Annex 22a Methods for the estimation of potential mitigation impacts

Heritage Colombia (HECO): Maximizing the Contributions of Sustainably Managed Landscapes in Colombia for Achievement of Climate Goals

V.5

May 10, 2022

NOTE: all detailed estimates and methods are included in Annex 22b: Spreadsheet used to run all mitigation estimates. All formulae used are described in Annex 22c.

Current Paradigm of Deforestation and Land Use Change

During the period 1990-2020, 7.28 million hectares were deforested throughout the country[1]. Historic annual forest loss at national scale is dynamic, with the highest value observed in 2017 with 219,552 ha deforested[2]. Deforestation is a complex phenomenon that involves different sub-systems, such as the economy, environment, society and policy. However, it is mainly caused by illegal activities, which are attractive as they generate economic income and have low or nonexistent punishment. The main illegal activities contributing to the current paradigm of deforestation are agricultural expansion (including illegal crops), land grabbing, illegal mining, illegal infrastructure, and illegal wood extraction.

According to Arias-Gaviria, et al. (2021) analysis of deforestation dynamics, agriculture (including ilegal crops), livestock, timber extraction unplanned infrastructure have been the main drivers. **The balancing forces that could slow down and stop deforestation are determined by governance schemes (sustainable territorial planning), the self-regulation of local communities, and financial mechanisms for conservation.** [3] Detailed driver assessment results for each project geography are included in the full proposal[4].

The Intensity of deforestation in recent years is putting pressure on Colombia's protected areas, with historical deforestation trends showing hotspots to the northeast of the Heart of the Amazon and the south of San Lucas. The area-weighted deforestation peak shows the year where larger areas are deforested, indicating that northeast of the Heart of the Amazon is experiencing more recent significant losses. Intensity is increasing to the south of San Lucas in more recent years (Figure 1).

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[1] Instituto de Hidrología, Meteorología y Estudios Ambientales - IDEAM. 2019. Subdirección de Ecosistemas e Información Ambiental. Grupo de Bosques 2019. Sistema de Monitoreo de Bosques y Carbono (SMBYC). Bogotá, D. C., Colombia

[2] 2020 FREL submission: https://redd.unfccc.int/files/02012019_nref_colombia_v8.pdf

[3] Arias-Gaviria et al 2021. Drivers and effects of deforestation in Colombia: a systems thinking approach. Regional Environmental Change (2021) 21:91.https://doi.org/10.1007/s10113-021-01822-x

[4] https://static-content.springer.com/esm/art%3A10.1007%2Fs10113-021-01822-x/MediaObjects/10113_2021_1822_MOESM1_ESM.pdf)

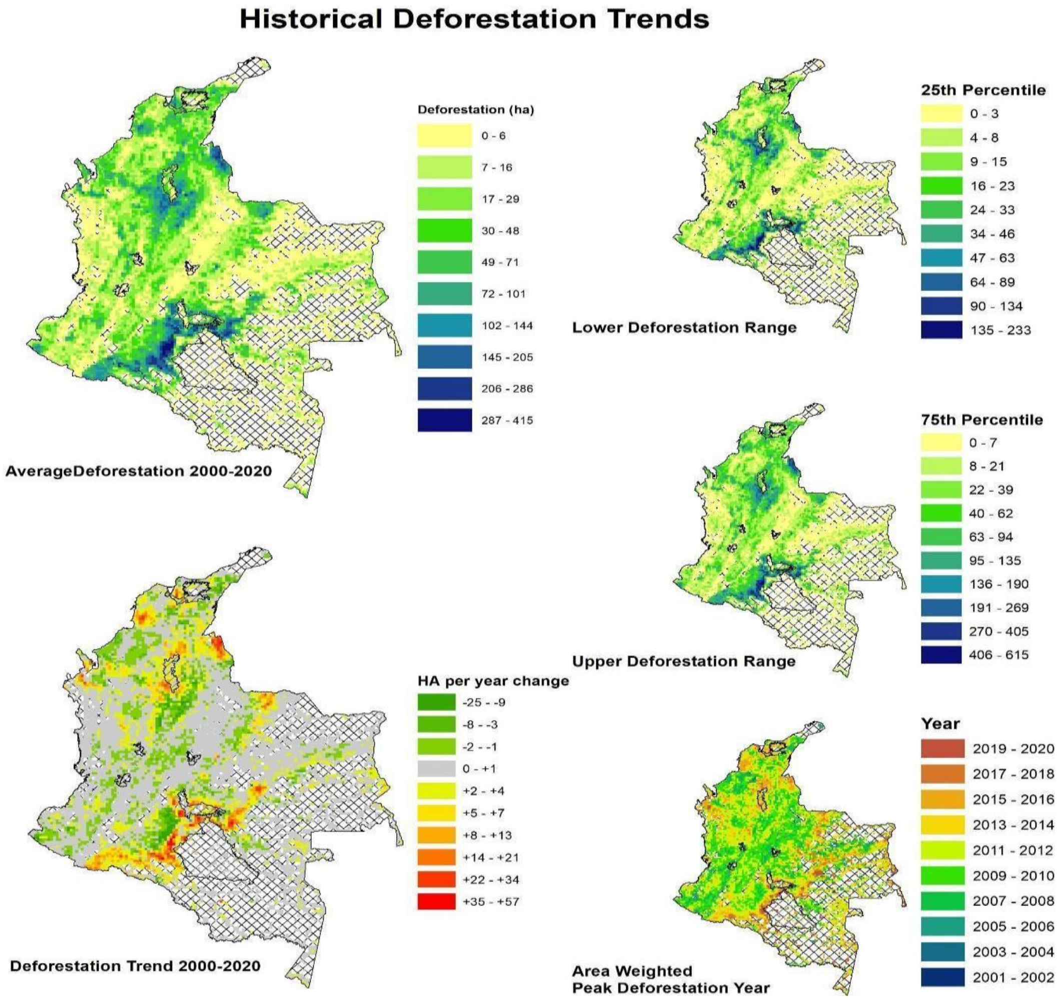

Figure 1. Historical deforestation ranges and long-term trends.

1. Avoiding Deforestation

The project expects to deliver on avoided deforestation via the combined impact the interventions considered under the scope of this proposal as well as the synergies with other relevant strategies under implementation. The interventions under this proposal contributing to these targets include the enhancement in the management capacity of the protected areas in each mosaic as well as the engagement of drivers of deforestation via the implementation of sustainable productive systems such as agroforestry and silvo pastoral systems (Fig. 2).

The estimation of avoided emissions is based on the methods used for the formulation of Colombia's 2020 Forest Reference Emissions Level submission to the UNFCCC[5]. This approach was selected to maintain coherence with national mitigation targets, accounting and contributions towards NDC and PA agreement stock take. This also enables assessment of project area specific results under the scope of national performance as to assess potential issues pertaining leakage. This will also avoid discrepancies in accounting between the numbers reported for this project and the national ones. It is the scope of this

[5] The reference level technical Exchange and subsequent modified submission and technical assessment report are currently being finalized. Based on conversations with both parties. No major changes are expected in the modified submission. Particularly regarding the aspects relevant to this project proposal. Currently only the original submission is available https://redd.unfccc.int/files/02012019_nref_colombia_v8.pdf

project to make use of, add value to and complement the national accounting process as oppose to generating parallel systems that would result in potential conflicts and significant inefficiencies. As such, the forest definition, activity data, emissions factors are consistent with the FREL 2020[6] methodologies and data (from the National Hydrological, Meteorological and Environmental Studies Institute [IDEAM] and its Forest and Carbon Monitoring System [SMByC]). In the case of the FREL, Colombia presented both: historical emissions estimates for the 2008-2017 period as well as projected estimates applied over eligible forest areas under different criteria[7]. The use of projected estimates towards the FREL was justified by Colombia based on national circumstances as explained in the FREL For this proposal all estimated avoided emissions estimates are based on the historical average emissions shown within its geographic scope. This is a means of delivering a conservative estimate compared to the projected one, while not generating discrepancies with the FREL. It is also relevant to consider, the geographic scope of this proposal is complementary to the one of the FREL 2020 as it excludes protected areas, indigenous territories and afro-colombian territories that are included in this proposal

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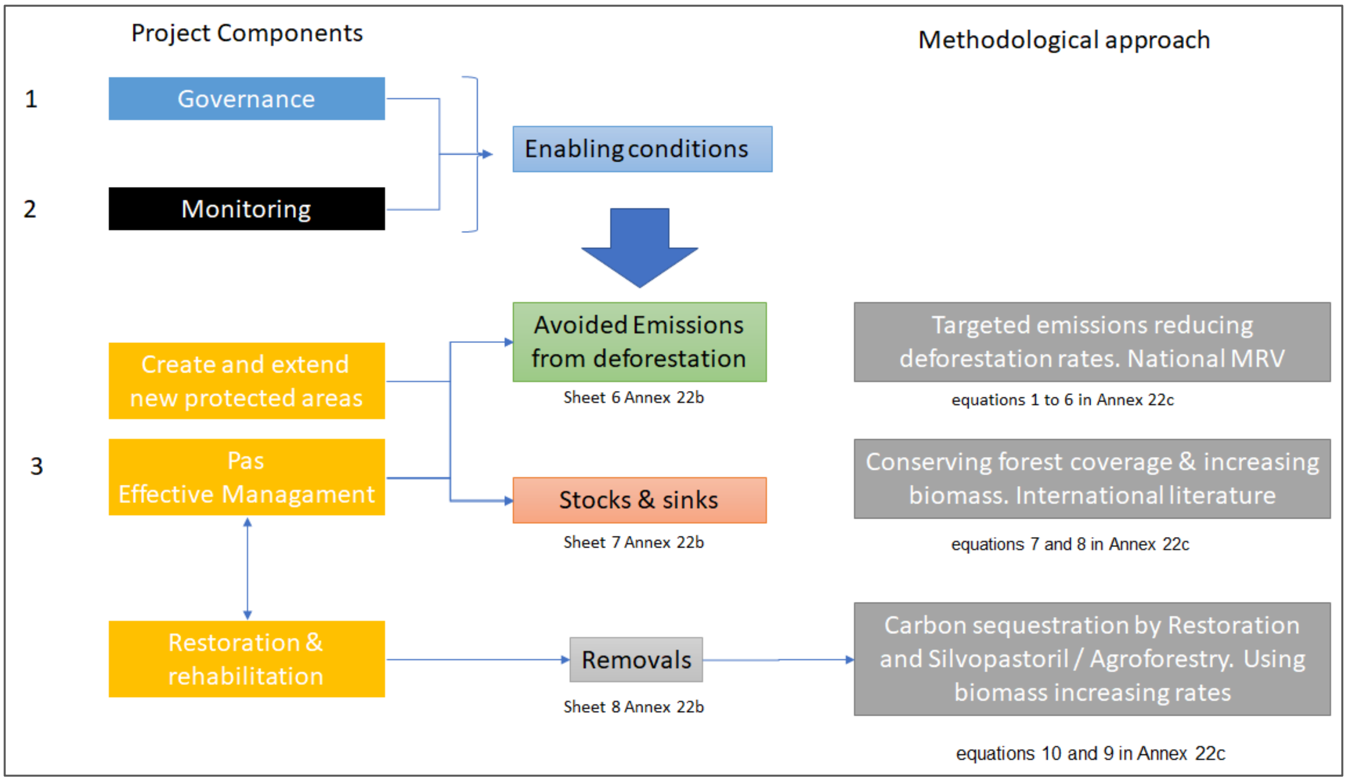

Figure 2. Technical scheme for project emissions

The geographic scope are key corridors, its protected areas and key landscapes to be declared as new protected areas that were prioritized under adaptation and mitigation criteria. The key proceedings to calculate the total avoid emissions are explained as follow:

1.1 Stratification of Natural Forests

For this analysis, we used the regional framework adopted by the Colombian government on the deforestation forest emissions reference level (FREL 2020)[1] where the national forest inventory (IFN its acronym in Spanish) was considered to calculate above ground, belowground biomass and organic

[6] 2020 FREL submission: https://redd.unfccc.int/files/02012019_nref_colombia_v8.pdf
[7] Methods used for the FREL model adjustment and use: https://redd.unfccc.int/files/31122019_anexo_circunstancias_nref_nal_v7.pdf

carbon soil for each natural region in Colombia (Fig. 3; Amazonia, Caribe, Andes, Orinoquia and Pacifico).

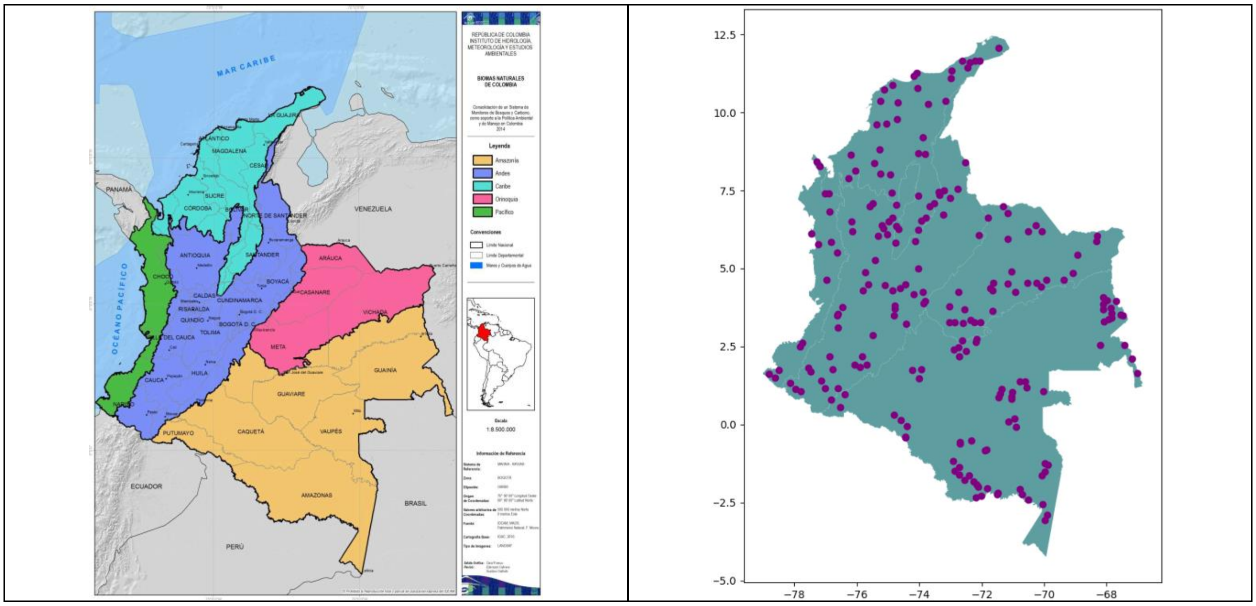

Figure 3. Natural regions Vs IFN data. Source (MADS & IDEAM 2019)

1.2 Activity Data

Activity data for the proposal are the same Colombia used for its FREL 2020 submission to UNFCCC. Data were obtained directly from IDEAM[8]. The data are based on the analysis of the time series of forest cover change for the 2008-217 period (Fig 4), produced based on Landsat data cloud free mosaics, change mapps production and classification and subsequent accuracy assessment. Data were clipped to the geographic scope areas of this proposal.

The construction of the FREL of the activity to reduce emissions from deforestation (gross deforestation) in Colombia is based on the information generated by the Forest and Carbon Monitoring System (SMByC), led by IDEAM, under the guidelines of the Ministry of Environment and Sustainable Development (MADS) and consistent with the decisions of the UNFCCC and the guidelines of the Intergovernmental Panel on Climate Change (IPCC). Specifically to obtain activity data, biennial maps of changes in forest cover were used from 2008 to 2012 and annually from 2013 provided by IDEAM.

[8] http://smbyc.ideam.gov.co/MonitoreoBC-WEB/reg/indexLogOn.jsp

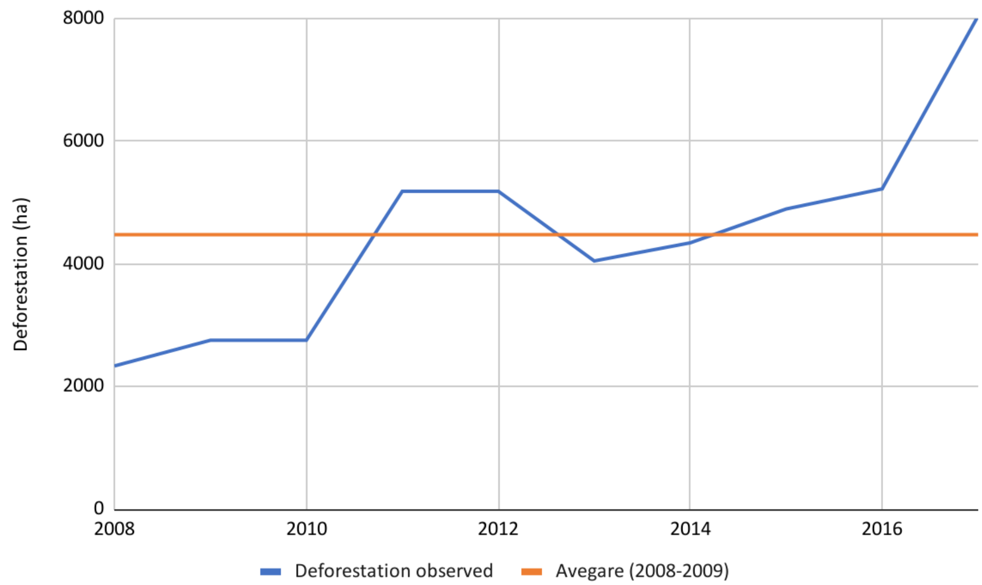

Figure 4. Forest change monitoring at the project level (period 2008-2017)

The thematic accuracy of the national deforestation data was reported at 9% in the FREL. This was estimated following the methods developed by Olofsson et al. (2014)[9], in line with what is proposed in the methods document and guidance generated by the Global Forest Observation Initiative (GFOI[10]). The accuracy assessment includes calculating the uncertainty of the estimators. In the case of the FREL, area estimates are based on mapped change areas (no statistical sample was derived). We assume data used for the proposal show the same qualities.

The results of forest monitoring activity data allow us to identify that for the reference period 2008 - 2017, deforestation is 4,478 ha / year at the project level (orange line in Figure 4). At the mosaic level, it is identified that the Heart of Amazon is the mosaic that consistently concentrates the largest deforested areas, followed by the San Lucas new protected area and the Caribbean mosaic in third place, as shown in Figure 5.

[9] Olofsson et al. 2014. Good practices for estimating area and assessing accuracy of land change: https://doi.org/10.1016/j.rse.2014.02.015
[10]https://www.reddcompass.org/uncertainty?p_p_id=pyramid_WAR_gfoimgdwamrvsystemportlet_INSTANCE_66u8qECQZ63L&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2a-1&p_p_col_count=1&p_r_p_1316845383_MGD_THEME=Measurement+%2B+Estimation&p_r_p_1316845383_MGD_CONCEPT=Uncertainty&fid=%2Fmgd%2F3.7#gfoi-mgd-content

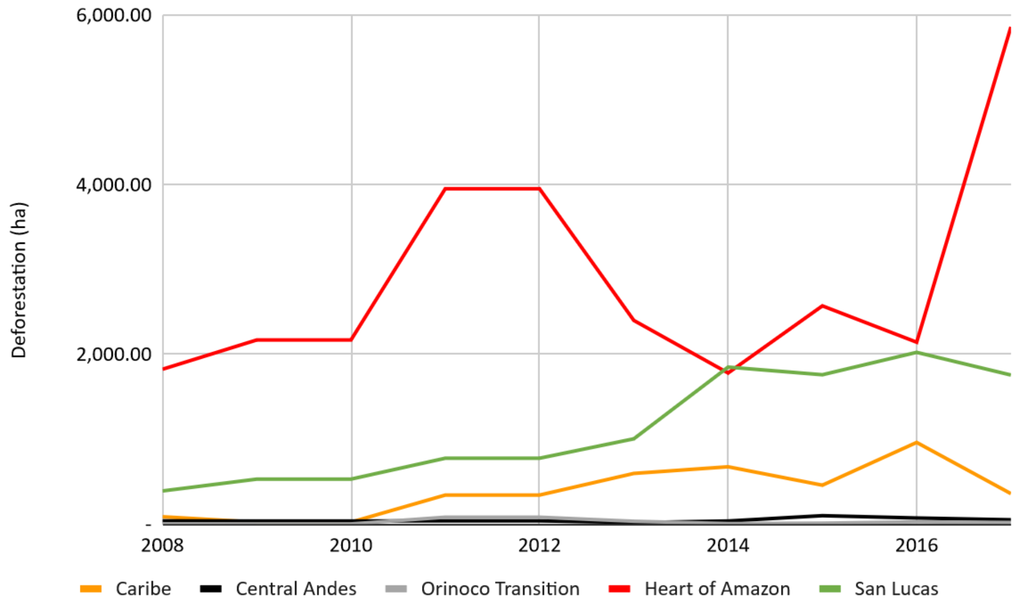

Figure 5. Forest change monitoring at mosaic level (Period 2008-2017)

1.3 Emissions factors

To calculate the carbon content in natural forests, the values of total biomass for the five natural regions including the aboveground and belowground biomass by hectare, were taken from the National Forest Inventory (NFI[11]) and the national reference level (FREL 2020). The total carbon content per hectare in each natural region was calculated taking into consideration the total remaining forest area as of 2019 multiplied by the biomass estimates for above ground (ABG), below ground (BGG) and soil biomass, multiplied by the dry carbon fraction (0.47). Equivalent carbon dioxide (CO_{2e}) corresponds to the measure used to compare the emissions of various GHGs, based on the global warming potential (Phillips et al IDEAM, 2011). For this, we follow the recommendation of the IPCC (2003, 2006) multiplying the number of tons of carbon by a constant of 3.67 or 44/12 (FREL 2020). As in the FREL, the baseline assumes the instant oxidation of all biomass upon deforestation occurring.

Furthermore, the deforestation emissions in soil stocks were assumed in equal proportions during 20 years after the deforestation event. The table 1 shows the final emission factors to each natural region including Aboveground biomass (BA), belowground biomass (BS), total biomass (BT) and soil organic carbon (COS)

Table 1. Emissions factor of natural forest in each region in Colombia. Source (FREL 2020)

Region	BA (t CO_2/ha)	BS (t CO_2/ha)	BT (t CO_2/ha)	COS 20 years (t CO_2/ha)	Total Emissions (t CO_2 ha^{-1} $year^{-1}$)
Amazonia	445	98	543	14	557
Andes	265	60	326	23	349
Caribe	224	52	276	19	295
Orinoquia	148	36	184	12	196
Pacifico	241	55	296	17	313

[11] http://www.siac.gov.co/en/inventario-forestal-nacional

As in the case of the FREL, the emissions estimates are based on committed emissions: it is assumed all biomass is oxidized upon land cover change occurring (MADS & IDEAM 2019).

Emissions estimates within each mosaic were produced overlaying the strat used for the NFI and applying the corresponding emissions factors to the activity data observed in the time series of the historical period. (MADS & IDEAM 2019)

1.4 Reference level

The reference level proposed for this project is based on the historical emissions estimated over the 2008-2017 period as is the case for the FREL 2020. As in the 2020 FREL submission by Colombia to the UNFCCC, AD and EF have been combined accordingly. This process was followed for each of the mosaics as well as for each of the areas in which each intervention approach is to be implemented (Figure 6).

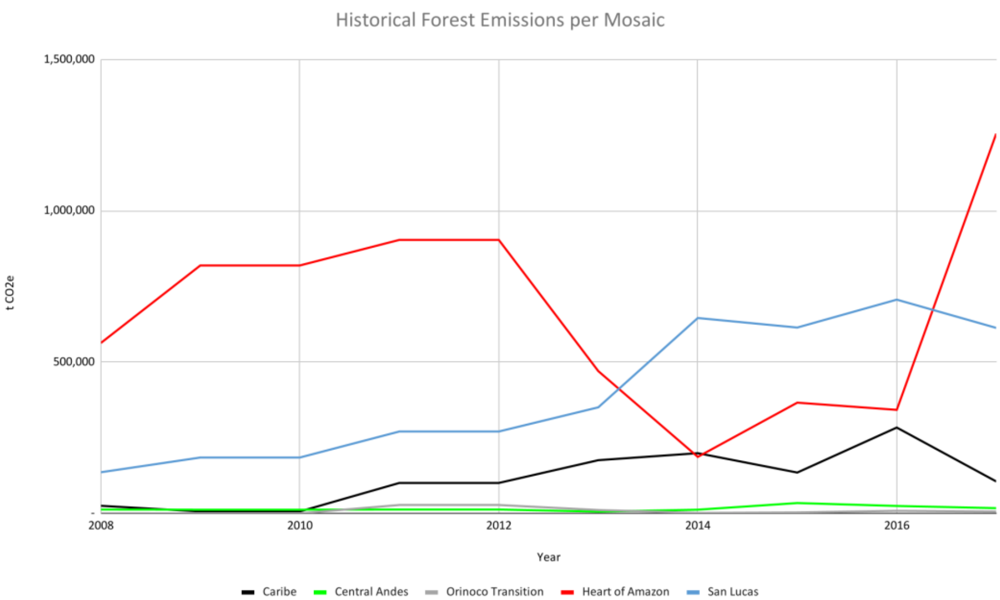

Figure 6. Forest reference emissions per mosaic

The 2020 FREL submission to UNFCCC, uses a logistic model fit to the observed emission between 2008 and 2017, applied to areas considered susceptible of being deforested after a statistical analysis was performed[12],[13] to compare their deforestation rates. This project's geographic scope is complementary to the one considered under Colombia's FREL 2020 as it targets areas set aside by the FREL as protected areas, and afro-colombian and indigenous territories. Based on this, we have proposed the use of a conservative historical baseline, without model fit, as to not generate the possibility of double accounting or conflicts regarding model fit to the specific areas under consideration as the use of the model was deems relevant for the high risk areas a not the low risk areas this project targets. Table 2. presents the historical baseline estimates for each mosaic as well as for the different areas of intervention.

[12] 2020 FREL submission: https://redd.unfccc.int/files/02012019_nref_colombia_v8.pdf
[13] Technical annex to the 2020 FREL submission: https://redd.unfccc.int/files/31122019_anexo_circunstancias_nref_nal_v7.pdf

Table 2. Historical deforestation, emissions and remaining area and stocks in the project areas (sources: IDEAM 2020 and processed data). The colors represent the type of intervention as follows: a. dark green = protected areas whose effective management is to be improved. b. clear green = new proposed protected areas or expansion to existing ones. c. blue = basin management areas within proposed corridors and d. remaining corridor areas.

	Forest 2019 (ha)	Socks 2019 (tCO2eq)	Deforestation (ha) (2008-2017)	Annual forest lost (ha) (2008-2017)	Annual Average Emissions from deforestation T CO2e
Effective Management of the Sierra Nevada de Santa Marta National Park	174,138	51,370,582	1,710	171	50,447
Expansion of the Sierra Nevada National Park (North sector)	11,763	3,470,106	325	33	9,599
Expansion of the Sierra Nevada National Park (South sector)	70,081	20,673,926	673	67	19,863
Effective Management of Cienaga Grande de Santa Marta National Santuary	13,069	3,855,445	443	44	13,061
Fundación river middle and low basin management	10,015	2,954,484	605	61	17,848
Effective Management of Los Besotes Forest Reserve	59	17,304	-	-	-
Effective Management Serrania del Perija Regional Park	3,980	1,174,225	12	1	346
Seco river basin management. Guacoche/Guacochito locations	753	222,094	90	9	2,650
Totals	**283,858**	**83,738,164**	**3,858**	**386**	**113,814**
Andes centrales					
Effective Management of Hermosas National Park	55,806	19,476,214	138	14	4,824
Amaime river basin management	20,358	7,104,869	225	22	7,848
Effective Management of los Nevados National Park	8,662	3,023,208	5	1	187
Chinchina river basin management	9,344	3,261,170	81	8	2,842

Totals	**94,170**	**32,865,461**	**450**	**45**	**15,700**
Transicion Orinoquia					
Effective Management of Chingaza National Park	34,617	6,784,885	112	11	3,913
Gachala Junin	4,492	880,371	9	1	308
Upper Guatiquia river basin management	24,811	4,862,918	119	12	4,156
Upper Guayuriba river basin management	7,172	1,405,660	10	1	354
Totals	**71,091**	**13,933,833**	**250**	**25**	**8,730**
Corazon Amazonia					
Effective Management of Sierrania de Chiribiquete	4,007,247	2,232,036,511	5,785	579	322,242
Effective Management of Sierra de la Macarena	527,769	293,967,357	16,060	1,606	894,517
Effective Management of La lindosa Forest Reserve	11,429	6,365,840	868	87	48,370
Nucleo 1 Puerto Nuevo	14,221	7,920,965	2,802	280	156,053
Nucleo 2 Picalojo	4,951	2,757,804	2,639	264	147,003
Restoration of Caño Dorado river	3,942	2,195,867	5,321,072	50	28,022
Effective Management Capricho & Mirolindo Forest Reserves	3,402	1,895,146	174	17	9,719
Totals	**4,572,961**	**2,547,139,489**	**5,349,401**	**2,883**	**1,605,926**
San Lucas					
Declaration of New protected Area (San Lucas)	420,202	146,650,585	11,394	1,139	397,661
Overall totals	**5,442,283**	**2,824,327,532**	**5,365,353**	**4,478**	**2,141,832**
% of national totals	9.11%	10.78%	3.12%	3.12%	2.28%

1. *Deforestation mitigation targets setting*

Deforestation mitigation targets for the project duration (10 years) were established based on historic average deforestation/emissions rates, the specific context of each region (Caribbean, Andes, Amazon, Orinoquia and the Area de Manejo Especial de la Macarena [AMEM]) and the management regime being considered (expansion/new protected area, improved management of protected areas and corridors). Additionally, provisions under Colombia's first NDC submission to UNFCCC, a commitment to emission by minimum 30% from historical levels with the support of international collaboration by 2030, were considered as well [14]. Colombia submitted an updated NDC in 2020[15]. This updated version stipulates specific targets for number of hectares and emissions reductions from deforestation and removals from restoration this proposal seeks to contribute with. A decision tree (Figure 7) was developed to incorporate the different criteria used and assign the targets for each area. Implementation activities are aimed towards delivery and compliance with such targets.

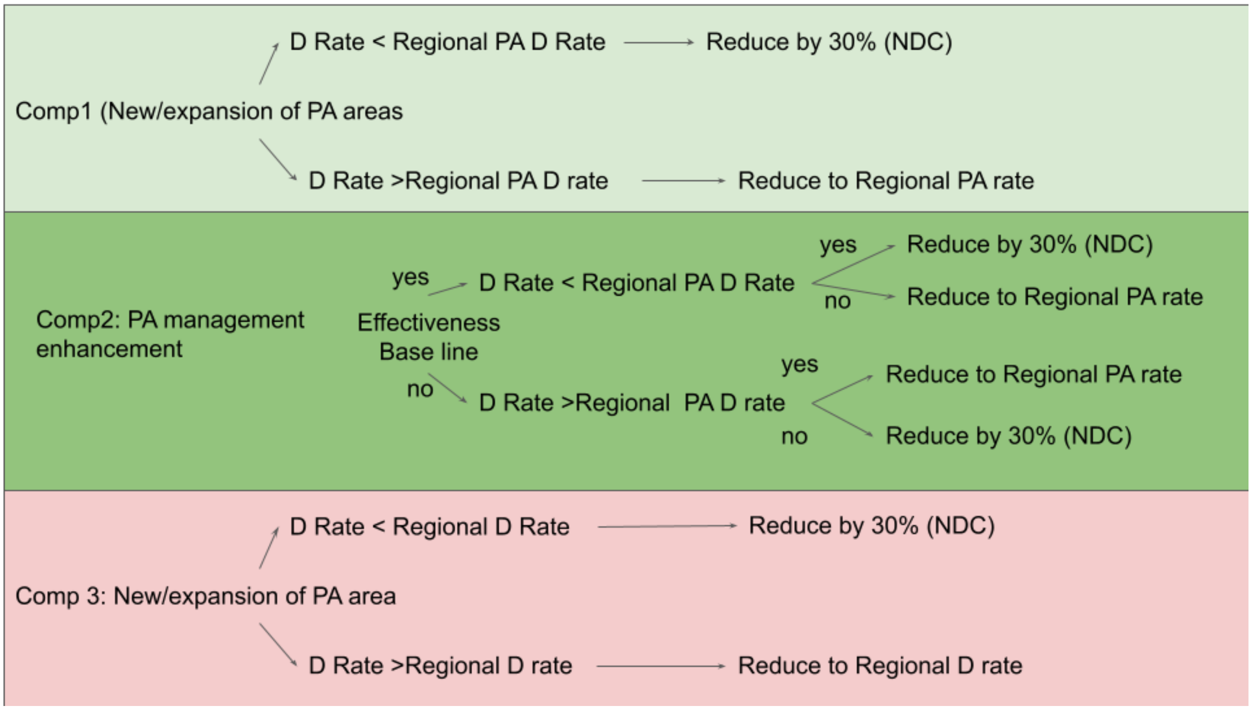

Figure 7. Decision tree emissions reductions target definition for each corresponding area. a. dark green = protected areas whose effective management is to be improved. b. clear green = new proposed protected areas or expansion to existing ones. c. proposed corridors with specific basins. The criteria used compare the specific intervention type area historic deforestation/emissions rate with the average rates (%) observed for the same period in the same region PA system or the regional deforestation rate and incorporate the 30% reduction NDC target depending on the case. Reference rates are reported in table 3.

Table 3. Reference areas and average reference deforestation rates 2008-2017

Reference Areas used for target Setting	Deforestation rate
National Parks System	0.072%
National parks in the Area de Manejo Especial de la Macarena (AMEM)	0.505%
National parks in the Caribbean region	0.221%
National parks in the Andes region	0.054%
National parks in the Amazonia region	0.038%
Nacional territory	0.246%
Orinoquia Region	0.428%
Amazonia Region	0.203%
Andina Region	0.274%

[14] Colombia's first NDC 2018: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Colombia%20First/INDC%20Colombia.pdf\
[15] Colombia NDC Update 20202:
https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Colombia%20First/NDC%20actualizada%20de%20Colombia.pdf

Caribe Region	0.734%

Table 4. Target deforestation rates after 10 and 30 years for each area of intervention

Corridor	Management	LANDSCAPE	Target of Annual Deforestation rate at 10 years (%)	Target of Annual Deforestation rate at 30 years (%)
Caribbean	Improve Effective management in PAs	Sierra Nevada de Santa Marta	0.064%	0.000%
	New Protected Areas	Ampliación Sierra Nevada Norte	0.221%	0.000%
	New Protected Areas	Ampliación Sierra Nevada Sur	0.066%	0.000%
	Improve Effective management in PAs	Cienaga Grande de Santa Marta	0.221%	0.000%
	Landscape/basin management	Cuenca Media y Baja río Fundación	0.420%	0.300%
	Improve Effective management in PAs	Los Besotes	0.000%	0.000%
	Improve Effective management in PAs	Serrania del Perija	0.011%	0.000%
	Landscape/basin management	Cuenca Río Seco y Corr. Guacoche/Guacochito	0.729%	0.521%
Central Andes	Improve Effective management in PAs	Las Hermosas	0.014%	0.000%
	Landscape/basin management	Cuenca Rios Amaime Cerritos	0.077%	0.055%
	Improve Effective management in PAs	Los Nevados	0.004%	0.000%
	Landscape/basin management	Cuenca Rio Chinchina	0.054%	0.039%
Orinoco Transition	Improve Effective management in PAs	PNN Chingaza	0.018%	0.000%
	Landscape/basin management	Gachala Junin	0.004%	0.003%
	Landscape/basin management	Cuenca Guatiquia	0.019%	0.014%
	Landscape/basin management	Cuenca Guayuriba	0.004%	0.003%
Heart of Amazon	Improve Effective management in PAs	Sierra de la Macarena	0.187%	0.000%
	Improve Effective management in PAs	Serrania La Lindosa - Angosturas II	0.318%	0.000%
	Landscape/basin management	Nucleo 1 Puerto nuevo	0.932%	0.666%
	Landscape/basin management	Nucleo 2 Picalojo	2.323%	1.659%
	Landscape/basin management	Ronda Caño Dorado	0.592%	0.423%
	Improve Effective management in PAs	RPN Capricho y Mirolindo	0.038%	0.000%
	Improve Effective management in PAs	Serrania de Chiribiquete	0.006%	0.000%

San Lucas	New Protected Areas	San Lucas	0.054%	0.000%

Table 5 presents the estimated avoided emissions for each landscape component after 5, 10 and 30 years of intervention and as per designated target rates. According to the latest NDC update[7], Colombia expects to reduce emission from deforestation by 2030 to between 45.574 and 58.69 million tCO2eq with respect to its 2020 FREL. Our estimated avoided emissions would represent between 13.8 and 17.8% of such volume; even though our estimates are based on a much more conservative historical average; which makes the comparative contribution even larger.

Estimated avoided emission were estimated following equations 1 to 6 in Annex 22c.

Table 5. Estimated avoided emissions from deforestation as per decision trees targets.

Estimated Mitigation Impacts	Avoided Deforestation (ha) 30 yrs	Avoided Emissions 5yrs (tCO2eq)	Avoided Emissions 10 yrs (tCO2eq)	Avoided Emissions 30 yrs (tCO2eq)
Caribe				
Effective Management of the Sierra Nevada de Santa Marta National Park	2,756	39,689	115,100	816,109
Expansion of the Sierra Nevada National Park (North sector)	452	3,330	11,796	133,348
Expansion of the Sierra Nevada National Park (South sector)	1,034	10,782	36,454	305,485
Effective Management of Cienaga Grande de Santa Marta National Santuary	686	1,394	18,924	202,279
Fundación river middle and low basin management	667	9,881	34,508	198,459
Effective Management of Los Besotes Forest Reserve	-	-	-	-
Effective Management Serrania del Perija Regional Park	26	958	2,043	7,830
Seco river basin management. Guacoche/Guacochito locations	126	4,358	10,461	42,609
Totals Caribe	**5,746**	**70,393**	**229,285**	**1,706,119**
Andes				
Effective Management of Hermosas National Park	245	6,294	15,538	86,015
Amaime river basin management	226	4,127	14,176	80,508
Effective Management of los Nevados National Park	8	213	544	3,223
Chinchina river basin management	98	3,872	9,474	39,504
Totals Andes	**578**	**14,505**	**39,732**	**209,250**
Orinoquia				
Effective Management of Chingaza National Park	201	5,272	12,912	70,329
Gachala junin	21	1,117	2,304	7,361
Upper Guatiquia river basin management	221	10,150	22,062	77,471
Upper Guayuriba river basin management	22	1,132	2,369	7,779
Totals Orinoquia	**466**	**17,671**	**39,648**	**162,940**

Amazonas				
Effective Management of Sierra de la Macarena	27,461	977,189	2,562,979	15,472,287
Effective Management of La lindosa Forest Reserve	1,850	116,962	256,423	1,048,784
Nucleo 1 Puerto Nuevo	5,031	326,024	747,291	2,853,009
Nucleo 2 Picalojo	5,553	353,456	811,225	3,077,019
Restoration of Caño Dorado river	887	59,072	133,838	502,544
Effective Management Capricho & Mirolindo Forest Reserves	448	24,225	63,362	250,953
Effective Management of Sierrania de Chiribiquete	12,082	753,324	1,648,315	6,840,346
Totals Amazonas	**53,313**	**2,610,253**	**6,223,434**	**30,044,942**
San Lucas				
Declaration of New protected Area (San Lucas)	25,794	514,211	1,805,558	9,020,234
Overall totals	**85,897**	**3,227,033**	**8,337,657**	**41,143,485**

This project intends to reduce emissions by 54.15% from historic averages for deforestation by 2030 (Figure 13) contributing towards the national commitment to achieve carbon neutrality by midcentury in accordance with Colombia's 2020 NDC commitment. Total avoided emissions are estimated to be 8.3 million tCO2e at project completion (10 years) and 41.1 million tCO2e over the project lifespan (30 years) (Figure 8 and Table 5).

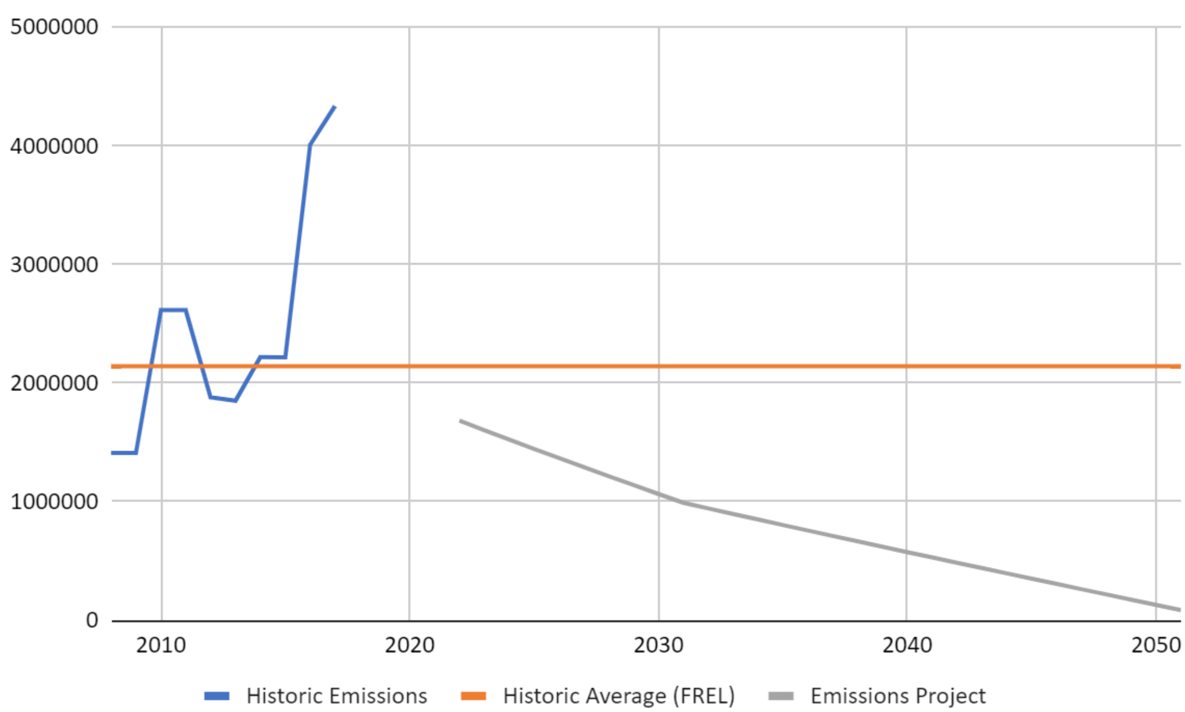

Figure 8. Forest emission comparison between historic average and project scenario

2. Carbon Stocks and Sinks

2.1. Carbon stocks

Because of its geographic scope, a key component of this project relates to the preservation of large carbon stocks and their related sinks. The mosaics considered are largely forested, with relatively low historical deforestation rates, surrounding existing protected areas. This project seeks to preserve up to 2,843,725,891 tCO2eq (10.85%) of remaining stocks nationally as of 2019. Stock estimates were produced using data from IDEAM (2020) on remaining forest area, combined with the estimated rate of loss under this project and emissions factors used for the FREL submission by Colombia to UNFCCC in 2020 (table 6).

2.2. Carbon sinks

Remaining standing forests potential carbon sinks were considered in this project because forests represent a major component of the global carbon sink[16],[17],[18];[19] a fact often overlooked by compensation schemes that needs to be accounted for and preserved. Sink estimates were based on 2 conservative assumptions: 1. All remaining forests are mature; which significantly decreases their estimated rate of carbon sequestration and 2. sinks have decreased significantly due to climate change as per recently published evidence for amazon and african forests[20]. Sink rates estimates were taken from table 1 in Hubau et al (2020)[21] (see table below) for the period 2020-2030 for the Amazon region at 0.12 tC/ha/yr.

Table 1 | Carbon sink in structurally intact old-growth tropical forests in Africa, Amazonia and the pan-tropics, 1980–2040

Period	Number of plots		Per unit area aboveground live biomass C sink (Mg C ha^{-1} yr^{-1})			Total C sink (Pg C yr^{-1})[a]		
	Africa	Amazon	Africa	Amazon	Pan-tropics[b]	Africa	Amazon	Pan-tropics[b]
1980–1990	45	73	**0.33** (0.06–0.63)	**0.35** (0.06–0.59)	**0.35** (0.07–0.62)	**0.28** (0.05–0.53)	**0.49** (0.08–0.82)	**0.87** (0.16–1.52)
1990–2000	96	172	**0.67** (0.43–0.89)	**0.53** (0.42–0.65)	**0.57** (0.39–0.74)	**0.50** (0.32–0.66)	**0.68** (0.54–0.83)	**1.26** (0.88–1.63)
2000–2010	194	291	**0.70** (0.55–0.84)	**0.38** (0.26–0.48)	**0.50** (0.35–0.64)	**0.46** (0.37–0.56)	**0.45** (0.31–0.57)	**0.99** (0.70–1.25)
2010–2015[c]	184	172	**0.66** (0.40–0.91)	**0.24** (0.00–0.47)	**0.40** (0.15–0.65)	**0.40** (0.24–0.56)	**0.27** (0.00–0.52)	**0.73** (0.25–1.18)
2010–2020[d]	–	–	***0.63*** *(0.36–0.89)*	***0.23*** *(−0.05–0.50)*	***0.38*** *(0.11–0.65)*	***0.37*** *(0.21–0.53)*	***0.25*** *(−0.05–0.54)*	***0.68*** *(0.17–1.16)*
2020–2030[d]	–	–	***0.59*** *(0.24–0.93)*	***0.12*** *(−0.29–0.51)*	***0.30*** *(−0.08–0.67)*	***0.31*** *(0.13–0.49)*	***0.12*** *(−0.29–0.52)*	***0.47*** *(−0.15–1.07)*
2030–2040[d]	–	–	***0.55*** *(0.08–0.99)*	***0.00*** *(−0.54–0.49)*	***0.21*** *(−0.29–0.67)*	***0.26*** *(0.04–0.47)*	***0.00*** *(−0.50–0.46)*	***0.29*** *(−0.46–0.97)*

This table covers 1 January 1980 to 31 December 2014 and predictions to 31 December 2039. Mean values are in boldface, future predictions in italics, uncertainties in parentheses: 95% bootstrapped confidence intervals for 1980–2015, and 2σ for the predictions (2010–2040).

[a]The total continental C sink is the per unit area aboveground C sink multiplied by intact forest area (from ref. [1]; see Extended Data Table 2) and includes continent-specific estimates of three carbon-stock components that were not measured in the inventory plots: trees with a diameter at breast height of <100 mm, lianas and roots (see Methods).

[b]The per unit area pan-tropical aboveground live biomass C sink is the area-weighted mean of African, Amazonian and Southeast Asian sink values. Southeast Asian values were from published per unit area carbon sink data[15] (n = 49 plots) for 1990–2015, with 1980–1990 assumed to be the same as 1990–2000 owing to very low sample sizes. The pan-tropical total C sink is the sum of African, Amazonian and Southeast Asian total continental carbon sink values. The continental sink in Southeast Asia is a modest and declining contribution to the pan-tropical sink, owing to the very small area of intact forest remaining, at 0.11 Pg C yr^{-1}, 0.08 Pg C yr^{-1}, 0.07 Pg C yr^{-1} and 0.06 Pg C yr^{-1} in the 1980s, 1990s, 2000s and 2010s, respectively; hence uncertainty in the Southeast Asian sink cannot reverse the pan-tropical declining sink trend.

[c]The Amazonian sink in the 2010–2015 time window was calculated from 172 plots that were mostly measured between 1 January 2010 and mid-2011. The lack of temporal coverage later in this period probably has little impact on the results; adding modelled results for 1 January 2012 to 31 December 2014 gives a per unit area aboveground sink of 0.25 Mg C ha^{-1} yr^{-1} (0.00–0.49), which would increase the pan-tropical total C sink by 0.01 Pg C yr^{-1}.

[d]Per unit area total C sink for 2010–2020, 2020–2030 and 2030–2040 was predicted using parameters from Table 2, except for the 2010–2020 sink in Africa, which is the mean of the measured sink from 2010–2015 and the modelled sink from 2015–2020. For the Asian sink we assumed the same parameters as for Africa, because Asian forest median CRT is 61 years, close to the African median of 63 years.

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[18] Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., … Hayes, D. (2011). A large and persistent carbon sink in the world's forests. *Science*, *333*(6045), 988–993. doi: 10.1126/science.1201609 [Crossref], [PubMed], [Web of Science ®], [Google Scholar]

[19] Sean L. Maxwell, Tom Evans, James E. M. Watson, Alexandra Morel, Hedley Grantham, Adam Duncan, Nancy Harris, Peter Potapov, Rebecca K. Runting, Oscar Venter, Stephanie Wang, Yadvinder Malhi. (2019) Degradation and forgone removals increase the carbon impact of intact forest loss by 626%. Science Advances 5:10, pages eaax2546. DOI: 10.1126/sciadv.aax2546.https://advances.sciencemag.org/content/5/10/eaax2546

[20] Hubau et al. 2020. Asynchronous carbon sink saturation in African and Amazonian tropical forests. Nature, Vol 579. p80: https://www.nature.com/articles/s41586-020-2035-0

[21] opt cit.

This rate was considered conservative (almost 2.7 times lower) when compared with the default rate for primary tropical forests in South America in the 2019 refined version of the IPCC 2006 guidelines for greenhouse gas inventories (0.7 t.biomass/ha/yr x 0.47 = 0.329 tC/ha/yr..see screen capture below)[22]. It was also assumed the rate will remain the same over the 30 years.

ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS[1,2,3,4] (TONNES D.M. HA^{-1} YR^{-1})

Ecological Zone[4]	Continent	Status/ Condition	Aboveground biomass growth [tonnes d.m. ha^{-1} yr^{-1}]	Uncertainty	Uncertainty type	References
Tropical rainforest	North and South America	Primary	1.0	2.0	SD	2, 10, 11
		Secondary> 20 years	2.3	1.1	SD	3, 4, 12-15
		Secondary≤ 20 years	5.9	2.5	SD	3, 4, 6, 12-14

.

Sinks estimates were produced for both, the total area expected to remain at project completion and the area loss difference expected from the baseline scenario, thanks to the implementation of this project and achievement of designated targets (additional sink). The total sink expected to be preserved amounts to 11,503,767 tCO2eq at project completion and 34,193,056 tCO2eq after 30 years, of which 16,387 tCO2eq and 223,993 tCO2eq are considered additional sinks because of avoided deforestation preserving related sinks (additional sinks) (table 6).

Estimated sinks were estimated following equations 7 and 8 in Annex 22c.

Table 6. Estimated preserved sinks from remaining stocks and preserved following avoided loss

.

Estimated Mitigation Impacts	Preserved Stocks (tCO2eq)	Preserved Sink total (tCO2eq/5yrs)	Preserved Sink total (tCO2eq/10 yrs)	Preserved Sink total (tCO2eq/30 yrs)	Preserved additional Sink (tCO2eq/5yrs)	Preserved additional Sink (tCO2eq/10yrs)	Preserved additional Sink (tCO2eq/30yrs)
Caribe							
Effective Management of the Sierra Nevada de Santa Marta National Park	51,503,855	182,687	364,700	1,088,758	72	355	6,341
Expansion of the Sierra Nevada National Park (North sector)	3,389,150	12,337	24,528	72,384	5	33	919
Expansion of the Sierra Nevada National Park (South sector)	20,712,185	73,494	146,708	437,904	18	105	2,276

[22] Table 4.9 (Updated): ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS (TONNES D.M. HA-1 YR-1). IPCC 2009 refined guideline, AFOLU VOL 4, Chapter 4. Forest Land. page 4.34. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch04_Forest%20Land.pdf

Effective Management of Cienaga Grande de Santa Marta National Santuary	3,721,245	13,581	26,972	79,519	(2)	36	1,459
Fundación river middle and low basin management	2,671,277	10,388	20,527	59,214	16	96	1,677
Effective Management of Los Besotes Forest Reserve	17,441	61	122	367	-	-	-
Effective Management Serrania del Perija Regional Park	1,166,745	4,101	8,199	24,577	2	7	74
Seco river basin management. Guacoche/Guacochito locations	182,280	766	1,500	4,204	6	26	339
Totals Caribe	**83,364,177**	**297,414**	**593,257**	**1,766,927**	**116**	**657**	**13,085**
Andes							
Effective Management of Hermosas National Park	18,724,589	55,670	111,292	333,492	10	44	607
Amaime river basin management	6,816,380	20,613	41,131	122,470	5	32	569
Effective Management of los Nevados National Park	2,694,161	7,996	15,989	47,951	0	1	19
Chinchina river basin management	2,730,937	8,229	16,427	48,978	4	20	265
Totals Andes	**30,966,067**	**92,507**	**184,839**	**552,891**	**20**	**97**	**1,460**
Orinoquia							
Effective Management of Chingaza National Park	6,788,016	35,956	71,875	215,320	9	37	504
Gachala junin	891,282	4,711	9,421	28,252	2	7	66
Upper Guatiquia river basin management	5,011,782	26,585	53,142	159,144	18	68	663
Upper Guayuriba river basin management	1,278,228	6,757	13,512	40,518	2	8	69
Totals Orinoquia	**13,969,308**	**74,009**	**147,949**	**443,235**	**30**	**120**	**1,302**
Amazonas							
Effective Management of Serrania de Chiribiquete National Park	288,081,778	552,663	1,099,423	3,251,748	934	4,275	66,030
Effective Management of Sierra de la Macarena National Park	6,045,130	11,864	23,512	68,846	120	474	5,122

Effective Management of La lindosa Forest Reserve	6,314,648	14,687	28,617	78,907	332	1,356	14,522
Nucleo 1 Puerto Nuevo	1,501,455	4,947	9,121	22,388	448	1,491	15,884
Nucleo 2 Picalojo	1,903,600	4,086	8,035	22,823	61	246	2,579
Restoration of Caño Dorado river	1,887,926	3,555	7,080	21,127	24	108	1,292
Effective Management Capricho & Mirolindo Forest Reserves	2,263,562,307	4,210,279	8,526,575	25,352,825	781	3,063	33,231
Totals Amazonas	**2,569,296,844**	**4,802,081**	**9,702,363**	**28,818,664**	**2,700**	**11,222**	**139,261**
San Lucas							
Declaration of New protected Area (San Lucas)	146,129,495	439,183	875,359	2,611,339	701	4,289	68,886
Overall totals	**2,843,769,397**	**5,705,196**	**11,503,767**	**34,193,056**	**3,567**	**16,387**	**223,993**

3. Restoration and Rehabilitation

Restoration and rehabilitation activities under this project seek to implement such measures in areas targeted for such interventions from a national scope at the local level inside each mosaic and complementing efforts under the deforestation CONPES (even though these areas have been highlighted, because of the location and relation to deforestation fronts, these are not among the top priority). This complementarity implies these interventions will be additional. The impact estimation approach used seeks to add value to and complement national efforts for the inclusion of removals into its national reference level and its MRV. As such, it is based on IPCC guidelines as these relate to GHG is as opposed to CDM methodologies, which are more suitable for project scales. This proposal although aimed at mosaics, has a general national vision to it as it seeks to complement national accounting and efforts. As such, it is opportune to highlight the intended added value in data generation and capacity building for removals assessment in the monitoring activities proposed as well as their proposed budgeting.

The carbon restoration and rehabilitation sequestration estimates were produced based on the previously specified number of potential hectares to be restored and rehabilitated in 10 years, with a cost effectiveness analysis carried out by National Parks. The number of restored/rehabilitated hectares was assumed to occur gradually so that 100% were established after 10 years 1/9th added per year beginning year 2 of the project. The total area to be restored corresponds to 11,287 ha. The area to be rehabilitated corresponds to 9,168 ha. Of those, 4,179 ha will be under agroforestry systems and 4,988 ha under silvopasture systems. The estimates for rate of biomass accumulation make use of tier 1 rate estimates from the 2019 refinement to the 2006 IPCC guidelines[23](there is no national accumulation data). Table 4.9 of Chapter 6, Volume 4 (Forests) for restoration, according to the forest type in each mosaic, and table 5.1. from chapter 5 (Cropland) - *see tables below*. In the case of restoration areas planting density will be at 100% (nominally, 600 tree/ha) whereas for rehabilitation intervention needed expected is at 75% of restoration effort (nominally, 400 trees/ha). Growth rates have been modified to fit a Chapman

[23] opt cit

Richards growth model following Bernal et al 2018[24], based on the Chapman-Richards equation[25][26] (see equation below). This project will implement the necessary methodologies and systems to monitor the biomass accumulation in restoration and rehabilitation areas, following adequate statistical design, implementation of methods and data processing and reporting. All with complete transparency and access to the public.

$$y(t) = y_{max}[1-e^{-kt}]^p$$

where Y max is the maximum yield for the forest are productive system type., k is a constant =0.091 for restoration and 2 for production systems and p = 4 for both. In the case of Restoration Ymax was fit using the solver tool in excel based on the average growth rates reported in table 4.9. of the IPCC guidelines for years 1-20 and then 21-30 for the corresponding forest types (see table 7).

In the case of restoration, after 20 year of establishment, rates have been estimated based on those reported in the guidelines for secondary forests older than 20 years. Table 7 presents the estimated expected carbon accumulation achieved for each mosaic by years 10 and 30. All detailed calculations are presented in Annex 22-R for restoration, 22-S for silvopasture and 22-AF for agroforestry. Overall total estimates are presented in Annex 22-b.

Table 7 presents the removal rates used per intervention type. In the case of restoration, the defining parameters is the average growth rate. In the case of rehabilitation, it is the maximum estimated yield at the end of the harvest cycle as reported in the IPCC table. When data were presented as a range, the mean was used.

Table 7. restoration and rehabilitation input parameters for yearly rate estimates in tCO2eq.

	Restoration growth rate (tCO2eq)		Solver Estimated *Ymax* (t C/ha)	Rehabilitation *Ymax* (tCO2eq)	
Mosaic	< 20 yrs	> 20 yrs		Silvopasture	Agroforestry
Caribe	6.90	1.72	162.15		
Amazon	18.97	5.35	239.16		
Orinoquia	18.97	5.35	239.16		
Andes	5.61	1.55	137.82	100.39	82.80

It is expected that restoration areas will sequester an estimated 214,438 tCO2eq and 2,550,458 tCO2eq after 10 and 30 years respectively, while rehabilitation areas are expected to sequester 318,253.t CO2eq and 1,327,533 tCO2eq from Silvopasture and 222,428 tCO2eq and 1,035,261 tCO2eq from Agroforestry over the same time frames. Overall removal estimates correspond to **755,119 tCO2eq** and **4,913,252 tCO2eq** for both restoration and rehabilitation after 10 and 30 years (tables 7- 9).

In both cases (Restoration and rehabilitation) estimates assume the biomass content upon initiating the process is equal to zero (0) tCO2eq/ha.

Estimated removals were estimated following equations 10 and 9 in Annex 22c.

[24] Bernal et al 2018. Global carbon dioxide removal rates from forest landscape restoration activities. Carbon Balance and Management https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-018-0110-8
[25] Richards FJ. A flexible growth function for empirical use. J Exp Bot. 1959;10(2):290–301. https://doi.org/10.1093/jxb/10.2.290
[26] Pienaar LV, Turnbull KJ. The Chapman-Richards generalization of Von Bertalanffy's growth model for basal area growth and yield in even-aged stands. For Sci. 1973;19(1):2–22. https://doi.org/10.1093/jxb/10.2.290

Table 8. Restoration mitigation impacts estimates (tCO2eq)

Estimated Mitigation Impacts	Restoration Area (ha)	Restoration Removals (tCO2eq/5yrs)	Restoration Removals (tCO2eq/10 yrs)	Restoration Removals (tCO2eq/30 yrs)
Caribe	4,169	5,213.68	64,144.60	740,589.79
Andes	1,134	1,248.04	15,272.74	176,531.40
Orinoquia	856	1,624.14	19,895.67	239,962.06
Amazonas	5,128	9,338.36	115,124.57	1,393,374.36
Total	11,287	17,424.22	214,437.58	2,550,457.61

Table 8. Silvopasture mitigation impacts (tCO2eq)

Estimated Mitigation Impacts	Silvopasture Area (ha)	Restoration Removals (tCO2eq/5yrs)	Restoration Removals (tCO2eq/10 yrs)	Restoration Removals (tCO2eq/30 yrs)
Caribe	990	5,581.31	63,181.42	263,549.14
Andes	448	2,524.96	28,582.96	119,228.33
Orinoquia	438	2,470.88	27,970.82	116,674.89
Amazonas	3112	17,536.67	198,518.27	828,080.71
Total	4988	28,113.81	318,253.47	1,327,533.05

Table 9. Agroforestry mitigation impacts (tCO2eq)

Estimated Mitigation Impacts	Silvopasture Area (ha)	Restoration Removals (tCO2eq/5yrs)	Restoration Removals (tCO2eq/10 yrs)	Restoration Removals (tCO2eq/30 yrs)
Caribe	1,992	9,579.09	106,013.60	493,425.30
Andes	155	746.99	8,267.04	38,477.76
Orinoquia	188	902.10	9,983.69	46,467.67
Amazonas	1,844	17,536.67	98,164.00	456,890.47
Total	4,179	20,097.99	222,428.33	1,035,261.20

TABLE 4.9 ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS				
Domain	**Ecological zone**	**Continent**	**Above-ground biomass growth (tonnes d.m. ha^{-1} yr^{-1})**	**Reference**
Tropical	Tropical rain forest	Africa (≤20 y)	10	IPCC, 2003
		Africa (>20 y)	3.1 (2.3-3.8)	IPCC, 2003
		North America	0.9-18	Clark *et al*., 2003 ; Hughes *et al*., 1999
		South America (≤20 y)	11	Feldpausch *et al*., 2004
		South America (>20 y)	3.1 (1.5-5.5)	Malhi *et al*., 2004
		Asia (continental ≤20 y)	7.0 (3.0-11.0)	IPCC, 2003
		Asia (continental >20 y)	2.2 (1.3-3.0)	IPCC, 2003
		Asia (insular ≤20 y)	13	IPCC, 2003
		Asia (insular >20 y)	3.4	IPCC, 2003
	Tropical moist deciduous forest	Africa (≤20 y)	5	Harmand *et al*., 2004
		Africa (>20 y)	1.3	IPCC, 2003
		North and South America (≤20 y)	7.0	IPCC, 2003
		North and South America (>20 y)	2.0	IPCC, 2003
		Asia (continental ≤20 y)	9.0	IPCC, 2003
		Asia (continental >20 y)	2.0	IPCC, 2003
		Asia (insular ≤20 y)	11	IPCC, 2003
		Asia (insular >20 y)	3.0	IPCC, 2003
	Tropical dry forest	Africa (≤20 y)	2.4 (2.3-2.5)	IPCC, 2003
		Africa (>20 y)	1.8 (0.6-3.0)	IPCC, 2003
		North and South America (≤20 y)	4.0	IPCC, 2003
		North and South America (>20 y)	1.0	IPCC, 2003
		Asia (continental ≤20 y)	6.0	IPCC, 2003
		Asia (continental >20 y)	1.5	IPCC, 2003
		Asia (insular ≤20 y)	7.0	IPCC, 2003
		Asia (insular >20 y)	2.0	IPCC, 2003
	Tropical shrubland	Africa (≤20 y)	0.2-0.7	Nygård *et al*., 2004
		Africa (>20 y)	0.9 (0.2-1.6)	IPCC, 2003
		North and South America (≤20 y)	4.0	IPCC, 2003
		North and South America (>20 y)	1.0	IPCC, 2003
		Asia (continental ≤20 y)	5.0	IPCC, 2003
		Asia (continental >20 y)	1.3 (1.0-2.2)	IPCC, 2003
		Asia (insular ≤20 y)	2.0	IPCC, 2003
		Asia (insular >20 y)	1.0	IPCC, 2003
	Tropical mountain systems	Africa (≤20 y)	2.0-5.0	IPCC, 2003
		Africa (>20 y)	1.0-1.5	IPCC, 2003
		North and South America (≤20 y)	1.8-5.0	IPCC, 2003
		North and South America (>20 y)	0.4-1.4	IPCC, 2003
		Asia (continental ≤20 y)	1.0-5.0	IPCC, 2003
		Asia (continental >20 y)	0.5-1.0	IPCC, 2003
		Asia (insular ≤20 y)	3.0-12	IPCC, 2003
		Asia (insular >20 y)	1.0-3.0	IPCC, 2003
Subtropical	Subtropical humid forest	North and South America (≤20 y)	7.0	IPCC, 2003
		North and South America (>20 y)	2.0	IPCC, 2003
		Asia (continental ≤20 y)	9.0	IPCC, 2003
		Asia (continental >20 y)	2.0	IPCC, 2003
		Asia (insular ≤20 y)	11	IPCC, 2003
		Asia (insular >20 y)	3.0	IPCC, 2003
	Subtropical dry forest	Africa (≤20 y)	2.4 (2.3-2.5)	IPCC, 2003
		Africa (>20 y)	1.8 (0.6-3.0)	IPCC, 2003
		North and South America (≤20 y)	4.0	IPCC, 2003

TABLE 5.1 (UPDATED[1]) DEFAULT COEFFICIENTS FOR ABOVE-GROUND BIOMASS AND HARVEST/MATURITY CYCLES IN AGROFORESTRY SYSTEMS CONTAINING PERENNIAL SPECIES[2]							
Climate Region	Agroforestry system[3]	N	Tree density (Stems ha^{-1})	Maximum above-ground biomass carbon stock at harvest *** L_{max} (tonnes C ha^{-1})	Harvest /Maturity cycle** (yr)	Biomass accumulation rate (G)* (tonnes C ha^{-1} yr^{-1})	Mean biomass carbon loss *** (L_{mean}) (tonnes C ha^{-1} yr^{-1})
Tropical	Fallow	69	6074	22.1 ± 52%	5 ± 50%	4.42 ± 15%	11.1 ± 26%
	Hedgerow[4]	3	1481	9.4 ± 59%	20 ± 50%	0.47 ± 31%	4.7 ± 29%
	Alley cropping	90	8568	47.4 ± 52%	20 ± 50%	2.37 ± 13%	23.7 ± 26%
	Multistrata	51	929	65.0 ± 54%	20 ± 50%	3.25 ± 21%	32.5 ± 27%
	Parkland	7	152	11.8 ± 76%	20 ± 50%	0.59 ± 58%	5.9 ± 38%
	Shaded Perennial	28	4236	48.0 ± 55%	20 ± 50%	2.4 ± 24%	24.0 ± 28%
	Silvoarable	22	880	72.2 ± 60%	20 ± 50%	3.61± 33%	36.1 ± 30%
	Silvopasture	18	1609	58.2 ± 80%	20 ± 50%	2.91 ± 63%	29.1 ± 40%
Temperate	Hedgerow[4]	12	816	26.1 ± 59%	30 ± 33%	0.87 ± 49%	13.1 ± 29%
	Silvoarable	14	202	27.3 ± 62%	30 ± 33%	0.91 ± 52%	13.7 ± 31%
	Silvopasture	10	854	69.9 ± 61%	30 ± 33%	2.33 ± 52%	35.0 ± 31%

*Source: biomass carbon accumulation rate, G, from Cardinael *et al* (2018). Uncertainty = 95% CI.

** Harvest/Maturity cycle and uncertainty are nominal estimates.

*** calculated (L_{max} = G * Maturity cycle; Lmean = L_{max}/2)

[1] Replaces Table 5.1 from the *2006 IPCC Guidelines*

[2] See Table 5.3 for monocultures

[3] See Table 5.4 for agroforestry system definitions

[4] Biomass storage rates and tree density for hedgerows are presented per kilometer of hedgerows, not per hectare of agricultural field or per hectare of hedgerow

4. Total Mitigation Impact

The project is expected to deliver and preserve an overall total estimated mitigation of 20.25 million tCO2eq by year 10 and 79.8 million tCO2eq by year 30. These consider the total sink estimates by all preserved standing forests. Mitigation estimates that can be deemed additional (not possible without the project) and considering only the preserved sink of avoided deforested areas, correspond to 8.997 million tCO2eq by year 10 and 46.28 million by year 30 (Annex 22b and Figure 9). Table 6 presents the estimates per mosaic with their proportional contribution to overall additional mitigation impact estimates by year 30. The percentage color scheme highlights the percent contribution level of intervention in each area, with yellow depicting lower contributions, orange intermediate and red for major contributions (conditional formatting based on min-max values with percentile mid-point). It becomes apparent that most mitigation impact will come from avoided emissions in the Heart of the Amazon mosaic, with 71% of the overall estimated impact, particularly inside recent expansion of Chiribiquete National park. The role of expansion of the new protected area of San Lucas is a key action to avoid deforestation and reduce emission in 9 Mt CO2e representing 19.3% of overall estimated impact.

Table 10. Overall mitigation impact estimates with percent contribution of overall programmatic targets.

Estimated Mitigation Impacts	Total Climate Mitigation (tCO2eq/5 yrs)	Total Climate Mitigation (tCO2eq/10 yrs)	Total Climate Mitigation (tCO2eq/30 yrs)	Total Additional Climate Mitigation (tCO2eq/5 yrs)	Total Additional Climate Mitigation (tCO2eq/10 yrs)	Total Additional Climate Mitigation (tCO2eq/30 yrs)	% of total estimated additional Mitigation impact
Caribe	388,181.25	1,055,881.9	4,970,610	90,883	463,282	3,216,768	6.95%
Andes	111,532.18	276,694.1	1,096,379	19,045	91,953	544,947	1.18%
Orinoquia	96,677.51	245,447.4	1,009,280	22,698	97,619	567,347	1.23%
Amazonas	7,448,079.0	16,230,306.1	61,435,043	2,648,698	6,646,463	32,862,549	71.01%
San Lucas	953,394.68	2,680,916.3	11,631,572	514,912	1,809,847	9,089,119	19.64%
Overall totals	8,997,865	20,489,246	80,142,884	3,296,236	9,109,164	46,280,730	100.00%

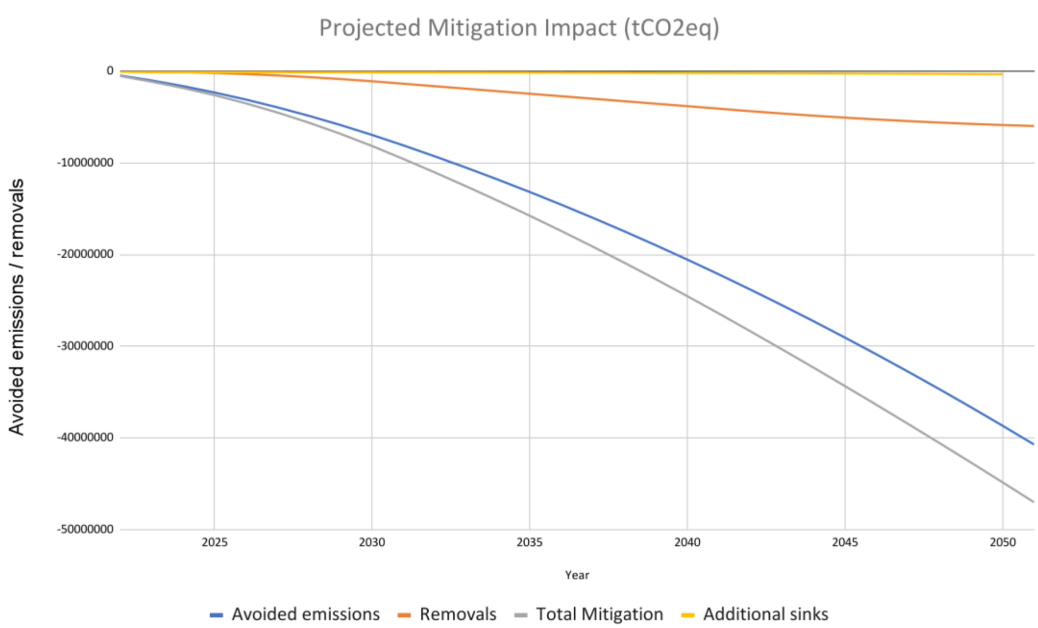

Figure 9. Estimated Mitigation impact for avoided emissions from deforestation, removals from restoration and rehabilitation and additional preserved sink from avoided deforestation.

As in the case of the FREL submission in 2020, it is assumed overall baseline estimates uncertainties are at 20.4% (see)

FREL Reported Uncertainties to Historic Emissions	Above Ground Biomass		Below Ground Biomass		Soil Biomass			Total EF	AD x EF Uncertainty
	AGB (TC/ha)	CVE	BGB (T C/ha)	CVE	COSf20 (TC/ha)	COS (TC/ha/20 AÑOS)	CVE COSf20 (TC/ha)	tCO2e/ha	
Nacional	-	-	-	-		-	-	-	**20.40%**

Amazonia	121.2	2.10%	27.0	20.00%	73.8	3.7	6.00%	**557**	**18.20%**
Andes	72.2	6.00%	16.6	5.60%	124.6	6.2	16.00%	**349**	**20.80%**
Caribe	61.2	9.70%	14.1	8.90%	101.3	5.1	20.00%	**295**	**24.60%**
Orinoquía	40.2	11.40 %	9.7	10.20%	64.5	3.2	13.00%	**196**	**26.50%**
Pacífico	65.9	8.80%	15.2	8.10%	92.5	4.6	11.00%	**313**	**23.60%**

5. Monitoring, Reporting and Verification (MRV)

Patrimonio Natural will lead overarching programmatic reporting. Patrimonio in coordination with IDEAM will coordinate the MRV process, including the implementing partners of this Project (research institutes, national park systems and regional environmental authorities) who will validate and/or collect the data in the field and submit it as part of the participatory process with technical leads for each participating institution. The PMRV team will submit that information to a central, official IDEAM platform located in Bogota, and will develop a report of the performance of the Project based on that information, as a component of the broader HECO program.

The project will produce and use for reporting, locally derived data to replace and/or complement the default values and assumptions used in the ex-ante estimation of potential impact. As such, activity data and removal factors will be tailored to the specific circumstances in each one of the mosaics. Particularly as these relate to emissions removals (in the case of removal rates).. Basic aspects such as forest definition to be used, stratification, minimum mapping unit, pools and gases reporting will be aligned with what is included in the 2021 FREL.

5.1. Avoided emissions

Reduced emissions from deforestation will be monitored following the same methods used for FREL Setting in conjunction with those used for the Biennial Update Reports (BUR) Colombia will be presenting to the UNFCCC. Colombia produces and communicates annually to fulfill its commitments under bi and multilateral agreements as well as to the general public. Activity data will be derived from those used for annual reporting and BUR as well as for any performance based mechanism program Colombia is reporting to. Emissions factors will remain the same as well as the approaches used to estimation of uncertainties.

Avoided emissions will be the result of the difference between the FREL reported here and the observed performance for each year. Reductions estimates will be presented in total and partially as each area makes progress towards its intended intermediate and final targets.

5.2. Emissions Removals from Restoration Rehabilitation and Mature forests Sinks.

Emissions removals will be assessed establishing permanent plots following a statistical design that will contribute to generate unbiased estimates as required per IPCC 2006 guidelines. The specific methods will combine and complement the approach used for the National Forest Inventory (NFI) as well as other relevant guidance from e.g. CDM AR-AM0002 and GFOI Methods and Guidance V.3.0.

This approach should guarantee consistency with and complementarity to the NFI as it should help Colombia inform the future inclusion of removals in its FREL scope of activities and removal factors while it should inform the specific estimated removals under this project. The stratification will be based on the same strata used for the FREL in combination with the specific implementation measures: restoration and rehabilitation. In the case of restoration, initial biomass will be assessed to better inform net emissions removals estimates.

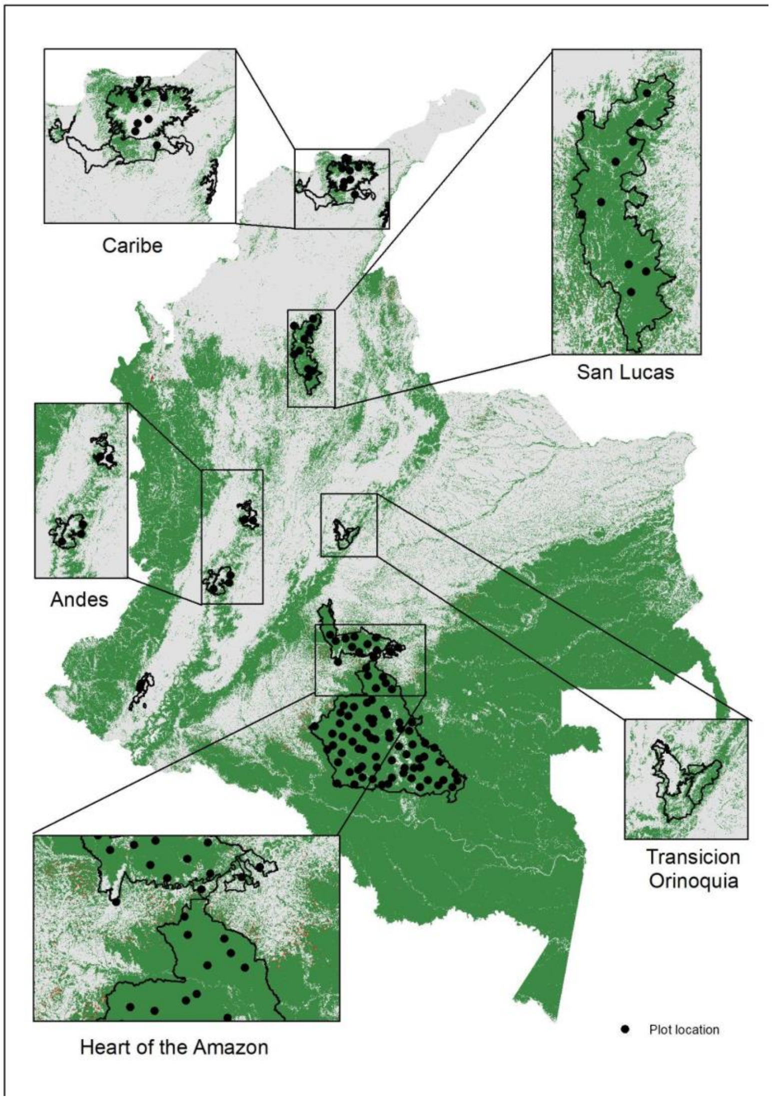

Figure 10. National Forest Monitoring cluster planned for the Mosaic areas. The project will complement ongoing efforts to establish a subset of these.

Activity data will be produced from a combination of methods used per [Colombia's National Forest Cover and Carbon Monitoring System] and locally generated data with on the ground methods for with local partners will contribute to the participatory monitoring process. It is intended that both: national and local monitoring efforts will be coordinated so they cross validate and complement each other. Plot data is also intended to be collected by the local teams.

In the case of mature forests sinks, plots will me assessed periodically as to generate the necessary baseline and trend data to keep track of how forests sinks is evolving under the pressures of climate change itself as it has been documented by recent literature (e.g. Hubau *et al.* 2020, Xu *et al.* 2021). The plots will generate local data that will be used both at local and national levels.

All mitigation impacts estimates will be reported to the National Registry of Emissions Reductions (RENARE). This will guarantee the transparency of the estimates and their complementarity towards the NDC. This will establish the level of contribution by HECO towards Colombia's mitigation commitments to 2030.

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