDD+ Strategy Action 2.1.2): SINAC managed who participated in the units. Men and women forest firefighters came from official institutions, private companies, non-governmental organizations, and civilians are part of the brigades. SINAC provided adequate training to the men and women firefighters (both officials and volunteers). In 2019 the "First National Encounter of women Forest Firefighters assigned to the National System of Conservation Areas" was held. During this event, the REDD+ Secretary identified the main gender gaps in the forest fire brigades initiative and placed them in the Gender action plan.

Strengthening the Forest Fire Control Program (REDD+ Strategy Action 2.1.3): The strengthening of the National Fire Management Strategy 2012-2021 included the planning, formulation, follow-up, monitoring, and accountability related to the integral management of fire, within governmental institutions, non-governmental organizations, local governments, private companies, and civil society. SINAC also developed and implemented the Early Warning System for Forest Fires (its acronym in Spanish is SATIF), which evaluates the different elements that affect the probable occurrence and potential fire behavior nationwide. Within the National Fire Management Program, given the possibility of the El Niño phenomenon in 2019, the SINAC Fire Prevention and Control Department, through the National Technical Committee for Forest Fires, prepared in 2018 a Contingency Plan for Attention to Forest Fires.

Strengthening the Illegal Logging Control Program (REDD+ Strategy Action 2.2.1): SINAC implemented law enforcement actions to prevent illegal logging and the land-use change in forest lands. SINAC controlled the illicit use of forest resources, such as illegal logging activities in protected areas and the supervision of sustainable forest management activities. SINAC implemented two systems to grant forest use permits in private lands. These permits are processed online. They are a. System of Management Plans (its acronym in Spanish is SIPLAMA) for wood harvest in forest lands and b. Information System for the Control of Forest Use (its acronym in Spanish is SICAF) for logging permits in pasture and agricultural lands. Both systems required a series of improvements and adjustments. The SICAF system is now linked with the Forest Resources Information System (its acronym in Spanish is SIREFOR), allowing authorized permits' tracking from forest to primary industry.

2.2.2. Reactivation of natural resource surveillance committees (its acronym in Spanish is COVIRENAS): SINAC engaged different actors at the national level to promote participation in protecting and safeguarding natural resources. It is a mechanism that allows state institutions responsible for ensuring these resources to establish surveillance actions together with communities in compliance with the national legal framework. During 2019, SINAC held a series of training workshops to reactivate COVIRENAS, aimed at local

[1] Costa Rica's proposal to the FCPF Carbon Fund is based on a subset of policy actions that were derived from multi-stakeholder participatory formulation processes of the National REDD+ Strategy and the information and pre-consultation phases of the SESA. The ERP includes only four of the measures proposed in the National REDD+ Strategy.

actors interested in their formation, and training in the use of integrated environmental reporting process systems (its acronym in Spanish is SITADA), among others.

2.3.1 Administration and management of Protected Areas (PA): SINAC is responsible for designing, updating, monitoring, evaluating, and systematizing policies, plans, programs, projects, procedures, and manuals of a national application for their accomplishment in the terrestrial and marine Protected Areas. Robust strategies were in place for the management of Protected Areas, such as Natural Resource Management Plans, Sustainable Tourism Plans, a guide to the design and formulate the General Management Plan in Protected Wild Areas. Also, SINAC developed instruments to assess Protected Wild Areas' management effectiveness. With the instrument's application, you get the PA and Conservation Areas (its acronym in Spanish is AC) monitoring reports and their improvement plans. Also, in 2019 SINAC created a System of Land Tenure Management in Natural State Heritage Lands with REDD+ readiness resources.

3.1.2. Expansion and improvement of financial mechanisms to promote natural regeneration. FONAFIO implemented actions to promote natural regeneration through the Program of Payment for Environmental Services (PPES). FONAFIFO included the financial mechanisms to promote natural regeneration in the procedure manual of the PPES. During 2018 and 2019, FONAFIFO reformed the PPES procedure manual to make possible joint work with private and public sectors. The main changes included in the PPES procedures are a. Update of changes in legislation, b. Implementation of a new digital platform, c. Improvement of public access to information, d. Adding of new PES sub-activities (e.g., mixed systems).

Update on the strategy to mitigate and/or minimize potential Displacement: The risk of displacement is still considered minimal in Costa Rica, as the ER Program's implementation area covers the national territory. Policies, actions, and measures of the REDD+ National Strategy continued to focus on strengthening incentives and policies without corrective measures. Also, the benefit-sharing plan increases and expands stakeholders' opportunity to receive benefits from REDD+ activities and thus eliminate risks to curb deforestation and forest degradation. FONAFIFO continued promoting forest protection; it had a significant boost to increase coverage in 2018 and 2019. A FONAFIFO´s Board agreement raised PES funds for forest protection.

During the monitoring period, most indigenous peoples participated through information, pre-consultation, and consultation mechanisms. The government promoted indigenous peoples' participation and developed with their endorsement a consultation process that consisted of three phases: information, pre-consultation, and consultation, and that respects Free Prior and Informed Consent. The country has also developed a General Consultation Mechanism that must be considered in the participation processes of these populations for activities that impact indigenous territories.

The Government issued the decree for the implementation of REDD+ in Costa Rica in 2017. During the monitoring period, REDD governance operated satisfactorily. REDD+ Secretariat implemented the Steering Committee, made up of the executive directorates of SINAC and FONAFIFO and the Vice Ministry of Environment of MINAE. Also, the Monitoring Committee was established with broad citizen participation, and the Government reconfirmed the REDD+ Secretariat with the participation of SINAC and FONAFIFO.

Effectiveness of the organizational arrangements and involvement of partner agencies: SIMOCUTE (National Monitoring System for Land Use, Land Use Cover, and Ecosystems) is the official platform for coordination, linkage, and institutional and sectoral integration of the Costa Rican State, to facilitate the management and distribution of knowledge and information on land-use change and ecosystem monitoring. SIMOCUTE provides technical guidance for the monitoring, reporting, and verification (MRV) of land-use change in the AFOLU sector (agriculture, forests, and other land use). SIMOCUTE started in 2017 by implementing technical working groups, such as the working group, to estimate land-use change based on multitemporal visual evaluation of high-resolution images, the Mapping working group and the Monitoring of land-use change on agricultural lands working group.

The Government has not officialized the SIMOCUTE initiative yet. However, REDD+ Secretariat is implementing the National Forest Monitoring System for REDD+ considering the methods on land-use change monitoring adopted by SIMOCUTE. With this early implementation, Costa Rica has completed the first monitoring event and the first estimate of emission reductions as part of ER Program.

The U.S. Forest Service, Silvacarbon, FAO, PNUD, and GIZ provided technical support and collaboration, such as training on Multitemporal Visual Assessment with High-Resolution Image, Planet Images use, and Tools for Statistical Analysis to the sampling-based estimation of areas. Their support and cooperation have been vital to complete the Emission Reduction monitoring report of the Emission Reduction Program and the capacity building on MRV in CENIGA, IMN, and REDD+ Secretary of Costa Rica.

Financial plan. The REDD+ National Strategy implementation plan requires an incremental investment of $95,362,967 to achieve REDD+ targets. A portion of this investment will be covered by the sale of emissions reduction with the Carbon Fund. However, more investment is required to complement activities within the Emissions Reduction Program. In this regard, the REDD+ National Secretariat has been working on raising additional financial resources by accessing other carbon market mechanisms and instruments. As part of this strategy, in November 2020, the Green Climate Fund approved Costa Rica a Pay-per-Results project. This project will provide Costa Rica with $54.1 million in Emissions Reduction for 2014-2015. Additionally, a Jurisdictional Program Document is being validated under the Jurisdictional and Nested REDD standard that would allow us to access additional funds in the voluntary market. Also, conversations have been initiated to submit a program document under the ART TREES standard for the 2016-2017 reporting period.

1.2 Update on major drivers and lessons learned

Deforestation in Costa Rica has historically been driven by the following direct drivers:

Lack of value of ecosystem services: A lack of value for ecosystem services associated with forest land, which creates an incentive to convert forest land to agriculture and pasture. Other economic activities are more profitable per hectare than conservation for purposes of tourism or timber-related income from forest management. Depending on the original use of the land before deforestation, close to 70% of the deforested lands are for pastureland; slightly over 20% for crops, and almost 10% for plantations. However, it is worth highlighting that of the total degenerated area, more than 65% used to be pasturelands, over 20% were crops and close to 10% were plantations. Towards the end of the land use changes time series, cattle raising lost relative importance and agricultural crops increased. Also, most natural forest regeneration eventually returns to other uses, most often to the same use given prior to regeneration, reinforcing the idea that the main reason for abandonment that results in new forests is the recovery of land ́s productive capacity and, therefore, is an integral part of the dominant land use system in a region. The R-PP studies (MINAE, 2011) show greater deforestation in new forests (secondary) than in mature forests. The new land use times series helps show that the rate of deforestation of forests that are 15 years old or less is close to 4.5% while for forests between 15 and 25 years the rate is about 2%, and less than 1% for forests over 25 years of age.

Lack of property rights: A lack of formal property rights for small landowners and indigenous peoples, as well as non-indigenous groups occupying indigenous territories (also known as “lands under special regimes”). This prevented these lands from being incorporated into the existing payment for environmental services (PES) programs. Indigenous territories need to be allowed to use their forests for their own cultural purposes. The presence of non-indigenous people controlling lands in the area is an issue. Existing mechanisms are not enough to add more territories to REDD+ actions.
Furthermore, indirect drivers like agriculture, tourism, and urban market growth in proximity to the central valley resulted often in increased deforestation[2].

There have not been any new deforestation drivers identified, and those listed above are now being addressed through the recently released (2020) Benefit Sharing Plan in the National REDD+ Strategy[3] in the following ways:

1) Regarding the incentives for forest protection against forest conversion, Costa Rica has established, expanded, and improved the financial mechanisms to strengthen natural reforestation and to foster forest management.

[2] Plan de Implementación de la Estrategia Nacional REDD+ Costa Rica, V.7. Secretaria Ejecutiva REDD+ Costa Rica. 2017.
[3] Benefit Sharing Plan, National REDD+ Strategy. June 2020. Ministry of Environment and Energy (MINAE), Costa Rica. Retrieved from http://documents1.worldbank.org/curated/en/785151594625278269/pdf/Benefit-Sharing-Plan.pdf

This is currently being accomplished through the creation of payment for regeneration and reforestation (PES), promotion of sustainable production and consumption of wood products, and promotion of the establishment of deforestation-free commodity supply chains. The country has also created and implemented a Contract for Emission Reductions from Forests which aims to incentivize forest protection by private agents, conserve existing forests, and carry out sustainable forest management. Overall, these mechanisms reduce forest conversion as they increase the areas where forestry is more cost-effective than agriculture thanks to the sale of forestry products along with PES program payments. Since this activity is based on incentives and not coercive measurements, there is minimal risk of displacement/leakage. The productive area of Costa Rica's relevant global agricultural commodities (i.e. African oil palm and pineapple crops as well as livestock) was maintained throughout the 1998-2011 period despite the implementation of REDD+, as shown in the historical land cover map series.

2) To address the issue of property ownership, Costa Rica expanded the PES scheme to include indigenous territories, which should allow indigenous peoples to influence and benefit from REDD+ activities in the country. Similar to the action above, there is no risk of leakage as this activity is based on improving financial incentives for all landowners. Stakeholders in these lands were part of a consultative process that led to the implementation of a comprehensive government-led plan on socioeconomic and environmental safeguards[4], as well as the benefit-sharing mechanisms[5].

With respect to the drivers of forest degradation, illegal selective logging from the private forestry sector was once an issue that the country struggled to monitor and regulate. However, forest degradation has been addressed since 2002 when MINAE established strategies to control illegal logging and grant wood harvesting permits in agricultural lands, shifting the sources of Costa Rica's wood supply entirely. Now it is estimated that 49% of wood products come from forest plantations, 34% is imported, 12% is from agricultural lands, and 5% is from natural forests[6]. Costa Rica is addressing degradation through the financing mechanisms of PES and sustainable timber production initiative. However, despite these efforts, the emissions due to forest degradation have significantly increased during the monitoring period (see table 1). Furthermore, the country is actively engaged in commercial reforestation and restoration activities in lands with degradation potential (i.e. land that was overused and degraded in the past). No other degradation drivers have been identified.

By addressing drivers of forest loss Costa Rica has demonstrated that emissions can be reduced effectively, as planned in the ER Program. Regarding degradation, it is necessary to implement adjustments to reduce its emissions. This is shown in table 1 below.

Table 1. Comparison of the emissions and sinks in the reference period (1998-2011) and the pre-ERPA monitoring period (2019-2019).

Period	Average emissions from deforestation, t CO_2e/y	Average removals from reforestation (secondary forests), t CO_2e/y	Average emissions from degradation, t CO_2e/y	Average emissions from enhancements (forest remaining forests), t CO_2e/y	Net forest land cover change emissions, t CO_2e/y	Net forest remaining forests emissions, t CO_2e/y	Total net emissions, t CO_2e/y
Reference period (1998-2011)	5,985,795	-4,372,155	1,383,974	-411,896	1,613,640	972,078	2,585,717
Monitoring period, pre-ERPA (2018-2019)	840,167	-5,607,368	2,513,265	-403,491	-4,767,201	2,109,774	-2,657,427

[4] Resumen del Diseño del Sistema de Información sobre Salvaguardas REDD+ en Costa Rica. 2017. FONAFIFO. 28 pp.
[5] Benefit Sharing Plan, National REDD+ Strategy. June 2020. Ministry of Environment and Energy (MINAE), Costa Rica.
[6] Santamaria et al. 2015. Mercado de la madera y derivados en Costa Rica. 216pp.

2 SYSTEM FOR MEASUREMENT, MONITORING AND REPORTING EMISSIONS AND REMOVALS OCCURRING WITHIN THE MONITORING PERIOD

2.1 Forest Monitoring System

2.1.1 Organizational structure

Costa Rica's National Forest Monitoring System (NFMS), which generates information for the REDD+ Monitoring, Reporting, and Verification (MRV), has already been created[7]. The process started in 2015 when the National Center for Geospatial Information (CENIGA) initiated the designing process of the NFMS to cover all land uses and land use changes at the national level following IPCC's 2003 Good Practice Guidelines[8]. The NFMS is composed of two data collection mechanisms:

- The first is the Satellite Land Monitoring System (SLMS), which collects land use and land use change data. The agencies/institutions responsible for the SLMS are the National Meteorology Institute (IMN) and the REDD+ Secretariat, composed of the Fondo Nacional de Financiamiento Forestal (FONAFIFO) and the Sistema Nacional de Areas de Conservación (SINAC). The Instituto Metereológico Nacional (IMN) is also responsible for Costa Rica's National GHG Inventory (INGEI) and the development and submission of Biennial Update Reports (BURs). Therefore, the collaboration between IMN and FONAFIFO is crucial to maintain consistency between the REDD+ reporting and the national GHG inventory. The IMN is also tasked with developing indicators that follow IPCC's Good Practice Guidelines and SIMOCUTE´s structure.
- The second data collection mechanism is the National Forest Inventory (NFI), which gathers forest field data to estimate and update the country's emission factors. This piece of the NFMS is led by the SINAC, which is also responsible for promoting sustainable forest management, logging permits, and control of illegal logging.

Other government entities involved in the REDD+ Program are: Ministerio de Ambiente y Energia (MINAE), which gives political support to the process; Colegio de Ingenieros Agrónimos (CIAgro), which supervises forestry professionals in charge of REDD+ Program implementation; Oficina Nacional Forestal (ONF) is the interlocutor between these government entities and the private sector; and Asociaciones de Desarrollo Integral Indigena (ADII), which supports indigenous groups. The inter-institutional REDD+ Board of Directors is responsible for issuing policies, making decisions, and resolving conflicts or grievances related to REDD+.

[7] https://redd.unfccc.int/files/4863_2_sistema_nacional_monitoreo_forestal_costa_rica.pdf
[8] Available at: https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html

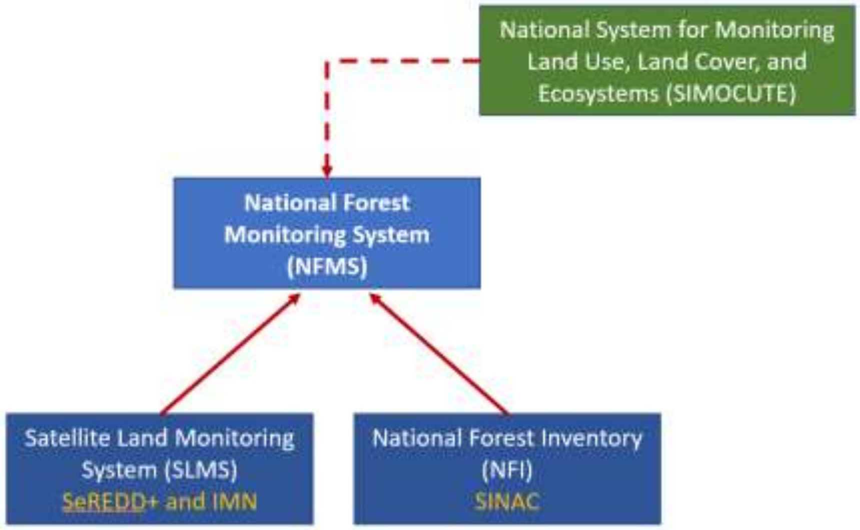

Figure 1. Organizational structure of the National Forest Monitoring System in Costa Rica.

The SIMOCUTE (National Monitoring System for Land Use, Land Use Cover, and Ecosystems) is the official platform for coordination, linkage, and institutional and sectoral integration of the Costa Rican State management and distribution of knowledge and information on land-use change and ecosystem monitoring. SIMOCUTE provides technical guidance for the monitoring, reporting, and verification (MRV) of land-use change in the AFOLU sector (agriculture, forests, and other land use). The technical working group of SIMOCUTE developed a monitoring methodology for the land-use change estimation area. The land-use change monitoring methodology is based on the visual interpretation of high-resolution imagery over 10,588 georeferenced systematic grid points. The procedure is designed to meet the country's forest monitoring needs by integrating all geospatial information produced in the country at the national, regional, and local levels. An early implementation phase of SIMOCUTE took place in 2017. Through this early implementation, Costa Rica conducted a first monitoring event and the first estimate of emission reductions as part of its ER-Program. SIMOCUTE is now a fully operational platform[9], and is designed to integrate the information of MRV system of emissions and removals of GHG from the AFOLU sector, doing so in compliance with the national REDD+ program, the NAMAs, the national carbon trading system, and the progress of NDC implementation[10].

[9] Accessible at https://simocute.go.cr/

[10] www.sinac.go.cr/ceniga/?q=content/sistema-de-monitoreo-de-la-cobertura-y-uso-de-la-tierra-y-ecosistemas-simocute

Figure 2. Conceptual Framework of Costa Rica's SIMOCUTE (National Monitoring System for Land Use, Land Use Cover, and Ecosystems). Source: MINAE 2017.

Costa Rica's National Forest Monitoring System (NFMS) was consolidated in 2019 and comprised a Terrestrial Satellite Monitoring System (SMST) and an INF. Through the SMST, national data on land-use changes are collected. The INF collects data to develop emission factors to estimate emissions and removals to be reported in the National Inventory of GHG for the AFOLU sector. The NFMS seats under a broader umbrella platform to coordinate all environmental information in the country, called SIMOCUTE (Sistema Nacional de Monitoreo de la Cobertura y el Uso de la Tierra y Ecosistemas in Spanish)[11].

REDD+ Secretariat counts with the support of the Costa Rica REDD-plus Result-Based Payments Project (RPB Project). This project will provide additional human resources and material inputs such as satellite imagery, hardware, software, and field monitoring equipment necessary for the Monitoring and reporting of REDD+ implementation. This activity will strengthen national capacities for REDD+ monitoring, reporting, and verification. Furthermore, this project will also provide support to meet the requirements of emerging market standards such as "The REDD+ Environmental Excellency Standard" (TREES) within the scope of the "Architecture for REDD+ Transactions" (ART) Program. RBP project will combine the market standards with Warsaw Framework for REDD+ results-based payments to maximize REDD+ financing for Costa Rica. Indeed, these standards can be made consistent with UNFCCC decisions for REDD+ while also including additional rules that reduce uncertainties and the risks of leakage and reversals. This activity will also support the verification of results by independent third parties. More specifically, this support will include

- Development and implementation of a diversified strategy for capturing REDD+ results-based payments from market and non-market sources based on international partnerships in line with the San Jose principles.
- Updating the FREL for a future submission, methodological improvements in response to technical assessment recommendations, and consolidating methodological consistency with the national GHG inventory and the NDC monitoring framework.
- Preparation of the second technical annex of REDD+

[11] For further detail on the System for Measurement, Monitoring And Reporting Emissions And Removals occurring within the Monitoring Period, please See Section 2 of ER-Monitoring Report.

- Support for participation of Costa Rica in market mechanisms including the REDD+ Environmental Excellence Standard (TREES) of the Architecture for REDD+ transaction programme (ART).
- Support for validation and verification processes.

2.1.2 Processes for collecting, processing, consolidating and reporting GHG data and information

The processes for collecting, processing, consolidating, and reporting GHG data and information employed during the monitoring period will be identical to the ones used for the construction of the reference level. Costa Rica will monitor the same activities and carbon pools and will implement these same procedures for future monitoring events.

SIMOCUTE is responsible for establishing the methods and protocols to generate the activity data and emission factors. Specifically:

- **Obtaining activity data (AD):** Instituto Meteorológico Nacional (IMN) has produced to date all land use cover maps and national GHG inventories in Costa Rica. The REDD+ Secretariat has been the entity responsible for developing the land use cover maps for the historical series that were used to develop the FRL/FREL submitted to the UNFCCC.
- **Obtaining emission factors (EFs):** SINAC is responsible for Costa Rica's NFI, which determines regularly the forest stocks in the country. The NFI outcomes are used to develop emission factors for Costa Rica's REDD+ MRV. SINAC will update the NFI to allow future resampling of a portion of the existing plots, with the support of US Forest Service (USFS) and FAO, which will consist on a resampling of a portion of SIMOCUTE's 10,588 sampling plots (Figure 3). Costa Rica's intention is to start in 2020 (or later, depending on the global covid-19 pandemic situation) the measurement 441 sampling points over a 5-year period to estimate biomass transitions[12].
- **Estimating emissions and sinks:** IMN, responsible for the national GHG inventories in Costa Rica, maintains the capacity to estimate GHG from AFOLU (agriculture, forestry, and other land use) and LULUCF (land use, land use change, and forestry).
- **Reporting:** Technical reports and annexes on REDD+ are developed by the REDD+ Secretariat and supported by IMN experts estimating emissions and sinks. These include reports to the FCPF Carbon Fund (FC), safeguards reports, and BURs for payment for performance under REDD+. The results from these reports then undergo a verification process by external reviewers and the REDD+ secretariat along with the IMN work team must adjust the FREL/FRL as needed.

To calculate the average annual historical emissions over the reference period, Costa Rica followed an activity-based approach where emissions and removals are estimated based on spatially explicit gross activity data and on net emission factors. Activity data was entered in land use matrices (see below) to ensure representation of all land use transitions and avoid double counting or omissions.

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

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

[12] MINAE, 2019. Technical Annex of the Republic of Costa Rica, in accordance with the provisions of Decision 14 / Cp.19. 64pp. Retrieved from https://unfccc.int/sites/default/files/resource/4863_3_iba-2019-anexotecnico_Edited.pdf .

Once AD and EFs for the forest that remain forests and forest cover change are generated and the corresponding GHG fluxes estimated with excel-based calculators, the uncertainty of the estimates is assessed by IMN and technical advisors from academia as needed (Figure 3).

To develop NFMS methods and protocols, SIMOCUTE follows the UNFCCC AFOLU requirements for monitoring land use cover emissions and establishes technical working groups to determine the procedures to implement methodologies and protocols, as well as to update them if needed. These technical working groups are conformed by experts from the institutions involved in the monitoring of ecosystems and land use / land cover.

The key elements of the SLMS and the NFI, including the source of data, the forest area covered, and the frequency of monitoring can be found in the Technical Annex Document[13]. There are QA/QC procedures for the AD and FE calculation as follows:

- **Activity Data:** The QA/QC procedures applied during the calculation of AD for the reference and monitoring period are summarized in Tables 2, 3, 6, and 7, further information may be found in Agresta (2005)[14], Ortiz-Malavassi (2017)[15], and Aguilar (2020)[16].
- **Emission Factors:** The QA/QC procedures applied during the calculation of EF for deforestation and degradation are summarized in Tables 4 and 5, further information may be found in Ministerio de Ambiente y Energía (2015)[17], Rodriguez (2018)[18], Coto (2018)[19], and Obando (2019)[20].

Costa Rica's first National Forest Inventory (NFI) was finished in 2015, under the supervision of SINAC. The NFI plots have been found to pose challenges for SINAC to conduct forest change assessments over time because of an uneven plot distribution among forest strata[21] and thus, SINAC is currently evaluating changes to the NFI structure through redistributing the plots to enhance compatibility with SIMOCUTE.

Role of communities in the forest monitoring system:

The NFMS, conceived as an official information system, must adhere in its design and function to the current standards applicable to the processes of generating official information, which are regulated by several corresponding entities: The National Geographic Institute (IGN) and its national territorial information systems, the National Institute of Statistics and Census (INEC) regarding data usage, etc. That is why in principle, community

[13] MINAE, 2019. Technical Annex of the Republic of Costa Rica, in accordance with the provisions of Decision 14 / Cp.19. 64pp. Retrieved from https://unfccc.int/sites/default/files/resource/4863_3_iba-2019-anexotecnico_Edited.pdf .

[14] Agresta, Dimap, Universidad de Costa Rica, Universidad Politécnica de Madrid. 2015. Final Report: Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level: Methodological Protocol. Report prepared for the Government of Costa Rica under the Carbon Fund of the Forest Carbon Partnership (FCPF). 44 pp. https://www.dropbox.com/s/ygjw6zq00a1qtbm/Informe_tecnico_feb_2015.pdf?dl=0

[15] 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. Retrieved from https://drive.google.com/file/d/1GXdN43f-DNKelkM8y7gBLrKou-f7LI-G/view?usp=sharing

[16] Aguilar, L. (2020). Evaluación Visual Multitemporal para la determinación de la degradación forestal para los periodos 2014-2015-2017-2019 y determinación de datos de referencia para periodo 2017-2019. Tercer Informe. Retrieved from https://drive.google.com/file/d/1ERutZo6vNI6MXUCmlrky7wiaeOqOLMqh/view?usp=sharing

[17] Ministerio de Ambiente y Energía. (2015). Volumen 4 Marco conceptual y metodológico para la Inventario forestal nacional de Costa Rica. Retrieved from https://www.sirefor.go.cr/pdfs/Volumen4-MarcoC-Imprenta.pdf

[18] 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

[19] 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

[20] Obando, G. (2019). COORDINACIÓN GENERAL DE LA IMPLEMENTACIÓN DEL PLAN DE MEJORA DEL NIVEL DE REFERENCIA. Tercer Informe de Consultoría N ° 016-2018-REDD. Retrieved from https://drive.google.com/file/d/1MEHZ6dvQKY52X58UtlG02o4Uw9x1HV6v/view?usp=sharing

[21] Recomendaciones para la Medición, Reporte, y Verificación (MRV) de REDD+. 2016. Report from the CDI, US Forest Service, and FAO UN-REDD. 33 pp.

participation is not expected in these systems, unless it becomes necessary at some points to fill gaps in the generation of data that may involve these forms of participation.

However, ER-Program envisions supporting measures lead to robust participation by communities and organizations in control actions related to forest resources. For example, SINAC efforts to strengthen the involvement of communities in firefighting through the so-called “Forest fire brigades” that are mainly composed of volunteers in zones with high susceptibility to these phenomena (see section 1.1). Also, SINAC efforts to strengthen the “Natural Resources Monitoring Committees” (COVIRENAS) and the activities of the Volunteers Association (ASVO), non-government entities that contribute through different activities coordinated with the appropriate government agencies, monitoring compliance with government legislation, in the first case, and in supporting the management of protected areas in the second.

SINAC engaged different actors at the national level to promote participation in protecting and safeguarding natural resources. It is a mechanism that allows state institutions responsible for ensuring these resources to establish surveillance actions together with communities in compliance with the national legal framework. During 2019, SINAC held a series of training workshops to reactivate COVIRENAS, aimed at local actors interested in their formation, and training in the use of integrated environmental reporting process systems (its acronym in Spanish is SITADA), among others.

In addition to this, the Colegio de Ingenieros Agrónomos (Agronomists’ Association) as the governing entity of the “Certified Foresters” who are responsible for preparing and following-up on the management plans of the different modalities of payment for environmental services agreements, have an essential task in monitoring the beneficiaries´ compliance with their respective commitments or actions they have agreed to take with regard to conservation, restoration, reforestation or management. In that same sense, there are many local and regional forestry producer organizations that provide regency services to interested parties, and that have their capacities strengthened through PES. It is envisioned to strengthen these capacities through different lines of work incorporated in policies, actions and tasks of the PRE.

2.2 Measurement, monitoring and reporting approach

2.2.1 Line Diagram

The diagrams below show a step-by-step description of the measurement and monitoring approach applied for establishment of the Reference Level and estimating Emissions and Emissions reductions during the Monitoring / Reporting Period for estimating the emissions and removals from the Sources/Sinks, Carbon Pools and greenhouse gases selected in the ER-PD (Figure 2).

Costa Rica has developed a tool to estimate emission and removals from deforestation and reforestation - FREL & MRV TOOL CR.xlsx[22], and other for the estimate of emission and removals from degradation in permanent forest lands – Herramienta-degradacion.xlsx[23].

FREL tool: Details of FREL tool can be found in START spreadsheet, and its manual (Manual de la Herramienta FREL & MRV Tool – UNFCCC.pdf in Spanish[24]). The tool is organized in the following sections:

Setting sections that must not be modified by users:

i. START: This spreadsheet explains the general information of the Tool: i. name and contact information of the person who made the last modification of the Tool, ii. date of the changes and iii. keyword used to lock spreadsheets.
ii. FREL&FRL: In this spreadsheet the user can recalculate the FREL/FRL by selecting i. carbon gases and reservoirs to be included in the FREL/FRL; ii. REDD + activities to be included in the FREL/FRL; iii. the years of the historical reference period of the FREL/FRL.
iii. C-STOCKS: The objective of this spreadsheet is to calculate the carbon stocks (in tCO_2-e ha^{-1}) of the land use categories represented in the Land Cover Maps (MCS) of Costa Rica. The calculation is done separately for each gas and carbon pool, whether or not it is included in the FREL/FRL. The spreadsheet also reports uncertainty values, at 90% or 95%, associated with estimates of average carbon existence. The calculations of these uncertainty values are made in a separate Excel file ("Carbon Database> 4. Carbon Densities"[25]) using the IPCC uncertainty propagation method (Equation 3.1 and 3.2 of IPCC-GL, 2006 - Volume 2). At the end of the spreadsheet, all the data, parameters and default values used in the calculation of carbon stock estimates and their respective sources are listed.
iv. REDD+ ACT: This spreadsheet defines REDD + activities in such a way that it is not possible to count the same source or the same GHG sink in more than one REDD + activity and ensuring, at the same time, that all GHG sources and sinks are considered in the analysis. The approach taken to meet this objective is to represent in a matrix of land use changes all possible transitions between land use categories and then assign each cell in the matrix to a single REDD + activity.
v. LIST: This spreadsheet contains the drop-down lists that appear in the rest of the Tool's pages and additional information related to the stratification of Costa Rica's forests. No calculation is made on this sheet.

Input section:

vi. LCM AAAA-AA: In this spreadsheet the activity data of the "AAAA-AA" period are reported, where "AAAA and AA" are the beginning ("AAAA") and end ("AA") years of the period. This is done by filling in a matrix of land use changes with all possible transitions. The structure of the matrix is identical to the matrix presented in the "REDD + ACT" spreadsheet, which allows the activity data to be related to REDD + Activities.
The "LCM AAAA-AA" spreadsheets are the only ones that must be filled in for REDD + monitoring. When activity data is entered in the matrices of the "LCM AAAA-AA" sheets, the Tool will automatically calculate the annual activity data ("AD AAAA" sheets) and annual emissions and removals ("ER AAAA" sheets) up to the "AA" year (= last year of the "AAAA-AA" period). The "FREL & FRL" sheet will be updated with the data

[22] The FREL Tool can be accessed in the following link:
https://drive.google.com/file/d/1wiVsHpP_b5kEVkbb4GdQqWaQDDzwyZnw/view?usp=sharing
[23] Degradation tool can be accessed in the following link:
https://drive.google.com/file/d/1GG3Z_QMWBKGNRdXnF_TdWP1ipH9dX5iH/view?usp=sharing
[24] A copy of the FREL Tool Manual can be download at the following link:
https://drive.google.com/file/d/14CsE_rpBBrEJgyUTplziKKsGGVm_YtL_/view?usp=sharing
[25] A copy of Carbon Densities database can be download at the following link:
https://drive.google.com/file/d/1LJ8pbd0EuiVoS7JuMc8ps_OwlD12MUuH/view?usp=sharing

calculated up to the "AA" year and the results of the mitigation actions (or emission reduction program) on the "RESULTS" sheet.

Calculation section:

vii. AD AAAA: In this sheet the annual activity data are calculated from the values entered in the "LCM AAAA-AA" sheets. The calculation is made in matrices of land use changes and is based on the assumption that in the "AAAA-AA" period the areas converted annually are equal.

viii. ER AAAA: These spreadsheets calculate GHG emissions and removals related to the land use change summarized by type of forest and REDD + activities. The calculation is performed automatically in each of the cells of the land use change matrices by multiplying the activity data by their corresponding emission factors. The activity data are the values calculated in the matrices of the "AD AAAA" spreadsheets. The emission factors are calculated as the difference between the carbon contents existing at the beginning and end of the year, taking the carbon stock values of the "C-STOCKS" spreadsheet.

Results sections:

ix. RESULTS: This spreadsheet calculates and shows the results of the mitigation action. Results are calculated considering the same gases, carbon reservoirs, emission factors and REDD + activities that were included in the FREL / FRL. The calculation of the results is simply the difference between the actual emissions / removals and the emissions / removals of the FREL/FRL.

x. CHARTS: This spreadsheet contains graphs and tables that were included in the FREL / FRL description documents of Costa Rica that were submitted to the UNFCCC (MINAE, 2016). The content of this sheet is informative and there are no parameters that the user can change (except the working language) or calculations that are not performed on other spreadsheets.

Uncertainty analysis are performed in a separated tool using Monte Carlo simulation as described in section 5.

Degradation tool: Costa Rica used a methodology of visual interpretation of high-resolution images to detect changes in the canopy of permanent forest areas to estimate emissions and removals from degradation. This analysis resulted in a database of canopy cover percentages in 4,377 points in forest lands of Costa Rica for several years. Details of the Degradation tool can be found in Winrock International, (2018)[26]. The tool facilitates the following calculations:

- Segregation of interpretation points between anthropic and natural carbon flux areas to eliminate natural changes from emissions accounting since the ER program cannot control them.
- Calculation of the number of points in each forest state transition. In this step, the canopy interpretation assessment of the three forest status classes of the initial year and the final year of the monitoring period are classified. The three classes of forest status are: a. Intact: forest areas with canopy percentage between 85-100%; b. Slightly degraded: forest areas with canopy percentage between 60-85%; c. Very degraded: forest areas with canopy percentage less than 60%.
- Extrapolate the area of each transition of forest states. This step is necessary to extrapolate the carbon flows detected at the interpretation points to the entire permanent forest area for the monitoring period.
- Calculation of the average canopy percentage for each forest state. In this step, the tool calculates the average canopy percentage of each forest state for the beginning and the end of the monitoring period.
- Estimation of carbon fluxes (emissions and removals) of each type of transition is the final step. The tool uses the relationship between the percentage of canopy cover and biomass to estimate carbon fluxes in each transition from forest state.

The Degradation tool is organized as follows:

i. Descripcion_Variables: This sheet contains descriptions of the High-Resolution Image Visual Interpretation Analysis database attributes. Take note of the attributes *Arbol+Palma_AAAA* variables. These attributes show the percentage of canopy cover in the initial and final year of the monitoring period.

ii. Base_de_Datos: This sheet contains the database for the visual interpretation of high-resolution images.

[26] Winrock International. (2018). Ejercicio : estimación de emisiones por actividades en bosques que permanecen como tales. Retrieved from https://drive.google.com/file/d/1Mk8MACXEKDROXQg2UP7t4FDqQmc8Q5S9/view?usp=sharing

iii. Resumen_de_puntos: This sheet calculates the number of points and extrapolates the area for each transition from the forest state.

iv. Deg_ems_antro_RP_AA-AA: This sheet calculates the average canopy percentage of each forest state and the anthropic carbon fluxes (emissions and removals) of each type of transition for the Reference Period.

v. Deg_ems_nat_RP_AA-AA: This sheet calculates the average canopy percentage of each forest state and the natural carbon fluxes (emissions and removals) of each type of transition for the Reference Period.

vi. Deg_ems_antro_MP_AA-AA: This sheet calculates the average canopy percentage of each forest state and the anthropic carbon fluxes (emissions and removals) of each type of transition for the Monitoring Period.

vii. Deg_ems_nat_MP_AA-AA: This sheet calculates the average canopy percentage of each forest state and the natural carbon fluxes (emissions and removals) of each type of transition for the Monitoring Period.

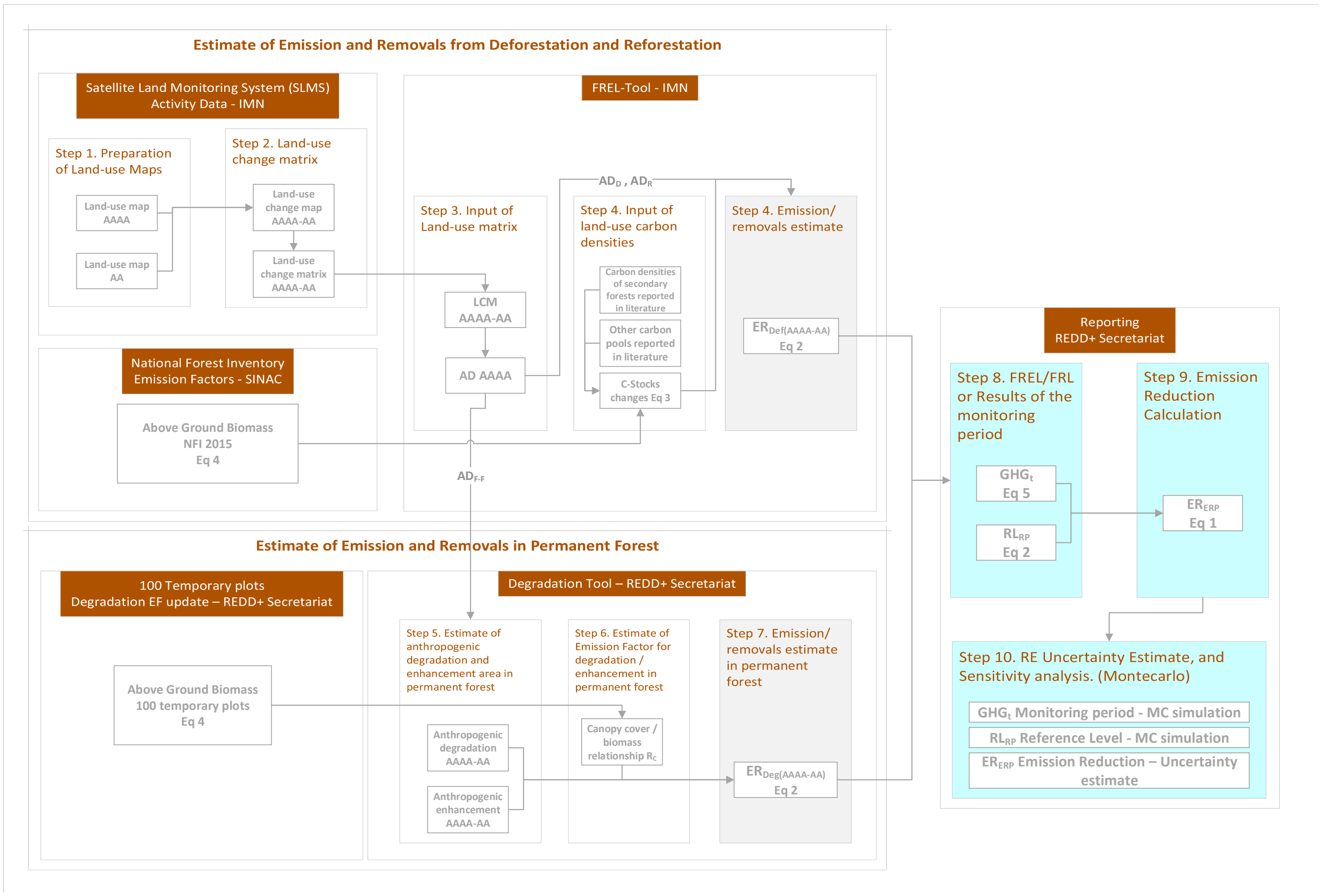

Figure 2: Step-by-step description of the measurement and monitoring approach applied for establishment of the Reference Level and estimating Emissions and Emissions reductions during the Monitoring / Reporting Period for estimating the emissions and removals from the Sources/Sinks, Carbon Pools and greenhouse gases selected in the ER-PD of Costa Rica. In this 2018-2019 monitoring report Costa Rica includes the update of the emission factors for degradation for the main forest types in the country (wet and rain forests, moist forests, dry forests, mangrove forests, and palm forests). This update is based on the 100 temporary plots sampled for aboveground biomass in 2018-2019. The details of this update are provided in the sections below.

2.2.2 Calculation

2.2.2.1 EMISSION REDUCTION CALCULATION

$$ER_{ERP,t} = RL_{RP} - GHG_t$$ **Equation 1**

Where:

ER_{ERP}	=	Emission Reductions under the ER Program in year t; $tCO_2e*year^{-1}$.
RL_{RP}	=	Gross emissions of the RL from deforestation and degradation over the Reference Period; $tCO_2e*year^{-1}$. This is sourced from Annex 4 to the ER Monitoring Report and equations are provided below.
GHG_t	=	Monitored gross emissions from deforestation at year t; $tCO_2e*year^{-1}$;
T	=	Number of years during the monitoring period; dimensionless.

2.2.2.1.1 Reference Level (RL_t)

The RL estimation may be found in Annex 4, yet a description of the equations is provided below. RL 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:

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

Equation 2

Where:

ER_{RA_t}	=	Emissions or removals associated to REDD+ activity *RA* in year *t*; tCO_2-e yr^{-1}
$AD_{RA_{i,t}}$	=	AD associated to REDD+ activity *RA* for the land use transition *i* in year *t*; ha yr^{-1}
$EF_{RA_{i,t}}$	=	EF associated to REDD+ activity *RA* applicable to the land use transition *i* in year *t*; tCO_2-e ha^{-1}
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)	$AD_{D_{i,t}} = \lvert D_{i,t}\rvert * 0.81$, **Equation 2.1**	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 2.2**	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 2.3**	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})	$AD_{Deg_{i,t}} = \frac{\lvert Deg_{i,t}\rvert}{N} * \sum_{i=1}^{I} AD_{F-F_{i,t}}$ **Equation 2.4**	Where $\lvert Deg_{i,t}\rvert$ is the count of sampling points where canopy change decrease (dimensionless), *N* is the total of sampling points (dimensionless), and

		$\sum_{i=1}^{I} AD_{F-F_{i,t}}$ is the total area of permanent forest (in hectares – ha) in the monitoring period.
Activity Data of Permanent Forest Regeneration (AD_E)	$AD_{E_{i,t}} = \frac{\lvert E_{i,t} \rvert}{N} * \sum_{i=1}^{I} AD_{F-F_{i,t}}$ **Equation 2.5**	Where $\lvert E_{i,t} \rvert$ is the count of sampling points where canopy change increase (dimensionless), *N* is the total of sampling points (dimensionless), and $\sum_{i=1}^{I} AD_{F-F_{i,t}}$ is the total area of permanent forest (in hectares – ha) in the monitoring period.

EFs were determined from C stocks. 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:

$$\Delta C = \frac{(C_{t2} - C_{t1})}{(t2 - t1)} * 44/12$$ **Equation 3**

Where:

ΔC	=	C stock changes associated to the land use transition *i* in year *t*; tCO_2-e ha^{-1}
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.
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[27] and 20[28] of the sheets "ER AAAA" (where "AAAA" stands for the year *t*) in the FREL TOOL.
t2-t1	=	In all cases the C stock changes were estimated annually, *i.e. t2-t1* = 1 year.
44/12	=	Conversion of C to CO_2

Forest C is determined from the NFI biomass data, converted to carbon as follows:

$$C_t = \sum_{j,i} (B_{tot}) \text{ x CF}$$ **Equation 4**

Where:

B_{tot} = Total biomass stock for the land use category *LU*; tCO_2-e ha^{-1}.
Total biomass is equivalent to the sum of all biomass pools: $B_{tot} = B_{AGB} + B_{BGB} + B_{DW} + B_L$
Where:
- AGB is above-ground biomass for land use category *LU*; tCO_2-e ha^{-1}
- BGB is below-ground biomass for land use category *LU*; tCO_2-e ha^{-1}
- DW is dead wood biomass for land use category *LU*; tCO_2-e ha^{-1}
- L is litter biomass for land use category *LU*; tCO_2-e ha^{-1}

CF = Carbon fraction of dry matter in tC per ton dry matter. The value used is:
0.47 is the default for (sub)tropical forest as per IPCC AFOLU guidelines 2006, Table 4.3.

[27] The C stock values reported in line 19 represent total C stocks existing in secondary forest and tree plantation 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 and conversions of other land use categories to permanent crops.

[28] 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 and conversion of other land use categories to permanent crops.

Carbon stocks of non-Forest land uses are estimated as the average values reported by the selected studies:

- *Cropland:* carbon stock values reported in selected studies showed high variability, depending on crop type (sugar cane, coffee, banana, cocoa, etc.). For this reason, the carbon stock data compiled were weighted by the surface area of the respective crops in Costa Rica to produce a single estimate of carbon stocks from cropland.
- *Grassland:* carbon stocks were estimated as the average values reported in different carbon pools in the selected studies.
- *Settlements and (non-forested) Wetlands:* no studies could be found reporting biomass values for these categories. It was assumed that their carbon stock is zero.
- *Other Land:* studies were found reporting carbon stocks for *Paramo.* In the case of *Bare Soil* it was assumed carbon stocks are zero.

Additional details on AD, EF, and calculations in the reference level and monitoring period are available in Section 3 and Annex 4 of this monitoring report.

2.2.2.1.2 Monitored emissions ($\mathbf{GHG_t}$)

Annual gross GHG emissions over the monitoring period in the Accounting Area ($\mathrm{GHG_t}$) are estimated as the sum of annual change in total biomass carbon stocks (ΔC_{B_t}).

$$\mathrm{GHG_t} = \frac{\sum_{t}^{T} \Delta C_t}{T}$$ **Equation 5**

Where:

ΔC_t	=	Annual change in total biomass carbon stocks at year t; tC*year^{-1}
T	=	Number of years during the monitoring period; dimensionless.

Changes in total biomass carbon stocks are calculated following Equation 3 above.

3 DATA AND PARAMETERS

3.1 Fixed Data and Parameters

Table 2: Source of Activity Data and description of the methods for developing the data for estimate emissions from deforestation during the reference period[29].

Parameters:	**Activity Data of Deforestation (AD_D) Eq. 2.1** **Activity Data of Reforestation (AD_R) Eq. 2.2** **Forest remaining forests (AD_{F-F}) Eq. 2.3**
Description:	Deforestation: Hectares of forest that changed to non-forest land in a year summed each year (i) of the reference period. Reforestation: Hectares of non-forest that changed to forest land in a year, summed for each year (i) of the reference period. Forest remaining forests: Hectares of Forest remaining forests in a year, summed for each year (i) of the reference period
Data unit:	Hectares
Source of data	
Introduction	AD for land-use change activities was derived from map-algebra by analyzing all land cover maps created for 1998-2011 and estimating multi-temporal data for the areas that remained in the same category or converted to other land cover categories. Annual AD was interpolated for years in which maps were not produced. A time-series of land use maps was created for 1985/86-2012/13 in a Geographical Information System (GIS)[30] 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 area covered by the land-use maps includes the country's continental territory (5,133,939.50 ha) but excludes Coco Island (238,500 ha). The land use maps were created using the methodology summarized here; further information may be found in separate reports [31,32,33] :
Data sources for estimating activity data:	The construction of the AD time series required the following sources of data: i. Remotely sensed data from four generations of the Landsat family (Landsat 4 TM, Landsat 5 TM, Landsat 7 ETM and Landsat 8 OLI/TIRS). ii. A "Life Zones" map according to the classification system of Holdridge (1966). This map was used to stratify "Forests" into the three sub-categories: "Wet and Rain Forests", "Moist Forests" and "Dry Forests". iii. Ancillary data 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. iv. The Global Forest Change project (Hansen et al., 2013) has been used to fill in pixels without information in the mosaic of classifications for each year of the series between 2000 and 2012.
Methods for mapping land-use and land-use change	

[29] All AD parameters listed in table 2 sourced from the same survey.

[30] 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

[31] Agresta, Dimap, Universidad de Costa Rica, Universidad Politécnica de Madrid. 2015. Final Report: Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level: Methodological Protocol. Report prepared for the Government of Costa Rica under the Carbon Fund of the Forest Carbon Partnership (FCPF). 44 pp. https://www.dropbox.com/s/ygjw6zq00a1qtbm/Informe_tecnico_feb_2015.pdf?dl=0

[32] 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

[33] Ministry of the Environment and Natural Resources of Costa Rica. (2018). Costa Rica Emission Reductions Program to the FCPF Carbon Fund (Second Revision). Retrieved from https://www.forestcarbonpartnership.org/system/files/documents/Costa_Rica_ERPD_EN_Oct24-2018_clean.pdf

Selection of images	Costa Rica prepared the FREL / FRL Costa Rica from a time series of satellite images for 1987-2013. The time series includes images from four generations of LANDSAT satellites: Landsat 4 TM, Landsat 5 TM, Landsat 7 ETM +, Landsat 8 OLI / TIRS. The analyst downloaded the satellite information through the USGS Earth Explorer server. It was necessary to work with seven LANDSAT scenes to cover the continental territory of Costa Rica in each of the years of the series: two scenes from path 14 (rows 53 and 54), three scenes from path 15 (rows 52, 53, and 54) and two scenes from path 16 (rows 52 and 53). Low cloud-coverage Landsat images were combined to minimize the area covered by clouds and cloud shadows. In most cases, the scenes were selected from the same year and season but, in some cases, it was necessary to choose scenes from different years within a 14-month timeframe.
Pre-processing and Geometric validation	All images were registered to a standard system of coordinates (CRTM05). The mean quadratic error in control points was less than one pixel (30 m). The maximum registration error was estimated at 2 pixels (60 m). The 2005 orthophotography generated with the IDB-Cadastral project's CARTA mission has been used to collect control points for the geometric validation of the reference runs. A mosaic of scenes is prepared for each path's available dates with the geometrically corrected images.
Radiometric normalization	All images were radiometrically normalized. This process is applied to reduce radiometric differences between images due to atmospheric conditions and the sensors' calibration at image acquisition dates. The radiometric normalization was done using the "Iteratively Reweighted Multivariate Alteration Detection" (IR-MAD), as described by Canty and Nielsen (2008)[34]. The normalization of the time series used as a reference the zenith angle 36.90° corresponding to February 17, 2013.
Random Forest classification	The classification of the images uses the Random Forest (RF) method. This methodology has 2 phases: (1) training or adjustment of the RF and (2) classification of the images using the generated RF classifier. Homogeneous regions of interest have been digitized according to the land cover classes between 2011 and 2014 (see Table 3 of Agresta, 2015) for the models' adjustment. The base information used for the digitization and photointerpretation of these regions has been i) the systematic grid of cover points taken on the RapidEye images by SINAC for the elaboration of the map of forest types of Costa Rica 2013 (10,000 points distributed in the national territory), ii) the RapidEye high spatial resolution images themselves, iii) both current and historical images available on Google Earth. Control points for RF training have been randomly generated from these regions of interest. In total, 20 predictor variables (also called covariates or auxiliary variables) were used for the adjustment of the RF models, divided into four groups: (1) Spectral information of the bands, (2) Indices of vegetation, (3) Variables related to the texture of the image, and (4) Variables derived from the Digital Elevation Model. The analyst applied the classifiers to all the images according to their path and sensor. The result is a classification file for each classified image.
Postprocessing	Final maps are presented at 30 meters resolution. The preparation of the final maps from the classified images included the following tasks: i. Union of the mosaic for each date from the classified images using a pixel prioritization algorithm. The analyst merged all the different images' classifications for each of the dates and paths, eliminating the extreme strip of the paths overlapping. If the classifier predicts several classes for the same pixel, the most common category was selected, according to band 2 of the results. ii. Filling gaps with global products: The Global Forest Change project (Hansen et al., 2013) has been used to fill in pixels without information in the mosaic of classifications for each year of the series between 2000 and 2012. iii. Multi-temporal analysis: the multi-temporal analysis of the series allowed assigning the age class to each of the forest pixels, analyzing the years that have elapsed from the date of appearance of a new forest. The forest from 1987 has been considered a primary forest. Also, the multi-temporal analysis improved land-uses classification, especially when the land cover has similar spectral information. The classifier confused native forests with forest plantations. For this reason, the forest plantations were reclassified as forest.

[34] 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.

	iv. Minimum mapping unit: The analyst replaced Forest Class groups of pixels smaller than 11 pixels with the LULC class of the largest neighboring group to comply with the minimum area threshold of the definition of "forest (1.00 ha), and setting the minimum mapping unit. Due to the pixels' dimensions in the Landsat images (30.00 m x 30.00 m), the minimum mapping area is 0.99 ha, equivalent to 11 pixels (11 x 30.00 m x 30.00 m). v. Manual editions: In order to improve land use mapping, several editions were made, largely aimed at decreasing high classification errors (for more detail please see section 4.3.3 in Ministry of the Environment and Natural Resources of Costa Rica, 2016[35]): a. "Forest Plantations" were merged with the "Forest land" category. 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". b. For estimating the area of "Coffee Plantations", the analyst used ancillary maps from the Ministry of Agriculture (MAG), the Costa Rican Coffee Institute (ICAFE), and the Costa Rican Meteorological Institute (IMN). These maps were used to correct the classified areas for the years 2000/01, 2007/08, 2011/12, and 2013/14. For previous maps, a mask representing potential "Coffee Plantation" areas was created using the location and elevation of all areas mapped as "Coffee Plantations" considering all available sources of information (MAG, ICAFE, and IMN). c. Paramo, Mangroves and Palm forests are ecosystems restricted to particular elevation, edaphic, inundation, and salinity conditions; it is challenging for such ecosystems to exist in other locations. Therefore, these forests were re-classified using the map of Forest types (MTB), prepared by Agresta (2015). 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. d. 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 e. A map of potential forest types was created to assign secondary forests to a forest type (Wet and Rain Forests, Moist Forests, Dry Forests, Mangroves, Palm Forests). This map will also be used in future measurements for determining the forest type of secondary forests. The map of potential forest types was created by combining the life-zones and then overlapping the map of the masks of potential areas of "Mangroves", "Palm Forests", and "Paramo".
Activity Data calculation	AD for land use change activities such as *deforestation* and *reforestation* were estimated by combining all land use maps created for 1998-2011 in a Geographical Information System (GIS) and then extracting from the combined set of multi-temporal data the values of the areas that remained in the same category or converted to other land use categories. The results of this operation are reported in land use change matrices prepared for each measurement period in the sheets "LCM 1986-91", "LCM 1992-97", "LCM 1998-00", "LCM 2001-07", "LCM 2008-11", and "LCM 2012-13" of the spreadsheets tool "FREL TOOL CR[36]".
Value applied in reference period:	
	<u>1998-2011</u>: • Total anthropogenic deforestation: 30,439 ha yr^{-1} • Primary forest anthropogenic deforestation: 13,147 ha yr^{-1} • Secondary forest and tree plantation anthropogenic deforestation: 17,292 ha yr^{-1}
QA/QC procedures applied	

[35] 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

[36] The FREL Tool can be accessed in the following link: https://drive.google.com/file/d/1wiVsHpP_b5kEVkbb4GdQqWaQDDzwyZnw/view?usp=sharing

Introduction	The QA/QC procedures applied during the preparation of the land-use maps used to calculate AD for the reference period are summarized here, further information may be found in Agresta (2005), Sections 3, 4, and 7:
Download and satellite image preparation	1. Verification of file storage errors in digital media that could affect reading the data by the analyst responsible for download support images. 2. Previewing and verification of the satellite image quality and metadata by the analyst responsible for downloading support images. 3. Previewing and verification of the satellite image quality and metadata by the supervisor.
Image orthorectification	1. Analyst's exhaustive visual inspection to identify errors in the orthorectification process, such as duplicated areas, pixel stretching, or geometric errors related to the digital terrain model (DTM). 2. Geometric control of orthorectified images by taking checkpoints in each scene in a regularly distributed grid. 3. Validation of root mean square error (RMSE) of the control points, by the analyst responsible for the orthorectification. In no case, RMSE is above the pixel size of the image. The number of correct points after debugging should not be less than 20 ground control points in each reference path. The RMSE obtained in the checkpoints is less than 1 pixel (30 meters), and the maximum error in any of the points, 2 pixels (60 meters). 4. Preparation of a "georeferencing validation datasheet," including a general image view with the checkpoints marked on it and a list of the coordinates and RMS obtained for each point. Annex 5 of Agresta (2015) includes the lists of checkpoints and RMSE of the dates processed.
Radiometric normalization*:*	5. Radiometric normalization to reduce the differences between the time-series images.
Generation of cloud and shadow masks	6. Validation of cloud and shadow mask by visual verification of a systematic random grid of checkpoints identified as a cloud (n), shadow (s), or clear (d). The analyst visually checked the original image in RGB or false color if the classification matches the cloud and shadow mask. The analyst must pay special attention to the verification of cloud masks in urban areas and coastlines with a high reflectance, adjusting some of the cloud and shadow mask degeneration parameters during the verification process. 7. The validation includes a random sample in each path of an image from each time series (3 paths x 6 series = 18 images). Table 2 of Agresta (2015) includes a summary of the results of the validation of the cloud and shadow maps.
Land use classification*:*	8. Analysts perform an iterative process of classification, verification of results, error detection, and review of areas and training points. 9. Progressive improvement of the areas and training points of the RF classifier before the final classification of the images. Review of the Random Forest classifiers' errors, identify classes that need improvement, and training points. 10. Visual verification and validation of classified images by comparing them with the available high-resolution image.
Preparation of land-use maps:	11. Visual check of mosaics and identify information gaps and sensor failures on each time series' images. 12. Visual verification of the maps generated after filling the gaps with global data. 13. Analysts implement an independent validation of the land-use change maps with ground validation points provided by the country's institutions not used in the classification phase. 14. Manual edition of the time-series classification to improve land use mapping, largely aimed at decreasing high classification errors.
Visual verification and validation of land-use change map:	15. Visual verification of the country's main deforestation and reforestation areas between consecutive years of the series to detect classification errors. 16. Validation of land-use changes between 2001 and 2011 based on photointerpretation of changes on a systematic random grid of points and using the Landsat, aerial orthophotography of the year 2005, and Rapid-eye images of the years 2011 and 2012.
Uncertainty associated with this parameter:	
Uncertainty associated with this parameter:	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 (i.e. the margin of error for a 90% confidence level divided by the estimate)

	associated with the process creating land use change maps from which the activity data are obtained. The accuracy assessment of the land-use change map 2001/02 – 2011/12 was done following Olofsson et al.'s (2014)[37] guidelines. Due 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). 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. For further detail please see section 12.2 in ERPD document (Ministry of the Environment and Natural Resources of Costa Rica, 2018)[38]. Finally, 699 checkpoints were assessed: 315 in stable forest areas (areas classified as forest in 2000/01 remaining forest in 2010/11), 237 in the non-stable forest (areas classified as non-forest in 2000/01 remaining non-forest in 2010/11), 53 in afforestation/reforestation areas (areas classified as non-forest in 2000/01 classified as forest in 2010/11) and 47 in deforested areas (areas classified as forest in 2000/01 classified as non-forest in 2010/11)[39]. The accuracy assessment analysis is presented in the Excel file "CDI_CostaRicaREL_AnalisisExactitud_MCS2000-2001 vs MCS2010-2011" [40]. The activity data's uncertainty is the bias between the adjusted (reference data) and estimated (land use maps) areas. The uncertainty values are as follows: Uncertainty of hectares of deforestation from 1998-2011: 26% Uncertainty of hectares of non-forest that changed to forest land: 31% Uncertainty of hectares of forests remaining forests in 1998-2011: 4%

Table 3: Source of Activity Data and description of the methods for developing the data for estimate emission from degradation during the reference period.

Parameters:	**Activity Data of Degradation (AD_{Deg}) Eq. 2.4** **Activity Data of Permanent Forest Regeneration (AD_E) Eq. 2.5**
Description:	Degradation: Hectares of forest with a reduction of canopy cover during the reference period. Forest Enhancement: Hectares of forest with an increase of canopy cover during the reference period
Data unit:	Hectares
Source of data	
Introduction	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)[41].
Type of sampling	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

[37] Olofsson et al. (2014) Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment 148, 42-57.
[38] Ministry of the Environment and Natural Resources of Costa Rica. (2018). Costa Rica Emission Reductions Program to the FCPF Carbon Fund (Second Revision). Retrieved from https://www.forestcarbonpartnership.org/system/files/documents/Costa Rica ERPD EN_Oct24-2018_clean.pdf
[39] Shape file with 716 checkpoints included in the accuracy assessment analysis can be accessed in the following link: https://drive.google.com/drive/folders/1ofSZs-IfdZ-BzFxefqrGO1pwbp537HL1?usp=sharing
[40] 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
[41] 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. Retrieved from https://drive.google.com/file/d/1GXdN43f-DNKelkM8y7gBLrKou-f7LI-G/view?usp=sharing

<table>
<tr><td></td><td>SIMOCUTE sampling units are permanent, which facilitates reinterpretation through time and easy temporal tracking of LULC changes.</td></tr>
<tr><td>Sampling Unit</td><td>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.</td></tr>
<tr><td>Number of Sampling Units</td><td>The forest degradation assessment was made on forest lands that remain as forest lands during 1998-2016. 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.</td></tr>
<tr><td>Classification scheme</td><td>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
i. Stable very degraded forest</td></tr>
<tr><td>Imagery Sources</td><td>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 or 2016). 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 on permanent forest for the reference period 1998-2011 are the following:
<table><tr><th>Monitoring Year</th><th>Imagery date range</th><th>Data sources</th></tr><tr><td>1998</td><td>January 1997 – December 2005</td><td>• Orthophotos TERRA 1997.
• Google Earth imagery repository
• Mission CARTA 2005</td></tr><tr><td>2011</td><td>July 2011 – June 2012</td><td>• Google Earth imagery repository</td></tr><tr><td>2016</td><td>July 2015 – June 2016</td><td>• Google Earth imagery repository</td></tr></table></td></tr>
<tr><td>Interpretation Key</td><td>The land cover class keys used to determine canopy cover for the years 1998, 2011, and 2016 are the following:
<table><tr><th>Code</th><th>Land cover class</th></tr><tr><td>1100</td><td>Trees</td></tr><tr><td>1200</td><td>Shrubs</td></tr><tr><td>1300</td><td>Herbaceous</td></tr><tr><td>1400</td><td>Palm</td></tr><tr><td>1500</td><td>Bromeliads</td></tr><tr><td>1600</td><td>Greenhouse</td></tr></table></td></tr>
</table>

1700	Other vegetation
2000	No vegetation
3000	Water
4000	Clouds and shadows
5000	Not classifiable

Data collection	See QA/QC procedures.
Data analysis	The country developed a tool for calculating emissions and removals on permanent forest lands (¨Herramienta_degradación.xlsx¨ [42]). The database for the visual interpretation of canopy cover for the reference period 1998-2011 and monitoring period 2012-2016 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 (1998-2011) 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 points inside protected areas and farther than 500 meters from a road[43] 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 monitoring period 2012-2016.
Value applied in reference period:	
	• **2,233,119** hectares of forests remaining forests in the reference period (1998-2011) • **145,556** hectares of anthropogenic degradation (1998-2011) • **157,739** hectares of anthropogenic forest enhancement (1998-2011)
QA/QC procedures applied	
	Ortiz-Malavassi (2017) prepared a land cover evaluation protocol to reduce the uncertainty of the land cover classification due to: a) the bias associated with the spatial registration of the reference image, b) the interpreter bias in the assignment of the land cover class; and c) interpreter variability. The protocol includes the operational definition of the canopy coverage with examples taken from high-resolution images and registration templates for Collect Earth Desktop. The following procedures were applied during the collection of reference data: **Data registry forms**: The canopy cover change information was recorded in standard Collect Earth Desktop forms. **Variability between interpreters**: The analysts recorded screenshots, plot numbers, and a brief description of the problem in case of doubts with the interpretation (land cover and land-use). Every two days, they sent the log to other analysts for feedback. This feedback was available to all team members. Meetings will be held at the end of the week to discuss complex cases to reduce interpreters' variability. **Validation of the coverage classification**: The supervisor validated land cover classification with National Forest Inventory land cover data. This information was available only for the supervisors. **Imagery co-registration:** Google Earth images can show displacements, which became evident when the interpreter compares the same area for different years. Potere (2008)[44] found that the

[42] Degradation tool can be accessed in the following link:
https://drive.google.com/file/d/1GG3Z_QMWBKGNRdXnF_TdWP1ipH9dX5iH/view?usp=sharing

[43] 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

[44] Potere, D. (2008). Horizontal positional accuracy of Google Earth`s high-resolution imagery archive. In: Sensors, 8,12: 7973-7981 p. Retrieved from: http://www.mdpi.com/1424-8220/8/12/7973/htm

	average displacement in developing countries is 44.4 meters. When this problem occurred, the analyst noted the maximum displacement detected in meters in Collect Earth form. **Data consistency:** The supervisor reviewed the existence of discrepancies between cover class and land use.
Uncertainty associated with this parameter:	
	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. Uncertainty of changes in canopy cover to identify areas of degradation and forest enhancement from 1998-2011 vary depending on the forest type and the conversion class. It is based on the sampling error.

Table 4: Source of Emission Factors and description of the methods for developing the emission factors for deforestation.

Parameters:	**Carbon density of aboveground tree or woody biomass (C_{AGB}) Eq. 4** **Carbon density of belowground biomass (C_{BGB}). Eq. 4.** **Carbon density of dead wood biomass (C_{DWB}). Eq. 4** **Carbon density of litter (C_L). Eq. 4**
Description:	• **C_{AGB}**: Amount of carbon (C) contained in aboveground biomass per forest hectare, converted to CO_2e multiplying by a factor of 44/12 (i.e., the molecular weight of a CO_2 molecule over the molecular weight of a C molecule). • **C_{BGB}**: Amount of C contained in belowground forest biomass per forest hectare, converted to CO_2e multiplying by a factor of 3.67 (i.e., the molecular weight of a CO_2 molecule over the molecular weight of a C molecule). • **C_{DWB}**: Amount of C contained in dead wood forest biomass (standing and lying) per forest hectare, converted to CO_2e multiplying by a factor of 3.67 (i.e., the molecular weight of a CO_2 molecule over the molecular weight of a C molecule). • **C_L**: Amount of CO_2e contained in litter forest biomass per forest hectare.
Data unit:	Tonnes of CO_{2e} per hectare
Source of Data	
Introduction	The emission factor for deforestation of primary forest 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 literature. • **Carbon pool of aboveground tree or woody biomass (C_{AGB}):** Carbon pool of aboveground tree or woody biomass for each Primary Forest type (C_{AGB}) is the area-weighted average of C_{AGB} stock value from 2015 field campaign performed for the National Forest Inventory. • **Carbon pool of belowground biomass (C_{BGB})**: Derived directly from C_{AGB} data following the Cairns et al., (1997) formula. • **Carbon pool of dead wood biomass (C_{DWB})**: Average values of direct measurements reported in literature. The value was used to develop a ratio of C_{DWB} over C_{AGB} used for AD_D, AD_{F-F}, and AD_R. The values obtained from the literature were used to develop an area-weighted average of DW:AGB ratios, assumed to be the same in primary and secondary forests. • **Carbon pool of litter (C_L):** Average values of direct measurements reported in literature. The value was used to develop a ratio of C_L over C_{AGB} used for AD_D, AD_{F-F}, and AD_R. The values obtained from the literature were used to develop an area-weighted average of L:AGB ratios, assumed to be the same in primary and secondary forests.
Source of Data of Above Ground Biomass for Primary Forest	**Type of sampling:** The INF-CR is a multipurpose inventory seeking to enhance the understating of Costa Rican forest resources and generate data to monitor and quantify their provision of ecosystem services, such as climate change mitigation. The INF-CR was led by the National Conservation Area System (SINAC) with measurements taken between 2013 and 2015. The INF-CR employed a stratified-systematic sampling approach covering the entirety of Costa Rica's continental territory. The stratification was based on a forest type map derived from RapidEye

	imagery (REDD/CCAD-GIZ-SINAC, 2015)[45] and plots were equidistantly allocated within each stratum. **Sampling Unit:** Rectangularly shaped plots with an area of 0.1 ha (20m x 50m) distributed on fixed sample intensities by forest class. The sampling unit design allows the measurements of the following (Ministerio de Ambiente y Energía, 2015)[46]: • Primary Sampling Unit (UMP for its acronym in Spanish) for measurement of live tree DBH and height of trees with DBH ≥ 10cm (light green area) • Secondary Sampling Unit (UMS for its acronym in Spanish) for measurement of saplings with 2cm ≤DBH<10cm, and height >1.5m. • Third-order Sampling Unit (UMT for its acronym in Spanish) for measurement of live non-tree vegetation, including seedlings (DBH<2cm and height<1.5m), were taken (light grey circles) • Fourth-order Sampling Unit (UMC for its acronym in Spanish) to measure the abundance of species. • Fifth-order Sampling Unit (UMH) to measure litter. • Lying deadwood sampling (UMM) to measure the lying deadwood's diameter in the 20m transects. Soil sampling of the first 30cm with cylinder method. **Number of Sampling Units:** The INF-CR installed a total of 286 single plots. Out of the 286 sampling units (SU), litter was sampled only in 54, and lying deadwood in 61 SUs. Because of inconsistent sampling of all carbon pools across all plots and lack of confidence in data where litter and deadwood, a decision to consider only aboveground biomass from INF-CR was made. Some SU presented zero as a result of litter and deadwood pools. It was not verified whether the SU represented the absence of litter and deadwood in the plots, or these carbon pools weren't sampled.
Source of Data of Above Ground Biomass for Secondary Forest	The AGB for secondary forest was estimated assuming the forest stand accumulated biomass since its restoration. The AGB of Wet and Rain Forests, Moist Forests and Dry Forests were estimated using the equations developed by Cifuentes (2008)[47] based on direct measurements in 54 plots located in age classes between 0 and 82 years. For Mangroves and Palm Forests, a linear function was assumed for estimating carbon stocks as a function of age. Wet and Rain Forests (Cifuentes, 2008, Table 2.5, p. 42, equation for "*Tropical Wet*"): $$TAGB_t = B_{max} * \left[1 - e^{(-0.0186*t)}\right]^1$$ Moist Forests (Cifuentes, 2008,, Table 2.5, p. 42, equation for "*Tropical Premontane Wet Transition to Basal-Atlantic*"): $$TAGB_t = B_{max} * \left[1 - e^{(-0.0348*t)}\right]^1$$ Dry Forests (Cifuentes, 2008,, Table 2.5, p. 42, equation for "*Tropical Dry*"): $$TAGB_t = B_{max} * \left[1 - e^{(-0.113*t)}\right]^{5.1411}$$ Mangroves and Palm Forest the following linear equation was applied: $TAGB_t = \frac{B_{max}}{100} * t$, when t <= 100 $TAGB_t = B_{max}$, when t > 100 It was assumed that the maximum biomass in secondary forests (B_{max}) equals the biomass estimated for primary forests.
Source of data of Litter and Deadwood in primary and secondary forest	The carbon stocks of litter and deadwood were estimated based on a compilation of values from published literature. All C stock estimates from the consulted sources were compiled in tons of carbon per hectare (tC ha-1), using IPCC's default carbon fraction (0.47) when the values were reported in tons of dry matter (t d.m. ha^{-1}). All information related to C stock estimates, such as information on land use, number of sampling units, plot size, the allometric equation used, etc.,

[45] Sistema Nacional de Áreas de Conservación (SINAC) - Programa REDD-CCAD-GIZ. (2015). Cartografía base para el Inventario Forestal Nacional de Costa Rica 2013-2014. Retrieved from https://www.sirefor.go.cr/pdfs/Documento-cartografia-Imprenta.pdf

[46] Ministerio de Ambiente y Energía. (2015). Volumen 4 Marco conceptual y metodológico para la Inventario forestal nacional de Costa Rica. Retrieved from https://www.sirefor.go.cr/pdfs/Volumen4-MarcoC-Imprenta.pdf

[47] Cifuentes, M. (2008). Aboveground Biomass and Ecosystem Carbon stocks in Tropical Secondary Forests Growing in Six Life Zones of Costa Rica (Oregon State University). Retrieved from https://drive.google.com/file/d/1FsiTVc78EHcU0gQ4JfFJFSlPqesm3JFW/view?usp=sharing

	were also recorded. For full detail please check BaseDeDatos_v5[48] and C-STOCKS sheet of FREL TOOL[49]. The literature review employed the following criteria for compiling the reported value: • The publication reported data from direct measurements carried out in Costa Rica • Measurements were carried out after the year 2005 • Data were sufficiently disaggregated by reporting values of carbon stocks per land use categories and per carbon pool sampled • The publications included information on uncertainties related to the carbon stock estimates
Source of data of carbon stocks of non-Forest land uses	C stocks in these non-forest land uses were estimated as the average values reported by the selected studies. For full detail please check BaseDeDatos_v5 and C-STOCKS sheet of FREL TOOL. • **Cropland**: carbon stock values reported in selected studies showed high variability, depending on crop type (sugar cane, coffee, banana, cocoa, etc.). For this reason, the carbon stock data compiled were weighted by the surface area of the respective crops in Costa Rica to produce a single estimate of carbon stocks from cropland. • **Grassland:** carbon stocks were estimated as the average values reported in different carbon pools in the selected studies. • **Settlements and (non-forested) Wetlands:** no studies could be found reporting biomass values for these categories. It was assumed that their carbon stock is zero. • **Other Land:** studies were found reporting carbon stocks for *Paramo.* In the case of *Bare Soil,* it was assumed carbon stocks are zero.
Methods for estimating C stocks and Emission Factors	
	• **Above ground biomass (AGB)**: Above ground of forest biomass is calculated as 47% of the biomass dry weight of standing trees in the forest, which is calculated using allometric equations. Aboveground biomass of each measured tree was estimated using Chave et al., (2005)[50] moist forests allometric equation as follows: $AGB = \exp\left(-2.977 + \ln\left(\rho * DBH^2 * HT\right)\right)$ *Where:* *AGB: aboveground biomass (kg)* *ρ: wood specific gravity (g/cm³). Obtained from literature.* *DBH: Diameter at breast height (cm)* *HT: Tree height (cm)* AGB estimates at the tree level are then summed per plot, and extrapolated to a per hectare basis by applying a scaling factor of 10, which represents the proportion of a hectare (10,000 m²) that is occupied by the plot as follows: $ScalingFactor = \frac{10{,}000m^2}{1{,}000m^2} = 10$ *Where:* *10,000m²: Area of one hectare (m²)* *1,000m²: Area of INF-CR rectangular plot (20m x 50m)* • **Below ground biomass (BGB)**: BGB is derived directly from Cairns et al., (1997).[51] equation, to estimate C_{BGB} from C_{AGB} data: $\mathrm{BGB} = \exp\left(-1.085 + 0.9256 * \ln\left(\mathrm{AGB}\right)\right)$ Where: BGB: belowground biomass (t d.m. ha⁻¹) AGB: aboveground biomass (t d.m. ha⁻¹) This equation was applied to both, primary and secondary forests. • **C stocks of forest** lands corresponds to the area-weighted average of C stocks by C pool and strata.

[48] BaseDeDatos_v5.xlsx can be accessed at the following link: https://drive.google.com/file/d/1d6QqYQci7_Qo7DJhS5eOKgCqLFDX-rFX/view?usp=sharing

[49] The FREL Tool can be accessed in the following link: https://drive.google.com/file/d/1wiVsHpP_b5kEVkbb4GdQqWaQDDzwyZnw/view?usp=sharing

[50] Chave J et al. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: pp. 87-99.

[51] 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.

- **C stock changes** (ΔC) are estimated using the Stock-Difference Method by applying IPCC (2006) equation 2.5 (cf. Volume 2, Chapter 2, Section 2.2.1.).

Value applied in reference period:

Carbon stocks in Primary forest

Primary Forest type	Area-weighted average		
	t C_{AGB} ha^{-1}	t C_{DWB} ha^{-1}	t C_L ha^{-1}
Wet and Rain Forests	131	13.5	2.7
Moist Forests	93	13.2	2.2
Dry Forests	62	15.4	6.2
Mangroves	72	1.9	0.3
Palm Forests	52	1.6	0.3

Carbon stocks in Secondary Forest

The table below shows the Bmax values used in the equations above to calculate $TAGB_t$ from the secondary forest stand age.

Secondary Forest Type	B_{max} (t dry mass ha^{-1})
Wet and Rain Forests	445
Moist Forests	262
Dry Forests	155

Carbon stocks of non-Forest land uses

Non-forest land uses	Area-weighted average t C_{AGB} ha^{-1}
Permanent crop, wooded, cropland	16
Annual crop, wooded, cropland	0
Permanent crop, non-wooded, cropland	7
Annual crop, non-wooded, cropland	23
Grasslands, wooded	8
Grasslands, non-wooded	4
Paramos	35

QA/QC procedures applied

AGB in primary forest

SINAC implemented the following QA/QC procedures during the National Forest Inventory of Costa Rica (for further details please see Ministerio de Ambiente y Energía, 2015)[52]:

Fieldwork organization: SINAC organized the fieldwork by regions: North Pacific and Central Valley (PN-VC), Central Pacific and South Pacific (PS), North-Caribbean North Zone (ZN-CN), Central-South Caribbean (CC-CS), and complex sites (Talamanca mountain range). SINAC prepared terms of reference, describing each member of the field crew's roles and responsibilities. An experienced dendrologist was part of the work team, and a field manual was prepared for identifying, collecting, transport, and processing botanical samples. The Crew was trained before the start of fieldwork, and an Excel template was designed for data typing.

Fieldwork supervision: During the NFI implementation, the coordinator made field visits to supervise the crews' work. A photographic registry of each plot was made.

Registry of information: The field crew filed field forms and prepared reports of the activities. The crew chief and fieldwork director reviewed the field forms. The IFN steering committee did the final review. If the supervisor detected errors, omissions, or inconsistencies, the records were returned to the crew leader with observations for their correction or documenting the discrepancies; the dendrological inventory component coordinator reviewed questionable species identifications.

[52] Ministerio de Ambiente y Energía. (2015). Volumen 4 Marco conceptual y metodológico para la Inventario forestal nacional de Costa Rica. Retrieved from https://www.sirefor.go.cr/pdfs/Volumen4-MarcoC-Imprenta.pdf

	Control procedures were applied to evaluate the coherence, integrity, and completeness of dasometric, dendrological, and positioning data. **Independent evaluation of forest inventory data quality:** A separate crew evaluated the quality of forest inventory data. The independent team made field visits and re-measures 10% of the plots established by stratum, both in the pre-sampling and inventory phase.
Uncertainty associated with this parameter:	AGB's uncertainty in primary forests is derived from NFI sampling errors. Since belowground biomass is a function of aboveground biomass, the belowground biomass values have the same level of uncertainty as the aboveground biomass. Uncertainty from values DWB and L is derived from values identified in the scientific literature. The statistical uncertainty reported in these documents takes into consideration the sampling error. Therefore, the current version of the reference level only considers this error source.

Primary Forest type	Uncertainty (%) of aboveground biomass
Wet and Rain Forests	150%
Moist Forests	152%
Dry Forests	152%
Mangroves	93%
Palm Forests	81%

Non-forest land uses	Area-weighted average t C_{AGB} ha^{-1}
Permanent crop, wooded, cropland	71%
Annual crop, wooded, cropland	0%
Permanent crop, non-wooded, cropland	68%
Annual crop, non-wooded, cropland	12%
Grasslands, wooded	0%
Grasslands, non-wooded	0%
Paramos	2%

Table 5: Source of Emission Factors and description of the methods for developing the emission factors for forest degradation.

Parameters:	Ratio AGB:Percent of canopy cover per forest type (R_C)
Description:	• **Canopy cover and biomass relationship (R_C)**: 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.
Data unit:	Tonnes CO_2e ha^{-1} / % canopy cover
Source of Data	
Introduction	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 (1998-2011) 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.
Sampling Unit	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.
Selection of Sampling Units	Rodriguez (2018)[53] and Coto (2018)[54] 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.
Number of Sampling Units	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:

[53] 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

[54] 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

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

Data collection

All trees, shrubs, palms, tree ferns, lianas, and vines with a Diameter at Breast High (DBH) > 10 cm were measured following the protocols of the National Forest Inventory (Ministerio de Ambiente y Recursos Naturales, 2017). The following data were collected:
Scientific Name: registry of the genus and species of each inventoried tree. Lianas and vines were identified at the level of life form, and no samples were collected.
Species Code: National Forest Inventory code of the scientific name (genus and species).
Diameter: registry of diameter in centimeters and at breast height (1.3 m).
Total height: registry of estimated total height for trees, shrubs, and palms; in the case of vines and lianas, it is not assessed. The crew member who estimated the heights performed periodic calibrations using the clinometer.
Specific Gravity: the GE values were obtained directly from the Biomass estimation tool developed by SINAC and specialized publications (IPCC, 2003[55]; Myers, 2013[56]; Tree Functional Attributes and Ecological Database, 2018[57]).

Data analysis

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[58]). 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.

Value applied in reference period

Ratio AGB:Percent of canopy cover per forest type (R_C)

Forest type	**R_c - Ratio Aboveground biomass (t CO_2e ha^{-1})/ % canopy cover**
Wet and Rain Forests	5.03
Moist Forests	3.86
Dry Forests	3.47
Mangroves	3.19
Palm Forests	4.26

QA/QC procedures applied

The REDD+ Secretariat of Costa Rica implemented the following QA/QC procedures during the measurement of the 100 temporary plots (for further details please see Rodriguez, 2018, Coto, 2018 and Obando, 2019):

[55] 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.
[56] 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
[57] Tree Functional Attributes and Ecological Database. (2018). Wood Density. Recuperado el 10 de 12 de 2018, de http://db.worldagroforestry.org/.
[58] Calculo_FE_041220.xlsx can be accessed in the following link: https://drive.google.com/file/d/1bqrLUfbUreR18MsNDHLWHRzZKEbF2RGr/view?usp=sharing

	Canopy cover assessments review: To reduce the error in the SU´s impairment category assignment, the imagen analyst reviewed Ortiz-Malavassi's (2017) database consulting additional image repositories available on e.g., SAS Planet and Global Mapper. **Review of selected sampling points:** the coordinator reviewed the selected sampling points to assure that SU corresponds to the degradation category. **Review of field information**: Once finished the field measurement work, the field crew chief verified that every tree, shrub, palm, etc., with DBH > 10 cm had been measured and had the paint mark. Also, the crew chief verified that the plot's central point was recorded in the GPS with the required precision and that the access track was recorded for its location. **Registry of information**: The field forms were reviewed and digitized daily to minimize errors during field measurements and errors during digitally recording data. The collection of all measured trees was managed in an MS Excel template. The data analyst daily reviewed the field forms to identify inconsistencies. If any error were detected, the data analyst requested the crew chief's clarifications. **Independent evaluation of forest inventory data quality:** A separate crew evaluated the quality of forest inventory data. The independent team made field visits and re-measures 5% of the plots (see Annex 1 in Obando, 2019)[59].
Uncertainty associated with this parameter:	
Uncertainty of R_c	The uncertainties were calculated from the standard deviations of the identified relationships.

Forest type	**Uncertainty of R_c (%)**
Wet and Rain Forests	16%
Moist Forests	22%
Dry Forests	24%
Mangroves	32%
Palm Forests	37%

[59] Obando, G. (2019). COORDINACIÓN GENERAL DE LA IMPLEMENTACIÓN DEL PLAN DE MEJORA DEL NIVEL DE REFERENCIA. Tercer Informe de Consultoría N ° 016-2018-REDD. Retrieved from https://drive.google.com/file/d/1MEHZ6dvQKY52X58UtlG02o4Uw9x1HV6v/view?usp=sharing

3.2 Monitored Data and Parameters

Table 6: Source of Activity Data and description of the methods for developing the data for estimate emissions from deforestation, degradation and carbon removals during the monitoring period.

Parameters:	**Activity Data of Deforestation (AD_D) Eq. 2.1** **Activity Data of Reforestation (AD_R) Eq. 2.2** **Forest remaining forests (AD_{F-F}) Eq. 2.3**
Description:	Deforestation: Hectares of forest that changed to non-forest land in a year summed each year (i) of the monitoring period. Reforestation: Hectares of non-forest that changed to forest land in a year, summed for each year (i) of the monitoring period. Forest remaining forests: Hectares of Forest remaining forests in a year, summed for each year (i) of the monitoring period
Data unit:	Hectares
Source of data	
Introduction	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. Córdoba-Peraza, (2020a;2020b) prepared the LULC Maps 2017 and 2019 of Costa Rica (MCS 2017/18[60] and MCS 2019/20)[61], 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). MCS 2017/18 and MCS 2019/20 maps were included in the 1987-2013 time-series geodatabase. Also, the geodatabase's table of uses, types, and ages of the forest was updated. To automate the workflow, AGRESTA (2015) generated the toolkit ***REDD tools Costa Rica package***. This toolbox runs on the geographic information system QGIS for the Microsoft Windows operating system. The programs were compiled in the QGIS Processing framework[62] allowing to run 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/) 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, QGIS, and IMN equipment. 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. The land use maps were created using the methodology summarized here; further information may be found in separate reports [63,64,65,66] :
Data sources for estimating activity data:	The construction of the AD time series required the following sources of data: i. Remotely sensed data from Landsat 8 OLI/TIRS.

[60] LULC map 2017 (MCS 2017/18) can be accessed at the following link: https://drive.google.com/drive/folders/1yARo588uxh_KYccBNaVpokPqqu_pMISL?usp=sharing
[61] LULC map 2019 (MCS 2019/20) can be accessed at the following link: https://drive.google.com/drive/folders/1NRxm3yRV6yT1NgLwhp_z00wxyA0fpMdx?usp=sharing
[62] https://docs.qgis.org/2.8/en/docs/user_manual/processing/
[63] Córdoba-Peraza, J. (2020 a). Informe final Elaboración del mapa de cobertura y uso de la tierra en Costa Rica 2017. Retrieved from https://drive.google.com/file/d/1_p4M48tpPuPrBzm4makYVELb5p6eDSB9/view?usp=sharing
[64] Córdoba-Peraza, J. (2020 b). Informe final Elaboración del mapa de cobertura y uso de la tierra en Costa Rica 2019. Retrieved from https://drive.google.com/file/d/1WPr46RFOu_1Vr5rAYO_QDUlaL090zWd3/view?usp=sharing
[65] Agresta, Dimap, Universidad de Costa Rica, Universidad Politécnica de Madrid. 2015. Final Report: Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level: Methodological Protocol. Report prepared for the Government of Costa Rica under the Carbon Fund of the Forest Carbon Partnership (FCPF). 44 pp. https://www.dropbox.com/s/ygjw6zq00a1qtbm/Informe_tecnico_feb_2015.pdf?dl=0
[66] 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

	ii. Mask of the country (in raster format) generated from map MCS 2013/14 iii. Land-use maps 2013 and 2015 (MCS 2013/14, MCS 2015/16[67]) and Forest's type map (MTB), prepared by AGRESTA (2015) 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. iv. The Global Forest Change project (Hansen et al., 2013) has been used to fill in pixels without information in the mosaic of classifications for land-use maps 2017 and 2019.
Methods for mapping land-use and land-use change	
Selection of images	To prepare the Land-use map 2017 and 2019 (MCS 2017/18 and MCS 2019/20, images from the LANDSAT 8 OLI / TIRS satellite were used for the period from June 2017 to June 2018 for the land-use map of 2017 and from June 2019 to June 2020 for land-use map of 2019. In both cases, to cover the continental territory of Costa Rica, it was necessary to work with two scenes of path 14 (rows 53 and 54), three scenes of path 15 (rows 52, 53, and 54), and two scenes of path 16 (rows 52 and 53) (see **Error! Reference source not found.**). The following bands used were 2, 3, 4, 5, 6, and 7.
Pre-processing and Geometric validation	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 mask of the country (in raster format) generated from map MCS 2013/14 of the geodatabase was used to ensure that the maps MCS 2017/18 and MCS 2019/20 are consistent in area, pixel resolution, and dimensions (same number of columns and rows X, Y) with the maps of the 1997-2013 time series. The MCS 2017/18 and MCS 2019/20 map has the same number of columns and rows (c 14554, r 14089) and a spatial resolution of pixels in XY (29.99951157, 29.9995115) to compare them geographically and to obtain the land-use change matrix. Also, a mask of clouds and shadows was prepared to improve the classification. According to the SLMP protocol in Agresta (2015), GRASS "r.mapcalculator" in QGIS 2.4 should have been used for cloud and shadow masking, as well as a SAGA majority filter. However, Fmask 4 (https://github.com/gersl/fmask) was used since this tool is an improved software for the generation of cloud and shadow masks in Landsat and Sentinel images. Finally, all those pixels that do not belong to the country's continental territory were included in the mask of clouds and shadows.
Radiometric normalization	All images were radiometrically normalized. This process is applied to reduce radiometric differences between images due to atmospheric conditions and the sensors' calibration at image acquisition dates. The conversion of digital values (6-band images) to reflectance was made using "Obtain reflectance" tool included in REDD tools Costa Rica package. The time normalization of the images was performed using the zenithal reference angle with a value of 36.90°, corresponding to February 17, 2013. For this procedure, "time normalization" of REDD tools Costa Rica package was used. Finally, for the radiometric normalization of the images, the tool "Radiometric Normalization" of REDD tools Costa Rica was used.
Random Forest classification	The classification of the images uses the Random Forest (RF) method. This methodology has 2 phases: (1) training or adjustment of the RF and (2) classification of the images using the generated RF classifier. Random Forest classifier was trained using homogeneous regions of interest known as ROI's, that provided "ground truth" information. ROIs were prepared by the technical team of the National Meteorological Institute together with the consultant. The ROIs are consistent with the land cover classes established in the satellite land monitoring protocol of Agresta (2015). ROI s were not collected for the paramo class, since a mask developed by Agresta (2015) was used to exclude this type of coverage from the analysis. The information used to define the training zones was the following: i. Google Earth's high-resolution image dataset. ii. Landsat 8 images used in the preparation of the land use map for the year 2017 (MCS 2017/18) and iii. ROIs provided by AGRESTA were used as a guide to delimit the polygons with the coverage classes. In total, 20 predictor variables (also called covariates or auxiliary variables) were used for the adjustment of the RF models, divided into four groups: (1) Spectral information of the bands, (2) Indices of vegetation, (3) Variables related to the texture of the image, and (4) Variables derived from the Digital Elevation Model. The classification of the images was done with the module "Classification of land cover Costa Rica" of REDD Tools Costa Rica in QGIS 2.18,

[67] 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

	using a ROIs shape file containing the training regions with LULC classes and the image of 20 bands (predictor variables) to be classified.
Postprocessing	Final maps are presented at 30 meters resolution. The preparation of the final maps from the classified images included the following tasks: i. The classified images were merged into a mosaic using the classification prioritization algorithm of the “FusionClass” module of REDD tools Costa Rica. ii. Information gaps due to the presence of clouds and shadows, although small, were filled with global data from the Global Forest Change project[68]. iii. MCS 2017/18 and MCS 2019/20 maps were re-projected, using the GDALWARP tool, from the OSGeo4W Shell console. This tool was used considering the geographical properties of the MCS 2013/14 map (pixel resolution, image extension X1-X2, Y1 Y2) as well as the number of rows and columns. iv. Minimum mapping unit: The analyst replaced Forest Class groups of pixels smaller than 11 pixels with the LULC class of the largest neighboring group to comply with the minimum area threshold of the definition of "forest (1.00 ha), and setting the minimum mapping unit. Due to the pixels' dimensions in the Landsat images (30.00 m x 30.00 m), the minimum mapping area is 0.99 ha, equivalent to 11 pixels (11 x 30.00 m x 30.00 m). v. MCS 2017/18 and MCS 2019/20 maps were reclassified according to the Land-use categories of the MCS 2013/14 map. The forests were separated into primary and secondary forest and by life zone (wet and rainy, wet, dry, mangrove and palm forest); permanent and annual crops also were grouped.
Activity Data calculation	For calculating the activity data, a cartographic comparison of the wall-to-wall maps MCS 2017/18 and MCS 1019/20 was made to subsequently count the pixel change and stable pixels in the 2018-2019 transition matrix. It was assured that both maps, MCS 2017/18 and MCS 2019/20 map, met the following requirements: i. Both maps must be in raster format; ii. Both maps must have the same number of rows and columns and the exact pixel resolution; iii. They should be in the same geographical reference system and not being displaced, and the projection should be EPSG 102305 CRTM05; iv. Both maps must share the same classification LULC key used in REDD+ Time Series maps, and v. Both maps must cover the same area. Using the ArcGIS / Zonal / Tabulate Area tool, the land-use change was obtained. The stable and converted areas are reported in land-use change matrices in the sheet “LCM 2018-19” of the FREL TOOL CR developed by Carbon Decision International (CDI) to estimate forest emissions for the period.
Value applied in monitoring period	
	2018-2019: • Total anthropogenic deforestation: **9,403** ha yr^{-1} • Primary forest anthropogenic deforestation: **1,458** ha yr^{-1} • Secondary forest and tree plantation anthropogenic deforestation: **7,945** ha yr^{-1}
QA/QC procedures applied	
Introduction	The QA/QC procedures applied during the preparation of the land-use maps used to calculate AD for the reference period are summarized here, further information may be found in Agresta (2005), Sections 3, 4, and 7:
Download and satellite image preparation	1. Verification of file storage errors in digital media that could affect reading the data by the analyst responsible for download support images. 2. Previewing and verification of the satellite image quality and metadata by the analyst responsible for downloading support images. 3. Previewing and verification of the satellite image quality and metadata by the supervisor (IMN specialist).
Image orthorectification	Landsat 8 images are already orthorectified, therefore it was not necessary to apply the QA / QC procedure.
Radiometric normalization:	4. Radiometric normalization to reduce the differences between the time-series images.
Generation of cloud and shadow masks	5. The cloud and shadows mask were not validated with checkpoints. Instead, the analysts performed an exhaustive visual inspection.

[68] Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, A., Tyukavina, D., Thau, D., Stehman, S.J.m Goetz, T.R., Loveland, T.R., Egorov, A., Chini, L., Justice, C.O. & Townshend, J.R.G. 2013: High – Resolution Global Maps of 21st-Century Forest Cover Change http://science.sciencemag.org/content/342/6160/850.

Land use classification:	6. Analysts perform an iterative process of classification, verification of results, error detection, and review of areas and training points. 7. Progressive improvement of the areas and training points of the RF classifier before the final classification of the images. Review of the Random Forest classifiers' errors, identify classes that need improvement, and training points. 8. Visual verification and validation of classified images by comparing them with the available high-resolution image.
Preparation and validation of land-use maps:	9. Visual check of mosaics and identify information gaps (sensor failures on each time series' images. It is essential to clarify that Landsat 8 does not present the banding problems of Landsat 7. Therefore, it was not necessary to check for sensor errors. 10. Visual verification of the maps generated after filling the gaps with global data. 11. Manual edition of the time-series classification to improve land use mapping, largely aimed at decreasing high classification errors.
Preparation and validation of land-use change map:	12. Visual verification of the country's main deforestation and reforestation areas between consecutive years of the series to detect classification errors. 13. Validation of land-use changes between 2018 and 2019 based on photointerpretation of changes on a systematic random grid of points with high-resolution images of the year 2018 and 2019.
Uncertainty associated with this parameter:	
	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 change map 2017/18 – 2019/20 was done following Olofsson et al.'s (2014)[69] guidelines. Reference data were collected by Ortiz-Malavassi (2020)[70]. The following is a summary of the sampling design for the collection of Refence Data: **Type of sampling:** Systematic Sampling **(**SYS) over the Level 1 Systematic Grid of 10,242 points of the Monitoring system of land use change and ecosystems (SIMOCUTE). The SIMOCUTE sampling units are permanent, which facilitates reinterpretation through time and easy temporal tracking of LULC changes. **Sampling Unit:** Multi-point Sampling Unit (SU). The SU is a 2-ha square plot with a 5x5 point sub-grid (25 points within the sampling plot). This plot size allowed 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 platform. A unique land-use dominance class is recorded at SU level for t1 and t2. The change class is calculated using the dominance class at t1 and t2 at SU level. **Number of Sampling Units:** A total of 9988 checkpoints were assessed in the country's territory (excluding Cocos's island). **Classification scheme:** Due 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). **Data sources**: The reference data for the validation of land-use changes during the period 2017/2018 -2019/2020 was collected from visual interpretation of high-resolution images, During the visual interpretation, priority was given to the high-resolution images available in Google Earth, for 2018 (July 1, 2017 to June 30, 2018) and 2019 (July 1, 2019 to June 30, 2020). In the absence of images of less than 4 m resolution, the Planet images available in the NICFI Program[71] were used, and in the second instance Sentinel-2 or Landsat 8 within the priority dates. **Interpretation Key**: A revised version of the SIMOCUTE key was used to interpret land-use, following specific rules and spatial contexts such as size and shape of forests and considerations regarding gallery forests, rivers, and lake protection zones (see Annex 1 of Ortiz-Malavassi, 2020). **Data collection**: The following procedures were applied during the collection of reference data: i. Cold checks: random check of the interpretations. Sixty points were randomly chosen, in which the supervisor reviewed the analysts' land use interpretations. Twenty sampling points were randomly selected from each analyst. An external analyst examined the results of the land-use classification and

[69] Olofsson et al. (2014) Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment 148, 42-57.
[70] Ortiz-Malavassi, E. (2020). Apoyo técnico para el registro de datos de cambio de uso del suelo mediante el método de Evaluación Visual Multitemporal (EVM) para el periodo 2018-2019. Retrieved from https://drive.google.com/file/d/1Bcv8qTLH8TGkbvYQpIPIGhAJ2xbzIYk8/view?usp=sharing
[71] Norway's International Climate and Forests Initiative Imagery Program https://www.planet.com/nicfi/

	provided feedback to the analysts. In case of discrepancy, the external analyst defines the use observed image. The minimum level of consistency between the analyst and the external analyst was 95%, for the transitions (stable forest, deforestation, and reforestation). ii. Hot checks: the supervisor provided immediate feedback to the analysts to improve the interpretations through the weekly review of points. 4 points are chosen per analyst each week, different from the sampling points selected for the cold checks. The "hot checks" also contemplate the revision of doubtful classification. **Data analysis**: The dominance class was defined considering a threshold of 30% forest cover. If the forest area is greater than 30%, the sampling plot is classified as forest land. The estimate of land-use change areas is not based on dominance class (DC) in t1 and t2. DC was used to identify potential land-use change points (See Figures 3A and 3B). A total of 54 sample plots were defined as possible deforestation or regeneration points. These plots were re-analyzed, and the change at point level in the 5x5 sub-mesh was recorded. Only the sampling plots where the supervisor confirmed the land-use change were considered valid points for estimating the change areas. The accuracy assessment analysis for the period 2018-2019 is presented in the Excel file ¨ReferenceData2018-2019Rev12Feb2021.xlsx”[72]. The Stratified sampling tool for area estimation was used to calculate land-use change areas, developed by FAO Open Foris project and available at https://github.com/openforis/accuracy-assessment. The activity data's uncertainty is the bias between the adjusted (reference data) and estimated (land use maps) areas. The uncertainty values are as follows: Uncertainty of hectares of deforestation from 1998-2011: 6% Uncertainty of hectares of non-forest that changed to forest land: 8% Uncertainty of hectares of forests remaining forests in 1998-2011: 1%

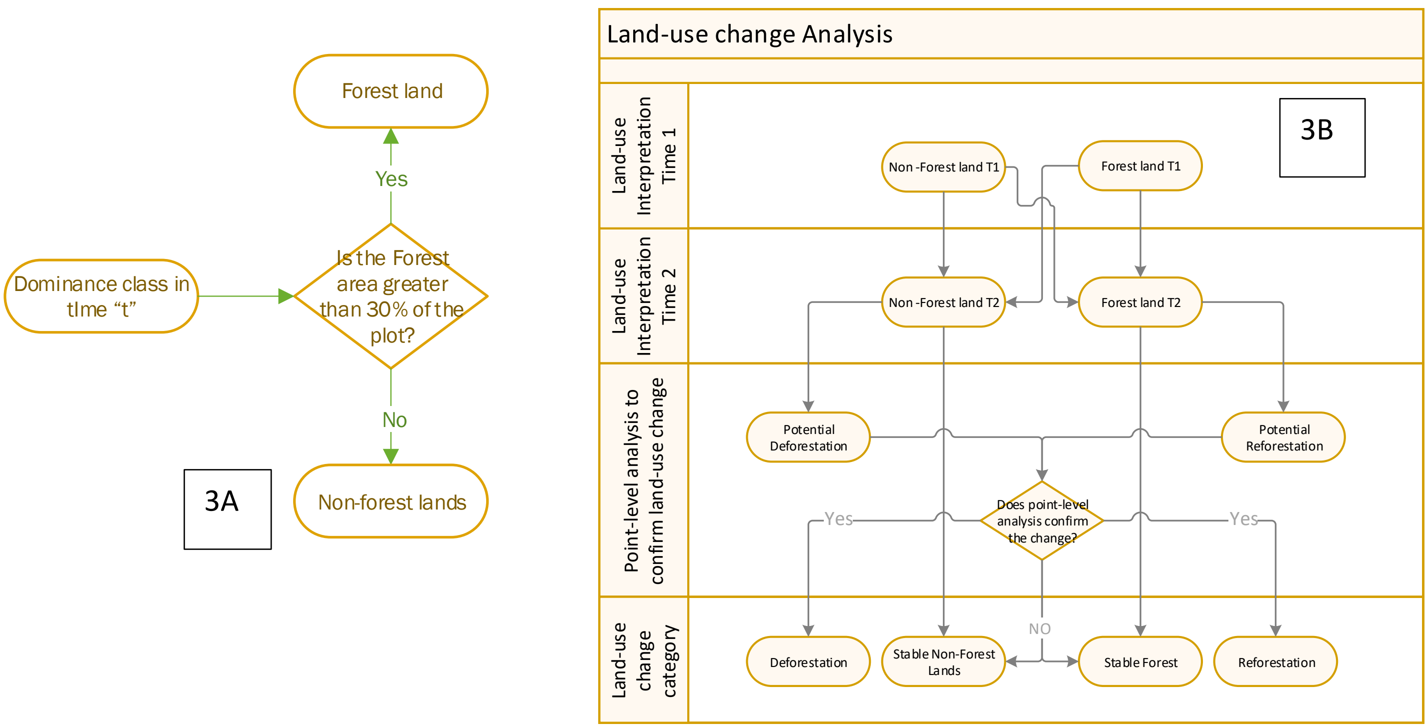

Figure 3: A. The dominance class was defined considering a threshold of 30% forest cover. If the forest area is greater than 30%, the sampling plot is classified as forest land. (B) The estimate of land-use change areas is not based on dominance class (DC) in t1 and t2. DC was used to identify potential land-use change sampling points. These plots were re-analyzed; only the sampling plots where the supervisor confirmed the land-use change were considered valid points for estimating the land-use change areas.

[72] Accuracy Assessment 2018-2019 analysis can be accessed in the following: link https://drive.google.com/file/d/1l-47qEum84ksEYC-ndmmePDFkxCj4SNz/view?usp=sharing

Table 7: Source of Activity Data and description of the methods for developing the data for estimate emissions from degradation during the monitoring period.

Parameters:	**Activity Data of Degradation (AD_{Deg}) Eq 2.4** **Activity Data of Permanent Forest Regeneration (AD_E) Eq. 2.5**
Description:	Degradation: Hectares of forest with a reduction of canopy cover during the monitoring period. Forest Enhancement: Hectares of forest with an increase of canopy cover during the monitoring period
Data unit:	Hectares
Source of data	
Introduction	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 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. Reference data to estimate Degradation AD were collected by Aguilar (2020)[73].
Type of sampling	A Systematic Sampling (SYS) over the updated version of Level 1 Systematic Grid with 10,825 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 2017-2019. The 4377 points classified as permanent forest land according to the MCS 2012/13 map were assessed in this monitoring period. 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 i. Stable very degraded forest
Data Sources	The range of dates of the images presented in the table below was used. Priority was given to operating with high-resolution dated imagery available in Google Earth. The next priority was to use the dated Planet images available in the NICFI Program.

[73] Aguilar, L. (2020). Evaluación Visual Multitemporal para la determinación de la degradación forestal para los periodos 2014-2015-2017-2019 y determinación de datos de referencia para periodo 2017-2019. Tercer Informe. Retrieved from https://drive.google.com/file/d/1ERutZo6vNI6MXUCmlrky7wiaeOqOLMqh/view?usp=sharing

Table 8: Data sources and Imagery date range used in the canopy cover evaluation on permanent forest for the monitoring period 2018-2019.

Monitoring Year	Imagery date range	Data sources
2018	July 2017 – June 2018	• Google Earth dated high-resolution imagery repository (CNES/Airbus, Maxar Technologies) • Planet dated imagery of NICFI Program • Other sources (Bing Map, Copernicus, Landsat 7, US Geological Survey)
2019	July 2019 – June 2020	

Interpretation Key

The Version 1.2. 2018. SIMOCUTE land cover class key was used to determine canopy cover:

Table 9: Land cover key used in the land cover evaluation protocol for the years 2018, and 2019.

Code	Land cover class
1100	Trees
1200	Shrubs
1300	Herbaceous
1400	Palm
Not included	Bromeliads
1500-1600	Greenhouse
1700	Other vegetation
2000-2200	No vegetation
3000	Water
4000	Clouds and shadows
5000	Not classifiable

Data collection

See QA/QC procedures.

Data analysis

The country developed a tool for calculating emissions and removals on permanent forest lands (¨Herramienta_degradación.xlsx¨ [74]). The database for the visual interpretation of canopy cover for the monitoring period 2016-2018 and monitoring period 2018-2019 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 (1998-2011) 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 points inside protected areas and farther than 500 meters from a road 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 monitoring period 2018-2019. It is important to indicate that it was unnecessary to update proximity analysis to roads and protected areas to estimate anthropogenic carbon flux since the 1: 5000 layer of roads and the layer of protected areas have not been updated.

Value applied in monitoring period:

- **2,194,030** hectares of forests remaining forests in the monitoring period (2018-2019)
- **55,130** hectares of anthropogenic degradation (2018-2019)
- **39,538** hectares of anthropogenic forest enhancement (2018-2019)

QA/QC procedures applied

[74] Degradation tool can be accessed in the following link:
https://drive.google.com/file/d/1GG3Z_QMWBKGNRdXnF_TdWP1ipH9dX5iH/view?usp=sharing

	Aguilar (2020) prepared a land cover evaluation protocol to reduce the uncertainty of the land cover classification due to: a) the bias associated with the spatial registration of the reference image, b) the interpreter bias in the assignment of the land cover class; and c) interpreter variability. The following procedures were applied during the collection of reference data: **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). **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. **Data registry forms**: The canopy cover change information was recorded in standard Collect Earth Desktop forms (see section 1.7 in Aguilar, 2020). **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. **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. **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. **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. **Consistency between reference and monitoring period data**: The analyst reviewed the consistency of 2018 canopy cover data with the 2016 evaluation performed by Ortiz-Malavassi (2017). **Treatment of plots with forest cover less than 30%:** The analyst made the degradation analysis over the systematic grid points 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.
Uncertainty associated with this parameter:	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. Uncertainty of changes in canopy cover to identify areas of degradation and forest enhancement from 2018-2019 vary depending on the forest type and the conversion class. It is based on the sampling error.

4 QUANTIFICATION OF EMISSION REDUCTIONS

4.1 ER Program Reference level for the Monitoring / Reporting Period covered in this report

Costa Rica made technical corrections to the Reference Level of the ER program. These corrections are not related to any change to policy and design decisions that could affect the Reference Level (carbon pools and gases, GHG sources, reference period, forest definition, REDD+ activities, Accounting Area, forest types, and REDD+ activities). The country has replaced emission/removal factors for degradation by higher precision EF based on additional sample plots and corrected an error in the canopy cover change database during the identification of very degraded forests. Paragraph 3 positive list of the Guideline on the application of Methodological Framework Number 2 includes these technical corrections. Costa Rica has updated the FREL/FRL by recalculating the forest degradation emissions, as follows:

a. Increasing the number of field observations, following the methodology used in the NFI to determine aboveground biomass 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 used to develop new degradation emission factors.

b. Updating the degradation categories in the aboveground biomass vs. canopy cover models as: intact forests have a cover of 85-100%, degraded forests have a cover of 60-85%, and very degraded forests a cover 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 (1998-2011) were classified as degraded, whereas primary forest areas that went from very degraded to degraded, very degraded to intact, or degraded to intact were identified as forest enhancement areas.

c. An error was corrected in the database identifying forests classified as previously degraded. Prior to this correction, forests with a canopy cover of between 0% and 59% were classified as very degraded. To account for the fact that areas with less than 30% canopy cover are identified as non-forests, this classification was corrected to only include forests with a canopy cover between 59% and 30%.

d. Further, the methodology to estimate total uncertainty was updated as the previous approach of estimating the final confidence interval of the final distribution of Monte Carlo simulations was deemed to have led to unrealistically low values.

Further detail about the adjustments made to the reference level as compared to that the estimates provided in the most recent version of the ER Program Document are presented in detail in Annex 4.

Year of Monitoring / Reporting period *t*	Average annual historical emissions from deforestation over the Reference Period (tCO_{2-e}/yr)	If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO_{2-e}/yr)	If applicable, average annual historical removals by sinks over the Reference Period (tCO_{2-e}/yr)	Adjustment, if applicable (tCO_{2-e}/yr)	Reference level (tCO_{2-e}/yr)
2018	5,985,795	1,383,974	-4,784,051	-1,547,370	2,585,717
2019	5,985,795	1,383,974	-4,784,051	-1,547,370	2,585,717
Total	**11,971,589**	**2,767,948**	**-9,568,102**	**-3,094,740**	**5,171,435**

4.2 Estimation of emissions by sources and removals by sinks included in the ER Program's scope

The quantification of emissions and removals during the Reporting Period was done following the measurement and monitoring procedures described in section 2.2.1-Figure 2, the equations 2-5 described in section 2.2.2 of this Monitoring Report, and applying the approaches to determine activity data and emission or removal factors included in the data and parameter tables on section 3 above. As in the Reference Level period, the total emissions or removals associated with each of the REDD+ activities were calculated as the Annual emissions or removals were estimated for all land transitions ¨*i*¨ by REDD+ activity, and then adding the results for all selected REDD+ activities for each year:

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

Equation 6

Where:

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

REDD+ Secretariat of Costa Rica estimated emissions by sources and removals by sinks included in the ER Program with two separate integration tools: deforestation and degradation[75]. The country also prepared an Emission Reduction Calculation Tool based on the FREL and Degradation tool results[76].

Year of Monitoring / Reporting Period	Emissions from deforestation (tCO_{2-e}/yr)	If applicable, emissions from forest degradation (tCO_{2-e}/yr)*	If applicable, removals by sinks (tCO_{2-e}/yr)	Net emissions and removals (tCO_{2-e}/yr)
2018	826,324	2,513,265	-6,098,753	-2,759,164
2019	854,009	2,513,265	-5,922,964	-2,555,690
Total	1,680,333	5,026,529	-12,021,717	-5,314,854

4.3 Calculation of emission reductions

Total Reference Level emissions during the Reporting Period (tCO_2-e)	5,171,435
Net emissions and removals under the ER Program during the Reporting Period (tCO_2-e)	-5,314,854
Emission Reductions during the Reporting Period (tCO_2-e)	10,486,289

[75] FREL and Degradation TOOL can be accessed in the following link: https://drive.google.com/drive/folders/1j5ogQjh6UBUkSw45m_eHmT60ey6FDeDS?usp=sharing

[76] Emission Reduction Calculation tool can be accessed in the following link: https://drive.google.com/file/d/1WDtlCl080dxOrlGRmydeOMCIy0eZdL_q/view?usp=sharing

5 UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS

5.1 Identification, assessment and addressing sources of uncertainty

Table 10: Sources of uncertainty to be considered under the FCPF MF

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	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?
		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 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	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?
		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 2018 canopy cover data with the 2016 evaluation performed by Ortiz-Malavassi (2017). ix. **Treatment of plots with forest cover less than 30%:** The analyst made the degradation analysis over the systematic grid points 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.			
Representative ness	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.	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?
		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.			
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)[77] guidelines. Due 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.	Low	Yes	Yes

[77] 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?
	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 Factor					
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

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?
Wood density estimation	Systematic and Random	The wood density values were obtained directly from specialized publications (Biomass estimation tool developed by SINAC, IPCC 2003[78]; Myers 2013[79]; Tree Functional Attributes and Ecological Database, 2018[80]). 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 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.	Low	No	No
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)[81]. 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
Representative ness	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[82], to avoid errors during the process of data preparation.	Low	Yes	No

[78] 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.

[79] 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

[80] Tree Functional Attributes and Ecological Database. (2018). Wood Density. Recuperado el 10 de 12 de 2018, de http://db.worldagroforestry.org/.

[81] 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.

[82] The manual of FREL Tool can be accessed in the following link: https://drive.google.com/file/d/1INuL5Jld7nlKVsAf7mRsEepm2n8WRVpT/view?usp=sharing

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?
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

5.2 Uncertainty of the estimate of Emission Reductions

Parameters and assumptions used in the Monte Carlo method

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Area (hectares) of deforestation	10,774 ha in 2018 and 2019	Sampling error	Truncated normal	Minimum value assumed to be 0
Area (hectares) of forests remaining forests	2,198,453 ha in 2018 and 2,194,822 ha in 2019	Sampling error	Truncated normal	Minimum value assumed to be 0
Area (hectares) of new forests	1,850,719 ha in 2018 and 2019	Sampling error	Truncated normal	Minimum value assumed to be 0
Change in percent canopy cover in degraded and regenerated forests	Varies depending on the level of degradation and regeneration	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for very moist and rain forests – primary	313.69	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for moist forests - primary	203.99	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for dry forests – primary	199.19	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for mangroves – primary	253.74	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for palm forest - primary	229.81	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for secondary forests	Varies depending on age (1-400 years) and forest type	Sampling error	Truncated normal	Minimum value assumed to be 0

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Aboveground biomass for annual cropland	83.57	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for permanent cropland	Varies depending on age (1-400 years)	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for paramos	126.87	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for very moist and rain forests – primary	71.97	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for moist forests - primary	48.32	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for dry forests – primary	47.27	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for mangroves - primary	53.96	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for secondary forests	Varies depending on age (1-400 years) and forest type	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for annual cropland	21.16	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for permanent cropland	Varies depending on age (1-400 years)	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for paramos	31.13	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for very moist and rain forests – primary	49.5	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for moist forests - primary	48.27	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for dry forests – primary	56.47	Sampling error	Truncated normal	Minimum value assumed to be 0

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Deadwood for mangroves - primary	6.95	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for palm forest - primary	5.97	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for secondary forests	Varies depending on age (1-400 years) and forest type	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for grassland	8.28	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for very moist and rain forests – primary	10.05	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for moist forests - primary	8.01	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for dry forests – primary	22.73	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for mangroves - primary	0.97	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for palm forest - primary	0.96	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for secondary forests	Varies depending on age (1-400 years) and forest type	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for permanent cropland	Varies depending on age (1-400 years)	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in very moist and rain forests	5.03	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in moist forests	3.86	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in dry forests	3.47	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in mangroves	3.19	Sampling error	Truncated normal	Minimum value assumed to be 0

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Aboveground biomass-canopy cover ratio in palm forests	4.26	Sampling error	Truncated normal	Minimum value assumed to be 0

Quantification of the uncertainty of the estimate of Emission Reductions

The country estimated the uncertainty of aggregated Emission Reductions based on Monte Carlo analysis. A total of 10,000 iterations were calculated for the cumulative emissions of reference and monitoring period[83].

		Total Emission Reductions*
A	**Median**	9,781,192
B	**Upper bound 90% CI** (Percentile 0.95)	16,347,028
C	**Lower bound 90% CI** (Percentile 0.05)	3,898,823
D	**Half Width Confidence Interval at 90% (B – C / 2)**	6,224,102
E	**Relative margin (D / A)**	63.6%
F	**Uncertainty discount**	12%

*Remove forest degradation if forest degradation has been estimated with proxy data.

5.3 Sensitivity analysis and identification of areas of improvement of MRV system

In order to identify the relative contribution of each parameter to overall uncertainty, a sensitivity analysis was conducted in which the uncertainty of each parameter was selectively removed prior to running Monte Carlo simulations and combining uncertainties. As shown in the table below, the carbon stocks used to estimate emission factors for deforestation were by far the largest source of uncertainty. When this uncertainty source was removed, total uncertainty decreased by over 54%. The mapping error of new forests during the reference period, the error of the ratio of aboveground biomass to percent canopy cover, and changes in canopy cover in forests remaining forests during the monitoring period also had sizable impacts on uncertainty. When the uncertainty for each of these was removed, uncertainty decreased by 6.9%, 6.8%, and 6.2% respectively[84].

For certain sources of uncertainty, when selectively removed, the overall uncertainty of the emission reductions increased, albeit minimally. This can be explained by the fact that, when Monte Carlo simulations of multiple error sources are combined (say through multiplication), depending on the spread and distributions of the different sources of error, the final distribution may end up being narrower than when there are fewer sources combined. For example, when values at one end of the distribution are multiplied by values at the other end of another distribution, the resulting final values may end up nearer to the average.

Sensitivity analysis results

Error source selectively removed from uncertainty analyses	Final % uncertainty of ERs	% change in total uncertainty of ERs
Mapping error (AD) of deforestation in the reference period	63.3%	0.6% decrease

[83] MC propagation analyses to estimate uncertainty of Emission Reductions can be found in the following link: https://drive.google.com/drive/folders/1sPjBD5kjd8JN6vXvLb6LaaTUjdRh8VtT?usp=sharing

[84] Sensitivity analyses of the uncertainty estimate for Emission Reductions can be found in the following link: https://drive.google.com/drive/folders/1sPjBD5kjd8JN6vXvLb6LaaTUjdRh8VtT?usp=sharing

Mapping error (AD) of deforestation in the monitoring period	63.6%	0.1% increase
Carbon stocks used to estimate deforestation emission factors	29.2%	54.2% decrease
Mapping error (AD) of new forests in the reference period	59.3%	6.9% decrease
Mapping error (AD) of new forests in the monitoring period	64.0%	0.5% increase
Carbon stocks used to estimate enhancements in new forests	62.3%	2.1% decrease
Mapping error (AD) of forests remaining forests in the reference period	63.7%	0.2% increase
Mapping error (AD) of forests remaining forests in the monitoring period	63.9%	0.4% increase
Changes in canopy cover in forests remaining forests in the reference period	63.2%	0.6% decrease
Changes in canopy cover in forests remaining forests in the monitoring period	59.7%	6.2% decrease
Ratio of aboveground biomass (in t CO_2e) to % canopy cover	59.3%	6.8% decrease
Carbon stocks used to estimate enhancements in forests remaining forests	63.7%	0.2% increase

6 TRANSFER OF TITLE TO ERS

6.1 Ability to transfer title

FONAFIFO will distribute direct payments or monetary benefits from the Emissions Rection Purchase Agreements (ERPA) to forest landowners according to Benefit Sharing Plan. REDD+ Secretary has designed a Standards and Procedure Manual for the Emissions Reduction Payment Program, setting the technical and legal requirements to enter the ER Program and sign a CREF. The landowners need a Forest Emissions Reduction Agreement (its acronym in Spanish is CREF) duly signed with FONAFIFO. The amount of compensation for forest owners is fixed and will depend on forest area contribution contributing to forest emissions reduction. A total of 635,000ha of natural forests and around 6,300 beneficiaries could participate in this mechanism. This area and beneficiaries would be added to active beneficiaries of the Payment Program Environmental Services (PPES) administered by FONAFIFO.

The REDD+ Secretary designed a recruitment plan with three options. This Plan seeks to recruit the most significant number of beneficiaries of the ER Program and ensure at least 55% of forest land in the country.

i. **Recruitment of former PES beneficiaries/applicants**: FONAFIFO's historic PES database consultation to identify potential beneficiaries who are no longer receiving PES or were not suitable to participate because they did not meet the priorities of the PPES. REDD Secretariat will contact the potential beneficiaries, phone calls or email to inform the ER Program and their participation.
ii. **Engagement of Forestry Organizations**: The principal forest owner organizations will be contacted, seeking their partners' involvement.
iii. **New call for participation**: a new call will be made to explain the ER Program and invite forest owners to participate.

6.2 Implementation and operation of Program and Projects Data Management System

In October 2020, the REDD+ Secretary of Costa Rica and FONAFIFO called for the first time participating in the Emissions Reduction Program (PRE) and later to sign Emissions Reduction Contracts (CREF). FONAFIFO invited forest owners to express their interest in participating and learn about the Program by filling out a form on FONAFIFO's website. Farm owners with forests, natural regeneration, forest management (primary or secondary), or forest plantations filled out the application. FONAFIFO promoted the campaign in different media such as national circulation newspapers, Facebook, website, and individual invitations to several organizations or relevant stakeholders. As part of the ER Program's entry process and to demonstrate ownership of emission reductions, REDD Secretariat is building a geospatial database with the potential ER Program beneficiaries, including private forest owners, Indigenous peoples, SINAC, FONAFIFO, and other institutions administering State Natural Heritage.

The geodatabase allowed the verification of the farms´ location, land tenure conflicts among private landowners, or the overlaying among the ER Program's different beneficiaries. Also, we have created a digital archive of land title studies and cadastral plans. The geodatabase includes a spatial registry by farm, with a forest areas polygon for each potential beneficiary of CREF.

The REDD+ Secretary has implemented the following steps to include a potential beneficiary in the geodatabase:

1. **FONAFIFO'S Database Review**: REDD+ Secretary is looking for expired PESs agreements and PES applications that have not entered the PPES. This analysis is in process and constitutes a significant percentage of the strategy for recruiting farms (second phase) that REDD+ Secretary expects to start in the coming months.
2. **Location of farm polygons**: To locate the farms, the analyst builds the farms' polygons from the cadastral plans' information (azimuth/distance table and the graph with the geographic location).
3. **Effective area calculation**: The analyst will determine the forest area's location according to the MCS 2019/20 land-use map. If a detailed analysis is required, the analyst will define forest area with high-resolution imagery, Google Earth, or planet imagery.

4. **Field visits**: The REDD+ Secretary visited the properties of the potential beneficiaries to identify and resolve any location issue. The Secretary has visited eighty locations with entry applications to the ER Program. During this first phase of visits, the potential participants have shown disinterest due to the possible payment. The emission reduction compensation has resulted unattractive for the landowners compared with the current PES amount. On the other hand, property accessibility has resulted in an issue. Remote properties usually do not maintain clear boundaries, complicating the cadastre plan's verification, increasing the recruitment cost.
5. **Spatial Overlay analysis**: The database allows REDD+ to locate overlayed areas between private owners. Also, to determine if the overlaying is due to location errors in the cadastre plan. The REDD Secretariat developed a procedure to implement the overlay analysis.
6. **Legal analysis**: After the overlay issues have been solved, the REDD Secretary does a legal analysis and then proceeds with the signature of the CREF.

The CREF mechanism's participation resulted from the ER Program's promotion in October 2020, is of 42,287 hectares of private farms. REDD+ Secretariat received 466 applications to participate in the ER Program, with 33,338 hectares of forest, of which 52% corresponds to registered farms and 48% to unregistered farms.

The unregistered farms have the most significant potential to enter the ER Program due to the impossibility of participating in PPES. However, unregistered farms lack several legal requirements that are difficult to obtain. The REDD+ Secretariat is looking for options to engage unregistered farms since they represent a high ownership and farm size percentage. These represent an average area of 139 has per farm. Also, their participation becomes vital to achieve the area target within the ER Program and recognizing the effort these holders make in conservation. These groups' involvement was low because they guessed the unregistered farms are not suitable to enter conservation programs such as PPES.

Also, the ER Program's promotion did not have the expected reaction in registered farms. The ER Program's payments and conditions were not attractive enough for the forest owners, especially for small farms. It is crucial to find a way to involve these small farm owners in the ER Program because they are the most prone to deforest their land.

We have significant challenges on reporting ownership of emissions reduction, which we are trying to solve. The preliminary results of the first call for participation in the ER Program are not satisfactory. The country preliminary estimated a transfer capacity of 55% of the total emission reductions. Until March 2021, the REDD Secretariat has achieved the documentation of 14% of the emission reductions (see Tables 11 and 12). The recruitment process will be open until November 2021. The final figure of Forest Area included in the ER Program will be defined in December 2021.

The Table 11 summarizes the potential land tenure conflicts identified between different forest owners, considering the geodatabase building process's progress until March 2021. The overlay analysis is in progress. Legal analysis of private farms has not been done yet. If the study reveals any issues, the total CREF area can be affected and lowered. Indigenous territory corresponds to the total area available and outside the PSA. The analysis of forest areas is pending for these lands. There is an overlay issue between indigenous territories and Protected Areas. REDD+ Secretariat has addressed this issue with the Minister of the Environment and the director of SINAC. It is expected to reach a forthcoming agreement for the corresponding claim of emission reductions. Regarding State Natural Heritage, SINAC is working on completing the information indicated in the table. Still, the documented percentage of forest lands in the State Natural Heritage is deficient.

Table 11: Potential land tenure conflicts identified by REDD Secretariat among different forest owners, considering the geodatabase building process's progress until March 2021.

Type of ownership	Emissions Reduction Program Beneficiaries	Number of properties	Area outside Protected Wild Areas (ha)	National Park, Biological Reserves or National Monument Area (ha)	Other Protected Areas (ha)	General Total (ha)	Potential Forest Effective area (ha)
a. Public owners	SINAC*	1,114.0	3,898.4	142,373.0	11,454.9	157,726.4	0.0
	Other state Institutions	1,524.0	5,564.1	550.1	383.4	0.0	6,497.6
	Carbon rights (PSA) from FONAFIFO	5,762.0	318,037.6	5,032.0	75,778.3	0.0	**398,847.8**
b. Private owners	Sustainable Biodiversity Fund	106.0	1,516.4	0.0	934.7	0.0	2,451.3
	Individual forest owners (CREF express of interest)	466.0	22,856.1	854.8	9,636.3	0.0	33,338.1
c. Indigenous Territories		25.0	199,798.1	5,646.9	15,779.9	221,224.9	0.0
**Total		**8,997.0**	551,670.6	154,448.0	86,732.6	378,951.3	**441,134.8**

*SINAC: Corresponds to the State-owned registered lands. Other's areas in National Parks, Biological Reserves, and State Natural Heritage are not yet included. SINAC is processing the information on private properties with pending payment.

**Total: Corresponds to the total forest area that can enter the ER Program processed until March 2021. The recruitment process will be open until November 2021. The final figure of Forest Area included in the ER Program will be defined in December 2021.

Table 12. Forest area identified until March 2021 as eligible to participate in the Emission Reduction Program of Costa Rica.

<table>
<tr><th colspan="2" rowspan="2">Type of Owner</th><th colspan="2">Forest Area (ha)</th><th rowspan="2">Percentage of total forest area</th><th rowspan="2">Information Source</th></tr>
<tr><th>Preliminary estimate of participation in ERP</th><th>Potential Area identified until March 2021</th></tr>
<tr><td colspan="2">SINAC</td><td>678,735</td><td>-</td><td>-</td><td>Inventory of Protected Wildlife Areas, State Natural Heritage - SINAC is processing the information on private properties with pending payment</td></tr>
<tr><td rowspan="5">Private owners</td><td>FONAFIFO: PES program</td><td>400,000</td><td>401,299.1</td><td>12.7%</td><td>PES agreements with assignment of current environmental services rights - Control and Monitoring, FONAFIFO.</td></tr>
<tr><td>Forest Owners Organizations</td><td>50,000</td><td>-</td><td>-</td><td>Portion of Associates to NGOs such as FUNDECOR, CODEFORSA, ASIREA, COOPEAGRI and others. People who are associated with an organization and who are not currently in the PSA program.</td></tr>
<tr><td>Private Reserves</td><td>25,000</td><td>-</td><td>-</td><td>Network of Private Reserves</td></tr>
<tr><td>Individual forest owners who failed to reach the required score to participate in the Payment for Environmental Services Program (PES)</td><td>390,000</td><td>33,338.1</td><td>1.1%</td><td>FONAFIFO database. For 2017, FONAFIFO had an oversupply of farms not covered by the PES, on 65,000 hectares. The PES covers 20% of national forests.</td></tr>
<tr><td>Indigenous Territories</td><td>170,000</td><td>-</td><td>-</td><td>Estimates in amount of forest in indigenous territories.</td></tr>
<tr><td colspan="2">PNE under Agreements</td><td>25,000</td><td>6,497.6</td><td>0.2%</td><td>Forest lands of JAPDEVA, ICE, Local Governments, others. Lands managed by public institutions that have not been assigned to SINAC, because it does not have the capacity to manage them and therefore, they are kept in the name of other institutions</td></tr>
<tr><td colspan="2">Other forest lands that do not meet the eligibility criteria for benefit sharing.</td><td>1,422,602</td><td>-</td><td>-</td><td>This group of owners is not included in any of the previous categories.</td></tr>
<tr><td colspan="2">Total Forest Area</td><td>3,161,337</td><td>441,134.8</td><td>14%</td><td></td></tr>
</table>

6.3 Implementation and operation of ER transaction registry

The Government of Costa Rica has decided to use the FCPF ER Transaction Registry in conjunction with its own national registry, which is currently being developed as part of the National Climate Change Metrics System (Sistema Nacional de Métrica de Cambio Climático, SINAMECC). As part of the measures to avoid double counting of ERs generated from Costa Rica FCPF ER Program in the national transaction registry and the FCPF ER Transaction Registry, once the national registry is operational the Government of Costa Rica will only recognize, including for purposes of reporting to the Trustee, authorization and/or corresponding adjustments units that are duly registered in the Costa Rican national registry. Both Parties will take all reasonable efforts to ensure that the Costa Rican national registry component of SINAMECC and the FCPF ER Transaction Registry will incorporate all features necessary to enable communication and operational compatibility between the systems.

6.4 ERs transferred to other entities or other schemes

No ERs from the ER Program were sold, assigned, or used by any other entity for sale, public relations, compliance, or any other purpose, including ERs that have been set aside to meet Reversal management requirements under other GHG accounting schemes.

7 REVERSALS

7.1 Occurrence of major events or changes in ER Program circumstances that might have led to the Reversals during the Reporting Period compared to the previous Reporting Period(s)

Costa Rica uses the Reversal Risk assessment tool to determine the Reversal Risk Set-Aside Percentages for each of them. These risk factors, as specified in the ER-PD, are:

1. Default risk set by the FCPF (10%)
2. Lack of broad and sustained stakeholder support (low, 0%)
3. Lack of institutional capacities and/or ineffective vertical/cross sectoral coordination (low, 0%)
4. Lack of long-term effectiveness in addressing underlying drivers (low, 0%)
5. Exposure and vulnerability to natural disturbances (low, 0%)

This analysis revealed that the overall risk of reversals in the country is 10%. Costa Rica's circumstances have not changed and thus this risk of reversals is maintained during the monitoring period (see section 7.3 below). Costa Rica manages Reversal Risks through the use of an ER Program CF Buffer; a buffer reserve account has been established for this purpose in an appropriate ER Transaction Registry, following FCPF's registry conditions.

As shown in section 4, there have not been reversals during the reporting period, and Costa Rica reduced net emissions by 10.486.289 t CO_2e during the reporting period.

7.2 Quantification of Reversals during the Reporting Period

No reversals occurred during the reporting period.

A.	**ER Program Reference level for this Reporting Period (tCO_2-e)**	*from section 4.1*		
B.	**ER Program Reference level for all previous Reporting Periods in the ERPA (tCO2-e).**	*from previous ER Monitoring Reports*		**+**
C.	**Cumulative Reference Level Emissions for all Reporting Periods [A + B]**			
D.	**Estimation of emissions by sources and removals by sinks for this Reporting Period (tCO_2-e)**	*from section 4.2*		
E.	**Estimation of emissions by sources and removals by sinks for all previous Reporting Periods in the ERPA (tCO_2-e)**	*from previous ER Monitoring Reports*		
F.	**Cumulative emissions by sources and removals by sinks including the current reporting period (as an aggregate accumulated since beginning of the ERPA) [D + E]**			**–**
G.	**Cumulative quantity of Total ERs estimated including the current reporting period (as an aggregate of ERs accumulated since beginning of the ERPA) [C – F]**			
H.	**Cumulative quantity of Total ERs estimated for prior reporting periods (as an aggregate of ERs accumulated since beginning of the ERPA)**	*from previous ER Monitoring Reports*		**–**
I.	**[G – H], negative number indicates Reversals**			
If I. above is negative and reversals have occurred complete the following:				

J.	**Amount of ERs that have been previously transferred to the Carbon Fund, as Contract ERs and Additional ERs**	
H.	**Quantity of Buffer ERs to be canceled from the Reversal Buffer account [J / H × (H – G)]**	

7.3 Reversal risk assessment

Risk Factor	Risk indicators	Default Reversal Risk Set-Aside Percentage	Discount	Resulting reversal risk set-aside percentage
Default risk	*N/A*	**10%**	*N/A*	*10%*
Lack of broad and sustained stakeholder support	Land tenure conflicts, carbon rights conflicts, insufficient stakeholder consultation. Costa Rica is undertaking REDD+ readiness activities targeting governance issues, such as the land tenure and carbon rights conflict that affect the forest land owned by indigenous people in the country. These activities entail adopting improved governance structures and processes[85] that aim to eliminate the conflict and abate the risk it poses, thereby enhancing the long-term effectiveness of the REDD+ program. In addition, the mechanism to resolve carbon right disputes is defined in the REDD+ Decree No. 40464, which states the mechanisms of carbon trading and REDD+ Strategy financing. The strategies to reduce deforestation have been developed in consultation with groups with land tenure/rights conflicts in the country through FONAFIFO's safeguards system, i.e. indigenous peoples and agroforestry producers	**10%**	*Reversal Risk is considered low: 10% discount*	*0%*
Lack of institutional capacities and/or ineffective vertical/cross sectorial coordination	Insufficient experience implementing programs and policies, lack of cross-sectoral cooperation and between gov. levels. FONAFIFO is the focal point for the REDD+ program in Costa Rica, with several other government agencies playing supporting roles across sectors and government levels. FONAFIFO also defined the reference level during the REDD+ readiness phase, runs a Service Comptroller, and manages both the Feedback and Grievance Redress Mechanism (FGRM) and the ongoing National REDD+ Consultation process. In addition, the national REDD+ program proposes to expand the PES (Payment for Ecosystem Services) program, which has been ongoing since 1997. The PES program regulated through FONAFIFO evidences Costa Rica's capacity to successfully coordinate and implement forest protection programs at the national scale.	**10%**	*Reversal Risk is considered low: 10% discount*	*0%*
Lack of long-term effectiveness in addressing underlying drivers	Limited decoupling of deforestation and degradation from economic activities, lack of laws and regulations conductive to REDD+ objectives. Costa Rica has developed a REDD+ Strategy Implementation Plan[86] that defines priority actions under the Emissions Reduction Program. One of these priority actions entails promoting deforestation-free supply chains of commodities and subsistence activities driving deforestation in the	**5%**	*Reversal Risk is considered low: 5% discount*	*0%*

[85] Rodríguez Zúñiga and Arce Benavides, 2017. Marco de Gestión Ambiental y Social (MGAS) para el Plan de Implementación de la Estrategia Nacional REDD+ de Costa Rica. FONAFIFO, MINAE. 95 pp.
[86] Plan de Implementación de la Estrategia Nacional REDD+ Costa Rica. 2017. Versión 7. 57 pp.

	country. Additional actions to address drivers of deforestation and degradation have been taken since the reference period, such as the inclusion of representative agents of deforestation (i.e. crop and livestock farmers) or degradation (i.e. illegal selective loggers) in stakeholder consultations and the benefit sharing plan. This has resulted in emission reductions and/or removals are listed in Section 7 of this monitoring report.			
Exposure and vulnerability to natural disturbances	Exposure and vulnerability to natural disturbances and disasters, limited capacity and/or experience in preventing them. Costa Rica considers the following natural risks affecting its forest lands: • Low-intensity natural disturbances are frequent and cause small and diffuse impacts that cannot be easily differentiated from the impacts caused by anthropogenic factors. The emissions caused by the these disturbances are measured through the degradation accounting approach but excluded from the degradation reference level and will be excluded in future measurement reports of the Program results, thereby posing no risk of reversals. • The high-intensity natural disturbances that can occasionally result in significant impact occur at a lower frequency. Examples of these disturbances are volcanic eruptions, earthquakes/tsunamis and extreme climate events. Most of the impact areas of volcanic eruptions are easily identifiable in the Landsat images and can be clearly separated from the impacts caused by anthropogenic activities. For this reason, the impacts on forests caused by these volcanic events have been excluded from the reference level, although they are transparently reported. The same will be done in future reports on the measurement of the program results. Since these areas have been excluded, their risk of reversals in Costa Rica is zero. Geological and extreme weather risks, on the other hand, are low.	**5%**	*Reversal Risk is consider ed low: 5% discount*	*0%*
		Total reversal risk set-aside percentage		*10%*
		Total reversal risk set-aside percentage from ER-PD or previous monitoring report (whichever is more recent)		*10%*

8 EMISSION REDUCTIONS AVAILABLE FOR TRANSFER TO THE CARBON FUND

A.	Emission Reductions during the Reporting period (tCO_2-e)	*from section 4.3*	10,486,289
B.	If applicable, number of Emission Reductions from reducing forest degradation that have been estimated using proxy-based estimation approaches (use zero if not applicable)		N/A
C.	Number of Emission Reductions estimated using measurement approaches (A-B)		10,486,289
D.	Conservativeness Factor to reflect the level of uncertainty from non-proxy based approaches associated with the estimation of ERs during the Crediting Period	*from section 5.2*	12%
E.	Calculate (0.15 * B) + (C * D)		1,258,355
F.	Emission Reductions after uncertainty set-aside (A – E)		9,227,934
G.	Number of ERs for which the ability to transfer Title to ERs is still unclear or contested at the time of transfer of ERs	*from section 6.1*	0
H.	ERs sold, assigned or otherwise used by any other entity for sale, public relations, compliance or any other purpose including ERs that have been set-aside to meet Reversal management requirements under other GHG accounting schemes	*From section 6.4*	0
I.	Potential ERs that can be transferred to the Carbon Fund before reversal risk set-aside (F – G – H))		9,227,934
J.	Total reversal risk set-aside percentage applied to the ER program	*From section* ***Error! Reference source not found.***	10%
K.	Quantity of ERs to allocated to the Reversal Buffer and the Pooled Reversal Buffer (multiply I and J)		922,793
L.	Number of FCPF ERs (I – L).		8,305,141

The following annexes are being completed and will be made public as soon as they are available:

ANNEX 1: INFORMATION ON THE IMPLEMENTATION OF THE SAFEGUARDS PLANS

ANNEX 2: INFORMATION ON THE IMPLEMENTATION OF THE BENEFIT-SHARING PLAN

ANNEX 3: INFORMATION ON THE GENERATION AND/OR ENHANCEMENT OF PRIORITY NON-CARBON BENEFITS

ANNEX 4: CARBON ACCOUNTING - ADDENDUM TO THE ERPD

Technical corrections

Technical corrections included in this annex are not related to any change to policy and design decisions that could affect the Reference Level (carbon pools and gases, GHG sources, reference period, forest definition, REDD+ activities, Accounting Area, forest types, and REDD+ activities).

The country has replaced emission/removal factors for degradation by higher precision EF based on additional sample plots and corrected an error in the canopy cover change database during the identification of very degraded forests. Paragraph 3 positive list of the Guideline on the application of Methodological Framework Number 2 includes these technical corrections. Costa Rica has updated the FREL/FRL by recalculating the forest degradation emissions, as follows:

e. Increasing the number of field observations, following the methodology used in the NFI to determine aboveground biomass 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 used to develop new degradation emission factors.
f. Updating the degradation categories in the aboveground biomass vs. canopy cover models as: intact forests have a cover of 85-100%, degraded forests have a cover of 60-85%, and very degraded forests a cover 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 (1998-2011) were classified as degraded, whereas primary forest areas that went from very degraded to degraded, very degraded to intact, or degraded to intact were identified as forest enhancement areas.
g. An error was corrected in the database identifying forests classified as previously degraded. Prior to this correction, forests with a canopy cover of between 0% and 59% were classified as very degraded. To account for the fact that areas with less than 30% canopy cover are identified as non-forests, this classification was corrected to only include forests with a canopy cover between 59% and 30%.
h. Further, the methodology to estimate total uncertainty was updated as the previous approach of estimating the final confidence interval of the final distribution of Monte Carlo simulations was deemed to have led to unrealistically low values.

Detailed information about these updates is provided below (sections 1 and 2 of this Annex).

Summary of technical corrections

Degradation emission factors:
Degradation emission factors were updated based on the updated data obtained in 2018 from the 100 plots established to assess forest degradation in the country. Previously, to estimate emissions per hectare of degraded forest, linear models of the relationship between crown cover and aboveground biomass had been used for different forest types: very moist and rain forests (BMHP), moist forests (BH), dry forests (BS), mangroves (M), and palms (P).

With the new data (from 2018), it was possible to improve the analysis. In particular, the average ratio between aboveground biomass and canopy cover was estimated for each forest type (Table 3). It was decided to use this methodology instead of the previous methodology (applying an equation of the linear relationship between crown cover and biomass), because the results of the other methodology showed very weak relationships in several of the forest types. In contrast, by applying an average fixed relationship between aboveground biomass and crown cover, their associated uncertainties were much lower. In other words, this new methodology better explains biomass losses. As in the previous case, biomass was converted to carbon by a factor of 0.47 and to CO_2 by a factor of 44/12. The uncertainties were calculated from the standard deviations of the identified relationships.

Table 3. Ratio aboveground biomass to percent canopy cover

	Ratio Aboveground biomass ($t\ CO_2e\ ha^{-1}$)/ % canopy cover	Uncertainty (%)
Wet and rain forest (BMHP)	5.03	16%
Moist forests (BH)	3.86	22%
Dry forests (BS)	3.47	24%
Mangroves (M)	3.19	32%
Palm forests (P)	4.26	37%

As a result, emissions due to annual losses of aboveground biomass from identified canopy cover changes were estimated. For example, if the canopy cover in a dry forest area was reduced by 20%, it was estimated that the biomass in this area was reduced by 69.4 t CO_2e per hectare (20*3.47 = 69.4 t CO_2e).

Corrections to the area of forests classified as severely degraded:
An error was corrected in the database identifying forests classified as previously degraded. Prior to this correction, forests with a canopy cover of between 0% and 59% were classified as very degraded. To account for the fact that areas with less than 30% canopy cover are identified as non-forests, this classification was corrected to only include forests with a canopy cover between 59% and 30%. This, in turn, reduced the area identified as being degraded as well as the area identified as being regenerated during the monitoring period (Table 4).

Table 4. Degraded and regenerated estimated areas prior to and post corrections

	Prior to corrections		Post corrections	
	Annual degraded area (ha)	Annual regenerated area (ha)	Annual degraded area (ha)	Annual regenerated area (ha)
Wet and rain forest (BMHP)	9,971	41,531	4,137	6,114
Moist forests (BH)	35,172	10,324	5,930	4,781
Dry forests (BS)	2,080	275	368	92
Mangroves (M)	-	1,060		46
Palm forests (P)	2,041	432		276
Total	49,264	53,621	10,435	11,308

Removal of accounting of degradation and regeneration within different degradation class:
Previously, all emissions and removals were calculated based on changes in canopy cover including within different degradation classes (i.e., within intact forests that remain intact, within degraded forests that remain degraded, and within very degraded forests that remain very degraded). The emissions and removals within these forest classes, however, were relatively small and their associated uncertainty were high. As a result, they were excluded, and only carbon fluxes between different degradation classes remained.

Updates to the calculations of final uncertainty:
To estimate the final uncertainties of emissions and removals from different REDD+ activities and the final uncertainty of net emissions from all these activities, the percentile method, in which the confidence interval was estimated by subtracting the 5^{th} percentile value from the 95^{th} percentile value of the final distribution of the Monte Carlo simulations, was applied instead of the bootstrapping method. This change was made because, since the most recent version of the ERPD, the bootstrapping method has been deemed to greatly underestimate uncertainty.

7. CARBON POOLS, SOURCES AND SINKS

7.1 Description of Sources and Sinks selected

Sources/Sinks	Included?	Justification/Explanation
Emissions from deforestation	Yes	According to the National GHG inventory and for purposes of the RL, deforestation was defined as Forest land converted to other land use categories in the year of conversion. Activity data 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. 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.
Emissions from forest degradation	Yes	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.
Enhancement of forest carbon stocks	Yes	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. of the ER-PD for more details on land classification). C stock enhancement in secondary[87] Forest land remaining Forest land was estimated using growth models developed in Costa Rica (Cifuentes, 2008) [88]. 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 of the ER-PD). 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.
Conservation of forest C stocks	No	Not applicable.

[87] 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.

[88] 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.

Sources/Sinks	Included?	Justification/Explanation
Sustainable management of forests	No	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[89] tCO_2-e yr^{-1}, and represent 1.7% of the yearly net emissions observed during the Reference Period (FREL/FRL 2,585,717 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 every 15 years.

7.2 Description of carbon pools and greenhouse gases selected

The following Carbon Pools and greenhouse gases will be accounted as part of the ER Program. The ER Program accounts all significant Carbon Pools and greenhouse gases except Soil Organic Carbon (SOC) due to the lack of sufficient reliable data available to estimate emission factors.

Regarding the SOC carbon pool, it is essential to mention that Costa Rica is committed to improve SOC data. The country aims to increase the organic carbon content of soils and make markets pay for ecological services through the RECSOIL program. The initiative is still on track after being announced at the end of 2020. RECSOIL is an FAO project designed to address the key challenges humanity faces today within an enabling framework integrated by a series of institutions and commitments related to climate change and sustainability. The program's main objective is to support and improve the national and regional GHG mitigation and carbon sequestration initiatives. This will be achieved by establishing a robust methodology that allows carbon credits to be traded.

Carbon Pools	Selected?	Justification/Explanation
Above Ground Biomass (AGB)	Included	Major carbon pool impacted by all REDD+ program activities. Data is derived from the National Forest Inventory.
Below Ground Biomass (BGB)	Included	Major carbon pool impacted by mortality of trees accounted under deforestation, and growth of trees accounted under carbon stock enhancements from reforestation. Data is derived from the National Forest Inventory.
Dead Wood	Included	Deforestation has a negative impact on this pool, whereas reforestation has a positive impact. Thus, it is included because reliable country-specific data exists. Data is derived from the National Forest Inventory.
Litter	Included	Deforestation has a negative impact on this pool, whereas reforestation has a positive impact. Thus, it is included because reliable country-specific data exists. Data is derived from the National Forest Inventory.
Soil Organic Carbon (SOC), including peat	Excluded	This pool was excluded from the reference level because of the lack of sufficient reliable data available to estimate emission factors. Soil carbon may increase due to implementation of REDD+ activities such as carbon stock enhancements and conservation, reductions in deforestation and improved sustainable forest management, and thus resulting in conservative estimate for such activities.

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

GHG	Selected?	Justification/Explanation
CO_2	Yes	The ER Program shall always account for CO_2 emissions and removals
CH_4	No	CH_4 and N_2O are important GHG released during biomass burning, a common method to eliminate residues after deforestation in Costa Rica (i.e. slash and burn). This pool, however, is excluded because this activity was banned after 1997, and the country considers it rarely occurs nowadays. Emissions from natural fires are not included in the accounting.
N_2O	No	

8. REFERENCE LEVEL

8.1 Reference Period

The Reference Period proposed in the ER-PD has not changed, it is 1998-2011.

Start date of the Reference Period (*1st January* *1998*): 1997 is the year when the current Forestry Law was passed, including key forest policy, instruments and mechanisms (*e.g.* PSA). 1998 is the closest date to 1997 for which Costa Rica has a map (please see previous footnote). Selecting 1998 as the base year of the historical reference period allows for the consideration of emission reductions that have resulted from the implementation of the current Forest Law. Because of this, the reference level can be used as a benchmark to measure emission reductions that are "additional" to the normal performance of current forest policies and programs. This date was strategically selected to show the impact of the Forestry Law and has an important role in the FREL/FRL to be submitted to the UNFCCC.

End of the Reference Period (*31st December* *2011*): according to Costa Rica's R-PP and ER-PIN[90], the country's National REDD+ Strategy began implementation in 2010. However, given that for 2009 Costa Rica does not have a map[91], the TAP recommended that Costa Rica selected the year 2011 instead to comply with the CF-MF. Costa Rica followed the TAP's recommendation.

8.2 Forest definition used in the construction of the Reference Level

The definition of "forest" used in the construction of the proposed FREL is:

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

This definition is consistent with the forest definition reported by Costa Rica under the Clean Development Mechanism (CDM) and is also consistent with the forest definition used in the context of the national GHG inventory. However, this definition is not consistent with Costa Rica's reports to FAO's Forest Resources Assessment (FRA). Under FAO-FRA, Costa Rica defines "forest" as:

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

[90] 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.

[91] According to the CF's TAP, the IPCC approach 3 included in **indicator 11.1** of the CF-MF requires countries to have spatially explicit information or a map. Costa Rica challenged this interpretation but decided to follow the TAP's recommendation to shift the end-date of the historical reference period to 2011.

Costa Rica deemed more appropriate to maintain consistency in all its GHG-related reports and therefore decided that using the definition already applied in the context of the national GHG inventory and the CDM would be more appropriate in the context of the REDD+ than using the definition applied in FAO´s FRA.

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

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

Although these definitions are not totally consistent, the definition of "forest" used in the context of REDD+ is broader and largely includes the definition in the law. In the context of the National REDD+ Strategy and the relevant national legislation, the definition of "forest" in the law is applicable for domestic purposes.

8.3 Average annual historical emissions over the Reference Period

Description of method used for calculating the average annual historical emissions over the Reference Period

This section describes method used for calculating the average annual historical emissions over the Reference Period as described in the ER-PD, including an update on the methods for forests remaining forests requested by the FCPF Carbon Fund[92] (see Section 1 of Annex 4, "Technical corrections").

REDD+ Program area:

The jurisdiction of the national REDD+ program includes the entire continental territory of Costa Rica, with an area of approximately 51,000 km^2 (over 5 million hectares), which excludes Cocos Island. Cocos Island has been excluded because it is inhabited solely by park rangers, distant from Costa Rica's continental territory and therefore not prone to potential REDD+ activities displacements, and is not subject to anthropogenic intervention. Areas classified as unknown with no available data due to cloud cover (2.26% of the total territory), and areas of high geological risk (0.03% of the total territory) or associated to river-meandering (0.33% of the total territory) were also excluded. Overall, the total excluded area is equivalent to 2.61% of the country, and there is no evidence of any other forest areas (beyond those on Cocos Island) that could be systematically excluded from the land use/land cover map as unmanaged. Costa Rica does not expect additional areas to be excluded in the future due to gaps in land use information, given the increasing availability of global forest cover data.

Land Cover Maps:

Five forest categories were defined, all of them further stratified into Primary and Secondary Forests: Wet and Rain Forests, Moist Forests, Dry Forests, Mangroves, and Palm Forests. The following maps were used for the construction of activity data time series of these five categories:

- remote sensing data from four generations of Landsat; a "Life Zones"[93] map used to stratify Forests into Wet and Rain Forests, Moist Forests, and Dry Forests;
- ancillary maps to edit the remote sensing data for the Primary and Secondary Forest stratification of the five forest categories.

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[92] Resolution CFM/14/2016/2. Selection of Emission Reductions Program Document of Costa Rica into the Portfolio of the Carbon Fund of the FCPF.

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

Satellite images were pre-processed to minimize cloud coverage gaps, using more than one image from the same year and season, and global data sources (e.g. Global Forest Change project[94]) to fill satellite information. When necessary, excluding areas covered by clouds in a given year was considered the best available solution. For the image pre-processing, Costa Rica is registering images to a common system of coordinates (CTRM05) with mean quadratic error of less than one pixel (i.e. 30 m) and maximum of two pixels and normalizing them radiometrically to minimize differences between images due to atmospheric conditions. Forest categories were classified using the Random Forest classifier[95]. Images were post-processed to a minimum mapping unit to comply with the minimum area for forest definition (i.e. 1 ha) and edited manually to decrease high classification errors and improve land use mapping. The ER-PD describes the following manual edits:

(1) merge the Forest Plantation with the Forest Land category because Forest Plantation presented a very high classification error;
(2) estimate Coffee Plantations from available government ancillary maps and define "potential" Coffee Plantations in all areas mapped based on elevation and location;
(3) create a mask for all potential areas of Mangroves and Palm Forests to reclassify forest areas as either Mangroves or Palm Forests, given that Mangroves and Palm Forests have very specific soil conditions and conversion from or to other forest types is highly unlikely;
(4) create a mask for Páramo to identify, based on elevation, the forest areas that need to be reclassified as Páramo.

Activity Data:

To calculate the average annual historical emissions over the reference period, Costa Rica followed an activity-based approach that accounts for emissions/removals from land use change activities (deforestation and reforestation). Under this approach, emissions and removals were estimated based on gross activity data that was spatially explicit, and on net emission factors. Activity data was entered in land use matrices (see Figure 5) to ensure representation of all land use transitions and avoid double counting or omitting emissions and removals and allowing the application of net emission factors for unique land use change conversions[96].

Accounting spatially-explicit gross activity data was possible thanks to a 1986-2013 time series specifically designed for REDD+ to ensure methodological consistency with the national GHG inventory. This time series was developed at the national level with land use maps derived from Landsat imagery. The maps, however, did not allow for differentiating between forest plantations and secondary forests in the baseline.

Figure 5. Simplified land use change matrix illustrating logic to define REDD+ activities in Costa Rica. Modified from: FREL/FRL Submission to the UNFCCC Secretariat, 2016. MINAE, Costa Rica.

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

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

[94] Hansen et al. 2013; available at: https://earthenginepartners.appspot.com/science-2013-global-forest

[95] Breiman, L., 2001. Random Forests. Machine Learning 45 (5-3): link.springer.com/article/10.1023/A%3A1010933404324

[96] Forest reference emission level/forest reference level. Submission to the UNFCCC Secretariat for technical review according to Decision 13/CP.19. Ministry of Environment and Energy, Costa Rica. 2016. https://redd.unfccc.int/files/2016_submission_frel_costa_rica.pdf

AD for land use change was estimated from the land use maps created for 1998-2011 and extracting multi-temporal values of the areas whose category remained unchanged and the areas that were converted to other land use categories.

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):

$$AD_t = AD_p/T$$

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:

$$AD_t = A_{(t-1)} - \Sigma(ADleft_t) - \Sigma(ADright_t)$$

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 average annual historical emissions over the reference period of activities in forest land remaining forest land (forest degradation and enhancements), a multi-temporal visual assessment of high resolution imagery Collect Earth software[97] detected forest canopy cover change in forest areas in 1998 and 2011, which were then extrapolated to the entire country through the application of the Olofsson et al (2014) methodology[98] for a proportional representation within the respective degradation classes (intact, degraded, and very degraded) and forestry type (Wet and Rain Forests, Humid Forests, Dry Forests, Mangrove Forests, and Palm Forests). Degradation classes were determined based on the reduction of the forest canopy cover, i.e. intact forests have a cover of 85-100%, degraded forests have a cover of 60-85%, and very degraded forests a cover 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 (1998-2011) were classified as degraded, whereas forest areas that went from very degraded to degraded, very degraded to intact, or degraded to intact were identified as forest enhancement areas. These images were aligned to the dates of the land use change maps so that all activities could maintain the same reference period (1998-2011). The AD available in Costa Rica is spatially explicit, yet the program does not assign REDD+ activities to different zones of the country, because there was no projection of the location where future land cover change might occur, thus it can only be used as an estimate of total net emissions and removals.

The details on how all activity data were calculated REDD+ activity are provided in the parameter tables in Section 3 of this monitoring report.

Emission and removal factors:
The 2015 National Forest Inventory (NFI) was used to develop deforestation emission factors (EF) for primary forests, even though the NFI sampling was concentrated in accessible forest areas and thus the NFI plots most likely represent forests that have been disturbed or degraded. Aboveground biomass data for all forest strata from the NFI campaign was then used to estimate the belowground, litter, and deadwood carbon pools. Scientific literature published since 2005[99] was used for soil carbon stocks and for aboveground growth rates in secondary forests. Forest

[97] Accessible through the WMS http://geos0.snitcr.go.cr/cgibin/web?map=ortofoto.map

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

[99] Emission Reductions Program, FCPF Carbon Fund. Ministry of Environment and Energy (MINAE), Costa Rica. 2018. https://www.forestcarbonpartnership.org/system/files/documents/Costa%20Rica%20ERPD%20EN_Oct24-2018_clean.pdf

remaining forests used the average ratio between aboveground biomass and canopy cover estimated for each forest type. This approach to estimate emission and removal factors from forests remaining forests is an update from the originally proposed linear model of canopy vs aboveground biomass approach. The new approach provides more robust estimates with lower uncertainties (see Section 1 of Annex 4, "Technical corrections" above for more details). The total carbon stock of each land use and forest category was estimated as the sum of all carbon pools.

To estimate average carbon stocks by carbon pool and land use category biomass data was converted to carbon using the carbon fraction of 0.47[100]. Carbon stocks were then converted to mean tons of CO_2e values with their associated uncertainties. Emission factors were estimated from carbon stock changes following the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and available literature (e.g., Cairn's equation was used to determine belowground biomass from aboveground biomass[101]). To avoid double-counting of reference level emissions between deforestation and forest degradation, the analysis of degradation was only performed on the area of forest remaining forest according to the land use change (AGRESTA) maps. This avoided any measurements of degradation that was also accounted for under deforestation.

The details on how these emission and removal factors were calculated for each carbon pool and REDD+ activity are provided in the parameter tables in Section 3 of this monitoring report. In-depth details of methodological changes to the reference level in forests remaining forests are provided in the beginning of Annex 4, under Section 1 "Technical corrections".

Development of average annual historical emissions over the Reference Period:
The average of the historical period (1998-2011) is the most robust of the possible reference periods for the following reasons: First, this period starts shortly after Costa Rica's Forest Law banning deforestation activities passed in 1996. Therefore, 1998 is the earliest year after the Forest Law for which Costa Rica has a land use country map. Second, selecting 1998 as the base year of the reference period allows for the consideration of emission reductions that have resulted from the implementation of the current Forest Law.

The Reference Level 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:

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

Equation 7

Where:

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

[100] 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.

[101] IPCC. IPCC guidelines for national greenhouse gas inventories. In: Eggleston S, Buendia L, Miwa K, Ngara T, Tanabe K, editors. Guidelines for national greenhouse gas inventories, vol. 4: Agriculture, Forestry, and Other Land Use. 2006.

Activity Data of Deforestation (AD_D)	$AD_{D_{i,t}} = \lvert D_{i,t} \rvert * 0.81$, **Equation 2.1**	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 2.2**	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 2.3**	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})	$AD_{Deg_{i,t}} = \frac{\lvert Deg_{i,t} \rvert}{N} * \sum_{i=1}^{I} AD_{F-F_{i,t}}$ **Equation 2.4**	Where $\lvert Deg_{i,t} \rvert$ is the count of sampling points where canopy change decrease (dimensionless), *N* is the total of sampling points (dimensionless), and $\sum_{i=1}^{I} AD_{F-F_{i,t}}$ is the total area of permanent forest (in hectares – ha) in the monitoring period.
Activity Data of Permanent Forest Regeneration (AD_E)	$AD_{E_{i,t}} = \frac{\lvert E_{i,t} \rvert}{N} * \sum_{i=1}^{I} AD_{F-F_{i,t}}$ **Equation 2.5**	Where $\lvert E_{i,t} \rvert$ is the count of sampling points where canopy change increase (dimensionless), *N* is the total of sampling points (dimensionless), and $\sum_{i=1}^{I} AD_{F-F_{i,t}}$ is the total area of permanent forest (in hectares – ha) in the monitoring period.

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

$$\Delta C = \frac{(C_{t2} - C_{t1})}{(t2 - t1)} * 44/12 \qquad \textbf{Equation 8}$$

Where:

ΔC	=	C stock changes associated to the land use transition *i* in year *t*; tCO_2-e ha^{-1}
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.
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[102] and 20[103] of the sheets "ER AAAA" (where "AAAA" stands for the year *t*) in the FREL TOOL.
t2-t1	=	In all cases the C stock changes were estimated annually, *i.e. t2-t1* = 1 year.
44/12	=	Conversion of C to CO_2

[102] The C stock values reported in line 19 represent total C stocks existing in secondary forest and tree plantation 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 and conversions of other land use categories to permanent crops.

[103] 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 and conversion of other land use categories to permanent crops.

Forest C is determined from the NFI biomass data, converted to carbon as follows:

$$C_t = \sum_{\mathbf{j,i}} (B_{tot}) \text{ x CF} \qquad \textbf{Equation 9}$$

Where:

B_{tot} = Total biomass stock for the land use category *LU*; tCO_2-e ha^{-1}.
Total biomass is equivalent to the sum of all biomass pools: $B_{tot} = B_{AGB} + B_{BGB} + B_{DW} + B_L$
Where:
AGB is above-ground biomass for land use category *LU*; tCO_2-e ha^{-1}
BGB is below-ground biomass for land use category *LU*; tCO_2-e ha^{-1}
DW is dead wood biomass for land use category *LU*; tCO_2-e ha^{-1}
L is litter biomass for land use category *LU*; tCO_2-e ha^{-1}

CF = Carbon fraction of dry matter in tC per ton dry matter. The value used is:
0.47 is the default for (sub)tropical forest as per IPCC AFOLU guidelines 2006, Table 4.3.

Carbon stocks of non-Forest land uses are estimated as the average values reported by the selected studies:

- *Cropland:* carbon stock values reported in selected studies showed high variability, depending on crop type (sugar cane, coffee, banana, cocoa, etc.). For this reason, the carbon stock data compiled were weighted by the surface area of the respective crops in Costa Rica to produce a single estimate of carbon stocks from cropland.
- *Grassland:* carbon stocks were estimated as the average values reported in different carbon pools in the selected studies.
- *Settlements and (non-forested) Wetlands:* no studies could be found reporting biomass values for these categories. It was assumed that their carbon stock is zero.
- *Other Land:* studies were found reporting carbon stocks for *Paramo.* In the case of *Bare Soil* it was assumed carbon stocks are zero.

Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period

Activity data

Table 13: Source of Activity Data and description of the methods for developing the data for estimate emissions from deforestation during the reference period[104].

Parameters:	**Activity Data of Deforestation (AD_D) Eq. 2.1** **Activity Data of Reforestation (AD_R) Eq. 2.2** **Forest remaining forests (AD_{F-F}) Eq. 2.3**
Description:	Deforestation: Hectares of forest that changed to non-forest land in a year summed each year (i) of the reference period. Reforestation: Hectares of non-forest that changed to forest land in a year, summed for each year (i) of the reference period. Forest remaining forests: Hectares of Forest remaining forests in a year, summed for each year (i) of the reference period
Data unit:	Hectares
Source of data	
Introduction	AD for land-use change activities was derived from map-algebra by analyzing all land cover maps created for 1998-2011 and estimating multi-temporal data for the areas that remained in the same category or converted to other land cover categories. Annual AD was interpolated for years in which maps were not produced. A time-series of land use maps was created for 1985/86-2012/13 in a Geographical Information System (GIS)[105] 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 area covered by the land-use maps includes the country's continental territory (5,133,939.50 ha) but excludes Coco Island (238,500 ha). The land use maps were created using the methodology summarized here; further information may be found in separate reports [106,107,108] :
Data sources for estimating activity data:	The construction of the AD time series required the following sources of data: v. Remotely sensed data from four generations of the Landsat family (Landsat 4 TM, Landsat 5 TM, Landsat 7 ETM and Landsat 8 OLI/TIRS). vi. A "Life Zones" map according to the classification system of Holdridge (1966). This map was used to stratify "Forests" into the three sub-categories: "Wet and Rain Forests", "Moist Forests" and "Dry Forests". vii. Ancillary data 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. viii. The Global Forest Change project (Hansen et al., 2013) has been used to fill in pixels without information in the mosaic of classifications for each year of the series between 2000 and 2012.

[104] All AD parameters listed in table 13 sourced from the same survey.

[105] 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

[106] Agresta, Dimap, Universidad de Costa Rica, Universidad Politécnica de Madrid. 2015. Final Report: Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level: Methodological Protocol. Report prepared for the Government of Costa Rica under the Carbon Fund of the Forest Carbon Partnership (FCPF). 44 pp. https://www.dropbox.com/s/ygjw6zq00a1qtbm/Informe_tecnico_feb_2015.pdf?dl=0

[107] 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

[108] Ministry of the Environment and Natural Resources of Costa Rica. (2018). Costa Rica Emission Reductions Program to the FCPF Carbon Fund (Second Revision). Retrieved from https://www.forestcarbonpartnership.org/system/files/documents/Costa_Rica_ERPD_EN_Oct24-2018_clean.pdf

Methods for mapping land-use and land-use change	
Selection of images	Costa Rica prepared the FREL / FRL Costa Rica from a time series of satellite images for 1987-2013. The time series includes images from four generations of LANDSAT satellites: Landsat 4 TM, Landsat 5 TM, Landsat 7 ETM +, Landsat 8 OLI / TIRS. The analyst downloaded the satellite information through the USGS Earth Explorer server. It was necessary to work with seven LANDSAT scenes to cover the continental territory of Costa Rica in each of the years of the series: two scenes from path 14 (rows 53 and 54), three scenes from path 15 (rows 52, 53, and 54) and two scenes from path 16 (rows 52 and 53). Low cloud-coverage Landsat images were combined to minimize the area covered by clouds and cloud shadows. In most cases, the scenes were selected from the same year and season but, in some cases, it was necessary to choose scenes from different years within a 14-month timeframe.
Pre-processing and Geometric validation	All images were registered to a standard system of coordinates (CRTM05). The mean quadratic error in control points was less than one pixel (30 m). The maximum registration error was estimated at 2 pixels (60 m). The 2005 orthophotography generated with the IDB-Cadastral project's CARTA mission has been used to collect control points for the geometric validation of the reference runs. A mosaic of scenes is prepared for each path's available dates with the geometrically corrected images.
Radiometric normalization	All images were radiometrically normalized. This process is applied to reduce radiometric differences between images due to atmospheric conditions and the sensors' calibration at image acquisition dates. The radiometric normalization was done using the "Iteratively Reweighted Multivariate Alteration Detection" (IR-MAD), as described by Canty and Nielsen (2008)[109]. The normalization of the time series used as a reference the zenith angle 36.90° corresponding to February 17, 2013.
Random Forest classification	The classification of the images uses the Random Forest (RF) method. This methodology has 2 phases: (1) training or adjustment of the RF and (2) classification of the images using the generated RF classifier. Homogeneous regions of interest have been digitized according to the land cover classes between 2011 and 2014 (see Table 3 of Agresta, 2015) for the models' adjustment. The base information used for the digitization and photointerpretation of these regions has been i) the systematic grid of cover points taken on the RapidEye images by SINAC for the elaboration of the map of forest types of Costa Rica 2013 (10,000 points distributed in the national territory), ii) the RapidEye high spatial resolution images themselves, iii) both current and historical images available on Google Earth. Control points for RF training have been randomly generated from these regions of interest. In total, 20 predictor variables (also called covariates or auxiliary variables) were used for the adjustment of the RF models, divided into four groups: (1) Spectral information of the bands, (2) Indices of vegetation, (3) Variables related to the texture of the image, and (4) Variables derived from the Digital Elevation Model. The analyst applied the classifiers to all the images according to their path and sensor. The result is a classification file for each classified image.
Postprocessing	Final maps are presented at 30 meters resolution. The preparation of the final maps from the classified images included the following tasks: vi. Union of the mosaic for each date from the classified images using a pixel prioritization algorithm. The analyst merged all the different images' classifications for each of the dates and paths, eliminating the extreme strip of the paths overlapping. If the classifier predicts several classes for the same pixel, the most common category was selected, according to band 2 of the results. vii. Filling gaps with global products: The Global Forest Change project (Hansen et al., 2013) has been used to fill in pixels without information in the mosaic of classifications for each year of the series between 2000 and 2012. viii. Multi-temporal analysis: the multi-temporal analysis of the series allowed assigning the age class to each of the forest pixels, analyzing the years that have elapsed from the date of appearance of a new forest. The forest from 1987 has been considered a primary forest. Also, the multi-temporal analysis improved land-uses classification, especially when the land cover has similar spectral information. The classifier confused native forests with forest plantations. For this reason, the forest plantations were reclassified as forest.

[109] 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.

	ix. Minimum mapping unit: The analyst replaced Forest Class groups of pixels smaller than 11 pixels with the LULC class of the largest neighboring group to comply with the minimum area threshold of the definition of "forest (1.00 ha), and setting the minimum mapping unit. Due to the pixels' dimensions in the Landsat images (30.00 m x 30.00 m), the minimum mapping area is 0.99 ha, equivalent to 11 pixels (11 x 30.00 m x 30.00 m). x. Manual editions: In order to improve land use mapping, several editions were made, largely aimed at decreasing high classification errors (for more detail please see section 4.3.3 in Ministry of the Environment and Natural Resources of Costa Rica, 2016[110]): a. "Forest Plantations" were merged with the "Forest land" category. 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". b. For estimating the area of "Coffee Plantations", the analyst used ancillary maps from the Ministry of Agriculture (MAG), the Costa Rican Coffee Institute (ICAFE), and the Costa Rican Meteorological Institute (IMN). These maps were used to correct the classified areas for the years 2000/01, 2007/08, 2011/12, and 2013/14. For previous maps, a mask representing potential "Coffee Plantation" areas was created using the location and elevation of all areas mapped as "Coffee Plantations" considering all available sources of information (MAG, ICAFE, and IMN). c. Paramo, Mangroves and Palm forests are ecosystems restricted to particular elevation, edaphic, inundation, and salinity conditions; it is challenging for such ecosystems to exist in other locations. Therefore, these forests were re-classified using the map of Forest types (MTB), prepared by Agresta (2015). 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. d. 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 e. A map of potential forest types was created to assign secondary forests to a forest type (Wet and Rain Forests, Moist Forests, Dry Forests, Mangroves, Palm Forests). This map will also be used in future measurements for determining the forest type of secondary forests. The map of potential forest types was created by combining the life-zones and then overlapping the map of the masks of potential areas of "Mangroves", "Palm Forests", and "Paramo".
Activity Data calculation	AD for land use change activities such as *deforestation* and *reforestation* were estimated by combining all land use maps created for 1998-2011 in a Geographical Information System (GIS) and then extracting from the combined set of multi-temporal data the values of the areas that remained in the same category or converted to other land use categories. The results of this operation are reported in land use change matrices prepared for each measurement period in the sheets "LCM 1986-91", "LCM 1992-97", "LCM 1998-00", "LCM 2001-07", "LCM 2008-11", and "LCM 2012-13" of the spreadsheets tool "FREL TOOL CR[111]".
Value applied in reference period:	
	<u>1998-2011</u>: • Total anthropogenic deforestation: 30,439 ha yr^{-1} • Primary forest anthropogenic deforestation: 13,147 ha yr^{-1} • Secondary forest and tree plantation anthropogenic deforestation: 17,292 ha yr^{-1}
QA/QC procedures applied	

[110] 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

[111] The FREL Tool can be accessed in the following link:
https://drive.google.com/file/d/1wiVsHpP_b5kEVkbb4GdQqWaQDDzwyZnw/view?usp=sharing

Introduction	The QA/QC procedures applied during the preparation of the land-use maps used to calculate AD for the reference period are summarized here, further information may be found in Agresta (2005), Sections 3, 4, and 7:
Download and satellite image preparation	9. Verification of file storage errors in digital media that could affect reading the data by the analyst responsible for download support images. 10. Previewing and verification of the satellite image quality and metadata by the analyst responsible for downloading support images. 11. Previewing and verification of the satellite image quality and metadata by the supervisor.
Image orthorectification	17. Analyst's exhaustive visual inspection to identify errors in the orthorectification process, such as duplicated areas, pixel stretching, or geometric errors related to the digital terrain model (DTM). 18. Geometric control of orthorectified images by taking checkpoints in each scene in a regularly distributed grid. 19. Validation of root mean square error (RMSE) of the control points, by the analyst responsible for the orthorectification. In no case, RMSE is above the pixel size of the image. The number of correct points after debugging should not be less than 20 ground control points in each reference path. The RMSE obtained in the checkpoints is less than 1 pixel (30 meters), and the maximum error in any of the points, 2 pixels (60 meters). 20. Preparation of a "georeferencing validation datasheet," including a general image view with the checkpoints marked on it and a list of the coordinates and RMS obtained for each point. Annex 5 of Agresta (2015) includes the lists of checkpoints and RMSE of the dates processed.
Radiometric normalization*:*	21. Radiometric normalization to reduce the differences between the time-series images.
Generation of cloud and shadow masks	22. Validation of cloud and shadow mask by visual verification of a systematic random grid of checkpoints identified as a cloud (n), shadow (s), or clear (d). The analyst visually checked the original image in RGB or false color if the classification matches the cloud and shadow mask. The analyst must pay special attention to the verification of cloud masks in urban areas and coastlines with a high reflectance, adjusting some of the cloud and shadow mask degeneration parameters during the verification process. 23. The validation includes a random sample in each path of an image from each time series (3 paths x 6 series = 18 images). Table 2 of Agresta (2015) includes a summary of the results of the validation of the cloud and shadow maps.
Land use classification*:*	24. Analysts perform an iterative process of classification, verification of results, error detection, and review of areas and training points. 25. Progressive improvement of the areas and training points of the RF classifier before the final classification of the images. Review of the Random Forest classifiers' errors, identify classes that need improvement, and training points. 26. Visual verification and validation of classified images by comparing them with the available high-resolution image.
Preparation of land-use maps:	27. Visual check of mosaics and identify information gaps and sensor failures on each time series' images. 28. Visual verification of the maps generated after filling the gaps with global data. 29. Analysts implement an independent validation of the land-use change maps with ground validation points provided by the country's institutions not used in the classification phase. 30. Manual edition of the time-series classification to improve land use mapping, largely aimed at decreasing high classification errors.
Visual verification and validation of land-use change map:	31. Visual verification of the country's main deforestation and reforestation areas between consecutive years of the series to detect classification errors. 32. Validation of land-use changes between 2001 and 2011 based on photointerpretation of changes on a systematic random grid of points and using the Landsat, aerial orthophotography of the year 2005, and Rapid-eye images of the years 2011 and 2012.
Uncertainty associated with this parameter:	
Uncertainty associated with this parameter:	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 (i.e. the margin of error for a 90% confidence level divided by the estimate)

	associated with the process creating land use change maps from which the activity data are obtained. The accuracy assessment of the land-use change map 2001/02 – 2011/12 was done following Olofsson et al.'s (2014)[112] guidelines. Due 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). 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. For further detail please see section 12.2 in ERPD document (Ministry of the Environment and Natural Resources of Costa Rica, 2018)[113]. Finally, 699 checkpoints were assessed: 315 in stable forest areas (areas classified as forest in 2000/01 remaining forest in 2010/11), 237 in the non-stable forest (areas classified as non-forest in 2000/01 remaining non-forest in 2010/11), 53 in afforestation/reforestation areas (areas classified as non-forest in 2000/01 classified as forest in 2010/11) and 47 in deforested areas (areas classified as forest in 2000/01 classified as non-forest in 2010/11)[114]. The accuracy assessment analysis is presented in the Excel file "CDI_CostaRicaREL_AnalisisExactitud_MCS2000-2001 vs MCS2010-2011" [115]. The activity data's uncertainty is the bias between the adjusted (reference data) and estimated (land use maps) areas. The uncertainty values are as follows: Uncertainty of hectares of deforestation from 1998-2011: 26% Uncertainty of hectares of non-forest that changed to forest land: 31% Uncertainty of hectares of forests remaining forests in 1998-2011: 4%

[112] Olofsson et al. (2014) Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment 148, 42-57.
[113] Ministry of the Environment and Natural Resources of Costa Rica. (2018). Costa Rica Emission Reductions Program to the FCPF Carbon Fund (Second Revision). Retrieved from https://www.forestcarbonpartnership.org/system/files/documents/Costa Rica ERPD EN_Oct24-2018_clean.pdf
[114] Shape file with 716 checkpoints included in the accuracy assessment analysis can be accessed in the following link: https://drive.google.com/drive/folders/1ofSZs-IfdZ-BzFxefqrGO1pwbp537HL1?usp=sharing
[115] 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

Table 14: Source of Activity Data and description of the methods for developing the data for estimate emission from degradation during the reference period.

Parameters:	**Activity Data of Degradation (AD_{Deg}) Eq. 2.4** **Activity Data of Permanent Forest Regeneration (AD_E) Eq. 2.5**
Description:	Degradation: Hectares of forest with a reduction of canopy cover during the reference period. Forest Enhancement: Hectares of forest with an increase of canopy cover during the reference period
Data unit:	Hectares
Source of data	
Introduction	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)[116].
Type of sampling	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 1998-2016. 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: j. Intact to Degraded forest k. Intact to Very degraded forest l. Degraded to Very degraded forest Forest enhancement: m. Very degraded to intact forest n. Very degraded to degraded forest o. Degraded to Intact forest No Condition changes p. Stable intact forest q. Stable degraded forest r. Stable very degraded forest
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

[116] 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. Retrieved from https://drive.google.com/file/d/1GXdN43f-DNKelkM8y7gBLrKou-f7LI-G/view?usp=sharing

available in Google Earth and Earth Engine was used as a data source, giving priority to images from the years to be evaluated (2011 or 2016). 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 on permanent forest for the reference period 1998-2011 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

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 collection

See QA/QC procedures.

Data analysis

The country developed a tool for calculating emissions and removals on permanent forest lands (¨Herramienta_degradación.xlsx¨ [117]). The database for the visual interpretation of canopy cover for the reference period 1998-2011 and monitoring period 2012-2016 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 (1998-2011) 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 points inside protected areas and farther than 500

[117] Degradation tool can be accessed in the following link: https://drive.google.com/file/d/1GG3Z_QMWBKGNRdXnF_TdWP1ipH9dX5iH/view?usp=sharing

	meters from a road[118] 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 monitoring period 2012-2016.
Value applied in reference period:	
	• **2,233,119** hectares of forests remaining forests in the reference period (1998-2011) • **145,556** hectares of anthropogenic degradation (1998-2011) • **157,739** hectares of anthropogenic forest enhancement (1998-2011)
QA/QC procedures applied	
	Ortiz-Malavassi (2017) prepared a land cover evaluation protocol to reduce the uncertainty of the land cover classification due to: a) the bias associated with the spatial registration of the reference image, b) the interpreter bias in the assignment of the land cover class; and c) interpreter variability. The protocol includes the operational definition of the canopy coverage with examples taken from high-resolution images and registration templates for Collect Earth Desktop. The following procedures were applied during the collection of reference data: **Data registry forms**: The canopy cover change information was recorded in standard Collect Earth Desktop forms. **Variability between interpreters**: The analysts recorded screenshots, plot numbers, and a brief description of the problem in case of doubts with the interpretation (land cover and land-use). Every two days, they sent the log to other analysts for feedback. This feedback was available to all team members. Meetings will be held at the end of the week to discuss complex cases to reduce interpreters' variability. **Validation of the coverage classification**: The supervisor validated land cover classification with National Forest Inventory land cover data. This information was available only for the supervisors. **Imagery co-registration:** Google Earth images can show displacements, which became evident when the interpreter compares the same area for different years. Potere (2008)[119] found that the average displacement in developing countries is 44.4 meters. When this problem occurred, the analyst noted the maximum displacement detected in meters in Collect Earth form. **Data consistency:** The supervisor reviewed the existence of discrepancies between cover class and land use.
Uncertainty associated with this parameter:	
	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 in Section 8.4. ERPD. Uncertainty of changes in canopy cover to identify areas of degradation and forest enhancement from 1998-2011 vary depending on the forest type and the conversion class. It is based on the sampling error.

[118] 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

[119] Potere, D. (2008). Horizontal positional accuracy of Google Earth`s high-resolution imagery archive. In: Sensors, 8,12: 7973-7981 p. Retrieved from: http://www.mdpi.com/1424-8220/8/12/7973/htm

Emission factors

Table 15: Source of Emission Factors and description of the methods for developing the emission factors for deforestation.

Parameters:	**Carbon density of aboveground tree or woody biomass (C_{AGB}) Eq. 4** **Carbon density of belowground biomass (C_{BGB}). Eq. 4.** **Carbon density of dead wood biomass (C_{DWB}). Eq. 4** **Carbon density of litter (C_L). Eq. 4**
Description:	• **C_{AGB}**: Amount of carbon (C) contained in aboveground biomass per forest hectare, converted to CO_2e multiplying by a factor of 44/12 (i.e., the molecular weight of a CO_2 molecule over the molecular weight of a C molecule). • **C_{BGB}**: Amount of C contained in belowground forest biomass per forest hectare, converted to CO_2e multiplying by a factor of 3.67 (i.e., the molecular weight of a CO_2 molecule over the molecular weight of a C molecule). • **C_{DWB}**: Amount of C contained in dead wood forest biomass (standing and lying) per forest hectare, converted to CO_2e multiplying by a factor of 3.67 (i.e., the molecular weight of a CO_2 molecule over the molecular weight of a C molecule). • **C_L**: Amount of CO_2e contained in litter forest biomass per forest hectare.
Data unit:	Tonnes of CO_{2e} per hectare
Source of Data	
Introduction	The emission factor for deforestation of primary forest 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 literature. • **Carbon pool of aboveground tree or woody biomass (C_{AGB}):** Carbon pool of aboveground tree or woody biomass for each Primary Forest type (C_{AGB}) is the area-weighted average of C_{AGB} stock value from 2015 field campaign performed for the National Forest Inventory. • **Carbon pool of belowground biomass (C_{BGB})**: Derived directly from C_{AGB} data following the Cairns et al., (1997) formula. • **Carbon pool of dead wood biomass (C_{DWB})**: Average values of direct measurements reported in literature. The value was used to develop a ratio of C_{DWB} over C_{AGB} used for AD_D, AD_{F-F}, and AD_R. The values obtained from the literature were used to develop an area-weighted average of DW:AGB ratios, assumed to be the same in primary and secondary forests. • **Carbon pool of litter (C_L):** Average values of direct measurements reported in literature. The value was used to develop a ratio of C_L over C_{AGB} used for AD_D, AD_{F-F}, and AD_R. The values obtained from the literature were used to develop an area-weighted average of L:AGB ratios, assumed to be the same in primary and secondary forests.
Source of Data of Above Ground Biomass for Primary Forest	**Type of sampling:** The INF-CR is a multipurpose inventory seeking to enhance the understating of Costa Rican forest resources and generate data to monitor and quantify their provision of ecosystem services, such as climate change mitigation. The INF-CR was led by the National Conservation Area System (SINAC) with measurements taken between 2013 and 2015. The INF-CR employed a stratified-systematic sampling approach covering the entirety of Costa Rica's continental territory. The stratification was based on a forest type map derived from RapidEye imagery (REDD/CCAD-GIZ-SINAC, 2015)[120] and plots were equidistantly allocated within each stratum. **Sampling Unit:** Rectangularly shaped plots with an area of 0.1 ha (20m x 50m) distributed on fixed sample intensities by forest class. The sampling unit design allows the measurements of the following (Ministerio de Ambiente y Energía, 2015)[121]:

[120] Sistema Nacional de Áreas de Conservación (SINAC) - Programa REDD-CCAD-GIZ. (2015). Cartografía base para el Inventario Forestal Nacional de Costa Rica 2013-2014. Retrieved from https://www.sirefor.go.cr/pdfs/Documento-cartografia-Imprenta.pdf

[121] Ministerio de Ambiente y Energía. (2015). Volumen 4 Marco conceptual y metodológico para la Inventario forestal nacional de Costa Rica. Retrieved from https://www.sirefor.go.cr/pdfs/Volumen4-MarcoC-Imprenta.pdf

	• Primary Sampling Unit (UMP for its acronym in Spanish) for measurement of live tree DBH and height of trees with DBH ≥ 10cm (light green area) • Secondary Sampling Unit (UMS for its acronym in Spanish) for measurement of saplings with 2cm ≤DBH<10cm, and height >1.5m. • Third-order Sampling Unit (UMT for its acronym in Spanish) for measurement of live non-tree vegetation, including seedlings (DBH<2cm and height<1.5m), were taken (light grey circles) • Fourth-order Sampling Unit (UMC for its acronym in Spanish) to measure the abundance of species. • Fifth-order Sampling Unit (UMH) to measure litter. • Lying deadwood sampling (UMM) to measure the lying deadwood's diameter in the 20m transects. Soil sampling of the first 30cm with cylinder method. **Number of Sampling Units:** The INF-CR installed a total of 286 single plots. Out of the 286 sampling units (SU), litter was sampled only in 54, and lying deadwood in 61 SUs. Because of inconsistent sampling of all carbon pools across all plots and lack of confidence in data where litter and deadwood, a decision to consider only aboveground biomass from INF-CR was made. Some SU presented zero as a result of litter and deadwood pools. It was not verified whether the SU represented the absence of litter and deadwood in the plots, or these carbon pools weren't sampled.
Source of Data of Above Ground Biomass for Secondary Forest	The AGB for secondary forest was estimated assuming the forest stand accumulated biomass since its restoration. The AGB of Wet and Rain Forests, Moist Forests and Dry Forests were estimated using the equations developed by Cifuentes (2008)[122] based on direct measurements in 54 plots located in age classes between 0 and 82 years. For Mangroves and Palm Forests, a linear function was assumed for estimating carbon stocks as a function of age. Wet and Rain Forests (Cifuentes, 2008, Table 2.5, p. 42, equation for "*Tropical Wet*"): $$TAGB_t = B_{max} * \left[1 - e^{(-0.0186*t)}\right]^1$$ Moist Forests (Cifuentes, 2008,, Table 2.5, p. 42, equation for "*Tropical Permontane Wet Transition to Basal-Atlantic*"): $$TAGB_t = B_{max} * \left[1 - e^{(-0.0348*t)}\right]^1$$ Dry Forests (Cifuentes, 2008,, Table 2.5, p. 42, equation for "*Tropical Dry*"): $$TAGB_t = B_{max} * \left[1 - e^{(-0.113*t)}\right]^{5.1411}$$ Mangroves and Palm Forest the following linear equation was applied: $TAGB_t = \frac{B_{max}}{100} * t$, when t <= 100 $TAGB_t = B_{max}$, when t > 100 It was assumed that the maximum biomass in secondary forests (B_{max}) equals the biomass estimated for primary forests.
Source of data of Litter and Deadwood in primary and secondary forest	The carbon stocks of litter and deadwood were estimated based on a compilation of values from published literature. All C stock estimates from the consulted sources were compiled in tons of carbon per hectare (tC ha-1), using IPCC's default carbon fraction (0.47) when the values were reported in tons of dry matter (t d.m. ha^{-1}). All information related to C stock estimates, such as information on land use, number of sampling units, plot size, the allometric equation used, etc., were also recorded. For full detail please check BaseDeDatos_v5[123] and C-STOCKS sheet of FREL TOOL[124]. The literature review employed the following criteria for compiling the reported value: • The publication reported data from direct measurements carried out in Costa Rica • Measurements were carried out after the year 2005

[122] Cifuentes, M. (2008). Aboveground Biomass and Ecosystem Carbon stocks in Tropical Secondary Forests Growing in Six Life Zones of Costa Rica (Oregon State University). Retrieved from https://drive.google.com/file/d/1FsiTVc78EHcU0gQ4JfFJFSlPqesm3JFW/view?usp=sharing
[123] BaseDeDatos_v5.xlsx can be accessed at the following link: https://drive.google.com/file/d/1d6QqYQci7_Qo7DJhS5eOKgCqLFDX-rFX/view?usp=sharing
[124] The FREL Tool can be accessed in the following link: https://drive.google.com/file/d/1wiVsHpP_b5kEVkbb4GdQqWaQDDzwyZnw/view?usp=sharing

	• Data were sufficiently disaggregated by reporting values of carbon stocks per land use categories and per carbon pool sampled • The publications included information on uncertainties related to the carbon stock estimates
Source of data of carbon stocks of non-Forest land uses	C stocks in these non-forest land uses were estimated as the average values reported by the selected studies. For full detail please check BaseDeDatos_v5 and C-STOCKS sheet of FREL TOOL. • **Cropland**: carbon stock values reported in selected studies showed high variability, depending on crop type (sugar cane, coffee, banana, cocoa, etc.). For this reason, the carbon stock data compiled were weighted by the surface area of the respective crops in Costa Rica to produce a single estimate of carbon stocks from cropland. • **Grassland:** carbon stocks were estimated as the average values reported in different carbon pools in the selected studies. • **Settlements and (non-forested) Wetlands:** no studies could be found reporting biomass values for these categories. It was assumed that their carbon stock is zero. • **Other Land:** studies were found reporting carbon stocks for *Paramo.* In the case of *Bare Soil,* it was assumed carbon stocks are zero.
Methods for estimating C stocks and Emission Factors	
	• **Above ground biomass (AGB)**: Above ground of forest biomass is calculated as 47% of the biomass dry weight of standing trees in the forest, which is calculated using allometric equations. Aboveground biomass of each measured tree was estimated using Chave et al., (2005)[125] moist forests allometric equation as follows: $$AGB = \exp\left(-2.977 + \ln\left(\rho * DBH^2 * HT\right)\right)$$ *Where:* *AGB: aboveground biomass (kg)* *ρ: wood specific gravity (g/cm³). Obtained from literature.* *DBH: Diameter at breast height (cm)* *HT: Tree height (cm)* AGB estimates at the tree level are then summed per plot, and extrapolated to a per hectare basis by applying a scaling factor of 10, which represents the proportion of a hectare (10,000 m²) that is occupied by the plot as follows: $$ScalingFactor = \frac{10{,}000m^2}{1{,}000m^2} = 10$$ *Where:* *10,000m²: Area of one hectare (m²)* *1,000m²: Area of INF-CR rectangular plot (20m x 50m)* • **Below ground biomass (BGB)**: BGB is derived directly from Cairns et al., (1997).[126] equation, to estimate C_{BGB} from C_{AGB} data: $$\mathrm{BGB} = \exp\left(-1.085 + 0.9256 * \ln\left(\mathrm{AGB}\right)\right)$$ Where: BGB: belowground biomass (t d.m. ha^{-1}) AGB: aboveground biomass (t d.m. ha^{-1}) This equation was applied to both, primary and secondary forests. • **C stocks of forest** lands corresponds to the area-weighted average of C stocks by C pool and strata. • **C stock changes** (ΔC) are estimated using the Stock-Difference Method by applying IPCC (2006) equation 2.5 (cf. Volume 2, Chapter 2, Section 2.2.1.).
Value applied in reference period:	
Carbon stocks in Primary forest	(see table below)

Primary Forest type	Area-weighted average		
	t C_{AGB} ha^{-1}	t C_{DWB} ha^{-1}	t C_L ha^{-1}
Wet and Rain Forests	131	13.5	2.7

[125] Chave J et al. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: pp. 87-99.
[126] 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.

<table>
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Moist Forests	93	13.2	2.2
Dry Forests	62	15.4	6.2
Mangroves	72	1.9	0.3
Palm Forests	52	1.6	0.3

</td></tr>
<tr><td>Carbon stocks in Secondary Forest</td><td>

The table below shows the Bmax values used in the equations above to calculate $TAGB_t$ from the secondary forest stand age.

Secondary Forest Type	B_{max} (t dry mass ha^{-1})
Wet and Rain Forests	445
Moist Forests	262
Dry Forests	155

</td></tr>
<tr><td>Carbon stocks of non-Forest land uses</td><td>

Non-forest land uses	Area-weighted average t C_{AGB} ha^{-1}
Permanent crop, wooded, cropland	16
Annual crop, wooded, cropland	0
Permanent crop, non-wooded, cropland	7
Annual crop, non-wooded, cropland	23
Grasslands, wooded	8
Grasslands, non-wooded	4
Paramos	35

</td></tr>
<tr><td colspan="2">QA/QC procedures applied</td></tr>
<tr><td>AGB in primary forest</td><td>

SINAC implemented the following QA/QC procedures during the National Forest Inventory of Costa Rica (for further details please see Ministerio de Ambiente y Energía, 2015)[127]:

Fieldwork organization: SINAC organized the fieldwork by regions: North Pacific and Central Valley (PN-VC), Central Pacific and South Pacific (PS), North-Caribbean North Zone (ZN-CN), Central-South Caribbean (CC-CS), and complex sites (Talamanca mountain range). SINAC prepared terms of reference, describing each member of the field crew's roles and responsibilities. An experienced dendrologist was part of the work team, and a field manual was prepared for identifying, collecting, transport, and processing botanical samples. The Crew was trained before the start of fieldwork, and an Excel template was designed for data typing.

Fieldwork supervision: During the NFI implementation, the coordinator made field visits to supervise the crews' work. A photographic registry of each plot was made.

Registry of information: The field crew filed field forms and prepared reports of the activities. The crew chief and fieldwork director reviewed the field forms. The IFN steering committee did the final review. If the supervisor detected errors, omissions, or inconsistencies, the records were returned to the crew leader with observations for their correction or documenting the discrepancies; the dendrological inventory component coordinator reviewed questionable species identifications. Control procedures were applied to evaluate the coherence, integrity, and completeness of dasometric, dendrological, and positioning data.

Independent evaluation of forest inventory data quality: A separate crew evaluated the quality of forest inventory data. The independent team made field visits and re-measures 10% of the plots established by stratum, both in the pre-sampling and inventory phase.

</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td>AGB’s uncertainty in primary forests is derived from NFI sampling errors. Since belowground biomass is a function of aboveground biomass, the belowground biomass values have the same level of uncertainty as the aboveground biomass. Uncertainty from values DWB and L is derived</td></tr>
</table>

[127] Ministerio de Ambiente y Energía. (2015). Volumen 4 Marco conceptual y metodológico para la Inventario forestal nacional de Costa Rica. Retrieved from https://www.sirefor.go.cr/pdfs/Volumen4-MarcoC-Imprenta.pdf

from values identified in the scientific literature. The statistical uncertainty reported in these documents takes into consideration the sampling error. Therefore, the current version of the reference level only considers this error source.

Primary Forest type	Uncertainty (%) of aboveground biomass
Wet and Rain Forests	150%
Moist Forests	152%
Dry Forests	152%
Mangroves	93%
Palm Forests	81%

Non-forest land uses	Area-weighted average t C_{AGB} ha^{-1}
Permanent crop, wooded, cropland	71%
Annual crop, wooded, cropland	0%
Permanent crop, non-wooded, cropland	68%
Annual crop, non-wooded, cropland	12%
Grasslands, wooded	0%
Grasslands, non-wooded	0%
Paramos	2%

8.4 Estimated Reference Level

ER Program Reference level

Crediting Period year *t*	Average annual historical emissions from deforestation over the Reference Period (tCO_{2-e}/yr)	If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO_{2-e}/yr)	If applicable, average annual historical removals by sinks over the Reference Period (tCO_{2-e}/yr)	Adjustment, if applicable (tCO_{2-e}/yr)	Reference level (tCO_{2-e}/yr)
2018	5,985,795	1,383,974	-4,784,051	-1,547,370	2,585,717
2019	5,985,795	1,383,974	-4,784,051	-1,547,370	2,585,717
2020	5,985,795	1,383,974	-4,784,051	-1,547,370	2,585,717
2021	5,985,795	1,383,974	-4,784,051	-1,547,370	2,585,717
2022	5,985,795	1,383,974	-4,784,051	-1,547,370	2,585,717
2023	5,985,795	1,383,974	-4,784,051	-1,547,370	2,585,717
2024	5,985,795	1,383,974	-4,784,051	-1,547,370	2,585,717

Calculation of the average annual historical emissions over the Reference Period

Costa Rica used the annual average historical emissions from deforestation and degradation, and annual average removals from enhancements of carbon stocks in forest remaining forests and reforestation during the proposed reference period (1998 to 2011), both of which were added for each year. The detailed equations to estimate these annual averages and assumptions made in calculations are included above. Because there was no clear trend line of emissions and of removals during the reference period 1998-2011, the baseline for the reporting period 2018-2024 was estimated as the average emissions of its reference period (i.e. 2,585,217 t CO2e yr^{-1}).

8.5 Upward or downward adjustments to the average annual historical emissions over the Reference Period (if applicable)

Explanation and justification of proposed upward or downward adjustment to the average annual historical emissions over the Reference Period

No adjustment was done to the average annual historical emissions over the reference period.

Quantification of the proposed upward or downward adjustment to the average annual historical emissions over the Reference Period

Not applicable.

8.6 Relation between the Reference Level, the development of a FREL/FRL for the UNFCCC and the country's existing or emerging greenhouse gas inventory

As described in the ER-PD, Costa Rica has made important efforts to harmonize GHG reporting under the UNFCCC, including National GHG inventories and REDD+. These are described below and summarized in Table 5[128].

Consistency with the National GHG Inventory (INGEI):

The historical data mentioned in Section 3 and further described in Annex 4 were used to recalculate the years 2005, 2010 and 2012 of the 2012 GHG Inventory, included in Costa Rica's first BUR (2015). Due to time and resources constraints, only these inventory years were considered in the recalculations. The years 1990, 1995 and 2000 will be recalculated as well and reported in the country's next National Communication to the UNFCCC.
For the AFOLU sector and in relation to REDD+, the current GHG Inventory included the following sources and sinks:

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

For the complete alignment of the GHG Inventory with the current FREL submission to the UNFCCC and RL to the FCPF Carbon Fund, the following inconsistencies remain (see Table 5):

- The current National GHG inventory comprises the years 2005, 2010 and 2012, while the reference level (RL) to the FCPF Carbon Fund covers 1998-2011.
- CH_4 and N_2O emissions from biomass burning in forests remaining forests were explicitly considered in the GHG inventory but not in the REDD+ RL. These estimates were derived from national statistics which are not spatially explicit and only cover 2011-2013[129]. Hence, for the REDD+ RL, there was not enough information to complete the time series for 1998-2011.
- Forest plantations were identified as part of forests remaining forests in the GHG inventory. For the estimation of C stock changes in plantations, ancillary information from the 2014 Agricultural Census was used specifically for 2012.
- Any differences in methods and data found are due to data gaps and the use of specific databases for building estimates for specific years. This has been necessary due to the lack of a continuous forest monitoring system in the country. Costa Rica has now built this system and methods and data for the GHG inventory, REDD+ MRV, and NAMA MRV will be streamlined.

Consistency with REDD+ FREL submitted to the UNFCCC:

Costa Rica's 2016 FREL submission to the UNFCCC includes two historical reference periods: 1986-1996 and 1997-2009. For the FCPF Carbon Fund and the ER-Program, Costa Rica proposed a 1998-2011 Reference Level.

The same REDD+ activities, greenhouse gases and C pools, AD and EF estimating methods and data sources, methods for mapping land use and emission calculation tools, were used in estimating annual average emission and removal of both Costa Rica FREL (see Table 5). For the UNFCCC FREL 2010-2025 uncertainty was not estimated. Likewise, uncertainty was not analyzed by the Technical Team of Experts of UNFCCC. However, uncertainty for the Carbon Fund Reference Level and its 2018-2019 monitoring period was estimated using Approach 2 of the IPCC 2006 Guidelines employing Monte Carlo simulations, and the uncertainties are reported in terms of 90% confidence intervals.

The methodology for estimating emissions of the FOLU sector in the Biennial Update Report is partially consistent with the methodology for estimating REDD+ results (see Table 5). The differences between methodologies are that the UNFCCC 2016 FREL includes:

- FOLU Sector emissions include Harvested Wood Products, and CH_4 and N_2O emissions.

[128] MINAE, 2019. Technical Annex of the Republic of Costa Rica, in accordance with the provisions of Decision 14 / Cp.19. 64pp.
[129] Additional information for different periods is available here: http://www.sirefor.go.cr/?page_id=1051

- Dead wood and litter carbon pools are excluded.

Table 16: Overview of the methods used to obtain the average annual emissions and removals for the Carbon Fund Reference Level (1998-2011) for the monitoring period 2018-2019, compared with those used to calculate the FREL/FRL submitted to the UNFCCC in 2016, and the FOLU emissions of INGEI in the latest Biennial Update Report (2015)[130].

Parameters	FREL for 2010-2025 submitted by Costa Rica to the UNFCCC in 2016	Costa Rica's Carbon Fund Reference Level (1998-2011) for the 2018-2019 monitoring period	Costa Rica's INGEI FOLU emissions on the Biennial Update Report (2015)
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 (CH_4) and nitrous oxide (N_2O) were excluded.		Methane (CH_4) and nitrous oxide (N_2O) are included.
C pools included	Above-ground biomass (AGB) Below-ground biomass (BGB) estimated following Cairns et al. (1997)[131] 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 (see section 3, Annex 4 of this monitoring report).	

[130] MINAE, 2019. Technical Annex of the Republic of Costa Rica, in accordance with the provisions of Decision 14 / Cp.19. 64pp.
[131] 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 2010-2025 submitted by Costa Rica to the UNFCCC in 2016	Costa Rica's Carbon Fund Reference Level (1998-2011) for the 2018-2019 monitoring period	Costa Rica's INGEI FOLU emissions on the Biennial Update Report (2015)
Mapping Land Use	The land use maps were created using the methodology detailed in Agresta et al (2015)[132], and postprocessing procedures described in MINAE (2016)[133] (see section 3, Annex 4 of this monitoring report)		
Methods for estimating AD	AD was estimated by combining all land use maps created for 1985/86-2013/14 in a Geographical Information System (GIS) and then extracting the values of the areas that remained in the same category or converted to other land use categories from the combined set of multi-temporal data. The results of this operation are reported in land use change matrices prepared for each measurement period in the sheets "LCM 1986-91", "LCM 1992-97", "LCM 1998-00", "LCM 2001-07", "LCM 2008-11", and "LCM 2012-13" of the spreadsheets in FREL TOOL CR.	AD was estimated by combining land use maps 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 of the spreadsheets in FREL TOOL CR[134].	
Emission Factors			
Data sources for estimating EF	National Forest Inventory (NFI)[135] 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)[136].		C stocks in above-ground biomass (AGB) of Forests Lands were estimated using the asymptotic value of the equations

[132] 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

[133] 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

[134] The FREL Tool can be accessed in the following link: https://drive.google.com/file/d/1wiVsHpP_b5kEVkbb4GdQqWaQDDzwyZnw/view?usp=sharing

[135] 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. Available at: http://www.sirefor.go.cr/?p=1170

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

Parameters	FREL for 2010-2025 submitted by Costa Rica to the UNFCCC in 2016	Costa Rica's Carbon Fund Reference Level (1998-2011) for the 2018-2019 monitoring period	Costa Rica's INGEI FOLU emissions on the Biennial Update Report (2015)
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 arithmetic mean was calculated. More detail in Ministry of the Environment and Natural Resources of Costa Rica. (2016), section 4.4.2, Table 8.		developed by Cifuentes (2008)[137]
Secondary forest AGB	C stocks in total net above-ground biomass (T_AGB) 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[138].		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	For the FREL 2010-2025 uncertainty was not estimated. Likewise, uncertainty was not analyzed by the Technical Team of Experts of UNFCCC.	Uncertainty for the Carbon Fund Reference Level and its 2018-2019 monitoring period was estimated using 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.

[137] 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.

[138] 2016.07.10 - FREL & MRV TOOL CR MapaIMN15v3.xlsx
https://drive.google.com/file/d/1ZV7eYpA5ab75VLKLF3KGp8rfPJ_U3wpz/view?usp=sharing

9 APPROACH FOR MEASUREMENT, MONITORING AND REPORTING

9.1. Measurement, monitoring and reporting approach for estimating emissions occurring under the ER Program within the Accounting Area

The processes for collecting, processing, consolidating, and reporting GHG data and information employed during the monitoring period will be identical to the ones used for the construction of the reference level. Costa Rica will monitor the same activities and carbon pools and will implement these same procedures for future monitoring events.

SIMOCUTE is responsible for establishing the methods and protocols to generate the activity data and emission factors. Specifically:

- **Obtaining activity data (AD):** Instituto Meteorológico Nacional (IMN) has produced to date all land use cover maps and national GHG inventories in Costa Rica. The REDD+ Secretariat has been the entity responsible for developing the land use cover maps for the historical series that were used to develop the FRL/FREL submitted to the UNFCCC.
- **Obtaining emission factors (EFs):** SINAC is responsible for Costa Rica's NFI, which determines regularly the forest stocks in the country. The NFI outcomes are used to develop emission factors for Costa Rica's REDD+ MRV. SINAC will update the NFI to allow future resampling of a portion of the existing plots, with the support of US Forest Service (USFS) and FAO, which will consist on a resampling of a portion of SIMOCUTE's 10,588 sampling plots (Figure 3). Costa Rica's intention is to start in 2020 (or later, depending on the global covid-19 pandemic situation) the measurement 441 sampling points over a 5-year period to estimate biomass transitions[139].
- **Estimating emissions and sinks:** IMN, responsible for the national GHG inventories in Costa Rica, maintains the capacity to estimate GHG from AFOLU (agriculture, forestry, and other land use) and LULUCF (land use, land use change, and forestry).
- **Reporting:** Technical reports and annexes on REDD+ are developed by the REDD+ Secretariat and supported by IMN experts estimating emissions and sinks. These include reports to the FCPF Carbon Fund (FC), safeguards reports, and BURs for payment for performance under REDD+. The results from these reports then undergo a verification process by external reviewers and the REDD+ secretariat along with the IMN work team must adjust the FREL/FRL as needed.

To calculate the average annual historical emissions over the reference period, Costa Rica follows an activity-based approach where emissions and removals are estimated based on spatially explicit gross activity data and on net emission factors. Activity data is entered in land use matrices (see below) to ensure representation of all land use transitions and avoid double counting or omissions.

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

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

[139] MINAE, 2019. Technical Annex of the Republic of Costa Rica, in accordance with the provisions of Decision 14 / Cp.19. 64pp. Retrieved from https://unfccc.int/sites/default/files/resource/4863_3_iba-2019-anexotecnico_Edited.pdf .

Once AD and EFs for the forest that remain forests and forest cover change are generated and the corresponding GHG fluxes estimated with excel-based calculators, the uncertainty of the estimates is assessed by IMN and technical advisors from academia as needed (Figure 3).

To develop NFMS methods and protocols, SIMOCUTE follows the UNFCCC AFOLU requirements for monitoring land use cover emissions and establishes technical working groups to determine the procedures to implement methodologies and protocols, as well as to update them if needed. These technical working groups are conformed by experts from the institutions involved in the monitoring of ecosystems and land use / land cover.

The key elements of the SLMS and the NFI, including the source of data, the forest area covered, and the frequency of monitoring can be found in the Technical Annex Document[140]. There are QA/QC procedures for the AD and FE calculation as follows:

- **Activity Data:** The QA/QC procedures applied during the calculation of AD for the reference and monitoring period are summarized in Tables 2, 3, 6, and 7, further information may be found in Agresta (2005)[141], Ortiz-Malavassi (2017)[142], and Aguilar (2020)[143].
- **Emission Factors:** The QA/QC procedures applied during the calculation of EF for deforestation and degradation are summarized in Tables 4 and 5, further information may be found in Ministerio de Ambiente y Energía (2015)[144], Rodriguez (2018)[145], Coto (2018)[146], and Obando (2019)[147].

Costa Rica's first National Forest Inventory (NFI) was finished in 2015, under the supervision of SINAC. The NFI plots have been found to pose challenges for SINAC to conduct forest change assessments over time because of an uneven plot distribution among forest strata[148] and thus, SINAC is currently evaluating changes to the NFI structure through redistributing the plots to enhance compatibility with SIMOCUTE.

Costa Rica already conducted a monitoring event and estimated emission reductions as part of the ER-Program. The methods and data employed are identical to the ones used for the construction of the reference level. The country will implement these same procedures for future monitoring events of ER Program. The FREL and Degradation tools contain a list of values and parameters (including their source and associated level of uncertainty) used to calculate the reference level and that are employed during the MRV. These values will not change during the term of the ERPA.

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140 MINAE, 2019. Technical Annex of the Republic of Costa Rica, in accordance with the provisions of Decision 14 / Cp.19. 64pp. Retrieved from https://unfccc.int/sites/default/files/resource/4863_3_iba-2019-anexotecnico_Edited.pdf .

141 Agresta, Dimap, Universidad de Costa Rica, Universidad Politécnica de Madrid. 2015. Final Report: Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level: Methodological Protocol. Report prepared for the Government of Costa Rica under the Carbon Fund of the Forest Carbon Partnership (FCPF). 44 pp. https://www.dropbox.com/s/ygjw6zq00a1qtbm/Informe_tecnico_feb_2015.pdf?dl=0

142 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. Retrieved from https://drive.google.com/file/d/1GXdN43f-DNKelkM8y7gBLrKou-f7LI-G/view?usp=sharing

143 Aguilar, L. (2020). Evaluación Visual Multitemporal para la determinación de la degradación forestal para los periodos 2014-2015-2017-2019 y determinación de datos de referencia para periodo 2017-2019. Tercer Informe. Retrieved from https://drive.google.com/file/d/1ERutZo6vNI6MXUCmlrky7wiaeOqOLMqh/view?usp=sharing

144 Ministerio de Ambiente y Energía. (2015). Volumen 4 Marco conceptual y metodológico para la Inventario forestal nacional de Costa Rica. Retrieved from https://www.sirefor.go.cr/pdfs/Volumen4-MarcoC-Imprenta.pdf

145 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

146 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

147 Obando, G. (2019). COORDINACIÓN GENERAL DE LA IMPLEMENTACIÓN DEL PLAN DE MEJORA DEL NIVEL DE REFERENCIA. Tercer Informe de Consultoría N ° 016-2018-REDD. Retrieved from https://drive.google.com/file/d/1MEHZ6dvQKY52X58UtlG02o4Uw9x1HV6v/view?usp=sharing

148 Recomendaciones para la Medición, Reporte, y Verificación (MRV) de REDD+. 2016. Report from the CDI, US Forest Service, and FAO UN-REDD. 33 pp.

LINE DIAGRAM

The diagrams below show a step-by-step description of the measurement and monitoring approach for establishment of the Reference Level and estimating Emissions and Emissions reductions during the Monitoring / Reporting Periods for estimating the emissions and removals from the Sources/Sinks, Carbon Pools and greenhouse gases selected in the ER-PD (Figure 2).

Costa Rica has developed a tool to estimate emission and removals from deforestation and reforestation - FREL & MRV TOOL CR.xlsx[149], and other for the estimate of emission and removals from degradation in permanent forest lands – Herramienta-degradacion.xlsx[150].

FREL tool: Details of FREL tool can be found in START spreadsheet, and its manual (Manual de la Herramienta FREL & MRV Tool – UNFCCC.pdf in Spanish[151]). The tool is organized in the following sections:

Setting sections that must not be modified by users:

xi. START: This spreadsheet explains the general information of the Tool: i. name and contact information of the person who made the last modification of the Tool, ii. date of the changes and iii. keyword used to lock spreadsheets.

xii. FREL&FRL: In this spreadsheet the user can recalculate the FREL/FRL by selecting i. carbon gases and reservoirs to be included in the FREL/FRL; ii. REDD + activities to be included in the FREL/FRL; iii. the years of the historical reference period of the FREL/FRL.

xiii. C-STOCKS: The objective of this spreadsheet is to calculate the carbon stocks (in tCO_2-e ha^{-1}) of the land use categories represented in the Land Cover Maps (MCS) of Costa Rica. The calculation is done separately for each gas and carbon pool, whether or not it is included in the FREL/FRL. The spreadsheet also reports uncertainty values, at 90% or 95%, associated with estimates of average carbon existence. The calculations of these uncertainty values are made in a separate Excel file ("Carbon Database> 4. Carbon Densities"[152]) using the IPCC uncertainty propagation method (Equation 3.1 and 3.2 of IPCC-GL, 2006 - Volume 2). At the end of the spreadsheet, all the data, parameters and default values used in the calculation of carbon stock estimates and their respective sources are listed.

xiv. REDD+ ACT: This spreadsheet defines REDD + activities in such a way that it is not possible to count the same source or the same GHG sink in more than one REDD + activity and ensuring, at the same time, that all GHG sources and sinks are considered in the analysis. The approach taken to meet this objective is to represent in a matrix of land use changes all possible transitions between land use categories and then assign each cell in the matrix to a single REDD + activity.

xv. LIST: This spreadsheet contains the drop-down lists that appear in the rest of the Tool's pages and additional information related to the stratification of Costa Rica's forests. No calculation is made on this sheet.

Input section:

xvi. LCM AAAA-AA: In this spreadsheet the activity data of the "AAAA-AA" period are reported, where "AAAA and AA" are the beginning ("AAAA") and end ("AA") years of the period. This is done by filling in a matrix of land use changes with all possible transitions. The structure of the matrix is identical to the matrix presented in the "REDD + ACT" spreadsheet, which allows the activity data to be related to REDD + Activities.
The "LCM AAAA-AA" spreadsheets are the only ones that must be filled in for REDD + monitoring. When activity data is entered in the matrices of the "LCM AAAA-AA" sheets, the Tool will automatically calculate the annual activity data ("AD AAAA" sheets) and annual emissions and removals ("ER AAAA" sheets) up to the "AA" year (= last year of the "AAAA-AA" period). The "FREL & FRL" sheet will be updated with the data

[149] The FREL Tool can be accessed in the following link:
https://drive.google.com/file/d/1wiVsHpP_b5kEVkbb4GdQqWaQDDzwyZnw/view?usp=sharing

[150] Degradation tool can be accessed in the following link:
https://drive.google.com/file/d/1GG3Z_QMWBKGNRdXnF_TdWP1ipH9dX5iH/view?usp=sharing

[151] A copy of the FREL Tool Manual can be download at the following link:
https://drive.google.com/file/d/14CsE_rpBBrEJgyUTplziKKsGGVm_YtL_/view?usp=sharing

[152] A copy of Carbon Densities database can be download at the following link:
https://drive.google.com/file/d/1LJ8pbd0EuiVoS7JuMc8ps_OwlD12MUuH/view?usp=sharing

calculated up to the "AA" year and the results of the mitigation actions (or emission reduction program) on the "RESULTS" sheet.

Calculation section:

xvii. AD AAAA: In this sheet the annual activity data are calculated from the values entered in the "LCM AAAA-AA" sheets. The calculation is made in matrices of land use changes and is based on the assumption that in the "AAAA-AA" period the areas converted annually are equal.

xviii. ER AAAA: These spreadsheets calculate GHG emissions and removals related to the land use change summarized by type of forest and REDD + activities. The calculation is performed automatically in each of the cells of the land use change matrices by multiplying the activity data by their corresponding emission factors. The activity data are the values calculated in the matrices of the "AD AAAA" spreadsheets. The emission factors are calculated as the difference between the carbon contents existing at the beginning and end of the year, taking the carbon stock values of the "C-STOCKS" spreadsheet.

Results sections:

xix. RESULTS: This spreadsheet calculates and shows the results of the mitigation action. Results are calculated considering the same gases, carbon reservoirs, emission factors and REDD + activities that were included in the FREL / FRL. The calculation of the results is simply the difference between the actual emissions / removals and the emissions / removals of the FREL/FRL.

xx. CHARTS: This spreadsheet contains graphs and tables that were included in the FREL / FRL description documents of Costa Rica that were submitted to the UNFCCC (MINAE, 2016). The content of this sheet is informative and there are no parameters that the user can change (except the working language) or calculations that are not performed on other spreadsheets.

Uncertainty analysis are performed in a separated tool using Monte Carlo simulation as described in section 5.

Degradation tool: Costa Rica used a methodology of visual interpretation of high-resolution images to detect changes in the canopy of permanent forest areas to estimate emissions and removals from degradation. This analysis resulted in a database of canopy cover percentages in 4,377 points in forest lands of Costa Rica for several years. Details of the Degradation tool can be found in Winrock International, (2018)[153]. The tool facilitates the following calculations:

- Segregation of interpretation points between anthropic and natural carbon flux areas to eliminate natural changes from emissions accounting since the ER program cannot control them.
- Calculation of the number of points in each forest state transition. In this step, the canopy interpretation assessment of the three forest status classes of the initial year and the final year of the monitoring period are classified. The three classes of forest status are: a. Intact: forest areas with canopy percentage between 85-100%; b. Slightly degraded: forest areas with canopy percentage between 60-85%; c. Very degraded: forest areas with canopy percentage less than 60%.
- Extrapolate the area of each transition of forest states. This step is necessary to extrapolate the carbon flows detected at the interpretation points to the entire permanent forest area for the monitoring period.
- Calculation of the average canopy percentage for each forest state. In this step, the tool calculates the average canopy percentage of each forest state for the beginning and the end of the monitoring period.
- Estimation of carbon fluxes (emissions and removals) of each type of transition is the final step. The tool uses the relationship between the percentage of canopy cover and biomass to estimate carbon fluxes in each transition from forest state.

The Degradation tool is organized as follows:

viii. Descripcion_Variables: This sheet contains descriptions of the High-Resolution Image Visual Interpretation Analysis database attributes. Take note of the attributes *Arbol+Palma_AAAA* variables. These attributes show the percentage of canopy cover in the initial and final year of the monitoring period.

ix. Base_de_Datos: This sheet contains the database for the visual interpretation of high-resolution images.

[153] Winrock International. (2018). Ejercicio : estimación de emisiones por actividades en bosques que permanecen como tales. Retrieved from https://drive.google.com/file/d/1Mk8MACXEKDROXQg2UP7t4FDqQmc8Q5S9/view?usp=sharing

x. Resumen_de_puntos: This sheet calculates the number of points and extrapolates the area for each transition from the forest state.

xi. Deg_ems_antro_RP_AA-AA: This sheet calculates the average canopy percentage of each forest state and the anthropic carbon fluxes (emissions and removals) of each type of transition for the Reference Period.

xii. Deg_ems_nat_RP_AA-AA: This sheet calculates the average canopy percentage of each forest state and the natural carbon fluxes (emissions and removals) of each type of transition for the Reference Period.

xiii. Deg_ems_antro_MP_AA-AA: This sheet calculates the average canopy percentage of each forest state and the anthropic carbon fluxes (emissions and removals) of each type of transition for the Monitoring Period.

xiv. Deg_ems_nat_MP_AA-AA: This sheet calculates the average canopy percentage of each forest state and the natural carbon fluxes (emissions and removals) of each type of transition for the Monitoring Period.

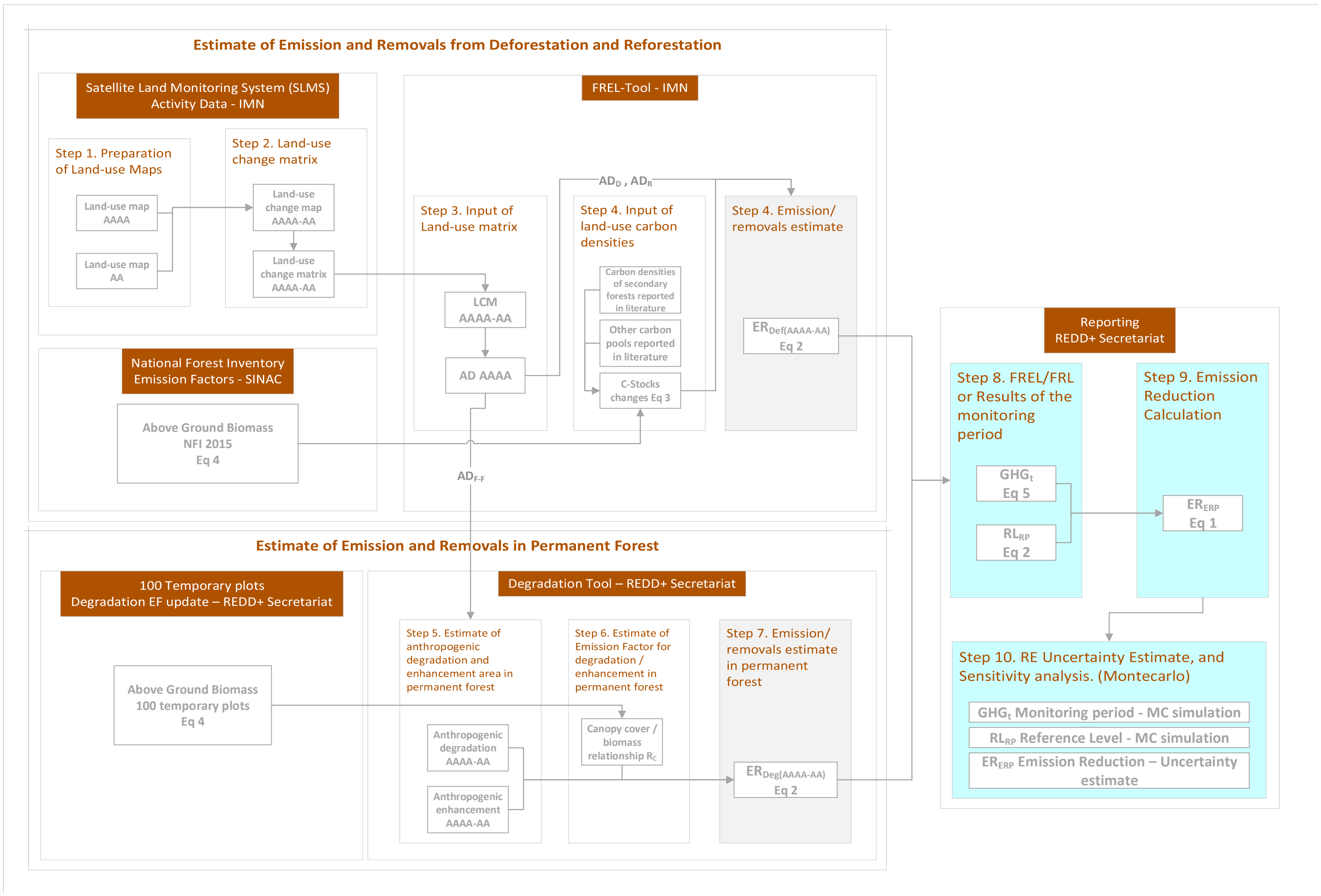

Figure 4: Step-by-step description of the measurement and monitoring approach applied for establishment of the Reference Level and estimating Emissions and Emissions reductions during the Monitoring / Reporting Periods for estimating the emissions and removals from the Sources/Sinks, Carbon Pools and greenhouse gases selected in the ER-PD of Costa Rica. This line diagram includes the update of the emission factors for degradation for the main forest types in the country (wet and rain forests, moist forests, dry forests, mangrove forests, and palm forests). This update is based on the 100 temporary plots sampled for aboveground biomass in 2018-2019.

CALCULATION STEPS

Emission reduction calculation

$$ER_{ERP,t} = RL_{RP} - GHG_t$$ **Equation 10**

Where:

ER_{ERP}	=	Emission Reductions under the ER Program in year t; $tCO_2e*year^{-1}$.
RL_{RP}	=	Gross emissions of the RL from deforestation and degradation over the Reference Period; $tCO_2e*year^{-1}$. This is sourced from Annex 4 to the ER Monitoring Report and equations are provided below.
GHG_t	=	Monitored gross emissions from deforestation at year t; $tCO_2e*year^{-1}$;
T	=	Number of years during the monitoring period; dimensionless.

Reference Level (RL_t)

The RL estimation may be found in Annex 4, yet a description of the equations is provided below. RL 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:

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

Equation 11

Where:

ER_{RA_t}	=	Emissions or removals associated to REDD+ activity *RA* in year *t*; tCO_2-e yr^{-1}
$AD_{RA_{i,t}}$	=	AD associated to REDD+ activity *RA* for the land use transition *i* in year *t*; ha yr^{-1}
$EF_{RA_{i,t}}$	=	EF associated to REDD+ activity *RA* applicable to the land use transition *i* in year *t*; tCO_2-e ha^{-1}
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)	$AD_{D_{i,t}} = \left|D_{i,t}\right| * 0.81$, **Equation 2.1**	Where $\left|D_{i,t}\right|$ 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)	$AD_{R_{i,t}} = \left|R_{i,t}\right| * 0.81$, **Equation 2.2**	Where $\left|R_{i,t}\right|$ 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})	$AD_{F-F_{i,t}} = \left|F - F_{i,t}\right| * 0.81$, **Equation 2.3**	Where $\left|F - F_{i,t}\right|$ 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})	$AD_{Deg_{i,t}} = \frac{\left|Deg_{i,t}\right|}{N} * \sum_{i=1}^{I} AD_{F-F_{i,t}}$ **Equation 2.4**	Where $\left|Deg_{i,t}\right|$ is the count of sampling points where canopy change decrease (dimensionless), *N* is the total of sampling points (dimensionless), and $\sum_{i=1}^{I} AD_{F-F_{i,t}}$ is the total area of permanent forest (in hectares – ha) in the monitoring period.
Activity Data of Permanent Forest Regeneration (AD_E)	$AD_{E_{i,t}} = \frac{\left|E_{i,t}\right|}{N} * \sum_{i=1}^{I} AD_{F-F_{i,t}}$ **Equation 2.5**	Where $\left|E_{i,t}\right|$ is the count of sampling points where canopy change increase (dimensionless), *N* is the total of sampling points (dimensionless), and $\sum_{i=1}^{I} AD_{F-F_{i,t}}$ is the total area of permanent forest (in hectares – ha) in the monitoring period.

EFs were determined from C stocks. 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:

$$\Delta C = \frac{(C_{t2} - C_{t1})}{(t2 - t1)} * 44/12$$ **Equation 12**

Where:

ΔC	=	C stock changes associated to the land use transition *i* in year *t*; tCO_2-e ha^{-1}
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.
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[154] and 20[155] of the sheets “ER AAAA” (where “AAAA” stands for the year *t*) in the FREL TOOL.
t2-t1	=	In all cases the C stock changes were estimated annually, *i.e. t2-t1* = 1 year.
44/12	=	Conversion of C to CO_2

[154] The C stock values reported in line 19 represent total C stocks existing in secondary forest and tree plantation 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 and conversions of other land use categories to permanent crops.

[155] 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 and conversion of other land use categories to permanent crops.

Forest C is determined from the NFI biomass data, converted to carbon as follows:

$$C_t = \sum_{\mathbf{j,i}} (B_{tot}) \text{ x CF}$$ **Equation 13**

Where:

B_{tot}	=	Total biomass stock for the land use category *LU*; tCO_2-e ha^{-1}. Total biomass is equivalent to the sum of all biomass pools: $B_{tot} = B_{AGB} + B_{BGB} + B_{DW} + B_L$ Where: AGB is above-ground biomass for land use category *LU*; tCO_2-e ha^{-1} BGB is below-ground biomass for land use category *LU*; tCO_2-e ha^{-1} DW is dead wood biomass for land use category *LU*; tCO_2-e ha^{-1} L is litter biomass for land use category *LU*; tCO_2-e ha^{-1}
CF	=	Carbon fraction of dry matter in tC per ton dry matter. The value used is: **0.47** is the default for (sub)tropical forest as per IPCC AFOLU guidelines 2006, Table 4.3.

Carbon stocks of non-Forest land uses are estimated as the average values reported by the selected studies:

- *Cropland:* carbon stock values reported in selected studies showed high variability, depending on crop type (sugar cane, coffee, banana, cocoa, etc.). For this reason, the carbon stock data compiled were weighted by the surface area of the respective crops in Costa Rica to produce a single estimate of carbon stocks from cropland.
- *Grassland:* carbon stocks were estimated as the average values reported in different carbon pools in the selected studies.
- *Settlements and (non-forested) Wetlands:* no studies could be found reporting biomass values for these categories. It was assumed that their carbon stock is zero.
- *Other Land:* studies were found reporting carbon stocks for *Paramo.* In the case of *Bare Soil* it was assumed carbon stocks are zero.

Additional details on AD, EF, and calculations in the reference level and monitoring period are available in Section 3 and Annex 4 of this monitoring report.

Monitored emissions (GHG_t)

Annual gross GHG emissions over the monitoring period in the Accounting Area (GHG_t) are estimated as the sum of annual change in total biomass carbon stocks (ΔC_{B_t}).

$$GHG_t = \frac{\sum_t^T \Delta C_t}{T}$$ **Equation 14**

Where:

ΔC_t	=	Annual change in total biomass carbon stocks at year t; tC*$year^{-1}$
T	=	Number of years during the monitoring period; dimensionless.

Changes in total biomass carbon stocks are calculated following Equation 3 above.

PARAMETERS TO BE MONITORED

The country will monitor the following parameters during the Monitoring Period (tables 17 and 18):

Table 17: Source of Activity Data and description of the methods for developing the data for estimate emissions from deforestation and carbon removals during the monitoring period.

Parameter:	**Activity Data of Deforestation (ADD) Eq. 2.1** **Activity Data of Reforestation (ADR) Eq. 2.2** **Forest remaining forests (ADF-F) Eq. 2.**

Description:	Deforestation: Hectares of forest that changed to non-forest land in a year summed each year (i) of the reference period. Reforestation: Hectares of non-forest that changed to forest land in a year, summed for each year (i) of the reference period. Forest remaining forests: Hectares of Forest remaining forests in a year, summed for each year (i) of the reference period
Data unit:	Hectares
Source of data or measurement/calculation methods and procedures to be applied (e.g. field measurements, remote sensing data, national data, official statistics, IPCC Guidelines, commercial and scientific literature), including the spatial level of the data (local, regional, national, international) and if and how the data or methods will be approved during the Term of the ERPA	The construction of the AD for monitoring periods requires the following sources of data: • Remotely sensed data from Landsat 8 OLI/TIRS. • Mask of the country (in raster format) generated from map MCS 2013/14 • Land-use maps and Forest's type maps (MTB), prepared by AGRESTA (2015) 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. • The Global Forest Change project (Hansen et al., 2013) to fill in pixels without information in the mosaic of classifications for land-use maps.
Frequency of monitoring/recording:	Every two years
Monitoring equipment:	GIS and Remote Sensing Laboratory of National Meteorological Institute.
Quality Assurance/Quality Control procedures to be applied:	According to the protocol described in Agresta *et al.* (2015.a)[156].
Identification of sources of uncertainty for this parameter	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 change map is done following Olofsson et al.'s (2014)[157] guidelines.
Process for managing and reducing uncertainty associated with this parameter	The contribution of the AD is about 8.7% of aggregated uncertainty of Emission Reductions estimation (see section 5 of ER-MR). No process for managing or reducing AD uncertainty is being developed.

Table 18: Source of Activity Data and description of the methods for developing the data for estimate emissions from degradation during the monitoring period.

Parameter:	**Activity Data of Degradation (AD_{Deg}) Eq 2.4** **Activity Data of Permanent Forest Regeneration (AD_E) Eq. 2.5**
Description:	Degradation: Hectares of forest with a reduction of canopy cover during the monitoring period. Forest Enhancement: Hectares of forest with an increase of canopy cover during the monitoring period
Data unit:	Canopy cover percentage (%)

[156]Agresta, Dimap, Universidad de Costa Rica, Universidad Politécnica de Madrid, 2015.a. Final Report: Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level: Methodological Protocol.Report prepared for the Government of Costa Rica under the Carbon Fund of the Forest Carbon Partnership (FCPF). 44 p.

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

Source of data or measurement/calculation methods and procedures to be applied (e.g. field measurements, remote sensing data, national data, official statistics, IPCC Guidelines, commercial and scientific literature), including the spatial level of the data (local, regional, national, international) and if and how the data or methods will be approved during the Term of the ERPA	The forest degradation assessment is made on forest lands that remain as forest lands. The analysis of degradation is 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 is collected following Ortiz-Malavassi, (2017)[158].
Frequency of monitoring/recording:	Every two years
Monitoring equipment:	Outsourced
Quality Assurance/Quality Control procedures to be applied:	Ortiz-Malavassi (2017) prepared a land cover evaluation protocol to reduce the uncertainty of the land cover classification due to: a) the bias associated with the spatial registration of the reference image, b) the interpreter bias in the assignment of the land cover class; and c) interpreter variability. The protocol includes the operational definition of the canopy coverage with examples taken from high-resolution images and registration templates for Collect Earth Desktop.
Identification of sources of uncertainty for this parameter	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. Uncertainty of changes in canopy cover to identify areas of degradation and forest enhancement from 1998-2011 vary depending on the forest type and the conversion class. It is based on the sampling error.
Process for managing and reducing uncertainty associated with this parameter	It is assumed that uncertainty will be reduced as higher-quality imagery becomes available on Google Earth and other sources. Given the low uncertainty of visual interpretation, efforts to reduce uncertainty are focused on refining the canopy cover – biomass relationship rather than improving the visual assessment.

9.2. Organizational structure for measurement, monitoring and reporting

Costa Rica's National Forest Monitoring System (NFMS), which generates information for the REDD+ Monitoring, Reporting, and Verification (MRV), has already been created[159]. The process started in 2015 when the National Center for Geospatial Information (CENIGA) initiated the designing process of the NFMS to cover all land uses and land use changes at the national level following IPCC's 2003 Good Practice Guidelines[160]. The NFMS is composed of two data collection mechanisms:

- The first is the Satellite Land Monitoring System (SLMS), which collects land use and land use change data. The agencies/institutions responsible for the SLMS are the National Meteorology Institute (IMN) and the REDD+ Secretariat, composed of the Fondo Nacional de Financiamiento Forestal (FONAFIFO) and the Sistema Nacional de Areas de Conservación (SINAC). The Instituto Metereológico Nacional (IMN) is also responsible for Costa Rica's National GHG Inventory (INGEI) and the development and submission of Biennial Update Reports (BURs). Therefore, the collaboration between IMN and FONAFIFO is crucial to maintain consistency between the REDD+ reporting and the national GHG

[158] 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. Retrieved from https://drive.google.com/file/d/1GXdN43f-DNKelkM8y7gBLrKou-f7LI-G/view?usp=sharing
[159] https://redd.unfccc.int/files/4863_2_sistema_nacional_monitoreo_forestal_costa_rica.pdf
[160] Available at: https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html

inventory. The IMN is also tasked with developing indicators that follow IPCC's Good Practice Guidelines and SIMOCUTE´s structure.

- The second data collection mechanism is the National Forest Inventory (NFI), which gathers forest field data to estimate and update the country's emission factors. This piece of the NFMS is led by the SINAC, which is also responsible for promoting sustainable forest management, logging permits, and control of illegal logging.

Other government entities involved in the REDD+ Program are: Ministerio de Ambiente y Energia (MINAE), which gives political support to the process; Colegio de Ingenieros Agrónimos (CIAgro), which supervises forestry professionals in charge of REDD+ Program implementation; Oficina Nacional Forestal (ONF) is the interlocutor between these government entities and the private sector; and Asociaciones de Desarrollo Integral Indigena (ADII), which supports indigenous groups. The inter-institutional REDD+ Board of Directors is responsible for issuing policies, making decisions, and resolving conflicts or grievances related to REDD+.

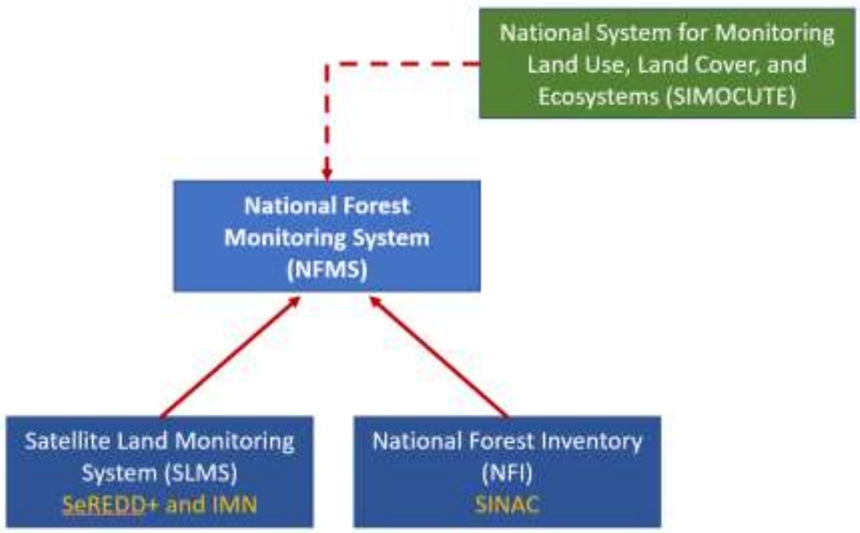

Figure 5. Organizational structure of the National Forest Monitoring System in Costa Rica.

The SIMOCUTE (National Monitoring System for Land Use, Land Use Cover, and Ecosystems) is the official platform for coordination, linkage, and institutional and sectoral integration of the Costa Rican State management and distribution of knowledge and information on land-use change and ecosystem monitoring. SIMOCUTE provides technical guidance for the monitoring, reporting, and verification (MRV) of land-use change in the AFOLU sector (agriculture, forests, and other land use). The technical working group of SIMOCUTE developed a monitoring methodology for the land-use change estimation area. The land-use change monitoring methodology is based on the visual interpretation of high-resolution imagery over 10,588 georeferenced systematic grid points. The procedure is designed to meet the country's forest monitoring needs by integrating all geospatial information produced in the country at the national, regional, and local levels. An early implementation phase of SIMOCUTE took place in 2017. Through this early implementation, Costa Rica conducted a first monitoring event and the first estimate of emission reductions as part of its ER-Program. SIMOCUTE is now a fully operational platform[161], and is designed to integrate the information of MRV system of emissions and removals of GHG from the AFOLU sector, doing so in compliance with the national REDD+ program, the NAMAs, the national carbon trading system, and the progress of NDC implementation[162].

[161] Accessible at https://simocute.go.cr/

[162] www.sinac.go.cr/ceniga/?q=content/sistema-de-monitoreo-de-la-cobertura-y-uso-de-la-tierra-y-ecosistemas-simocute

Figure 2. Conceptual Framework of Costa Rica's SIMOCUTE (National Monitoring System for Land Use, Land Use Cover, and Ecosystems). Source: MINAE 2017.

Costa Rica's National Forest Monitoring System (NFMS) was consolidated in 2019 and comprised a Terrestrial Satellite Monitoring System (SMST) and an INF. Through the SMST, national data on land-use changes are collected. The INF collects data to develop emission factors to estimate emissions and removals to be reported in the National Inventory of GHG for the AFOLU sector. The NFMS seats under a broader umbrella platform to coordinate all environmental information in the country, called SIMOCUTE (Sistema Nacional de Monitoreo de la Cobertura y el Uso de la Tierra y Ecosistemas in Spanish)[163].

REDD+ Secretariat counts with the support of the Costa Rica REDD-plus Result-Based Payments Project (RPB Project). This project will provide additional human resources and material inputs such as satellite imagery, hardware, software, and field monitoring equipment necessary for the Monitoring and reporting of REDD+ implementation. This activity will strengthen national capacities for REDD+ monitoring, reporting, and verification. Furthermore, this project will also provide support to meet the requirements of emerging market standards such as "The REDD+ Environmental Excellency Standard" (TREES) within the scope of the "Architecture for REDD+ Transactions" (ART) Program. RBP project will combine the market standards with Warsaw Framework for REDD+ results-based payments to maximize REDD+ financing for Costa Rica. Indeed, these standards can be made consistent with UNFCCC decisions for REDD+ while also including additional rules that reduce uncertainties and the risks of leakage and reversals. This activity will also support the verification of results by independent third parties. More specifically, this support will include

- Development and implementation of a diversified strategy for capturing REDD+ results-based payments from market and non-market sources based on international partnerships in line with the San Jose principles.
- Updating the FREL for a future submission, methodological improvements in response to technical assessment recommendations, and consolidating methodological consistency with the national GHG inventory and the NDC monitoring framework.

[163] For further detail on the System for Measurement, Monitoring And Reporting Emissions And Removals occurring within the Monitoring Period, please See Section 2 of ER-Monitoring Report.

- Preparation of the second technical annex of REDD+
- Support for participation of Costa Rica in market mechanisms including the REDD+ Environmental Excellence Standard (TREES) of the Architecture for REDD+ transaction programme (ART).
- Support for validation and verification processes.

9.3. Relation and consistency with the National Forestry Monitoring System

Please see section 8.6 in this annex.

9.4. Participation of other players in a variety of actions related to forest control and monitoring

The NFMS, conceived as an official information system, must adhere in its design and function to the current standards applicable to the processes of generating official information, which are regulated by several corresponding entities: The National Geographic Institute (IGN) and its national territorial information systems, the National Institute of Statistics and Census (INEC) regarding data usage, etc. That is why in principle, community participation is not expected in these systems, unless it becomes necessary at some points to fill gaps in the generation of data that may involve these forms of participation.

However, ER-Program envisions supporting measures lead to robust participation by communities and organizations in control actions related to forest resources. For example, SINAC efforts to strengthen the involvement of communities in firefighting through the so-called “Forest fire brigades” that are mainly composed of volunteers in zones with high susceptibility to these phenomena (see section 1.1). Also, SINAC efforts to strengthen the “Natural Resources Monitoring Committees” (COVIRENAS) and the activities of the Volunteers Association (ASVO), non-government entities that contribute through different activities coordinated with the appropriate government agencies, monitoring compliance with government legislation, in the first case, and in supporting the management of protected areas in the second.

SINAC is engaging different actors at the national level to promote participation in protecting and safeguarding natural resources. It is a mechanism that allows state institutions responsible for ensuring these resources to establish surveillance actions together with communities in compliance with the national legal framework. During 2019, SINAC held a series of training workshops to reactivate COVIRENAS, aimed at local actors interested in their formation, and training in the use of integrated environmental reporting process systems (its acronym in Spanish is SITADA), among others.

In addition to this, the Colegio de Ingenieros Agrónomos (Agronomists’ Association) as the governing entity of the “Certified Foresters” who are responsible for preparing and following-up on the management plans of the different modalities of payment for environmental services agreements, have an essential task in monitoring the beneficiaries´ compliance with their respective commitments or actions they have agreed to take with regard to conservation, restoration, reforestation or management. In that same sense, there are many local and regional forestry producer organizations that provide regency services to interested parties, and that have their capacities strengthened through PES. It is envisioned to strengthen these capacities through different lines of work incorporated in policies, actions and tasks of the PRE.

12. UNCERTAINTIES OF THE CALCULATION OF EMISSION REDUCTIONS

12.1 Identification and assessment of sources of uncertainty

An overview of the different sources of uncertainty can be found in Section 5, UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS of this monitoring report. Table 6 below provides the complete description of the analysis undertaken for the identification and assessment of sources of uncertainty of the Reference Level period.

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	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?
		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 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	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?
		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 2018 canopy cover data with the 2016 evaluation performed by Ortiz-Malavassi (2017).			

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?
		ix. **Treatment of plots with forest cover less than 30%:** The analyst made the degradation analysis over the systematic grid points 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	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?
		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.			
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)[164] guidelines. Due 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.	Low	Yes	Yes

[164] 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?
	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 Factor					
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

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?
Wood density estimation	Systematic and Random	The wood density values were obtained directly from specialized publications (Biomass estimation tool developed by SINAC, IPCC 2003[165]; Myers 2013[166]; Tree Functional Attributes and Ecological Database, 2018[167]). 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 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.	Low	No	No
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)[168]. 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[169], to avoid errors during the process of data preparation.	Low	Yes	No

[165] 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.

[166] 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

[167] Tree Functional Attributes and Ecological Database. (2018). Wood Density. Recuperado el 10 de 12 de 2018, de http://db.worldagroforestry.org/.

[168] 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.

[169] The manual of FREL Tool can be accessed in the following link: https://drive.google.com/file/d/1INuL5Jld7nlKVsAf7mRsEepm2n8WRVpT/view?usp=sharing

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?
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

12.2 Quantification of uncertainty in Reference Level Setting

Parameters and assumptions used in the Monte Carlo method

Parameter included in the model	Parameter values	Range: Margin of error (Half the 90% confidence interval)	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Area (hectares) of deforestation	426,148 ha from 1998-2011	120,871	Sampling error	Truncated normal	Minimum value assumed to be 0
Area (hectares) of forests remaining forests	2,233,119 ha from 1998-2011	79,861	Sampling error	Truncated normal	Minimum value assumed to be 0
Area (hectares) of new forests	10,646,850 ha from 1998-2011	3,274,836	Sampling error	Truncated normal	Minimum value assumed to be 0
Change in percent canopy cover in degraded and regenerated forests	Varies depending on the level of degradation and regeneration	Varies depending on the level of degradation and regeneration	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for very moist and rain forests – primary (t CO_2e)	313.69	63.54	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for moist forests - primary (t CO_2e)	203.99	41.86	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for dry forests – primary (t CO_2e)	199.19	302.80	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for mangroves – primary (t CO_2e)	253.74	31.83	Sampling error	Truncated normal	Minimum value assumed to be 0

Parameter included in the model	**Parameter values**	**Range: Margin of error (Half the 90% confidence interval)**	**Error sources quantified in the model (e.g. measurement error, model error, etc.)**	**Probability distribution function**	**Assumptions**
Aboveground biomass for palm forest – primary (t CO_2e)	229.81	25.03	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for secondary forests (t CO_2e)	Varies depending on age (1-400 years) and forest type	Varies depending on age (1-400 years) and forest type	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for annual cropland (t CO_2e)	83.57	9.69	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for permanent cropland (t CO_2e)	Varies depending on age (1-400 years)	Varies depending on age (1-400 years)	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass for paramos (t CO_2e)	126.87	2.16	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for very moist and rain forests – primary (t CO_2e)	71.97	14.58	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for moist forests - primary (t CO_2e)	48.32	9.92	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for dry forests – primary (t CO_2e)	47.27	71.86	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for mangroves – primary (t CO_2e)	53.96	7.42	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for palm forest – primary (t CO_2e)	53.96	5.88	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for secondary forests (t CO_2e)	Varies depending on age (1-400 years) and forest type	Varies depending on age (1-400 years) and forest type	Sampling error	Truncated normal	Minimum value assumed to be 0

Parameter included in the model	Parameter values	Range: Margin of error (Half the 90% confidence interval)	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Belowground biomass for annual cropland (t CO_2e)	21.16	9.69	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for permanent cropland (t CO_2e)	Varies depending on age (1-400 years)	Varies depending on age (1-400 years)	Sampling error	Truncated normal	Minimum value assumed to be 0
Belowground biomass for paramos (t CO_2e)	31.13	2.16	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for very moist and rain forests – primary (t CO_2e)	49.5	8.75	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for moist forests - primary (t CO_2e)	48.27	23.75	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for dry forests – primary	56.47	21.92	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for mangroves – primary (t CO_2e)	6.95	2.05	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for palm forest – primary (t CO_2e)	5.97	7.02	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for secondary forests (t CO_2e)	Varies depending on age (1-400 years) and forest type	Varies depending on age (1-400 years) and forest type	Sampling error	Truncated normal	Minimum value assumed to be 0
Deadwood for grassland (t CO_2e)	8.28	6.29	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for very moist and rain forests – primary (t CO_2e)	10.05	0.94	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for moist forests - primary (t CO_2e)	8.01	1.04	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for dry forests – primary (t CO_2e)	22.73	0.61	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for mangroves – primary (t CO_2e)	0.97	0.24	Sampling error	Truncated normal	Minimum value assumed to be 0

Parameter included in the model	Parameter values	Range: Margin of error (Half the 90% confidence interval)	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Litter for palm forest – primary (t CO_2e)	0.96	1.13	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for secondary forests (t CO_2e)	Varies depending on age (1-400 years) and forest type	Varies depending on age (1-400 years) and forest type	Sampling error	Truncated normal	Minimum value assumed to be 0
Litter for permanent cropland (t CO_2e)	Varies depending on age (1-400 years)	Varies depending on age (1-400 years)	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in very moist and rain forests (t CO_2e)	5.03	0.81	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in moist forests (t CO_2e)	3.86	0.84	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in dry forests (t CO_2e)	3.47	1.98	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in mangroves (t CO_2e)	3.19	1.01	Sampling error	Truncated normal	Minimum value assumed to be 0
Aboveground biomass-canopy cover ratio in palm forests (t CO_2e)	4.26	1.59	Sampling error	Truncated normal	Minimum value assumed to be 0

Quantification of the uncertainty of the estimate of the Reference level

		Deforestation	Forest degradation	Enhancement of carbon stocks
A	**Median**	86,209,025	19,016,994	-71,814,596
B	**Upper bound 90% CI** (Percentile 0.95)	128,233,984	26,926,056	-67,932,082
C	**Lower bound 90% CI** (Percentile 0.05)	49,450,792	12,501,392	-75,770,915
D	**Half Width Confidence Interval at 90% (B – C / 2)**	39,391,596	7,212,332	3,919,416
E	**Relative margin (D / A)**	46%	38%	5%
F	**Uncertainty discount**	8%	8%	4%

Sensitivity analysis and identification of areas of improvement of MRV system

The sensitivity analysis can be found in Section 5 UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS of this report.