2023

CARBON CAPTURE MONITORING REPORT

LT-007-SPA-072023 CÁCERES, SPAIN
Ecological restoration in Alia, Cáceres, Spain
Life Terra

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CONTEXT

This text aims to have a first calculation of the carbon sequestered per year by the Caceres project.

The methodology is mainly based on the book "Carbon Inventory Methods: Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Roundwood Production Projects", since its methodologies are based on or compiled from international bodies such as the IPCC.

This guide tells how the carbon inventory should be carried out depending on the type of reserve. For this exercise, the carbon from reserves of the reforested trees will be calculated. In addition, the reserves of secondary vegetation such as grasses, shrubs, among others, were taken into account. For both cases we are guided by the recommendations on above-ground biomass.

I. CARBON FROM PLANTED TREES

For this first step, a field visit was carried out where the heights and diameters of the plants were measured in 8 quadrants of 10m X 20m. These quadrants were distributed in the main reforested areas.

It was determined that these sampling points were appropriate since the reforested area has an irrigation system and the trees of the different species had very similar sizes.

After having the data, the allometric equations set out in the baseline were used for each species using the data obtained in the field.

II. COMPLEMENTARY VEGETATION CARBON

For this part, the sample space was first generated. The sample is a portion of the land that we are going to evaluate. Since, determining the percentage of secondary vegetation throughout the property is impractical due to time and effort. In this case, the sample will be a series of small polygons where the amount of carbon sequestered by vegetation within them will be calculated.

However, to have a good sample that represents the terrain as best as possible, it is necessary to keep in mind the shape of the polygons, their size, the number of polygons, and the way in which they will be distributed. In this first stage, it is described how each of the qualities of the sample was calculated or generated.

II.1. POLYGON SHAPE

Generally, in this type of exercise, circles or squares are used to census the space (Figure 1).

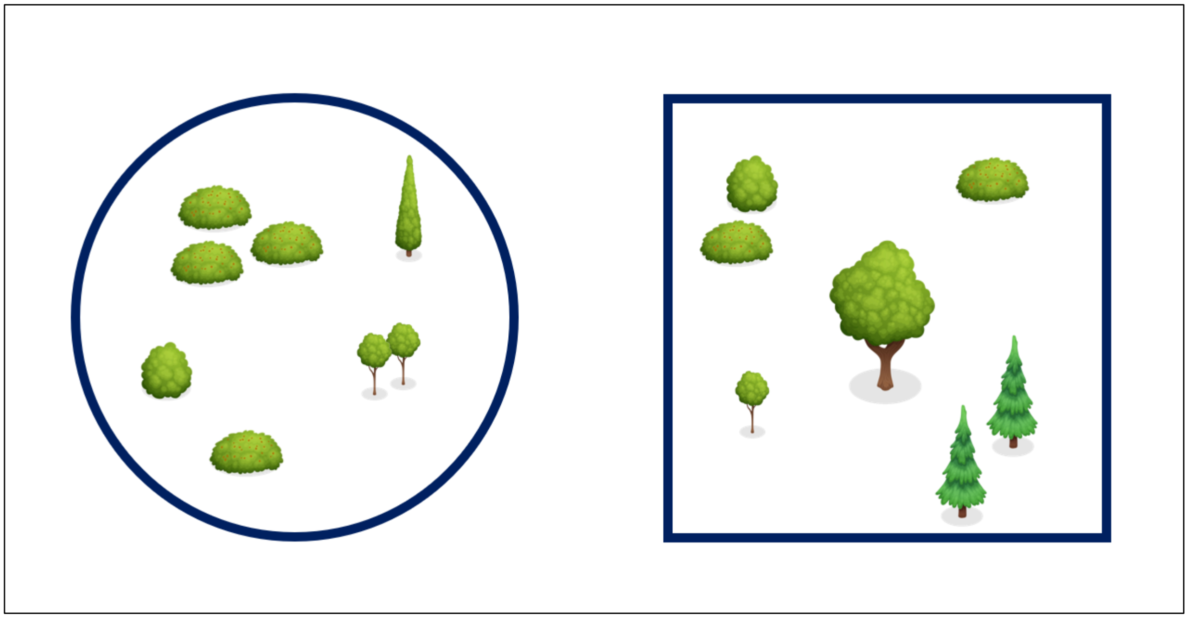


Image 1. Census polygons

In this case, our sample was based on squares.

II.2. Polygon size

Regarding the size of each object in the sample, the guide suggests the measurements in Table 1. The dimensions of the figure depend on the diameter of the trees on the property. For example, if the trees have diameters less than 5cm, it is suggested that in circular figures the diameter be 1 meter, while in squares the sides should be 2 meters.

Table 1. Size of the sample polygons

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

For this exercise, it was decided to make squares of 7m per side. Although the trees on this property still mostly have diameters less than 5cm, the soil is not homogeneous. Throughout the property, there is secondary vegetation such as bushes, and grasses, among others. In addition, there are several species of trees and there are soil works.

II.3. Sample size

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 respondents).

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

Zα value	1.28	1.65	1.69	1.75	1.81	1.88	1.96
Confidence level	80%	90%	91%	92%	93%	94%	95%

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

The guide comments that 10% precision and 95% confidentiality are usually used, therefore, Zα was given a confidence level of 95% (Zα=1.96). The sampling error assigned was 10% (e=10).

To obtain the population size, a series of processes were carried out using Arcgis. To begin, a fishnet of 7 meter by 7 meter squares was generated on top of the property. Then, all the squares that are completely within the reforested areas and the orthomosaic from the drone flight were selected. These polygons are the study population. In our case there were 1640 polygons, so N is equal to 1640. The other polygons were deleted.

When applying the equation with the determined values, it gives us a result of 91. That is, to have a sample with 95% reliability with 10% error for a population of 1640, we must census 91 polygons.

II.4. Sample distribution

For this exercise, a sample with a systematic distribution was chosen. This type of distribution is based on taking samples directly and in an orderly manner (Figure 2). This type was chosen because it gives more representativeness to the property because the sample is spread throughout almost the entire polygon. Furthermore, we avoid that the sampled polygons are all agglomerated.

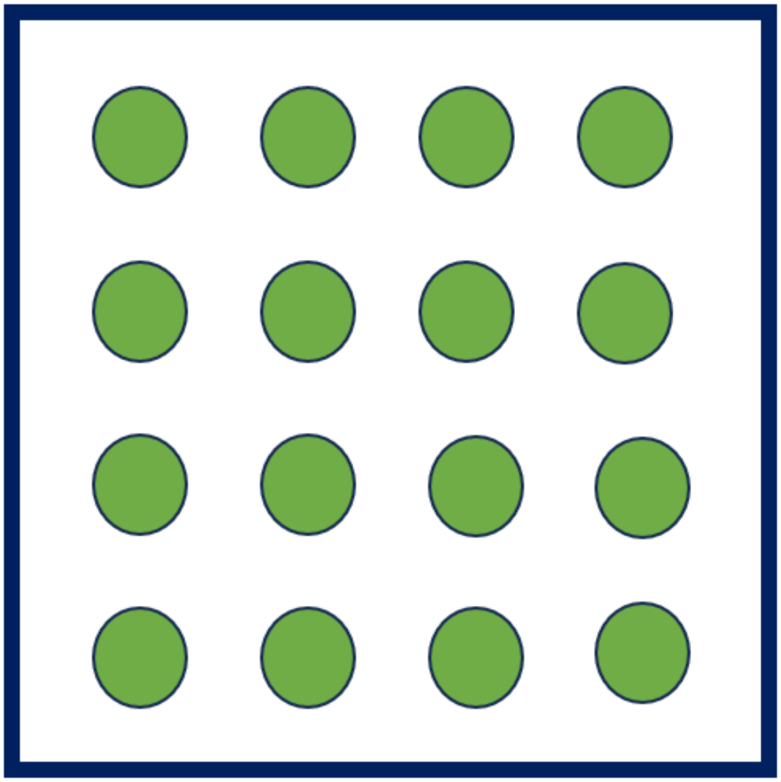


Image 2. Systematic distribution

II.5. Sample results

Following the previous steps, 91 squares of 7 meters per side were obtained that were used to carry out the carbon inventory. These polygons are shown in Figure 3. The figure shows the outline of the property in green. Also, you can see in yellow the 91 tables that will be used to calculate the carbon of secondary vegetation.

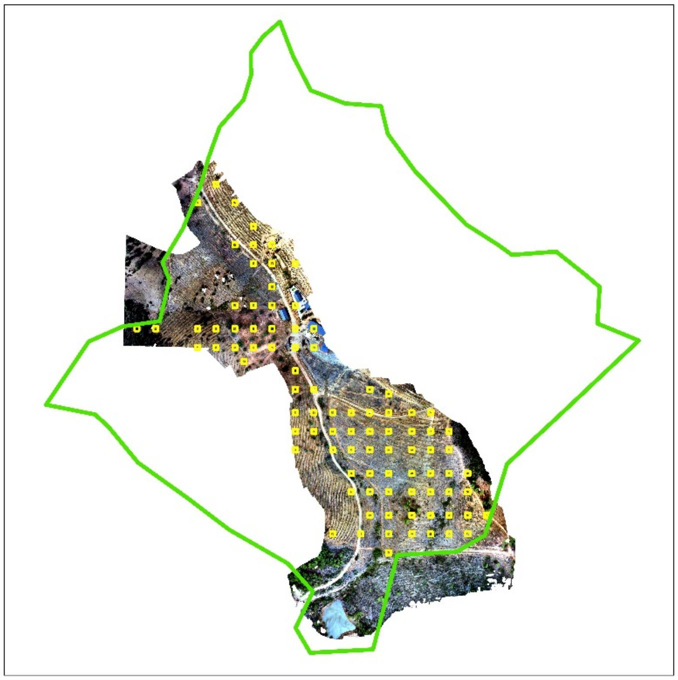


Image 3. Sample distribution

II.6. Obtaining the information

To determine the percentage covered by vegetation in each sampling square, the results generated with the drone flight were used (Figure 4). With this flight, an elevation model and an orthomosaic of 1.8cm resolution were obtained.

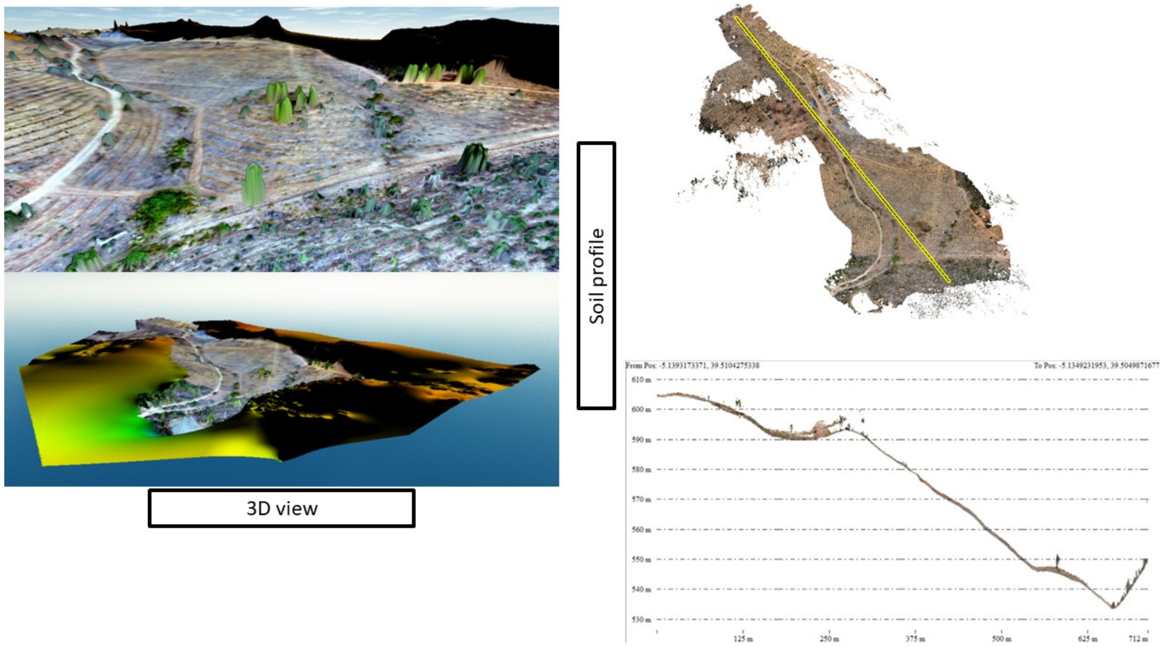
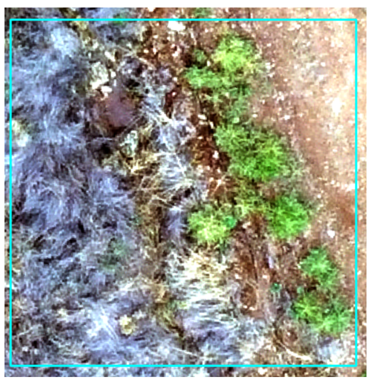


Image 4. Drone flight

II.7. Vegetation percentage

Regarding secondary vegetation such as shrubs or grasses, their percentage was established through photointerpretation. In addition, photographs obtained during the visit were used as support material, such as those shown below.

An approximate percentage was assigned to each quadrant depending on how green it was or the things that were observed.

Example	Established percentage
	75%
	25%
	1%

II.8. CARBON CALCULATION

To obtain the carbon sequestered by secondary vegetation, we first calculated the number of square meters of vegetation that each quadrant had (multiplying the percentage by 49 m^2 of each quadrat). It was then multiplied by 1200, which is the number of grams of dry matter per square meter, and then by 3.67 to convert it into sequestered carbon. Finally, it was divided by 1000 to have them in kilograms. This process is reflected in the following equation.

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

Where:

CV= Carbon sequestered from secondary vegetation

PV = Proportion of vegetation per quadrant

Sequestered carbon was divided by 49 to find out how much carbon is captured per square meter.

II.9. Final vegetation sequestration

In both cases, the results of sequestered carbon for the extent of the reforested areas were interpolated using the IDW algorithm. Then we continued by adding the two models to know the total carbon sequestered throughout the property.

III. Final results

III.1. Sequestration by trees

The accumulated carbon sequestration per sampling point of the trees ranges from 0.077 to 2.558 kilograms per square meter per year (kg/m ^{2} /year). You can see in the map on the left of the infographic (Figure 5) the sampling points with colors ranging from red to green depending on the amount of carbon sequestered. Additionally, spot size varies for the same reason, where larger ones capture more carbon. On the map you can see how the greenest and largest points are in the central part of the property, while on the edges there are the red to orange points (0.064 to 0.121 kg/ m2 /yr). On the other hand, the interpolation carried out with these points for the reforested areas is also shown, which is symbolized with the same color palette.

In the upper right corner (2) of the infographic there is a graph showing the accumulated capture per square meter at each point, where it stands out that points 7, 6 and 5 are the ones that capture the most carbon. This is highlighted in the figure below the previous one (5), where each bar represents a point and can be located on the property. Points 5 to 7 capture a lot more times more carbon than the rest. This is due to the species found in these areas.

The pure census trees capture an average of 0.5361 kg/ m ^{2} /yr. Taking into account that the reforested areas represent approximately 72,558.24 m ^{2}, a total of 38,923.984 kg/yr of carbon are captured by the trees.

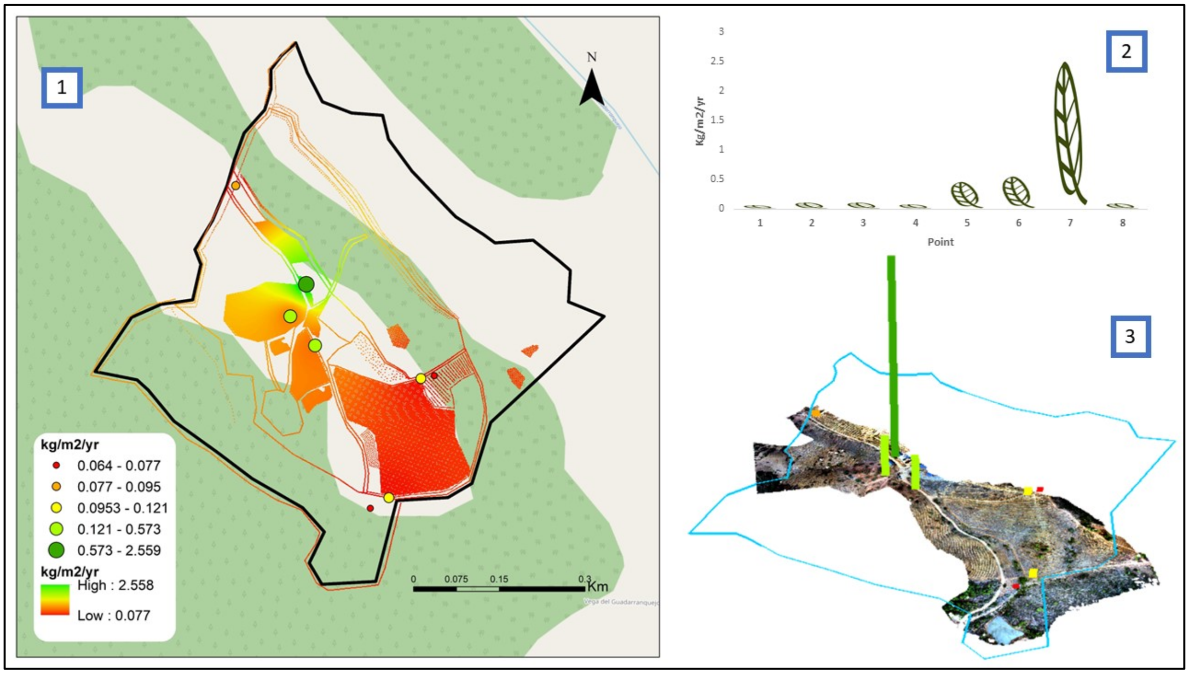


Image 5. Tree carbon sequestration infographic

III.2. Sequestration by secondary vegetation

The accumulated carbon sequestration per quadrant of secondary vegetation ranges from 0.0 to 3.3 kilograms per square meter per year (kg/m2/year). You can see in the map on the left of the infographic (Figure 6) the sampling points with colors ranging from red to green depending on the amount of carbon sequestered. Additionally, spot size varies for the same reason, where larger ones capture more carbon. This map behaves similar to the past, where the quadrants that capture the most carbon are in the center. However, there is a hotspot to the south and another further north.

In the upper right corner (2) of the infographic there is a histogram showing the number of quadrants that capture different amounts of carbon. It can be seen that 61 quadrants capture between 0 and 0.47 kg/ m2/yr, being the largest group. Secondly, there are the quadrants that capture between 0.047 and 0.94 kg/ m2/yr, with a total of 22 quadrants. The other groups have 0 to 2 quadrants. 8 quadrants capture more than 0.94 kg/ m2/yr.

The figure below the histogram (3) shows the distribution of the centroids of the quadrants and in bars compares by color and size the amount of carbon that is captured per square meter in each one.

Secondary vegetation captures an average of 0.507 kg/m2/yr. Taking into account that the reforested areas represent approximately 72,558.24 m2, this vegetation captures a total of 36,876.791 kg/yr.

Image 6. Infographic carbon sequestration of secondary vegetation

III.3. TOTAL CARBON SEQUESTERED

The results of the sum of the two interpolations yield a model that has values of 0.145 to 4.09 kg/m2/yr of carbon capture. Figure 7 shows the results in shades of red for the low values and in green for the high values. It can be seen in the same figure that the northern half is where the greatest carbon capture occurs, which in turn is the center of the main polygon.

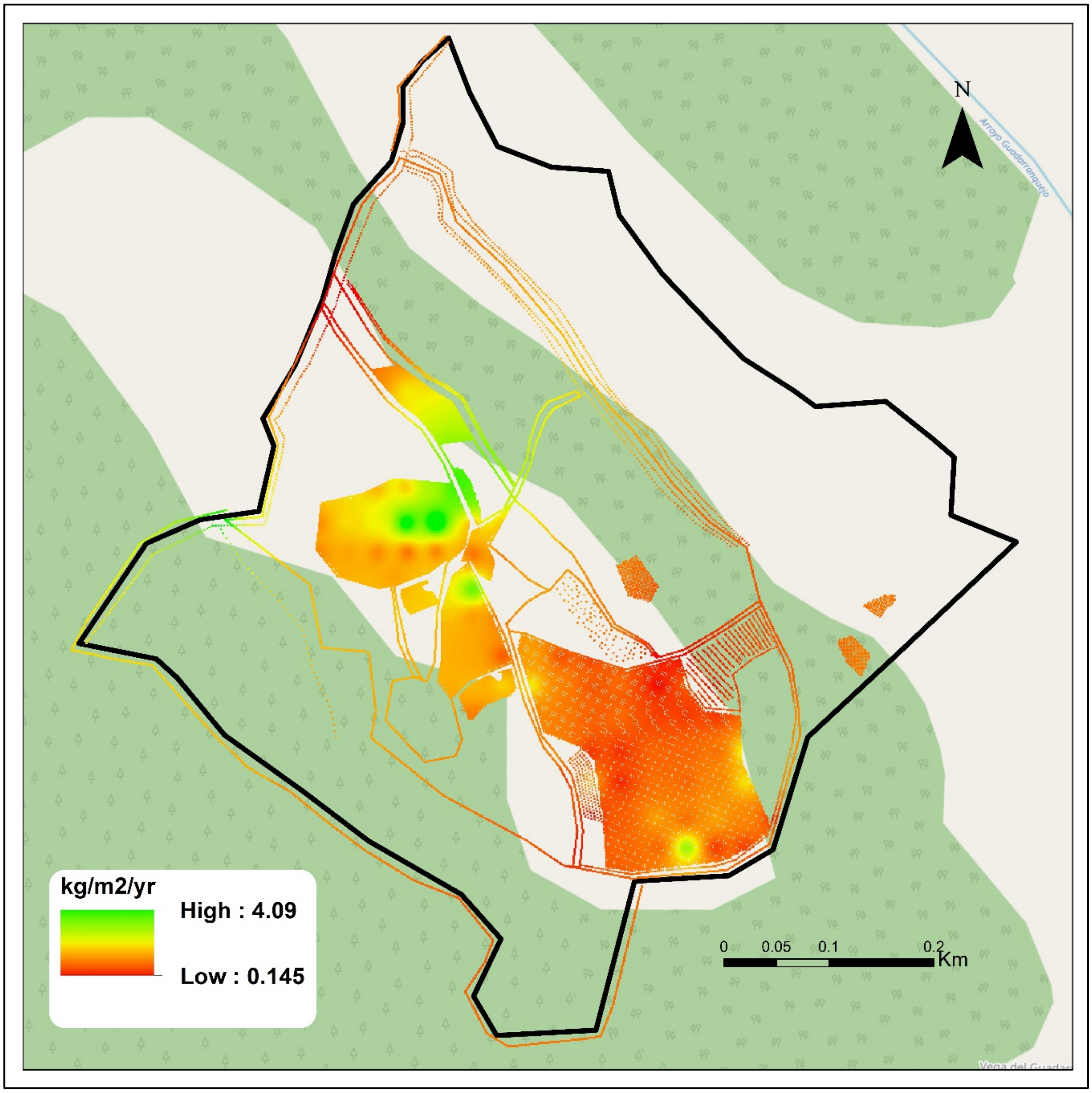


Image 7. Infographic carbon sequestration of secondary vegetation

The project currently captures in total an average of 1 kg of carbon per square meter per year and in total per year captures 75,798.53 kilograms. Of the total, 49% belongs to secondary vegetation and 51% to the capture of planted trees (Figure 8).

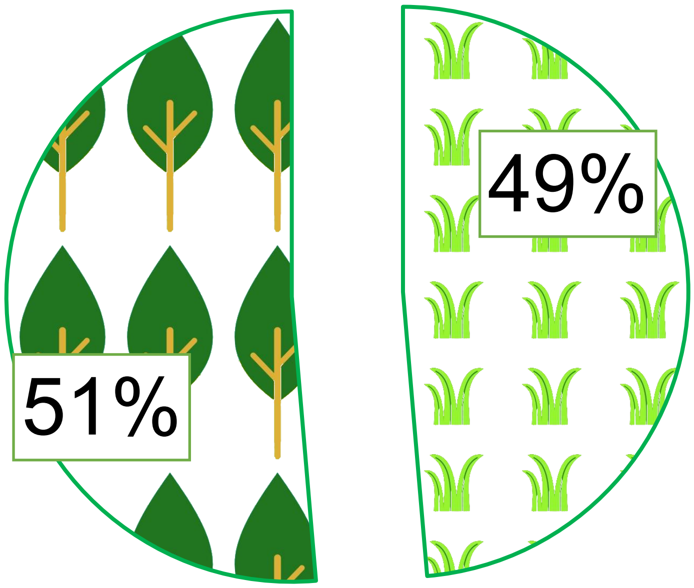


Image 8. Percent carbon captured

IV. FINAL REMARKS

During the visit it was observed that the trees still have small diameters. However, it was seen that there is a high level of survival. It is assumed that this survival is mainly due to the trees having an irrigation system. Therefore, it is expected that most trees will reach mature stages.

Trees that are not those proposed and some secondary vegetation were identified on the property, which, although they do not formally count in the project's carbon capture, were quantified and reported in this document. Having monitoring of this vegetation will allow us to realize the extra benefits provided by the soil works and the reforestation project in general.

It can be said that the results are positive and it is expected that carbon capture per year will increase.