ASES ON-CHAIN PROTOCOL

BASELINE FIELD REPORT

Forest 4Future Lentillères

LT-002-LEN-052023 LENTILLERES, ARDECHE
Lentillères, Ardèche
Type B Project

May 2023

https://www.nat5.bio

TABLE OF CONTENTS

INDEX OF TABLES

INDEX OF FIGURES

EXECUTIVE SUMMARY

The baseline report of the projects is a necessary activity for their certification since it will allow for establishing the initial parameter of the area through the NDVI index, which is an indicator used to evaluate the vegetation and the health of the plants, thus allowing us to establish the scenario prior to the planting activities. It will also be the comparative basis for the quarterly monitoring of the project, which will be prepared following the *"aOCP Methodology for satellite monitoring of projects V2.0"*. In addition, the Baseline report allows for establishing the number of credits to which each project may aspire according to the characteristics of the project that has been developed and based on the aOCP calculation Methodologies.

Forest 4Future is a project developed by the promoters Life Terra and 2°much!, which is located in the community of Lentillères, department of Ardèche, in the south of France. The project proponent has an agreement with the landowner for the use of the land for a term of 40 years, so that during this period no actions may be taken that disturb or damage the plantation and the groundworks.

The site where the project was developed is an area with high disturbance due to deforestation, so prior to the restoration activities the area had areas devoid of vegetation and problems due to water erosion.

The project consisted of planting 1078 trees of 30 different species in an area of 5680.48 m^2, with an average density of 1 or 2 individuals per square meter. In addition, 13.75 tn of biomass collected in the project area, mainly unused wood of the *Castanea Sativa* species, was used to build soil retention and water catchment works. The works consisted of the creation of barriers or retention structures that will reduce soil erosion.

Reforestation in addition to ground works promotes ecosystem restoration by controlling erosion, avoiding excessive loss of fertile soil, and preventing land degradation. They also contribute to improving soil quality, protecting local biodiversity, improving water quality, and are allies in the fight against climate change.

The Forest 4Future Project will allow the removal of **210 tons of carbon** during its useful life (40 years), calculated using the *"aOCP Methodology for carbon removal and storage in vegetation V2.0"*, which will be monitored quarterly as defined in the Project Monitoring Plan (Annex 1), following the *"aOCP Methodology for carbon removal monitoring V1.0"*. In addition, **390 Verified Biodiversity Based Credits (VBBCs)** will be issued for the project's biodiversity benefits, which were measured following the *"aOCP Methodology for biodiversity assessment V2.0".*

As the project has also generated benefits to erosion control and water retention, **1296 Verified Soil Credits (VSCs)** will be issued for erosion prevention, calculated from the *"aOCP Methodology for soil and erosion assessment V2.0";* in addition to **2112 Verified Water Credits (VWCs)**, estimated using the *"aOCP Methodology for water balance assessment V2.0".*

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 municipality of Lentillères, department 07 “Ardèche” belonging to the region “Auvergne-Rhône-Alpes ” (Figure 1). The central coordinate of the project area is X 802150 and Y 6390944 (RGE93 Lambert 93).

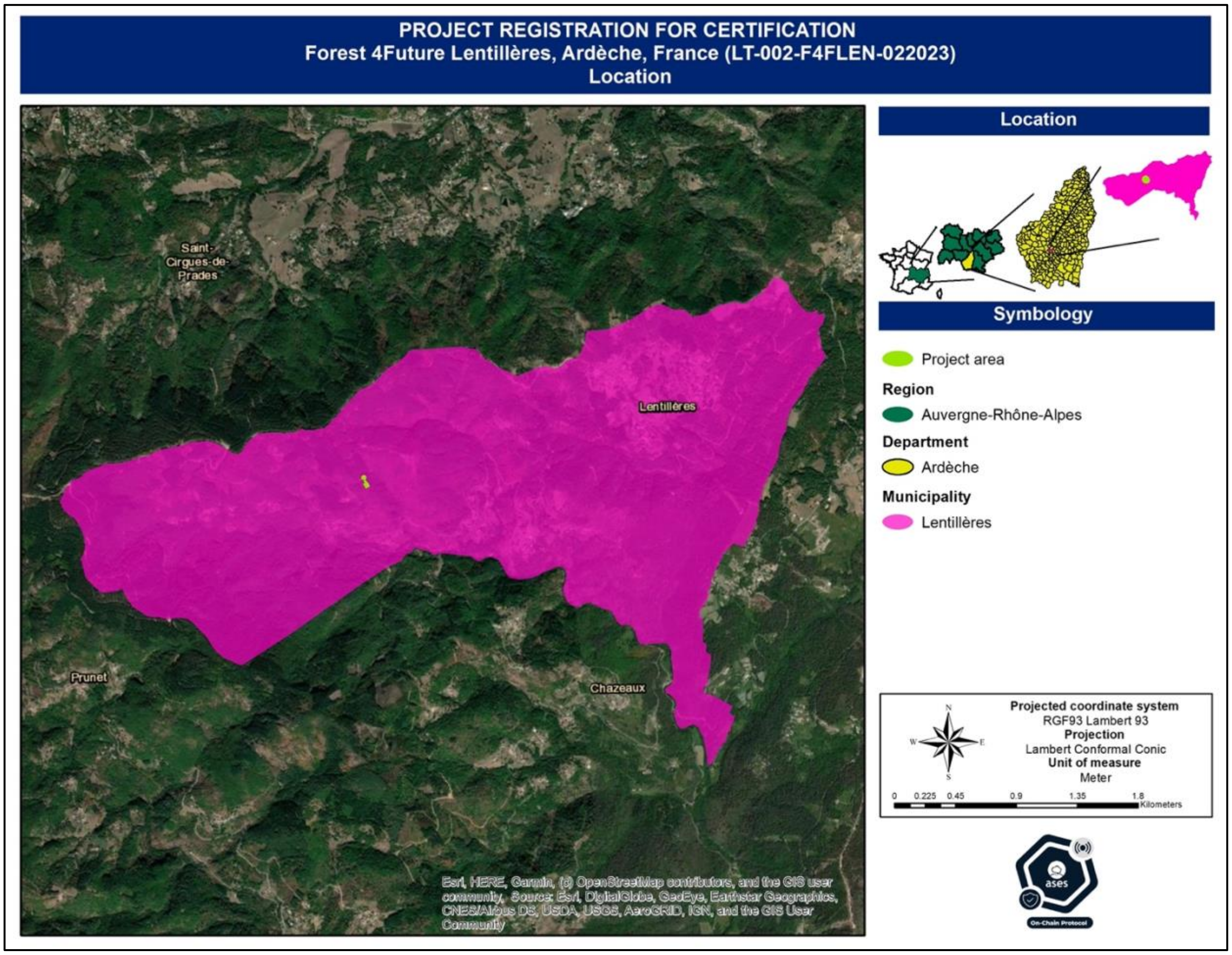


FIGURE 1. PROJECT LOCATION

I.2. Administrative specifications

The administrative specifications introduce the project developer and establish the roles and responsibilities of each of the parties involved, as well as clarify the status of land ownership and give certainty to the agreements reached with the land owners.

I.2.1. Project developer

Key project	LT-002-LEN-052023 LENTILLERES, ARDECHE
Title of the project activity	Lentillères, Ardèche, France
Company	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

Type of VNPCs the project is applying for	☒ Carbon Credit (VCC) ☒ Biodiversity Based Credit (VBBC) ☒ Water Credits (VWC) ☒ Climate action bond

II. PROJECT AREA BASELINE

According to mapping information from CORINE Land Cover (CLC) of France, the project area is located in a broadleaf forest zone (Figure 2), represented by vegetation formation composed mainly of trees, including shrubs and bush understorey. However, this area suffered degradation due to logging for the exploitation of its resources, specifically the species *Pseudotsuga menziess.*

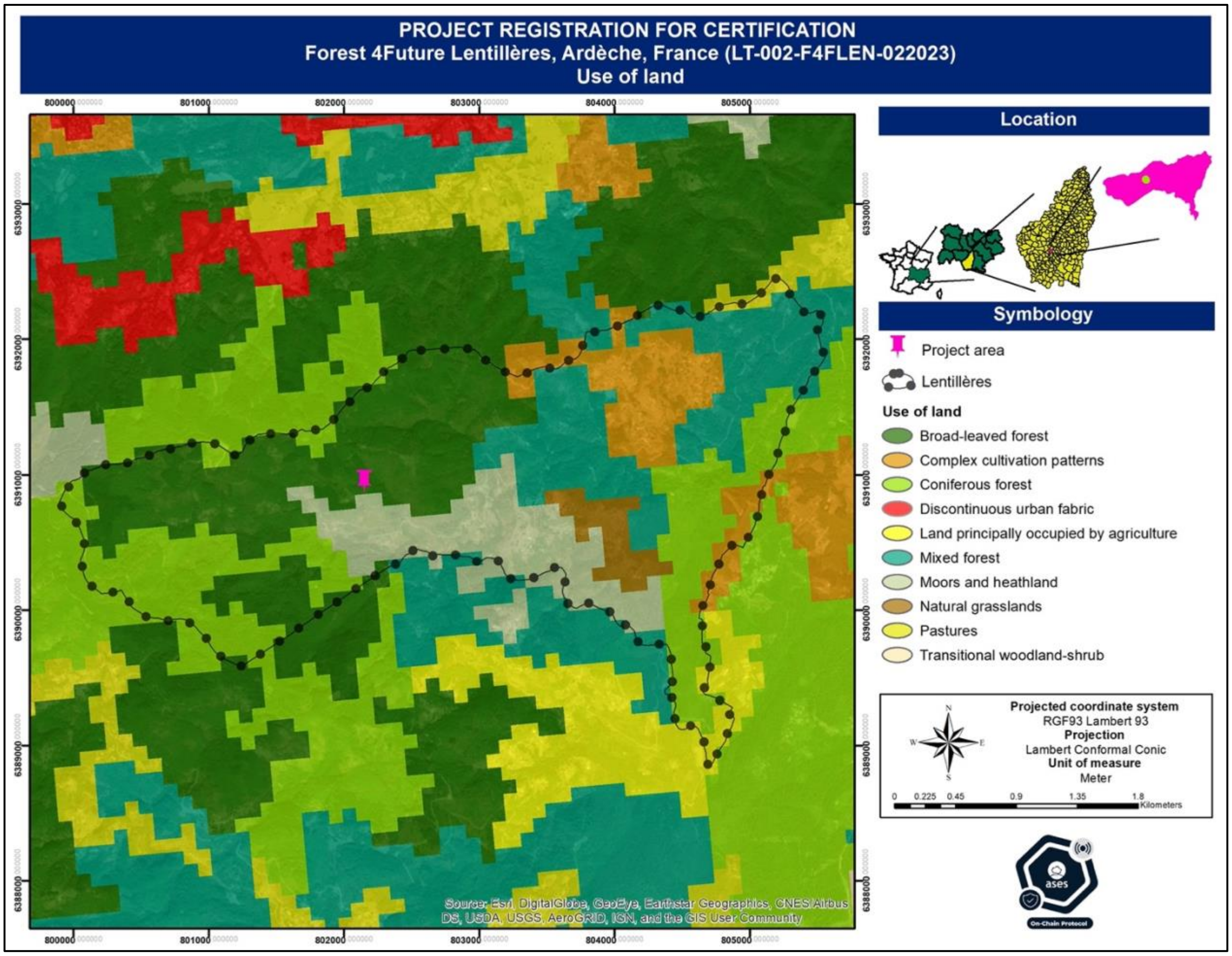


FIGURE 2. USE OF LAND

This excessive logging caused deforestation and soil degradation in the project area, resulting in areas highly impacted by erosion (Figures 3-4). Erosion is a natural process, but it is also caused by human activities (deforestation), this process causes the topsoil to be removed and transported mainly by water and wind. In turn, erosion causes other problems such as:

- **Loss of fertile soil:** the topsoil, which is rich in nutrients and organic matter, is removed and soil fertility is lost.
- **Waterbody sedimentation:** eroded and entrained sediments can be deposited in rivers, lakes, and streams, reducing water quality, blocking waterways, and raising the danger of inundation.

- **Biodiversity loss:** erosion damages natural ecosystems and puts at risk the survival of species, particularly those that depend on healthy and stable soils.

FIGURE 3. ERODED AREA

FIGURE 4. ERODED AREA

Soil loss due to erosion was calculated using the RUSLE methodology, resulting in a soil loss of 0.02 tn per year on the project area surface.

II.1. ECOLOGICAL ADDITIONALITY

II.1.1. LOCATION ECOSYSTEM CONTEXT

The plot is located in a "Broadleaved deciduous woodland" and "Mixed deciduous and coniferous woodland" ecosystem classified by the EUNIS system. In a radius of 300 meters and 500 meters, there are four types of ecosystems as showed in the image below. Where, "Broadleaved deciduous woodland" has the largest surface.

In this type of ecosystem lives many species of biodiversity. However, it is one of the most affected by deforestation because of human use of its fertile soil.

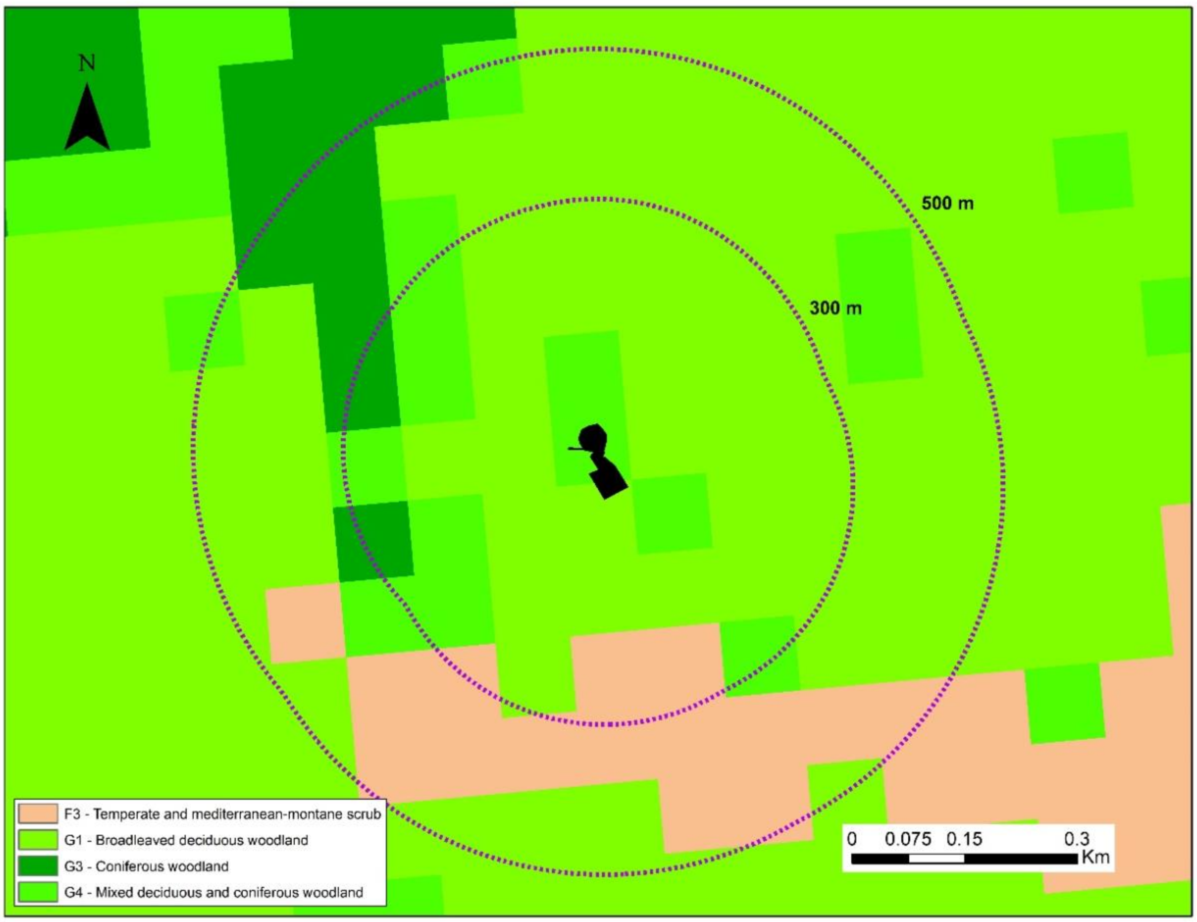


FIGURE 5. TYPE OF ECOSYSTEM

This reforestation helped to fill in a gap in the broadleaved deciduous woodland. Also, meenwile it is growing, the biodiversity will regain habitat.

II.1.2. MANAGE CONTEXT

In November 2021 the plot had an important deforestation that resulted in biodiversity lost, water erosion and discontinuity of the ecosystems as shown in the images below.

		
8/2015 (Google Earth)	**8/2018 (Google Earth)**	**6/2022 (Google Earth)**

Without the project, the soil would continue to erode since it would continue without vegetation cover. This erosion in turn generates an environmental imbalance, the soil is less and less fertile and the disappearance of species would follow. It is important to recover degraded soils to maintain a healthy environment. In addition, sustainable forest management is essential.

In the area there is an increment of gaps of deforestation because the human settlements are growing slowly so the benefits of this type of project are very beneficial. Not only because of the carbon capture. The reforestation brings more habitat for biodiversity and counter soil erosion.

II.1. Spectral response

When solar radiation strikes any object, one of three situations arises, a combination of some or all of them. - Radiation can be reflected. That is, it bounces off the object completely or partially. - Also, radiation can be absorbed. - Finally, radiation can be transmitted. That is, radiation passes from one object to another. The amount of radiation reflected, absorbed, or transmitted depends on the physicochemical characteristics of the objects. However, for identification, we are most interested in the reflected light or radiation at different wavelengths. For example, vegetation has low reflectance in the visible range, however, the reflectance in the green channel is increased by the chlorophyll in plants. On the other hand, the highest reflectance that plants have is in the near-infrared region of the spectromagnetic spectrum.

II.1.1. Index

Vegetation indices (VI) have been widely used to monitor and detect changes in vegetation and land cover. The development of vegetation indices is based on differential absorption, transmittance, and reflectance of energy by vegetation in the red and near-infrared regions of the electromagnetic spectrum. Several studies have indicated that only the Normalized Difference

Vegetation Index (NDVI) is less affected by topographic factors. Several studies have indicated that only the Normalized Difference Vegetation Index (NDVI) is the least affected by topographic factors. NDVI is often used as a general indicator of plant photosynthetic activity and associated above-ground primary production.

NDVI was calculated using Sentinel-2 satellite images from Copernicus Open Access Hub (https://scihub.copernicus.eu/dhus/#/home). The study area usually is covered with clouds, so for the observed period we selected the images closest to the event. Being there from June to October. This resulted in a collection of 8 images, 7 before and 1 after the works. Figure 5 shows the Sentinel-2 pixel locations and numbering used for the analyses. Figure 6 shows the comparison of NDVI at Square Lentillères before and after the project activities.

FIGURE 6. OVERLAY OF THE SENTINEL-2 PIXEL CONTOURS AND NUMBERS OVER AN IMAGE OF THE AREA OF INTEREST

Figure 6, the left panel corresponds to October, the first scene before reforestation, and the right panel, in March after reforestation.

We can see that there are lower values of NDVI in the scene post-reforestation.

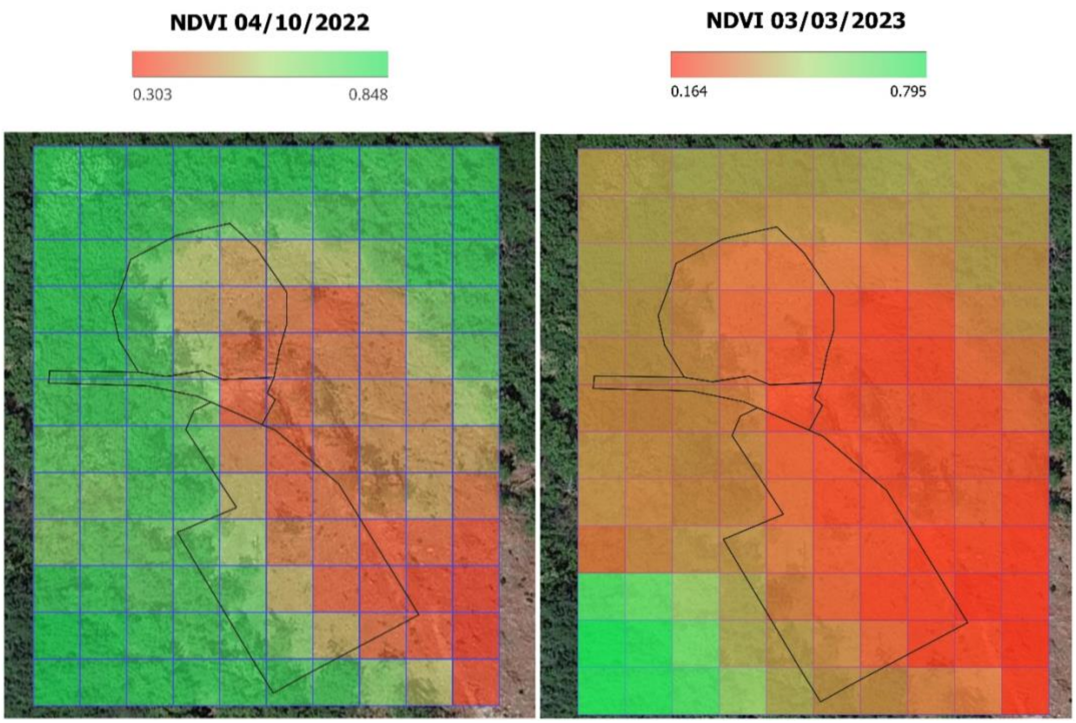


FIGURE 7. NDVI IN THE AREA OF INTEREST

From the NDVI time series, Figure 7 was produced for the pixels where project activities took place.

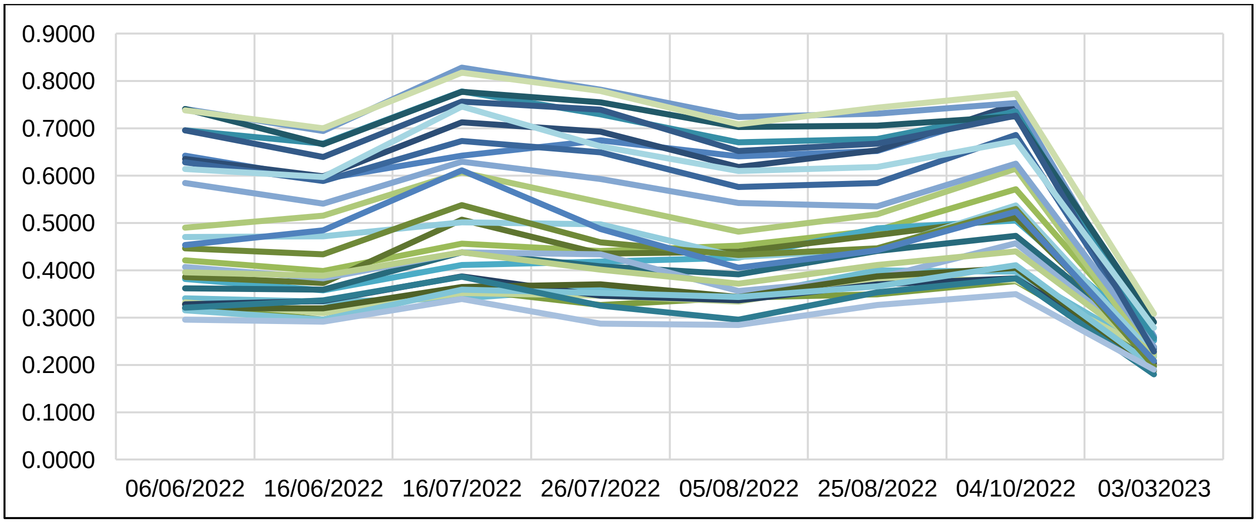


FIGURE 8. NDVI TIMELINE AT THE PROJECT AREA

Likewise, the average NDVI was calculated for each pixel of the Sentinel-2 images where reforestation activities were carried out, for 3 previous dates. The results are shown in Figure 8. It is observed that in all pixels there was a decrease in NDVI. The overall average NDVI in the pixels of interest was 0.5 before the works and 0.23 after the works.

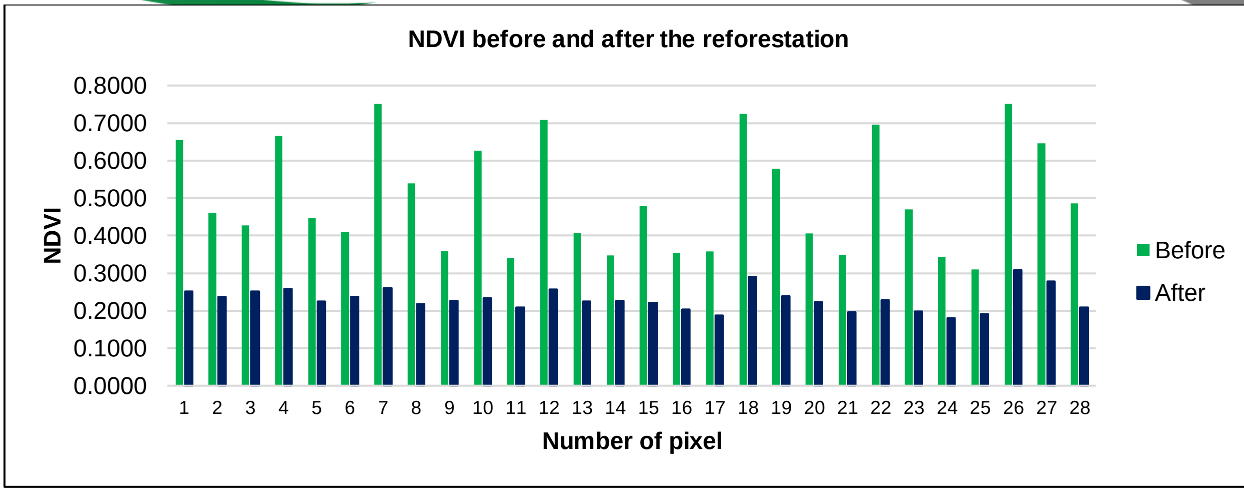


FIGURE 9. NDVI BEFORE AND AFTER THE REFORESTATION

II.2. SPECTRAL COMPOSITION

A false-color image is used to reveal or enhance features that would otherwise be invisible or inconspicuous to the human eye. In a false-color image made with the NIR (near infrared), red and green bands will give all vegetation a distinctive red color, allowing the human eye to more easily distinguish it from its surroundings. This is possible due to the high reflectance of the plants in the NIR region.

False color compositing was performed for the area of interest, before and after the reforestation activities (Figure 9).

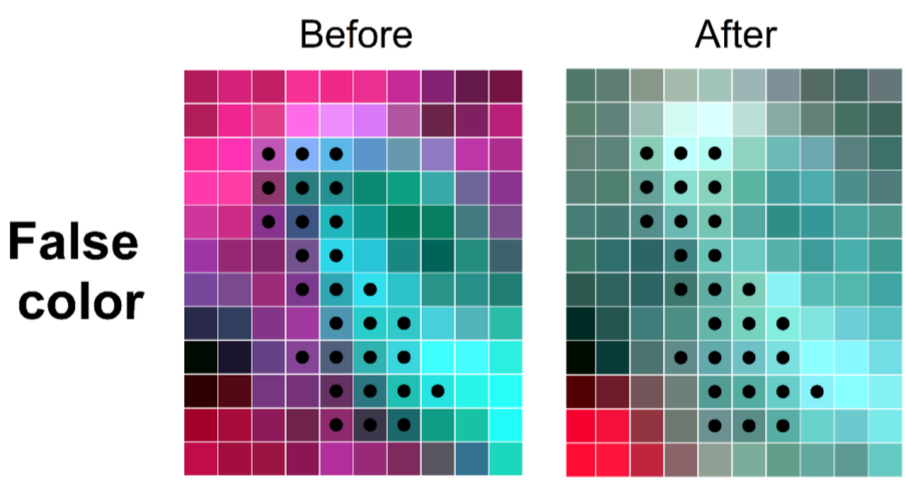


FIGURE 10. FALSE COLOR COMPOSITION (NIR, R, G) FOR THE AREA OF INTEREST BEFORE AND AFTER REFORESTATION

In the figure above, the reddish areas highlight the existence of vegetation, and the blues the lack of vegetation. In this case, there is a significant change before and after the reforestation.

II.3. Landscape

The satellite verification should also address the visual impact that the project generated in the area and its surroundings.

Figure 10 corresponds to a satellite image with an aerial view of the project area before the reforestation activities (the year 2022), in which the ecological disturbance of the area is observed as it is completely devoid of vegetation, causing an island of fragmentation in the ecosystem.

Fragmentation prevents local fauna from being present in the area, which reduces biodiversity and causes a series of environmental impacts. Reducing the fragmentation phenomenon by means of reforestation driven by water and soil restoration works will contribute to the complete recovery of the ecosystem system.

Figure 11. Aerial photo before groundwork, 2022

FIGURE 12. AERIAL PHOTO CAPTURED WITH A DRONE AFTER PROJECT IMPLEMENTATION (FEB2022)

III. TECHNICAL SPECIFICATIONS

III.1. CARBON REMOVAL

This section analyzes the carbon sequestration expected by the project from the reforestation and soil works constructed.

III.1.1. REFORESTATION

III.1.1.1. Reforested area

The project area covers an area of 5,680.48 m^2 and is composed of three segments: segment one with an approximate area of 1,919.04 m^2 is located to the north of the polygonal area, segment two in a rectangular shape is located in the center part and covers an area of 418.42 m^2 and finally, segment three is the largest in terms of area and has 3,342.10 m^2 covering the entire south part of the project area (Figure 12).

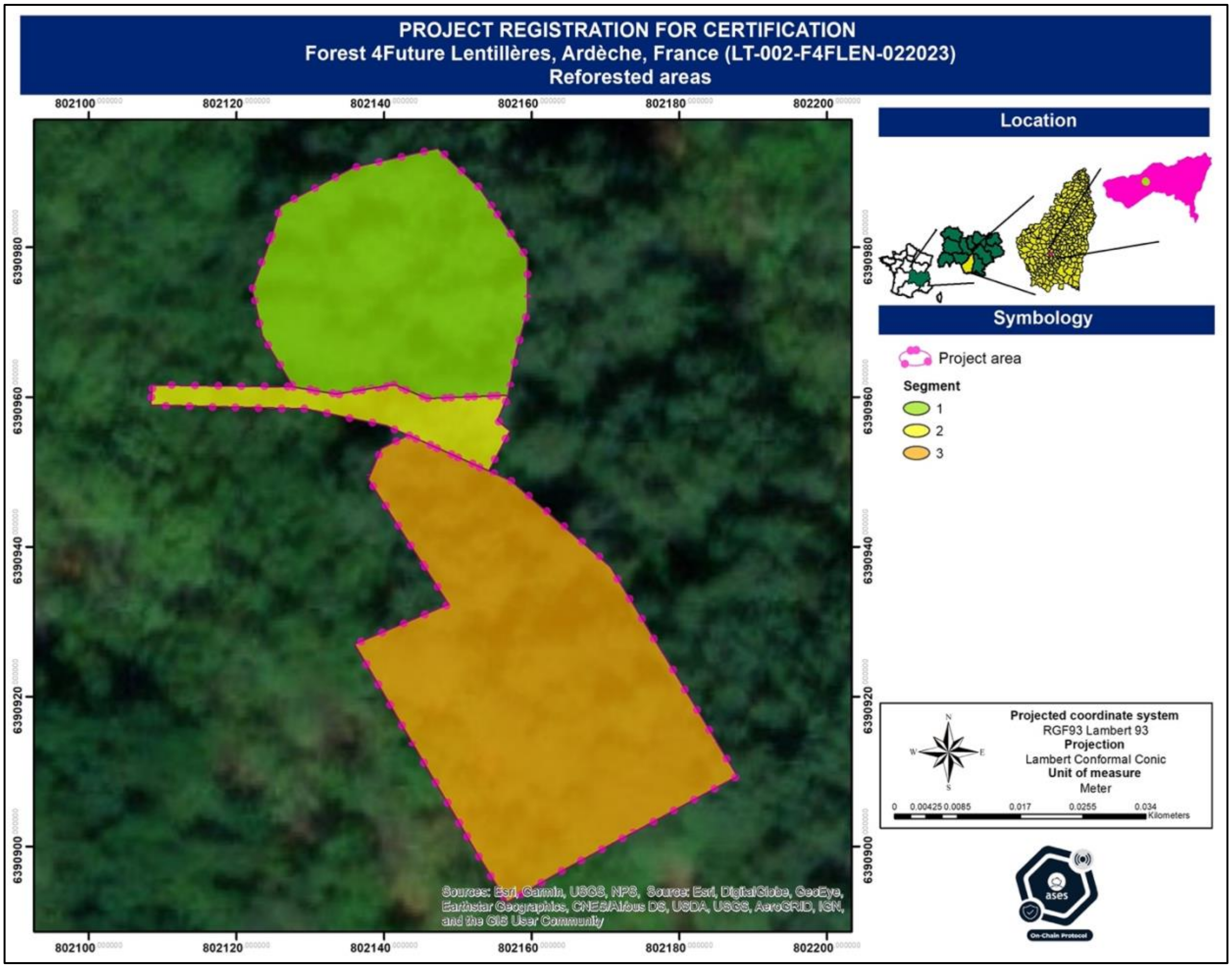


FIGURE 13. REFORESTATION AREA

III.1.1.2. Species

The reforestation was carried out with 30 different species (Table 1), species selection was determined by preliminary identification of the species present in the region based on existing bibliographic information as well as existing climatic, vegetational, and meteorological conditions.

Of the 1,078 trees planted, 9.65% are *Quercus coccifera* specie, 8.81% are *Quercus ilex,* 7.42% are *Ficus carica, 7.24%* are Ceratonia siliqua, 5.94% are *Quercus suber* and 60.95% are distributed among the remaining 25 species, as shown in Figure 13.

TABLE 1. NUMBER OF TREES BY SPECIESV

Specie	Number of trees	Percentage
Fraxinus angustifolia	5	0.46%
Pinus pinea	14	1.30%
Cedrus atlantica	15	1.39%
Cedrus libani	15	1.39%
Prunus spinosa	15	1.39%
Sequoia sempervirens	15	1.39%
Olea europea arberquina	18	1.67%
Acer monspessulanum	19	1.76%
Cupressus sempervirens	19	1.76%
Crataegus monogyna	20	1.86%
Quercus petrea	20	1.86%
Sequoiadendron giganteum	20	1.86%
Cryptomeria japonica	21	1.95%
Olea europea picual	21	1.95%
Prunus mahaleb	23	2.13%
Pseudotsuga menziessi	24	2.23%
Rhamnus lycioides	25	2.32%
Salix purpurea	34	3.15%
Pistacia terebinthus	37	3.43%
Pinus halepensis	40	3.71%
Taxus baccata	43	3.99%
Acer campestre	45	4.17%
Fraxinus excelsior	45	4.17%
Pistacia lentiscus	50	4.64%
Corylus colurna	54	5.01%
Quercus suber	64	5.94%
Ceratonia siliqua	78	7.24%
Ficus carica	80	7.42%

Specie	Number of trees	Percentage
Quercus ilex	95	8.81%
Quercus coccifera	104	9.65%
Total	**1078**	**100%**

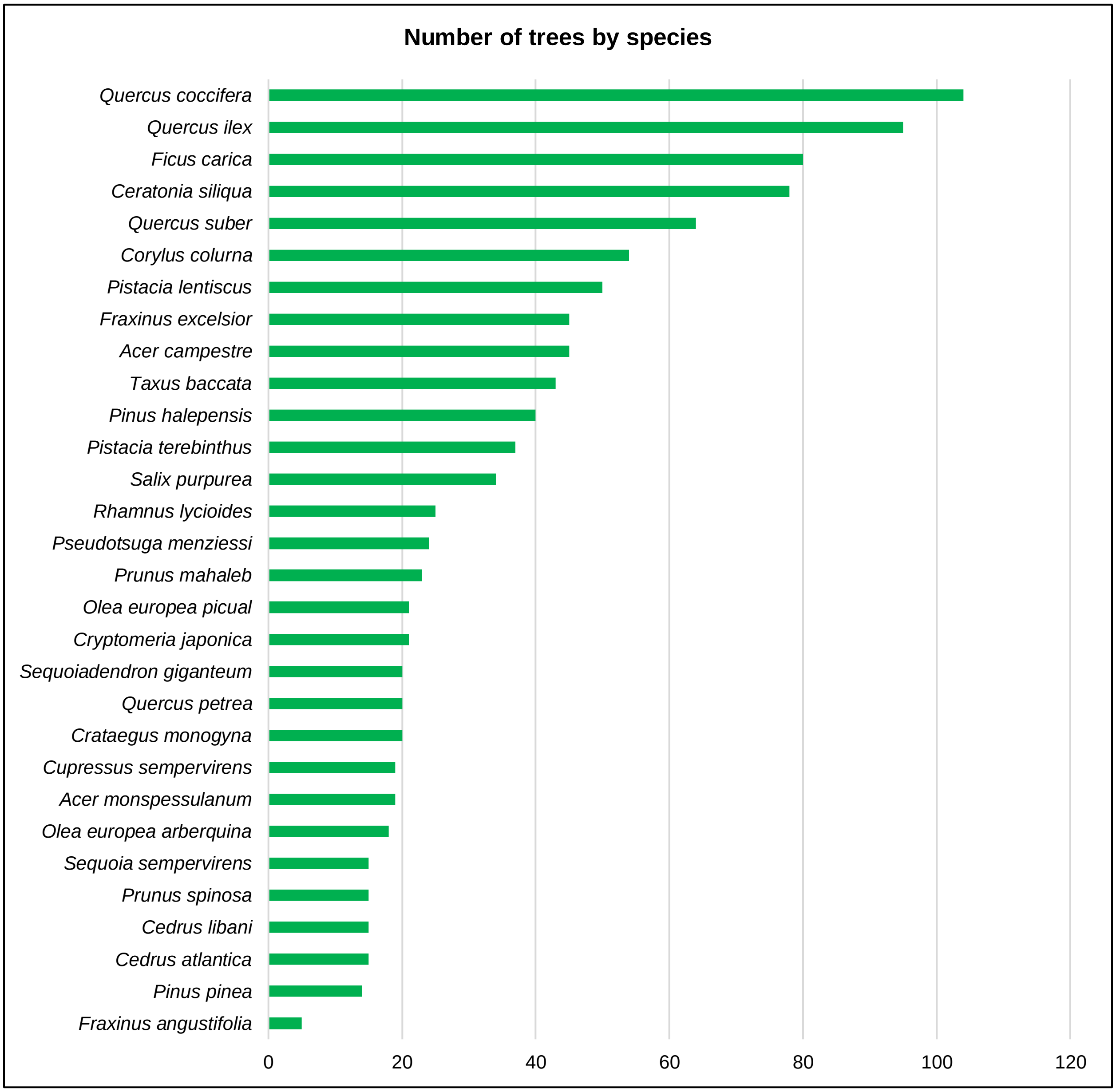


Figure 14. Number of trees by species

On average there is a density of 1 or 2 trees per square meter, which varies depending on the segment (Figure 14).

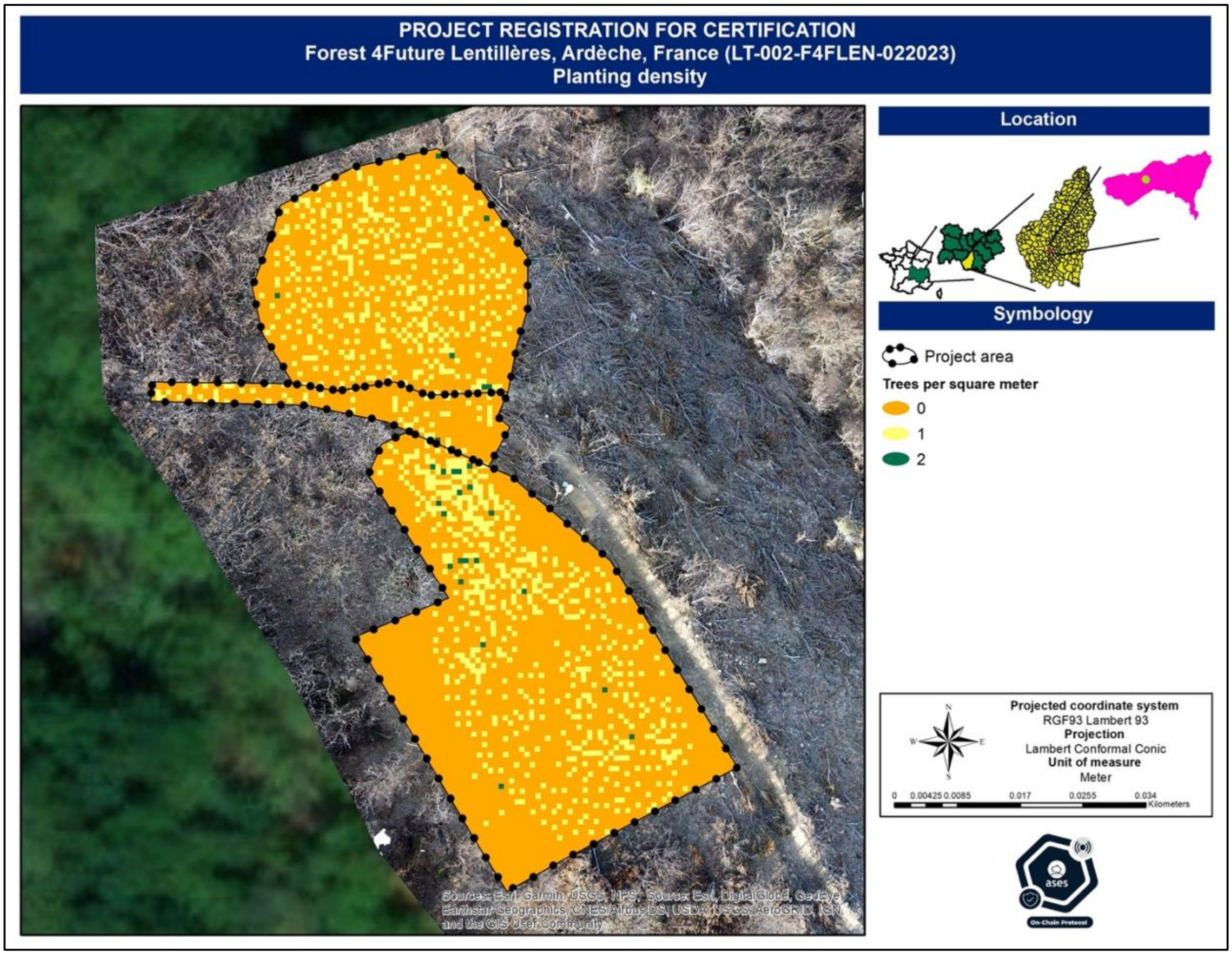


FIGURE 15. PLANTATION DENSITY

The technical data sheets of the species used for reforestation are included down below.

III.1.1.3. Reforestation technique

The project used the densified reforestation technique, which consists of planting a greater number of trees per unit area, and establishing seedlings closer together, compared to traditional reforestation techniques.

This technique benefits the acceleration of the forest recovery process by having more trees growing in the area, increasing competition for light, nutrients, and water, which stimulates faster tree growth. In addition, it benefits biodiversity by creating a denser environment, providing more habitats and resources for various plant and animal species, and promoting biodiversity.

III.1.1.3.1. Methodological process

The operational phase is divided into four steps shown in Figure 15.

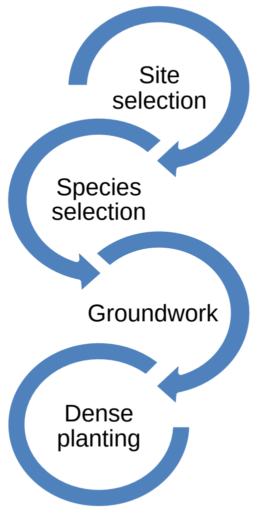


FIGURE 16. METHODOLOGICAL PROCESS

The planting area was selected in the first stage. This was based on climatic and soil feasibility, permits, and costs.

After the area restoration was selected and authorized, the second stage consisted of species selection. Thirty species of trees and shrubs were selected for reforestation, the mix of plant associations, complementarity between species, climate change resilience and adaptability, and capacity for soil restoration were taken into account.

The next step was the cleanup of the project areas (removing weeds, garbage, and other debris), following that, the three planting segments were chosen, and the plant holes were excavated.

In the last stage, the planting of tree seedlings was carried out with a dense of 1 to 2 trees per square meter. In addition, they were strategically mixed to create small communities of species.

III.1.1.4. Geolocalization of planted trees

The geolocation of the trees was carried out manually using the photointerpretation technique based on the ortho mosaic generated with the drone, which was obtained at a spatial resolution of 1.4 mm per pixel.

The distribution of the trees is 38.78% in segment one, 5.84% in segment two, and 55.38% in segment three, as shown in Figure 16.

Segment	Number of trees
1	418
2	63
3	597

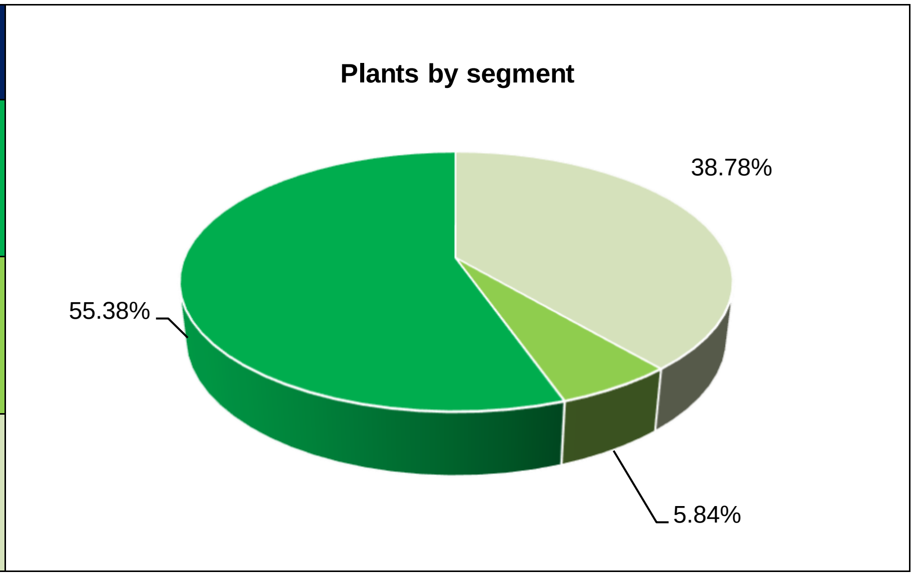


FIGURE 17. NUMBER OF PLANTS BY SEGMENT

The location of each tree is represented by dots shown in Figure 17.

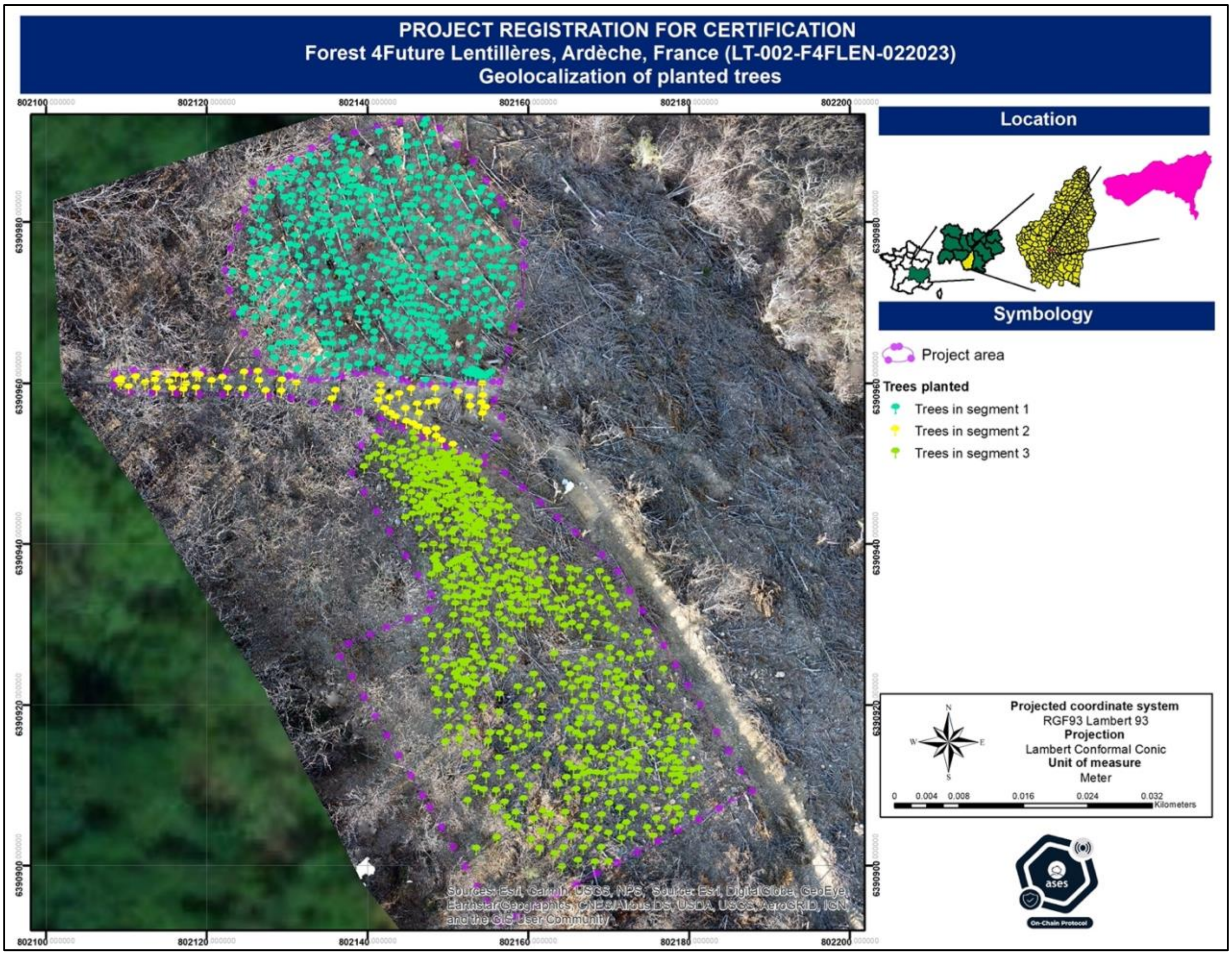


FIGURE 18. GEOLOCALIZATION OF PLANTED TREES

III.1.1.5. Project capacity

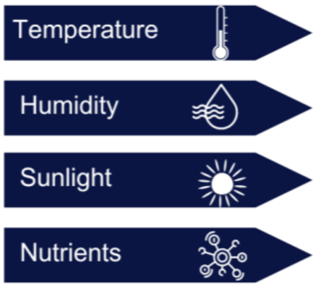
This section determines the project's and the area's capacity to absorb CO_2 using Net Primary Productivity (NPP) as a reference parameter. Then, the amount of CO_2 that can be captured is estimated with allometric equations taking into account the age and height of each species.

III.1.1.5.1. Net Primary Productivity (NPP)

Net Primary Productivity is the result of the production of organic matter through the photosynthesis process. However, primary productivity requires more than photosynthesis, particularly the uptake of inorganic nutrients and the incorporation of various organic compounds into protoplasm, essential for all photosynthetic organisms.

Among all ecosystem processes, NPP is the most measured because it reflects the carbon accumulation in ecosystems. The NPP is calculated based on the increase in biomass per area unit per time unit.

The NPP depends on the following factors:



Thus, the net primary productivity is equal to the carbon absorbed by the vegetation through photosynthesis (called Gross Primary Production or GPP) minus the carbon lost through respiration.

The NPP is limited by temperature and precipitation, it is assumed that it increases with both temperature and precipitation. However, in both cases, the saturation value of 3000 gDM/m2/year (DM means dry matter) must not be exceeded.

The NPP of the project area was calculated using the Miami methodology given in section "IV.1. aOCP Methodology for carbon removal and storage in vegetation." The process takes into account the following equations:

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

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)/m2/yr/(mm/yr) = gDM/ m2/mm and λT = ∂NPP/∂T in gDM/m2/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

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

A maximum NPP of 1,390.95 gr/m^2/year was attained for the project area (Figure 18). With these facts, the following formula was used to calculate biomass:

Biomass = Total area * NPP (kg)

Where:

Biomass = 5,680.48 m^2 ∗ 1.3 = 7,384.62 kg

To calculate the amount of CO_2 that has been fixed in the plant biomass, we use the *“CO_2 to carbon emissions conversion factor”* of 3.67 kg. For this, we use the following formula:

CO_2 = Biomass ∗ 3.67

Thanks to molar mass ratios, we can break CO2 down and find that it takes 3.67kg of CO2 to create 1kg of carbon in the tree. That’s because carbon has a molar mass of 12 and oxygen 16. Combined as CO2 that’s 44. And 44/12 = 3.67.

As a result of applying the biomass CO2 to the carbon transformation factor formula, we obtained:

CO_2 = 7,384.62 ∗ 3.67 = **27,101.57 kg per year in the whole project area**

Due to the ecosystem conditions (climatic and ecological) at the local level, it has been determined that **27.10 tn of CO_2/year** will serve as the base parameter for the estimation of annual CO_2 capture. This amount represents the maximum capacity for biomass generation and, consequently, for carbon capture.

Since climate change will lead to changes in ecosystem conditions, the ability of ecosystems to capture CO2 will also be affected. Therefore, we have also calculated the NPP, biomass, and CO2 capture capacity for the year 2050 with the climate change scenario. As a result, we have obtained that the local ecosystem will have a limiting capture capacity of **22.93 tn/CO_2/year**, reducing the yearly capacity by **4.17 tn** in the whole project area compared to the current scenario.

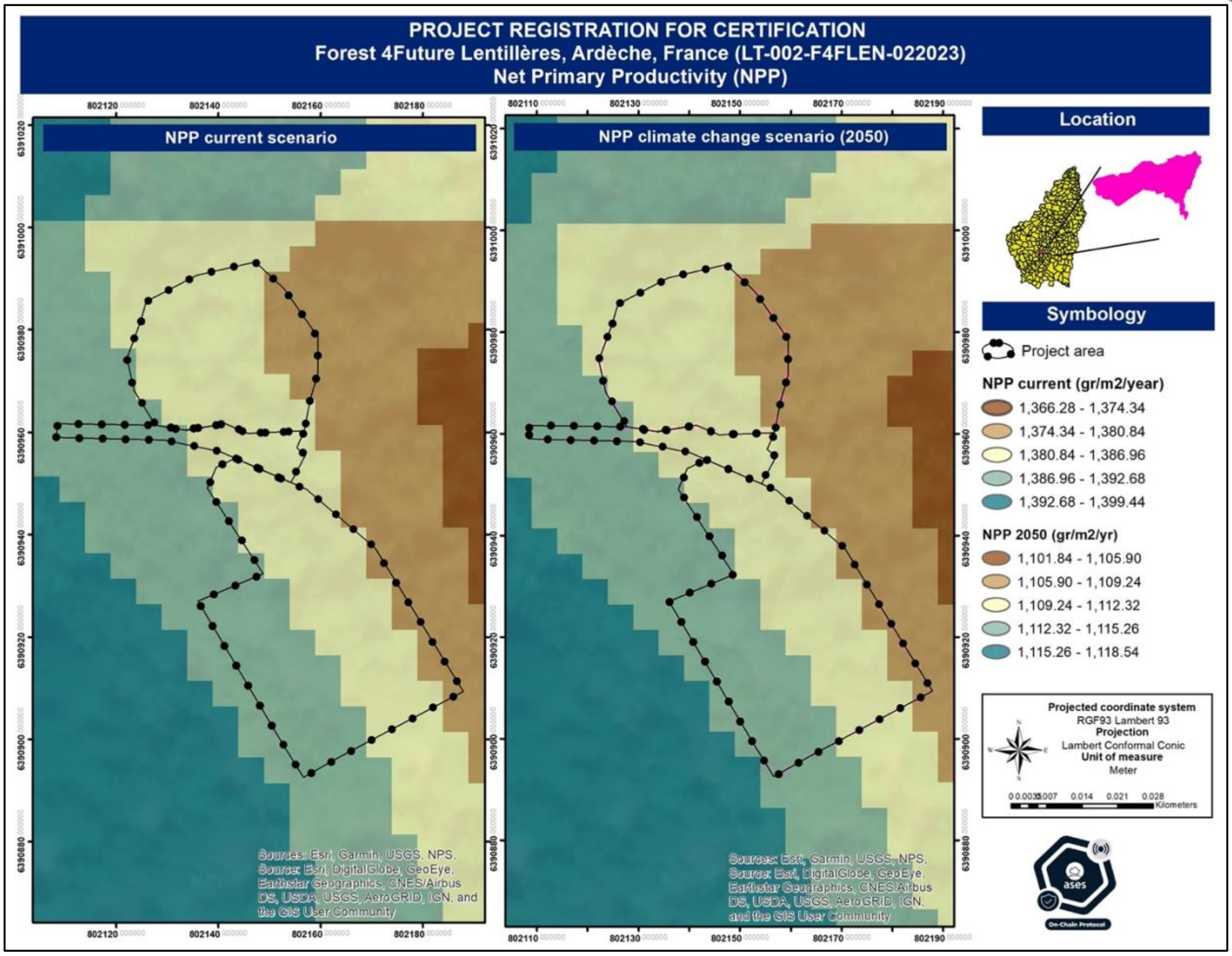


FIGURE 19. NET PRIMARY PRODUCTIVITY (NPP)

IIII.1.1.5.2. 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 crops. Table 3 shows the allometric equations used for each reforestation species.

TABLE 2. ALLOMETRIC EQUATIONS

Specie	Allometric equation CO2 absorbed (Kg)	Reference
Prunus mahaleb	**CO2 (kg) =** 0.078 * DBH2.83	Sciubba, L., Monti, A., & Ginocchio, R. (2015). Carbon sequestration and storage in Prunus mahaleb trees in central Italy. iForest, 8(2), 83–90.
Quercus coccifera	**CO2 (kg) =** 0.1 * height (m)^2 * diameter (cm)	Carbon sequestration potential of Quercus ilex in France" by Smith et al. (2018).
Quercus ilex	**CO2 (kg) =** 0.1 * height (m)^2 * diameter (cm)	Allometric scaling of carbon sequestration in trees" by Jones and Smith (2016)
Acer campestre	**CO2 (kg) =** 0,0405 x D^2,1412	Zuñiga-Feest, A., Gómez-Aparicio, L., García-Gonzalo, J., Peñuelas, J., & Zamora, R. (2013). An allometric equation for estimating carbon uptake of Acer campestre

Specie	Allometric equation CO2 absorbed (Kg)	Reference
Crataegus monogyna	**CO2 (kg) =** 0,619 * height - 0,0041 * DBH + 0,0025 * height * DBH+ 0,0008	López-Santiago, J., Prada De La Fuente, L. M., Villar, R. & Real, R. (2014). Modeling carbon storage in Mediterranean urban forests using tree allometry. Urban Forestry & Urban Greening, 13 (2), 285-292. doi: 10.1016/j.ufug.2014.03.005
Phyllirea angustifolia	**CO2 (kg) =** 0.0017 * Tree Height2 * Tree Diameter2	Ramirez-Villegas, J., Villalobos-Arce, C., & Zavala-Hurtado, J. (2006). Carbon sequestration by Phyllirea angustifolia Swartz in Jamaica. Forest Ecology
Pistacia terebinthus	**CO2 (kg) =** (Tree Height in Meters) * (Tree Diameter in cm) * 0.15	Wang, J., Tao, Y., Yang, Y., Zhang, J., & Li, T. (2019). Photosynthetic characteristics and carbon sequestration potential of a shrub-like species, Pistacia terebinthus L., in the semi-arid region of China. Atmospheric Pollution Research, 10(5), 2239-2247. Ashton, P., & Müller, J. (1998). Estimating carbon storage in trees. Journal of Arboriculture, 24(5), 173-176.
Cercis siliquastrum	**CO2 (kg) =** Tree's diameter (cm) * Height (m) * 0.0058	Shmulsky, R., & Pidgeon. (2010). Carbon sequestration in woody plants. In J. A. Torrey (Ed.), Carbon sequestration in woody plants (pp. 35-52). Boca Raton, FL: CRC Press. Köhl, M., & Kuhn, B. (2007). Estimation of carbon sequestration capacity of individual trees using allometric equations. European Journal of Forest Research, 126(4), 471-478.
Pistacia lentiscus	**CO2 (kg) =** 0.00673 * (age) ^2.08	Bell, M., & Ferrini, F. (2019). Carbon sequestration potential of Pistacia lentiscus trees in a rural landscape in southern Italy. Annals of Forest Science, 76(5), 1-10. Koundouri, P., & Langton, T. (2020). Estimating the Carbon Sequestration Potential of Pistacia lentiscus Trees in Greece. Forests, 11(4), 1-17.
Olea europaea	**CO2 (kg) =** Tree age (yrs) * tree height (m) * tree width (m) x 0.48	Carbon footprint of olive tree (Olea europaea L.) plantations", Karagiannis, D.G., et al., Agriculture, Ecosystems and Environment, Volume 117, Issue 4, 2007, Pages 355-362. 2. Carbon Sequestration of Traditional Mediterranean Olive Groves", Saiz, G., et al., Agronomy, Volume 9, Issue 9, 2019, Pages 786.
Quercus cerris	**CO2 (kg) =** 0.0059 x (Tree DBH ^ 2.37)	https://www.trees.org/wpcontent/uploads/2020/03/Trees-and-CO2-a-Trees-Ohio-Fact-Sheet.pdf).
Prunus spinosa	**CO2 (kg) =** 0.02 * tree diameter (in cm) ^2 * tree height (in m)	Rötzer, Thomas, and Sören Thiele. "CO2, Nitrogen, and Water Exchange of Blackthorn (Prunus Spinosa L.) in Central Europe." Plant Ecology, vol. 191, no. 1, 2008, pp. 1–11., doi:10.1007/s11258-007-9329-4. Larnier, Jean-Philippe, et al. "Carbon Stock and Carbon Allocation of Prunus Spinosa L. in Mediterranean Woodland." Agricultural and Forest Meteor
Acer monspessulanum	**CO2 (kg) =** 0,0405 x D^2,1412	S.G.A. Mommaerts, J. Hillemans, F. Franaux, and A. de Caluwé, 2015. "Alometric Equations for Estimating Carbon Sequestration in Corylus Avellana L. in Northwestern France," Trees-Structure and Function, vol. 29, no. 5, pp. 1411–1420.
Cedrus atlantica	**CO2 (kg) =** 0.032*DBH^2.064	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

Specie	Allometric equation CO2 absorbed (Kg)	Reference
Cedrus libani	**CO2 (kg) =** 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
Ceratonia siliqua	**CO2 (kg) =** 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 53, 495–503. https://doi.org/10.1051/forest:19960512
Corylus colurna	**CO2 (kg) =** 0.0156*DBH^2 + 0.4672*DBH + 2.649	F. Migliavacca, V. Botta, D. Marzuoli, E. Batandieri, G. Maracchi, M. Moghaddas, and G. Seufert, 2019. "Colonisation Dynamics of Corylus Avellanae L. in Southwestern Alps: Implications for Carbon Dynamics," Forests, vol. 10, no. 742.
Cryptomeria japonica	**CO2 (kg) =** -0.1186*Tree DBH^2 + 0.5182*Tree DBH + 0.4202	Saka, S., Kato, T., Seino, H., Tanaka, T., Nakamura, S., Abe, Y., … Shimizu, K. (2021). Allometric equations for estimating biomass of Cryptomeria japonica in France. Plant Species Biology, 36(3), 362–371. https://doi.org/10.1111/1442-1984.12330
Cupressus sempervirens	**CO2 (kg) =** 0.05*Height^2	asoglu, T., Sertel, E., Gokcel, A., and Yilmaz, A. (2006). Biomass and carbon relationships of Cupressus sempervirens L. Natural Resources 1, 115–120. DOI: 10.4236/nr.2006.12009
Ficus carica	**CO2 (kg) =** 0.654 DBH (m)2 + 0.0452	Gressent, A., Luc, D., Nowak, D. et al. CO2 capture of Ficus carica in France and its climate dependence: Allometric relations and environmental control. Urban For Urban Green 25, 49–59 (2017). https://doi.org/10.1016/j.ufug.2017.05.006
Fraxinus angustifolia	**CO2 (kg) =** 0.0022 x D2.25 x H0.810	Mortes, J., Cabezudo, B., Morales, R., Navarro, R., & González, C. (2016). Allometric equations for estimating aboveground carbon stocks and sequestration in Fraxinus angustifolia Vahl in Mediterranean Spain. Annals of forest science, 73(3), 374.
Fraxinus excelsior	**CO2 (kg) =** 0.0022 x D2.25 x H0.810	Mortes, J., Cabezudo, B., Morales, R., Navarro, R., & González, C. (2016). Allometric equations for estimating aboveground carbon stocks and sequestration in Fraxinus angustifolia Vahl in Mediterranean Spain. Annals of forest science, 73(3), 374.
Pinus halepensis	**CO2 (kg) =** 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
Pinus pinea	**CO2 (kg) =** 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
Pseudotsuga menziessi	**CO2 (kg) =** 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

Specie	Allometric equation CO2 absorbed (Kg)	Reference
Quercus petrea	**CO2 (kg) =** 0.55 x (tree diameter at breast height (cm))2	Camarero, J.J., Diaz-Villa, J., del Rio, M. (2008). Annual CO2 exchange and canopy development of Quercus petraea Mill. in a temperate mountain forest. Tree Physiology, 28(4), 545-552. doi: 1080/09291060802090302
Quercus suber	**CO2 (kg) =** 0.55 x (tree diameter at breast height (cm))2	Camarero, J.J., Diaz-Villa, J., del Rio, M. (2008). Annual CO2 exchange and canopy development of Quercus petraea Mill. in a temperate mountain forest. Tree Physiology, 28(4), 545-552. doi: 1080/09291060802090302
Rhamnus lycioides	**CO2 (kg) =** 0.00668 x (DBH (cm))^2.43	Duchamp, F., Bognar, A., Semer, B., Brown, A., Gil, L., Lautrey, J., Sásdi, S., Thébaut, B., Steinger, T., Messier, C., & Peyron, S. (2018). Estimation of Tree Carbon Capture and Storage using a Mixed-Modeling Approach: A Case Study of Rhamnus lycioides in the French Alps. Forests, 9(2), 99.
Salix purpurea	**CO2 (kg) =** 4.85 * (Diameter at Breast Height^2.66) * (Height ^ 0.77)	Scientific Reference: Helbing, C. D., Richards, G. D., Bragg, D. C., & Dunn, A. H. (2020). Estimation of carbon dioxide sequestration by the shrub willow Salix purpurea in the Loire region of France. Forests, 11(3), 355. https://doi.org/10.3390/f11030355
Sequoia sempervirens	**CO2 (kg) =** 0.08 + (0.026* DBH^2 * Height (m))	Lu, He-Ming, and Xiao Wang. “Carbon Efficiency and Carbon Storage of Coast Redwoods (Sequoia sempervirens) in California.” Ecological Research, vol. 30, no. 2, 2015, pp. 277–289., doi:10.1007/s11284-015-1283-3.
Sequoiadendron giganteum	**CO2 (kg) =** 0.08 + (0.026* DBH^2 * Height (m))	Bi, H., W. H. Schlesinger, and N. G. Phillips. 2009. Carbon sequestration by coast redwoods: implications of large scale management for carbon sequestration in a changing climate. Ecological Applications 19:821–831.
Taxus baccata	**CO2 (kg) =** 0.000232 x (Tree Height^2) x (Tree Diameter^2)	2. Garrido-Garrido, M., Salazar, A., López-Gallego, C., Martí, D., & Garnatje, T. (2003). Allometry of aboveground biomass of Taxus baccata L. trees. European journal of forest research, 122(4-5), 199-206.

III.1.1.6. Carbon capture in vegetation

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.

Thus, the reference density scenario is 16 square meters per tree; currently, the project has a density of 5 square meters per tree, which will generate an initial competition for resources. However, due to the mortality that occurs in each reforestation project, the planting density will progressively decrease and the trees that manage to adapt and survive will have more and more access to the available resources (water, sunlight, and nutrients) defined by the Net Primary Productivity (NPP) analyzed in the previous section, and will be able to continue growing.

Based on the density taken as a reference (16 square meters per tree) and the ecosystem capacity (NPP), it is estimated that the survival of the project at year 40 will be 31%. (Figura 19).

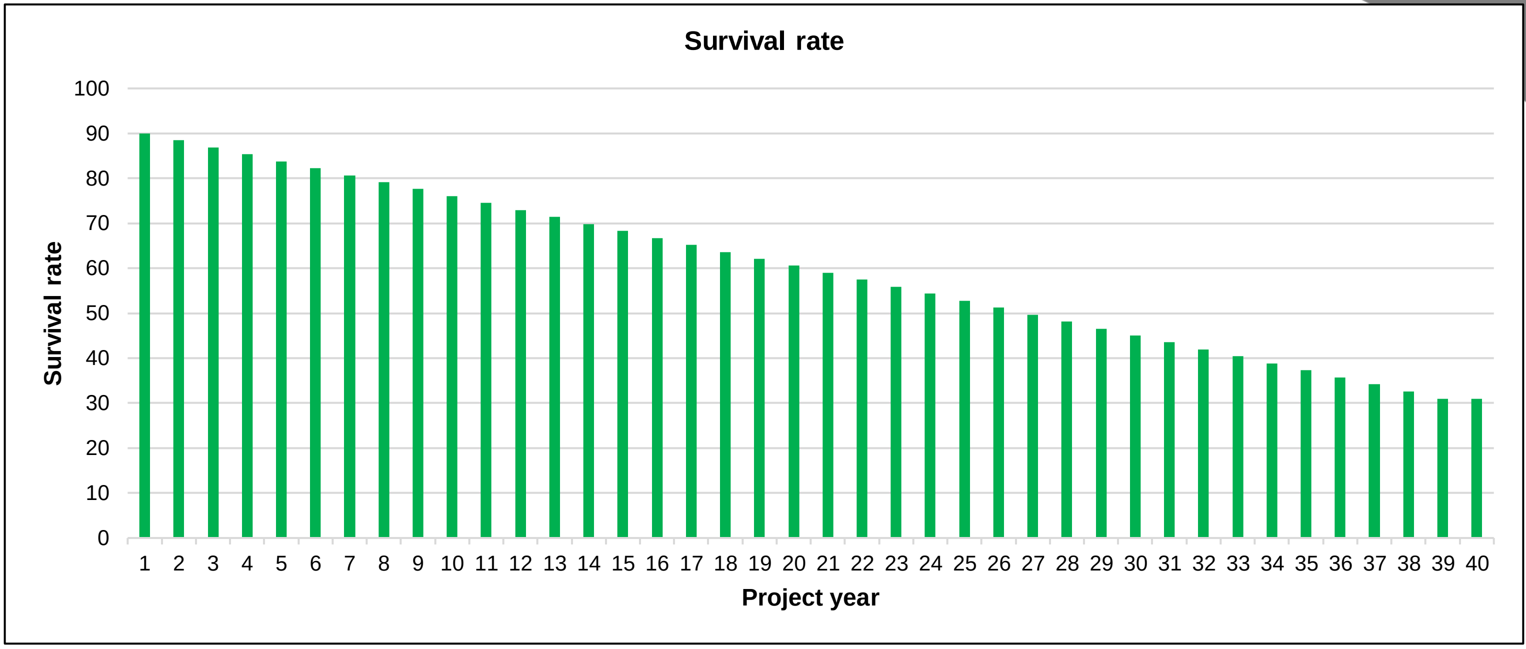


FIGURE 20. SURVIVAL RATE

Considering these survival rates, at the end of the project's life (year 40), a total survival of 334 trees is estimated (Figure 20).

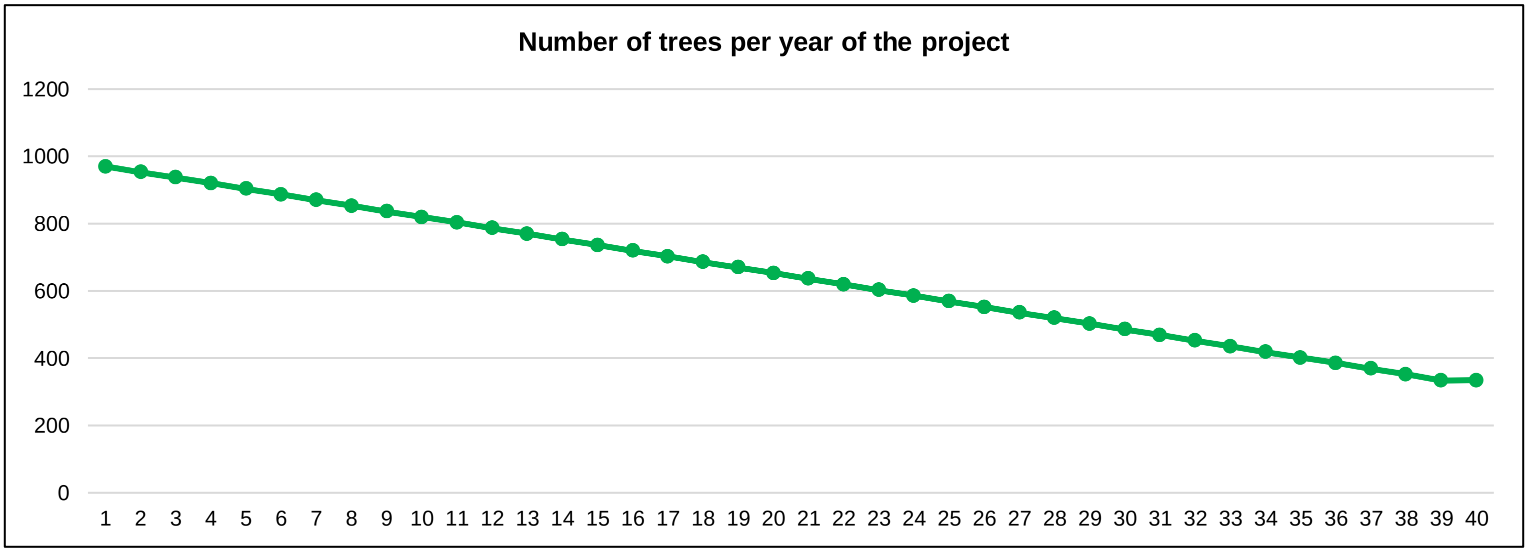


FIGURE 21. NUMBER OF TREES PER YEAR OF THE PROJECT

This conservative scenario estimates a total capture of **201 tons of CO_2** for the year 2040. It is important to mention that in the calculation the CO2 capture is aligned annually to the ecological capture capacity per square meter determined by the Net Primary Productivity (NPP), as well as to the annual tree density, thus avoiding overestimates.

Figure 23 shows the annual CO_2 capture expected by the Project.

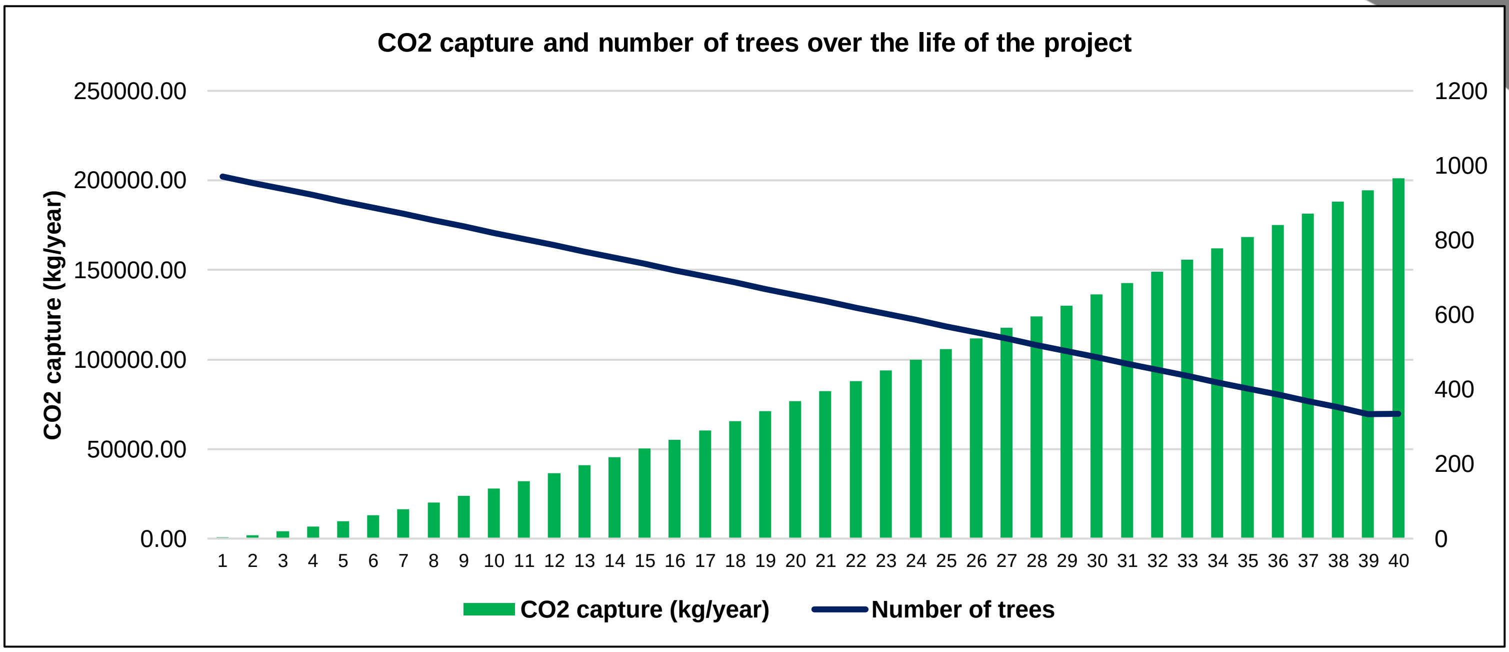


FIGURE 22. CO_2 CAPTURE AND NUMBER OF TREES OVER THE LIFE OF THE PROJECT

III.2. BIODIVERSITY

Biodiversity is fundamental to maintaining the stability and functioning of ecosystems; each species plays a specific role in its habitat, interacting with other species and contributing to the health and resilience of the ecosystem as a whole. Loss of species can trigger ecological imbalances and have negative effects on the food chain and natural processes.

Biodiversity credits have been developed as a way to address the problem of species loss by promoting their conservation and rewarding those who take positive actions for their creation.

Credits are generated through projects that encourage conservation or restoration, representing certain amounts of benefits. In the aOCP protocol, to calculate the benefit of the project and objectively estimate the number of credits, the actions taken in favor of biodiversity are evaluated based on three key variables:

- Area preserved
- Restored area
- Ecological condition of the intervened area

The method followed is an evaluation where each of the variables is relativized. The relativization function is performed in order to assign a common scale between 0 and 1 to all the amplitude indices.

When the index has a positive relationship on the study variable with reference to the factor, the following expression is used:

$$\textbf{Relativization} = \frac{\mathrm{X - m}}{\mathrm{M - m}}$$

$$\mathbf{VBBC} = \sum_{i=1}^{N_I} TS*(Fij)/100$$

$$\mathbf{VBBC} = \frac{TS*\,(F1)*\underline{\beta 1} + (F2)*\underline{\beta 2} + (F3)*\underline{\beta 3} + .. (Fn)*\underline{\beta n}}{100\ m^2}$$

Where:

X= Variable value to be relativized

m= Minimum variable value

M= Maximum variable value

The preserved areas variables correspond to the baseline of the project, analyzing the surface factor (in m^2) and the diversity index factor through Shannon. The areas restored are those created thanks to the construction of the project and their measurement will also consider the surface area factor (in m^2) and the diversity index factor measured with Shannon. Finally, the ecological condition variable of the intervened area is formulated by five factors that together will allow evaluating of the state of the ecosystem impacted by the project, taking into account the following:

- **Protection of key species:** Keystone species in an ecosystem are those that have a disproportionately large impact on its functioning and structure, despite their low numerical abundance. These species play fundamental roles in regulating ecological processes and maintaining balance in the ecosystem.
- **Fragmentation:** Landscape fragmentation refers to the division or separation of natural habitats into smaller, isolated units, a phenomenon that causes a series of consequences at the ecosystem level and for the species that depend on them. Among the main effects are the loss of biodiversity, alteration of ecological processes, loss of ecological connectivity, and increased human pressure.
- **Fractal dimension:** A fractal dimension index is a useful tool for assessing the spatial structure of the landscape and understanding how the configuration of habitat patches can influence ecological processes and ecosystem function.
- **Spatial continuity:** The spatial continuity of natural areas guarantees the survival of plant and animal species and, therefore, the continuous exchange of genes, thus ensuring the movement of species, the maintenance of ecological functions, resilience to disturbances, and the conservation of biodiversity.
- **Ecosystem vulnerability to climate change:** Climate change can influence the Net Primary Productivity (NPP) of ecosystems, which is the amount of energy that producers (such as plants) capture through photosynthesis. Variations in patterns of temperature, precipitation, and water availability can alter the quantity and quality of biomass produced, affecting the entire food chain and the availability of resources for consuming organisms.
- **Species vulnerability to climate change:** Climate change can lead to species extinctions and declines in biological diversity. Species that cannot adapt quickly to

changes in temperatures or precipitation patterns may have difficulty surviving and reproducing.

Once each one of the factors has been relativized, the following adapted formula will be applied to determine the number of Biodiversity Credits that will be awarded for the project:

$$\textbf{VBBCs} = \frac{\text{Tsurf} * (\text{F1} + \text{F2} + \text{F3} + \text{F4} + \text{F5} + \text{F6}) + (\text{RestSurf} * \text{F7}) + (\text{PresSurf} * \text{F8})}{100}$$

Where:

Tsurf= Total surface

F_1= Protection of key species

F_2= Fragmentation

F_3= Fractal dimension

F_4= Spatial continuity

F_5= Climate change vulnerability

F_6= Vulnerability of species to climate change

RestSurf= Restored surface

F_7= Biodiversity index in the area restored

PresSurf= Preserved surface

F_8= Biodiversity index in the preserved area

This formula incorporates the relativized factors, Shannon index values, benefits adjacent to the ecosystem and the areas of each variable to calculate the biodiversity credit. Multiplying each variable by its respective area ensures that the spatial extent of each factor is taken into account. The result is divided by 100, as each credit issued will represent a 100 m^2 unit that has been preserved or restored by the project.

One of the most widely used indices to quantify specific biodiversity is the Shannon index, also known as Shannon-Weaver (Shannon and Weaver, 1949), derived from information theory as a measure of entropy. The index reflects the heterogeneity of a community based on two factors: the number of species present and their relative abundance. The maximum potential diversity (Hmax= lnS) depends on the number of species present in the community, the more species there are, the higher the maximum potential diversity, and is reached when all species are equally represented. An index of homogeneity, also called equitability, associated with this measure of diversity can be calculated as the ratio H/Hmax, which will be equal to 1 if all the species that compose the community have the same number of individuals.

The index is calculated through the following equation:

$$\boldsymbol{H} = -\sum_{i=1}^{ps*} pi \ln(pi)$$

Where:

Pi (p_1,p_2, p_3… p_s*) = It is the relative abundance of target i in the collection

If only part of the area is sampled, biodiversity is expressed according to the following relationship.

$$\boldsymbol{H} = \sum_{i=1}^{s} [(\frac{ni}{n} \ln \frac{ni}{n})]$$

Where:

n i= It is the abundance of the category i

n= It is the abundance of all categories of the sample

The diversity is influenced by the distribution of the objects in the categories. The evenness (J) is calculated as follows:

$$J = \frac{D}{Dmax}$$

Where:

D= This is the diversity

Dmax= This is the maximum diversity that can be expressed through the sample

The following is a description of the variables of the Lentillères project, which will subsequently be ranked in the corresponding relativized value.

III.2.1. PROJECT EVALUATION VARIABLES

III.2.1.1. Preserved area variable

The preserved area corresponds to the area within the property boundary of the property where the project activities were carried out (11,998.21 m^2), subtracting the plantation area (5,600 m^2), resulting in a conservation area of 6,398.21 m^2 (Figure 22).

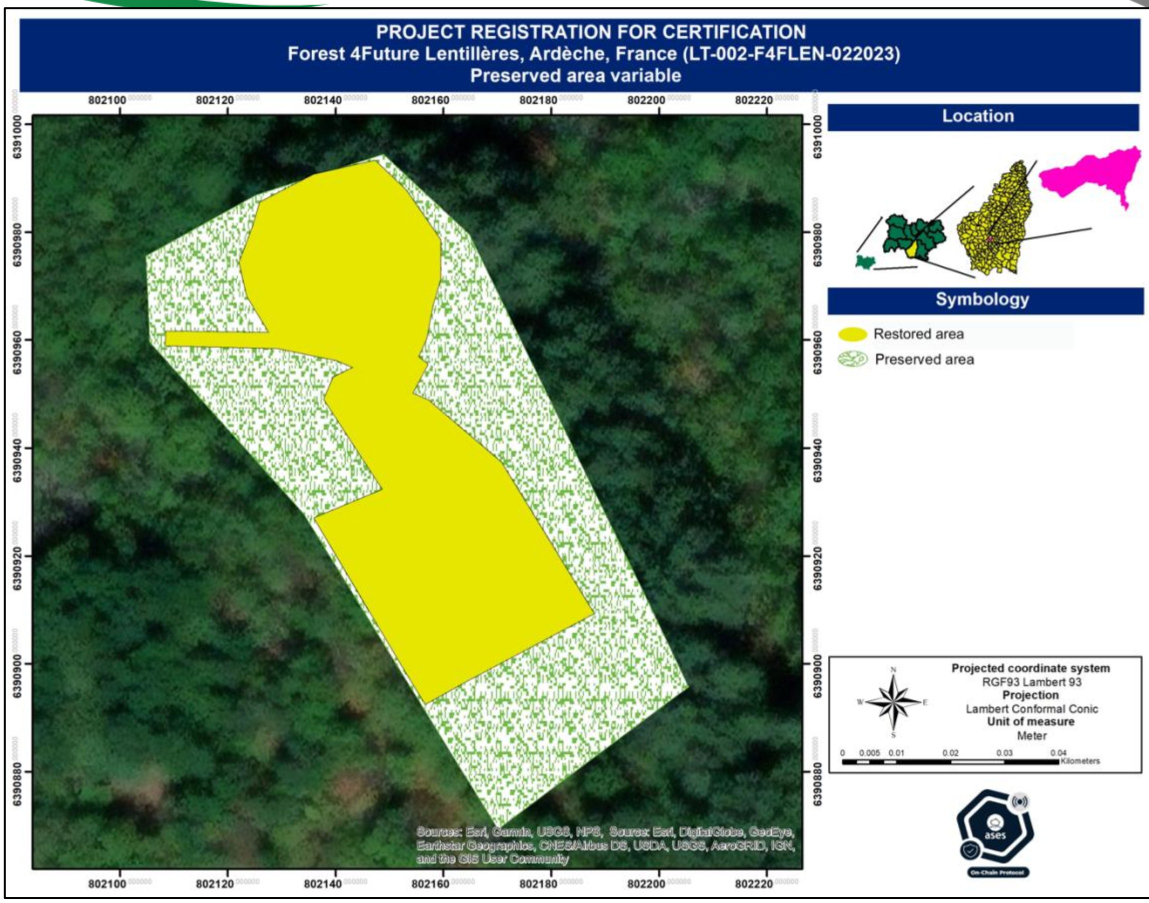


FIGURE 23. PRESERVED AREA VARIABLE

The results of the preserved flora and fauna indices are presented below.

III.2.1.1.1. Flora

To calculate the biodiversity index of flora present in the study area, a count of the trees and shrubs present in an approximate area of 2,860 m^2 was made (blue lines), which is equivalent to 24% of the total area analyzed in biodiversity (11, 998.21 m^2) (Figure 23).

FIGURE 24. COUNTING AREA

The count resulted in the presence of 610 individuals of 3 different tree species and one shrub (Figure 24).

- 568 individuals of the specie *Castanea sativa*
- 11 individuals of the specie *Cytisus scoparius*
- 1 i individuals of the specie *Rhamnus alternus*
- 30 individuals of the specie *Rubus fruticosa*

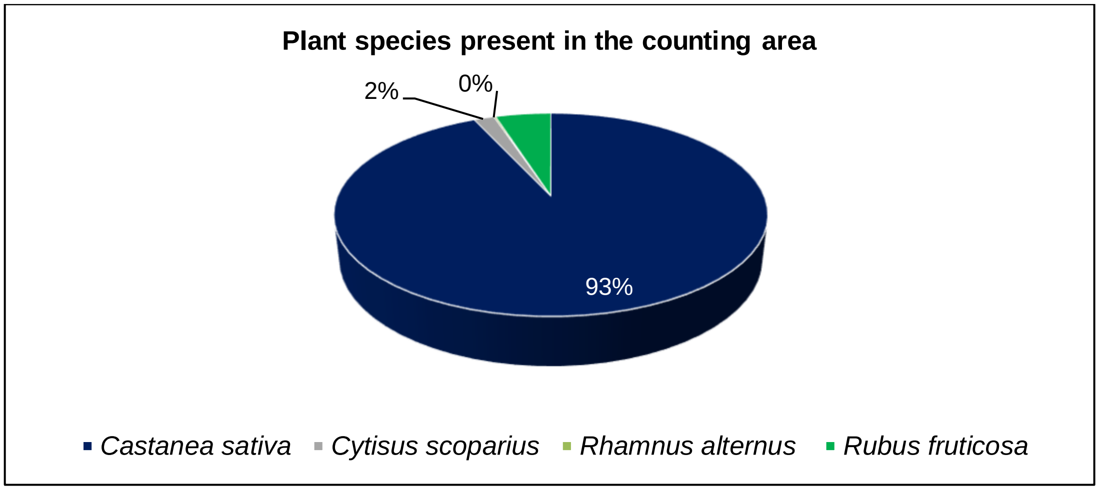


FIGURE 25. PLANT SPECIES PRESENT IN THE COUNTING AREA

The results of specific richness, Shannon-Weaver diversity index, maximum diversity and evenness of the tree and shrub community in the project conservation area are shown in Table 3.

TABLE 3. BIODIVERSITY PARAMETERS FOR THE PRESERVATION AREA

Parameters of flora diversity index	Preservation area
Species richness	4
Diversity (nats)	0.29
Maximum potential diversity (Hmax)	1.79
Equitability index (J)	0.16

When the value of the diversity index is 0, there is only one category, i.e., there is no diversity; and the index increases as the number of objects or classes increases or if the proportional distribution of the occupied area among the types of ecosystems or objects, species, etc., is more equitable. For the preservation area, a flora diversity index of 0.29 was obtained, which could be interpreted as a very low diversity according to the categories presented in Table 4.

TABLE 4. QUALITATIVE CATEGORIES OF INTERPRETATION OF THE SHANNON INDEX

Diversity	Shannon index (nats)
Very low	<1.02
Low	1.03 – 1.53
Medium	1.58 – 2.11
High	2.12 – 2.65
Very high	>2.65

Bibliographical source: Qualitative interpretation of the index based on the interpretations expressed by Margalef (1975;1993).

III.2.1.1.2. Fauna

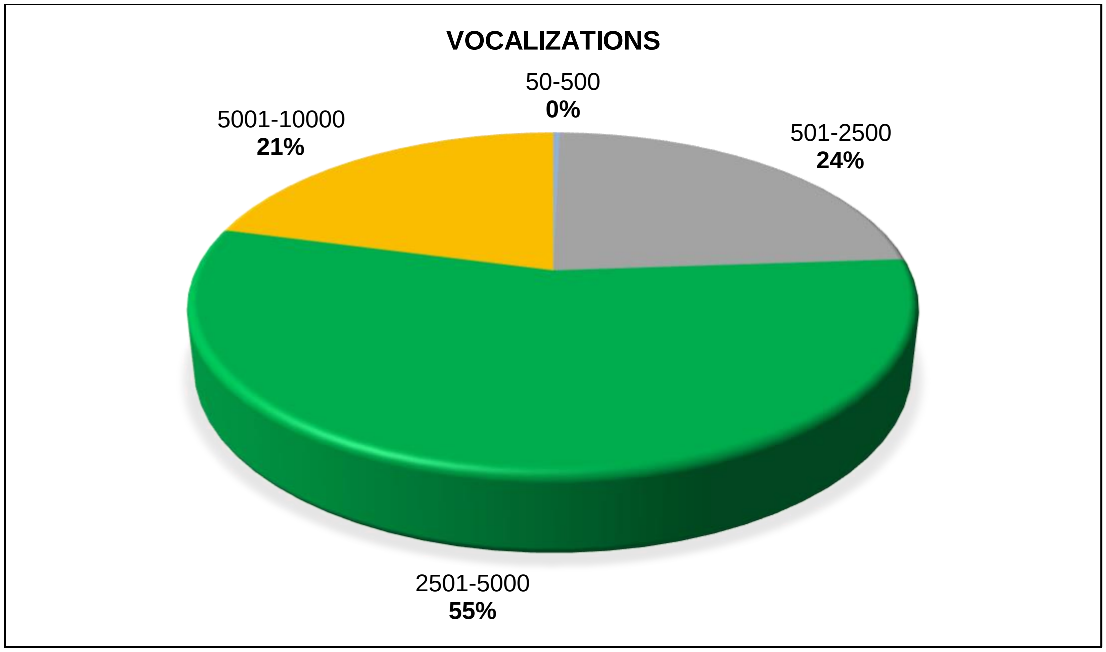
In order to generate fauna diversity indexes in the preserved area, bioacoustics recorders were installed at various points (Figure 25) which made it possible to identify, through the processing of vocalizations, the various groups distributed in the study area.

FIGURE 26. INSTALLATION OF BIOACUSTICS RECORDERS

Through the frequencies of the vocalizations obtained, the groups of fauna present in the project area were determined. Diurnal birds of prey, bees, amphibians, insects, small mammals and reptiles emit vocalizations with frequencies from 50 to 500 hertz (Hz), songbirds, raptors, forest birds and raptors their vocalizations range from 501 to 2500 Hz, nocturnal raptors, insects, amphibians, mammals and reptiles emit vocalizations with frequencies between 2501 and 5000 Hz, and owls, insects and migratory birds their frequencies range between 5001 and 10000 Hz (Table 5).

TABLE 5. FREQUENCY OF VOCALIZATION PER GROUP

Fq Hz	Vocalizations	Groups
50-500	81	Diurnal birds of prey, bees, amphibians, insects, small mammals, reptiles
501-2500	5486	Songbirds, birds of prey, forest birds, raptors
2501-5000	12873	Nocturnal raptors, insects, amphibians, mammals and reptiles
5001-10000	4863	Owls, insects and migratory birds



Once the data were obtained and processed, the following indexes were obtained:

- **Bioacoustic Index (BI):** This index measures the biological richness or diversity of a soundscape. It quantifies the number of different species or vocalizing individuals present in an acoustic recording. The Bioacoustic Index is calculated using species-specific vocalization patterns or vocal activity levels. A higher Bioacoustic Index value indicates a greater diversity of species or a higher vocal activity within the soundscape. The unit of the Bioacoustic Index is typically expressed as the number of species or individuals per unit of time
- **Acoustic Diversity/Evenness indices (ADI):** These are measures used to assess the variety and distribution of sound sources within a soundscape. These indices quantify the relative abundance of different sound classes or species present in the acoustic recording. They are calculated using statistical measures such as Shannon entropy or Simpson's index. Higher values of acoustic diversity and evenness indicate a more diverse and evenly distributed soundscape. The units of these indices are dimensionless.

TABLE 6. BIOACUSTICS INDEX RESULTS

Time	BI (Máx,)	ADI (Máx,)	AEI (Máx,)
00:04:52	20	2.010166	0.562409
01:04:53	8	0.979769	0.837053
02:04:52	7	0.302233	0.892296
03:04:52	10	0.127956	0.898354
04:04:52	45	1.087063	0.772342
05:04:52	40	1.940202	0.456969
06:04:52	29	2.033118	0.407101
07:04:53	50	1.805954	0.580544
08:04:52	25	0.641913	0.810242
09:04:52	65	0.339227	0.869191
10:04:52	45	0.366735	0.859617
11:04:52	34	0.526996	0.858452
15:04:52	35	0.709613	0.83325
16:04:52	33	0.425767	0.867338
17:04:52	35	1.001821	0.773466
18:04:52	31	0.899427	0.782088
19:04:53	79	1.721155	0.619852
20:04:52	6	0.326991	0.874195
21:04:52	7	2.167693	0.32566
22:04:52	30	2.259076	0.460868
23:04:52	16	2.27408	0.193807

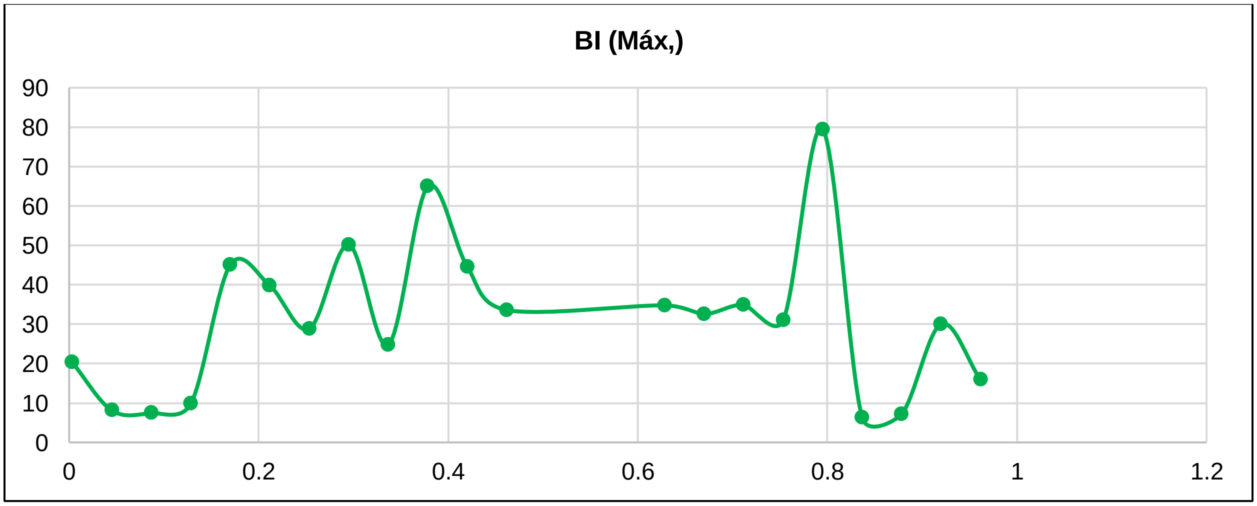


FIGURE 27. BI (MÁX)

In the Shannon index, diversity and evenness are two related but distinct components that influence the final value of the index. Diversity refers to the variety of different species or categories present in a sample or community, while evenness refers to how the abundance of those species or categories is distributed within the sample or community.

When diversity increases in the Shannon index, it means that there are a greater number of different species or categories present and contributing to the sample or community. This will be reflected in an increase in the number of categories in the denominator of the Shannon index, which can raise the total value of the index.

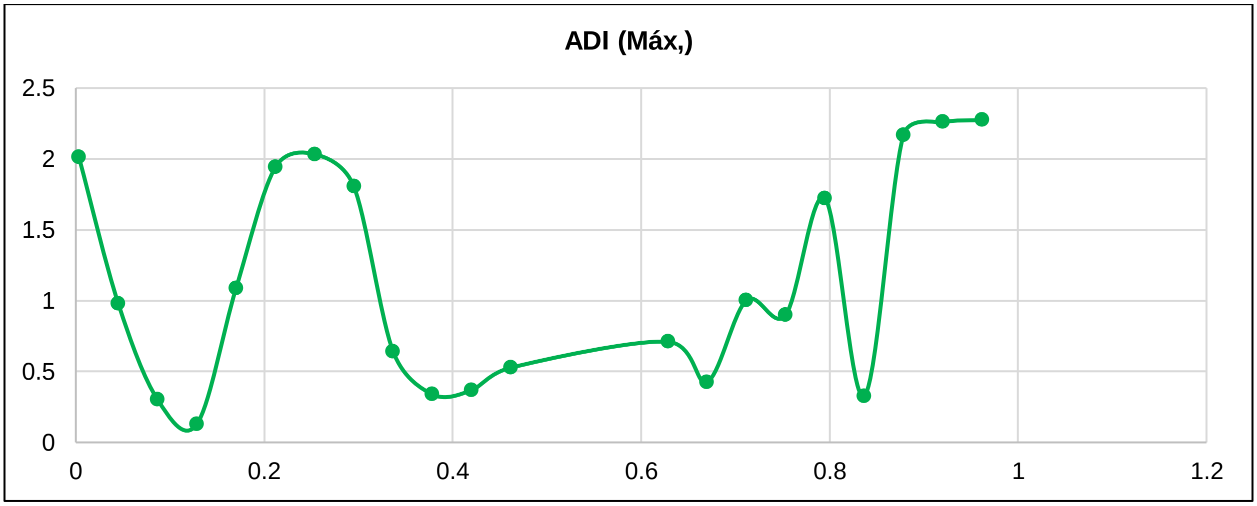


FIGURE 28. ADI (MAX)

However, if the distribution of abundances of these species or categories is not equal, that is, if some species or categories have a much higher abundance than others, the evenness will decrease. Evenness is calculated in the Shannon index through the relative distribution of abundances. If some species or categories are much more dominant than others, the relative distribution becomes uneven and evenness decreases.

In the Shannon index, when diversity increases, it means that more different species or categories are present, which can increase the value of the index. However, if the distribution of abundances is not equal, i.e., some species or categories are much more dominant than others, the evenness will decrease, which may partly offset the increase in diversity and decrease the overall value of the Shannon index.

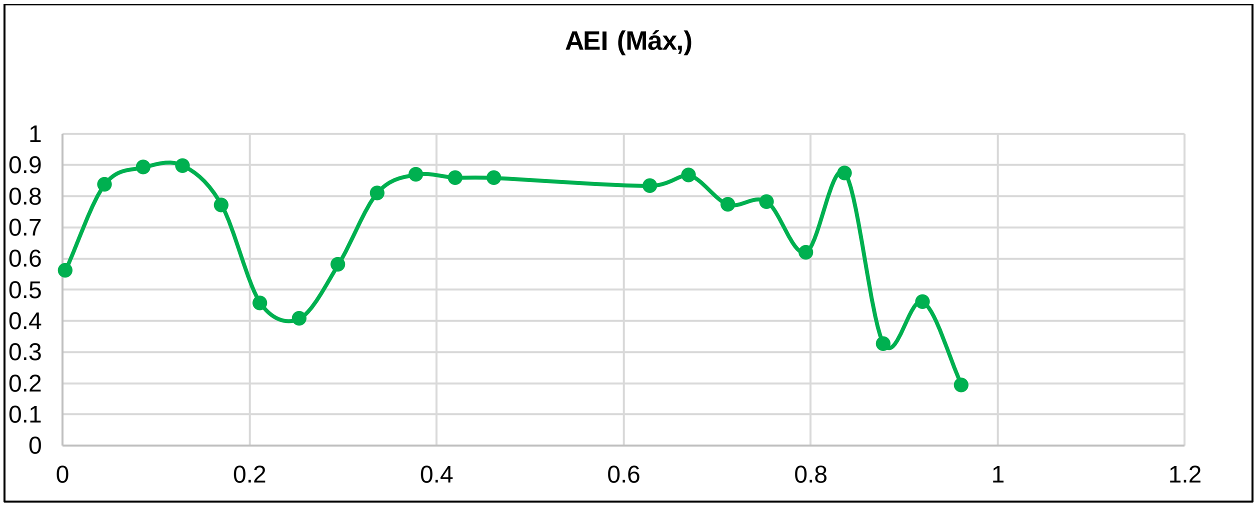


FIGURE 29. AEI (MAX)

With the 20 diversity indices (ADI) obtained in Table 7, the median was calculated to obtain a general index of faunal diversity in the conservation area, obtaining a diversity of 0.97. According to "Table 4 Qualitative categories of interpretation of the Shannon index" would be categorized as **very low** diversity.

TABLE 7. PRESERVATION AREA DIVERSITY INDEX

Parameters of fauna diversity index	Preservation area
Diversity (nats)	0.97
Equitability index (J)	0.78

In the species recorded by the echo-acoustic sensor, the presence of 10 bird species protected at the national level by the Bern Convention which is an international legal instrument aimed at protecting natural heritage, was identified (Table 8). Of these, one is classified as Endangered by the French List. Birds are indicator species of ecosystem health, as their populations and behaviors can reflect changes in the environment, such as the presence of pollutants, habitat degradation, or climate change.

TABLE 8. SPECIES PROTECTED

Name		Protection status				Evaluation (Red list)			
Latin name	**Common name**	**Berne Convention**	**Bird Directive**	**Directive habitat fauna flora**	**France**	**World**	**Europe**	**France**	**Region**
Luscinia megarhynchos	Rossignol philomèle	Annexe II - Espèces de faune strictement protégées.			Protected	LC	LC	LC	NE
Dendrocopos major	Pic épeiche	Annexe II - Espèces de faune strictement protégées.			Protected	LC	LC	LC	NE
Strix aluco	Chouette hulotte	Annexe II - Espèces de			Protected	LC	LC	LC	NE

Name		Protection status				Evaluation (Red list)			
Latin name	Common name	Berne Convention	Bird Directive	Directive habitat fauna flora	France	World	Europe	France	Region
		faune strictement protégées.							
Gallinago media	Bécassine double	Annexe II - Espèces de faune strictement protégées.	Annexe I - Espèces devant faire l'objet de mesures de conservation spéciale		Protected	NT	LC	NA	NE
Grus grus	Grue cendrée	Annexe II - Espèces de faune strictement protégées.	Annexe I - Espèces devant faire l'objet de mesures de conservation spéciale		Protected	LC	LC	EN	NE
Luscinia luscinia	Rossignol progné	Annexe II - Espèces de faune strictement protégées.			Protected	LC	LC	NA	NE
Sylvia borin	Fauvette des jardins	Annexe II - Espèces de faune strictement protégées.			Protected	LC	LC	NT	NE
Sylvia atricapilla	Fauvette à tête noire	Annexe II - Espèces de faune strictement protégées.			Protected	LC	LC	LC	NE
Fringilla coelebs	Pinson des arbres	Annexe III - Espèces de faune protégées.			Protected	LC	LC	LC	NE
Phoenicurus phoenicurus	Rougequeue à front blanc	Annexe II - Espèces de faune strictement protégées.			Protected	LC	LC	LC	NE

*Not Evaluated (NE); Data Deficient (DD); Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered (EN); Critically Endangered (CR); Extinct in the Wild (EW); Extinct (EX); Not applicable (NA).

III.2.1.2. Restored area variable

The area restored corresponds to the 5600 m^2 where the activities of the project were carried out. To evaluate this parameter, the benefits of reforestation were calculated through the diversity index, considering the 1078 new trees of 30 different species that were planted (Table 9).

TABLE 9. RESTORED AREA DIVERSITY INDEX

Parameters of flora diversity index	Restored area
Diversity (nats)	2.63
Maximum potential diversity (Hmax)	2.70
Equitability index (J)	0.97

According to "Table 4 Qualitative categories of interpretation of the Shannon index", the index value obtained would be categorized as **high** diversity**.**

IIII.2.1.3. Ecological condition of the intervened zone

III.2.1.3.1. Protection of key species

Keystone species are those that play a fundamental role and whose conservation has a positive impact on the preservation of other organisms and the ecosystem itself.

Bats contribute to health and ecological balance by providing various environmental services such as pollination, seed dispersal, pest control, and, therefore, disease reduction. Their presence and conservation are necessary to maintain biodiversity, ecological harmony, and the proper functioning of ecosystems.

From the ultrasonic recorders for bats installed in the project area, the presence of seven nationally protected species was identified by Annex IV - Species (animal and plant) in need of strict protection throughout the European territory. In addition, three of them are classified as Vulnerable (VU) by the Red List of continental mammals of continental France (2017), one is classified Endangered (EN) by the regional lit network, and one by the global list network.

TABLE 10. PROTECTION CATEGORY OF KEY SPECIES - BATS

Name		Protection status				Evaluation (Red list)			
Latin name	**Common name**	**Berne Convention**	**Bird Directive**	**Directive habitat fauna flora**	**France**	**World**	**Europe**	**France**	**Region**
Eptesicos serotinus	Sérotine commune	Annexe II - Espèces de faune strictement protégées.		Annexe IV -Espèces (animales et végétales) qui nécessitent une protection stricte sur l'ensemble du territoire européen	Protected	LC	NE	NT	LC
Miniopterus schereibersii	Minioptère de Schreibers	Annexe II - Espèces de faune strictement protégées.		Annexe IV -Espèces (animales et végétales) qui nécessitent une protection stricte sur l'ensemble du territoire européen	Protected	VU	NE	VU	EN
Myottis nattereri	Murin de Natterer	Annexe II - Espèces de faune strictement protégées.		Annexe IV -Espèces (animales et végétales) qui nécessitent une protection stricte sur l'ensemble du territoire européen	Protected	LC	NE	VU	LC
Nyctalus noctula	Noctule commune	Annexe II - Espèces de faune strictement protégées.		Annexe IV -Espèces (animales et végétales) qui nécessitent une protection stricte sur l'ensemble du territoire européen	Protected	LC	LC	VU	NT
Pipistrellus pipistrellus	Pipistrelle commune	Annexe III - Espèces de faune protégées.		Annexe IV -Espèces (animales et végétales) qui nécessitent une protection stricte sur l'ensemble du territoire européen	Protected	LC	NE	NT	LC
Pipistrellus pygmaeus	Pipistrelle pygmée	Annexe II - Espèces de faune strictement protégées.		Annexe IV -Espèces (animales et végétales) qui nécessitent une protection stricte sur l'ensemble du territoire européen	Protected	LC	LC	LC	NT
Tadarida teniotis	Molosse de Cestoni	Annexe II - Espèces de faune strictement protégées.		Annexe IV -Espèces (animales et végétales) qui nécessitent une protection stricte sur l'ensemble du territoire européen	Protected	LC	LC	NT	LC

*Not Evaluated (NE); Data Deficient (DD); Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered (EN); Critically Endangered (CR); Extinct in the Wild (EW); Extinct (EX).

To evaluate this factor, the diversity index of these 7 key species was calculated (Table 11), resulting in a diversity of 1.69, which according to “Table 4 Qualitative categories of interpretation of the Shannon index”, would be categorized as a **medium diversity.**

TABLE 11. PROTECTION OF KEY SPECIES DIVERSITY INDEX

Diversity parameters	Protection of key species
Species richness	7
Diversity (nats)	1.69
Maximum potential diversity (Hmax)	1.79
Equitability index (J)	0.94

III.2.1.3.2. Fragmentation

For greater precision, the fragmentation analysis was carried out at the micro-watershed scale because this scale of study allows the integration of the different elements of the landscape such as vegetation, hydrology, and land use patterns. The micro-watershed delimited for the project area has a total area of 49.38 ha.

The total fragmentation of the landscape is estimated through the ratio between the forest area and the total area, represented by the following formula:

Fragmentation = Area of forest (ha) / Total area (ha)

To determine the area of forest within the micro-watershed, the areas with forest vegetation were digitized using a satellite image. As a result, 87% (431,221.70 m^2) of the micro-watershed has natural vegetation (Figure 29).

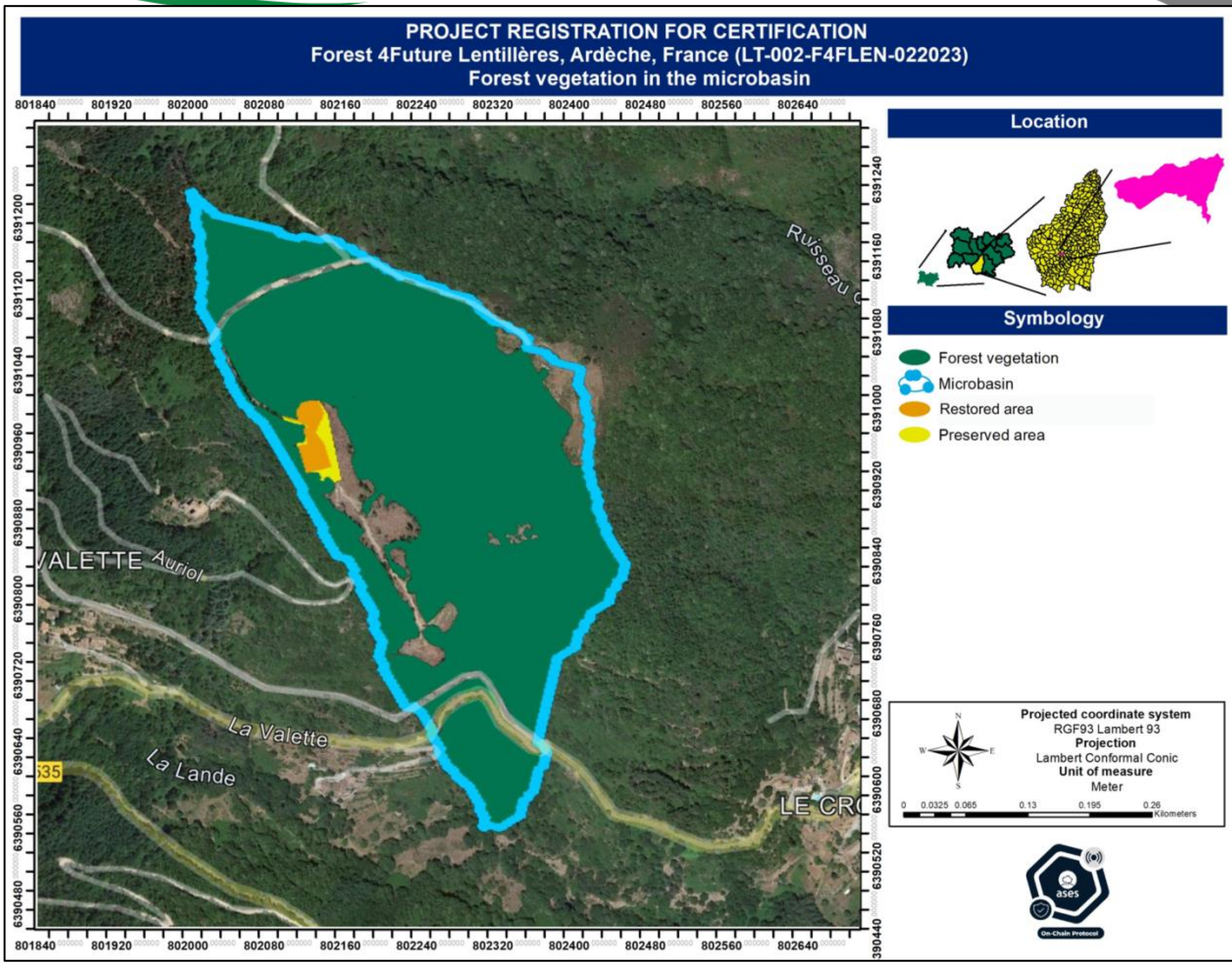


FIGURE 30. FOREST VEGETATION IN THE MICROBASIN

The fragmentation index gives values ranging from 0 to 1, where values less than 0.5 indicate an insularized degree of fragmentation, meaning that the landscape has a high level of fragmentation resembling the way islands are scattered in an ocean. While value 1 represents a landscape with no fragmentation (Table 12).

TABLE 12. FRAGMENTATION RANGE

Fragmentation range	Level
<0.5	Insularized
0.5 – 0.7	Highly fragmented
0.7 – 0.9	Moderate fragmentation
1	Without fragmentation

Bibliographical source: Díaz, A (2003)

Therefore, applying the formula to the project landscape resulted in the following:

Fragmentation = 43.12 / 49.38 = **0.87**

The fragmentation index was 0.87, which indicates that the micro-watershed has a **moderate degree** of fragmentation.

III.2.1.3.3. Fractal dimension

This index measures the complexity of shapes, its value lies between 1 and 2, where values closer to 1 correspond to the most regular perimeters, while values closer to 2 correspond to very complex shapes.

For the Lentillères project, the fractal dimension index was calculated with the Landscape Ecology Statistics (LecoS) plugin of QGIS, which was modeled at the micro-watershed scale and used as input for the forest area in raster format.

The result obtained was 1.1141 which indicates that the landscape structure is a **round** perimeter (Table 13).

TABLE 13. FRACTAL DIMENSION RANGE

Fractal dimension range	Level
< 1.25	Round
1.26 - 1.50	Oval-round
1.51 - 1.75	Oval oblong
1.76 - 1.99	Rectangular
2	Amorphous or irregular

Bibliographical source: Patton D.R. 1975

III.2.1.3.4. Spatial continuity

For the evaluation of spatial continuity as an indicator of fragmentation, the Volgelmann Index (FCI) applied at the micro-watershed scale of the project was used. The formula is made up as follows:

$$\mathbf{FCI} = \ln(\Sigma A / \Sigma P)$$

Where:

Σ A= Total area of forest patches in the landscape (m^2)

Σ P= Total perimeter of forest patches in landscape (m)

The total area of forest patches in the project's micro-watershed landscape is 431,221.70 m^2 (Figure 29) and its perimeter is 8,816 m, which applied to the above formula gives a result:

$$\mathbf{FCI} = \ln(431221.70 / 8816) = \mathbf{1.69}$$

Values less than zero indicate a landscape with spatial continuity, while higher values represent greater discontinuity and fragmentation of patches.

TABLE 14. SPATIAL CONTINUITY RANGE

Index value	Spatial continuity
< 0	Continuous
0.10 - 5	Discontinuous
> 5	Highly discontinuous

III.2.1.3.4. Ecosystem vulnerability to climate change

Vulnerability to climate change is a factor of great relevance to consider, and its evaluation will be made using the biomass data presented and described in section III.1.1.5.1 Net Primary Productivity (NPP). Biomass is fundamental for sustaining species diversity in ecosystems, and its reduction could lead to a reduction in habitats and resources available for species, which would have a direct impact on biological diversity.

Based on the results obtained in section III.1.1.5.1, the biomass in the project area is currently 7,384.62 kg, and in 2050 with the climate change scenario, it would be 6,247.95 kg, **decreasing by 1.13 tn of biomass.**

III.2.1.3.5. Species vulnerability to climate change

The vulnerability to climate change of the reforested species was evaluated based on the current and future potential distribution models (2050 RCP 45) of each planted species, using the Climpact Data Science tool (https://www.cdstoolbox.shop) with the objective of determining the percentage of ecological conditions that the project area has and that each planted species requires to ensure its adaptability and survival.

The probability of species occurrence is defined by the climatic, biological, structural and environmental conditions of the environment that allow the species to adapt and survive (Table 15). This probability of presence is represented by a percentage where 100% indicates that all the necessary conditions for the species exist in that area, and the more the percentage decreases, the more it can be interpreted as meaning that the environmental conditions are not optimal and therefore the species must make a greater effort to adapt to the new conditions and ensure their survival.

TABLE 15. VARIABLES OF THE POTENTIAL DISTRIBUTION MODEL

Climatic variables	Average annual temperature
	Average diurnal range
	Isothermability
	Temperature seasonality
	Maximum temperature of the warmest month
	Minimum temperature of the coldest month
	Annual temperature range
	Mean temperature of the wettest four-month period
	Average temperature of the driest four-month period
	Average temperature of the hottest four-month period
	Average temperature of the coldest four-month period

	Annual precipitation
	Precipitation of the wettest month
	Precipitation of the driest month
	Precipitation seasonality
	Precipitation of the wettest four-month period
	Precipitation of the driest quarter
	Precipitation of the warmest quarter
	Precipitation of the coldest quarter
Biological variables	Land use and vegetation
Natural environment variables	Soil science
	Topography
	Geology
	Slope
Structural variables	Carrying capacity from Net Primary Productivity index PPN

Table 16 indicates the percentage that the project area has of the total variables necessary for the species, presented in the current and future scenarios to 2050 under the climate change scenario. The green color shows those species that, due to variations in precipitation and temperature regimes caused by climate change, could have a better adaptation to the environment by 2050, since the conditions found there will be more similar to those they currently have. The red color identifies the species that in 2050 will find a lower percentage of the necessary conditions in the area, so they will have to make a greater effort to adapt to the new environment and ensure their survival.

TABLE 16. PERCENTAGE OF REQUIRED CONDITIONS IN THE PROJECT AREA

Species	Percentage of required conditions in the project area	
	Current	2050
Taxus baccata	97.22%	84.44%
Sequoiadendron giganteum	97.50%	91.39%
Sequoia sempervirens	53.33%	54.44%
Salix purpurea	91.67%	96.94%
Rhamnus lycioides	39.44%	85.83%
Quercus suber	46.67%	97.22%
Quercus petrea	99.72%	89.17%
Quercus ilex	96.67%	91.94%
Quercus coccifera	42.78%	97.22%
Pseudotsuga menziessi	100.00%	86.94%
Prunus spinosa	96.94%	92.50%
Prunus mahaleb	99.44%	93.89%
Platanus orientalis	51.11%	96.39%

Species	Percentage of required conditions in the project area	
	Current	2050
Pistacia terebenthus	42.22%	91.67%
Pistacia lentiscus	32.22%	69.44%
Pinus pinea	31.67%	81.94%
Pinus halepensis	50.56%	94.17%
Olea europaea	30.00%	80.28%
Fraxinus excelsior	100.00%	89.44%
Ficus carica	60.00%	100.00%
Cupressus sempervirens	90.28%	97.22%
Cryptomeria japonica	65.00%	96.94%
Crataegus monogyna	93.89%	97.22%
Corylus colurna	72.22%	100.00%
Ceratonia siliqua	28.06%	53.33%
Cedrus libani	90.83%	98.89%
Cedrus atlantica	91.67%	99.72%
Acer monspessulanum	91.11%	96.11%
Acer campestre	95.83%	90.56%
Average	**71.66%**	**89.49%**

As can be seen in the table above, at present the property has on average 71.66% of all the necessary conditions of the reforested species, and in 2050 the percentage will increase to 89.49%, that is, +17.83% of the conditions, which indicates that the planted species could have a good adaptation to the new environmental conditions and survive the climatic changes that the phenomenon will cause.

III.2.2. Classification of relativized variables

Factor		Value obtained for the project	Clasification	Value index	Relativized factor
F1	Biodiversity index of key protected species	1.69	Very low	< 1.02	0.01
			Low	1.03 - 1.53	0.14
			Medium	1.54 - 2.11	0.32
			High	2.12 - 2.65	0.67
			Very high	> 2.65	1.00
F2	Fragmentation	0.87	Insularized	<0.5	0.20
			Highly fragmented	0.5 – 0.7	0.33
			Moderate fragmentation	0.7 – 0.9	0.66
			Without fragmentation	1	1.00
F3	Fractal dimension	1.114	Round	< 1.25	1
			Oval-round	1.26 - 1.50	0.68
			Oval oblong	1.51 - 1.75	0.34
			Rectangular	1.76 - 1.99	0.26
			Amorphous or irregular	>2	0.16
F4	Spatial continuity	1.69	Continuous	< 0	1.00
			Discontinuous	0.10 - 5	0.02
			Highly discontinuous	> 5	0.01
F5	Ecosystem vulnerability to climate change	1.13 tn	Very low	0 - 1	1.00
			Low	1 - 3	0.67
			Medium	4 - 6	0.33
			High	7 - 10	0.16
			Very high	> 10	0.11
F6	Species vulnerability to climate change	17.83%	Species with very high resilience	<10	1.00
			Highly resilient species	11 - 20	0.72
			Species with medium resilience	21 - 40	0.44
			Species with low resilience	41 - 60	0.15
			Species with very low resilience	61 - 80	0.07
			Non-resilient species	80 - 100	0.01
F7	Biodiversity index in the area restored	2.63	Very low	< 1.02	0.01
			Low	1.03 - 1.53	0.14
			Medium	1.54 - 2.11	0.32
			High	2.12 - 2.65	0.67
			Very high	> 2.65	1.00
F8	Biodiversity index in the preserved area	Total 1.26 Flora 0.29 Fauna 0.97	Very low	< 1.02	0.01
			Low	1.03 - 1.53	0.14
			Medium	1.54 - 2.11	0.32
			High	2.12 - 2.65	0.67

Factor		Value obtained for the project	Clasification	Value index	Relativized factor
			Very high	> 2.65	1.00

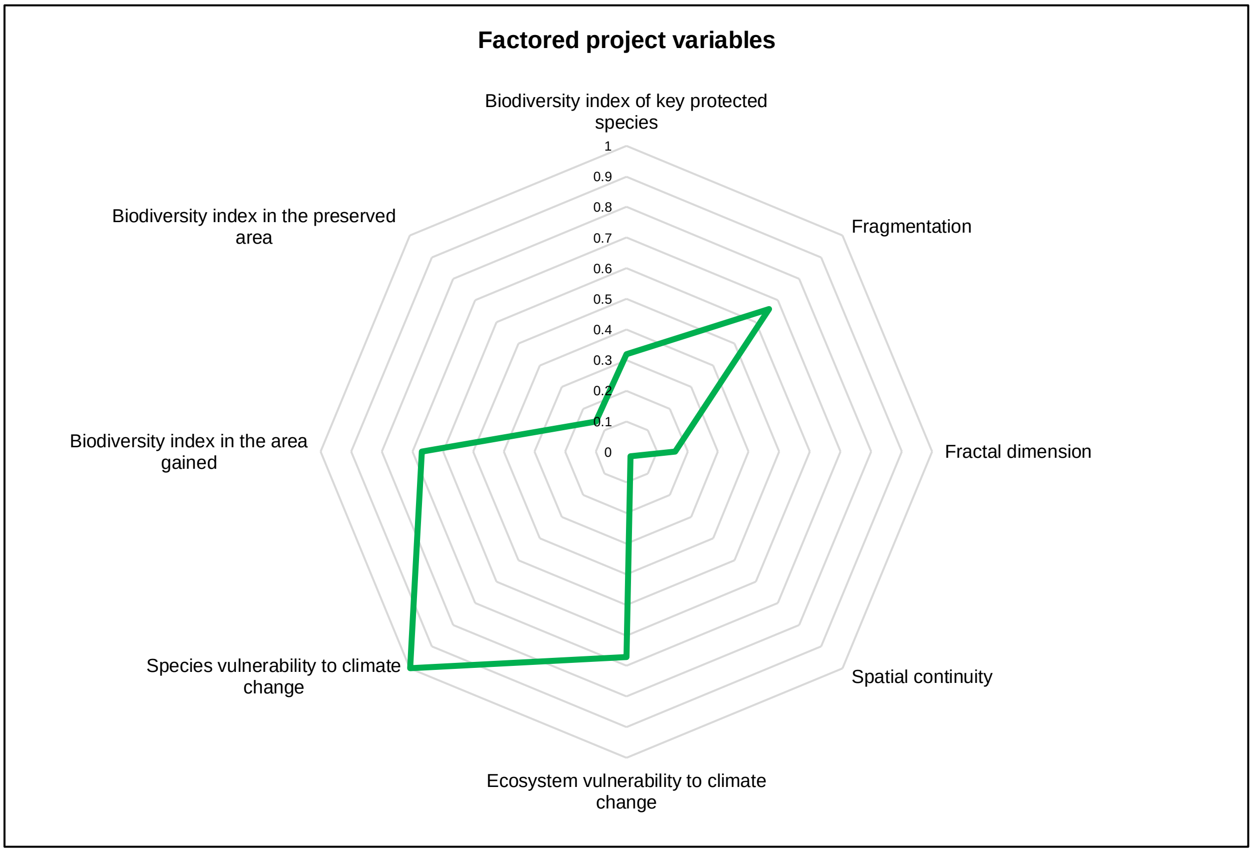


FIGURE 31. FACTORED PROJECT VARIABLES

Once the indices for each factor and their relativization were obtained, the formula proposed for the calculation of biodiversity credits was applied, obtaining a total of 390 credits for the Lentillères project, which will be issued according to the monitoring plan and the contingent table.

$$\mathbf{VBBCs} = \frac{11998*(0.32+0.66+0.20+0.02+0.67+1)+(5600*0.67)+(6398*0.14)}{100} = \mathbf{390}$$

It is considered **390** is the number of biodiversity credits that could be awarded by the Lentillères project based on the benefits it has generated in terms of diversity.

To estimate the maximum number of credits to which the project could aspire, a simulation was carried out considering that the variables analyzed would have a greater positive response to the different factors evaluated throughout the life of the project. That is if during the monitoring determined in the Monitoring Plan, results are obtained that demonstrate that the biodiversity index measured with Shannon significantly increased for the preserved area and key species, in addition to demonstrating that fragmentation decreased and therefore the fractal dimension, and that the project improved the spatial continuity of the landscape.

Once the above-mentioned variables have been ranked with the factor relativized to the maximum probable, it is determined that the Lentillères project could reach a maximum of **697 credits.**

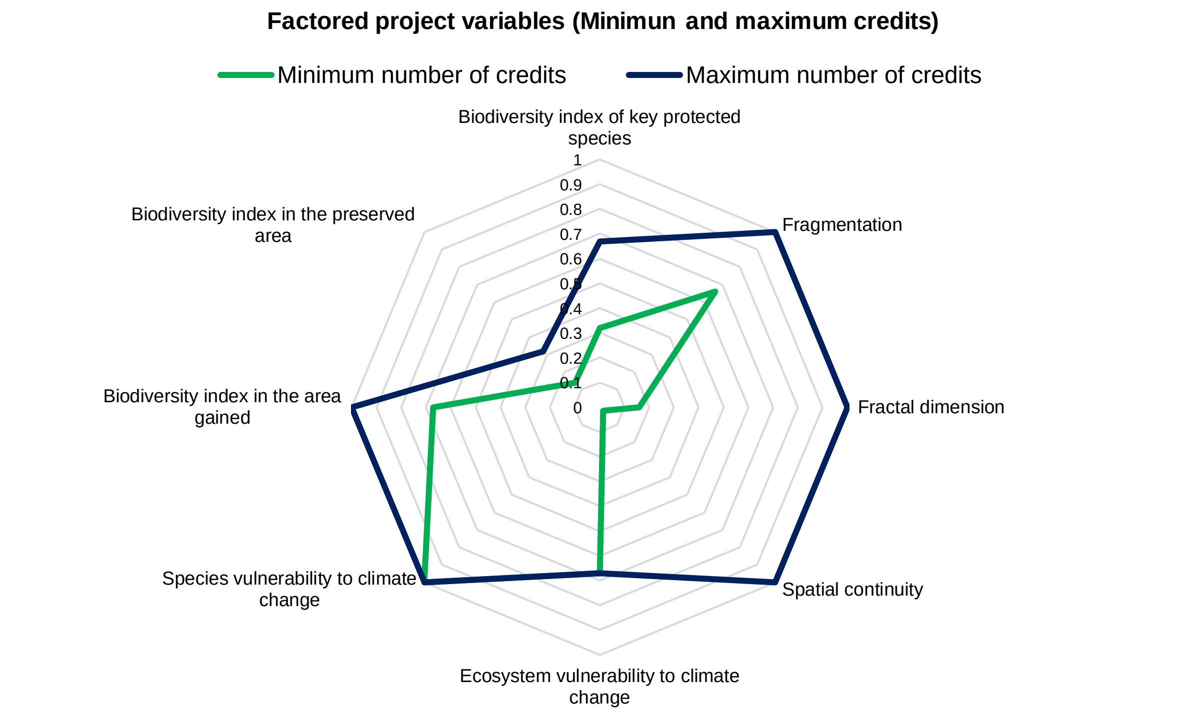


FIGURE 32. FACTORED PROJECT VARIABLES (MININUM AND MAXIMUM CREDITS)

TABLE 17. NUMBER OF BIODIVERSITY CREDITS AND CUMULATIVE CREDITS PER YEAR OF PROJECT

Project year	Number of corresponding credits		Accumulated per year	
	Minimum number of credits	Maximum number of credits	Minimum number of credits	Maximum number of credits
1	9.75	17.43	10	17
2	9.75	17.43	20	35
3	9.75	17.43	29	52
4	9.75	17.43	39	70
5	9.75	17.43	49	87
6	9.75	17.43	59	105
7	9.75	17.43	68	122
8	9.75	17.43	78	139
9	9.75	17.43	88	157

Project year	Number of corresponding credits		Accumulated per year	
	Minimum number of credits	Maximum number of credits	Minimum number of credits	Maximum number of credits
10	9.75	17.43	98	174
11	9.75	17.43	107	192
12	9.75	17.43	117	209
13	9.75	17.43	127	227
14	9.75	17.43	137	244
15	9.75	17.43	146	261
16	9.75	17.43	156	279
17	9.75	17.43	166	296
18	9.75	17.43	176	314
19	9.75	17.43	185	331
20	9.75	17.43	195	349
21	9.75	17.43	205	366
22	9.75	17.43	215	383
23	9.75	17.43	224	401
24	9.75	17.43	234	418
25	9.75	17.43	244	436
26	9.75	17.43	254	453
27	9.75	17.43	263	471
28	9.75	17.43	273	488
29	9.75	17.43	283	505
30	9.75	17.43	293	523
31	9.75	17.43	302	540
32	9.75	17.43	312	558
33	9.75	17.43	322	575
34	9.75	17.43	332	593
35	9.75	17.43	341	610
36	9.75	17.43	351	627
37	9.75	17.43	361	645
38	9.75	17.43	371	662
39	9.75	17.43	380	680
40	9.75	17.43	**390**	**697**

III.3. Soil

The project area has been assessed according to the aOCP Methodology for soil health assessment. The assessment has 2 components: soil health assessment and erosion assessment. Both are detailed below.

III.3.1. Soil erosion assessment

There are 2 relevant events that determine the assessment of the Project area: deforestation, which occurred in November 2021, and Project implementation, which took place in the first quarter of 2023.

Soil erosion was assessed for 4 scenarios:

1. **Before deforestation.** As deforestation in the Project area occurred in November 2021, spring and summer of that year are representative of the original forest.
2. **After deforestation.** Spring and summer 2022 are representative of the Area without tree cover, experiencing high rates of erosion.
3. **After project implementation.** Spring and summer 2023 are representative of the Project area once soil works and reforestation took place.
4. **Restored scenario.** Is the expected outcome of the project once the planted trees reach maturity and the forest recovers its original characteristics, as it was before deforestation.

Erosion was assessed using the RUSLE equation, which includes 5 components. A brief description of the source and calculation of each of them is provided below.

1. Rainfall erosivity (R-factor). Was obtained from the RUSLE2015 dataset, provided by the EUROPEAN SOIL DATA CENTRE (ESDAC) Joint Research Center, available at: https://esdac.jrc.ec.europa.eu/themes/rainfall-erosivity-europe

2. Soil erodibility (K-factor). Was obtained from the RUSLE2015 dataset, provided by the EUROPEAN SOIL DATA CENTRE (ESDAC) Joint Research Center, available at: https://esdac.jrc.ec.europa.eu/themes/soil-erodibility-europe

3. Slope length and slope steepness (LS- factor). The LS factor was calculated with the equation from Moore & Wilson (1992) [eq. 1] on a 5m spatial resolution DEM, the RGE ALTI® 5M dataset, downloaded from https://geoservices.ign.fr/rgealti.

$$LS = \left(\frac{A_s}{22.13}\right)^m \left(\frac{\sin(\theta)}{0.0896}\right)^n$$

Where As = unit contributing area (m), θ = slope in radians, m = 0.4 and n = 1.3.

4. Cover Management (C-factor). Was calculated with the equation developed by van der Knijff et al. (1999) [eq. 2] on the NDVI computed from Sentinel-2 images.

$$C_{VK} = exp\left(-\alpha \frac{NDVI}{(\beta - NDVI)}\right)$$

Where C_{VK} is the estimated C-factor, α and β are constants 2 and 1, respectively.

The NDVI was calculated in Google Earth Engine as follows:

- Images with cloudy pixel percentage lower than 50%, from 21-March to 4-June for the years 2021, 2022 and 2023 were obtained.
- NDVI was computed for all the images.
- For each year, a composite image was created obtaining the maximum NDVI for each pixel. The result is a single image per year in which each pixel has the highest NDVI observed during the selected dates.

5. Conservation Practices (P-factor). Was calculated according to the following classification (table 2), which is adequate for terraces. Slope was calculated for the same 5m DEM used for the LS-factor. Only the Project area where soil works were implemented was reclassified, assigning a P-factor value of 1 to the area outside.

TABLE 18. P-FACTOR REFERENCE TABLE FOR TERRACED LANDS

Slope %	P-factor value
1 - 2	0.12
3 - 8	0.10
9 - 12	0.12
13 - 16	0.14
17 - 20	0.16
21 - 25	0.18
> 25	0.20

David, 1998

The datasets used for computing each scenario are shown in Table 19. Only factors C- and P-change, while factors K-, LS- and R- are constant in all scenarios.

TABLE 19. COMBINATION OF DATASETS USED TO REPRESENT THE 4 SCENARIOS

Scenario	C-factor	P-factor
Before deforestation	NDVI 2021	Without soil works
After deforestation	NDVI 2022	Without soil works
After project implementation	NDVI 2023	With soil works
Future (successful restoration)	NDVI 2021	With soil works

Finally, the RUSLE equation was computed by multiplying the 5 abovementioned factors. The result is **soil erosion rate (t ha^{-1} yr^{-1})**. Figure 1 shows the results obtained. On the 2021 scenario, the parcel and the microbasin have both low soil erosion rates, inferior to 1 t ha^{-1} y^{-1}. In 2022 we observe an increase inside the deforested area due to the loss of vegetation cover, as well as in the northwest and south of the microbasin, both showing the path followed by trucks to extract the wood. In 2023, erosion on these non-official roads was more evident, while inside the deforested area it decreased where the project activities were implemented, staying high on the rest of the deforested area. The future scenario shows low erosion rates due to the growth of trees upto a mature state on all the previously deforested area and the restoration of the path used by the trucks.

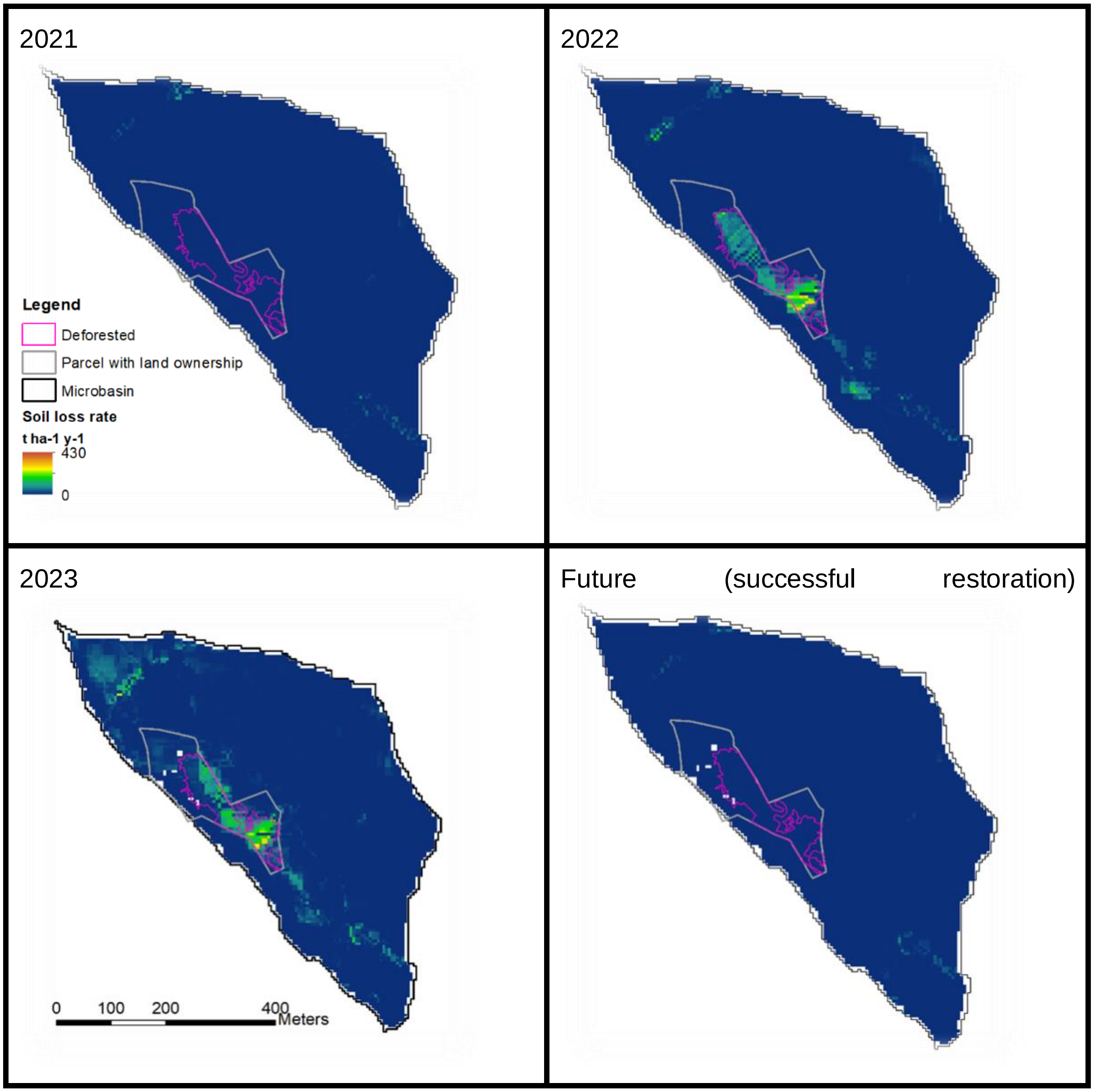


FIGURE 33.SOIL EROSION RATE ON THE MODELLED SCENARIOS. COLOR SCALE ON THE SYMBOLOGY IS CONSTANT

Table 20 shows the average erosion rate and the yearly soil loss, both at parcel and basin level, for the 4 scenarios. Table 21 shows the percent change between scenarios. From 2021 to 2022 the change inside the parcel was as high as 456,517.5%, evidently due to the loss of vegetation; at basin level, the increase was of 1,100.5% also due to deforestation, but mitigated by the rest of the basin where no changes occurred. From 2022 to 2023, erosion within the parcel increased in 21.4%, while on the microbasin it increased 77.2%, this reflects the positive impact of the Project activities because while the whole microbasin experienced lower NDVI values than the previous year (due to rainfall timing, discussed below) the soil works and reforestation helped to improve the P- and C- factors, respectively. In other words, without the Project, the parcel would have had a relative increase in erosion rate of 77.2% instead of 21.4%. However, in absolute terms, erosion rate increased in 6.77 and 3.56 t ha^{-1} y^{-1} at the parcel and microbasin, respectively. In the future scenario, erosion dropped even below the 2021 values, because even if vegetation recovered its original coverage, the implementation of soil works for erosion control (terraces) provide an additional benefit.

TABLE 20. SOIL EROSION RATE AND YEARLY SOIL LOSS IN THE PROJECT AREA

Scenario	Average erosion rate (t ha^{-1} y^{-1})		Soil loss per year (t y^{-1})	
	Parcel	Basin	Parcel	Basin
2021	0.01	0.38	0.02	9.64
2022	31.59	4.61	79.10	115.70
2023	38.36	8.17	96.07	205.03
Future	0.01	0.33	0.01	8.37

TABLE 21. PERCENTAGE OF CHANGE IN YEARLY SOIL LOSS AT PARCEL AND BASIN LEVEL

Period	Parcel (%)	Basin (%)
2021-2022	456,517.5	1,100.5
2022-2023	21.4	77.2
2023-future	-100.0	-95.9

During the analysis, it was found that NDVI is not consistent when comparing the same month in different years, even if forest cover remains unchanged. The analysis of the rainfall abundance and temporality (Figure 33) revealed that in 2021, rain in March was low, increasing in April and more in May, this led to a delayed development of vegetation; in June it remained high. In contrast, in 2022, important rain started since March and decreased towards April and May, which triggered early development of vegetation. Finally, in 2023, rain had moderate levels since March, continuing more or less constant until May; June records are not yet available.

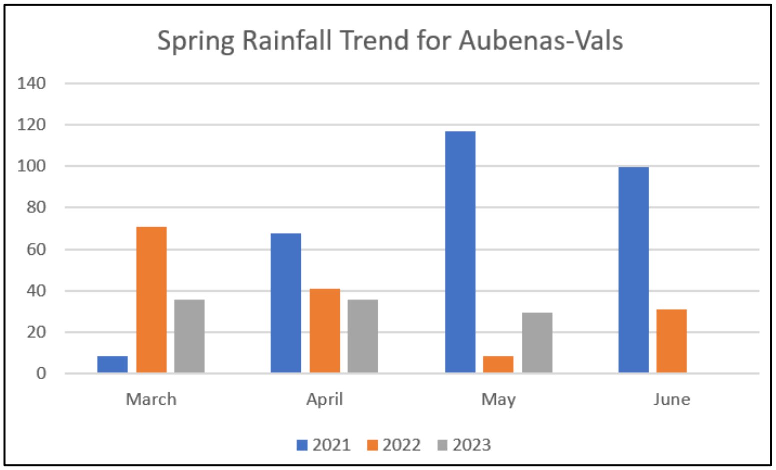


FIGURE 34. RAINFALL (MM) RECORDED AT THE AUBENAS-VALS STATION IN THE MONTHS AND YEARS ASSESSED.

III.3.2. Calculation of soil loss reduction credits

For the calculation of amount of soil that was prevented from eroding, we use the percent change. From 2022 to 2023, the erosion rate increased 77.2% in the microbasin and 21.4% inside the parcel.

The estimated total soil loss inside the parcel is 79.105 tons in 2022 and 96.065 tons in 2023. If the Project activities were not implemented and the parcel experienced the same increase as all the microbasin, the soil loss inside the parcel would be 140.289 tons. This means that **44.22 tons of soil inside the parcel will not be lost in 2023 thanks to the implementation of soils works and reforestation**.

As planted trees continue to grow, vegetation cover will increase and contribute to decrease the erosion rate. It is expected that erosion rate will descend to the value it had before deforestation and even less, considering the soil works. Therefore, when trees reach maturity the Project's contribution will be a reduction of the erosion rate of -31.58 t ha^{-1} y^{-1}, which for the Parcel area means 79.09 tons of soil per year that will not be lost thanks to soil works. It is worth noting that this estimate relies on the assumption that the deforested area would remain uncovered, however we know that ecological succession and natural regeneration would eventually lead to the development of some vegetation cover, though not as important in terms of species richness and time as the restored forest.

III.3.3. Notes for future erosion assessments

The future scenario is calculated with a C-factor assuming that trees were planted on all the deforested area, but the P-factor only reflects the soil works implemented at this moment (as of June 2023), if P-factor will reflect terracing all along the deforested area, the erosion will be even lower than the reported here.

Variations in the amount and temporality of rain and temperature cause variations in NDVI measured in a particular month on different years. This was accounted for by calculating the C-factor utilizing a composite NDVI image of the yearly maximum NDVI on each pixel.

Yearly erosion calculated using a C-factor from spring /summer can be underestimated because in winter, the vegetation cover is less vigorous and contributes less to prevent erosion. A good approach can be the quarterly or even monthly calculation of C-factor and RUSLE to get a more precise yearly average.

III.3.4. Soil health assessment

Five indicators were selected for the assessment, based on the availability of regional data (Table 22).

Regional data was obtained from SoilGrids.org and analyzed according to the above mentioned methodology. In summary, the centroid from the parcel was computed, then a 50Km buffer was created, followed by a 2 Km x 2 Km point grid. The points inside the buffer area were used to extract the values of the indicators from the raster layers downloaded from SoilGrids, same for the centroid point. Each indicator's records were used to compute the Cumulative Normal

Distribution function, i.e. the scoring curve. Finally, the value of each indicator at centroid point was scored with the corresponding CND.

The results obtained are presented in table 22. For each indicator, mean and standard deviation for the records (N=1972) used to compute the CND are provided, together with the value at the location of the selected centroid.

TABLE 22. INDICATORS USED TO CALCULATE THE SQI, REFERENCE VALUES AND SCORE AT THE PROJECT AREA

Indicator	Units	Type of curve	Mean	Std	Value	Score	Category
Cation exchange capacity	mmol(C)/kg	MIB	202.25	32.11	190	35.1	chemical
Bulk density	cg/cm^3	LIB	126.76	20.60	114	73.2	physical
Nitrogen	cg/kg	MIB	568.99	174.33	658	69.5	chemical
pH	pHx10	optimal	65.53	10.09	66	?	chemical
SOC %	dg/kg	MIB	752.89	221.61	774	53.8	biological

The Soil Quality Index was calculated as the unweighted average of the 4 scores available. **The SQI for this assessment is 57.9**. It is worth noting that the values used for establishing this baseline proceed from the SoilGrids website and may differ from values measured on site. Nonetheless, the scoring curves remain valid as reference of the range of variation of the indicators in the region and can be used in the following monitoring campaigns.

Additional information obtained from SoilGrids is presented in table 23, to help characterize the soil properties at the study area.

TABLE 23. SOIL GRANULOMETRY AND ORGANIC CARBON STOCKS

Name	Units	Mean	std	Value	Category
SOC stocks	t/ha	68.54	18.44	65	Biological
Sand content	g/kg	330.60	68.62	337	Physical
Silt content	g/kg	366.55	61.28	370	Physical
Clay content	g/kg	284.08	49.08	296	Physical
Coarse fragments content	cm^3/dm^3	132.73	29.25	129	Physical

III.3.5. CALCULATION OF CARBON CREDITS FROM SOIL

The potential for generation of water credits was calculated based on the maximum value of soil carbon stocks found within a radius of 1 Km from the Project area. The data was obtained from the SoilGrids.org website. The maximum Value is 72 T/ha.

According to soilgrids, there are currently 65 tons of organic carbon per hectare, or 36.4 tons of SOC in the project area (5600 m2), which is equivalent to 133.6 tons of CO2.

If the potential of 72 tons/ha is reached, the project area will have 148 tons of CO2.

The increase will be 14.4 tons of CO2 in the project area. This can be either in 40 years or the time it takes for the project to reach maturity. In order to attribute this entirely to the project, it would be necessary to know how much this would increase or decrease naturally if the project were not carried out.

TABLE 24. CARBON CREDITS

Year	SOC T/ha	SOC/project	CO2/project
0	65.0	36.4	133.6
1	65.2	36.5	133.9
2	65.4	36.6	134.3
3	65.5	36.7	134.7
4	65.7	36.8	135.0
5	65.9	36.9	135.4
6	66.1	37.0	135.7
7	66.2	37.1	136.1
8	66.4	37.2	136.5
9	66.6	37.3	136.8
10	66.8	37.4	137.2
11	66.9	37.5	137.5
12	67.1	37.6	137.9
13	67.3	37.7	138.3
14	67.5	37.8	138.6
15	67.6	37.9	139.0
16	67.8	38.0	139.3
17	68.0	38.1	139.7
18	68.2	38.2	140.1
19	68.3	38.3	140.4
20	68.5	38.4	140.8
21	68.7	38.5	141.1
22	68.9	38.6	141.5
23	69.0	38.7	141.9
24	69.2	38.8	142.2
25	69.4	38.9	142.6
26	69.6	38.9	142.9
27	69.7	39.0	143.3
28	69.9	39.1	143.7
29	70.1	39.2	144.0
30	70.3	39.3	144.4
31	70.4	39.4	144.7
32	70.6	39.5	145.1
33	70.8	39.6	145.5

Year	SOC T/ha	SOC/project	CO2/project
34	71.0	39.7	145.8
35	71.1	39.8	146.2
36	71.3	39.9	146.5
37	71.5	40.0	146.9
38	71.7	40.1	147.3
39	71.8	40.2	147.6
40	72.0	40.3	148.0

III.4. WATER INFILTRATION

The project area has been assessed according to the aOCP Methodology for the assessment of groundwater recharge restoration.

The methodology establishes 3 approaches for the assessment of infiltration, which is then used as input for the Thornthwaite-Mather water balance model:

1) Soil Conservation Service Curve Number (SCS-CN) Method
2) Literature data
3) Machine learning model based on field and satellite data

At this moment (June 15th, 2023), only the first 2 approaches were available due to lack of field data to run the machine learning model.

The process of implementing the SCS-CN is outlined below, including its integration with the water balance method. This approach has the potential to track the evolution of restoration projects since it is based on satellite imagery from Sentinel-2, which has a temporal resolution of 5 days.

Literature data on infiltration depending on soil texture is used to compare and discuss the results obtained.

III.4.1. GROUND WATER STORAGE ASSESSMENT

There are 2 relevant events that determine the assessment of the Project area: deforestation, which occurred in November 2021, and Project implementation, which took place in the first quarter of 2023.

Ground water storage was assessed for 3 scenarios:

1. Before deforestation. As deforestation in the Project area occurred in November 2021, spring and summer of that year are representative of the original forest.
2. After deforestation. Spring and summer 2022 are representative of the Area without tree cover, experiencing high rates of runoff and low infiltration.
3. After project implementation. Spring and summer 2023 are representative of the Project area once soil works and reforestation took place.

The dates of the satellite images used for the analysis are the following:

Scenario	Date of Sentinel-2 image
Before deforestation	02-04-2021
After deforestation	27-04-2022
After project implementation	02-05-2023

In summary, the methodology follows the next steps for the calculation of ground water storage (GWS):

1. Use the LSMA method to calculate the proportion of impervious surface, vegetation and soil of each pixel in a Sentinel-2 image of the microbasin where the study area is located.
2. Calculate the composite curve number (CNc), as the weighted* average of:
   a. Soil CN: based on the hydrologic soil group, defined by soil texture.
   b. Impervious CN: given a fixed value of 98, according to literature.
   c. Vegetation CN: determined by NDVI class and percentage of vegetation in the pixel, according to Bera et al. (2022).

   *The weights correspond to the percentage of each land cover class, obtained from the LSMA.

3. Calculate slope corrected CN (CNsc).
4. Calculate runoff and infiltration.
5. Calculate evapotranspiration (ET) (potential or real), here we used potential ET in order to isolate the effect of the Project activities on infiltration as the only factor determining change in GWS.
6. Calculate ground water storage, using runoff from step 6, ET from step 7 and mean annual precipitation (P). Mean annual precipitation, from 1993 to 2022, was calculated on Google Earth Engine from the “CHIRPS Daily: Climate Hazards Group InfraRed Precipitation With Station Data (Version 2.0 Final)” dataset (Funk et al., 2015). This dataset has a spatial resolution of 5566 meters, so a single pixel covered the microbasin. The same value was used for the 3 years assessed (P = 930.17 mm).

Figure 34 shows spatially the results obtained. The first observation is that the microbasin and surrounding area are in water deficit, since GWS has negative values ranging from -380 to -510 mm per year, this means that the volume of water lost in evapotranspiration and runoff is higher than the volume of precipitation.

Figure 35 shows the mean groundwater storage in each of the polygons compared (microbasin, parcel with land ownership, deforested and reforested). These polygons don’t overlap; their characteristics are:

- Microbasin: area outside the parcel with land ownership;
- Parcel: area with land ownership, where no deforestation or reforestation took place;

- Deforested: area where deforestation occurred and without reforestation;
- Reforested: area where deforestation occurred and restoration activities were implemented (reforestation and soil works).

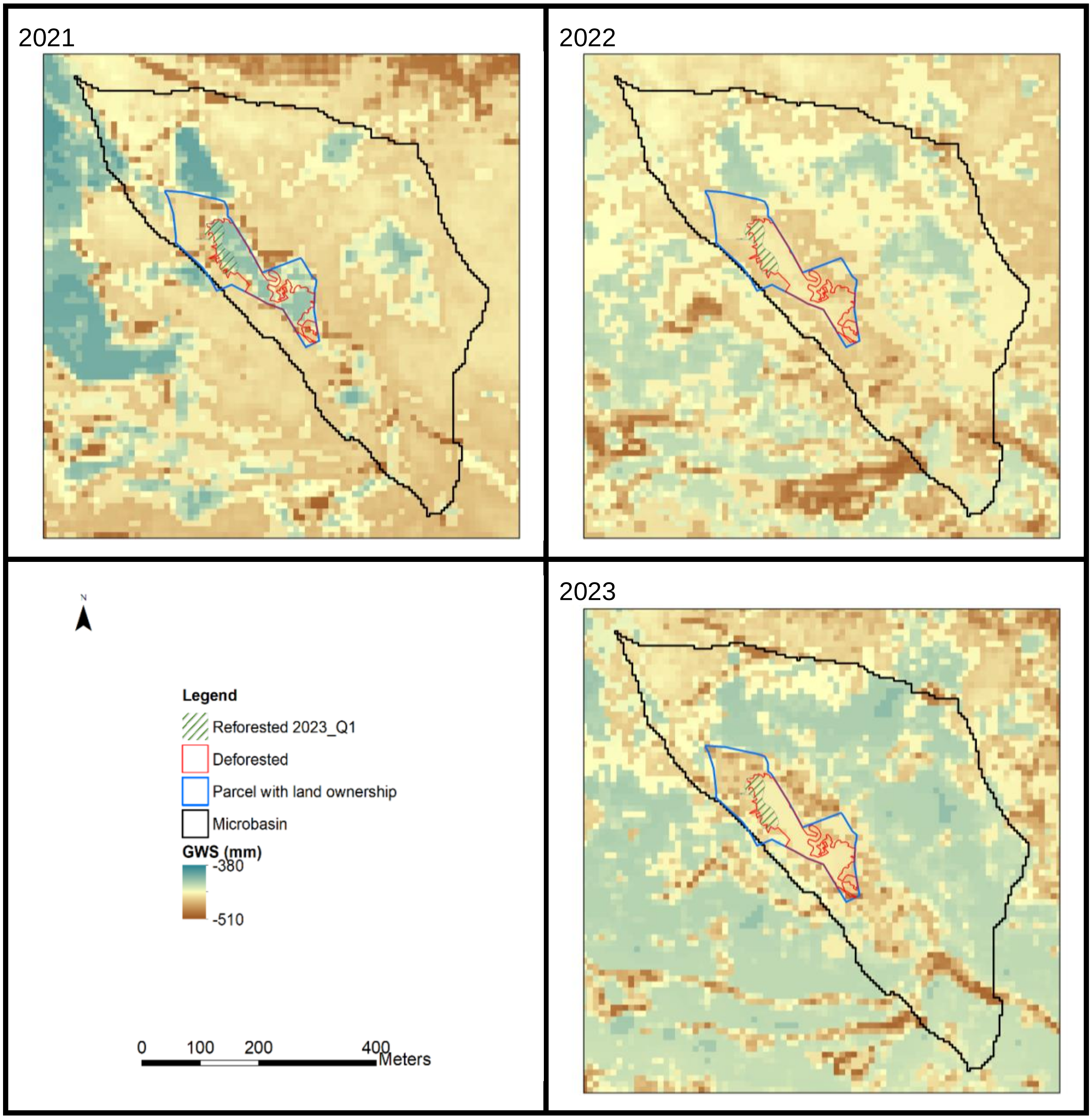
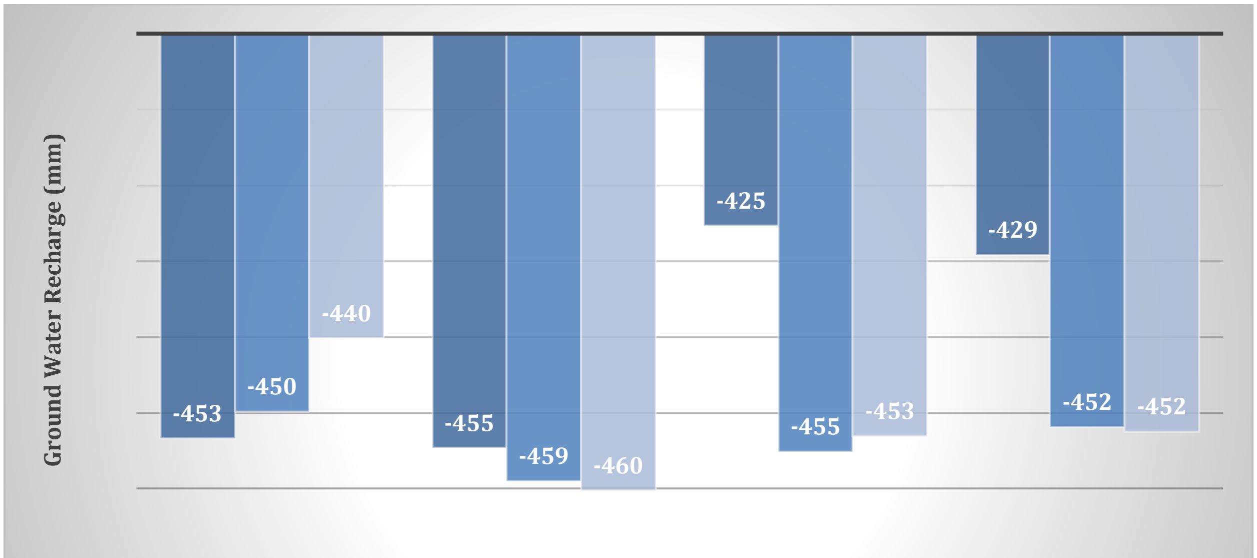


FIGURE 35. GROUND WATER STORAGE FROM 2021 TO 2023. COLOR SCALE ON THE SYMBOLOGY IS CONSTANT

The microbasin's water deficit decreased from -453 mm, in 2021, to -440 mm, in 2023, i.e 2.9%. Contrastingly, the parcel's water deficit increased from -455 mm in to -460 mm, in 2023, i,e, -1.3%. The deforested and reforested polygons had at 2021 lower water deficit than the basin and the parcel, -425 and -429 mm, respectively. This can be explained because the trees that were logged were *Pseudotsuga menziesii* , a coniferous species from the Pinaceae family. As an evergreen tree, the values of NDVI and percentage of vegetation per pixel were higher than in the surrounding area, dominated by *Castanea sativa*, a broad-leaf deciduous species. This difference is specially notorious on the dates compared, which are April and May, when *C. sativa* had not yet fully developed the crown cover. In these 2 polygons, the effect of deforestation is notorious. The deforested polygon went from -425 mm, in 2021, to -455 mm, in 2022, i.e. -7.0%, and to -453 mm, in 2023, i.e. a 0.4% improvement. The reforestation polygon went from -429 mm, in 2021, to -452 mm, in 2022, i.e. -5.3%, and to -452 mm, in 2023, i.e. -0.1%.



	basin	parcel	deforested	reforested
2021	-453	-455	-425	-429
2022	-450	-459	-455	-452
2023	-440	-460	-453	-452

FIGURE 36. MEAN GROUND WATER STORAGE ON EACH POLYGON (NON-OVERLAPPING).

The effect of restoration activities on the “reforested” polygon is not yet noticeable (at the date of the satellite image, 02-may-2023). It is however expected that when trees reach maturity (approximately in 5 years) and vegetation cover gets to levels similar to those before deforestation, the groundwater recharge (deficit) will improve by around **23 mm.**

TABLE 25. PERCENTAGE OF CHANGE IN GROUNDWATER RECHARGE

Polygon	2021-2022 (%)	2022-2023 (%)
Microbasin	0.8	2.1
Parcel	-1.0	-0.3
Deforested	-7.0	0.4
Reforested	-5.3	-0.1
Whole Microbasin	0.4	1.9

III.4.2. CALCULATION OF WATER CREDITS

The potential for generation of water credits was calculated based on the expected groundwater recharge. Assuming that the project leads to the restoration of the Project area in 40 years, it will improve from the current -452 mm up to -429 mm per year. This calculation is based on a linear progression. Each mm in GWS equals 1 L/m^2 . Given that the surface of the restored area is 5,600 m^2, each mm increase represents an increase in groundwater recharge of 5.6 m^3.

The column *Groundwater storage (S)* shows the modelled evolution of this parameter. Column *delta S* shows the increase in S respect to the initial state, before project implementation. Column *m^3/year=Credits per year* shows the credits to issue each year, considering the Project surface. Column *Accumulated credits* shows the potential of the project to generate Water Credits, **at year 40 the Project will have generated a total of 2640 Water credits.**

If S remains constant from year 41 and on, the project will generate 128 credits yearly. However, if the project improves further the Groundwater storage, the number of yearly credits will be higher.

Year	Groundwater storage (S)	delta S	m^3/year = Credits per year	Accumulated credits
0	-452	0	0	0
1	-451.4	0.6	3.2	3.2
2	-450.9	1.2	6.4	9.7
3	-450.3	1.7	9.7	19.3
4	-449.7	2.3	12.9	32.2
5	-449.1	2.9	16.1	48.3
6	-448.6	3.5	19.3	67.6
7	-448	4	22.5	90.2
8	-447.4	4.6	25.8	115.9
9	-446.8	5.2	29	144.9
10	-446.3	5.8	32.2	177.1
11	-445.7	6.3	35.4	212.5
12	-445.1	6.9	38.6	251.2
13	-444.5	7.5	41.9	293
14	-444	8.1	45.1	338.1
15	-443.4	8.6	48.3	386.4
16	-442.8	9.2	51.5	437.9
17	-442.2	9.8	54.7	492.7
18	-441.7	10.4	58	550.6
19	-441.1	10.9	61.2	611.8
20	-440.5	11.5	64.4	676.2

Year	Groundwater storage (S)	delta S	m^3/year = Credits per year	Accumulated credits
21	-439.9	12.1	67.6	743.8
22	-439.4	12.7	70.8	814.7
23	-438.8	13.2	74.1	888.7
24	-438.2	13.8	77.3	966
25	-437.6	14.4	80.5	1046.5
26	-437.1	15	83.7	1130.2
27	-436.5	15.5	86.9	1217.2
28	-435.9	16.1	90.2	1307.3
29	-435.3	16.7	93.4	1400.7
30	-434.8	17.3	96.6	1497.3
31	-434.2	17.8	99.8	1597.1
32	-433.6	18.4	103	1700.2
33	-433	19	106.3	1806.4
34	-432.5	19.6	109.5	1915.9
35	-431.9	20.1	112.7	2028.6
36	-431.3	20.7	115.9	2144.5
37	-430.7	21.3	119.1	2263.7
38	-430.2	21.9	122.4	2386
39	-429.6	22.4	125.6	2511.6
40	-429	23	128.8	**2640.4**

ANNEX 1. MONITORING PLAN

Key project	LT-002-LEN-052023 LENTILLERES, ARDECHE
Title of the project activity	Forest 4Future Lentillères, Ardèche
Company	Life Terra - 2°much!

Year	2023				2024				2025				2026				2027				2028				2029				2030				2031				2032				2033				2034				2035				2036				2037 to 2063				END OF THE PROJECT
Project year	1				2				3				4				5				6				7				8				9				10				11				12				13				14				15 to 41				
Quarter (1: may; 2: august; 3: november; 4: february	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Carbon in vegetation																																																													
Survival assessment on-site		1				1				1				1				1				1				1				1				1				1																							
Satellite monitoring (NDVI)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1		1		1		1		1		1		1		1		1		1				1				1				1				1			
Biomass sampling on-site (biometry)																						1				1				1				1				1																							
Biomass assessment by drone images		1				1				1				1				1				1				1				1				1				1																							
Biomass assessment remotely (ML)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1		1		1		1		1		1		1		1		1		1				1				1				1				1			
Carbon in soil																																																													
On-site sampling & lab tests		1				1				1				1				1				1				1				1				1				1																							
Satellite & ML assessment	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1		1		1		1		1		1		1		1		1		1				1				1				1				1			
Biodiversity (on-site only)																																																													
Plant diversity		1				1				1				1				1				1				1				1				1				1																							
Eco-acoustic sensors		1				1				1				1				1				1				1				1				1				1																							
Groundwater recharge																																																													
On-site infiltration assessment & ML training		1				1				1				1				1				1				1				1				1				1																							
ML infiltration assessment	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1		1		1		1		1		1		1		1		1																					
Remote sensing CN+waterbalance model	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1		1		1		1		1		1		1		1		1		1				1				1				1				1			
Soil health and erosion																																																													
Soil health indicators sampling on-site & lab test		1				1				1				1				1				1				1				1				1				1																							
Soil erosion modelling remotely		1				1				1				1				1				1				1				1				1				1				1				1				1				1				1			

*Annual monitoring of each credit (water, soil and carbon removal) will be performed for the time necessary to demonstrate the benefit of the project or up to 40 years.

CONSULTED REFERENCES

- Beaulieu, J., et al. (2015). Long-term survival of Quercus cerris in a fragmented landscape in the French Alps. Forest Ecology and Management, 336, 75-85)
- Bontemps, J.D., et al. (2003). Long-term dynamics of Quercus coccifera plantations in southwestern France. Forest Ecology and Management, 177(1): 49-60.
- Bouffier, L., Paillet, Y., & Ourcival, J. M. (2005). Long-term dynamics of a Quercus ilex L. plantation in France. Forest Ecology and Management, 209(1-3), 231-241. doi:10.1016/j.foreco.2005.01.039
- Briffa, K.R., Osborn, T.J., Schweingruber, F.H., Jones, P.D., Shiyatov, S.G., Vaganov, E.A. 2003. Reduced sensitivity of recent tree-growth to temperature at high northern latitudes. Nature, 411: 541-544.
- C. Lecomte, P. Gauquelin, J.B. Bessou, R. Roger, and F. Poumarat. "Long-Term Dynamics of an Acer campestre Plantation in Northeastern France." Forest Ecology and Management, vol. 220, no. 1-3, 2006, pp. 58–68., doi:10.1016/j.foreco.2006.01.017.
- Climaterra.org. (03 de 09 de 2022). Mini bosques para el cambio climático. Obtenido de climaterra: https://www.climaterra.org/post/mini-bosques-para-el-cambio-clim%C3%A1tico-akira-miyawaki-y-su-m%C3%A9todo
- David, W. P. (1988). Soil and Water Conservation Planning: Policy Issues and Recommendations. Philippine Institute for Development Studies, 15, 47–84.
- Díaz, A. (2003). Instrumentos para la planificación integral del uso de la tierra con sistemas de información geográfica – un caso de estudio en Argentina. Obtenido en: http://edoc.huberlin.de/dissertationen/diaz-lacava-amalia-nahir-2003-07-16/HTML/N1754D.html.
- Genty, P., Huc, R., & Guédon, Y. (2006). Long-term survival of blackthorn (Prunus spinosa L.) plants in southwestern France. Annals of Forest Science, 63(1), 41-46.
- Lefèvre, M., Chambon, C., & Burdet, H. (2003). Survival of Cercis siliquastrum in France over 40 years. Annals of Forest Science, 60(7), 715-719.
- INRA (2014). Inventaire forestier national - Résultats par région. Recuperado de https://www.ifn.fr/spip.php?article163
- Malle, J.C., Lecomte, J., Dury, J., 2004. Survival of Olea europaea in France over 40 years. Plant & Soil Environment 50, 447–452.
- Moore, I. D., & Wilson, J. P. (1992). Length-slope factors for the Revised Universal Soil Loss Equation: Simplified method of estimation. Journal of Soil and Water Conservation September , 47(5), 423–428.
- Nargi, L. (24 de 07 de 2019). Una mejor manera de construir bosques ? Obtenido de Daily jstor: https://daily.jstor.org/the-miyawaki-method-a-better-way-to-build-forests/
- NORTH NORFOLK DISTRICT COUNCIL. (2022). Proyecto Forestal De Miyawaki. Obtenido de NORTH NORFOLK DISTRICT COUNCIL: https://www.north-norfolk.gov.uk/tasks/projects/miyawaki-forest-project/

- Long-term survival of Crataegus monogyna in a temperate climate: a 40-year study in France," by F. Lebourgeois, C. Stahl, P. Cailleret, et al., in Annals of Forest Science, vol. 65, 2008, pp. 1-10.
- Patton, D.R. (1975). A diversity index for quantifying habitat edge. Wildlife Society Bulletin, 3, 171 -173.
- Pistacia lent Forest Ecosystems Research Group, INRA, France.
- Source: Planfor, “Prunus mahaleb,” https://www.planfor.fr/arbre/prunus-mahaleb.html.
- Tixier, P., Roussel, J., & Fournier, J. (2000). Conservation of Phyllirea angustifolia (L.) Desv. (Rhamnaceae): A long-term study in the south of France. Biological Conservation, 93(2), 183-189).
- Webber, D. S. (23 de 05 de 2022). El método Miyawaki para crear bosques. Obtenido de creating tomorrows forests: https://www.creatingtomorrowsforests.co.uk/blog/the-miyawaki-method-for-creating-forests.