ASES ON-CHAIN PROTOCOL

BASELINE FIELD REPORT

Verified Carbon Credits (VCCs)

Ecological Restoration in Santa Clara a Velha, Odemira (Portugal), Phase II

LT-015-POR-25012024 LUZIANES-GARE PHASE 2, PORTUGAL

Stichting Life Terra

Type B Project

June 7, 2024

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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 in Santa Clara a Velha, Odemira (Portugal), Phase II** project, involved the planting of a total of 38,000 trees, representing six distinct species. The primary objective of this initiative was to enhance biodiversity and improve soil quality, and water infiltration. This initiative covered plots located within the Odemira municipality, encompassing a vast area measuring 550,363.5 square meters.

The moderate-density technique was employed in this project which offers several advantages including increased yield and enhanced resource utilization. The average planting density within all plots was 1 tree every 14.5 square meters equivalent to 692 trees per hectare. The total CO_2 capture for the entire project area was calculated to be between 3,855.51 TCO_2-eq and 6,670.43 TCO_2-eq considering survival scenarios of 57.8% 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 Ecological Restoration in Santa Clara a Velha, Odemira (Portugal), Phase II demonstrates the positive impact of employing dense planting techniques and strategically selecting 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 Santa Clara a Velha, within the Odemira Municipality, Portugal. The afforested plot lies close to adjoining Scrubland and Agricultural areas. A project location map is illustrated in Figure 1. Table 1 shows the coordinates of the reforested Plots.

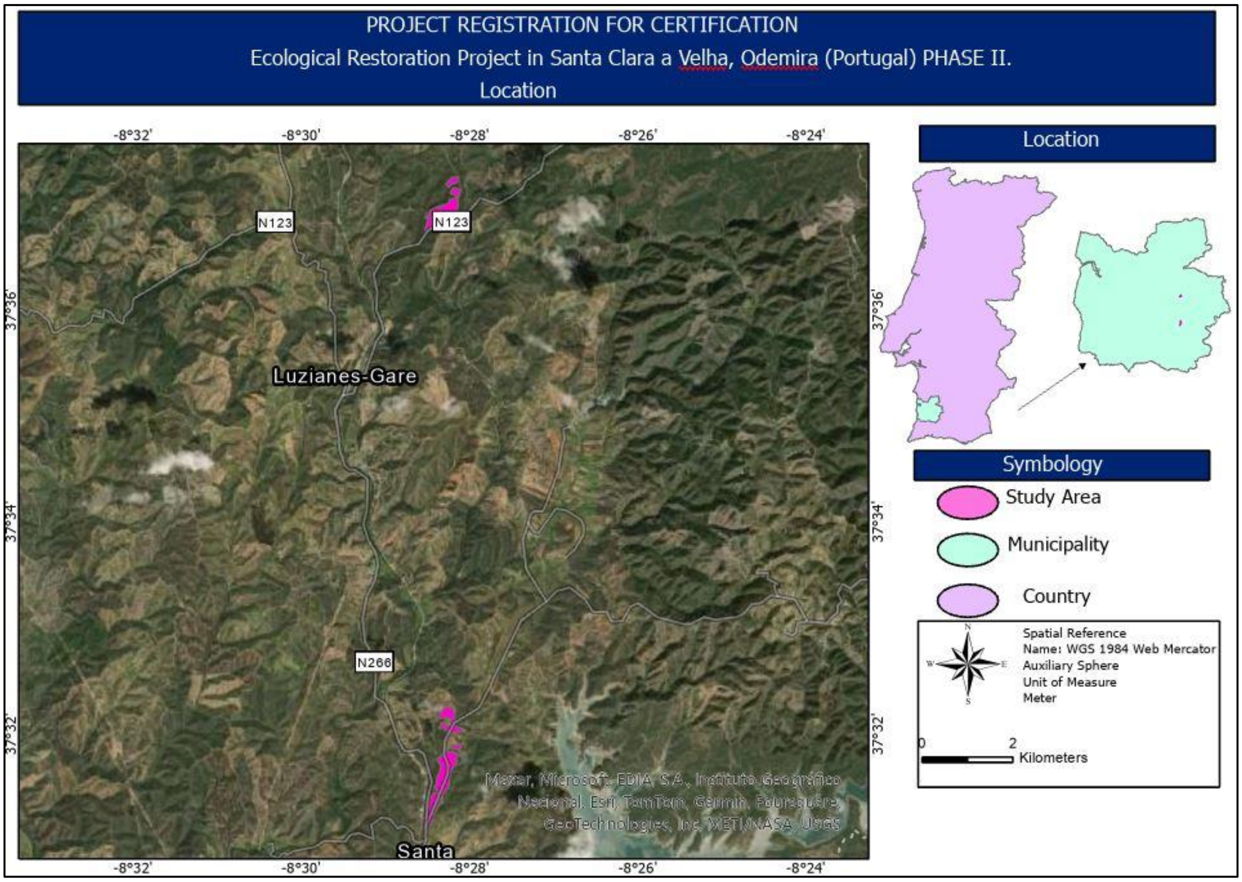


FIGURE 1. PROJECT LOCATION

TABLE 1. COORDINATES OF REFORESTED PLOTS

Plots	Coordinates	
	Latitude	Longitude
1	37.5355672°N	8.4705987°W
2	37.5314116°N	8.4691530°W
3	37.5277529°N	8.4707054°W
4	37.5219313°N	8.4740169°W
5	37.6201126°N	8.4699713°W
6	37.6143462°N	8.4733824°W

I.2. ADMINISTRATIVE SPECIFICATIONS

The administrative specifications introduce the project developer and provide 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	**LT-015-POR-25012024 LUZIANES-GARE PHASE 2, PORTUGAL**
Project name	Ecological Restoration in Santa Clara a Velha, Odemira (Portugal), Phase II
Project Developer	Stichting Life Terra
Person responsible	Sven Kallen
Fiscal address	1043 CR Ámsterdam – The Netherlands
Telephone	+31.20 2620240
Mail of the person authorized to receive notifications	sven@lifeterra.eu

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 Credit (VCC) ☒ 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 Broad-leaved Forest and Transitional woodland- shrub regions in the Odemira municipality Portugal. Adjoining land cover includes Agro-forestry areas. An evaluation of the ESA-world cover-v200 for 2021, focusing on land use and land cover, revealed that the project site was situated within shrublands, and areas predominantly covered by trees. 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, specifically selecting images with cloud cover below 30%. The assessment focused on the average monthly NDVI time series spanning from January 2019 to October 2023. The findings are presented in Figure 2, which covers both pre- and post-project implementation periods. To delineate the pre- and post-project implementation periods, it is important to note that the reforestation activities took place between December 2023 and January 2024. Consequently, all months before these dates are considered the pre-project implementation period, while months after are regarded as the post-project implementation period for this analysis. NDVI analysis shows average yearly values have remained constant since 2019, with values between 0.5 and 0.6. Regular oscillations follow precipitation patterns. No drastic changes in NDVI are observed before the second half of 2023. NDVI decrease starting in August 2023 reflects the removal of eucalyptus trees as part of the ecological restoration project.

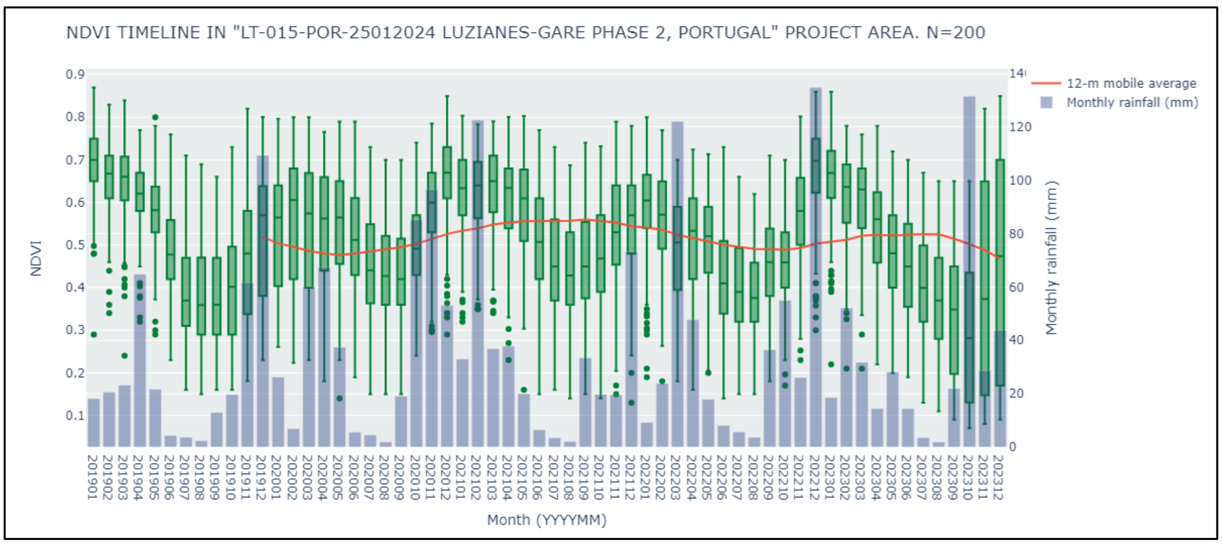


FIGURE 2. NDVI TIMELINE

II.2. IMPACT ON THE LANDSCAPE

Before reforestation, the landscape had been overrun by an invasion of Eucalyptus trees, known for their soil-depleting characteristics and their tendency to hinder natural regeneration, particularly when grown in monoculture. Given that the climatic regime of this area is characterized by extreme temperature conditions and low rainfall, this poses significant challenges as these invasive species outcompete native vegetation, alter soil composition, reduce biodiversity, and affect water availability in this region hence disrupting ecosystems.

However, the removal of these invasive species and reintroduction of autochthonous species aim to enrich biodiversity and restore soil fertility. Additionally, this plantation facilitates the colonization of native plants in the interstitial spaces, effectively doubling the restoration endeavors. Moreover, 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. A blend of species, including fruit-bearing trees and pine trees, was planted, potentially offering economic advantages alongside other benefits.

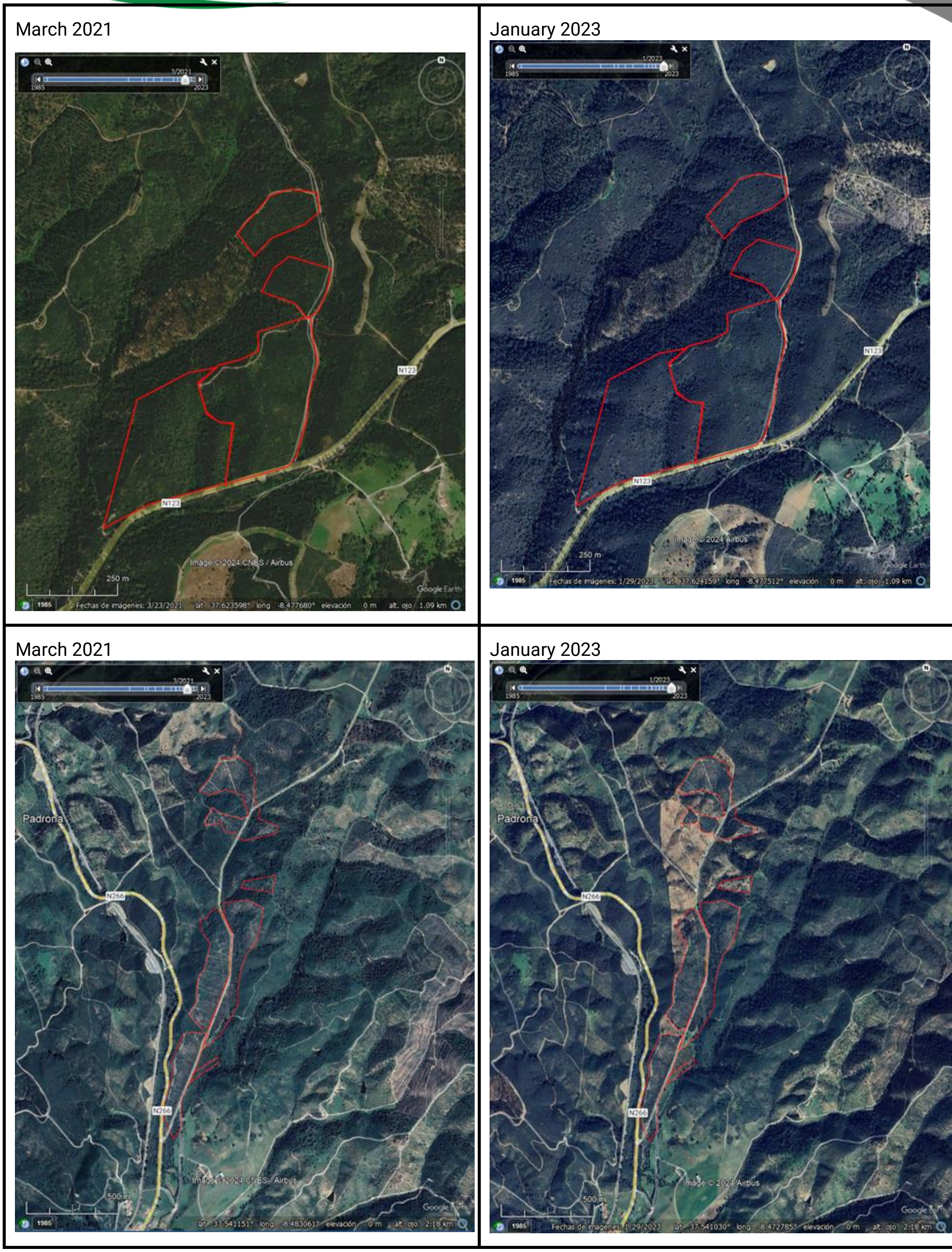


FIGURE 3. SATELLITE AERIAL VIEW OF PROJECT AREA BEFORE PROJECT IMPLEMENTATION

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 vast area measuring 550,363.5 m^2. These demarcated plots are shown in Figure 4.

III.1.2. SPECIES

The reforestation project successfully planted a total of 38,000 trees, encompassing six 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 (38,000), the percentage by species is presented in Table 2.

TABLE 2. NUMBER OF TREES BY SPECIES

Species	Number of trees	Percentage (%)
Arbutus unedo	29000	76.32
Ceratonia siliqua	2000	5.26
Olea europaea	2000	5.26
Pinus pinea	3500	9.21
Prunus dulcis	500	1.32
Quercus suber	1000	2.63
Total	**38,000**	**100%**

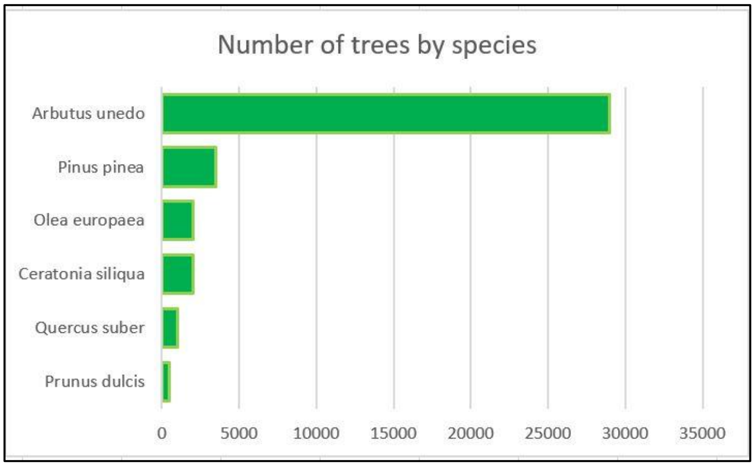


FIGURE 4. TREE SPECIES DISTRIBUTION IN PROJECT AREA

The assessment revealed an average planting density across all plots to be 1 tree every 14.5 square meters thus equivalent to 692 trees per hectare. Figure 5 shows the map planting density of the geolocalized trees within each plot with the location of each tree represented by dot symbols. 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, and 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 a “wide spacing" planting strategy, the reforestation project is well-positioned to maximize carbon sequestration potential, promote wildlife habitat, and provide essential ecosystem services.

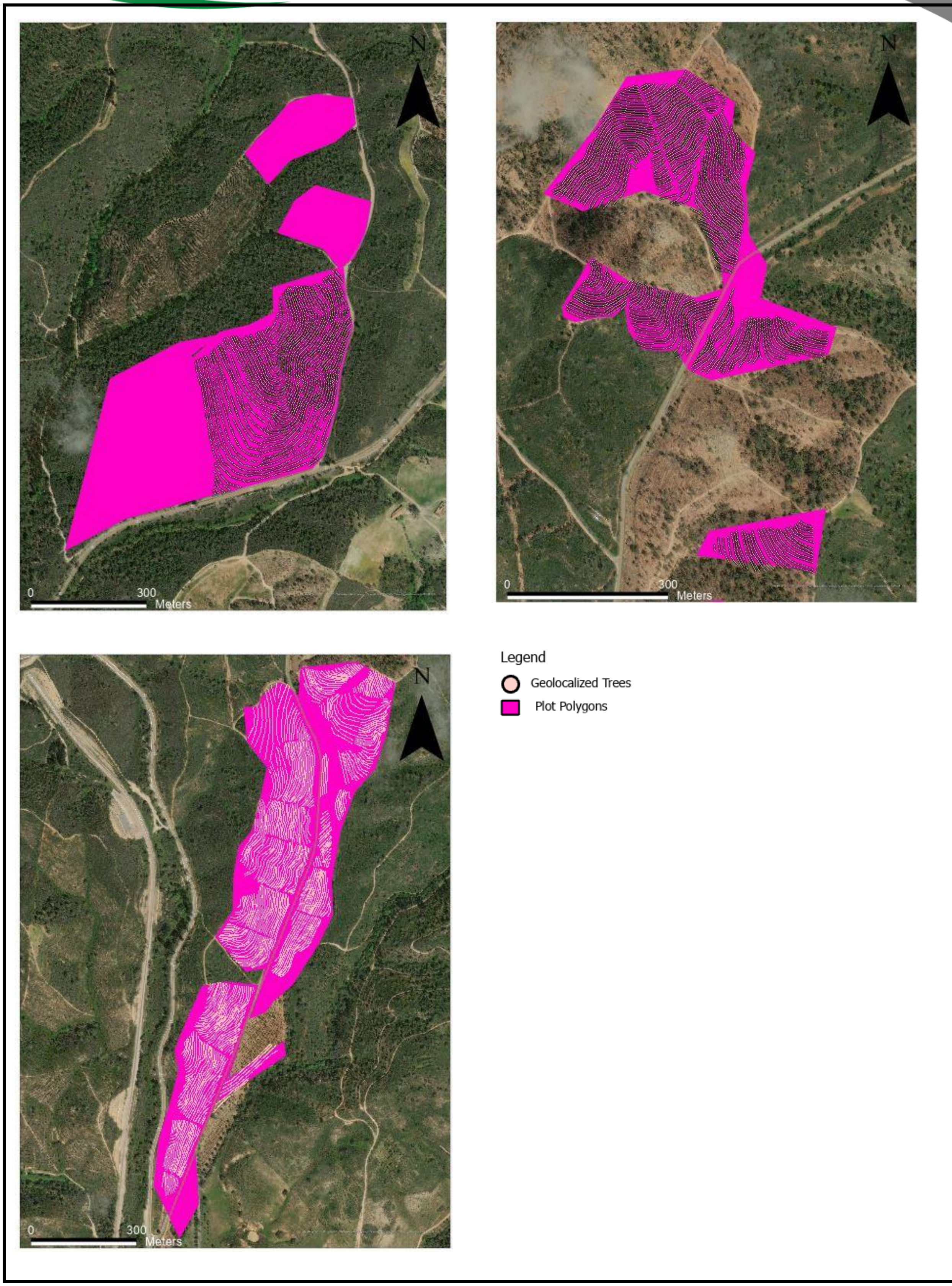


FIGURE 5. PLANTATION DISTRIBUTION

III.1.2.1. Distribution of the species selected for reforestation

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

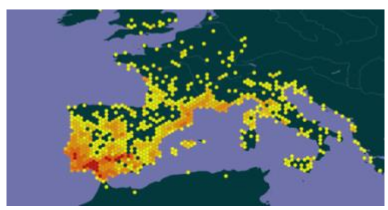
- Climate
- Soil
- Topography
- Hydrology
- Competition between plants for resources
- Seed dispersal

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.

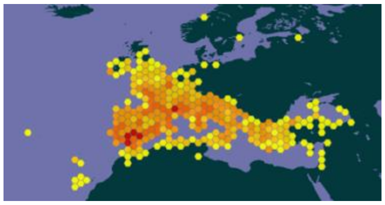
To achieve this, each species was consulted in the Global Biodiversity Information Facility GBIF (https://www.gbif.org). This database allows you to know the species classified as introduced in each country, their EUNIS habitat, their native range, and observation records.

- ***Pinus pinea***

Recorder as introduced in Portugal	☐ Yes ☒ No
Habitat EUNIS	• Coastal habitats (B level 1) • Coniferous woodland (G3 level 2) • Cultivated areas of gardens and parks (I2 level 2) • Marine habitats (A level 1)
Native range	• Europe • Southeastern Europe • Southwestern Europe • Western Asia
Georeferenced records	

- ***Arbutus unedo***

Recorder as introduced in Portugal (GRIIS)	☒ Yes ☐ No *Arbutus unedo* is a species listed as introduced in the GRIIS registry focused on the Madeira region, Portugal.

Habitat EUNIS	• Woodland and forest habitats and other wooded land (G level 1)
Native range	• Europe
Georeferenced 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 species that are widespread, 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.

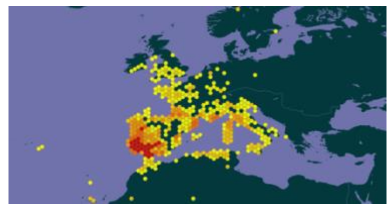
The species *Arbutus unedo*, with the taxon identifier number 38673, is **not classified as an invasive alien species** according to the GRIIS database of Madeira region, Portugal: https://www.gbif.org/species/148735798/verbatim. Therefore, its integration and counting in the project is accepted.

- ***Olea europaea***

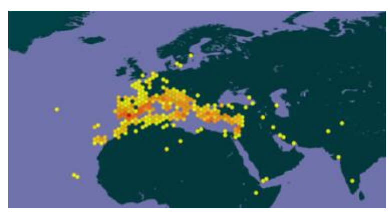
Recorder as introduced in Portugal (GRIIS)	☐ Yes ☒ No
Habitat EUNIS	Not specified
Native range	• Europe • Northern Africa

Georeferenced records	

- ***Quercus suber***

Recorder as introduced in Portugal (GRIIS)	☐ Yes ☒ No
Habitat EUNIS	Not specified
Native range	Not specified
Georeferenced records	

- ***Ceratonia siliqua***

Recorder as introduced in Portugal (GRIIS)	☐ Yes ☒ No
Habitat EUNIS	• Coastal habitats (B level 1) • Inland cliffs, rock pavements and outcrops (H3 level 2) • Low density buildings (J2 level 2)
Native range	• Europe • Northern Africa • Southeastern Europe • Southwestern Europe
Georeferenced records	

- ***Prunus dulcis***

Recorder as introduced in Portugal (GRIIS)	☐ Yes ☐ No Not specified
Habitat EUNIS	Not specified

Native range	Not specified
Georeferenced records	Not specified

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 reforestation efforts.

TABLE 3. TECHNICAL DATA SHEETS OF SPECIES USED FOR REFORESTATION

Pinus pinea • Also known as the Italian stone pine, is native to the Mediterranean region, occurring in Southern Europe and the Levant. • They have been cultivated for their edible pine nuts and are widespread in horticultural cultivation as ornamental trees, planted in gardens and parks around the world. • A coniferous evergreen tree that can exceed 25 metres in height, but 12–20 m is more typical. • Upon maturity an umbrella canopy on a thick trunk with a broad and flat crown over 8 m in width is formed.	
Arbutus unedo • Also known as the Strawberry tree is an evergreen shrub belonging to family Ericaceae. • It is native to the Mediterranean Basin and Western Europe well known for its fruits, the arbutus berry. • Grows to 4–7 m height rarely up to 15 m with a trunk diameter of up to to 80 cm. • it is fairly drought resistant, frost resistant, shade tolerant and salt tolerant.	

Olea europaea • Also known as European olive is a species of small tree or shrub in the family Oleaceae, found traditionally in the Mediterranean Basin. • A drought tolerant evergreen tree which grows up to 20-30 ft tall and 6-9 m wide. • The olive's fruit is of major agricultural importance in the Mediterranean region as the source of olive oil.	
Quercus suber • Commonly called the cork oak, is a medium-sized, evergreen oak tree native to southwest Europe and northwest Africa. • It endures drought and makes little demand on the soil quality and is regarded as a defense against desertification. • Matured tress reaches an average height of 10 to 15 meters or in rare cases up to 25 m with a trunk diameter 50 to 100 centimeters forming a dense and asymmetrical crown that starts at a height of 2–3 m. • Grown for the production of cork without killing the tree in several Mediterranean countries.	
Ceratonia siliqua • A flowering evergreen tree or shrub native to the Mediterranean region and the Middle East. • Frost-tolerant tree which grows up to 15 meters tall with broad crown supported by a thick trunk with rough brown bark and sturdy branches. • Carob trees can survive long periods of drought can adapt to a wide variety of soil conditions and are fairly salt-tolerant.	

Prunus dulcis • Commonly known as Almond is a species of tree native to Iran and surrounding countries however prospers in a moderate Mediterranean climate with warm, dry summers and mild, wet winters. • A deciduous tree growing to 4 –12.2 meters in height with a trunk of up to 30 centimeters.	

III.1.3. Reforestation technique

The reforestation technique implemented is moderate-density Planting. 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 four steps shown in Figure 6.

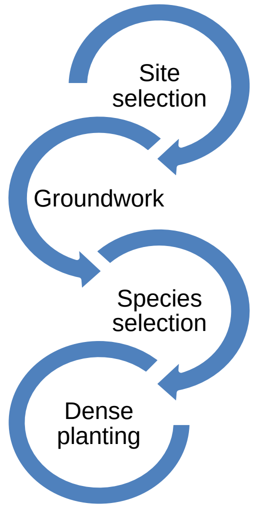


FIGURE 6. METHODOLOGICAL PROCESS

The reforestation process involved a well-defined series of steps. Firstly, a thorough evaluation was conducted to select the most suitable reforestation area, taking into account restoration needs, climatic and soil feasibility, permit requirements, and cost considerations. It ensured that the chosen location was conducive to successful reforestation. Removal of the invasive Eucalyptus species was done, after which the land was prepared with machinery for planting. Additionally, small terraces were constructed on the slopes to minimize surface runoff and optimize water retention on the site. 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 plots. The results indicate the distribution of trees across the plots as follows: 16% in Plot 1 and 84% in Plot 2. For a visual representation, refer to Figure 7, which illustrates the proportional distribution of trees among the different plots.

Plot	Number of Trees
Plot 1	32,012
Plot 2	5,988

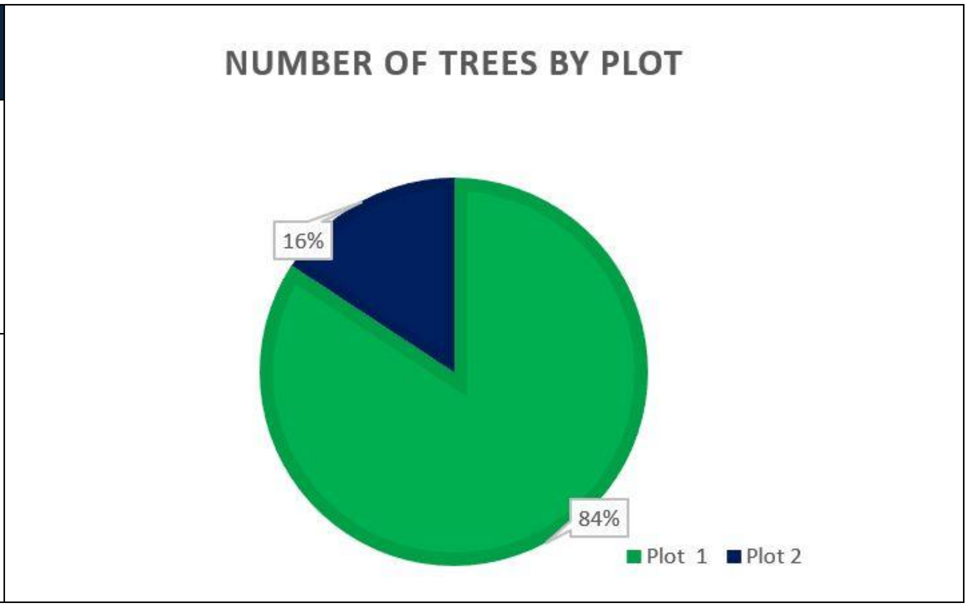


FIGURE 7. NUMBER OF TREES BY PLOT

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. 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. Distribution percentages indicate variations in tree density, highlighting areas with greater carbon absorption. Combining tree count with species-specific data allows the estimation of biomass and carbon capture potential. This provides a quantitative measure of the project's ability to absorb and sequester CO_2.

III.2. 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 at 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.

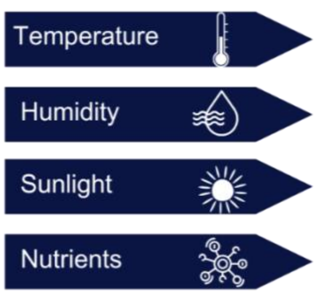
For all three approaches, Net Primary Productivity (NPP) is regarded as the upper limit, representing the maximum achievable carbon sequestration potential based on biophysical considerations.

Using Net Primary Productivity (NPP) as a reference parameter. The amount of CO_2 that can be captured is then estimated with allometric equations taking into account 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.2.1. 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 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) in either case.

For the calculation of NPP in the Luzianes-Gare (Phase 2) 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

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

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

o

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

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

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

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 CO2:C. CO2 molar mass is 44 and C is 12, therefore, 44/12 = 3.67. The conversion was done using the following equation:

$$\boldsymbol{CO_2}\ \textbf{capture capacity} = 3.67(\mathrm{NPP_c})$$

Finally, the maximal CO2 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 (Table 4) indicate that the project area currently has an NPP of 677.28 gDM m^{-2} yr^{-1}, which, due to the climatic conditions, will decrease to 600.24 gDM m^{-2} yr^{-1} in 2062. This change, of -77.04 gDM m^{-2} yr^{-1}, represents a decrease of -11.4%. In terms of CO_2, **the Project restoration area (54.91 ha) is currently capable of capturing 641,485.87 kgCO_2 yr^{-1} and is expected to capture around 568,517.62 kgCO_2 yr^{-1} by 2062**.

Based on these results, it has been determined that **568.5 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 **22,740 TCO_2-eq.**

TABLE 4. NPP AND BIOMASS ATTAINED BY ALL PLOTS WITHIN THE PROJECT SITE

NPP	Present Real Data	Present CMIP	2062 CIMP	CMIP Change	CMIP % Change	2062 Based On Real Data	Real Data Change
gDM/m2/yr	677.28	1030.15	912.97	-117.18	-11.37	600.24	-77.04
gCO2/m2/yr	1,168.24	1776.90	1,574.78	-202.12	-11.37	1,035.35	-132.89
gC/m2/yr	318.32	484.17	429.10	-55.07	-11.37	282.11	-36.21
KgCO2/plot/yr	641,485.87	975,708.91	864,723.19	-110,985.72	-11.37	568,517.62	-72,968.25

III.2.2. 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

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
Prunus dulcis	CO_2 absorbed (kg) = 3.06 + 0.30 × Total DBH (cm)	Vayreda, J., A. Quintano, A. Estiarte, and C. Romanyà. 2009. Aboveground biomass and structure of two Mediterranean coppice stands (NW Spain): role of site conditions. Forest Ecology and Management 257:1364-1372.
Ceratonia siliqua	Biomass = 0.0069 × Tree DBH (cm) × Height (m) + 0.879 × Tree DBH (cm)	Monteil, C., Beaudouin, E., Doussineau, M., Noret, G., 1996. Alometric equation for estimating CO2 capture of Ceratonia siliqua species in France. Annals of Forest Science

Species	Allometric Equation CO_2 absorbed (Kg	Reference
		53, 495–503. https://doi.org/10.1051/forest:19960512"
Pinus pinea	CO_2 capture (kg/ha/yr) = 0.032*DBH^2.063	Bourrier, A., Damesin, C., Gauthier, P., Negrón-Juárez, R., Buffo, A., Berbigier, P., & Heinesch, B. (2020). Estimation of carbon dioxide fluxes of Cedrus libani A. Richard stands in south-eastern France. Annals of Forest Science, 77(4), 21. https://doi.org/10.1007/s13595-020-00930-4
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
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.

Carbon stocks in planted trees and shrubs at year 40 were calculated by applying these allometric equations to the tree dimensions expected at age 40. The total carbon storage at year 40 for the 38,000 trees and shrubs is estimated to be 6,670.43 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.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 14.5 square meters per tree, which is fairly close to the desired 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.

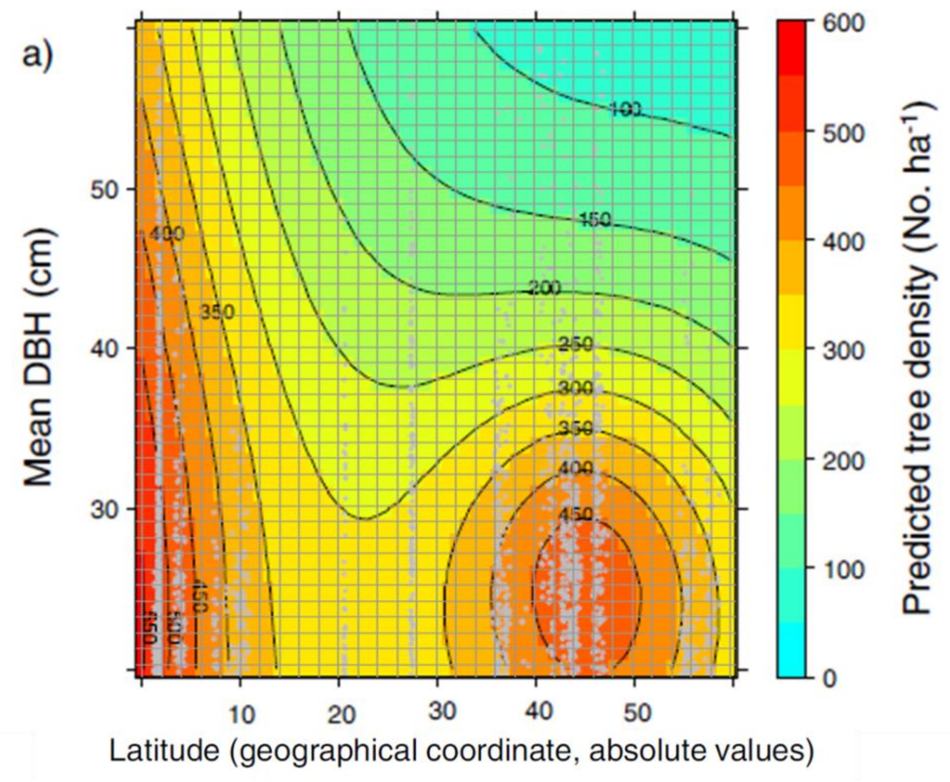
The avoidance of resource competition promotes optimal access to sunlight for photosynthesis, sufficient water uptake, and efficient nutrient absorption from the soil as defined by the Net Primary Productivity (NPP). These factors are crucial for the establishment of a sustainable and resilient forest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

III.3.1. Survival rate based on forest tree density

III.3.1.1. 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 8).

According to this reference, the predicted tree density for an area located at latitude 37°N, and with a mean tree diameter of 25.8 cm is around 400 trees per hectare. Considering that 38,000 trees and shrubs were planted in the restoration area (54.9 ha), i.e. 692 trees per hectare, a survival of 57.8% would lead to the density of 400 trees ha-1, proposed by Madrigal-González et al. (2023).



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

Figure 8. Predicted tree density as a function of mean DBH and latitude. Source: Madrigal-González et al. (2023)

III.3.1.2. 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 Mediterranean conifers, they report a stand density at year 40 from the plantation, of 1169 trees per hectare. Since the plantation in the restoration area has a density of 692 trees ha-1, a survival of 168.9% would lead to the final density reported by the authors.

In conclusion, currently, the project has a density of 692 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. One estimates survival at 57.8% and the other at over 100%.

III.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 survival of 57.8% of planted trees and shrubs. Therefore, 57.8% of the carbon removal potential equals 3,855.51 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 the survival of 100% of planted trees and shrubs. Therefore, 100% of the carbon removal potential equals 6,670.43 T CO2-eq along 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 3,855.51 and 6,670.43 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 22,740 TCO_2-eq, to ensure adherence to biophysical ecological limits, thus avoiding overestimates.

III.4. VERIFIED CARBON CREDITS VCC CALCULATION

According to *aOCP Methodology for carbon removal and storage in vegetation V2.0,* this ecological restoration project in Luzianes- Gare Phase 2 (Portugal) spanning an area of 55.04 hectares with 38,000 trees and shrubs planted, has the potential to generate between 3,855.51 and 6,670.43 Verified Carbon Credits (VCC) from removals. This range considers survival scenarios of 57.8% 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 2,713.00 tons over the project's lifetime, with a 50% survival rate by year 40. Applying this survival rate to the initially aOCP-determined carbon capture yields 3,335.21 TCO_2-eq. Table 5 presents a summary of the of the aforementioned considerations.

Therefore, based on the information and considerations outlined above, the estimated carbon capture of this project ranges from **2,713.00** to **3,335.21** TCO_2-eq using both the aOCP and the project developer's methodology.

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

Survival Scenarios			Carbon Capture (TCO_2-eq)	Verified Carbon Credits (VCC)
aOCP Determined	Total Derived	100.00%	6,670.43	6,670
	Madrigal-González et al. (2023).	57.80%	3,855.51	3,855
	Plantation Tables	100.00%	6,670.43	6,670
	Project Developer expected survival	**50.00%**	**3,335.21**	**3,335**
Project Developer Determined	Project Developer	50.00%	2,713.00	2,713
	Project Developer	100.00%	5,426.00	5,426

The Project Developer has estimated a 50% survival rate, the calculation to determine the number of credits will be carried out with this survival percentage (50%), resulting in a total of **3,335 Verified Carbon Credits** which will be granted for the project benefits.

III.4.1. ISSUANCE OF VCC

As established in section *III.1.5.* of the *Project Procedures V.2.2* document, **25%** 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 (834 credits), resulting in a total of **2,501 Verified Carbon Credits** to be delivered to the Project proponent according to the Contingency Table (Table 7).

TABLE 7. VERIFIED CARBON CREDITS ISSUED ANNUALLY

Verified Carbon Credits issued annually												
Project Size (total GHG reductions & removals)	Percentage of VCCs issued on each year (%)											
	After project implementation	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	Total
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	875	250	250	250	125	125	125	125	125	125	125	**2,501**

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