ASES ON-CHAIN PROTOCOL

BASELINE REPORT

Verified Carbon Credits (VCC)

Ecological restoration in La Junquera, Murcia

LT-011-SPA-041023 MURCIA, SPAIN

Life Terra (Foundation)

Type B Project

February 7, 2025

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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 La Junquera, Murcia (Spain) entailed planting a total of 17,461 trees, representing twenty-one (21) distinct species mainly native to the region and well-suited for adverse environmental conditions. 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 La Junquera municipality, covered 341,424.60 square meters.

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 19.6 square meters, equivalent to an average of 509 trees per hectare in the plot.

The total CO_2 capture for the entire project area was calculated to be between 1,984.92 and 3,104.41 TCO_2-eq considering survival scenarios of 50% and 78.2% 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 La Junquera 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 La Junquera municipality, in the province of Murcia (Spain). 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.

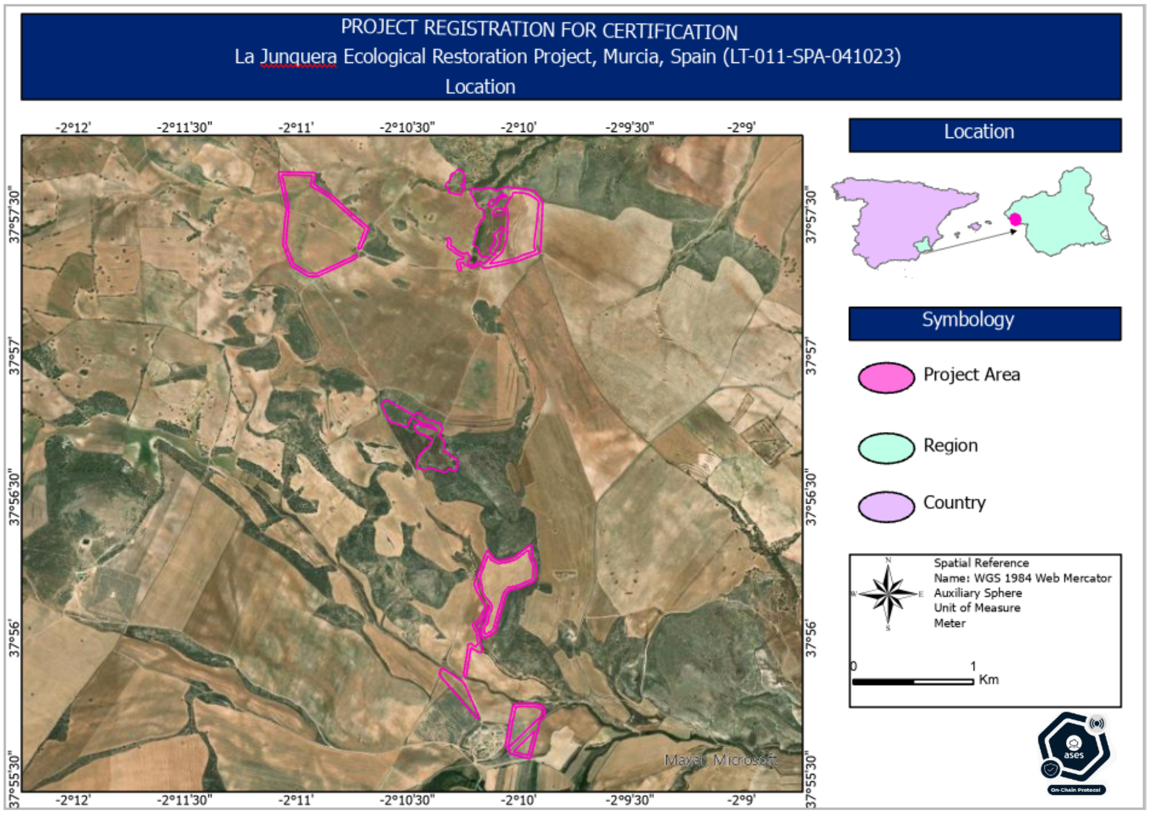


FIGURE 1. PROJECT LOCATION

TABLE 1. LOCATION OF PROJECT PLOT

Plot	Coordinates	
	Latitude	**Longitude**
1	37.9475358°N	2.1712176°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 landownership, ensuring transparency and certainty regarding the agreements made with the landowners.

I.2.1. Project developer

Key project	LT-011-SPA-041023 MURCIA, SPAIN
Title of the project activity	Ecological restoration in La Junquera, Murcia (Spain).
Company	Life Terra
Person responsible	Sven Kallen

I.2.2. Type of project

Project registration year	2025 – Retroactive project (2023)
Project duration	40 years
Issuance of credits	Annual to 10 years
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) ☐ Biodiversity Based Credit (VBBC) ☐ Water Credits (VWC) ☐ Soil Credits (VSC) ☐ Climate action bond

II. PROJECT AREA BASELINE

According to the Corine Land Cover mapping, the project area falls within Agricultural and Arable lands with herbaceous vegetation associations, as well as grasslands in the La Junquera municipality, Spain. Adjoining land covers include Agricultural and Pasture areas extending a few kilometers from the site. An evaluation of the ESA-worldcover-v200 for 2021, focusing on land use and land cover, revealed that the project site was situated within a predominantly Cropland area. 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 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 January 2025. To delineate the pre- and post-project implementation periods, it is important to note that the reforestation activities took place between 2022 and 2023. Consequently, all months prior to these dates are considered as the pre-project implementation period, while months after are regarded as the post-project implementation period for the purpose of this analysis. 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 findings are presented in Figure 2, which covers both pre- and post-project implementation periods, and are updated as of February 2025. The NDVI values in this dataset show considerable fluctuations, with an overall declining trend in the 12-month moving average (MA). In early 2019, NDVI values were low but exhibited minor seasonal variability, with a peak in mid-2020. A sharp decline followed from July 2020 to October 2021, reaching a low point in late 2021. Although there were brief periods of recovery in mid-2022 and mid-2023, the overall trend remained downward. The most recent data indicates continued low NDVI values, suggesting persistent vegetation stress or land degradation. The 12-month MA also declined significantly from 2021 onward, indicating a prolonged period of lower vegetation productivity. While some seasonal recoveries occurred, they were not sustained, reflecting ongoing environmental challenges that may require further investigation and mitigation efforts. **Although the current vegetation cover remains poor and a field visit in September 2024 revealed high mortality rates, the project developers have proposed an updated restoration plan aimed at improving survival.**

Given that a healthy, dense vegetation canopy typically exhibits NDVI values above 0.5, while sparse vegetation ranges between 0.2 and 0.5, the assessment suggests that the reforestation project still holds the potential to drive an upward trend in NDVI as the landscape transitions toward a more forested state. With the implementation of the revised plan, NDVI is expected to increase over time, eventually reaching levels characteristic of a healthy and thriving ecosystem.

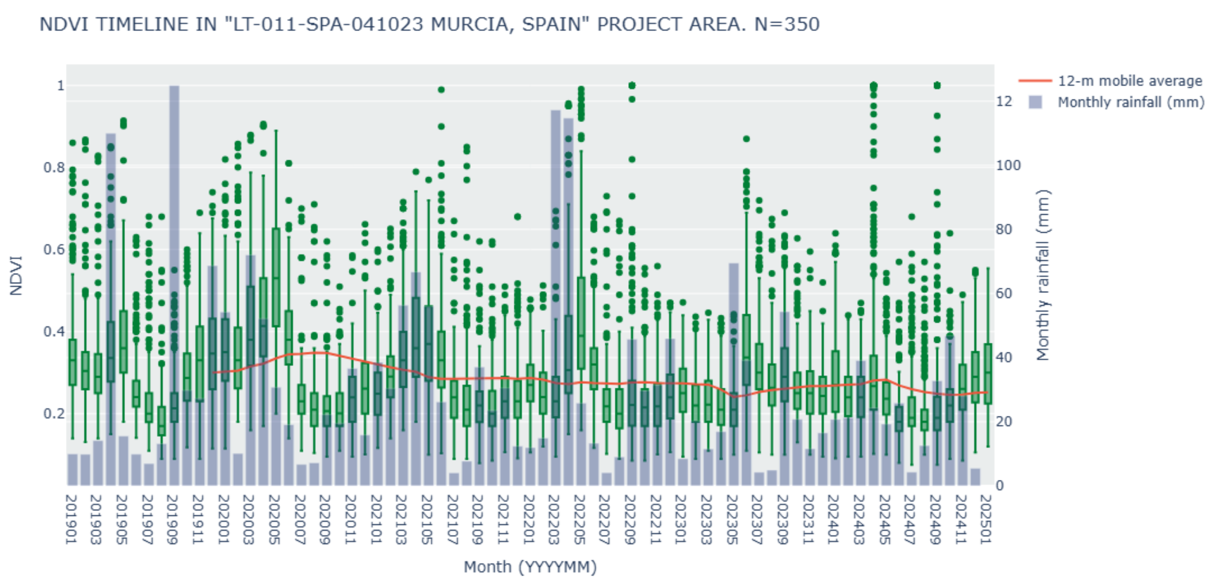


FIGURE 2. NDVI TIMESERIES IN THE PROJECT AREA

II.2. Impact on the landscape and social additionality

Recognized as one of the most desertified areas on the Iberian Peninsula, the project site had experienced decreased biodiversity, and reduced ecosystem services prior to undergoing reforestation efforts. However, this ecological restoration initiative plays a pivotal role in safeguarding various plant and animal species by establishing new habitats and reinstating wildlife corridors as healthy forests are crucial for the survival of many species. Furthermore, reforestation contributes to the re-establishment of natural hydrological cycles, by slowing down runoff, enhancing water infiltration, and reducing soil erosion. This helps regulate water flow, improve water quality, and mitigate the impacts of flooding.

An added advantage is the reforested landscapes offering aesthetic beauty and recreational opportunities. They can provide green spaces for leisure activities, such as hiking, wildlife observation, and eco-tourism, enhancing the well-being of local communities and visitors. La Junquera also serves as an educational hub through initiatives like Camp Altiplano which supports research, fosters entrepreneurship, and champions ecosystem restoration, thus creating opportunities for environmental education. The implemented project is therefore poised to amplify the effectiveness of these endeavors. Figure 3 shows Google Earth satellite imagery of the project area pre- and post-project implementation.

Figure 3. Satellite aerial view of Pre- (2019) & Post-Afforestation project (2023)

Comparing satellite imagery from August 2019 (pre-project) and November 2023 (post-project), there is a noticeable increase in vegetation and implemented structures in the later image. However, the project zone and its surroundings remain visibly dry and affected by desertification. Some variations in color can also be attributed to seasonal differences.

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 341,424.60 m^2 situated in La Junquera municipality, Murcia province (Spain). The demarcated plot is shown in Figure 4.

III.1.2. SPECIES

The reforestation project successfully planted a total of 17,461 trees, encompassing twenty-one different species. The number of individuals of each species is shown 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. Out of the total number of trees planted (17,461), the percentage by species is presented in Table 2.

TABLE 2. NUMBER OF TREES BY SPECIES

Species	Number of trees	Percentage (%)	Origin
Arbutus unedo	275	1.57	Native
Crataegus monogyna	967	5.54	Native
Euonymus europaeus	30	0.17	Native
Ficus carica	30	0.17	Native
Juniperus oxycedrus	1408	8.06	Native
Juniperus phoenicea	800	4.58	Native
Juniperus thurifera	600	3.44	Native
Olea europaea	781	4.47	Native
Pinus halepensis	2587	14.82	Native
Pistacia lentiscus	1133	6.49	Native
Pistacia terebinthus	2284	13.08	Native
Populus alba	75	0.43	Native
Quercus coccifera	1310	7.5	Native
Quercus ilex	1485	8.5	Native
Quercus suber	2	0.01	Native
Retama sphaerocarpa	1681	9.63	Native
Rhamnus lycioides	1004	5.75	Native
Ribes rubrum	10	0.06	Introduced
Rosa canina	836	4.79	Native
Salix alba	45	0.26	Native
Sambucus nigra	118	0.68	Native

Total	**17,461**	**100%**	

The assessment revealed an average planting density of one tree per 19.6 square meters, equivalent to an average of 509 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 “wide spacing" 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.

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.

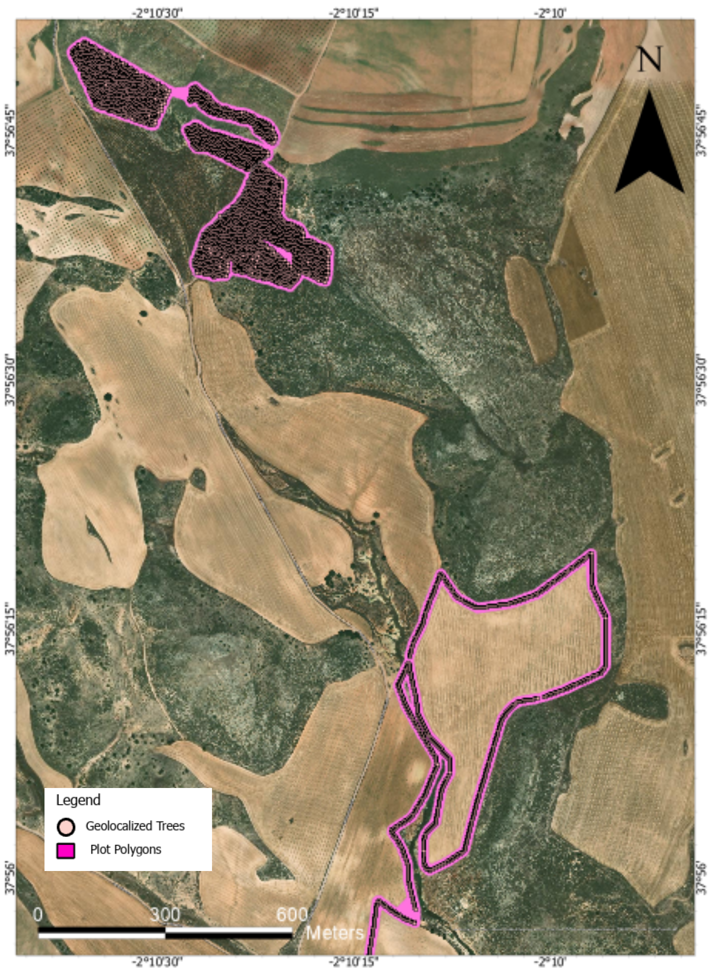


FIGURE 4. TREE PLANTING DISTRIBUTION

TABLE 3. TECHNICAL DATA SHEETS OF SPECIES USED FOR REFORESTATION

Arbutus unedo	Produces edible red berries Evergreen shrub or small tree	

Crataegus monogyna	Has thorny branches Important for pollinators	
Euonymus europaeus	Bright pink and orange fruits Toxic to humans	
Ficus carica	Produces edible figs Deciduous tree	
Juniperus oxycedrus	Has sharp needle-like leaves Used for essential oils	

Juniperus phoenicea	Grows in coastal areas Produces small berry-like cones	
Juniperus thurifera	Can tolerate extreme cold Produces aromatic resin	
Olea europaea	Cultivated for olives and oil Can live for centuries	
Pinus halepensis	Adapted to fire-prone environments Fast-growing conifer	

Pistacia lentiscus	Source of mastic resin Evergreen shrub	
Pistacia terebinthus	Produces aromatic resin Deciduous tree or shrub	
Populus alba	Fast-growing Leaves have a white underside	
Quercus coccifera	Hosts Kermes scale insects (used for red dye) Shrubby oak	

Quercus ilex	Drought-resistant Important for acorn-feeding wildlife	
Quercus suber	Source of cork Thick bark protects from wildfires	
Retama sphaerocarpa	Drought-resistant Produces yellow pea-like flowers	
Rhamnus lycioides	Small drought-tolerant shrub Berries eaten by birds	

Ribes rubrum	Produces red currants Prefers cooler climates	
Rosa canina	Produces vitamin C-rich rose hips Thorny climbing shrub	
Salix alba	Prefers wet habitats Bark contains salicin (aspirin precursor)	
Sambucus nigra	Produces edible elderberries Used in traditional medicine	

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.

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 5.

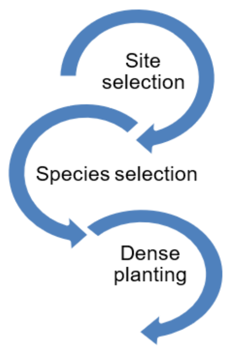


FIGURE 5. METHODOLOGICAL PROCESS

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. GEOLOCALIZATION OF PLANTED TREES

Using Spatial Analyst tools in ArcGIS Pro environment, a detailed count of geolocalized trees was conducted within the project plot. The results indicate the distribution of 17,461 trees within the reforested plot spaced at approximately a 5-meter interval for larger tree species and 2-meter intervals for smaller shrubs as illustrated in Figure 4 above.

This analysis provides valuable insights into the spatial relative abundance of trees within each plot. The distribution percentages highlight the varying densities and concentrations of trees, indicating areas with higher and lower tree populations in cases where the reforested plots are segmented. These findings help understand tree distribution and estimate the project's carbon absorption capacity. The number of trees and their carbon sequestration capacity are crucial for the estimation of the Project's carbon sequestration potential. The count of geolocalized trees provides an overall measure, serving as a basis for estimating carbon sequestration. Combining tree count with species-specific data allows estimation of biomass and carbon capture potential. This provides a quantitative assessment of the project's capacity to absorb and sequester CO_2.

III.1.5. 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 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.

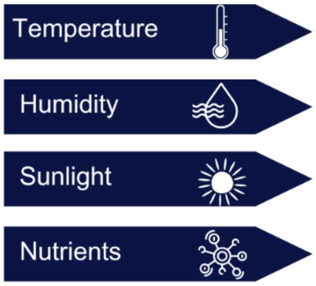
For all three approaches, Net Primary Productivity (NPP) is regarded as the upper limit, representing the maximum achievable carbon sequestration potential based on biophysical considerations.

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.1.5.1. 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 Murcia Ecological Restoration 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 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

The climate sensitivity of the NPP can be defined as the derivative of the NPP concerning changes in climate variables, λP = ∂NPP/∂P in $g(DM)/m^2/yr/(mm/yr) = gDM/m^2/mm$ and λT = ∂NPP/∂T in $gDM/m^2/year/°C$, respectively.

Direct differentiation leads to

$$\lambda T = \frac{3000 * 0.199 \exp(1.315 - 0.119 * T)}{(1+\exp(1.315-0.119*T))^2} \quad \text{, if } NPP_T < NPP_P$$

o

$$\lambda P = 3000 * 0.000664 \exp(-0.000664 * P) \text{ , if } NPP_P < NPP_T$$

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 modelled 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 (**Erreur ! Source du renvoi introuvable.**4) indicate that the project area currently has an NPP of 502.34 gDM m^{-2} yr^{-1}, which, due to the climatic conditions, will decrease to 426.99 gDM m^{-2} yr^{-1} in 2062. This change, of -75.35 gDM m^{-2} yr^{-1}, represents a decrease of -15%. In terms of CO_2, **the Project restoration area (34.12 ha) is currently capable of capturing 295,605.19 kgCO_2 yr^{-1} and is expected to capture around 251,264.41 kgCO_2 yr^{-1} by 2062**.

Based on these results, it has been determined that **251.3 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 **10,052 TCO_2-eq.**

TABLE 4. NPP AND BIOMASS CALCULATED FOR THE PLOT WITHIN THE PROJECT AREA.

NPP	Present Real Data	Present CMIP	2062 CIMP	CMIP Change	CMIP % Change	2062 Based On Real Data	Real Data Change
$gDM/m^2/yr$	502.34	681.70	579.47	-102.22	-15.00	426.99	75.35
$gCO_2/m^2/yr$	866.49	1175.86	999.53	-176.33	-15.00	736.52	129.97
$gC/m^2/yr$	236.10	320.40	272.35	-48.05	-15.00	200.69	35.41
$KgCO_2$/plot/yr	295605.19	401210.65	341046.60	-60164.05	-15.00	251264.41	44340.78

III.1.5.2. Allometric Equations

Allometric equations are mathematical formulas used to estimate the amount of CO2 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 USED FOR CARBON CAPTURE QUANTIFICATION

Species	Allometric Equation CO_2 absorbed (Kg)	Reference
Arbutus unedo	Biomass=-2.7563+0.3045*(DBH)^2	Brandini, P. and Tabacchi, G. 1996. Biomass and volume equations for holm oak and straberry-tree in coppice stands of Southern Sardinia. ISAFA Communicazioni di Ricerca : (96) 59-69
Crataegus monogyna	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
Euonymus europaeus	Biomass = 0.171*((D10)^2.554)	Li, X., Guo, Q., et al. (2010). "Allometry of Understory Tree Species in a Natural Secondary Forest in Northeast China." Scientia Silvae Sincae 46(8): 22-32
Ficus carica	Biomass = 0.0421* (DBH2 * H)0.9440	Shaheen, H., Khan, R. W. A., Hussain, K., Ullah, T. S., Nasir, M., & Mehmood, A. (2016). Carbon stocks assessment in subtropical forest types of

Species	Allometric Equation CO_2 absorbed (Kg)	Reference
		Kashmir Himalayas. Pak. J. Bot, 48(6), 2351-2357.
Juniperus oxycedrus	Biomass=0+0*(DBH)+0.1632*((DBH)^(2.2454))	Schnell; R; 1976; Biomass estimates of eastern redcedar tree components; Tech; Note B15; Norris; TN; Tennessee Valley Authority; Division of Forestry; Fisheries and Wildlife Development;
Juniperus phoenicea	Biomass=0+0*(DBH)+0.1632*((DBH)^(2.2454))	Schnell; R; 1976; Biomass estimates of eastern redcedar tree components; Tech; Note B15; Norris; TN; Tennessee Valley Authority; Division of Forestry; Fisheries and Wildlife Development;
Juniperus thurifera	Biomass=0+0*(DBH)+0.1632*((DBH)^(2.2454))	Schnell; R; 1976; Biomass estimates of eastern redcedar tree components; Tech; Note B15; Norris; TN; Tennessee Valley Authority; Division of Forestry; Fisheries and Wildlife Development;
Olea europaea	Biomass= 8.87-(0.75*(DBH))-(1.44*((DBH)^(2)))	Abbas, M., Nizami, S. M, Saleem, A., Gulzar, S.& Khan, I.A. 2011. Biomass expansion factors of Olea ferruginea (Royle) in sub tropical forests of Pakistan. African Journal of Biotechnology, 10(9): 1586?1592.
Pinus halepensis	Biomass= 0.1129 DBH2.4241	Montero, G. (2004). Cuantificacion de la biomasa forestal aerea y radical de distintas especies arboreas. Montes y energyıas renovables. Ponencias y Comunicaciones Santiago de Compostela, 115-131.
Pistacia lentiscus	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

Species	Allometric Equation CO_2 absorbed (Kg)	Reference
		Karnataka. Indian Forester, 110(9): 901-913.
Pistacia terebinthus	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.
Populus alba	Biomass = 0.0194(D2H)0.9669	Hussain, M., & Ali, F. Assessing Carbon Sequestration Potential of Selected Woody Tree Species Growing in Hattar Industrial Estate, Haripur, Pakistan.
Quercus coccifera	Biomass = (0.089*(DBH)^2.5226)	Návar, J. 2009. Allometric equations for tree species and carbon stocks for forests of northwestern Mexico. Forest Ecology and Management 257:427-434
Quercus ilex	Biomass = 0.089*(DBH)^2.5226	Návar, J. 2009. Allometric equations for tree species and carbon stocks for forests of northwestern Mexico. Forest Ecology and Management 257:427-434
Quercus suber	Biomass= (0.089*(DBH)^2.5226)	Návar, J. 2009. Allometric equations for tree species and carbon stocks for forests of northwestern Mexico. Forest Ecology and Management 257:427-434
Retama sphaerocarpa	Biomass=0.4+0.02*((D10)^(2)*(H))	Iglesias, MD; Barchuk, A; Grilli, MP. 2012. Carbon storage, community structure and canopy cover: A comparison along a precipitation gradient. Forest Ecology and Management 265:218-229. Disponible en ://WOS:000299981900024
Rhamnus lycioides	Biomass = 0.125*((D10)^2.555)	Li, X., Guo, Q., et al. (2010). "Allometry of Understory Tree Species in a Natural Secondary

Species	Allometric Equation CO_2 absorbed (Kg)	Reference
		Forest in Northeast China." Scientia Silvae Sincae 46(8): 22-32
Ribes rubrum	Biomass = 0.125*((D10)^2.555)	Li, X., Guo, Q., et al. (2010). "Allometry of Understory Tree Species in a Natural Secondary Forest in Northeast China." Scientia Silvae Sincae 46(8): 22-32
Rosa canina	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
Salix alba	logBiomass=-0.391+0*(DBH)+1.6514*(LOG((DBH)^(1)))	Young, H. E.; Ribe, J. H.; Wainwright, K. 1980. Weight tables for tree and shrub species in Maine. Misc. Rep. 230. Orono, ME: University of Maine, Life Sciences and Agriculture Experiment Station.
Sambucus nigra	Biomass = 0.024*((D10)^1.797)	Li, X., Guo, Q., et al. (2010). "Allometry of Understory Tree Species in a Natural Secondary Forest in Northeast China." Scientia Silvae Sincae 46(8): 22-32

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 17,461 trees and shrubs is estimated to be **3,969.83 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.

After a field visit in September 2024, around 40% of the planted trees were recorded as dead. Measures will be implemented to address this issue, and the revised mortality rate and credits are detailed in Section IV.

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 square meters per tree. At present, the project has achieved a density of 19.6 square meters per tree, close to 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 6).

According to this reference, predicted tree density for an area located at latitude 38°N, and with a mean tree diameter of 21.7 cm is around 400 trees per hectare. Considering that 17,461 trees and shrubs were planted in the restoration area (34.1 ha), i.e., 512 trees per hectare, a survival of 78.2% would lead to the density of 400 trees ha^{-1}.

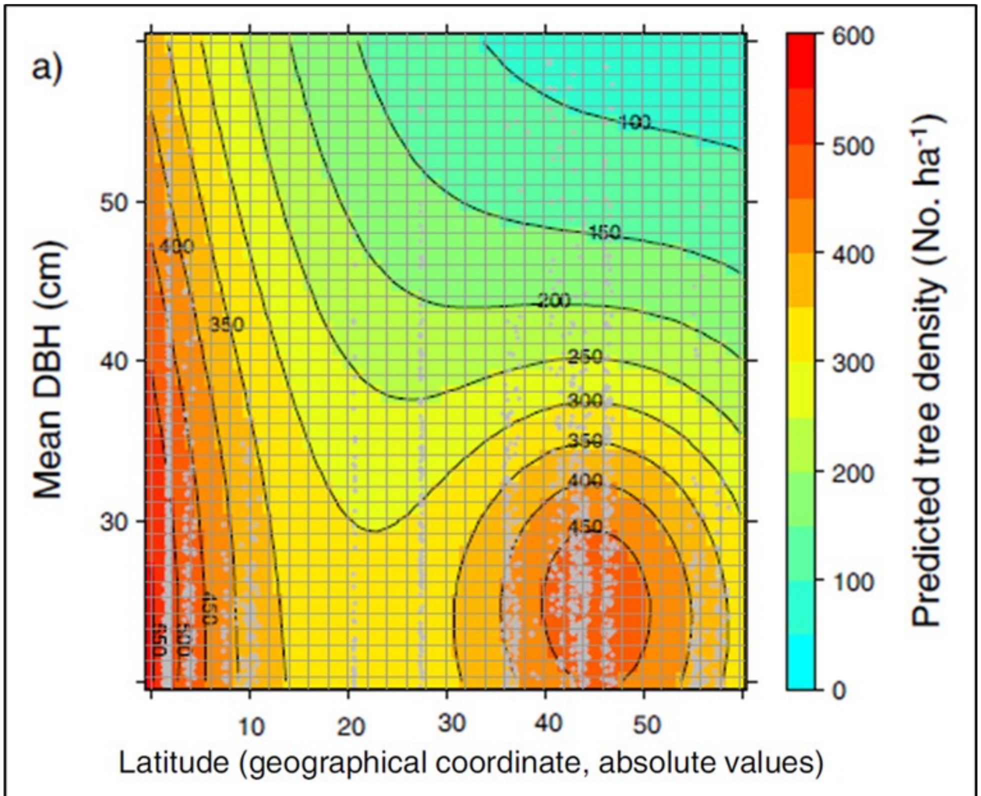


FIGURE 6. PREDICTED TREE DENSITY AS A FUNCTION OF MEAN DBH AND LATITUDE. SOURCE: MADRIGAL-GONZÁLEZ ET AL. (2023).

Tree density according to timber plantation tables.

Cienciala et al. (2022) elaborated a list of estimated survival rate due to tree mortality and management interventions by biogeographic regions and species group types. For mediterranean conifers, they report a stand density at year 40 from plantation, of 1169 trees per hectare. Since the plantation in the restoration area has a density of 512 trees ha-1, a survival of 228.3% would lead to the final density reported by the authors.

In conclusion, currently the project has a density of 512 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 survival rate of the project at year 40. Scenario 1 estimates survival at 78.2%, and Scenario 2 estimates the 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 78.2% of planted trees and shrubs.

Therefore, 78.2% of the carbon removal potential equals 3,104.41 T CO_2-eq along 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 3,969.83 T CO_2-eq along the 40 years of the project.

Considering these 2 scenarios, the amount or carbon removals the project can generate attributable to the planted trees and shrubs lies between 3,104.41 and 3,969.83 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 10,052 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 Murcia (Spain) spanning an area of 34.1 hectares with 17,461 trees and shrubs planted, has the potential to generate between 3,104 and 3,969 Verified Carbon Credits (VCC) from removals. This range considers survival scenarios of 78.2% 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 methodology indicates a carbon capture of 1,197.50 tons over the project's lifetime, with a 50% survival rate by year 40. Applying this survival rate to the initial aOCP determined carbon capture, yields 1,984.92 TCO_2-eq. Table 6 presents a summary of the of the considerations.

Therefore, based on the information and considerations outlined above, the estimated carbon capture of this project ranges from 1,197.50 to 1,984.92 TCO_2-eq.

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%	3,969.83	3,969
	Madrigal-González et al. (2023)	78.20%	3,104.41	3,104
	Plantation Tables	100.00%	3,969.83	3,969
	Project Developer expected survival	50.00%	1,984.92	1,984
Project Developer Determined	Project Developer	50.00%	1,197.50	1,197

IV. MORTALITY RATES (PROJECT VISIT: SEPTEMBER 25-26, 2024)

The ecological restoration project "*Ecological restoration in La Junquera, Murcia*" took place between 2021 and 2024 at La Junquera farm, an area characterized by arid Mediterranean conditions with continental climatic influences due to its altitude. With an average annual rainfall of 380 mm and an average temperature of 15°C, the region presents significant environmental challenges. The soils, degraded by past intensive agriculture, are undergoing restoration through soil conservation practices and a transition to ecological almond farming. Additional measures, such as the creation of ponds and swales, have been implemented to enhance water availability.

The reforestation effort, led by Life Terra, prioritized native and resilient species, planting in both small plots and linear formations surrounding agricultural fields. Some areas were enriched with a broader range of plant species to boost biodiversity. Given the harsh environmental conditions, a high mortality rate of approximately 50% was anticipated, leading to a decision to plant at a higher density than standard for similar plots. Irrigation was provided by local workers and volunteers during the initial phase and throughout the summer months. However, during a field visit on September 25–26, 2024, Life Terra's project manager and the Nat5 audit team identified some unexpected irregularities.

Despite irrigation efforts, 2024 proved to be one of the driest years on record, resulting in significant plant mortality, estimated at 35–40%.

Moving forward, several corrective and preventative measures have been implemented:

1. Annual irrigation will be provided during the driest months.
2. Future years are not expected to be as dry as 2024.
3. Revenue from carbon credits will be shared with the landowner to support ongoing maintenance.
4. The originally projected 50% mortality rate remains within acceptable limits.
5. Replanting will occur in phases—up to 10% in Year 2 and up to 5% in Year 3.
6. The issues with livestock access and machinery have been identified and corrected.
7. All incidents were transparently communicated to the certifier and landowner.

Given these mitigation strategies, the project remains eligible for issuing carbon removal and biodiversity credits, and no further increases in mortality rates are anticipated that would impact its alignment with certification requirements. A conservative estimate of 60% survival is assumed for credit calculation following replanting in Year 2 and 3 of the project. Table 7 provides the revised carbon calculations based on findings from the field visit.

TABLE 7. ESTIMATED CARBON CAPTURE OF ECOLOGICAL RESTORATION PROJECT AT YEAR 40 FOLLOWING SEPTEMBER 2024 FIELD VISIT

	Survival Scenarios		Carbon Capture (TCO_2-eq)	Carbon credits (VCC)
aOCP Determined Pre-Visit	Total Derived	100.00%	3,969.83	3,969
	Madrigal-González et al. (2023).	78.20%	3,104.41	3,104

	Plantation Tables	100.00%	3,969.83	3,969
	Project Developer expected survival	50.00%	1,984.92	1,984
Project Developer Determined Pre-Visit	Project Developer	50.00%	1,197.50	1,197
Updated Credits Post-Project Visit	Updated aOCP Derived	60.00%	2,381.90	2,381
	Updated Project Developer	60.00%	1,437.00	1,437

Derived from the survival scenarios presented above, a **conservative approach** will be maintained for the allocation of carbon credits. This means that VCC will be awarded based on 60% of the survival rate estimated by the project developer after the project site visit (1,437 VCC).

It is important to note that carbon credits will be calculated annually in the dynamic baseline. This baseline will be adjusted based on the results of audits, monitoring, and the action plan implemented by the project developer.

35% of the credits generated by the project will be withdrawn for the buffer pool as a measure to guarantee the permanence of the project benefits (503 VCC), resulting in a total of **934 Verified Carbon Credits** to be issued according to the Contingency Table (Table 8).

TABLE 8. CONTINGENCY TABLE

Project Size (total GHG reductions & removlas)	Percentage of VCCs issued on each year (%)											
	API	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Percentage of VCCs issued on each year (%)	35	10	10	10	5	5	5	5	5	5	5	**100**
Number of VCCs issued each year	327	93	93	93	47	47	47	47	47	47	47	**934**

*API: After Project Implementation

V. RELEVANT SUSTAINABLE DEVELOPMENT GOALS

The 17 Sustainable Development Goals (SDGs), established by the United Nations in 2015, are essential in guiding restoration projects toward meaningful and enduring outcomes by addressing the interconnected nature of global challenges such as biodiversity loss, climate change, poverty, and social inequalities (https://sdgs.un.org/goals). Acting as a comprehensive framework, the SDGs enable project activities and their associated restoration and conservation efforts to align environmental, social, and economic objectives, ensuring that projects contribute not only to ecological recovery but also to broader sustainable development. By embedding these principles into restoration efforts, projects contribute not only to ecological recovery but also to the broader pursuit of sustainable development envisioned by the UN. Project initiatives can foster ecosystem resilience, support climate adaptation, enhance community livelihoods, and promote responsible resource use. This holistic approach acknowledges the intricate linkages between healthy ecosystems and human well-being, emphasizing that environmental restoration is also a pathway to achieving social equity and economic stability.

Moreover, aligning restoration projects with specific SDGs facilitates measurable progress, enhances accountability, and ensures the initiatives' relevance within a global context. It also opens pathways to partnerships with stakeholders who share a commitment to these goals, from local communities and governments to international organizations and private entities. By adopting this approach, restoration projects can amplify their impact, making meaningful contributions to global sustainability targets. The following table (Table 9) highlights the SDGs most relevant to the project initiatives, illustrating how each goal serves as a guiding principle in shaping the strategies and ensuring the long-term success of the project.

TABLE 9. SUSTAINABLE DEVELOPMENT GOALS APPLICABLE TO THE PROJECT

SDG #	Goal	Positive Benefits / Indicator
4 QUALITY EDUCATION	***Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all***	Education for sustainable development and global citizenship – Camp Altiplano, located at the site of the plantation, is responsible for planting with volunteers and schools, while providing a space for environmental education. The planting was done strictly through this organization.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	***Ensure sustainable consumption and production patterns***	Sustainable Management and use of natural resources - Life Terra engages in the compromise of sustainable management and use of natural resources through good practices reflected in the Collaboration Agreement between the foundation and the landowners.
13 CLIMATE ACTION	***Take urgent action to combat climate change and its impacts***	Enhances carbon sequestration through biomass generation and tree planting. It promotes ecological restoration, which helps enhance ecosystem resilience against climate change impacts like desertification and extreme weather events.

SDG #	Goal	Positive Benefits / Indicator
15 LIFE ON LAND	***Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss***	The reforestation effort restores degraded landscapes by planting 17,461 trees of 21 native species, supporting biodiversity and improving ecosystem functions. The project enhances soil quality, water infiltration, and overall forest health, ensuring long-term sustainability and habitat restoration.
17 PARTNERSHIPS FOR THE GOALS	***Strengthen the means of implementation and revitalize the global partnership for sustainable development***	Knowledge sharing and cooperation for access to science, technology and innovation - Life Terra's transparent action-taking enhances the possibility of third parties to access our methodologies and learn from our process. Target 17.16.: Enhance the global partnership for sustainable development - Key in Life Terra's mission, as our information and strategies are shared with our partners in several countries around the world.

This project presents a nature-based solution to environmental degradation, highlighting how strategic reforestation can enhance climate resilience, restore biodiversity, and promote sustainable land management. By sequestering carbon, improving soil quality, and increasing water infiltration, it contributes to global sustainability goals while providing long-term ecological, economic, and educational benefits to the local community.

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