Mangroves for climate: Public, private and community partnerships for mitigation and adaptation in Ecuador

Annex 22: Greenhouse Gas Emissions Estimates

Contents

Figures and Tables

Introduction

Mangroves are one of the most productive ecosystems per unit area in the world. As mangrove trees grow, they remove carbon from the atmosphere and water column, as well as trap organic debris in their root structures. Organic carbon is then stored in their woody biomass (tree trunks, branches and roots) and also accumulates in mangrove soils. The saline nature of their environment inhibits breakdown of organic material, meaning that the carbon – sometimes referred to as “blue carbon” – can be locked away for millennia.

GCF requires the AE to “apply available and credible GHG methodologies and provide sufficient information on the results of such calculations and underlying assumptions,” among these are included voluntary standards, CDM methodologies and 2006/2013 IPCC Guidelines for National Greenhouse Gas Inventories. This report explains the method used for calculating GHG emissions for the project in accordance with GCF’s requirements and the sources of data used. The report also summarizes the key results of GHG emissions calculations. The information on methods is also relevant for planned monitoring of the project’s GHG emissions reductions (see also the project’s Monitoring and Evaluation Plan).

Project baseline and Business as Usual GHG emissions

The methods of the project for design, measurement, reporting and verification (MRV) of reduced GHG emissions from deforestation is consistent with the Government of Ecuador´s Forest Reference Emissions Level (FREL) submitted to the UNFCCC in January 2020 (Ministerio del Ambiente del Ecuador, 2020).

Ecuador´s FREL follows approaches established in the Intergovernmental Panel on Climate Change´s 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

The overall framework of Ecuador´s FREL guides project design and MRV, with certain modifications for the scale, scope and nature of project activities, as noted below.

<u>Area</u>

The area covered in Ecuador's FREL consists of 100% of its continental territory (approximately 24,898,059.9 hectares) and excludes the Galapagos Islands, and certain other smaller islands.

- *Project application and adjustment**:*** Area for project design and MRV for reducing gross deforestation is defined as areas of mangrove forest in 2018 within target jurisdictions (cantons and parishes and national protected areas). Areas for project design and MRV for afforestation and reforestation are those where project activities lead directly to mangrove reforestation.

<u>Forest definition</u>

Land units bearing "a single minimum tree crown cover value of 30%; a single minimum land area value of 1 hectare; and, a single minimum tree height value of 5.00 meters" are considered as forests. This definition is consistent with Ecuadorian government official policy (Acuerdo Ministerial 116 of 7 November 2016 (MAE, 2016)) and is the same definition used in Ecuador's national GHG Inventory as reported to the UNFCCC.

- *Project application and adjustment:* Project design and MRV employs the same definition of forest as the FREL and national GHG inventories.

<u>Activities</u>

Ecuador's FREL includes only gross deforestation. Gross deforestation is defined as a process of conversion of the forest into another land use/land cover; below the thresholds of height, canopy cover or area established in the definition of forest, without considering areas of regeneration during the same period.

- *Project application and adjustment:* Project design and MRV employs the same definition of gross deforestation. In addition, the project accounts for net sequestration from reforestation activities directly attributable to project investments.

<u>Baseline deforestation (historical reference period)</u>

Ecuador's FREL is based on activity data for the period 2000-2014 and defines the reference emissions level as the annual average of emissions for deforestation during that period. Ecuador's FREL for this period was presented to the UNFCCC in January, 2020.

Project application and adjustment: Project design and MRV uses a similar approach but is based on a historical period of 2008-2018, including data from more recent years that better represents current, and likely future, deforestation and land-use dynamics. The use of this more recent reference period is conservative, given the net increase in mangrove area reported since 2006. The use of shorter, more recent baseline periods is also in line with emerging guidance and best practice from voluntary carbon standards.

Emissions factors

Activity data in the FREL is stratified by 9 forest types, including mangroves. Gross deforestation for each of these forest types is multiplied by emissions factors to determine emissions during the baseline period. Emissions factors were calculated following 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Emissions factors include aboveground and belowground biomass and assume that in each period post-deforestation carbon stocks are equivalent to 0. Carbon stocks for 9 forest strata were based on Ecuador's national forest inventory (ENF). The ENF has reported carbon stock estimates on 4 forest carbon pools: Aboveground biomass (AGB); Belowground biomass (BGB); Litter (L); Deadwood (DW) - including the following components: standing dead wood (DW.S); lying dead wood (DW.L); and dead coarse roots (DW.R). The underlying field measurements were made between 2011 and 2014 and are therefore recent enough to be used for estimating emission factors in the construction of Ecuador´s proposed FREL for deforestation. Ecuador´s FREL does not incorporate results of carbon stock measurements for the Soil Organic Carbon (SOC) pool. FREL values for these pools are summarized in Table 1.

Table 1. Mangrove carbon stocks for pools included in Ecuador FREL (2020), in tCO2eq/ha

Pool	tCO2eq/ha
Aboveground biomass (arboreal) - AGB.A	183.77
Aboveground biomass (non-arboreal) - AGB.NA	70.33
Belowground biomass (arboreal) - BGB.A	44.11
Belowground biomass (non-arboreal) - BGB.NA	16.88
Standing dead wood - DW.S	3.41
Lying dead wood -DW.L	14.52
Dead coarse roots -DW.R	1.5
-	
Total	**334.52**

***Project application and adjustment**:* Project design and MRV employs the emissions factor of Ecuador´s FREL for biomass, deadwood and litter. The project also incorporates emissions and reductions in Soil Organic Matter which is particularly important for mangroves. The soil pool in terrestrial forests is dry with high availability of oxygen, thus allowing microbial breakdown of organic matter that is released back into the atmosphere.

This means the soil carbon stock in terrestrial forests fluctuates widely and does not have the opportunity to accumulate much deeper than 30 cm. Given the heterogenous nature of terrestrial forest carbon, the expense in measuring the soil carbon compared to the size of the pool, the soil carbon component is skipped in many carbon accounting methods.

However, in coastal marine systems, like mangroves, where the soil is inundated with salt and brackish water regularly through tides and flooding, the soil is saturated with water keeping it in an anaerobic state (low to no oxygen) prohibiting microbial breakdown of organic matter making the soil pool extremely high in organic carbon content. On average, 40-60% of the organic carbon in a hectare of mangrove ecosystem is found in the soil pool. In addition, because organic matter doesn't break down, the soil pool continuously accretes resulting in high rates of continuous build-up of carbon over time and long-term storage of the carbon for decades to millennia. If the soil is ever drained or dredged (i.e., for land conversion to fish ponds or agriculture) and allowed to dry, microbial action restarts and all of the carbon stored can be released to the atmosphere, turning a significant carbon sink into a significant carbon source.

Therefore, the soil in coastal marine ecosystems like mangrove is a significant carbon pool and needs to be included in order to determine the true cost of land-conversion and the accurate benefit of conservation and restoration activities.

To accurately quantify the soil carbon pool see the Coastal Blue Carbon Manual (Howard et al., 2014)[1] but briefly, soil cores must be collected, subsampled, and analyzed for a specific depth (usually 1 m). Three parameters must be quantified for each field plot, sub-plot, and/or coring site to estimate the soil carbon pool:

1) Soil depth;

2) Dry bulk density; and

3) Soil organic carbon content (%Corg)

Soil depth is determined with a soil depth probe or during the coring and sampling process. The dry bulk density and %Corg of soil are used to calculate carbon density. Because soil bulk density and %Corg vary with depth and location, there is not always a consistent pattern of carbon density with depth. Consequently, it is essential that an adequate number of soil cores (1 per plot, at least 3 plots per stratum) are collected and studied for a three-dimensional assessment of the carbon stock in each stratum.

Soil carbon is measured using a simple modified PVC pipe or special soil augur to extract a soil core down to 1 meter. Soil samples are taken at intervals down core, stored at 4°C or frozen and analyzed within 24 hours of collection to minimize decomposition of organic matter and microbial growth. Samples are transported to a lab where carbon content is measured. Ideally each sample would be homogenized, inorganic carbon removed, and run on a CHN Analyzer (Carbon, Hydrogen, Nitrogen Analyzer). CHN analysis is more accurate but requires special equipment and is more expensive. As an alternative it may be decided to analyze all samples using a "loss on ignition" technique which is easier and cheaper to do but is semi-quantitative and relies on empirically determined relationships between carbon content and organic matter. In this case all samples would be analyzed using loss on ignition but a subsample of soil samples will be run on a CHN analyzer and a correction factor determined and applied to all samples.

[1] https://www.thebluecarboninitiative.org/manual

Once carbon content of the soil samples is determined, that information can be extrapolated for the entire plot and stratum (specific calculation methods can be found in the Blue Carbon Field Guide and are compatible with IPCC recommendations and other international standard (i.e., VCS) requirements.

Assumptions for GHG calculations

The following assumptions were used for the GHG emissions reductions calculations:

- Assumed project start date: Jan 2024 (However, note that the start date does not affect expected project GHG emissions reductions under the assumptions used)
- Assumed project lifespan: 20 years
- 2018 mangrove coverage of 156,633 hectares
- Annual gain of mangrove coverage of 1516 hectares (i.e. assumed average 2008-2018 trend) continues in both the 'with' and 'without' project scenario.
- Annual loss of mangrove coverage of 990 hectares (i.e assumed average of 2008-2018 trend) continues in the 'without' project scenario
- The parameters for carbon stock, sequestration and emissions from deforestation and drainage of mangroves are based on country specific data from Ecuador's FREL and IPCC guidance on calculating GHG emissions in coastal wetlands published in the 'Wetlands Supplement' (IPCC, 2014), as indicated in Table 2.

Table 2. Default parameters for carbon stocks, sequestration and emissions from deforestation and mangrove drainage

	tC/ha	tCO_2eq/ha	Assumptions and Sources
Carbon Stocks			
a. Aboveground and belowground biomass	91.2	334.5	Ecuador FREL (2020)
b. Soil Carbon, top meter	386	1415.3	IPCC Wetlands Supplement (2014)
Total	477.2	1749.9	
Sequestration			
c. Soil (per year)	1.62	5.9	Assumes a 5-year lag and then ongoing sequestration in the soil. From IPCC Wetlands Supplement
d. Biomass (per year)	4.56	16.7	Derived from the FREL. 91.2 tC/ha in biomass at maturity; 20 years to reach maturity
Emissions from deforestation and drainage			
e. Biomass and soil (Year 1)	110.52	405.3	Derived from a and b above. Following the

f. Biomass and soil (Year 2 to 20)	7.9	29.0	IPCC Wetlands Supplement, assume all emissions from biomass are lost in year 1 and all emissions from soil are done by year 20.

These data demonstrate the importance of maintaining mangrove forest cover and how restoring mangroves does not completely compensate for lost mangrove even over long time periods. For example, over 20 years (assumed time for mangrove to reach full biomass) the carbon sequestered by newly planted hectares will average 423tCO_2e (see Table 3) whereas the emissions from a hectare of lost mangrove over a 20 year period will be 914tCO_2e (see Table 4) due to the emissions from soils. Carbon sequestration will continue beyond the 20-year period but under the assumptions used in this model it will take over 100 years for a hectare of restored mangrove to mitigate for GHG emissions associated with the loss of a single hectare of existing mangrove.

Table 3. Carbon sequestered in restored areas of mangrove forests

	tC per hectare per year	**tCO2e per hectare per year**
Biomass	4.56	16.72
Soils	1.62	5.94
Total	6.18	22.66
Total over 20 years		**423.5**

Table 4. Emissions from loss of mangrove

	tC per hectare per year	**tCO2 eq per hectare**
Mangrove biomass	91.2	334.52 (in year 1 only)
Mangrove soils	7.90	28.97 per year (for 20 years)
Total over 20 years		**913.91**

Results

Baseline and the project scenario

Under the project baseline, mangrove loss continues at a rate of 990ha per year resulting in net emissions of 11,062,246 tCO2e over a 20-year period (the assumed lifetime of the project) and 2,428,986 tCO2e over the 6-year project implementation period. Under the proposed project scenario, mangrove loss is reduced by 250 ha per year and mangrove restoration of 4850 ha occurs, resulting in emissions of 6,452,776 tCO2e over a 20-year period and 1,696,875 tCO2e over the 6-year project implementation period. Therefore, the net emissions reductions due to the project are estimated at 4,609,470 tCO2e over a 20-year period and 732,111 tCO2e over the 6-year implementation period (Table 5).

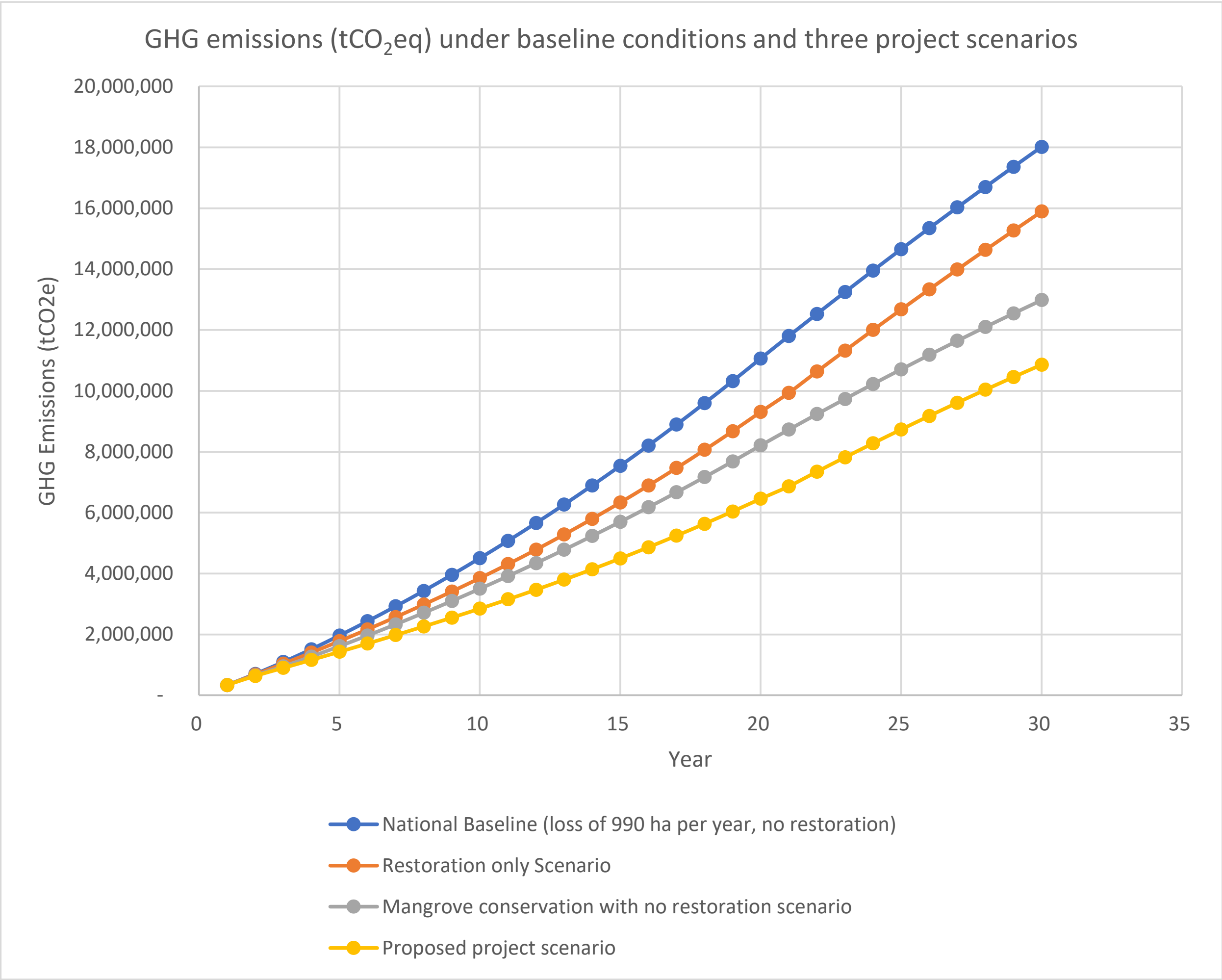
Two alternative project scenarios were considered: a scenario under which only the restoration activities of the proposed project were undertaken (4,850 ha restored), and a scenario under which only the mangrove protection activities were undertaken (reducing deforestation by 250 ha annually). The results for these scenarios are presented in Table 5 and show that these alternative project designs would achieve intermediate results. A restoration only project would result in an estimated 9,308,357 tCO2e over a 20-year period (2,163,9508 tCO2e over the 6-year project implementation period). A project focused only on the mangrove conservation activities would result in an estimated 8,206,666 tCO2e over a 20-year period and 1,961,912 tCO2e over the 6-year implementation period.

Figure 1, based the data provided in Table 5, shows how GHG emissions are projected to vary over the 20-year lifetime of the project.

Table 5. Estimates of annual GHG emissions under the baseline and three potential project scenarios

Year of project	National Baseline (loss of 990 ha per year, no restoration)	Restoration only Scenario	Mangrove conservation with no restoration scenario	Proposed project scenario
1	334,612	334,612	334,612	334,612
2	697,911	679,518	652,439	634,045
3	1,089,899	1,034,718	949,894	894,713
4	1,510,575	1,400,213	1,268,792	1,158,430
5	1,959,940	1,776,003	1,609,134	1,425,197
6	2,428,986	2,163,950	1,961,912	1,696,875
7	2,917,715	2,565,045	2,327,126	1,974,456
8	3,426,125	2,979,286	2,704,778	2,257,939
9	3,954,217	3,406,676	3,094,866	2,547,324
10	4,501,992	3,847,212	3,497,391	2,842,612
11	5,069,448	4,304,758	3,912,353	3,147,663
12	5,656,587	4,781,985	4,339,752	3,465,150
13	6,263,407	5,278,895	4,779,587	3,795,075
14	6,889,910	5,795,486	5,231,860	4,137,436
15	7,536,094	6,331,759	5,696,569	4,492,234
16	8,201,960	6,887,715	6,173,714	4,859,469
17	8,887,509	7,463,352	6,663,297	5,239,141
18	9,592,739	8,058,672	7,165,316	5,631,249
19	10,317,652	8,673,673	7,679,773	6,035,794
20	11,062,246	9,308,357	8,206,666	6,452,776
21	11,797,834	9,934,034	8,724,552	6,860,752
22	12,524,416	10,631,804	9,233,433	7,340,821
23	13,241,992	11,320,568	9,733,307	7,811,883
24	13,950,562	12,000,326	10,224,175	8,273,940
25	14,650,125	12,671,078	10,706,037	8,726,990
26	15,340,682	13,332,824	11,178,893	9,171,034
27	16,022,233	13,985,563	11,642,742	9,606,072
28	16,694,778	14,629,296	12,097,585	10,032,104
29	17,358,316	15,264,023	12,543,422	10,449,129
30	18,012,849	15,889,744	12,980,253	10,857,148

Figure 1. Graph of GHG emissions (tCO2e) under baseline conditions and three project scenarios



Contribution of each project component to reducing GHG emissions

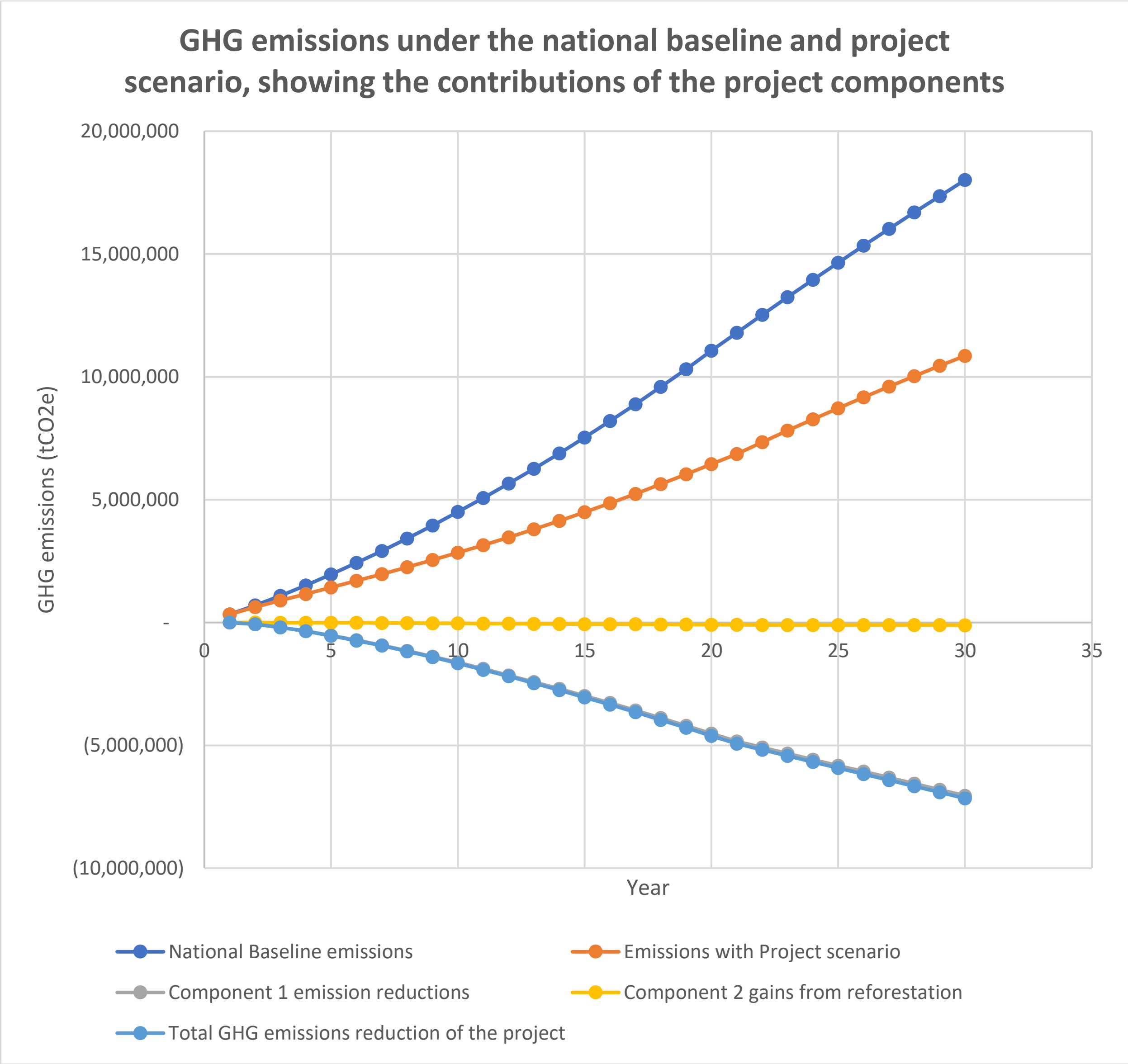
Table 6 and Figure 2 show how components 1 and 2 of the project contribute to achieving emissions reductions over time. Component 1, which includes public sector and community forest management activities to reduce loss of existing mangroves by 250 ha annually and restoration of 2000ha, is estimated to achieve 3,566,685 tCO_2e over 20 years and 567,404 tCO_2e over the 6-year project implementation period. Component 2, which includes private sector activities to restore 2850 ha, is estimated to achieve 1,042,785 tCO_2e over 20 years and 164,707 tCO_2e over 6 years.

The GHG reduction contributions of Component 3 are difficult to separate from the results of the other 2 components because Component 3 involves creating the enabling conditions for the continued protection of mangroves over the long term (estimated up to 20 years for the project). Hence the contributions of Component 3 are included in the figures provided in Table 6 and component 3 is particularly important for ensuring that GHG emissions reductions continue to be achieved after the end of the project implementation period.

Table 6. GHG emissions under the baseline and project scenarios, including calculations for the contributions of project components

·ar	National Baseline emissions	Emissions with Project scenario	Component 1 emission reductions	Component 2 gains from reforestation	Total GHG emissions reduction of the project
1	334,612	334,612	-	-	-
2	697,911	634,045	(63,030)	(836)	(63,866)
3	1,089,899	894,713	(192,678)	(2,508)	(195,186)
4	1,510,575	1,158,430	(347,129)	(5,016)	(352,145)
5	1,959,940	1,425,197	(526,382)	(8,361)	(534,743)
6	2,428,986	1,696,875	(719,570)	(12,541)	(732,111)
7	2,917,715	1,974,456	(926,240)	(17,019)	(943,258)
8	3,426,125	2,257,939	(1,146,393)	(21,793)	(1,168,186)
9	3,954,217	2,547,324	(1,380,029)	(26,864)	(1,406,893)
10	4,501,992	2,842,612	(1,627,147)	(32,233)	(1,659,380)
11	5,069,448	3,147,663	(1,883,887)	(37,898)	(1,921,786)
12	5,656,587	3,465,150	(2,147,872)	(43,564)	(2,191,436)
13	6,263,407	3,795,075	(2,419,103)	(49,229)	(2,468,332)
14	6,889,910	4,137,436	(2,697,578)	(54,895)	(2,752,473)
15	7,536,094	4,492,234	(2,983,299)	(60,561)	(3,043,860)
16	8,201,960	4,859,469	(3,276,265)	(66,226)	(3,342,491)
17	8,887,509	5,239,141	(3,576,477)	(71,892)	(3,648,368)
18	9,592,739	5,631,249	(3,883,933)	(77,557)	(3,961,490)
19	10,317,652	6,035,794	(4,198,635)	(83,223)	(4,281,857)
20	11,062,246	6,452,776	(4,520,582)	(88,888)	(4,609,470)
21	11,797,834	6,860,752	(4,842,529)	(94,554)	(4,937,082)
22	12,524,416	7,340,821	(5,087,557)	(96,039)	(5,183,596)
23	13,241,992	7,811,883	(5,332,585)	(97,524)	(5,430,109)
24	13,950,562	8,273,940	(5,577,613)	(99,009)	(5,676,622)
25	14,650,125	8,726,990	(5,822,641)	(100,494)	(5,923,135)
26	15,340,682	9,171,034	(6,067,669)	(101,979)	(6,169,648)
27	16,022,233	9,606,072	(6,312,697)	(103,464)	(6,416,161)
28	16,694,778	10,032,104	(6,557,725)	(104,950)	(6,662,674)
29	17,358,316	10,449,129	(6,802,753)	(106,435)	(6,909,187)
30	18,012,849	10,857,148	(7,047,781)	(107,920)	(7,155,700)

Figure 2. Graph showing GHG emissions under the national baseline and project scenario, highlighting the contributions of the project components



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