ASES ON-CHAIN PROTOCOL

BASELINE REPORT

Verified Carbon Credits (VCCs)

Manejo forestal en El Cuyo, Emiliano Zapata, Tabasco

BEL-001-MEX-04092023 EL CUYO, TABASCO, MÉXICO

Desarrollos Sostenibles BELMEX S.A. de C.V.

Type B Project

August 1, 2024

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On-Chain Protocol

TABLE OF CONTENTS

INDEX OF FIGURES

INDEX OF TABLES

Executive summary

The baseline report for plantation projects is an essential undertaking for their certification process. This step is vital as it lays the groundwork for determining the initial metrics of biomass production and subsequent carbon sequestration in each project. The report will encompass the computation of NDVI and biomass indices, both derived through a specific methodology utilizing satellite imagery and high-resolution ortho mosaics.

The ecological restoration of a forested area in El Cuyo, Tabasco, Mexico entails planting a total of 172,562 trees, representing five (5) distinct species mainly native to the region and well-suited for adverse environmental conditions. As of February 2024, 68,063 individuals of three (3) species have been planted. By March 2024, two (2) additional species were planted, bringing the total number of trees planted to 71,895. This number of trees will be used for the present analysis. The primary objective of this initiative was to enhance biodiversity, improve soil quality, water infiltration, and create opportunities for environmental education. The project area, situated within the Emiliano Zapata municipality, covers 575,160 m².

The moderate-density technique was employed, providing numerous benefits such as improved yield and efficient resource utilization. The average planting density within the plot was one tree per 8 m², equivalent to an average of 1,250 trees per hectare in the plot.

The total CO_2 capture for the entire project area was calculated to be between 3,361.89 and 21,233.75 TCO_2-eq considering survival scenarios of 20% and 100% respectively at the end of the 40 years of the project's lifetime. These figures underscore the project's significant contribution to carbon sequestration and overall environmental restoration.

The successful reforestation endeavor in El Cuyo demonstrates the positive impact of employing dense planting techniques and strategically selecting native species to reclaim and revitalize degraded landscapes, providing ecological, economic, and social benefits for the region and its communities.

I. Project Design

This section is based on the information compiled in the PSF Format - Project Submission Form prepared by the project developer.

I.1. Project Location

The project is located in the Emiliano Zapata municipality, in the province of Tabasco (Mexico). The afforested plot lies close to adjoining Agricultural and Pasture areas. A project location map is illustrated in Figure 1. Table 1 shows the coordinates of the reforested Plots.

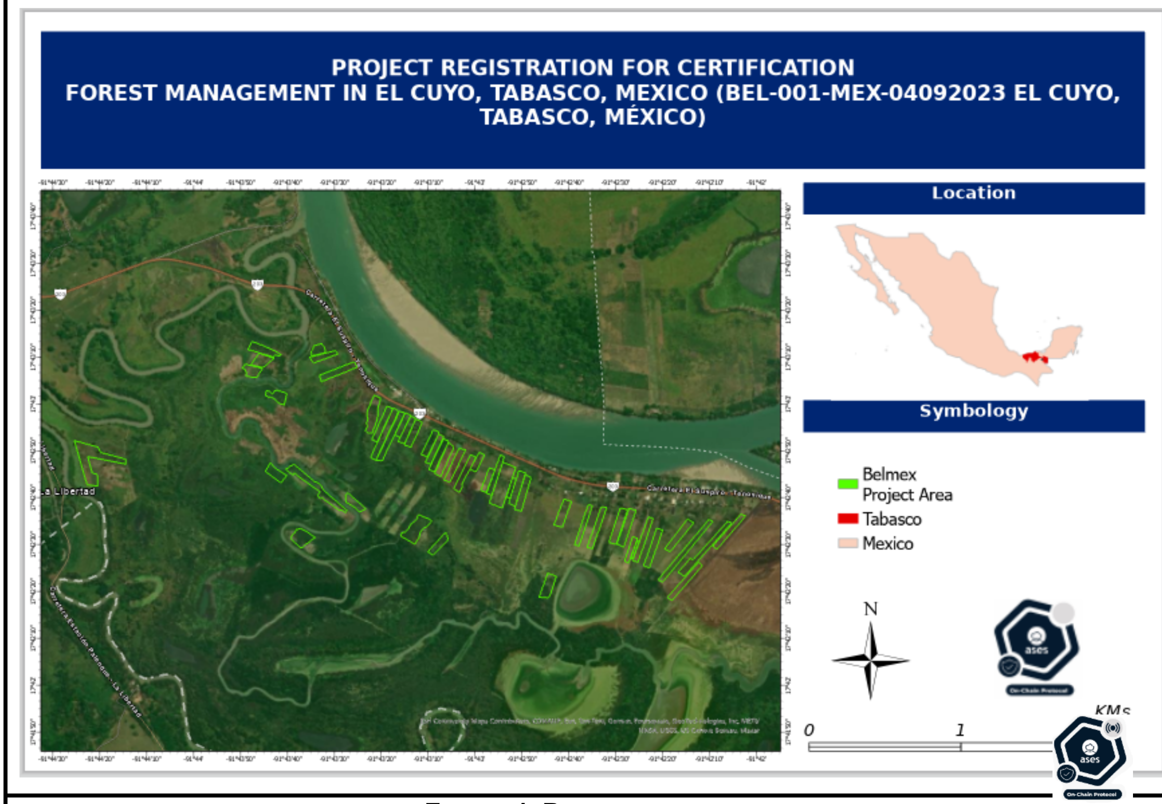

Figure 1. Project location

Table 1. Location of Project plot

Plot	Coordinates	
	Latitude	Longitude
1	17.715194°N	91.721464°W

I.2. ADMINISTRATIVE SPECIFICATIONS

This section introduces the project developer and provides a clear understanding of the roles and responsibilities assigned to each party involved. It also addresses the status of land ownership, ensuring transparency and certainty regarding the agreements made with the landowners.

I.2.1. PROJECT DEVELOPER

Key project	BEL-001-MEX-04092023 EL CUYO, TABASCO, MÉXICO
Title of the project activity	Forest Management in El Cuyo, Emiliano Zapata (Mexico)
Company	Desarrollos Sostenibles BELMEX S.A. de C.V
Person responsible	Carlos Sandoval Miranda
Fiscal address	Calle Laguna de Términos 221, Torre A Of-09 piso 15, Col. Granada Miguel Hidalgo, Ciudad de México 11520 Mexico
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I.2.2. TYPE OF PROJECT

Type	☒ Forest management ☐ Regenerative agriculture ☐ Silvopastoral management ☐ Individual tree-based climate action / urban forest ☐ Water flow restoration ☐ Biochar

I.2.3. VNPCS THE PROJECT IS APPLYING TO

Type of VNPCs the project is applying for	☒ Carbon Removals (VCRm) ☐ Carbon Removals (VCRd) ☒ Biodiversity Based Credit (VBBC) ☐ Water Credits (VWC) ☐ Soil Credits (VSC) ☐ Climate action bond

II. PROJECT AREA BASELINE

According to the North American Land Cover (Landsat: 30 m resolution) mapping, the project area falls within cropland in the Emiliano Zapata municipality, Mexico. The site is located alongside a river, and the surrounding area is composed of cropland used for agriculture and rangeland for livestock. To further ascertain the project's potential contributions to biodiversity, a survey was conducted to count and identify the plant species present in the vicinity of the project area. This will be further elaborated in the biodiversity section of the baseline report.

II.1. SPECTRAL RESPONSE

When solar radiation interacts with an object, one of three situations can occur, either individually or in combination:

- Reflection: The radiation can bounce off the object partially or entirely, resulting in reflection.
- Absorption: The object can absorb the radiation, taking in its energy.
- Transmission: Radiation can pass through one object and reach another, known as transmission.

The extent to which radiation is reflected, absorbed, or transmitted depends on the specific physicochemical characteristics of the objects involved. However, for object identification purposes, our primary interest lies in the reflected light or radiation at different wavelengths. For instance, vegetation exhibits low reflectance in the visible range, but the presence of chlorophyll in plants increases reflectance in the green channel. On the other hand, plants demonstrate the highest reflectance in the near-infrared region of the electromagnetic spectrum.

II.1.1. INDEX

Vegetation indices (VI) are extensively employed for monitoring and detecting changes in vegetation and land cover. These indices are created by considering the contrasting absorption, transmittance, and reflectance of energy by vegetation across the red and near-infrared portions of the electromagnetic spectrum. Numerous studies have demonstrated that the Normalized Difference Vegetation Index (NDVI) is particularly resilient against the influence of topographic factors. NDVI is commonly utilized as a broad indicator of photosynthetic activity in plants and the corresponding aboveground primary production. It provides information on the quantity and quality of vegetation in a given area. It varies from -1 to +1, where values closer to +1 indicate dense and healthy vegetation, while values close to -1 suggest a lack of vegetation or the presence of artificial surfaces.

The calculation of NDVI was performed using Sentinel-2 satellite images in the Google Earth Engine platform. Images with less than 20% cloud cover were selected for each month. The assessment focused on the average monthly NDVI time series spanning from January 2019 to June 2024. To delineate the pre- and post-project implementation periods, it is important to note that the reforestation activities are still underway as only 68,063 trees of the intended 172,562 trees have been planted thus far. Random control points were created within the reforestation area and the monthly NDVI and rainfall value at each point were extracted. Google Colab was then used to generate a box plot showing the distribution of NDVI values at the control points.

The NDVI results are illustrated in Figure 2. Over the entire period, the average monthly NDVI values were consistently around 0.6, except for a significant drop to approximately 0.5 between September 2019 and December 2021. The project proponent reported no deforestation or alterations in the project area, suggesting that this decline is likely due to various environmental factors, such as fluctuations in rainfall or other environmental conditions.

Given the known information a healthy, dense vegetation canopy typically exhibits NDVI values above 0.5, while sparse vegetation generally falls within the range of 0.2 to 0.5. The current assessment indicates that the reforestation project has the potential in fostering an increasing trend in the plot's NDVI as it transitions to a more densely forested area. With the project in place, it is anticipated that the NDVI will continue to rise further, eventually reaching a level indicative of a healthier and thriving vegetation cover.

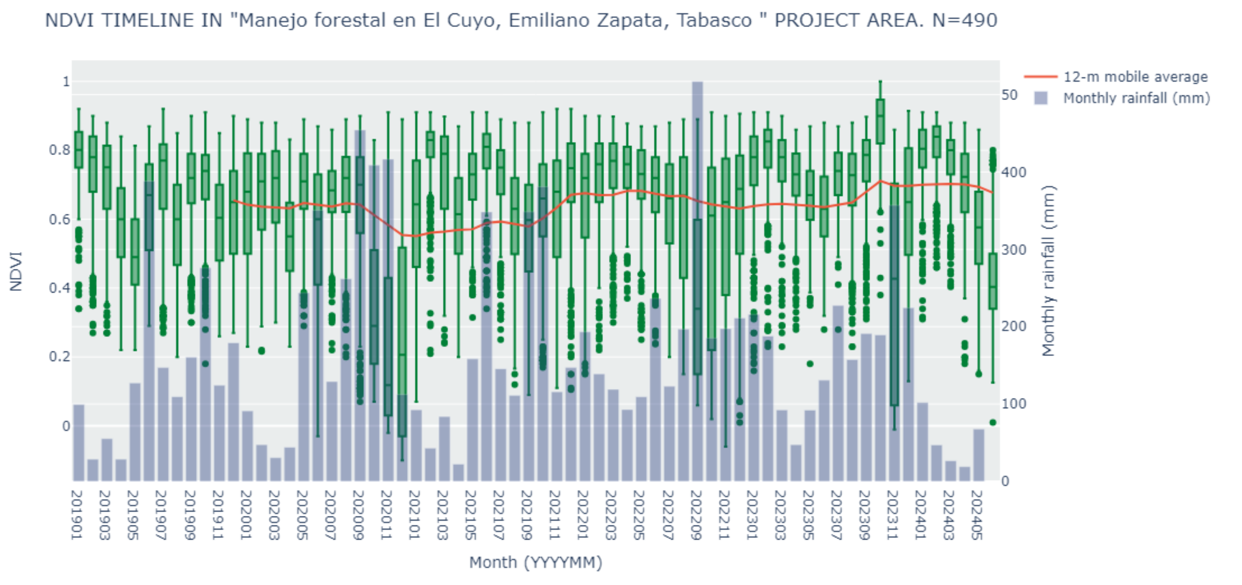


FIGURE 2. NDVI TIMESERIES IN THE AREA OF INTEREST

II.2. IMPACT ON THE LANDSCAPE AND SOCIAL ADDITIONALITY

The El Cuyo project, oriented towards forest management, aims to address the low-quality rangeland and flood-prone conditions of the El Cuyo community in Emiliano Zapata Municipality, Tabasco. The project area, characterized by flat topography and significant tree species, suffers from flooding due to its location in the Usumacinta River floodplains. The community primarily engages in fishing, with some small-scale agriculture and livestock activities. The forest inventory highlights key species such as the Tinto (*Haematoxylum campechianum*), Macuilí Tree (*Tabebuia rosea*), Caracolillo (*Albizia guachapele*), Gusano (*Lonchocarpus guatemelensis)*, and Bolocote (*Eugenia domingensis),* which are well-suited to the local conditions and will enhance soil stabilization and aquifer protection. The project involves manual land clearing, compost-based fertilization, fire protection measures, tree pruning, and pest control. It plans to plant a total of

172,562 trees, complementing the existing 71,895 trees, to convert agricultural areas into forest plantations, thereby stabilizing river channels and reducing soil erosion. Figure 3 shows an aerial view of the project area.

FIGURE 3. SATELLITE AERIAL VIEW OF PROJECT AREA (2024)

III. TECHNICAL SPECIFICATIONS

III.1. CARBON REMOVAL

This section analyzes the carbon sequestration expected by the project from the reforestation.

III.1.1. REFORESTED AREA

The project encompasses a plot with a total area measuring 575,160 m^2 in the Emiliano Zapata municipality of Morelos (Mexico).

III.1.2. SPECIES

The reforestation project successfully planted a total of 71,895 trees, encompassing five different species. Out of the total number of trees planted (71,895), the number of individuals per species, percentage of each species, and origin is presented in Table 2. The selection of species was based on a preliminary assessment of the region, considering available bibliographic information, as well as the prevailing climatic, vegetational, and meteorological conditions. All species chosen are indigenous to the area and well-suited to the local climate and environmental conditions.

TABLE 2. NUMBER OF TREES BY SPECIES

Species	Number of trees	Percentage (%)	Origin
Haematoxylum campechianum	66,350	92.29	Native
Tabebuia rosea	2,037	2.83	Native
Albizia guachapele	1,263	1.76	Native
Lonchocarpus guatemalensis	2,020	2.81	Native

Species	Number of trees	Percentage (%)	Origin
Eugenia domingensis	225	0.31	Native
Total	**71,895**	**100%**	

III.1.2.1. Distribution/Origin of the species selected for reforestation

The distribution of plant species is influenced by a variety of abiotic and biotic factors, including:

- Climate
- Soil
- Topography
- Hydrology
- Competition between plants for resources
- Seed dispersal

These factors interact in complex ways to determine the distribution of plant species across a landscape.

Understanding and knowing the distribution of the flora species that have been selected for reforestation is important to ensure the adaptation of the new trees and their survival, to secure the long-term benefits of the project, and to avoid altering the ecosystem balance by introducing non-adapted species.

To achieve this, each species was consulted in the Global Biodiversity Information Facility GBIF (https://www.gbif.org). This database allows you to know the species classified as introduced in each country, their EUNIS habitat, their native range, and observation records.

The Global Register of Introduced and Invasive Species (GRIIS) presents validated lists of introduced (alien) and invasive alien species at the country, territory, and associated island level. The International Union for Conservation of Nature (IUCN) describes an introduced/alien and invasive alien species as follows:

- **Introduced/alien species:** A species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e., outside the area, it could occupy without human intervention) and which has been transported by human activity; this includes any parts, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.
- **Invasive alien species**: A species that becomes established in natural or semi-natural ecosystems or habitats, is an agent of change, and threatens native biological diversity. This includes widespread species, rapidly expanding, or present in high abundance and that hurt biodiversity.

According to the aOCP's eligibility criteria, species classified as invasive alien species cannot be counted towards the project's benefits.

- *Haematoxylum campechianum*

Recorded as introduced in Mexico	☐ Yes ☒ No
Habitat EUNIS	Not specified
Native range	Not specified
Georeferenced records	

- *Tabebuia rosea*

Recorded as introduced in Mexico	☐ Yes ☒ No
Habitat EUNIS	Not specified
Native range	Not specified
Georeferenced records	

- *Albizia guachapele*

Recorded as introduced in Mexico	☐ Yes ☒ No
Habitat EUNIS	Not specified
Native range	Not specified
Georeferenced records	

- *Lonchocarpus guatemalensis*

Recorded as introduced in Mexico	☐ Yes ☒No
Habitat EUNIS	Not specified

Native range	Not specified
Georeferenced records	

- *Eugenia domingensis*

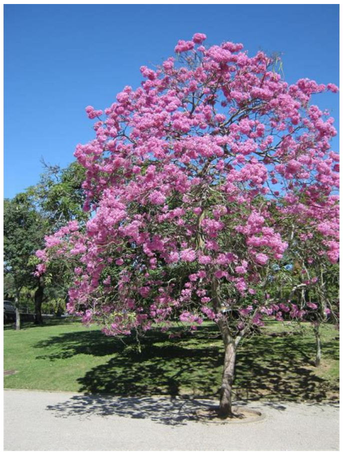
Recorded as introduced in Mexico	☐ Yes ☒ No
Habitat EUNIS	Not specified
Native range	Not specified
Georeferenced records	

From the 5 implemented plants species, all species are considered native to Mexico. No species are considered invasive; therefore, all species can be considered for biodiversity or carbon credit generation for the project.

The technical data sheets providing detailed information about the species utilized for the reforestation project are included below, in Table 3. These sheets offer comprehensive insights into the characteristics, growth patterns, environmental requirements, and other relevant details of the selected plant species. These data sheets serve as valuable references for understanding the specific attributes and suitability of each species for the reforestation efforts.

TABLE 3. TECHNICAL DATA SHEETS OF SPECIES USED FOR REFORESTATION

Haematoxylum campechianum • This tree is commonly known as the Logwood tree. • The heartwood of the tree is a significant source of natural dye, producing a reddish-blue dye called hematoxylin, historically used in the textile industry. • It has been used in traditional medicine for its astringent properties, treating various ailments such as diarrhea and dysentery. • Native to southern Mexico and northern Central America, it thrives in tropical and subtropical climates, often found in coastal and riverine environments.	

Tabebuia rosea • Also known as the Pink Trumpet Tree. • Notable for its large, showy pink to lavender flowers that bloom in the dry season. • Its wood is valued for its strength and durability, used in construction and furniture making. • Native to Central America, it thrives in tropical climates and is often found in deciduous forests	
Albizia guachapele • Commonly referred to as Guachapele or Jícaro. • Features a wide, spreading canopy with bipinnate leaves and small, fragrant flowers. • Wood is highly valued for its quality, used in fine woodworking, cabinetry, and musical instruments. • Found in tropical regions of Central and South America, preferring well-drained soils in lowland forests.	
Lonchocarpus guatemalensis • Known locally as Gusano or Jícara Gusano. • Characterized by its compound leaves and clusters of purple or blue flowers. • Traditionally used in folk medicine for its supposed anti-parasitic properties. • Native to Central America, it grows in tropical forests, often near rivers and streams.	
Eugenia domingensis • Commonly referred to as Bolocoté. • Small to medium-sized tree with dark green leaves and white, fragrant flowers. • The fruit is edible and the wood is sometimes used in local carpentry. • Found in the Caribbean, particularly in the Dominican Republic, thriving in subtropical forests and coastal areas.	

III.1.3. Reforestation technique

The reforestation technique implemented is the wide spacing or moderate-density planting technique. Wide spacing or moderate density planting is a reforestation technique where tree seedlings are planted with relatively larger gaps between them. This approach contrasts with high-density planting, where seedlings are placed closer together. The wide spacing technique aims to provide individual trees with more access to essential resources such as sunlight, water, and nutrients, allowing them to grow with reduced competition. The goal of this technique is to optimize the use of available resources, such as sunlight, water, and nutrients, by creating a more efficient growing environment as trees have ample room to establish strong root systems and develop healthier canopies, potentially leading to better long-term growth. Additionally, with wider spacing, there's a reduced risk of disease transmission between trees compared to denser plantings.

The assessment revealed an average planting density of one tree per 8 m², equivalent to an average of 1250 trees per hectare in the plot. This moderate-density approach offers several ecological, environmental, and economic advantages. The moderate tree density, combined with the implementation of various tree species, will foster biodiversity and enhance ecological resilience within the restored ecosystem. Moreover, the density will expedite canopy closure, creating a continuous cover as the tree canopies interlock. This canopy closure plays a crucial role in weed suppression, creating improved microclimates, moisture retention, and reducing soil erosion. However, it's important to note that high planting densities can also lead to competition for resources among trees, which may result in stunted growth, reduced health, and increased mortality of some trees. In addition, the proximity between trees can facilitate the rapid spread of diseases and pests. Controlling and managing these issues becomes more complex in densely planted areas.

As a result of this moderate density with planting strategy, the reforestation project is well-positioned to maximize carbon sequestration potential, promote wildlife habitat, and provide essential ecosystem services. The management of this densely planted plot will be critical to ensure the continued success and long-term sustainability of the reforestation efforts. Figure 4 shows the mapped planting density of the geolocalized trees within the plots with the location of each tree represented by dot symbols.

Nonetheless, it is important to note that the suitability of wide spacing depends on factors like soil type, climate, and water availability. Also, choosing tree species adaptable to wider spacing is crucial for successful establishment. It is a balance between optimizing individual tree growth and considering the overall ecosystem dynamics.

III.1.3.1. Methodological process

The operational phase is divided into three steps shown in Figure 4.

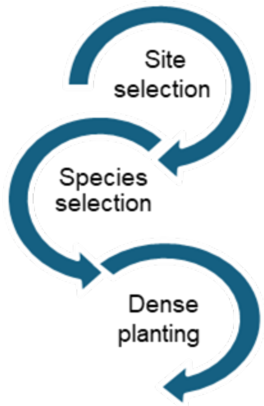


FIGURE 4. METHODOLOGICAL PROCESS

The reforestation process involved a well-defined series of steps. Firstly, a thorough evaluation was conducted to select the most suitable reforestation area, considering restoration needs, climatic and soil feasibility, permit requirements, and cost considerations. It ensured that the chosen location was conducive to successful reforestation. To preserve the ecological integrity of the region, afforestation was not carried out on scarified ground. This approach aimed to leverage the existing ecosystem to facilitate the growth and development of the newly planted trees, promoting biodiversity and increasing the chances of successful reforestation. Local community stakeholders were actively involved in the process, fostering a sense of ownership and sustainability in the reforestation initiative.

III.1.4. PROJECT CAPACITY

This section determines the project's and the area's capacity to absorb CO_2 using Net Primary Productivity (NPP) as a reference parameter. Three approaches are used to arrive to a sound result considering various ecological aspects and data sources:

A. Species-specific allometric equations, survival/mortality defined by tree density according to mean DBH of trees and latitude, according to (Madrigal-González et al., 2023).
B. Species-specific allometric equations, survival/mortality defined by tree density according to regional timber plantation tables,
C. Carbon stocks are derived through a machine learning model trained with the Global Forest Aboveground Carbon Stocks and Fluxes from GEDI and ICESat-2, a global carbon dataset.

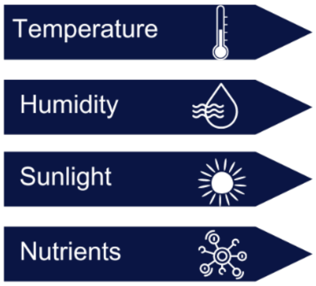
For all three approaches, Net Primary Productivity (NPP) is regarded as the upper limit, representing the maximum achievable carbon sequestration potential based on biophysical considerations.

Using Net Primary Productivity (NPP) as a reference parameter. The amount of CO_2 that can be captured is then estimated with allometric equations considering the age and height of individual species. Subsequently, the estimation of survival rates is derived from tree density projections published in the study by Madrigal-González et al. (2023).

III.1.4.1. Net Primary Productivity (NPP)

Net Primary Productivity (NPP) is the result of organic matter production through the process of photosynthesis. However, primary productivity involves more than photosynthesis; it also encompasses the uptake of inorganic nutrients and the assimilation of diverse organic compounds into protoplasm, which are vital for all photosynthetic organisms. Among various ecosystem processes, NPP is extensively measured due to its ability to reflect carbon accumulation in ecosystems. The calculation of NPP is based on the increase in biomass per unit area over a specified time period.

NPP is influenced by several factors, including:



Hence, the net primary productivity (NPP) can be expressed as the difference between the carbon absorbed by vegetation through photosynthesis (referred to as Gross Primary Production or GPP) and the carbon lost through respiration. Temperature and precipitation are key limiting factors for NPP, and it is generally assumed that NPP increases with both temperature and precipitation. However, it is important to note that the NPP cannot exceed the saturation value of 3000 gDM/m^2/year (DM stands for dry matter).

For the calculation of NPP in the Belmex project, the Miami methodology outlined in section “IV.1. aOCP Methodology for carbon removal and storage in vegetation” was employed. Present and future NPP were computed to take into consideration ecosystem’s vulnerability to climate change and to define the threshold for carbon sequestration. Both were computed on Google Earth Engine using the resources available in the catalog. Present NPP was calculated for 2022 from 2 data sources: a) precipitation data from the “CHIRPS Daily: Climate Hazards Group InfraRed Precipitation with Station Data (Version 2.0 Final)” dataset (Funk et al., 2015) and b) temperature data from the MODIS/Terra Land Surface Temperature/Emissivity Daily L3 Global 1km SIN Grid V061 [Dataset] (Wan et al., 2021). Future NPP was computed using precipitation and temperature data for the year 2062, from the NEX-GDDP-CMIP6 dataset (Thrasher et al. 2022). This dataset, comprised of global downscaled climate scenarios derived from the General Circulation Model (GCM), runs conducted under the Coupled Model Intercomparison Project Phase 6; the CMIP6 GCM runs were developed in support of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6).

This methodology incorporates the following equations to determine NPP:

$$\mathbf{NPP} = \mathbf{min}\ (\mathbf{NPP_T}, \mathbf{NPP_P})$$

Where:

$NPP_T = 3000(1 + exp(1.315 - 0.119 * T))^{-1}$

$NPP_P = 3000(1 - \exp(-0.000664 * P))$

Where:

T: average annual temperature

P: accumulated precipitation

Carbon capture capacity was calculated using the conversion factor 0.47 (IPCC, 2006), using the following equation:

$$NPP_c = NPP_{dm} \times 0.47$$

Where:

NPP_c: Net primary productivity, gC m-2 yr-1

NPP_{dm}: Net primary productivity, gDM m-2 yr-1

Then, the equivalence to carbon dioxide was calculated using the conversion factor of 3.67. This factor represents the molar mass ratio of CO_2: C. CO_2 molar mass is 44 and C is 12, therefore, 44/12 = 3.67. The conversion was done using the following equation:

$$CO_2 \text{ capture capacity} = 3.67(NPP_c)$$

Finally, the maximal CO_2 capture capacity for the Project area was computed by multiplying the previous result by the Project area surface. The calculation was repeated for each scenario (present with real data, present with CMIP data, and future with CMIP data). Real data is privileged over modeled data for the present scenario. To estimate future NPP, the percent change was calculated between present and future estimates done with CMIP6 data. This percent change was then applied to the present estimate done with real data, this way we obtain a future NPP estimate based on present real data.

The results indicate that the project area currently has an NPP of 2,249.86 gDM m^{-2} yr^{-1}, which, due to the climatic conditions, will decrease to 2,210.58 gDM m^{-2} yr^{-1} in 2062. This change, of -39.28 gDM m^{-2} yr^{-1}, represents a decrease of -1.75%. In terms of CO_2, **the Project restoration area (57.52 ha) is currently capable of capturing 1,879,172.19 kgCO_2 yr^{-1} and is expected to capture around 1,846,362.28 kgCO_2 yr^{-1} by 2062**.

Based on these results, it has been determined that **1,846.36 TCO_2-eq/year** will serve as the base parameter for the estimation of maximum achievable annual CO_2 capture. For the 40 years of the project, it equals **73,854.49 TCO_2-eq.**

TABLE 4. MAXIMUM ATTAINABLE NPP AND BIOMASS WITHIN PROJECT SITE

NPP	Present Real Data	Present CMIP	2062 CIMP	CMIP Change	CMIP % Change	2062 Based On Real Data	Real Data Change
$gDM/m^2/yr$	2,249.86	2,182.25	2,220.35	-38.10	-1.75	2,210.58	-39.28
$gCO_2/m^2/yr$	3,880.78	3,764.16	3,829.88	-65.72	-1.75	3,813.03	-67.76
$gC/m^2/yr$	1,057.43	1,025.66	1,043.56	-17.91	-1.75	1,038.97	-18.46
$KgCO_2/plot/yr$	1,879,172.19	1,822,699.16	1,854,523.1	-31,823.91	-1.75	1,846,362.28	-32,809.9

III.1.5.2. Allometric Equations

Allometric equations are mathematical formulas used to estimate the amount of CO_2 that can be captured and stored in certain types of vegetation, such as trees or shrubs, depending on their morphometry. Table 5 shows the allometric equations used for each species planted.

TABLE 5. ALLOMETRIC EQUATIONS FOR EACH IMPLEMENTED SPECIES

Species	Allometric Equation CO_2 absorbed (Kg)	Reference
Haematoxylum campechianum	Biomass =(0.5825*(DBH)^1.6178)	Návar, J. 2009. Allometric equations for tree species and carbon stocks for forests of northwestern Mexico.Forest Ecology and Management 257:427-434
Tabebuia rosea	Biomass=0.007*(DBH)^2.7063	Hung, N.D., Bay, N.V., Binh, N.D., Tung, N.C. (2012) Tree allometric equations in Evergreen broadleaf, Deciduous, and Bamboo forests in the South East region, Vietnam, in (Eds) Inoguchi, A., Henry, M. Birigazzi, L. Sola, G. Tree allometric equation development for estimation of forest above-ground biomass in Viet Nam, UN-REDD Programme, Hanoi, Viet Nam
Albizia guachapele	Biomass=0.0102*((DBH)^(2.5848))	Hung, N.D., Giang, L.T., Tu, D.N., Hung, P.T., Lam, P.T., Khanh, N.T., Thuy, H.M. (2012) Tree allometric equations in Evergreen broadleaf and Bamboo forests in the North East region, Viet Nam, in (Eds) Inoguchi, A., Henry, M. Birigazzi, L. Sola, G. Tree allometric equation development for estimation of forest above-ground biomass in Viet Nam, UN-REDD Programme, Hanoi, Viet Nam. 2. DBH reference ; https://stri.si.edu/sites/default/files/hall_j.s._ashton_m.s._2016._guide_to_early_growth_and_survival_of_64_native_tree_species.pdf
Lonchocarpus guatemalensis	Biomass=5.825+1.982*(DBH)	Rai, S.N. 1984. Bole, branch, current year twig, leaf and root biomass production in tropical rain forests of western ghats of Karnataka. Indian Forester, 110(9): 901-913
Eugenia domingensis	Biomass=5.825+1.982*(DBH)	Rai, S.N. 1984. Bole, branch, current year twig, leaf and root biomass production in tropical rain forests of western ghats of Karnataka. Indian Forester, 110(9): 901-913

Carbon stocks in planted trees and shrubs at year 40 were calculated applying these allometric equations to the tree dimensions expected at age 40. The total carbon storage at year 40 for the 71,895 trees and shrubs is estimated to be 16,809 Tons CO_2.

Due to natural ecological processes, a fraction of the planted trees and shrubs will die. The survival/mortality percentages were computed with two different approaches, as described in the following subsection.

III.1.5.3. CO_2 Capture

In reforestations carried out in degraded areas, a planting density of 1 tree every four meters is considered, since distributing the trees in this way allows each tree to have enough space to grow and develop adequately, avoiding excessive competition for resources such as sunlight, water, and soil nutrients. The reference density for this scenario is 16 m² per tree. At present, the project has achieved a density of 8 m² per tree, which is half of the targeted reference density. This planting density has significant implications for the success of reforestation efforts. By providing adequate space for individual tree growth, the chances of survival and healthy development are increased. However, in this case, proper management practices will be essential to ensure the optimal utilization of resources, especially as the trees grow and compete for sunlight, water, and nutrients. Maintaining the appropriate balance between tree density and resource availability will be crucial to sustaining the health and productivity of the reforested ecosystem over time.

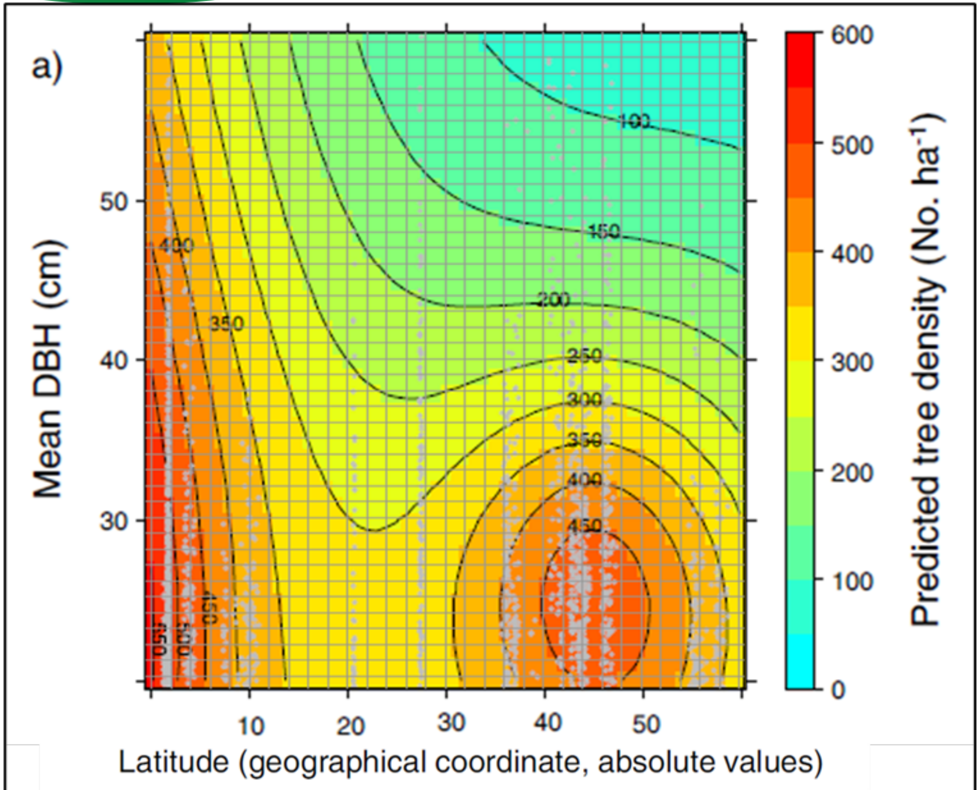
The avoidance of resource competition promotes optimal access to sunlight for photosynthesis, sufficient water uptake, and efficient nutrient absorption from the soil as defined by the Net Primary Productivity (NPP). These factors are crucial for the establishment of a sustainable and resilient forest ecosystem.

III.1.5.3.1 Survival rate based on forest tree density.

Tree density as a function of mean DBH and latitude.

The estimation of survival rate is based on the results from Madrigal-González et al. (2023). These authors established the relationship between mean Diameter at Breast Height (DBH) and latitude in determining forests' tree density (Figure 5).

According to this reference, predicted tree density for an area located at latitude 38°N, and with a mean tree diameter of 36 cm is around 250 trees per hectare. Considering that 71,895 trees and shrubs were planted in the restoration area (57.52 ha), i.e. 1250 trees per hectare, a survival of 20% would lead to the density of 250 trees ha^{-1}.



Source: Madrigal-González et al. (2023), figure 2a.

FIGURE 5. PREDICTED TREE DENSITY AS A FUNCTION OF MEAN DBH AND LATITUDE. SOURCE: MADRIGAL-GONZÁLEZ ET AL. (2023).

Tree density according to timber plantation tables.

Cienciala et al. (2022) elaborated a list of estimated survival rates due to tree mortality and management interventions by biogeographic regions and species group types. For Continental Broadleaves, they report a stand density at year 40 from the plantation, of 1,579 trees per hectare. Since the plantation in the restoration area has a density of 1,250 trees ha-1, a survival of 126.3% would lead to the final density reported by the authors.

In conclusion, the project currently has a density of 1,250 trees and shrubs per hectare, which will generate an initial competition for resources. However, due to the expected mortality that occurs in each reforestation project, the planting density will progressively decrease and the trees that manage to adapt and survive will have increasing access to the available resources (water, sunlight, and nutrients), and will be able to continue growing.

Based on the 2 density references, there are 2 scenarios for the survival rate of the project at year 40. Scenario one estimates survival at 20%, and Scenario two estimates survival at over 100%.

III.1.5.3.2. Carbon capture in vegetation

The carbon removal potential, calculated using the allometric equations, was adjusted to account for survival/mortality, as follows. Survival scenario 1, calculated from tree density predicted by Madrigal-González et al. (2023), results in a survival of 20% of planted trees and shrubs.

Therefore, 20% of the carbon removal potential equals 3,361.89 T CO_2-eq during the 40 years of the project. Survival scenario 2, calculated from tree density predicted by Cienciala et al. (2022), results in a survival of 100% of planted trees and shrubs. Therefore, 100% of the carbon removal potential equals 16,809.49 T CO_2-eq during the 40 years of the project.

Considering these 2 scenarios, the amount of carbon removals the project can generate attributable to the planted trees and shrubs lies between 3,361.89 and 16,809.49 T CO_2-eq. However, it is important to note that this ex-ante estimation excludes carbon removals from vegetation that develops in the project area natural regeneration, triggered by Project activities. As the reforestation matures, it is expected that monitoring campaigns reveal carbon stocks higher than those estimated ex-ante. These estimates were and will continue to be cross-referenced with the maximum carbon removal determined through Net Primary Productivity (NPP), which for this project equals **1,846.36** TCO_2-eq, to ensure adherence to biophysical ecological limits, thus avoiding overestimates.

III.1.5.4. Carbon Credits

According to *aOCP Methodology for carbon removal and storage in vegetation V2.0,* this ecological restoration project in Emiliano Zapata (Mexico) spanning an area of 57.52 hectares with 71,895 trees and shrubs planted, has the potential to generate between 3,361 and 21,233 Verified Carbon Credits (VCC) from removals. This range considers survival scenarios of 20% and 100%, as elaborated above. However, the inclusion of carbon capture calculations conducted by the project developers will further refine these estimates and provide a more comprehensive assessment of the project's environmental impact.

The project developer's PSF indicates a 90% survival rate by year 40. Applying this survival rate to the initially aOCP-determined carbon capture yields 15,128.54 TCO_2-eq. Table 6 presents a summary of the of the aforementioned considerations.

TABLE 6. ESTIMATED CARBON CAPTURE OF ECOLOGICAL RESTORATION PROJECT AT YEAR 40.

	Survival Scenarios		Carbon Capture (TCO_2-eq)	Carbon credits (VCC)
aOCP Determined	Total Derived	100.00%	16,809.49	16,809
	Madrigal-González et al. (2023).	20.00%	3,361.89	3,361
	Plantation Tables	126.32%	21,233.75	21,233
	Project Developer expected survival	90.00%	15,128.54	15,128
	aOCP Determined	80.00%	13,447.59	13,447
Project Developer Determined	Project Developer	90.00%	Not specified	Not specified

To maintain a conservative scenario, 13,447 VCC will be generated from the project's benefits. However, in accordance with the aOCP Procedures document, 25% of these will be allocated to the *buffer pool* as a reserve, leaving a total of **10,086 Verified Carbon Credits**.

A 30% post-project emission will be made, corresponding to **3,026 VCC**. Annually, the capture will be calculated based on the *Dynamic review baseline*, adjusting the number of credits as necessary and issuing the corresponding credits.

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