ASES ON-CHAIN PROTOCOL

# CARBON SEQUESTRATION REPORT

## FOREST 4FUTURE LENTILLÈRES

**July 2023 Batch 1**

LT-002-LEN-052023
Ardèche,France

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## Carbon Calculation

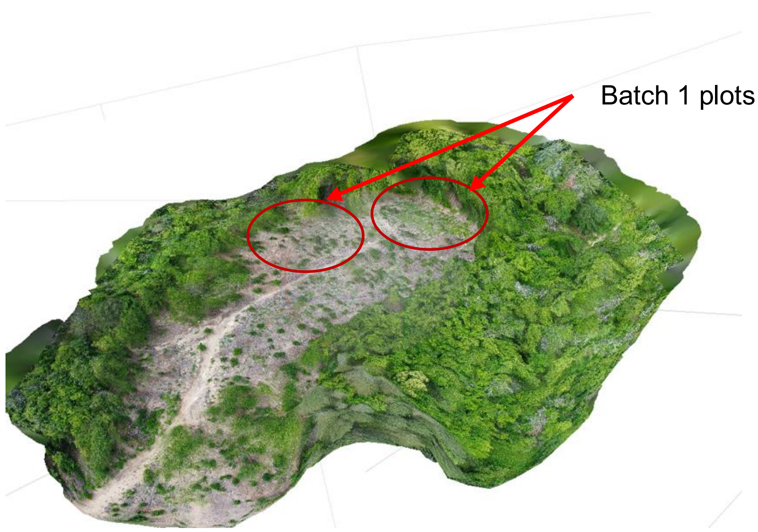
This guide aims to accurately quantify the carbon sequestered in the Forest 4Future Lentillères project.

To determine the amount of sequestered carbon, the calculation relied on the guidelines presented in the book "Carbon Inventory Methods: Handbook for Greenhouse Gas Inventory, Carbon Mitigation, and Roundwood Production Projects." since these methodologies are consolidated from renowned international bodies such as the IPCC.

This manual explains the process of conducting a carbon inventory based on the type of stock involved. Specifically, it focuses on reforested tree stocks, as well as secondary vegetation stocks like grasses, shrubs, and herbaceous. The recommendations for assessing above-ground biomass serve as our guide for both cases.

### I. Sample

The initial step involves determining the samples for evaluation purposes. Instead of conducting a comprehensive census of all trees across the entire property, which would be impractical in terms of time, money, and effort, a representative sample of the entire dataset is selected. These samples consist of a series of small polygons within which the amount of sequestered carbon will be calculated. However, to ensure a representative sample that accurately reflects the terrain, several factors need to be considered. These include the shape, size, number, and distribution of the polygons. In this preliminary stage, we describe the methods used to calculate or generate each of these sample attributes.



### I.1. Polygon shape

Typically, circular or square shapes are employed for samples in this type of assessment (see Figure 1). In our case, the samples consist of systematically distributed squares across the property. This choice is based on the ease of locating square boundaries in the field compared to circles.

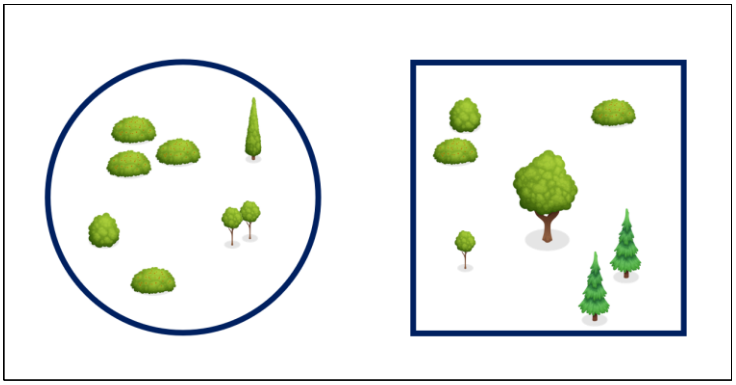


**Figure 1. Census polygons**

### I.2. Size of the polygon

Regarding the size of each object in the sample, the recommended measurements by the guide are provided in Table 1. The specific dimensions of the polygons depend on the diameter of the trees found on the property. For instance, if the trees have diameters less than 5 cm, it is suggested to use a 1-meter radius for circular polygons or 2-meter sides for squares. However, for this exercise, it was decided to create squares with sides measuring 7 meters. This decision was influenced by the presence of various factors on the property. Although most trees on the property still have diameters less than 5 cm, they will grow and also the soil composition is not homogenous. Secondary vegetation such as shrubs and grasses can be found throughout the property, and there are also different species of trees and soil works implemented.

**Table 1. Size of the sample polygons**

| Tree diameter | Circle radius (m) | Square polygon (m per side) |
|---|---|---|
| <5 | 1 | 2x2 |
| 5-20 | 4 | 7x7 |
| 21-50 | 14 | 25x25 |
| >50 | 20 | 35x35 |

### I.3. SIZE OF THE SAMPLE

To determine the sample size, the following formula was used:

$$n = \frac{Z_\alpha^2 Npq}{e^2(N-1) + Z_\alpha^2 pq}$$

Where:

N: is the size of the population or universe (total number of possible quadrats).

Zα: is a constant that depends on the level of confidence that we assign.

e: is the desired sampling error, as a percentage.

**TABLE 2. VALUE OF ZA AND CORRESPONDING CONFIDENCE INTERVAL.**

| Value of Zα | 1.28 | 1.65 | 1.69 | 1.75 | 1.81 | 1.88 | 1.96 |
|---|---|---|---|---|---|---|---|
| Confidence level | 80% | 90% | 91% | 92% | 93% | 94% | 95% |

According to the guide, it is common to aim for 10% precision and 95% confidence level. Thus, a 95% confidence level corresponds to Zα=1.96. Additionally, a sampling error of 10% (e=10) was assigned.

To determine the population size, the following process was followed using ArcGIS. Initially, a fishnet measuring 7 meters by 7 meters was generated over the study area. Subsequently, only the squares fully encompassed within the polygon were selected, representing the study population. In our case, there were 80 polygons, resulting in N=80. The remaining polygons were deleted. By applying the equation using the specified values, the result indicates a sample size of 44. Therefore, to achieve a 95% confidence level with a 10% error for a population of 80, it is necessary to take a census of 44 polygons.

### I.4. SAMPLE DISTRIBUTION

In this exercise, a systematically distributed sample was selected. This distribution approach involves acquiring samples in a systematic and orderly manner (refer to Figure 2). This particular distribution was chosen to ensure greater representativeness of the property, as the samples are spread across almost the entire polygon. Furthermore, it helps to prevent the sampled polygons from being clustered together.

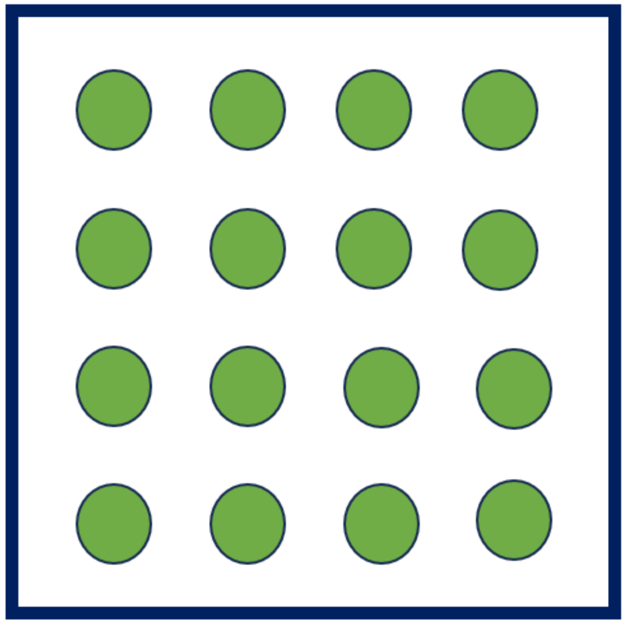


FIGURE 2. SYSTEMATIC DISTRIBUTION OF SAMPLES

### I.5. SAMPLE RESULTS

By following the aforementioned steps, a total of 44 squares with sides measuring 7 meters were obtained for conducting the carbon inventory. These polygons, depicted in Figure 3, represent the sampled area. In the figure, the reforested section of the study area is depicted in gray, and the 44 sample squares used for the inventory are clearly marked and listed.

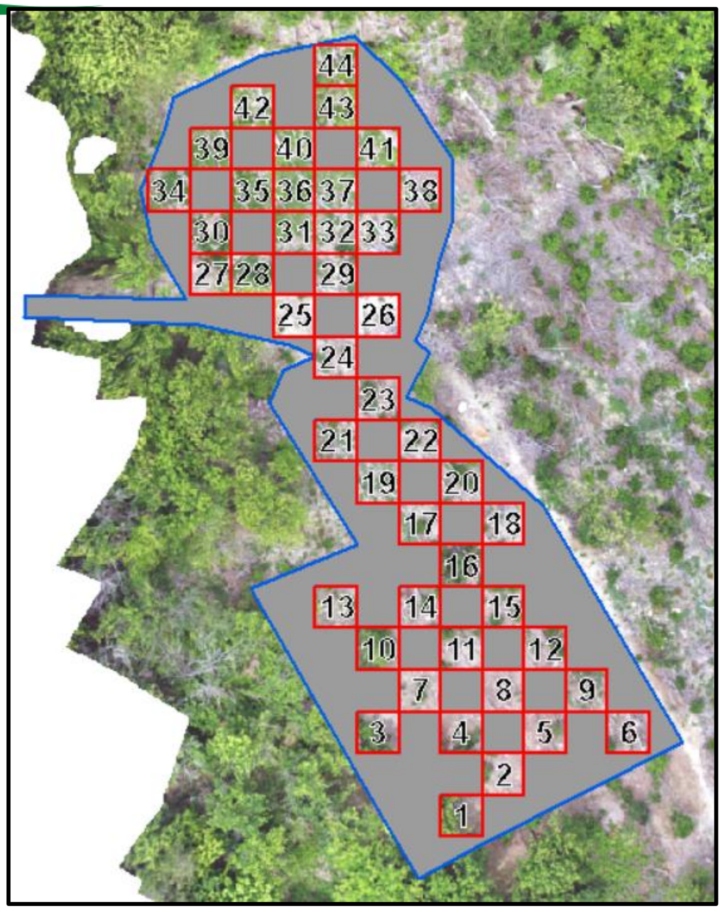



**FIGURE 3. DISTRIBUTION OF SAMPLES**

## II. OBTAINING THE INFORMATION

### II.1. TREE HEIGHTS

To determine the vegetation height, a drone flight was conducted (Figure 4). Subsequently, the collected data points were classified based on their elevation. Two elevation models were created: one for the ground points and another for the points classified as vegetation. By subtracting the ground model from the vegetation model, an estimation of the vegetation height was obtained.

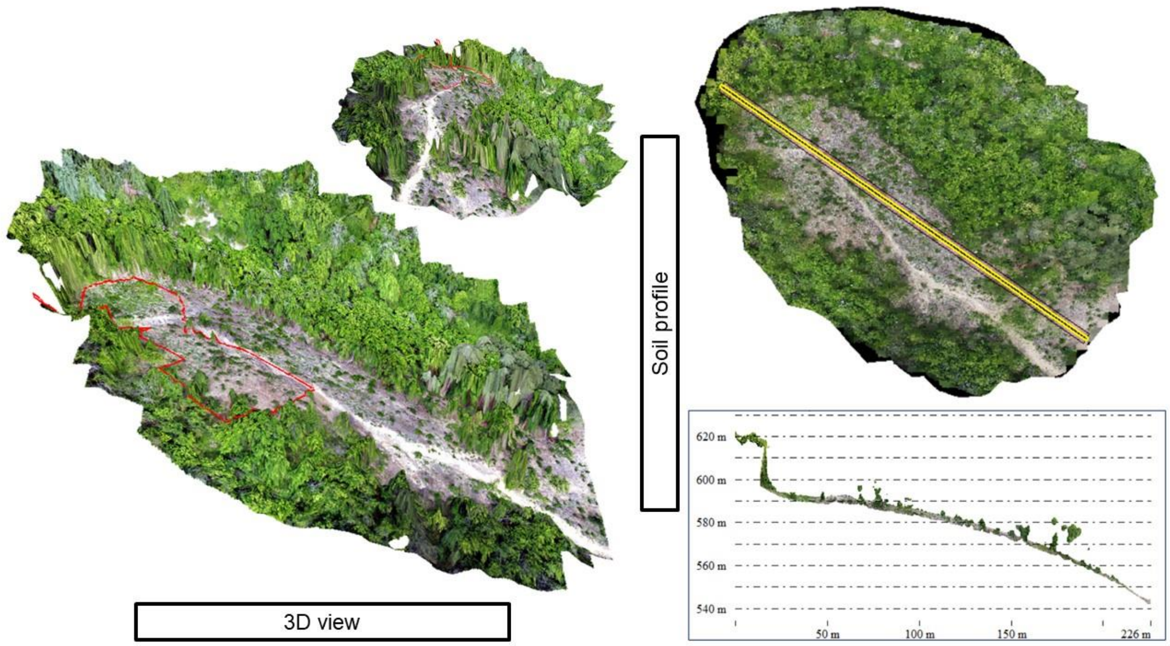



**FIGURE 4. DRONE FLIGHT**

Next, we extracted the height values of the georeferenced trees located within the sample squares. Out of a total of 1,047 georeferenced trees, 472 trees were selected for analysis. These 472 trees, highlighted in red in Figure 5, represent the chosen subset. The average height of these 472 trees was found to be 0.47 meters.

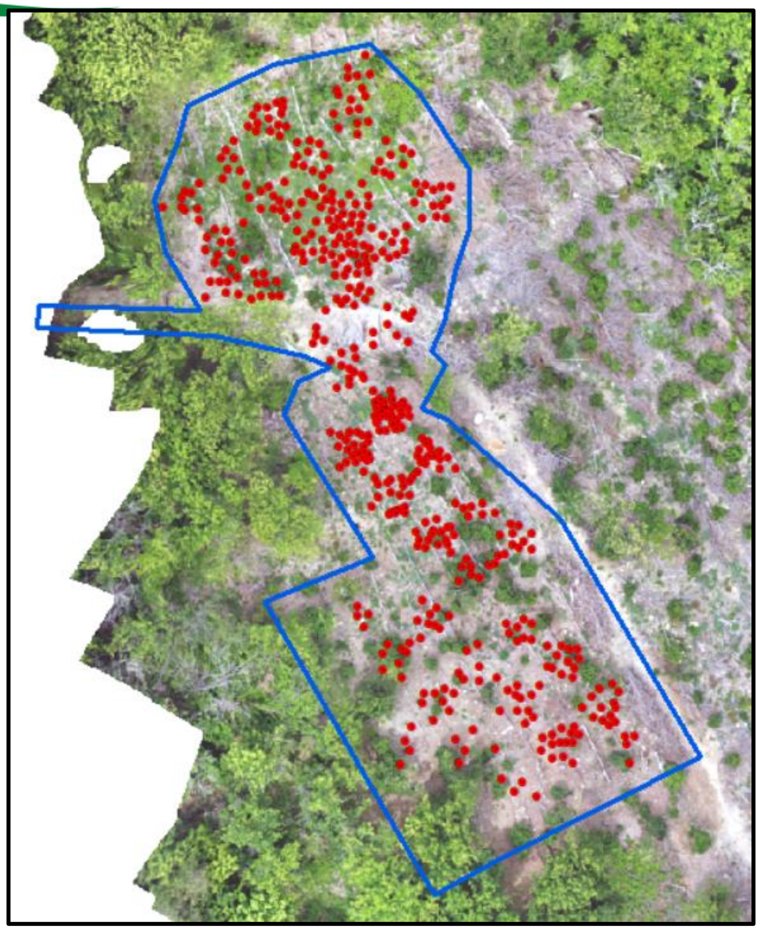
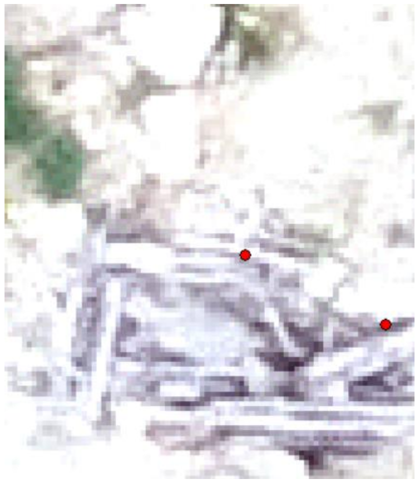
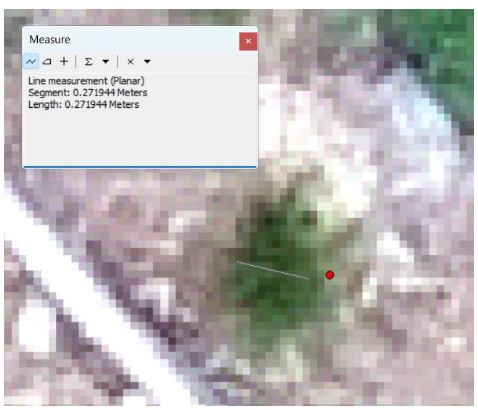


**FIGURE 5. TREES SELECTED FOR ANALYSIS**

### II.2. TREE DIAMETER

The tree diameter was determined through photointerpretation using the orthomosaic created from the drone images. For points that corresponded to tree locations in the orthomosaic, the diameter was measured. However, for points without visible trees, a value ranging from 2cm to 3cm was assigned based on the size of the surrounding vegetation. In cases where the points fell on dense vegetation, a value of 5cm was assigned.

| Example | Assigned diameter |
|---|---|
|  | 2 cm |
|  | 5 cm |
|   | 2.7 cm |

### II.3. Percentage of vegetation coverage

In terms of secondary vegetation like shrubs or grasses, their percentage was determined through photointerpretation. Each quadrant was assessed based on its greenness, and an approximate percentage was assigned accordingly.

| Example | Assigned percentage |
|---|---|
|  | 15% |
|  | 1% |
|  | 75% |

# III. CALCULATION OF CARBON SEQUESTRATION

## III.1. TREES

To calculate the carbon sequestration of the trees, we used the species-specific allometric equations used in the baseline study.

## III.2. SECONDARY VEGETATION

In order to determine the carbon sequestered by secondary vegetation, the surface of vegetation (in square meters) within each quadrat was calculated by multiplying the assigned percentage by 49 $m^2$ (the area of each quadrat). Next, this value was multiplied by 1,200, representing the grams of dry matter per square meter (according to the Net Primary Productivity), and then by 3.67 to translate it into sequestered $CO_2$. Finally, the result was divided by 1000 to obtain the value in kilograms. This process is represented by the following equation:

$$CV = \frac{(PV * 49) * 1200 * 3.67}{1000}$$

Where:

CV= $CO_2$ sequestered in secondary vegetation

PV = Proportion of vegetation per quadrat.

## III.3. FINAL SEQUESTRATION OF VEGETATION

After determining the carbon sequestered by both the trees and other vegetation, the total amount for each category was divided by 49 to calculate the carbon sequestration per square meter within each polygon. Subsequently, the centroids of each polygon were determined, and the carbon sequestration value per square meter was extracted for both trees and vegetation. This data was then interpolated across the entire polygon to estimate the carbon sequestration occurring throughout the property for both, trees and secondary vegetation. Finally, both models for trees and vegetation were combined by adding their respective values.

# IV. FINAL RESULTS

## IV.1. SEQUESTRATION BY TREES

The accumulated carbon sequestration by trees ranges from 0 to 45.291 kg $m^{-2}y^{-1}$ among quadrats. In Figure 6, the top left corner of the infographic (1) predominantly shows quadrats reporting carbon sequestration between 0 and 12 kg $m^{-2}y^{-1}$. Additionally, as the amount of captured $CO_2$ increases, the number of quadrats with that recorded capture rate decreases.

On Figure 6, at the right of the infographic (2), the centroids of the sampled quadrats are depicted with colors ranging from red to green, representing the amount of carbon sequestered. Furthermore, the size of the dots varies based on the same criterion, with larger dots indicating greater carbon capture. The map demonstrates that the northern part of the property exhibits the highest concentration of larger and greener points, while the southern part is dominated by red and orange points (0 to kg $m^{-2}y^{-1}$).

The lower left side (3) of Figure 6, it provides a visual comparison of carbon sequestration by trees in the quadrats. Longer lines represent higher levels of carbon sequestration. Notably, the aggregated green lines are significantly longer than the red and orange ones.

Trees alone capture an average of 14.871 kg $y^{-1}$, and a total of 654.335 kg $y^{-1}$. Additionally, the average contribution of carbon capture per square meter is 0.303 kg.

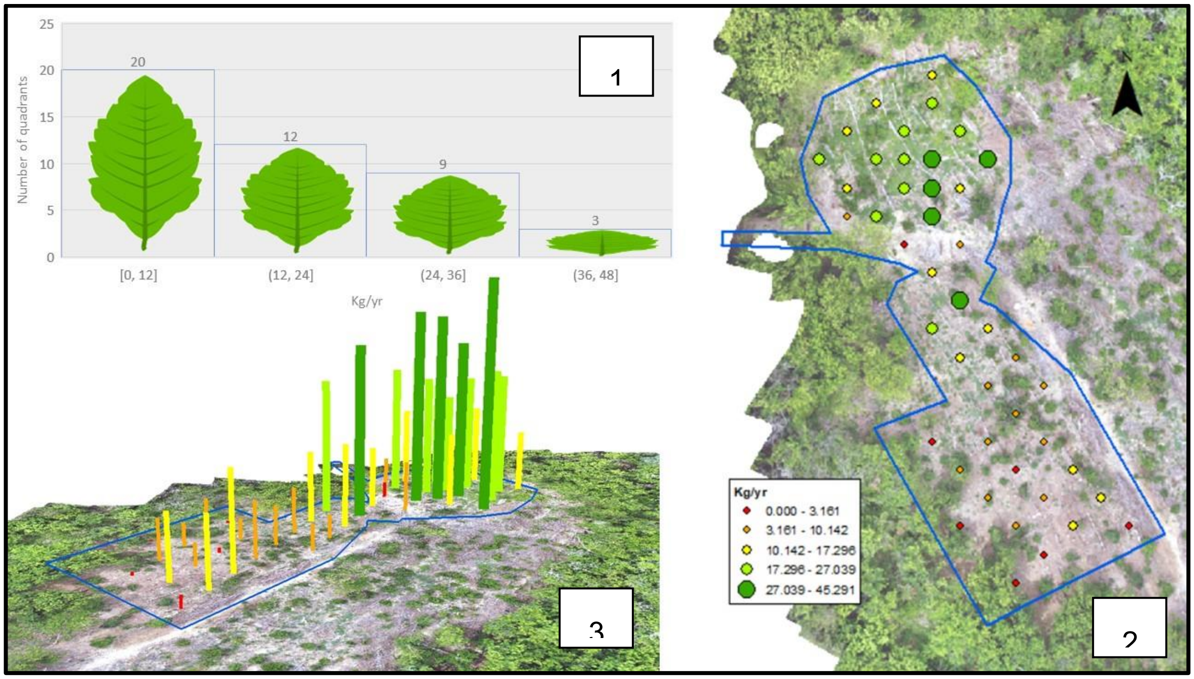



**FIGURE 6. CARBON SEQUESTRATION BY TREES**

### IV.2. CARBON SEQUESTRATION BY SECONDARY VEGETATION

The accumulated carbon sequestration per quadrant of secondary vegetation ranges from 2.157 to 194.216 kg $y^{-1}$. In Figure 7, the upper left corner (1) predominantly shows quadrats reporting carbon sequestration between 2 and 60 kg $y^{-1}$. The second most significant group consists of 12 quadrats with sequestration levels between 118 and 176 kg $y^{-1}$.

On the right side (2) of figure 7, the centroids of the sampled quadrats are depicted with colors ranging from red to green, representing the amount of carbon sequestered. Additionally, the point size varies based on the same criterion. Notably, there is a clear polarization observed, where the majority of larger and greener dots are located in the northern part of the property, while the south predominantly exhibits red, orange, and yellow dots. However, two green spots (140.267 to 194.16 kg $y^{-1}$) are visible in the southern area of the property.

The lower left side (3) of figure 7 provides a visual comparison of carbon sequestration by secondary vegetation in the quadrats. Longer lines indicate higher levels of carbon sequestration. Notably, the clustered green lines are significantly longer than the red and orange ones.

The registered secondary vegetation sequesters an average of 71.55 kg $y^{-1}$, totaling 3,148 kg $y^{-1}$. Additionally, the average contribution of carbon sequestration from secondary vegetation is 1.46 kg $m^{-2}y^{-1}$.

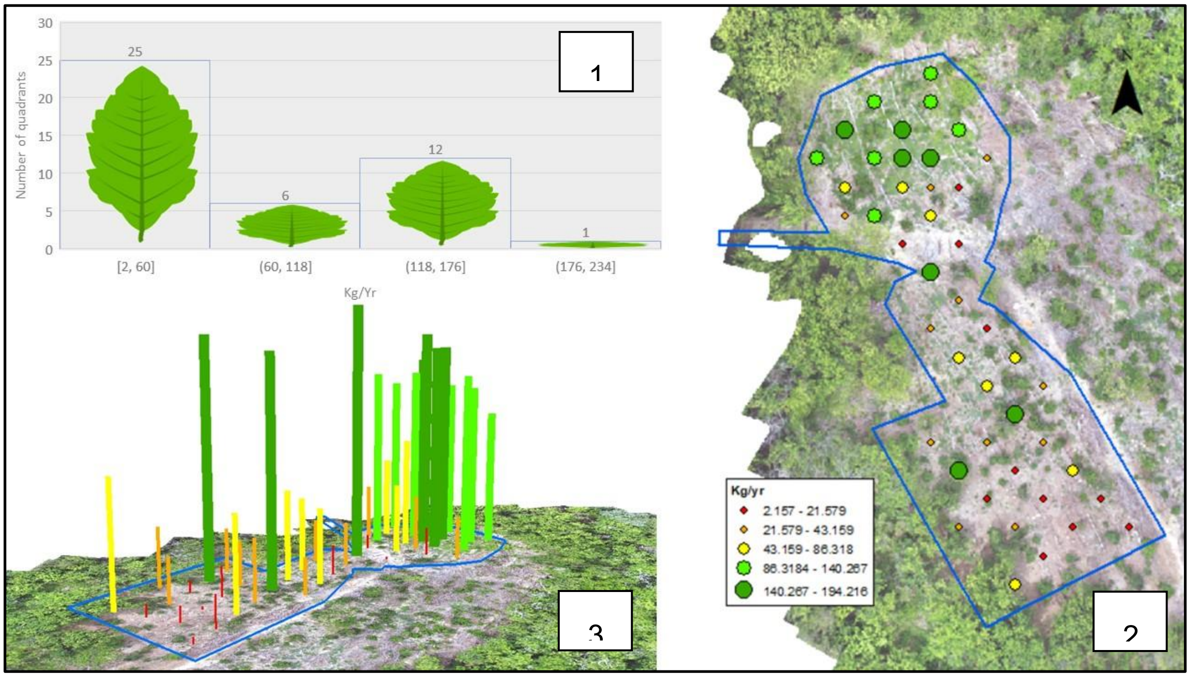



**FIGURE 7. CARBON SEQUESTRATION BY SECONDARY VEGETATION**

### IV.3. TOTAL SEQUESTRATION (SAMPLE)

The samples indicate that the property is capturing an average of 1.76 kg$CO_2$ $m^{-2}y^{-1}$. The range of carbon sequestration varies from a minimum of 0.128 kg$CO_2$ $m^{-2}y^{-1}$ to a maximum of 4.21 kg$CO_2$ $m^{-2}y^{-1}$.

In Figure 8, the distribution of sampling quadrats centroids across the property and the corresponding carbon sequestration rates are depicted. The size and color of the dots vary based on their respective carbon sequestration values. It is evident that the northern part of the property exhibits higher levels of carbon capture. However, there are also points with significant sequestration values in the southern region, which, upon closer examination of the orthophoto, correspond to patches of vegetation.

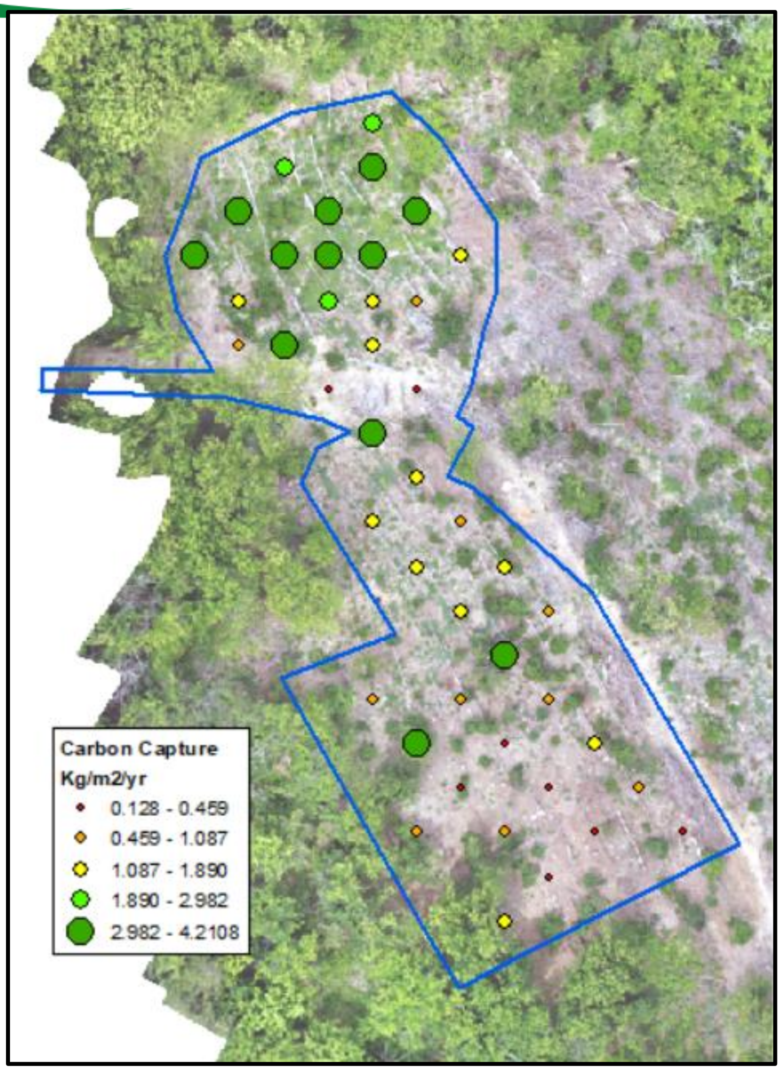



**FIGURE 8. CARBON CAPTURE IN CENTROIDS**

Figure 8 show the clustering of green bars (higher carbon capture rates), which are notably skewed and concentrated on one side of the Project area.

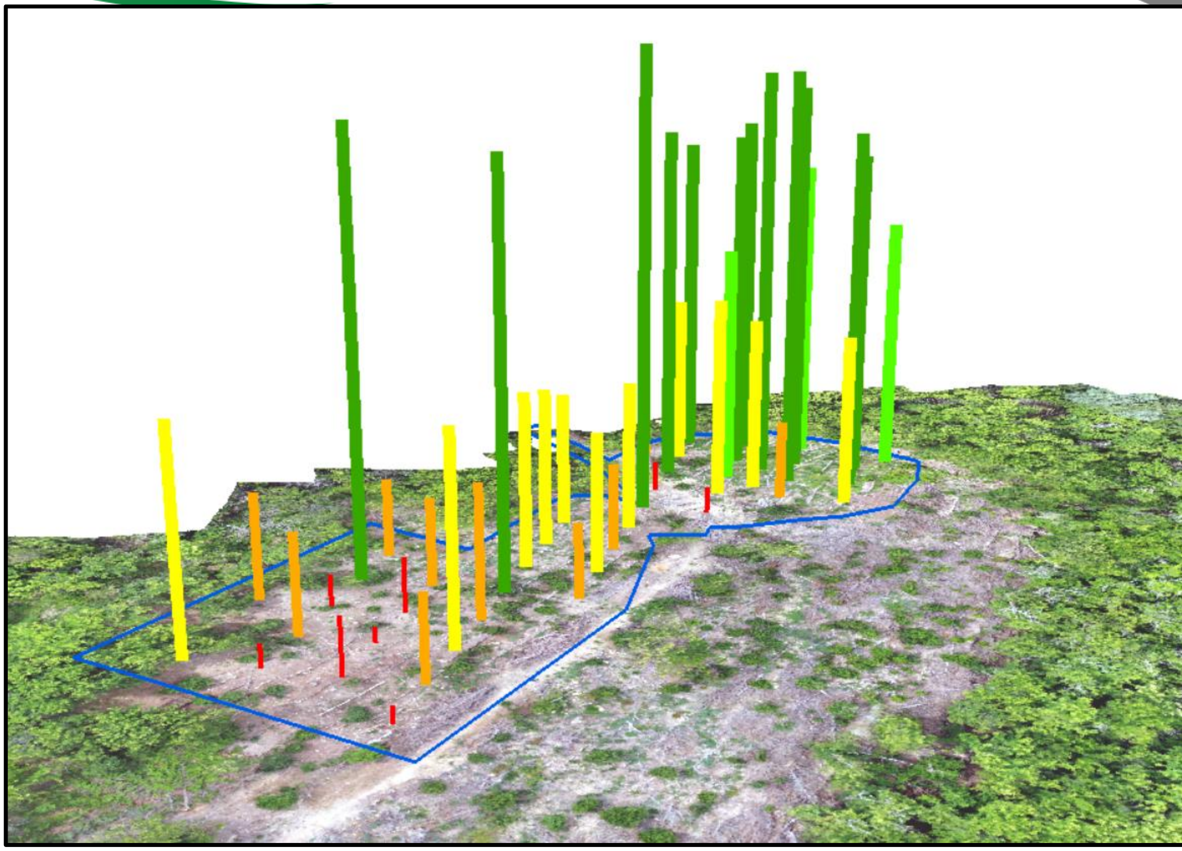


**FIGURE 9. COMPARISON OF CAPTURE BY QUADRANT**

## IV.4. TOTAL SEQUESTRATION BY THE STUDY AREA

In terms of interpolation, the preference was given to IDW results (Figure 10) as the bull's-eye patterns generated by this method visually depict dense vegetation patches more accurately. On the other hand, kriging interpolation (Figure 9) tends to homogenize these patches.

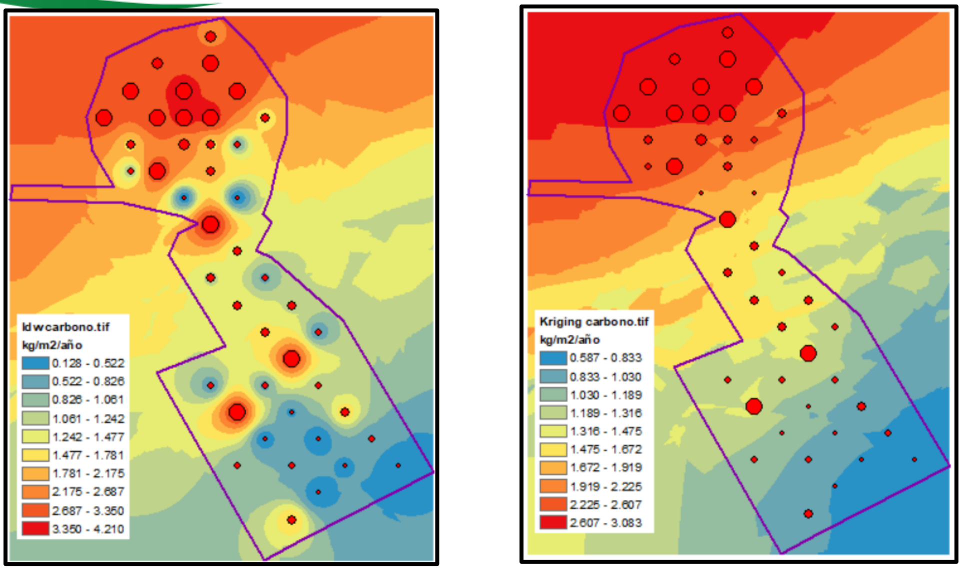



**FIGURE 10. INTERPOLATIONS OF THE TOTAL CARBON CAPTURE. IDW ON THE LEFT, KRIGING ON THE RIGHT**

Considering the interpolations, the plot captures a total of 1.587 tons of $CO_2$ thanks to the reforested trees. Additionally, the vegetation that emerged after the soil works and reforestation has sequestered 7.9265 tons of $CO_2$. **Consequently, to date, the batch1 plot has sequestered a total of 9.514 tons of $CO_2$.**

Figure 11 illustrates that the majority of the carbon capture, accounting for 83% of the total study area, is attributed to the herbaceous vegetation. The trees, on the other hand, contribute to 17% of the total capture.

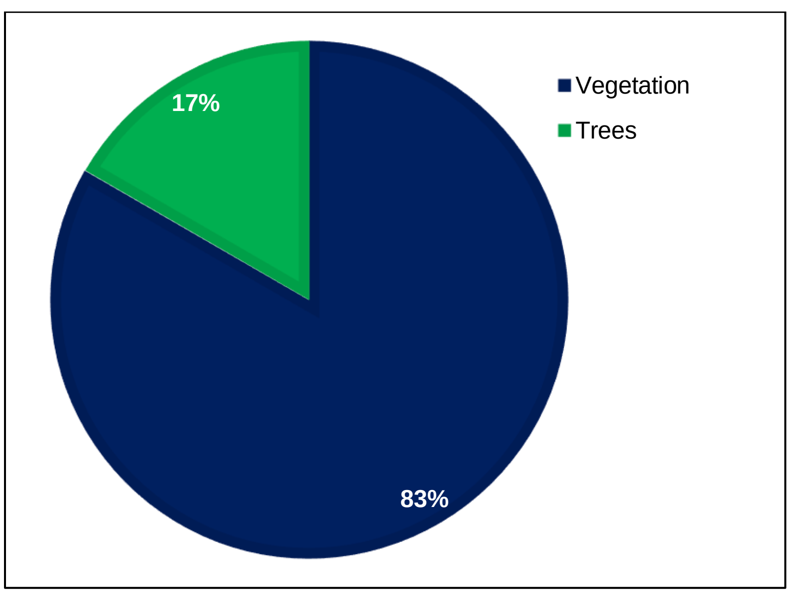



**FIGURE 11. PERCENTAGE OF CARBON SEQUESTRATION BY VEGETATION STOCKS**

## V. CONCLUDING REMARKS

At the time of this monitoring, the trees still exhibit slender diameters. Nevertheless, based on previous visits, it can be confirmed that the survival rate is significantly high (>85%). This observation demonstrates the success of reforestation efforts to date. Furthermore, noticeable regeneration of local vegetation has been observed following the completion of the restoration work in the area. This development is highly favorable for ecosystem restoration and enhances biodiversity. It also contributes to the establishment of a diverse landscape, which is crucial for the effective restoration of the ecosystem. At present, the reforestation outcomes align with initial expectations. However, future monitoring endeavors will continue to provide a comprehensive assessment of the project's success, allowing for a broader understanding of the overall environmental benefits.