TECHNICAL ANNEX
OF THE REPUBLIC OF
COSTA RICA

In Accordance with The Provisions of Decision 14 / Cp.19

2019

GOVERNMENT OF COSTA RICA
MINISTRY OF ENVIRONMENT AND ENERGY

MINAE
Ministerio de Ambiente y Energía

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Costa Rica
October 25th, 2019

GOVERNMENT OF COSTA RICA
MINISTRY OF ENVIRONMENT AND ENERGY

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1. Summary information from the final report containing the assessed forest reference emission level/forest reference level (FREL/FRL)

Costa Rica has submitted a **modified REDD+ Forest reference emission level/forest reference level (FREL/FRL)** on May 23rd 2016 to the UNFCCC Secretariat[1] to address several comments by the Assessment Team (AT), according to the procedures set out in the annex to decision 13/CP.19 for the review of REDD+ reference levels (see details of outcomes of the technical analysis in section 1.6).

1.1. The assessed forest reference emission level/forest reference level

The FREL/FRL has been estimated as the sum of the annual average emissions from deforestation and the annual average removals[2] from enhancements of forest C stocks in the following two historical reference periods:

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

Is relevant to distinguish two periods of enhanced mitigation actions in Costa: 1997-2009 and 2010-2025. The **first period**[3] was defined to reflect

1 Relevant documents related Costa Rica FREL/FRL are available at: https://redd.unfccc.int/submissions.html?country=cri

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

3 The first period started with the adoption of the current Forestry Law, passed in 1996, which includes various innovative policy instruments such as the PSA program. This Law entered into force with the publication of its regulation on January 23, 1997. Starting the first historical reference period in 1986 up to December 1996 would allow for the measurement, reporting and verification of emissions and removals additional to a business-as-usual (BAU) performance, considering policies and programs implemented since 1997.

the adoption of relevant policies and regulations to reduce deforestation and enhance forest coverage while the **second period**[4] is marked by the adoption of enhanced commitments by the government of Costa Rica and additional public spending on mitigation action.

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

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

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

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

Emissions from deforestation	**8,590,840**	**100.0%**
Deforestation from primary forest	6,477,346	75.4%
Deforestation from secondary forest	2,133,494	24.6%
Removals through C-stock enchantments	**-4,225,681**	**100.0%**

Table 1 shows annual emissions from deforestation and removals from forest C stock enhancement for 1986-2009 and the estimation of total and annual average emissions and removals for two historical periods: 1986-1996 and 1997-2009. For the results presented in this technical annex the FREL related to the period 2010-2025 has been used.

The proposed FREL/FRLs are:
For the REDD+ implementation period 1997-2009: **14,911,467 t CO_2e yr^{-1}**
For the REDD+ implementation period 2010-2025: **4,365,159 t CO_2e yr^{-1}**

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

1.2. The activity or activities referred to in decision 1/CP.16, paragraph 70, included in the forest reference emission level/forest reference level

According to Decision 1/CP.16, paragraph 70, the following activities were included in the FREL/FRL: **emission reductions from deforestation, and enhancement of forest C stocks**.

The proposed FREL/FRL includes carbon dioxide (CO_2) emissions and removals associated to changes in C stocks in the following pools: above-ground biomass (AGB), below-ground biomass (BGB), dead wood (DW), and litter (L). Soil organic carbon (SOC) and Harvested Wood Products (HWP) were not included considering the limited availability of data. Costa Rica will consider these C pools in light of the potential inclusion of additional REDD+ activities, such as forest degradation and forest management, in future FREL/FRL submissions.

Before 1997, slash-and-burn was the common practice for land use change in Costa Rica, as this was the easiest way to convert forests to grasslands and croplands (Sader and Joyce, 1988[5]). In 1997, conversion of forest became illegal with the current Forest Law; hence, slash-and-burn dramatically decreases after 1996. For this reason, biomass burning and related emissions of methane (CH_4) and nitrous oxide (N_2O) were included in conversions of forests to cropland and grassland that occurred in the period 1986-1996 and excluded in the post-1996 period.

Data on C stocks were obtained from recent (2005-2015) scientific literature and the NFI. As shown in Table 2, the tree below-ground biomass was estimated following Cairns et al. (1997)[6], while non-tree below-ground biomass was obtained from IPCC default values.

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

Please note that the enhancement of forest C stocks through natural regeneration included in the proposed FREL is anthropogenic. Natural regeneration is vegetation that grows on lands previously used for agriculture, grazing or other purposes, and occurs after a conscious decision by the landowner to

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

6 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.

Table 1. Forest reference emission level/forest reference level proposed by Costa Rica.

Year	Emissions from deforestation			Removals through enhancement of C stocks			Net emission		
	PF	SF	Total	PF	SF	Total	PF	SF	Total
	tCo2-e yr1	tCo2-e yr1	tCo2-e yr1	tCo2-e yr1	tCo2-e yr1	tCo2-e yr1	tCo2-e yr1	tCo2-e yr1	tCo2-e yr1
1986	20 137 007,00	2 631 044,00	22 768 051,00		- 133 643,00	- 133 643,00	20 137 007,00	2 497 401,00	22 634 408,00
1987	20 137 007,00	2 638 486,00	22 775 493,00		- 615 380,00	- 615 380,00	20 137 007,00	2 023 106,00	22 160 113,00
1988	20 137 007,00	2 645 724,00	22 782 731,00		- 1 084 191,00	- 1 084 191,00	20 137 007,00	1 561 533,00	21 698 540,00
1989	20 137 007,00	2 652 766,00	22 789 773,00		- 1 540 369,00	- 1 540 369,00	20 137 007,00	1 112 397,00	21 249 404,00
1990	20 137 007,00	2 659 616,00	22 796 623,00		- 1 984 169,00	- 1 984 169,00	20 137 007,00	675 447,00	20 812 454,00
1991	20 137 007,00	2 666 281,00	22 803 288,00		- 2 415 773,00	- 2 415 773,00	20 137 007,00	250 508,00	20 387 515,00
1992	8 623 426,00	1 397 098,00	10 020 524,00		- 2 918 659,00	- 2 918 659,00	8 623 426,00	- 1 521 561,00	7 101 865,00
1993	8 623 426,00	1 488 297,00	10 111 723,00		- 3 050 859,00	- 3 050 859,00	8 623 426,00	- 1 562 562,00	7 060 864,00
1994	8 623 426,00	1 576 882,00	10 200 308,00		- 3 182 205,00	- 3 182 205,00	8 623 426,00	- 1 605 323,00	7 018 103,00
1995	8 623 426,00	1 662 922,00	10 286 348,00		- 3 312 517,00	- 3 312 517,00	8 623 426,00	- 1 649 595,00	6 973 831,00
1996	8 623 426,00	1 746 481,00	10 369 907,00		- 3 440 872,00	- 3 440 872,00	8 623 426,00	- 1 694 391,00	6 929 035,00
1997	8 623 426,00	1 827 616,00	10 451 042,00		- 3 567 221,00	- 3 567 221,00	8 623 426,00	- 1 739 605,00	6 883 821,00
1998	12 396 451,00	2 936 065,00	15 332 516,00		- 3 457 118,00	- 3 457 118,00	12 396 451,00	- 521 053,00	11 875 398,00
1999	12 396 451,00	3 168 688,00	15 565 139,00		- 3 728 836,00	- 3 728 836,00	12 396 451,00	- 560 148,00	11 836 303,00
2000	12 396 451,00	3 394 316,00	15 790 767,00		- 4 002 603,00	- 4 002 603,00	12 396 451,00	- 608 287,00	11 788 164,00
2001	4 455 983,00	1 381 703,00	5 837 686,00		- 4 458 316,00	- 4 458 316,00	4 455 983,00	- 3 076 613,00	1 379 370,00
2002	4 455 983,00	1 509 820,00	5 965 803,00		- 4 431 811,00	- 4 431 811,00	4 455 983,00	- 2 921 991,00	1 533 992,00
2003	4 455 983,00	1 633 999,00	6 089 982,00		- 4 410 160,00	- 4 410 160,00	4 455 983,00	- 2 776 161,00	1 679 822,00
2004	4 455 983,00	1 754 367,00	6 210 350,00		- 4 393 061,00	- 4 393 061,00	4 455 983,00	- 2 638 694,00	1 817 289,00
2005	4 455 983,00	1 871 041,00	6 327 024,00		- 4 378 745,00	- 4 378 745,00	4 455 983,00	- 2 507 704,00	1 948 279,00
2006	4 455 983,00	1 984 133,00	6 440 116,00		- 4 367 188,00	- 4 367 188,00	4 455 983,00	- 2 383 055,00	2 072 928,00
2007	4 455 983,00	2 093 750,00	6 549 733,00		- 4 358 413,00	- 4 358 413,00	4 455 983,00	- 2 264 663,00	2 191 320,00
2008	3 600 417,00	1 874 696,00	5 475 113,00		- 4 648 116,00	- 4 648 116,00	3 600 417,00	- 2 773 420,00	826 997,00
2009	3 600 417,00	2 045 235,00	5 645 652,00		- 4 732 261,00	- 4 732 261,00	3 600 417,00	- 2 687 026,00	913 391,00
Total 1986-1996	**169 939 172,00**	**23 765 598,00**	**187 704 769,00**		**- 23 678 638,00**	**- 23 678 638,00**	**163 939 172,00**	**86 960,00**	**164 026 132,00**
Average 1986-1996	**14 903 561,00**	**2 160 509,00**	**17 064 070,00**		**- 2 152 603,00**	**- 2 152 603,00**	**14 903 561,00**	**7 905,00**	**14 911 467,00**
Total 1997-2009	**84 205 492,00**	**27 475 426,00**	**111 680 919,00**		**- 54 933 848,00**	**- 54 933 848,00**	**84 205 494,00**	**- 27 458 420,00**	**56 747 071,00**
Average 1997-2009	**6 477 346,00**	**2 113 494,00**	**8 590 840,00**		**- 4 225 681,00**	**- 4 225 681,00**	**6 477 346,00**	**- 2 112 186,00**	**4 365 159.00**

PF = non-managed primary forest; SF = managed secondary forest
For the results presented in this technical annex the FREL related to the period 2010-2025 has been used.

Table 2. Greenhouse gasses and carbon pools included in the FREL

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

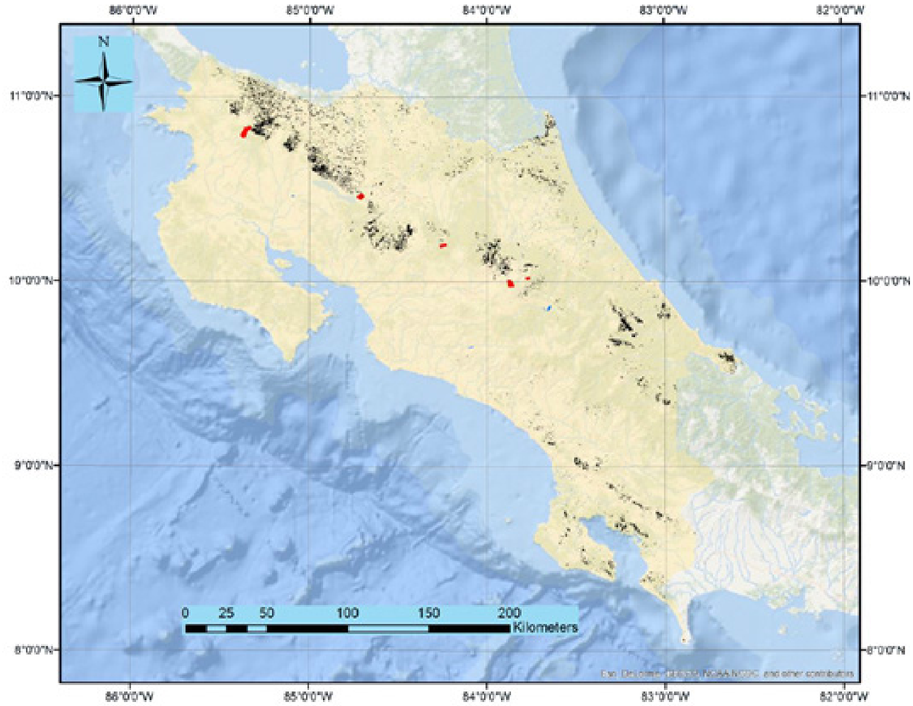
let the forest re-grow. Some lands where natural regeneration is fostered may continue to be Forest land remaining Forest land permanently, while in other cases, natural regeneration is removed after a period of time to revert to agricultural practices[7]. If at any point in time this natural regeneration complies with the definition of forest and is later removed, it is considered as deforestation in the FREL. Emissions from deforestation, but also absorptions due to natural regeneration are included in the FREL.

1.3. The territorial forest area covered

The territorial forest area covered by the FREL/FRL includes the country's continental territory (5,133,939.50 ha) but excludes the Coco Island (238,500 ha)[8]. Within the accounting area, special considerations were

7 An assessment made during the preparation of FREL for the Carbon Fund, indicates that *temporarily stocked* areas (1,000 ha*yr^{-1}) represented less than 3% of the total deforested area (30,321 ha*yr^{-1}) during the period 1997 - 2011. Due to very low participation in the total deforested area, the risk of overestimation of emission can be neglected.

8 The Coco Island, a World Heritage site at 532 km from the Pacific coast, is inhabited solely by park rangers and is not subject to anthropogenic intervention. The island is also too distant from Costa Rica's continental territory and is therefore not prone to displacements that may be caused by Costa Rica´s REDD+ activities. The exclusion of the Coco Island is consistent with the estimation of emissions by sources and removals by sinks in the national GHG inventory.



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

Figure *1*. Areas with special considerations within the accounting area of the proposed FREL/FRL.

made for two types of areas: those without land use information due to clouds and shadows, and those where forest losses are associated to natural disturbances (see Figure 1).

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

1.4. The date of the forest reference emission level/forest reference level submission and the date of the final technical assessment report

- FREL/FRL original submission: January 4th 2016[9]
- FREL/FRL modified submission: May 23rd 2016[10]
- Report of the technical assessment of the proposed forest reference emission level of Costa Rica submitted in 2016: April 3rd 2017[11]

1.5. The period (in years) of the assessed forest reference emission level/forest reference level.

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

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

Table 3 presents the estimated average C stock values per C pool and land use category and their corresponding 90% confidence intervals. Note that in the case of secondary forests, only the estimated C stock values at selected ages are shown. For the complete list of C stock values calculated for each age class (from 1 to 400 years), please see "C-STOCKS" in FREL TOOL CR[12].

1.6. Summary of the technical analysis of the submitted FREL and actions taken by Costa Rica.

The modified submission presents different FREL/FRL values compared to the original submission, specifically due to the exclusion of Harvested Wood Products (HWP). Based on comments from the Assessment Team and

9 https://redd.unfccc.int/files/2016_submission_frel_costa_rica.pdf
10 https://redd.unfccc.int/files/frel_costa_rica_modified.pdf
11 https://unfccc.int/resource/docs/2017/tar/cri.pdf
12 FREL TOOL CR can be accessed in the following link: https://drive.google.com/file/d/1WzEZbNwUmO_x74R7udQSD4YmcO5GiFF4/view?usp=sharing

considering the ongoing work on forest degradation and management, Costa Rica decided to exclude HWP from this FREL/FRL submission, in order to improve methods and obtain more accurate data for future submissions.

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

According to the AT[13]:

- "The information used by Costa Rica in constructing its FREL/FRL for reducing emissions from deforestation and the enhancement of forest carbon stocks was improved in the modified submission of 23 May 2016, but its transparency and completeness should be further improved. The modified submission is in overall accordance with the guidelines for the submission of information on FRELs/FRLs (as contained in the annex to decision 12/CP.17);
- The AT acknowledges that Costa Rica included in the FREL/FRL the most significant activities, and the most significant pools in terms of emissions related to forests. In doing so, the AT considers that Costa Rica followed decision 1/CP.16, paragraph 70, on activities undertaken, paragraph 71(b) and decision 12/CP.17, paragraph 10, on implementing a stepwise approach …;
- … The AT notes that the transparency and completeness of information improved in the modified FREL/FRL submission, without the need to alter the approach or values used to construct the FREL, except for removing the [inclusion of the] HWP pool and commends Costa Rica for the efforts it made. The new information provided in the modified submission, including through the data made available on websites and the examples on how estimates of CO_2 emissions from deforestation were calculated, increased the completeness of FREL/FRL calculations. However, the AT notes that the transparency of the FREL/FRL is an area for improvement, in relation to some assumptions made in the FREL/FRL assessment (e.g. forest classification, primary and secondary forest areas estimation);

13 Extracted from the "Report of the technical assessment of the proposed forest reference emission level of Costa Rica submitted in 2016". Available at: https://unfccc.int/resource/docs/2017/tar/cri.pdf

Table 3. Estimated average C stocks per hectare and related 90% confidence intervals.

					Above-ground biomass		CO_2 Below-ground biomass		Dead wood	Litter	Total carbon stock	Non-CO_2 Biomass burning (LFIRE)	
					CAGB.t	CAGB.n	CBGB.t	CBGB.n	CDW	CL	CTOT	CH_4	N_2O
					TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}
				AVG	481,10		106,92		49,50	10,05	647,57	11,10	4,82
		PF			443,65		98,60		40,75	9,11	608,21	4,50	1,96
				90%CI	518,56		115,24		58,25	11,00	686,94	17,71	7,69
				AVG	34,50		9,33		3,74	0,36	47,92	0,97	0,42
			4 yr		31,59		8,54		3,43	0,27	44,89	0,48	0,21
FL	wet and Rain Forest			90%CI	37,40		10,11		4,06	0,44	50,95	1,46	0,64
				AVG	117,13		28,92		12,71	1,21	159,96	3,3	1,43
		SF	15 yr		107,34		26,50		11,65	0,92	149,82	1,64	0,71
				90%CI	126,92		31,33		13,77	1,50	170,11	4,97	2,16
				AVG	205,74		48,71		22,33	2,12	278,90	5,80	2,52
			30 yr		188,72		44,68		20,48	1,62	261,30	2,88	1,25
				90%CI	222,77		52,74		24,18	2,63	296,5	8,73	3,79
				AVG	339,71		77,48		48,27	8,01	473,46	8,27	3,59
		PF			311,51		71,04		25,02	6,96	436,33	3,31	1,44
				90%CI	367,91		83,91		71,52	9,05	510,58	13,23	5,74
				AVG	44,14		11,72		5,1	0,85	61,81	1,28	0,55
			4yr		40,80		10,83		2,67	0,72	57,58	0,63	0,27
FL	Moist Forest			90%CI	47,49		12,61		7,53	0,98	66,05	1,93	0,84
				AVG	138,15		33,69		15,96	2,67	190,47	4,00	1,74
		SF	15 yr		127,50		31,09		8,37	2,25	177,13	1,96	0,85
				90%CI	148,79		36,28		23,56	3,08	203,81	6,04	2,62
				AVG	220,12		51,85		25,43	4,25	301,65	6,37	2,77
			30 yr		202,84		47,78		13,32	3,58	280,15	3,12	1,35
				90%CI	237,39		55,92		37,54	4,91	323,14	9,62	4,18
				AVG	225,58		53,04		56,47	22,73	357,82	6,74	2,92
		PF			207,62		48,82		34,54	22,12	329,16	2,69	1,17
				90%CI	243,54		57,26		78,39	23,35	386,48	10,78	4,68
				AVG	15,64		4,49		1,88	1,51	23,51	0,51	0,22
			8yr		14,40		4,13		1,34	1,38	22,10	0,25	0,11
FL	Dry Forest			90%CI	16,89		4,84		2,41	1,64	24,92	0,77	0,33
				AVG	79,50		20,20		9,54	7,68	116,92	2,60	1,18
		SF	15 yr		73,17		18,59		6,81	7,02	109,81	1,29	0,56
				90%CI	85,83		21,81		12,26	8,33	124,03	3,91	1,70
				AVG	189,12		45,05		22,68	18,26	275,12	3,18	2,68
			30 yr		174,07		41,47		16,19	16,71	258,27	3,06	1,33
				90%CI	204,18		48,64		29,17	19,82	291,98	9,29	4,03

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Table 3. Continuation.

					CO_2							Non-CO_2	
					Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (LFIRE)	
					CAGB.t	CAGB.n	CBGB.t	CBGB.n	CDW	CL	CTOT	CH_4	N_2O
					TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}
FL	Mangroves			AVG	264,78		61,52		6,95	0,97	334,22		
		PF			233,57		54,27		4,90	0,73	302,11		
				90%CI	269,00		68,77		8,99	1,22	366,33		
				AVG	10,59		3,13		0,27	0,03	14,02		
			4yr		9,34		2,76		0,17	0,00	12,71		
				90%CI	11,84		3,50		0,37	0,06	15,32		
				AVG	39,72		10,63		1,02	0,11	51,47		
		SF	15 yr		35,04		9,37		0,64	0,00	46,60		
				90%CI	44,40		11,88		1,39	0,21	56,33		
				AVG	79,43		20,18		2,03	0,21	101,86		
			30 yr		70,07		17,81		1,28	0,00	92,17		
				90%CI	88,80		22,56		2,78	0,43	111,56		
FL	Palm Forests			AVG	189,57		45,15		5,97	0,96	241,66		
		PF			148,68		35,41		-1,05	-0,17	199,03		
				90%CI	230,47		54,89		12,98	2,10	284,29		
				AVG	7,58		2,29		0,24	0,04	10,16		
			4 yr		5,95		1,80		-0,10	-0,01	8,41		
				90%CI	9,22		2,79		0,57	0,08	11,90		
				AVG	28,44		7,80		0,89	0,14	37,28		
		SF	15 yr		22,30		6,12		-0,37	-0,03	30,79		
				90%CI	34,57		9,48		2,15	0,32	43,76		
				AVG	56,87		14,82		1,79	0,29	73,77		
			30 yr		44,60		11,62		-0,73	-0,05	60,84		
				90%CI	69,14		18,01		4,31	0,63	86,70		
				AVG		83,57		21,16			101,72		
CL	Annual					73,88		18,70			94,73		
				90%CI		93,26		23,61			114,72		
				AVG	38,54	17,35	10,33	4,94	0,81	5,06	77,04		
			4 yr		11,34	5,54	3,04	1,58	0,53	2,65	46,22		
				90%CI	65,74	29,17	17,63	8,30	1,10	7,47	107,87		
				AVG	48,18	21,69	12,71	6,07	1,02	6,33	95,99		
CL	Permanent		5 yr		14,17	6,92	3,74	1,94	0,66	3,32	57,51		
				90%CI	82,18	36,46	21,67	10,20	1,38	0,34	134,47		
				AVG	57,81	26,03	15,04	7,19	1,22	7,59	114,89		
			6 yr		17,01	8,31	4,43	2,29	0,79	3,98	68,75		
				90%CI	98,61	43,76	25,66	12,08	1,65	11,20	161,03		

Table 3. Continuation.

				CO2							Non-CO2	
				Above-ground biomass		Below-ground biomass		Dead wood	Litter	Total carbon stock	Biomass burning (LFIRE)	
				CAGB.t	CAGB.n	CBGB.t	CBGB.n	CDW	CL	CTOT	CH_4	N_2O
				TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}	TCO_2-e ha^{-1}
Bare Soil	CL		AVG	28,48	14,23	7,81	4,11	8,28		62,92		
				28,48	14,23	7,81	4,11	1,00		56,62		
			90%CI	28,48	14,23	7,81	4,11	14,58		69,21		
	SL		AVG									
			90%CI									
	WL	Natural	AVG									
			90%CI									
		Artificial	AVG		126,87		31,13			158,00		
					124,70		30,60			155,77		
			90%CI		129,03		31,67			160,23		
		Paramo	AVG									
			90%CI									
		Natural	AVG									
			90%CI									
		Artificial	AVG									
			90%CI									

- The AT notes that, overall, the FREL/FRL maintains partial consistency, in terms of sources for the AD and the emission factors, with the GHG inventory included in Costa Rica's BUR.
- In assessing the pools and the gases included in the modified FREL/FRL submission, pursuant to paragraph 2(f) of the annex to decision 13/CP.19, the AT notes that the current omissions of pools and gases is unlikely to be leading to an overestimation of emissions in the context of the FREL/FRL…".

2. Results estimate of emission reductions for the 2014-2015 period.

This Technical Annex reports the results obtained by reducing emissions from deforestation for the period 2014 and 2015. Carbon net emissions from deforestation and growth of secondary forest in Costa Rica, were calculated using the methodology described in the Modified REDD+ Forest reference emission level/forest reference level (FREL/FRL) submitted by Costa Rica to UNFCCC Secretariat for technical review according to decision 13/CP19[14].

The reduced emissions (ER) for 2014 and 2015 correspond to the difference between the FREL and the estimated emissions for each year. The methodology for the calculation of actual emissions (AE) is described in the following section.

The estimation is made on annual basis, from activity data obtained for the monitoring period. The average forest emissions for the 2014-2015 period were calculated at 7,397,374 ± 1,128,100 t CO_2e * yr^{-1} (see Annex 2: Uncertainty analysis of forest emission for the period 2014-2015.).

The ER for 2014 have been estimated at 7,489,243 t CO2e and for the year 2015 at 7,305,504 t CO2e. Total ER in these two years have been estimated at 14,794,749 t CO_2e (see Figure 2 and Table 4).

$$ER_{2014} \quad FREL_{2010-2025} - AE_{2014}$$

$$ER_{2014} = 4{,}365{,}160\ tCO_2e * yr^{-1} - (-3{,}124{,}084\ tCO_2e * yr^{-1})$$

$$ER_{2014} = 7{,}489{,}244\ tCO_2e * yr^{-1}$$

2.1. Trend of emission reductions (RE) in Costa Rica

Since 2010, Costa Rica has demonstrated a sustained effort in the implementation of REDD+ actions at the national level. The country has historically operated its national system of protected areas (ASP) and its program of payments for environmental services (PES), which together cover 35% of the

14 https://redd.unfccc.int/files/frel_costa_rica_modified.pdf

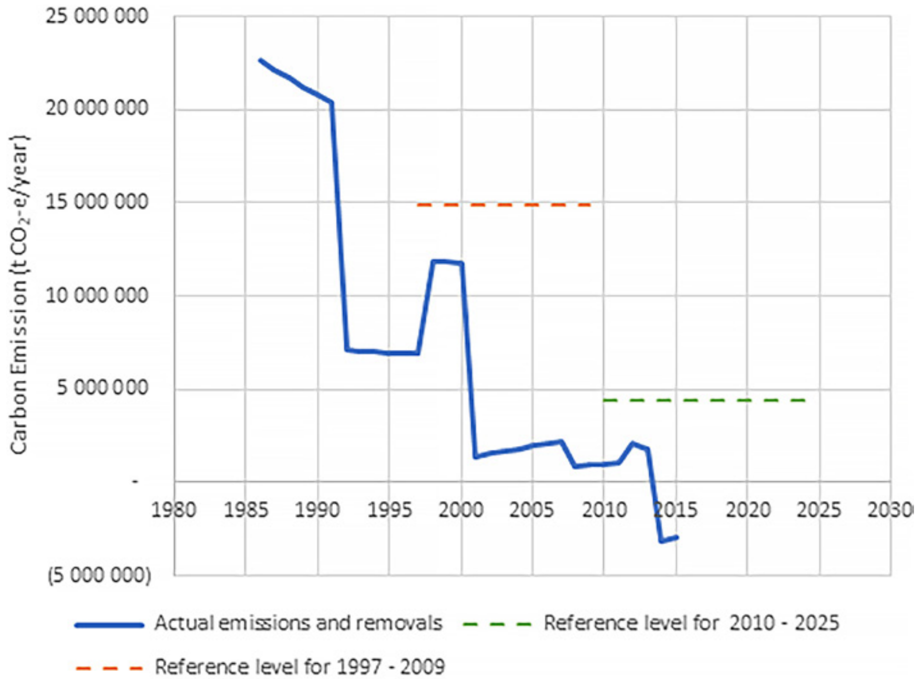

Figure 2. Net forest emissions in Costa Rica for the years 1988 to 2015 and Reference levels for the periods 1997 – 2009 and 2010 2015, based on the FREL submitted by Costa Rica to the UNFCCC in May 2016 , considered in the estimated results of emission reductions presented in this REDD+ Annex.

Table 4. Emission Reductions calculated for 2010 - 2015 period, based on FREL submitted by Costa Rica to the UNFCCC in May 2016.

Year	Total actual emissions from deforestation ($tCO_2e * yr^{-1}$)	Actual removals from forest C-stock enhancement ($tCO_2e * yr^{-1}$)	Actual emissions and removals ($tCO_2e * yr^{-1}$)	Reference Level for 2010 – 2025 ($tCO_2e * yr^{-1}$)	Emission Reductions[1] ($tCO_2e * yr^{-1}$)
2010	5,811,115	(4,818,778)	992,338	4,365,159	*3,372,822*
2011	5,971,634	(4,907,778)	1,063,856	4,365,159	*3,301,303*
2012	6,648,047	(4,568,633)	2,079,414	4,365,159	*2,285,745*
2013	6,853,722	(5,084,977)	1,768,745	4,365,159	*2,596,414*
2014	2,768,235	(5,892,319)	(3,124,084)	4,365,159	7,489,243
2015	2,877,093	(5,817,438)	(2,940,345)	4,365,159	7,305,504
				Total 2010-2015	26,351,032
				Total 2014-2015	14,794,747

Source: Emission calculated for 2010-2015 period in FREL Tool. https://drive.google.com/file/d/1ZV7eYpA5ab75VLKLF3KGp8rfPJ_U3wpz/view?usp=sharing

[1] Only reduced emissions during the 2014-2015 period are submitted to analysis of the Technical Team of Expert appointed by UNFCCC.

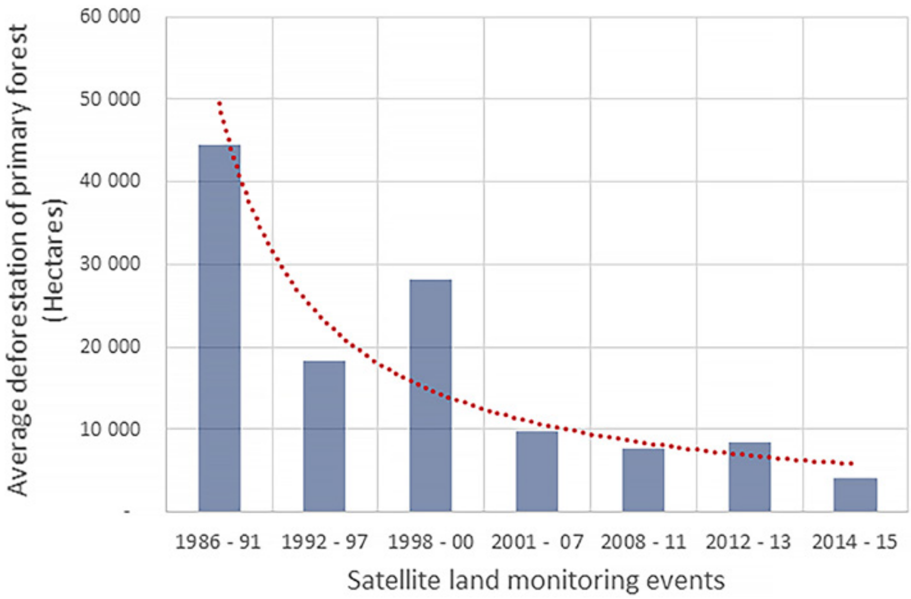

Figure 3. Decreasing trend of average deforestation of primary forest observed during the different satellite land monitoring events made in Costa Rica since 1986 to 2015.

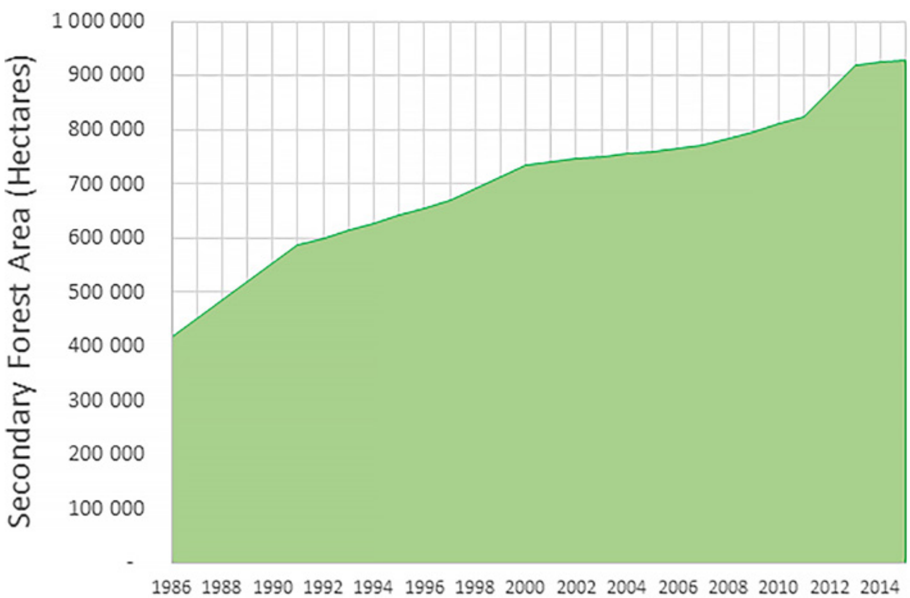

Figure 4. Growth of secondary forest area that produce forest carbon removals due to carbon stock enhancement, since 1986 to 2015 in Costa Rica.

country and 70% of forests (Ministerio de Ambiente y Energía, 2018)[15]. This has been reflected in the growth trend of the emission reductions observed

15 Ministerio de Ambiente y Energía. (2018). Estrategia Nacional REDD+ Costa Rica. San José, Costa Rica.

during the 2010-2015 period. During this period, more than 26 million tCO2 emission reductions have been reached, resulting in doubling emission reductions observed in 2010. (see Table 4).

The trend of increasing emission reductions demonstrates the country's performance in implementing REDD policies and measures, significantly influencing the following factors:

1. Conservation of primary forests.
2. Reduction of deforestation in primary and secondary forests, which has significantly reduced carbon emissions.
3. Recovery of native forests, improving carbon stocks and significantly increasing carbon removals due to forest growth.

Costa Rica shows a clear tendency to recover forest resources. The country halted the net loss of forest and has begun to gain native forests. Between 1986 and 2015 the deforested area fell gradually (see Figure 3), and the area of secondary forest has grown steadily, evidencing a trend of increase in forest cover (see Figure 4).

3. Consistency of the methods used to obtain the average annual emissions and removals for the 2014-2015 period with those used to calculate the assessed FREL / FRL

The methods used to obtain the average annual emissions and removals for the 2014-2015 period are consistent with those used to calculate the reference level of forest emissions and / or forest reference level submitted by Costa Rica to the UNFCCC in May 2016.

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 and monitoring period 2014-2015 (see Table 5).

For the FREL 2010-2025 uncertainty was not estimated. Likewise, uncertainty was not analyzed by the Technical Team of Experts of UNFCCC. However, for the 2014-2015 monitoring period, the uncertainty estimation was done using Approach 2 of the IPCC 2006 Guidelines, employing Monte Carlo simulations, and the uncertainties are reported in terms of 90% confidence intervals (See Section 5.3).

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). Main differences between methodologies are the following:

- FOLU Sector emissions include Harvested Wood Products, and methane and nitrous oxide emissions.
- Dead wood and litter carbon pools are excluded.
- C stocks in above-ground biomass (AGB) of Forests Lands were estimated using the asymptotic value of the equations developed by Cifuentes (2008).

Table 5. Consistency of the methods used to obtain the average annual emissions and removals for the 2014-2015 period with those used to calculate the reference level of forest emissions and / or forest reference level submitted by Costa Rica to the UNFCCC in May 2016, and FOLU emissions of INGEI in Biennial Update Report 2015 of Costa Rica

Parameters	FREL for 2010 – 2025 submitted by Costa Rica to the UNFCCC in May 2016.	REDD+ Annex 2014-2015	INGEI[1] FOLU emissions 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 (CH4) and nitrous oxide (N2O) were excluded.		Methane (CH4) and nitrous oxide (N2O) are included.
C pools included	Above-ground biomass (AGB) Below-ground biomass (BGB) estimated following Cairns et al. (1997)[2] 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 Annex 1).	
Mapping Land Use	The land use maps were created using the methodology detailed in Agresta et al (2015)[3], and postprocessing procedures described in MINAE (2016)[4], section 4.3.3 (See Annex 1).		

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 created for 2013/14 – 2015/2016 in a Geographical Information System (GIS) and then extracting the values of the areas that remained in the same category or converted to other land use categories from the combined set of multi-temporal data. The results of this operation are reported in land use change matrices in the sheet “LCM 2014-15” of the spreadsheets in FREL TOOL CR (see Annex 3).
Emission Factors		
Data sources for estimating EF	National Forest Inventory (NFI)[5] 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) [6].	C stocks in above-ground biomass (AGB) of Forests Lands were estimated using the asymptotic value of the equations developed by Cifuentes (2008) [7]
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.	

1 Personal communication, Ana Rita Chacón, Coordinator of the National Inventory of Greenhouse Gases - National Meteorological Institute.

2 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.

3 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.

4 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

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

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

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

Parameters	FREL for 2010 – 2025 submitted by Costa Rica to the UNFCCC in May 2016.	REDD+ Annex 2014-2015	INGEI[1] FOLU emissions Biennial Update Report 2015
Secondary forest AGB	C stocks in total net above-ground biomass (TAGB) of Wet and Rain Forests, Moist Forests and Dry Forests were estimated using the equations developed by Cifuentes (2008) for Costa Rican secondary forests. For Mangroves and Palm Forests, a linear function was assumed for estimating C stocks as a function of age. More detail in Ministry of the Environment and Natural Resources of Costa Rica. (2016), section 4.4.2, page 39.		
Methods for estimating EF	C stock changes (ΔC) were estimated using the Stock-Difference Method by applying IPCC (2006) equation 2.5 (cf. Volume 2, Chapter 2, Section 2.2.1.). More detail in Ministry of the Environment and Natural Resources of Costa Rica. (2016), section 4.4.3.		
DA and EF integration tool			
DA and EF integration tool	The annual average emissions from deforestation and annual removals from enhancements of forest C stocks were calculated using in FREL TOOL CR[8].		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.	Uncertainties associated with activity data (AD) and emission factors (EF) were considered separately. Uncertainty estimate for AD was derived form an accuracy assessment carried out for the land-cover change map 2013/14 – 2015/16 using the guidelines from Olofsson et al (2014)[9]. The uncertainty of the aboveground biomass carbon stock for primary forests used to estimate deforestation emission factors from Costa Rica's first NFI is derived from its sampling error. The uncertainty of the annual average emissions for 2104-2015 period is estimated by combining the uncertainty of activity data and emission factors. Combination of uncertainties has been done through Approach 2 of the IPCC 2006 Guidelines, employing Monte Carlo simulations, and the uncertainties are reported in terms of 90% confidence intervals (See Annex 2).	Uncertainty of INGEI, including FOLU sector emissions is estimated using the Error Propagation Method, following approach 1 of the IPCC guidelines.

8 2016.07.10 - FREL & MRV TOOL CR MapaIMN15v3.xlsx https://drive.google.com/file/d/1WzEZbNwUmO_x74R7udQSD4YmcO5GiFF4/view?usp=sharing
9 Olofsson et al. (2014) Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment 148, 42-57.

- Annual average emissions from deforestation and annual removals from enhancements of forest C stocks were calculated using a spreadsheet developed by the IMN.
- Uncertainty of INGEI, including FOLU sector emissions is estimated using the Error Propagation Method, following approach 1 of the IPCC guidelines.

4. National forest monitoring system of Costa Rica.

The National Forest Monitoring System of Costa Rica (NFMS) aims to provide periodic information on forest resources, in order to prepare officials reports on forest emissions to be submitted to REDD+ result-based payments programs, including the REDD+ Annex of the BUR, and monitoring reports of Emission Reduction Program of the Carbon Fund.

The NFMS includes a Satellite land Monitoring System (SLMS) and a National Forest Inventory (NFI[16]). The land use and its change (activity data) is collected with the SLMS (see Table 6); the NFI compiles data for the development of emission factors, for the estimation of emissions and removals (see Table 7).

The country has established the institutional arrangements to ensure the operation of its NFMS. The National Meteorological Institute (IMN) is responsible for preparing the INGEI and Biennial Update Report (BUR) including REDD+ Annex. The IMN is also in charge of the SLMS together with the REDD + Secretariat. The National System of Conservation Areas is responsible for the National Forest Inventory.

The main functions of the NFMS are completed by the following institutions (see Figure 5):

- IMN: Preparation of INGEI report and Biennial Update Report.
- IMN-SeREDD+ technical team: Calculation of activity data and LULC maps verification, uncertainty analysis and emission reductions (RE) estimate for REDD+ Annex result report and Monitoring Reports to the Carbon Fund
- SINAC: Estimate of Emission Factor (NFI).

It should be noted that the country has an official platform for coordination, and institutional and sectoral integration, to facilitate the management and distribution of knowledge and information regarding land cover, land use and ecosystems, called National system for monitoring land use, land cover and ecosystems (SIMOCUTE- https://simocute.org). This platform integrates the National Environmental Information System (SINIA - http://sinia.go.cr/

16 The database of the National Forest Inventory of Costa Rica can be accessed at the following link: http://inventarioforestal.sirefor.go.cr/mapnew.php

Table 6. Key elements of the Satellite Land Monitoring System (SLMS) of Costa Rica

Methodology aspect	Description
Parameter	Activity data (DAAAAA-AA) of each category represented in the land use change matrixes "LCM AAAA-AA" of the FREL TOOL CR.
Territorial forest area covered	The territorial forest area covered by the SLMS includes the country's continental territory (5,133,939.50 ha) but excludes the Coco Island (238,500 ha)[1].
Source of data	To prepare the LULC map, images from the LANDSAT 8 OLI / TIRS satellite are used, using selected scenes from June to June for the year under monitoring.
Classification methodology	"Random Forest" (RF) by Breiman (2001)[2] was employed. This is implemented in two phases: (1) training or adjustment of the RF classifier, and (2) image classification using the RF classifier.
Minimum mapping unit	To avoid the "salt and pepper" effect and comply with the minimum area parameter of the definition of "forest: (1.00 ha), the products of the digital classification are filtered in order to represent the land use categories with a minimum mapping unit of 0.99 ha. Due to the dimensions of the pixels in the Landsat images (30.00 m x 30.00 m) the minimum mapping area is 0.99 ha, which is equivalent to 11 pixels (11 x 30.00 m x 30.00 m).
Frequency of monitoring:	Every two years
Quality assurance and quality control procedures	*Download and image preparation:* • Review of storage errors in digital media that affect the reading of the data • Verification of the quality of the images by analyzing the metadata and previewing the original image. *Image orthorectification:* • Verification of control points, the average square error never exceeds the pixel size of the image. • Comprehensive visual inspection to ensure that there has been no defect in the orthorectification process: i.e. duplicate areas, pixel deformation or geometric errors caused by errors in the digital terrain model. • Geometric control of rectified images by taking checkpoints, in each scene, regularly distributed on a grid. *Generation of cloud and shadow masks:* • Visual check of cloud and shadow masks of all images by comparing them with the original image in RGB or false color. • Validation of cloud and shadow masks in a sample of 18 images by visual verification of a systematic grid of checkpoints. *Land use classification:* • Performing an iterative process of classification, verification of classification, error detection and review of areas and training points. • Review of errors of the Random Forest classifiers, identification of classes that need to be improved and training points. • Visual check of the classification in high resolution images. *Preparation and validation of final maps:* • Visual check of mosaics and identification of information gaps and sensor failures on each of the dates in the series. • Independent validation of the final maps on three of the dates of the series with samples of validation points provided by institutions of the country not used in the classification phase.

1 The Coco Island, a World Heritage site at 532 km from the Pacific coast, is inhabited solely by park rangers and is not subject to anthropogenic intervention. The island is also too distant from Costa Rica's continental territory and is therefore not prone to displacements that may be caused by Costa Rica´s REDD+ activities. The exclusion of the Coco Island is consistent with the estimation of emissions by sources and removals by sinks in the national GHG inventory.

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

Table 7. Key elements of National Forest Inventory of Costa Rica.

Methodology aspect	Description
Parameter	Emission Factors (C-STOCKS of FREL TOOL CR) estimated from carbon stocks per hectare of the categories of forest lands represented in the Land Cover Maps (MCS) of Costa Rica.
Territorial forest area covered	The territorial forest area covered by the NFI includes the country's continental territory (5,133,939.50 ha) but excludes the Coco Island (238,500 ha).
Source of data	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 several parameters as follows: • Primary Sampling Unit (UMP for its acronym in Spanish): Where measurements of live tree DBH and height were taken for trees with DBH ≥ 10cm (light green area) • Secondary Sampling Unit (UMS for its acronym in Spanish): Where measurements of saplings with 2cm ≤DBH<10cm and height >1.5m were taken (dark green area in center of the plot) • Tertiary Sampling Unit (UMT for its acronym in Spanish): Where measurements 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): Where abundance of species was measured (dark grey square) • Fifth-order Sampling Unit (UMH): Where measurements of the litter layer were taken (dark green squares at the corners of the plot) • Lying deadwood sampling (UMM): Where the diameter of the lying deadwood is measured where it crosses the 20m transect (red line) • Soil sampling: Where a sample of the first 30cm of is extracted utilizing the cylinder method (red triangles).

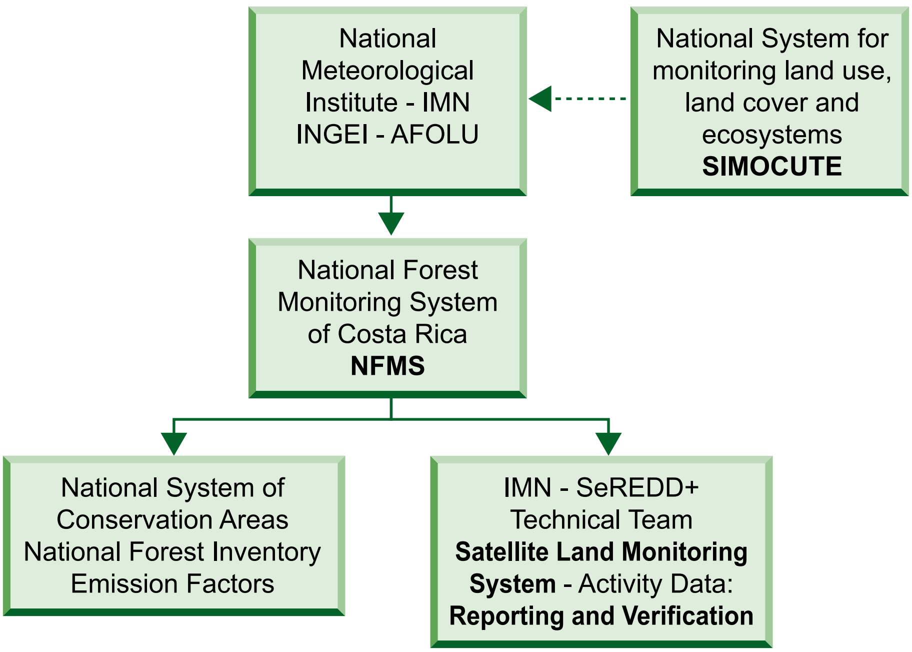

Figure 5. Institutional arrangements to ensure the operation of National Forest Monitoring System of Costa Rica.

Table 7. Continuation.

Methodology aspect	Description
Methods for estimating C stocks and Emission Factors	• Aboveground biomass of each measured tree is estimated using Chave et al. (2005)[1] • Below-ground tree biomass (BGB) is calculated using Cairns et al. (1997)[2]. • C stocks of forest lands corresponds to the 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.).
Frequency of monitoring:	The monitoring frequency has not been defined.
Quality assurance and quality control procedures	The following procedures were used in the National Forestlinventory of Costa Rica to measure and control the quality of the data collected by the field crews: Field work organization • Organization of field work by operational 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 difficult sites (Talamanca mountain range). • Preparation of terms of reference, including a description of the roles and responsibilities of each member of the field crew. An experienced dendrologist is part of the work team. • Preparation of field manual, including a protocol for the identification, collection, transport and processing of botanical samples. • Crew training prior to the start of field work. • Template preparation in Excel for data typing. Field work supervision • Field visits to supervise the work of the crews. • Photographic field record for each of the plots. Registry of information • File of field forms and preparation of reports of the activities carried out by the field crew. • The templates are reviewed by the crew chief and the fieldwork director. A final review is carried out by the IFN steering committee. In case of detecting errors / omissions / inconsistencies the forms are returned to the crew leader with the pertinent observations for their correction or to document the discrepancies. Questionable species identifications are reviewed by the coordinator dendrological inventory component. • Application of controls to evaluate the coherence, integrity and completeness of dasometric, dendrological and positioning data. Independent evaluation of the quality of forest inventory data • The evaluation of the quality of forest inventory data is carried out by an independent crew that visits and re-measures 10% of the plots established by stratum both in the pre-sampling and inventory phase.

1 Chave J., Andalo, C., Brown, S., Cairns, M.A., Chambers, J.Q., Eamus, D., Fölster, H., Fromard, F., Higuchi, N., Kira, T., Lescure, J.-P., Nelson, b.W., Ogawa, H., Puig, H., Riéra, B., Yamakura, T. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: pp. 87-99.

2 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.

) and the National Territorial Information System (SNIT - http://www.snitcr.go.cr/).

Likewise, the SIMOCUTE aims to generate and disseminate standardized information on land cover and land use and ecosystems. For this purpose, SIMOCUTE supports the development of protocols, methodologies and tools in order to standardize and ensure the quality of the information.

In the case of methodologies, parameters or indicators derived from international agreements or organizations of which the country is a party, the information is generated in accordance with the guidelines established in the agreements or organizations (e.g Forest Emission Reduction Program and REDD + Strategy, IPCC guidelines).

4.1. Activity data calculation

The calculation of activity data is made applying the satellite land monitoring protocol (SLMP see Section 5.1). The SLMP is implemented by a technical group trained in remote sensing and Geographic Information Systems (GIS), and with experience in the application of IPCC guidelines and the Carbon Fund Methodological Framework. The IMN has produced its own land use maps and has prepared, so far, all national GHG inventories in Costa Rica. Likewise, the REDD+ Secretariat has produced a time series of consistent land use maps, used for estimating the FREL / FRL, submitted to the Convention.

The SLMP protocol is generally implemented by a third party, under the supervision of a Work Team composed for 3 specialists from IMN and the REDD + Secretariat. In addition to the supervising of the specialist's work, technical dialogue spaces are provided in the working group, and additional experts can be invited for specific topics according to the identification of needs.

4.2. Emission Factor Estimation

In 2014, with the support of the REDD-CCAD-GIZ Program, Costa Rica completed its first IFN. With this inventory, the stocks of forest resources in the country are quantified and characterized, and the Emission Factors required for MRV of carbon emission are established within the framework of the National REDD + Strategy. The design of the NFI plots allows the monitoring of carbon pools related to emissions for the Forestry and other land uses (AFOLU), although some pools have not been yet measured and should be measured in the future.

After finishing the INF 2014 a series of questions arose that led to the identification of improvements for the next Inventory. SINAC with the support of the United States Forest Service (USFS) and FAO, together with the members of the SIMOCUTE technical groups, are working on the required adjustments and improvements of the NFI, for the next measurement cycle, planned for 2020. The NFI will be focused on the measurement of biomass changes in land cover/use transitions using the SIMOCUTE level 1 systematic grid (10 588 sampling points). In total, 441 plots will be measured in five years.

4.3. Estimation of emissions and removals

The IMN is the institution responsible for the National GHG Inventory (INGEI) and the technical team have the capacities to complete the GHG estimation of the FOLU sector. Therefore, IMN is the entity in charge of calculating forest emissions / removals. This also guarantees that the estimate is made within the framework of INGEI and that a single estimate of emissions and removals for REDD + is made.

4.4. Reporting and Verification

The REDD + Technical Reports or Annexes are prepared by the REDD + Secretariat of Costa Rica, supported by IMN experts for the final estimation of emissions and removals. The REDD + Secretariat must also complete the reports submitted to the Carbon Fund of the FCPF, as well as on implementation of the REDD+ safeguards that must accompany the Technical Annex submitted in the BUR, for the result-based payments initiatives.

The FREL / FRL and the report of the results presented by the country in the REDD + Technical Annex are subject to verification processes by external reviewers. As indicated previously, in the case of the Carbon Fund of the FCPF, the revisions are in charge of the Technical Advisory Panel and, in the case of the UNFCCC, by the Technical Team of Experts appointed by the UNFCCC Secretariat.

In all these cases, a Work Team of experts from the IMN and the REDD + Secretariat, supported by external professionals, will be responsible for addressing the comments received and making the necessary adjustments to the FREL / FRL or reported results.

5. Information necessary for the reconstruction of the results of the implementation of activities.

5.1. Steps for preparation of Activity Data:

To avoid that changes registered in the cartographic comparison of LULC maps were product of the combination of different techniques and methods, a unique and uniform methodology was used both for FREL / FRL and for the forest emission monitoring results. Córdoba-Peraza (2019) [17] prepared the LULC Map 2015 of Costa Rica (MCS 2014/15), following the satellite land monitoring protocol (SLMP) developed by AGRESTA (2015)[18] and the protocol for post-processing developed by Carbon Decisions International[19].

The MCS 2015/16 map was included in the geo-database of the 1987-2013 time series of LULC maps. Also, the table of uses, types and ages of forest of the geo-database was updated. The MCS 2015/16 map was validated following the guidelines from Olofsson et al (2014)[20], using reference data obtained from the visual evaluation of the land use and land cover change in high resolution images, on the systematic grid of 10,000 points of the Monitoring system of land use change and ecosystems (SIMOCUTE). This information was collected by Ortiz-Malavassi (2017)[21] (see Annex 2: Uncertainty analysis of forest emission for the period 2014-2015.).

17 Córdoba-Peraza, J. (2019). Informe final Elaboración del mapa de cobertura y uso de la tierra en Costa Rica 2015. San José, Costa Rica. https://drive.google.com/file/d/1xL5XMV7xJs4FCTXC0uMF9fWT60XiaYf6/view?usp=sharing

18 AGRESTA (2015). Generating a consistent historical time series of activity data from land use change for the development of Costa Rica's REDD plus reference level. San José, Costa Rica. https://drive.google.com/file/d/1xL5XMV7xJs4FCTXC0uMF9fWT60XiaYf6/view?usp=sharing

19 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

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

21 Ortiz-Malavassi, E. (2017). Evaluación Visual Multitemporal (EVM) del Uso de la tierra,

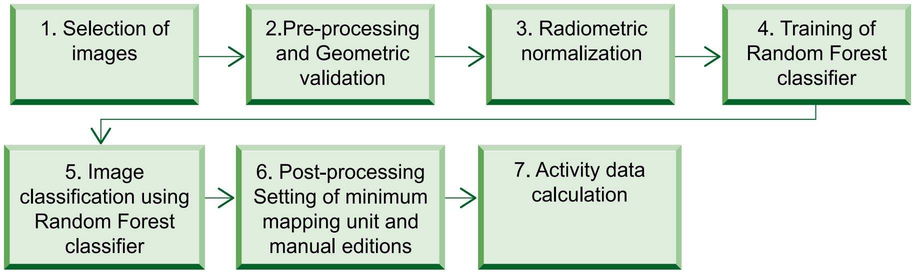

Figure 6. Standard operative procedures for mapping land use and land cover in Costa *Rica. Steps 1 to 5 are described in Agresta (2016); Steps 6 and 7 are described in Ministry of the Environment and Natural Resources of Costa Rica (2016).*

To automate the workflow, AGRESTA (2015) generated the toolkit REDD tools Costa Rica package to facilitate the preparation of the LULC map for 2015 (MCS 2014/15). This toolbox runs on the geographic information system QGIS for the Microsoft Windows operating system. The programs were compiled in the QGIS Processing framework (https://docs.qgis.org/2.8/en/docs/user_manual/processing/), which allows 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/)

In order to apply this toolkit, it was necessary to migrate them to updated versions of QGIS. Also, the libraries were updated to their corresponding 64-bit versions, in order to get the most out of the most recent versions of Windows, QGIS and IMN equipment, thus It was also necessary to change the syntax of the libraries. The updated guide for the installation of the software tools and the necessary programs for the preparation of LULC maps can be consulted in Annex 1 of Córdoba-Peraza (2019) report. It is important to note that none of these updates results in a change in methodology.

Figure 6 summarizes the methods included in the satellite land monitoring protocol. The steps followed in the elaboration of the MCS 2015/16 map are detailed below.

5.1.1. Image selection

For the complete time series (1987-2013), images from four different sensors and satellites of the Landsat family were used (Landsat 4 TM, Landsat

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. San José, Costa Rica.

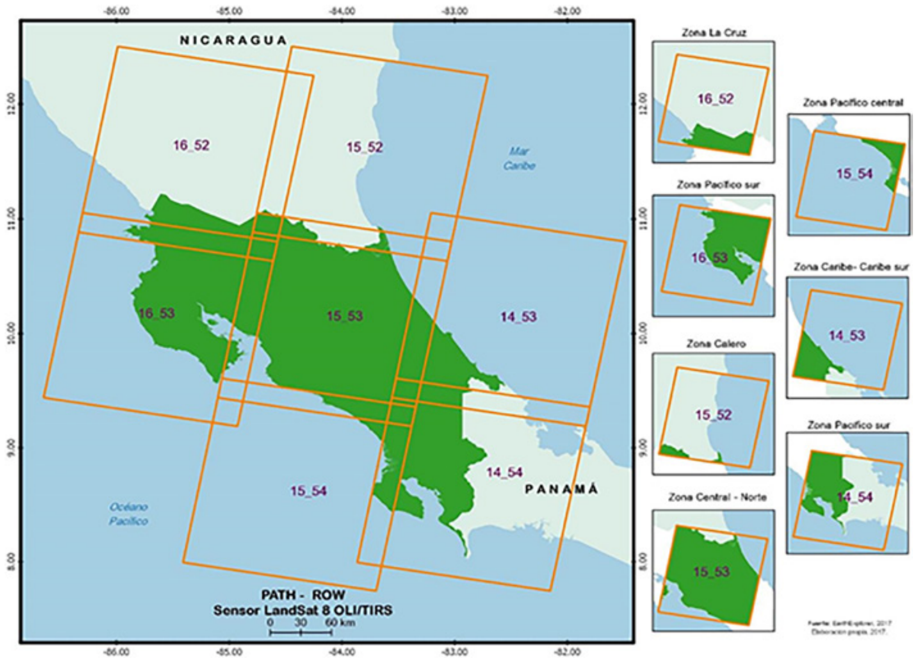

Figure 7. Paths and Rows of LANDSAT 8 OLI / TIRS sensor, used for the preparation of the LULC 2015 map.

5 TM, Landsat 7 ETM +, Landsat 8 OLI / TIRS). To prepare the LULC map 2015 (MCS 2015/16), images from the LANDSAT 8 OLI / TIRS satellite were used for the period from June 2015 to June 2016. To cover the continental territory of Costa Rica it was necessary to work with two scenes of path 14 (rows 53 and 54), 3 scenes of path 15 (rows 52, 53 and 54) and two scenes of path 16 (rows 52 and 53) (see Figure 6). The following bands used were used: 2, 3, 4, 5, 6 and 7.

5.1.2. 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) which is 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 geo-database was used, to ensure that the MCS 2015/16 map is consistent in area, spatial resolution (pixel resolution) and dimensions (same number of columns and rows X, Y) with the maps of the 1997-2013 time series. The MCS 2015/16 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) in order to compare them geographically with the MCS 2013/14 map 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, GRASS "r.mapcalculator" in QGIS 2.4 should have being 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, to reduce the work area, all those pixels of the image that do not belong to the territorial delimitation of Costa Rica were included to the mask of clouds and shadows.

5.1.3. Radiometric normalization

A radiometric standardization has been made, in order to reduce the radiometric differences between the images used to prepare MCS 2015/16 due to the different atmospheric conditions and sensor calibration on the dates on which they were captured.

Landsat 8 images includes a quantified and calibrated series of digital levels that can be scaled to radiance and reflectance values using radiometric coefficients provided in the metadata file that are downloaded with each image. 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 17th, 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.

5.1.4. Training of Random Forest 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[22]. Table 8 shows the classes defined for the Random Forest classification. The base information used to define the training areas (ROI´s) is the following:

- High-resolution data set of mages available on Google Earth.

22 ROI ☐s were not developed for the paramo class, since a mask developed by Agresta (2015) was used to exclude this type of coverage from the analysis.

Table 8. Classes defined for the Random Forest classification

Class	Description
1	Forest
2	Forest plantation
3	Mangrove
4	Oil palm cultivation
5	Urban areas
6	Grasslands
8	Water
9	Bare soil
10	Palm forests
11	Annual crops
12	Coffee plantations
13	Pineapple plantations
14	Banana permanent crop
15	Permanent citrus cultivation
16	Sugarcane cultivation

- Landsat 8 images selected for the elaboration of the land cover and land use map for the year 2015 in Costa Rica (MCS 2015/16).
- ROI's dataset provided by AGRESTA that were reviewed and used as a guide to delimit the polygons with the coverage classes.

5.1.5. *Image classification using Random Forest classifier:*

For the classification of the images, the predictor variables described in Table 9 were combined in a single file. For this purpose, the "combine bands tool" of the REDD Tools Costa Rica package was used.

Once all the images were grouped, processed, normalized, calibrated and visually validated, we proceeded to classify them by implementing an automated learning technique using the Random Forest algorithm (Breiman, 2001)[23] based on the following techniques: Decision Trees, Bagging and Random Subspace. The R package (http://www.r-project.org/) and the following packages required to work with Random Forest were used: Maptools, sp, randomForest, raster, rgdal and RSAGA.

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, using a ROIs

23 Breiman, L.2001: Random Forest. Machine Learning https://link.springer.com/article/10.1023%2FA%3A1010933404324?LI=true [June 5th, 2017].

Table 9. Predictor variables used in image classification.

ID	Predictor variables	Type of information
1	Blue (Band 2 OLI/TIRS)	Spectral information
2	Green (Band 3 OLI/TIRS)	
3	Red (Band 4 OLI/TIRS)	
4	NIR (Band 5 OLI/TIRS)	
5	SWIR-1 (Band 6 OLI/TIRS)	
6	SWIR-2 (Band 7 OLI/TIRS)	
7	NDVI, Normalized Difference Vegetation Index)	Vegetation Index
8	Mean	Textures
9	Sum Entropy	
10	Difference of Entropies	
11	Difference of Variances	
12	IC1	
13	IC2	
14	Elevation	Information derived from Digital Elevation Model (DEM)
15	Slope	
16	Hillshade	
17	Plan curvature	
18	Profile curvature	
19	Convergence Index	
20	MRVBF	

shape file containing the training regions with LULC classes and the image of 20 bands (predictor variables) to be classified.

5.1.6. Post-processing

For the post-processing of the images the procedures of the satellite land monitoring protocol (SLMP) were followed. The classified images were merged into a mosaic using the classification prioritization algorithm of the "FusionClass" module of REDD tools Costa Rica. Information gaps due to the presence of clouds and shadows, although small, were filled with global data from the Global Forest Change project (Hanse et al., 2013)[24].

24 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 [Consulta: 5 junio de 2017].

Since mangroves and palm forest are ecosystems restricted to particular edaphic, inundation and salinity conditions, it is very difficult for such ecosystems to exist in other locations. Therefore, these forests were re-classified using the mangrove and palm forest masks included in Forest types map (MTB), prepared by AGRESTA (2015).

The MCS 2015/16 map 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.

Subsequently, to eliminate small groups of pixels (salt and pepper effect), the MCS 2015/16 map was processed with the "sieve" tool in Qgis2.18. This tool removes groups of pixels smaller than a certain expected threshold size (in pixels) and replaces them with the LULC class of the largest neighboring group.

Finally, MCS 2015/16 map is reclassified according to the 56 LULC 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 (see Figure 7).

5.1.7. Activity Data calculation

For the calculation of the activity data, a hartographic comparison of the wall-to-wall maps MCS 2013/14 and MCS 2015/16 was made, to sub- sequently count the change and stable pixels in a transition matrix. In order to prepare the 2014-2015 transition matrix, it was reviewed that the MCS 2013/14 map of the REDD+ Time Series and the MCS 2015/16 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 same pixel re- solution; iii. They should be in the same geographical reference system and not being displaced; iv. Both maps must share the same classification LULC key used in REDD+ Time Series maps; and v. Both maps must have the same accounting area.

Using the ArcGis / Zonal / Tabulate Area tool, the land use change was obtained. The areas that remained in the same category or converted to other land use categories are reported in land use change matrices in the sheet "LCM 2014-15" of the spreadsheets in FREL TOOL CR[25] developed by Carbon Decision International (CDI) to estimate forest emissions for the period.

25 Pedroni, L., & Villegas, J. F. (2016). Manual de la Herramienta Excel "AAAA.MM.DD - FREL&MRV TOOL CR.xlsx." Carbon Decisions International. https://drive.google.com/file/d/14CsE_rpBBrEJgyUTplziKKsGGVm_YtL_/view?usp=sharing

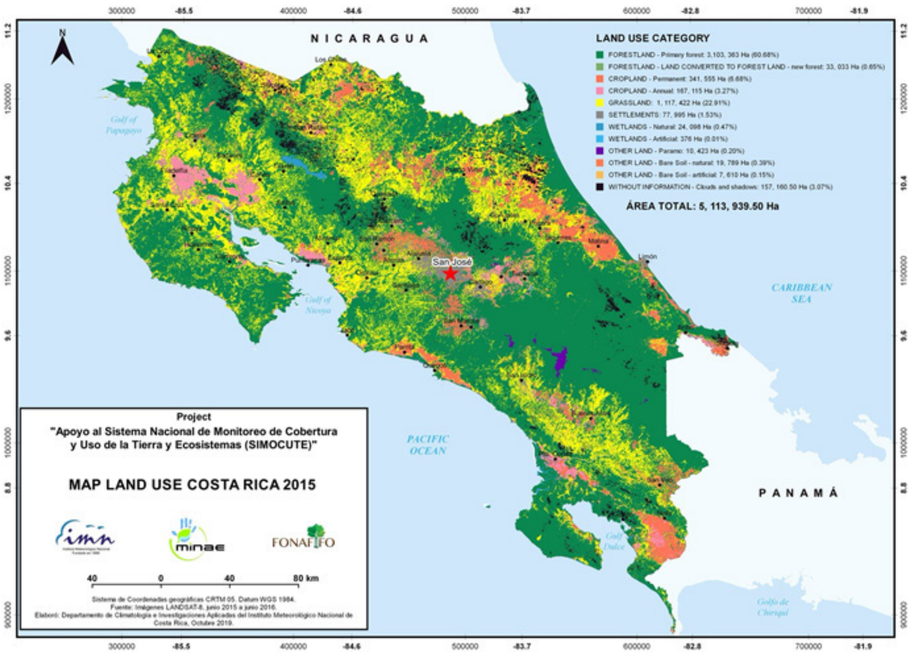

Figure 8. Costa Rica Land use / land cover map 2015 (MCS 2015/16).

5.2. Steps for estimating results.

Costa Rica has developed a tool to estimate FREL and the results (FREL & MRV TOOL CR.xlsx)[26]. Details of this tool can be found in START spreadsheet, and the manual (Manual de la Herramienta FREL & MRV Tool – UNFCCC.pdf in Spanish[27]). The tool is organized in the following sections:

Setting sections that must not be modified by users:

1. 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 block spreadsheets.
2. 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.
3. 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

26 A clean copy of FREL Tool can be download at the following link: https://drive.google.com/file/d/1WzEZbNwUmO_x74R7udQSD4YmcO5GiFF4/view?usp=sharing

27 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

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"[28]) 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.

4. 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.
5. 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:

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

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

Calculation section:

7. 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.
8. 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:

9. 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.
10. 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.

To allow for the reconstruction of the results, the following procedures could be applied in the FREL Tool:

- Enter the activity data provided in Table 10 (Activity Data 2014-2015), directly on the LCM 2014-15 sheet of the FREL Tool.
- Follow the procedure in Annex 7 of the FREL Tool Manual, to calculate the activity data for the period using the maps provided in Table 10 (LULC map 2013 and LULC map 2015) and enter AD data in the LCM 2014-15 spreadsheet.

Uncertainty analysis are performed in a separated tool using Monte Carlo simulation as described in section 5.3.

5.3. Steps for estimating uncertainties

Table 10. Parameters and associated information for the reconstruction of results.

Parameter	Link to access information
Activity data	
LULC map 2013 (MCS 2012/13)	MCS 2012/13 of time series LULC maps 1997/2013 (SpatialDataSubmission20122016.zip in ArcGIS format), and final report (Generating a consistent historical.zip in Spanish, see summary of methods in Annex 1). https://drive.google.com/drive/folders/1pb1eSxY9kQ3DopCqgcEg6ht0oaSbAZlh?usp=sharing
LULC map 2015 (MCS 2015/16)	LULC map 2015 (available in tiff format for QGIS) including Final Report (INFORME_FINAL_MC15_29_9_2019.PDF in Spanish, see summary of methods in Section 5.1). https://drive.google.com/drive/folders/1rvO_NS9M64-bClMt9pOULkg465N36iwC?usp=sharing
Activity data 2014-2015	Land use change matrix obtained through the cartographic comparison of the MCS 2012/13 and MCS 2015/16 maps. https://drive.google.com/file/d/1yHgfpIljqa1kKxKU7wox3xIZZmoDc7w4/view?usp=sharing
Reference data for validation of LULC change area calculation for the period 2014-2015	Reference data base (Referencedata1415V3.csv) used for the accuracy of activity data and Final Report (II_Informe_Consultoria_EvaluacionMulti-temporalUsodelaTierra.pdf in Spanish). https://drive.google.com/drive/folders/1qpnJdH-_-0CJD9Eeena7uOQG9_wUtoOu?usp=sharing
Emission factors	
Carbon stocks	C-STOCKS spreadsheet of FREL tool (2016.07.10 - FREL & MRV TOOL CR MapaIMN15v3.xlsx) and tool manual (Manual de la Herramienta FREL & MRV Tool – UNFCCC.pdf in Spanish) https://drive.google.com/drive/folders/1qpnJdH-_-0CJD9Eeena7uOQG9_wUtoOu?usp=sharing
Uncertainty	
Uncertainty analysis	FREL tool with Monte Carlo analysis (2016.07.10 - FREL & MRV TOOL CR-Uncertainty.xlsx, SimVoi add-in is required for run the Monte Carlo analysis) and summary of Monte Carlo result, Activity Data Error and Emission Factor Error (Uncertainty.xlsx). https://drive.google.com/drive/folders/1BjxEScZrONIQQPYX267xfidbXKvemxGo?usp=sharing

5.3.1. Identification and assessment of sources of uncertainty

Uncertainties associated with activity data (AD) and emission factors (EF) were considered separately.

Activity Data: The uncertainties of the activity data for land use change activities (deforestation and reforestation) come from the uncertainties associated with the process creating land use change maps from which the activity data are obtained. An accuracy assessment was carried out for the land-cover change map MCS 2013/14 – MCS 2015/16 using the guidelines from Olofsson et al (2014)[29]. The uncertainty estimation for each land cover change class was derived from the results of the accuracy assessment.

Emission factors: The uncertainty of the aboveground biomass carbon stock for primary forests used to estimate deforestation emission factors from Costa Rica's first NFI is derived from its sampling error[30]. For deforestation and reforestation, the carbon stocks in other pools and strata and their associated uncertainty are based on data from scientific literature. The statistical uncertainty reported in these documents takes into consideration the sampling error. Therefore, forest emission estimate only considers this error source.

5.3.2. *Quantification of uncertainty*

5.3.2.1. *CALCULATING UNCERTAINTY OF THE ACTIVITY DATA*

Due to the large number of land use change transitions they were aggregated into four change classes to be used in the accuracy assessment following the guidelines provided in Olofsson et al (2014): 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 change between the years 2013/2014 and 2015/2016 was carried out through photointerpretation using the high-resolution image repository available in Google Earth and Earth Engine, giving priority to images of the years to be evaluated. In case of absence of a high-resolution imagen, the use was recorded in the year closest to these years. A Collect Earth template was also used to use Google Earth Engine scripts to facilitate interpretation of the type of vegetation in MODIS time series, and the NDVI calculated using Landsat images, as well as to interpret Landsat 7, Landsat 8, and Sentinel 2 images.

These reference data are in accordance with the guidelines of Olofsson et al. (2014) since they have higher quality and spatial resolution than the maps and are independent of the sample used to produce the maps.

The results of the accuracy assessment show the higher user and producer accuracy values (>0.74) in the stable categories (i.e., forest remaining forest and non-forest remaining non-forest). The categories that changed show lower accuracies, under 0.02, which indicate higher uncertainty of the activity data, were deforestation and reforestation have occurred. The same

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

30 For dry forest, there was only one observation and, therefore, no sampling error. The sampling error for moist forests was applied as a percentage to estimate the uncertainty of aboveground biomass in dry forests because it had the highest error among the other 4 life zones and therefore was a conservative estimate.

Table 11. Accuracy statistics for cover changes in land-cover map 2013/14 and land-cover map 2015/16.

Class	User Accuracy	Producer Accuracy
Deforestation (*Forest to Non-Forest*)	0.00	0.00
Secondary Forest (*Non-Forest to Forest*)	0.03	0.02
Stable forest (*Forest remaining Forest*)	0.80	0.87
Stable non-forest (*Non-Forest remaining Non-Forest*)	0.82	0.74

Table 12. Estimated areas and their error at 90% confidence levels for land use changes between land-cover map 2013/14 and land-cover map 2015/16 considering the forest and non-forest change categories.

Class	Estimated area (ha)	Adjusted area (ha)	Bias (%)	Error relative at 90% of the significance level (ha)	Error relative at 90% of the significance level (%)	Standard Error	Standard error as percentage of estimated area
Deforestation (Forest to Non-Forest)	29,774	40,976	-38%	9,359	31%	5,689	19%
Secondary forests (Non-Forest to Forest)	33,034	28,121	15%	7,738	23%	4,704	14%
Stable forest (Forest remaining Forest)	3,103,394	2,805,944	10%	40,520	1%	24,632	1%
Non-stable forest (Non-Forest remaining Non-Forest)	1,790,668	2,081,829	-16%	40,281	2%	24,487	1%

Table 13. Decrease of bias between the estimated area and the adjusted area of land use change for the 2014-2015 period.

	Map Area (ha)				Bias (%)		
Land Use Change	Version 2	Version 3	Final version	Adjusted Area (ha)	Version 2	Version 3	Final version
Deforestation (Forest to Non-Forest)	153,272	28,976	29,774	40,976	73%	-41%	-38%
Secondary forests (Non-Forest to Forest)	640,819	339,688	33,034	28,121	96%	92%	15%
Stable forest (Forest remaining Forest)	2,980,736	3,104,192	3,103,394	2,805,944	6%	10%	10%
Stable non-forest (Non-Forest remaining Non-Forest)	1,339,076	1,524,860	1,790,668	2,081,829	-55%	-37%	-16%

situation is observed in the bias for the categories of change of use (between 38 and 15%) and the stable categories (between 10 and 16%).

The user and producer accuracy can be affected by i). the short period of the evaluated period (2 years), ii. extremely low deforestation and regeneration is less than 1% of the national territory (> 41,000 ha), iii. the filters applied that change the resolution of LULC map from 30x30 m to 90x90 m to obtain the minimum mapping unit, and iv. the limited availability of high-resolution images for the exact start and end dates for the evaluated period.

It is also important to note that the same analysis was performed for FREL 97-2011 (15 years period analysis) of the ER-Program submitted to the Carbon Fund[31], where both the accuracy of the producer and the user were greater than those observed for 2014-2015 period: i. 0.62 and 0.49 for user and producer accuracy of Deforestation ii.0.75 and 0.50 for user and producer accuracy of Secondary Forest.

It is important to highlight that this is the first monitoring event made by the IMN technical team, applying the satellite land use monitoring protocol (SLMP). It was necessary to prepare three versions of the LULC map 2015 to reduce the bias between the estimated area and the adjusted area of land use change for the 2014-2015 period (see Table 13).

5.3.2.2. CALCULATING UNCERTAINTY OF EMISSION FACTORS

For values that were obtained from the bibliography that served as input parameters for the equations used to estimate carbon stocks, the uncertainty estimates were made by following the IPCC guidelines (Chapter 2, Volume 1 of IPCC GL 2006). The uncertainties described in the different publications or determined from the forest inventory data were identified, and when it was necessary to combine values from different sources, approach 1 of the IPCC guidelines, propagation of errors, was applied. In the case of summing two parameters and, that the square of their uncertainties and were summed and then the square root of the sum was calculated:

$$\text{Uncertainty } (x + y) = \sqrt{U_x^2 + U_y^2}$$

In case of a multiplication of parameters and , it was considered that their uncertainties and , would be combined using the following equation:

$$\text{Uncertainty } (x * y) = \frac{\sqrt{(U_x \times x)^2 + (U_y \times y)^2}}{|x+y|}$$

31 See Table 12.2.1 on Section 12 of Emission Reduction Program Document https://www.forestcarbonpartnership.org/system/files/documents/Costa%20Rica%20ERPD%20EN_Oct24-2018_clean.pdf.

These equations are equivalent to those indicated in Chapter 3 of Volume 1 of IPCC GL 2006.

The uncertainties of the aboveground biomass values for the different forest types were calculated by estimating the standard error of the biomass estimates from the Costa Rica NFI data.

The uncertainties of these parameters are shown in Table 14 and Table 15. As these tables shows, the uncertainties (the margin of error for 90% confidence level divided by the estimate) of carbon stocks vary from 1% to 141% . The uncertainty of dead wood (the pool with the largest carbon stock in the different forest types) has the biggest uncertainty reaching 141% at the 90% confidence level.

The quantified uncertainties for the different emission factors were then used to generate Monte Carlo simulations which were applied to the emissions equations as described in the following section.

5.3.2.3. UNCERTAINTY OF THE FOREST EMISSION OF THE PERIOD 2014-2015

The uncertainty is estimated by combining the uncertainty of activity data and emission factors as described in the previous section. This combination of uncertainties has been done through Approach 2 of the IPCC 2006 Guidelines, employing Monte Carlo simulations, and the uncertainties are reported in terms of 90% confidence intervals.

The following steps were conducted to estimate final uncertainty:

1. Estimation of activity data uncertainty: The results of the accuracy assessment of the land use change maps were used to estimate uncertainty. The 90% confidence interval was reported relative to the estimated area of each land use change class.
2. Estimation of the uncertainty of the input data to estimate emission factors: As explained in the previous section, the emission factor input data were estimated using the Costa Rica NFI and the values obtained from the bibliography for non-forest land uses. The errors of all these input data were estimated using a 90% confidence interval.
3. Monte Carlo simulations: Monte Carlo simulations were run 10,000 times for each activity data and emission factor value and applied to the equations used to identify the final distributions of emissions and removal estimates in the different activities using the Monte Carlo simulation software SimVoi[32]. The following assumptions were made about each value: a) that they had a normal (i.e., Gaussian) distribution and b) the estimated values are the means of the normal

32 https://treeplan.com/simvoi/

Table 14. Uncertainty at 90% confidence interval of carbon stocks estimated for each category and pool by using Method 1 of IPCC.

				Aboveground Biomass		Belowground Biomass		Dead Wood		Litter	Total
				BARA	BNAA	BARS	BNAS	MMA	MMS	H	
				Include	Include	Include	Include	Include	Include	Include	
				tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}
TF & TCF	Bhp	bp	i	37.46	-	8.32	-	8.75	-	0.94	39.37
		bs	1	0.75	-	0.22	-	0.08	-	0.02	0.79
			2	1.48	-	0.42	-	0.16	-	0.04	1.55
			399	37.44	-	8.32	-	4.06	-	1.17	38.59
			400	37.45	-	8.32	-	4.06	-	1.17	38.59
	Bh	bp	i	28.20	-	6.43	-	23.25	-	1.04	37.12
		bs	1	0.88	-	0.26	-	0.58	-	0.03	1.12
			2	1.73	-	0.48	-	1.15	-	0.07	2.19
			399	28.20	-	6.43	-	18.72	-	1.04	34.47
			400	28.20	-	6.43	-	18.72	-	1.04	34.47
	Bs	bp	i	17.96	-	4.22	-	21.92	-	0.61	28.66
		bs	1	0.00	-	0.00	-	0.00	-	0.00	0.00
			2	0.00	-	0.00	-	0.00	-	0.00	0.01
			399	17.96	-	4.22	-	7.74	-	1.85	20.09
			400	17.96	-	4.22	-	7.74	-	1.85	20.09
	Man	bp	i	31.21	-	7.25	-	2.05	-	0.24	32.11
		bs	1	0.31	-	0.10	-	0.03	-	0.01	0.34
			2	0.62	-	0.19	-	0.05	-	0.01	0.66
			399	31.21	-	7.25	-	2.51	-	0.69	32.15
			400	31.21	-	7.25	-	2.51	-	0.69	32.15
	Bp-Y	bp	i	40.89	-	9.74	-	7.02	-	1.13	42.63
		bs	1	0.41	-	0.14	-	0.08	-	0.01	0.44
			2	0.82	-	0.26	-	0.17	-	0.02	0.87
			399	40.89	-	9.74	-	8.40	-	1.14	42.88
			400	40.89	-	9.74	-	8.40	-	1.14	42.88

				Aboveground Biomass		Belowground Biomass			Dead Wood	Litter	Total
				BARA	BNAA	BARS	BNAS	MMA	MMS	H	
				Include	Include	Include	Include	Include	Include	Include	
				tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}	tCO_2-e ha^{-1}
C	an			-	9.69	-	2.45	-	-	-	9.99
C	per		1	6.8	2.95	2.02	0.93	0.07	-	0.60	7.76
C	per		2	13.60	5.91	3.84	1.77	0.14	-	1.20	15.47
C	per		3	20.40	8.86	5.59	2.58	0.21	-	1.81	23.15
C	per		4	27.20	11.82	7.29	3.36	0.29	-	2.41	30.82
C	per		5	34.00	14.77	8.97	4.13	0.36	-	3.01	38.48
C	per		6	40.80	17.72	10.62	4.89	0.43	-	3.61	46.14
C	per		400	40.80	17.72	10.62	4.89	0.43	-	3.61	46.14
P				-	-	-	-	6.29	-	-	6.29
AU				-	-	-	-	-	-	-	-
H			nat	-	-	-	-	-	-	-	-
H			art	-	-	-	-	-	-	-	-
OT		para		-	2.16	-	0.53	-	-	-	2.23
OT		sd	nat	-		-	-		-	-	-
OT		sd	art	-		-	-		-	-	-
SI				-		-	-		-	-	-

Notes: TF & TFC = Forest Lands and Lands turned into Forest Lands; C = Crops: P = Grasslands; H = Wetlands; AU = Settlements; OT = Other Lands; SI = Without Information. Bhp = Wet and rain forests; Bh = Rain forests; Bs = Dry forests; Man = Mangroves; Bp-Y = Palm forests – Yolillales; bp = primary forests; bs = scondeary forests; i = intact; int = intervened; 1 ... 400 = age in years; an = annual; per = permanent; para = Moors; sd = Bare lands;; nat = natural; art = artificial; BARA = Aboveground tree biomass; BNAA = Aboveground Non-Arboreal Biomass; BARS = Belowground Arboreal Biomass; BNAS = Belowground Non-Arboreal Biomass; MMA = Aboveground Dead Wood; MMS = Belowground Dead Wood; H = Litter; SOC = Soil organic carbon; CO2= carbon dioxide.

Table 15. Average relative uncertainties (%) at 90% confidence interval of estimated carbon stocks for each category and pool by using Method 1 of the IPCC.

				Aboveground Biomass		Underground Biomass			Dead Wood	Litter	Total
				BARA	BNAA	BARS	BNAS	MMA	MMS	H	
				Include	Include	Include	Include	Include	Include	Include	
				tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1
TF & TCF	Bhp	bp	i	8%	-	18%	-	18%	-	9%	6%
		bs	1	8%	-	8%	-	8%	-	24%	6%
			2	8%	-	8%	-	8%	-	24%	6%
			399	8%	-	8%	-	8%	-	24%	6%
			400	8%	-	8%	-	8%	-	24%	6%
	Bh	bp	i	8%	-	8%	-	48%	-	13%	8%
		bs	1	8%	-	8%	-	48%	-	16%	7%
			2	8%	-	8%	-	48%	-	16%	7%
			399	8%	-	8%	-	48%	-	16%	7%
			400	8%	-	8%	-	48%	-	16%	7%
	Bs	bp	i	8%	-	8%	-	39%	-	3%	8%
		bs	1	8%	-	8%	-	29%	-	9%	6%
			2	8%	-	8%	-	29%	-	9%	6%
			399	8%	-	8%	-	29%	-	9%	6%
			400	8%	-	8%	-	29%	-	9%	6%
	Man	bp	i	12%	-	12%	-	29%	-	25%	10%
		bs	1	12%	-	12%	-	37%	-	101%	9%
			2	12%	-	12%	-	37%	-	101%	9%
			399	12%	-	12%	-	37%	-	101%	10%
			400	12%	-	12%	-	37%	-	101%	10%
	Bp-Y	bp	i	22%	-	22%	-	118%	-	117%	18%
		bs	1	22%	-	22%	-	141%	-	117%	17%
			2	22%	-	22%	-	141%	-	118%	17%
			399	22%	-	22%	-	141%	-	118%	18%
			400	22%	-	22%	-	141%	-	118%	18%

				Aboveground Biomass		Underground Biomass			Dead Wood	Litter	Total
				BARA	BNAA	BARS	BNAS	MMA	MMS	H	
				Include	Include	Include	Include	Include	Include	Include	
				tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1	tCO2-e ha-1
C	an			-	12%	-	12%	-	-	-	10%
	per		1	71%	68%	71%	68%	35%	-	48%	39%
			2	71%	68%	71%	68%	35%	-	48%	40%
			3	71%	68%	71%	68%	35%	-	48%	40%
			4	71%	68%	71%	68%	35%	-	48%	40%
			5	71%	68%	71%	68%	35%	-	48%	40%
			6	71%	68%	71%	68%	35%	-	48%	40%
			400	71%	68%	71%	68%	35%	-	48%	40%
P				-	-	-	-	76%	-	-	10%
AU				-	-	-	-	-	-	-	-
H			nat	-	-	-	-	-	-	-	-
			art	-	-	-	-	-	-	-	-
OT		para		-	2%	-	2%	-	-	-	1%
		sd	nat	-	-	-	-	-	-	-	-
			art	-	-	-	-	-	-	-	-
SI				-	-	-	-	-	-	-	-

Notes: TF & TFC = Forest Lands and Lands turned into Forest Lands; C = Crops: P = Grasslands; H = Wetlands; AU = Settlements; OT = Other Lands; SI = Without Information. Bhp = Wet and raom forests; Bh = Rain forests; Bs = Dry forests; Man = Mangroves; Bp-Y = Palm forests – Yolillales; bp = primary forests; bn = new forests; i = intact; int = intervened; 1 … 400 = age in years; an = annual; per = permanent;; para = Moors; sd = Bare lands;; nat = natural; art = artificial; BARA = Aboveground tree biomass; BNAA = Aboveground non-Arboreal Biomass; BARS = Belowground Arboreal Biomass; BNAS = Belowground Non-Arboreal Biomass; MMA = Aerial Dead Wood; MMS = Underground Dead Wood; H = Litter; SOC = Soil organic carbon; CO2= carbon dioxide.

Table 16. Uncertainties calculated for Average emission from primary and secondary forest loss, carbon enhancement and net emissions in Costa Rica, for 2014 -2015 period.

	Deforestation ($tCO_2e * yr^{-1}$)			Carbon Enhancement ($tCO_2e * yr^{-1}$)	Net Emissions ($tCO_2e * yr^{-1}$)
	Primary Forest	Secondary Forest	Total		
Percentile 95%	2,087,022	1,092,508	3,089,647	(5,471,692)	(2,567,430)
Percentile 5%	1,621,764	853,647	2,560,967	(6,229,583)	(3,490,266)
Mean	1,851,123	972,957	2,824,079	(5,850,653)	(3,026,573)
CI	465,258	238,861	528,680	757,892	922,836
ME	232,629	119,431	264,340	378,946	461,418
% Uncertainty	12.57%	12.28%	9.36%	6.48%	15.25%

distributions. The simulated distributions were also truncated to prevent unrealistic values from being generated. For all parameters where the value could not be less than 0, such as activity data, the distributions were truncated to a minimum value of 0.

4. Uncertainty estimation: Based on the Monte Carlo simulations produced for emissions and removals in the different activities, the 90% confidence interval was derived by subtracting the 5% percentile value from the 95% percentile value of the distribution of iterations. Half the confidence intervals (i.e. the margins of error) were then divided by the mean of the distribution and then multiplied by 100% to come up with the percent uncertainty.

Table 16 shows the results of the Monte Carlo simulations for each REDD+ activity **when including both activity data and emission factor uncertainty**. The results are shown at the 90% confidence interval.

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