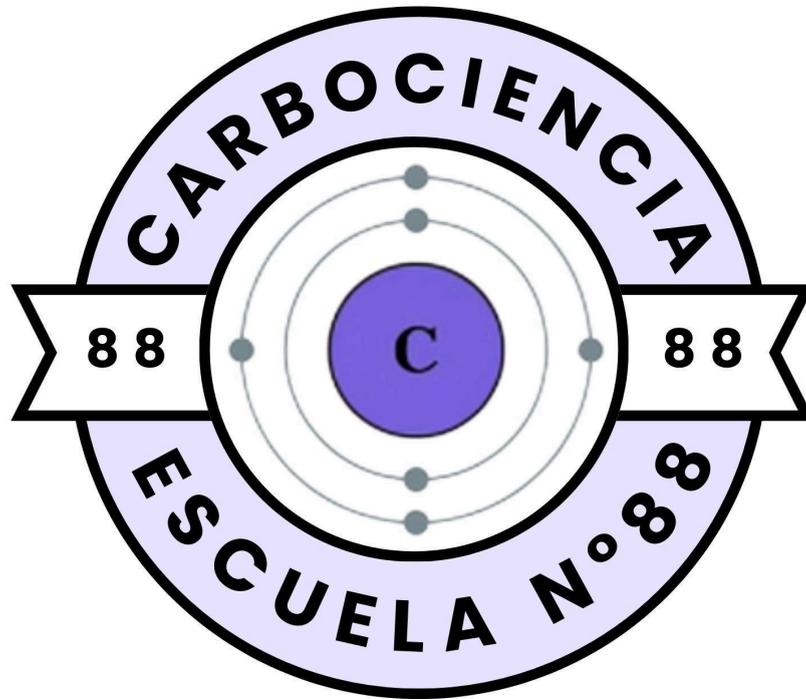


# International Virtual Science Symposium - GLOBE 2026



## Comparative analysis of carbon storage in the trees of a school property (2024–2025)

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## **TITLE**

### **Comparative analysis of carbon storage in the trees of a school property (2024–2025)**

## **SUMMARY**

Carbon sequestration by trees is a key process for mitigating climate change, as forest ecosystems act as temporary reservoirs of atmospheric carbon. In this context, the present study aimed to analyze and compare the variation in carbon stored in the aboveground biomass of trees on a school property between 2024 and 2025, considering the dynamics of the tree system based on the growth of existing trees, the addition of new specimens, and tree loss between the two periods. The study was based on field measurements of the diameter at breast height (DBH) at 1.30 m and the height of the trees present on the school property. A total of 45 trees belonging to native and exotic species were analyzed. From these measurements, individual aboveground biomass and stored carbon were estimated using allometric equations specific to each species group, following the GLOBE Programme protocols. The analysis was based exclusively on an empirical comparison of data obtained in 2024 and 2025, without resorting to projection models. The results show that the carbon stored on the school grounds exhibits significant interannual variations associated with the structure and evolution of the tree population. Native trees, although less numerous, made significant contributions to total carbon when represented by large, mature specimens, such as the native willow. However, the loss of some of these trees between the two years resulted in an immediate decrease in stored carbon. Exotic species, represented by a greater number of trees, contributed steadily to the total carbon of the system, mainly through the growth of young trees and the addition of new individuals to the analysis in 2025. The comparison between 2024 and 2025 allowed for an understanding of carbon sequestration as a dynamic process, resulting from the balance between tree growth, addition, and loss, rather than as a fixed value. Furthermore, the study revealed that carbon storage capacity depends largely on the size and stage of development of the trees, regardless of whether they are native or exotic. Finally, this work highlights the value of continuous monitoring of school trees as a scientific and educational tool, consolidating the school grounds as a living laboratory for the study of the carbon cycle and the training of students in the analysis of real environmental problems.

Keywords: carbon sequestration, native species, exotic species, climate change, forest management.

## RESEARCH QUESTION

*How does the total carbon sequestration capacity of the school grounds vary between 2024 and 2025 based on the growth of existing trees, the addition of new specimens, and the loss of tree individuals?*

The research question arises from the need to deepen the analysis of carbon sequestration on school grounds from a dynamic and temporal perspective, going beyond the strictly comparative approach used in the initial study conducted in 2024. In that work, the carbon storage capacity of native and exotic trees was analyzed at a given time, which allowed for a first approximation of the role of school trees as a carbon sink.

However, forest ecosystems are not static systems. On the contrary, they are constantly transforming as a result of individual tree growth, the incorporation of new trees into the system, and the loss of specimens due to natural or human-caused factors. Between 2024 and 2025, the school grounds experienced significant changes in their tree structure: some trees that did not reach the minimum measurement threshold in 2024 were included in the analysis in 2025, while there was a loss of adult specimens of *Salix babylonica* (creole willow), a native species with a high capacity for biomass and carbon storage.

These changes pose a new scientific challenge: understanding how tree dynamics affect the overall carbon balance of the system. The loss of mature trees implies the progressive release of carbon previously stored in their biomass, while the introduction of young trees represents a still incipient carbon capture. Analyzing whether the growth and incorporation of new trees compensate, in the short term, for the carbon loss associated with tree mortality is key to evaluating the actual efficiency of the school grounds as a carbon sink.

This question also allows us to investigate whether the differences previously observed between native and exotic species persist when the analysis is conducted temporally rather than solely structurally. Incorporating the time variable enables a more complex understanding of the role of each species group, considering not only its current storage capacity but also its future contribution and vulnerability to loss.

From an educational and environmental perspective, this research question is relevant because it transforms the school grounds into a living laboratory where students can analyze real ecological processes related to climate change, tree management, and informed

decision-making. Furthermore, the longitudinal approach reinforces the value of the continuous monitoring proposed by the GLOBE Program, providing concrete evidence of the importance of maintaining systematic observations over time.

## **HYPOTHESIS**

To address the research question of how carbon storage capacity varies between native and exotic trees present on the school grounds, the following hypotheses were formulated:

### **Null hypothesis (H0)**

There are no significant differences in the total amount of carbon stored and projected by the trees on the school grounds between 2024 and 2025, considering the growth, incorporation and loss of specimens.

### **Alternative hypothesis (H1)**

The total carbon sequestration capacity of the school grounds shows significant variations between 2024 and 2025 as a result of the growth of existing trees, the incorporation of new individuals into the system and the loss of specimens, particularly of native species, which modifies the carbon balance of the ecosystem.

### **Complementary specific hypothesis**

The loss of adult specimens of *Salix babylonica* generates a net decrease in stored carbon that is not fully compensated, in the short term, by the entry of young trees into the system.

## **GOALS**

### **General objective**

Analyze and compare the variation in the carbon sequestration capacity of the trees on the school grounds between 2024 and 2025, considering the growth, incorporation and loss of trees, as well as the differences between native and exotic species.

## Specific objectives

- Compare aboveground biomass and carbon stored by trees measured in 2024 and 2025.
- Identify the specimens that enter the system in 2025 because they have reached the minimum measurement threshold.
- Analyze the impact of tree loss (especially native willow) on the total carbon balance of the property.
- Estimate the variation in the 20-year carbon sequestration projection between the two study years.
- Evaluate whether the trends observed in 2024 between native and exotic species are maintained, attenuated, or modified in 2025.
- Interpret the results from a perspective of school tree management and environmental education.

Carbon is an essential element for life on Earth and plays a central role in the processes that regulate the global climate. Through photosynthesis, trees capture carbon dioxide (CO<sub>2</sub>) from the atmosphere and store it in their biomass, acting as carbon sinks and contributing to mitigating climate change (Sedjo, 1990; Perry, 1994). This process makes forest ecosystems key components of the Earth's climate system. However, carbon storage is neither a permanent nor a unidirectional phenomenon. Trees also release carbon as part of their natural physiological processes, and more significantly through senescence, biomass degradation, and the death of individual trees (Watson and Casper, 1984; Figueroa-Navarro, 2005). For this reason, carbon sequestration must be understood as a dynamic process, closely linked to the management and evolution of forest systems.

From a systemic perspective, carbon is distributed among different reservoirs—atmosphere, biosphere, soils, oceans, and lithosphere—connected by flows that make up the global carbon cycle. Within this framework, forest ecosystems function as temporary reservoirs, whose role depends both on the amount of biomass present and on the carbon inflows and outflows associated with growth and the loss of organic matter (GLOBE, 2005). Analyzing these flows is fundamental to understanding the real impact of trees on climate regulation.

The capacity of forests to store carbon is conditioned by multiple factors, including climatic and soil conditions, the specific composition of the tree population, and forest management practices (Bor et al., 2023). In this sense, native trees, defined as those species that are part

of a region's natural biodiversity, having evolved there without human intervention, tend to exhibit greater adaptation to local conditions. This adaptation translates into greater resilience to diseases, pests, and environmental variations, as well as more efficient use of available resources (Richardson et al., 2000). Several studies suggest that these characteristics can promote greater stability in carbon storage, in addition to contributing to soil conservation, water balance, and the maintenance of local biodiversity (Arhuire-Ossio et al., 2022; Qian et al., 2024).

On the other hand, exotic trees (introduced outside their natural range intentionally or accidentally) can offer advantages associated with faster growth rates and more uniform development patterns, allowing them to capture carbon more quickly, especially in the early stages of their growth (Richardson et al., 2000; Pötzelsberger et al., 2020). This difference has generated significant debate regarding the comparative role of native and exotic species in climate change mitigation strategies, particularly when considering different time scales.

In 2024, a study conducted on the school grounds focused on measuring and comparing the carbon sequestration capacity of native and exotic trees at a specific point in time. Using GLOBE Program protocols and allometric equations, the aboveground biomass and carbon stored by the trees on the grounds were estimated. This analysis identified significant differences between the two groups of species and laid the groundwork for understanding the role of the school's trees as a carbon sink.

However, between 2024 and 2025, the tree system on the property underwent significant structural changes. Some trees that did not meet the minimum measurement threshold in 2024 were included in the analysis in 2025, while there was a loss of mature trees, particularly *Salix babylonica* (criollo willow), a native species with high biomass and carbon storage capacity. These changes demonstrate that carbon sequestration cannot be analyzed solely as a static value, but rather as the result of a balance between the growth, addition, and loss of trees.

In this context, the present study proposes to broaden the initial approach and incorporate a temporal dimension, analyzing the variation in the carbon sequestration capacity of the school grounds between 2024 and 2025. This approach allows us to evaluate how the growth of existing trees, the introduction of new specimens, and the loss of individuals affect the overall carbon balance of the system, as well as to determine whether the trends previously observed between native and exotic species are maintained or modified over time.

From an educational perspective, this project establishes the school grounds as a living laboratory where students can analyze real and complex ecological processes related to climate change, tree management, and evidence-based environmental decision-making. Furthermore, continuous monitoring strengthens the pedagogical value of the GLOBE protocols, allowing for the integration of knowledge from natural sciences, mathematics, and data analysis within an authentic context. In this way, the study not only contributes to the generation of contextualized scientific knowledge but also fosters a deeper understanding of carbon sequestration as a dynamic and fundamental process for ecosystem sustainability.

## **RESEARCH METHOD**

This study comparatively analyzed data collected in 2024 and 2025 regarding the trees on the school grounds. The analysis included native and exotic tree species, considering both specimens measured in both years and those that reached the minimum height threshold for inclusion in the study in 2025. The loss of trees recorded between the two periods, particularly of native species, was also considered to assess its impact on the variation of carbon stored in the ecosystem.

The methodology focused on estimating the aboveground biomass of each tree from measurements of height and trunk circumference at 1.30 m above ground level (DBH), carried out in the field following the GLOBE Program protocols. From these measurements, allometric equations specific to each species group were applied, allowing the calculation of individual aboveground biomass and the estimation of the carbon content stored in each tree.

The comparative analysis between both years allowed us to evaluate the variation in the total amount of carbon stored on the school grounds, considering the growth of existing trees, the incorporation of new individuals into the system, and the loss of specimens between 2024 and 2025. This approach enabled a dynamic evaluation of carbon sequestration, understood as the result of the balance between the processes of carbon capture and release associated with the structure and evolution of the school's trees.

### **Study site**

The chosen study site was Rural School No. 88 in Las Violetas, Canelones, Uruguay, located at -34.5668 latitude and -56.2975 longitude (Figure 1). This site covers an area of just over half a hectare. The vegetation surrounding the study area acts as a natural barrier against winds from the south and southwest, contributing to a higher surface and air

temperature compared to areas lacking this type of vegetation cover. Furthermore, the area is surrounded by fields with natural vegetation, such as grasses, chilca ( *Baccharis salicifolia* ), and carqueja ( *Baccharis trimera* ).

For the GLOBE Program, climatic variables are fundamental elements for describing the atmospheric conditions of a place at a given time. In this regard, the climate in the area is temperate, with rainfall distributed throughout the year. Winters have average temperatures above 8°C, while summer average temperatures are around 20°C. In general, the country's climate is classified as temperate subtropical, with relatively mild winters and rainfall that, although irregular, does not exhibit a marked dry season. The variability in climatic elements, both between seasons and within the same season, is one of the most prominent characteristics of the Uruguayan climate. According to the Köppen-Geiger classification, the climate is defined as Cfa, meaning a temperate, humid climate with warm summers.

Several factors determine the climate of this region, including its latitude, which places Uruguay in the temperate zone of insolation. Atmospheric circulation, influenced by the Atlantic anticyclone, which brings humid winds from the northeast, and by the South Pacific anticyclone, which brings cold, dry winds from the southwest, also plays a crucial role. The country's low altitude, with a topography that does not exceed 514 meters above sea level, means that temperatures do not vary significantly due to altitude. Furthermore, its proximity to the Atlantic Ocean, with more than 150 km of coastline, acts as a moderator of temperatures, especially in coastal areas.

The average annual temperature is 17.5°C, ranging from 16.5°C in the south to nearly 20°C in the north. Rainfall, although distributed throughout the year, shows an increasing pattern from south to northeast, with annual values ranging from over 1000 mm on the Río de la Plata coast to between 1300 and 1500 mm in the northeast of the country. Despite its annual distribution, rainfall is extremely irregular and varies from year to year, influenced by phenomena such as El Niño and La Niña. August is the driest month, with an average of 70 mm. The average annual relative humidity is between 70% and 75%, with July being the wettest month (80%) and January the driest (60%).

In summary, Uruguay's four seasons are clearly differentiated by temperature, although the weather is highly variable, with rapid changes in meteorological conditions due to the interaction of the aforementioned factors. These temperature and precipitation characteristics place Uruguay within the warm temperate moist forest life zone.

The ground cover on the property consists mainly of grasslands, along with areas partially shaded by the 45 trees studied. These trees vary in age, size, and species, allowing for a diverse assessment of carbon storage (Figure 2).

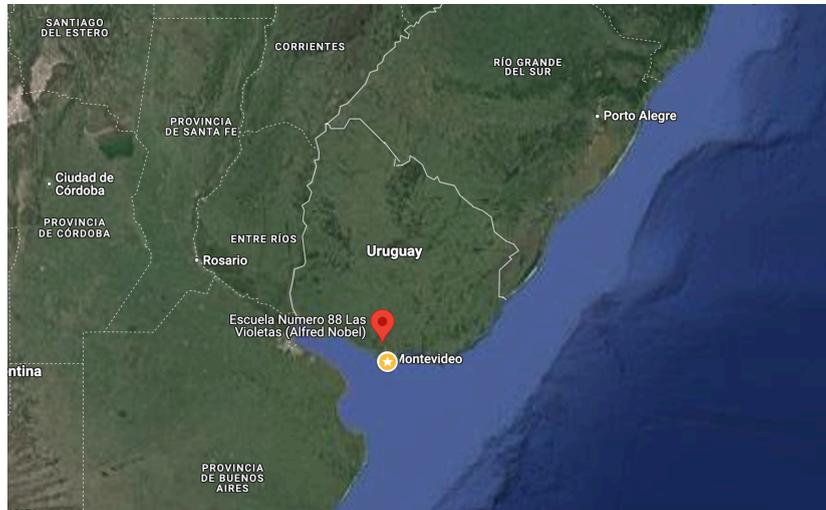


Figure 1: Location of the study site



Figure 2: Image of the school grounds showing tree cover

## Data collection

The data were collected using the GLOBE Programme protocols, specifically those designed to measure tree biomass and estimate carbon storage. The protocols used were as follows:

- **Tree height protocol**
  - Measurement of the height of each of the 45 trees using a clinometer and the GLOBE Observer digital application. (<https://www.globe.gov/documents/355050/bcc8abd6-68c9-4c2c-9f0c-cc60c7141701>)
- **Tree trunk circumference protocol**
  - Measurement of trunk circumference at a height of 1.35 meters (DBH) using a measuring tape. (<https://www.globe.gov/documents/355050/3f715849-b7c0-4a39-92b7-3ab251a6dce7>)
- **Species identification :**
  - The species identification of each tree was done using the Guide to the Identification of Native Tree Species. Uruguay (2023 version)

**Figure of the methodology**



The sampling method included measuring the trees on the property. The data were entered directly into the GLOBE Programme website, following the aforementioned data collection protocols and data entry instructions established by the GLOBE Programme (Figure 3).

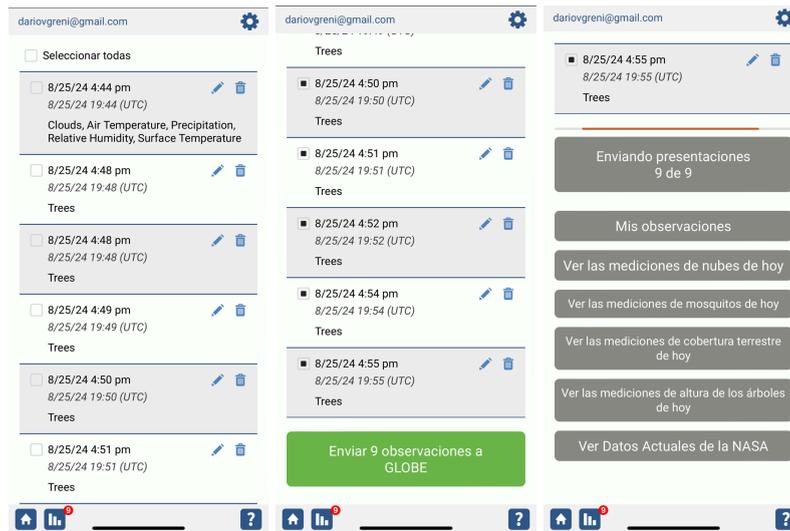


Figure 3: Screenshots of the GLOBE Observer app showing the sending of measurements to the GLOBE database

## Data analysis

To analyze the collected data, the following mathematical calculations were applied:

### 1. Biomass estimation:

- a. The specific equation was used to estimate the biomass of each tree in kilograms.  $Biomasa\ de\ un\ \acute{a}rbol(Kg) = Exp(B + B * lnDAP)$   
<https://www.globe.gov/documents/355050/41927208/TreeBiomassCarbonAnalysis.pdf/6dad96c7-7b04-432b-b02e-1038a026062f>

### 2. Calculation of carbon content:

- a. Approximately 50% of a tree's dry biomass is carbon. Therefore, the carbon content was calculated as:

$$\text{Carbon Content (kg)} = \text{Biomass (kg)} \times 0.50$$

These calculations were applied to the trees measured in 2024 and 2025, allowing for the estimation and comparison of the amount of carbon stored in the aboveground biomass of each tree and of the school grounds as a whole during both periods. The comparative analysis provided sufficient information to assess the variations in stored carbon resulting from the growth of existing trees, the addition of new specimens to the system, and the loss of individuals from one year to the next. Thus, the results obtained allowed us to answer the research question of how the dynamics of the school's tree population modify the grounds' capacity to act as a carbon sink over time, as well as to analyze the relative role of native and exotic species in this process.

Table summarizing the tree data below	
	Total Aboveground
Plot Biomass (g/plot)	142.265.249
Plot Carbon Storage (g C/plot)	71.132.625
Biomass (g/m2)	25,885
Carbon Storage (g C/m2)	12,943

Figure 4: Carbon stored by the 45 tree specimens in 2024

Table summarizing the tree data below	
	Total Aboveground
Plot Biomass (g/plot)	140.354.491
Plot Carbon Storage (g C/plot)	70.177.245
Biomass (g/m2)	25,538
Carbon Storage (g C/m2)	12,769

Figure 6: Carbon stored by the 59 tree specimens in 2025

## Impact when working with a scientist

The impact of working with a project mentor has been a key factor in the success and enrichment of this study. Collaboration with experts allowed us to approach the topic with greater rigor and depth. First and foremost, Ana Prieto was fundamental in all aspects of calculating allometry and biomass, as well as in estimating carbon storage. Her expertise in these areas enabled us to obtain accurate and reliable data and to better understand the processes involved in carbon sequestration by trees. This knowledge was essential for developing our conclusions and projections.

On the other hand, working with Claudia Caro was equally crucial, as she guided us in the statistical analysis of the data obtained. Claudia not only provided us with the tools to perform the corresponding calculations but also helped us to interpret these results appropriately. Furthermore, she was invaluable in defining the specific technical vocabulary, ensuring that the report used precise and appropriate terminology for a scientific context. A particularly enriching aspect of this collaboration was the series of videoconferences in which Claudia explained specific topics related to statistical analysis in detail, clarifying doubts and allowing us to apply the concepts directly to our study. These sessions resulted in profound learning that positively impacted the quality of our analysis.

Finally, contact with María del Pilar Castro Díez, a university professor of Ecology, added another dimension to the project. Through her guidance, we received relevant scientific articles that broadened our knowledge and provided us with an updated and pertinent theoretical framework for our work. Furthermore, this contact opened the door to future collaborations and information exchanges, which will undoubtedly enrich future projects.

In summary, the support of these mentors not only significantly improved the technical and scientific quality of the project, but also fostered collaborative learning that allowed all those involved to expand their knowledge and skills in key areas such as biomass, carbon storage, and statistical analysis. This experience has profoundly impacted our ability to develop rigorous and well-founded research projects.

## RESULTS

### **Tree species identified on the school grounds (2024–2025)**

The survey conducted on the school grounds during 2024 and 2025 identified a total of 45 trees, including both native and exotic species. In 2025, the trees analyzed included those already measured in 2024, as well as those added to the study after reaching the minimum height and circumference thresholds required for measurement. The loss of some trees was also recorded between the two years, altering the tree structure and the carbon balance of the system.

The specific composition of the tree population continues to show a predominance of exotic species. Among them, *Fraxinus americana* (American ash) remains the most abundant species, with 10 specimens, followed by *Fraxinus excelsior* (European ash), with 9 individuals. Other relevant exotic species present on the property are *Melia azedarach* (Chinaberry), *Populus deltoides* (Columbine poplar), and *Eucalyptus camaldulensis* (*Eucalyptus camaldulensis*). In total, exotic species represent 37 trees out of the total surveyed.

Regarding native species, eight specimens were identified on the school grounds. The most represented native species is *Salix babylonica* (criollo willow), with three individuals, followed by *Peltophorum dubium* (ibirapitá) and *Erythrina crista-galli* (ceibo), with two specimens each. Additionally, one specimen of *Enterolobium contortisiliquum* (timbó) and one of *Araucaria angustifolia* (araucaria) were recorded.

The inclusion of new trees in the analysis in 2025 reflected the natural growth of specimens that, in 2024, did not reach the minimum dimensions required for measurement. This process reflects the dynamics of the school tree population and allowed for an expansion of the dataset available to assess the variation in stored carbon between the two years.

### **Aboveground biomass and stored carbon in 2025**

Based on trunk circumference measurements at 1.30 m above ground (DBH) and tree height recorded in 2025, individual aboveground biomass was estimated using allometric equations specific to each species group. Subsequently, the carbon stored in the aboveground biomass of each specimen was calculated.

The results obtained for 2025 show high variability in biomass and stored carbon among the different trees on the property, mainly associated with the size, species, and stage of development of the individual trees. The highest aboveground biomass value corresponds to a *Salix babylonica* specimen (record 36), with a circumference of 479 cm and a diameter of 152.47 cm, whose estimated biomass reaches 17,827.03 kg. This tree constitutes the largest single contribution to the carbon stored on the school property.

In contrast, the lowest values of biomass and stored carbon were observed in young or smaller specimens, such as some individuals of *Peltophorum dubium* (ibirapitá), which shows the strong dependence of carbon storage on the size and stage of development of the tree.

Among the exotic species, some specimens of *Eucalyptus camaldulensis* and *Populus deltoides* stand out with high aboveground biomass values, reflecting their rapid growth and their capacity to accumulate carbon when they reach large sizes. However, within the same species, marked differences are observed between individuals, indicating that the stored carbon depends not only on the species' origin but also on the particular characteristics of each tree.

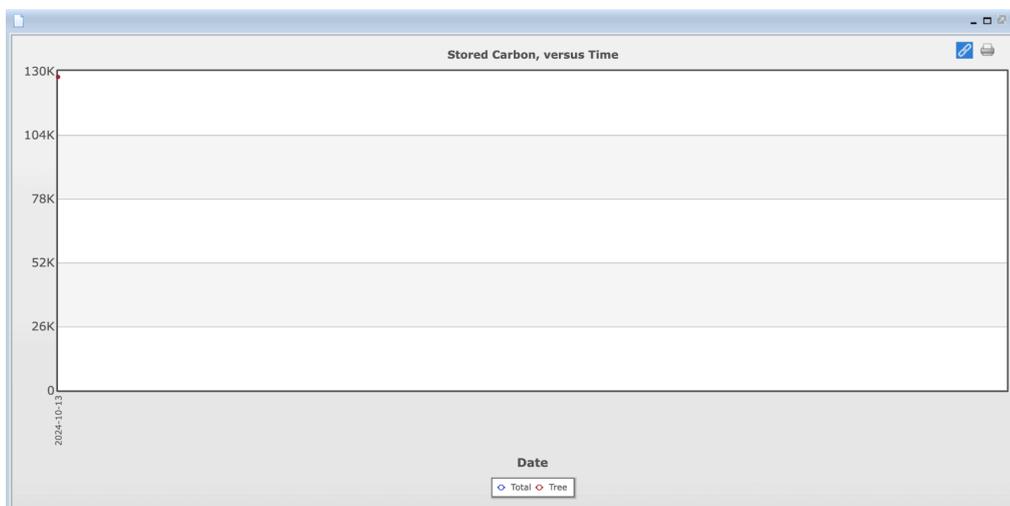
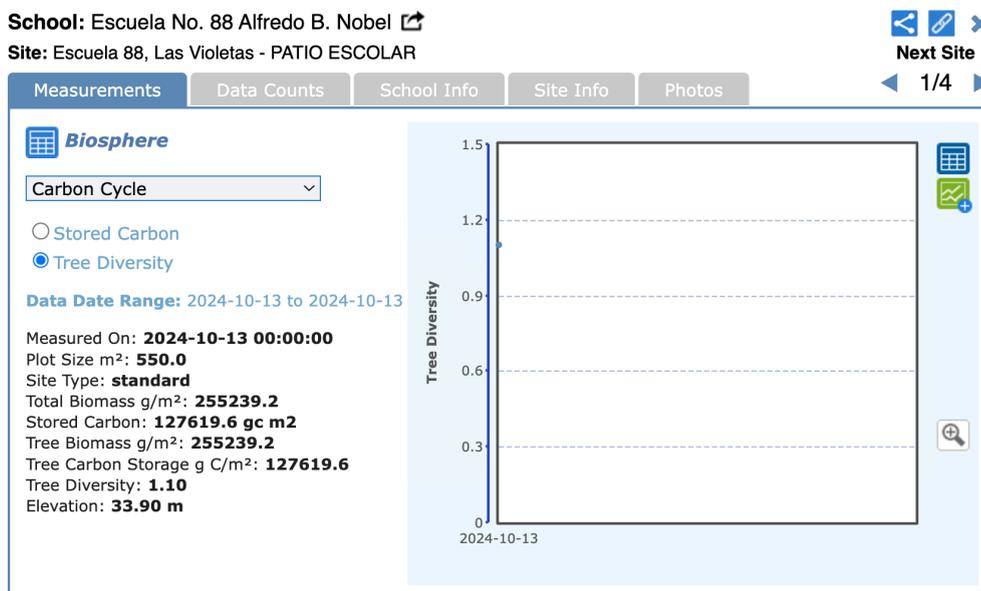
### **Comparison of carbon stored between 2024 and 2025**

Comparing the data from 2024 and 2025 allowed for an analysis of the variation in carbon stored in the aboveground biomass of the school grounds. Between the two years, an increase in carbon was observed, associated with the growth of the trees measured in both periods and the incorporation of new specimens into the system. However, this increase was partially offset by the loss of mature trees between years, particularly native species, which resulted in the release of carbon previously stored in their biomass.

This balance shows that the school grounds' capacity to store carbon results from the equilibrium between the growth, addition, and loss of trees. In this sense, native trees, although less numerous, continue to make significant contributions to the total stored carbon when they are represented by large, mature specimens. Meanwhile, exotic species, due to their greater abundance, contribute significantly to the total carbon of the system, especially as young trees increase their biomass over time.

Taken together, the results obtained for 2025 allow us to characterize the current structure of school trees and analyze how their interannual dynamics modify the carbon stored in the aboveground biomass, providing empirical evidence to understand the role of the school grounds as a carbon sink in a real and changing context.

### Data capture from the GLOBE website



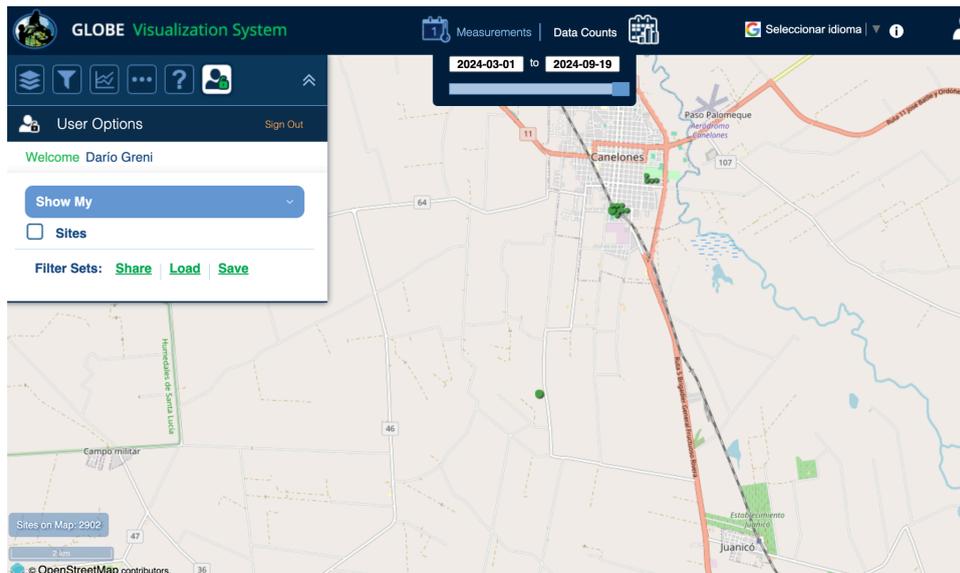


Figure 6: Data visualization on the GLOBE website.

The results obtained from comparing the 2024 and 2025 data show that the carbon storage capacity of the school grounds is not a static value, but rather the result of the dynamics of the tree population over time. Between the two years, variations in stored carbon were observed, primarily associated with the growth of the trees measured in both periods, the addition of new specimens that reached the minimum measurement threshold, and the loss of trees.

Regarding the origin of the species, native trees continue to make significant contributions to stored carbon when represented by large, mature specimens. In particular, the presence of native willows with high biomass values accounts for a significant portion of the total carbon recorded on the property. However, the loss of some of these specimens between 2024 and 2025 highlighted that the disappearance of mature trees leads to an immediate decrease in stored carbon, underscoring the importance of their conservation from both a climate and ecosystem perspective.

Exotic species, being represented by a greater number of individuals, contributed significantly to the total carbon of the system in both years. The comparative analysis shows that the increase in carbon stored in this group was mainly associated with the growth of young specimens and the incorporation of new trees into the analysis in 2025. However, the high variability observed among individuals indicates that carbon storage depends more on the size and developmental stage of each tree than exclusively on its native or exotic origin.

Overall, the year-on-year comparison reveals that the carbon balance of the school grounds results from the equilibrium between tree growth, addition, and loss. This approach allows us to understand carbon sequestration as a dynamic process, conditioned by the structure of the tree population and its evolution over time.

### **Possible sources of error**

Among the potential sources of error in the study is the use of general allometric equations to estimate aboveground biomass and stored carbon. While these equations are widely used and accepted, they may not accurately reflect the characteristics of each species or the specific conditions of the study site. Similarly, small inaccuracies in circumference and height measurements can lead to variations in the estimated biomass and carbon values.

Another source of uncertainty is related to structural changes in the tree population between the two years. The loss of trees, especially mature ones, can significantly affect total stored carbon, while the addition of young trees contributes relatively small amounts. Furthermore, the sample size, limited to the school grounds, does not allow for extrapolating the results to other contexts without considering differences in species, management practices, and environmental conditions.

### **Comparison with similar studies**

The results obtained are consistent with previous research analyzing carbon storage in forest systems from a structural and dynamic perspective. Studies such as those by Bor et al. (2023) indicate that the amount of carbon stored in a forest depends on both species composition and the distribution of tree sizes and ages. Furthermore, it has been documented that forests with large, mature trees concentrate a high proportion of total carbon, making them particularly relevant from the standpoint of climate change mitigation.

In line with this background, the results of the present study show that, although native trees are less abundant, their contribution to stored carbon can be high when mature specimens are present. Similarly, the greater abundance of exotic species makes a significant contribution to the total carbon of the system, especially when individuals increase their biomass over time. These patterns reinforce the idea that the structural diversity of the tree population is a key factor for the stability of stored carbon.

### **Support for the hypothesis**

The study's results support the hypothesis that the carbon sequestration capacity of the school grounds varies significantly between 2024 and 2025 as a result of tree growth,

addition, and loss. The year-on-year comparison confirms that the loss of mature trees, particularly native species, has a direct impact on stored carbon, while the growth and addition of young trees help to partially offset this loss.

These findings reinforce the need to consider carbon sequestration as a dynamic process dependent on tree management. They also highlight the importance of conservation and management strategies that include both the protection of mature trees and the regeneration and growth of new specimens, in order to sustain the school grounds' capacity to act as a carbon sink over time.

## **CONCLUSIONS**

The comparative analysis of data from 2024 and 2025 revealed that the carbon storage capacity of the school grounds is closely linked to the dynamics of the tree population and is not a fixed value. The variations observed between the two years reflect the combined effect of tree growth measured in both periods, the addition of new trees that reached the minimum measurement threshold, and the loss of trees.

In both years of the study, native trees made significant contributions to stored carbon when represented by large, mature specimens. In particular, native willows concentrated a significant proportion of the total carbon in the area, confirming the importance of mature native trees to the current carbon storage capacity. However, the loss of some of these trees between 2024 and 2025 highlighted that the disappearance of mature trees leads to an immediate reduction in stored carbon, underscoring the need for their conservation.

Exotic trees, being represented by a greater number of individuals, contributed significantly to the total carbon of the system in both years. The increase observed in carbon stored in this group between 2024 and 2025 was mainly associated with the growth of existing trees and the addition of new specimens to the analysis. However, the results show high variability among individuals, indicating that carbon storage depends largely on the size and developmental stage of each tree, regardless of whether it is native or exotic.

The year-on-year comparison revealed that the carbon balance of the school grounds results from the equilibrium between tree growth, addition, and loss. In this sense, the study confirms that the tree structure—in terms of species diversity and size distribution—is a key factor in sustaining the grounds' capacity as a carbon sink.

From a school tree management perspective, the results suggest that preserving mature trees, especially native species, is essential for maintaining high levels of stored carbon. At

the same time, monitoring the growth of young trees and gradually incorporating new specimens helps sustain and strengthen stored carbon over time, partially offsetting the inevitable losses associated with tree mortality.

Finally, this project demonstrated the value of continuous monitoring as a scientific and educational tool. The comparison between 2024 and 2025 allowed students to understand carbon sequestration as a dynamic process, linked to real changes in the ecosystem, and not as a theoretical or static value. In this way, the study not only provided relevant empirical evidence for the analysis of carbon stored on the school grounds, but also strengthened students' scientific training and environmental awareness, consolidating the school grounds as a long-term learning and observation space.

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## ANNEX 1

Badges to which it applies:

## **1. I AM A DATA SCIENTIST**

The carbon sequestration project includes a detailed analysis of data collected both locally and from the GLOBE database. Organized tables have been created that clearly present biomass and stored carbon data, along with graphs illustrating relevant trends. Furthermore, a statistical analysis was performed to interpret the results and validate the conclusions. The report discusses the limitations of the data used and how these may influence the conclusions, as well as proposing future research. With these elements, the project demonstrates a rigorous approach to scientific data handling.

## **2. I MAKE AN IMPACT**

The project establishes a direct link between a global environmental problem, such as climate change, and practical solutions at the local level. Through research, the potential of native trees to capture carbon was identified, leading to specific proposals, such as promoting reforestation with these species in the region. Furthermore, the report describes how these actions raise environmental awareness within the school community and contribute to mitigating the effects of climate change.

## **3. I AM A COLLABORATOR**

The project integrates collaborative work among students, faculty, and experts, who contributed to the analysis and training in advanced techniques. The roles and contributions of each collaborator have been clearly documented, highlighting how this cooperation improved the project's development. This approach meets the requirements for this badge, demonstrating the value of teamwork.

## **ANNEX 2**

### **Trees processed in 2024**

Tree #	Species Group	Circumference/ CBH (cm)	Diameter/ DBH (cm)	Total Aboveground Biomass (kg)	Aboveground Biomass (g)	Aboveground Carbon Storage (g C)
#	Group	Circ	Day	TotAboveBio	TotAboveBio-g	Coal
1	MixedHardwood	250.0	79.58	4401.11	4,401,107.61	2,200,553.81
2	MixedHardwood	120.0	38.20	711.09	711,090.05	355,545.02
3	MixedHardwood	85.0	27.06	301.99	301,988.13	150,994.07
4	MixedHardwood	140.0	44.56	1042.77	1,042,766.22	521,383.11
5	MixedHardwood	81.0	25.78	267.92	267,917.15	133,958.58
6	MixedHardwood	306.0	97.40	7270.55	7,270,547.88	3,635,273.94
7	MixedHardwood	152.0	48.38	1279.05	1,279,047.07	639,523.53
8	MixedHardwood	94.0	29.92	387.74	387,740.35	193,870.18
9	MixedHardwood	82.0	26.10	276.21	276,207.00	138,103.50
10	MixedHardwood	71.0	22.60	193.14	193,142.61	96,571.30
11	MixedHardwood	42.0	13.37	52.43	52,434.56	26,217.28
12	MixedHardwood	41.0	13.05	49.39	49,388.60	24,694.30
13	MixedHardwood	56.0	17.83	107.13	107,127.99	53,563.99
14	MixedHardwood	67.0	21.33	167.24	167,237.92	83,618.96
15	MixedHardwood	106.0	33.74	522.55	522,546.68	261,273.34
16	MixedHardwood	49.0	15.60	76.89	76,891.78	38,445.89
17	MixedHardwood	90.0	28.65	348.05	348,048.08	174,024.04
18	MixedHardwood	89.0	28.33	338.52	338,522.90	169,261.45
19	MixedHardwood	96.0	30.56	408.55	408,553.17	204,276.58
20	SoftMapleBirch	180.0	57.30	2126.35	2,126,348.77	1,063,174.38
21	SoftMapleBirch	191.0	60.80	2446.59	2,446,591.80	1,223,295.90
22	SoftMapleBirch	235.0	74.80	3994.86	3,994,864.92	1,997,432.46
23	SoftMapleBirch	363.0	115.55	11171.84	11,171,838.71	5,585,919.36
24	SoftMapleBirch	205.0	65.25	2892.13	2,892,134.96	1,446,067.48
25	SoftMapleBirch	59.0	18.78	152.03	152,030.80	76,015.40
26	SoftMapleBirch	36.0	11.46	47.26	47,260.74	23,630.37
27	AspenAlder	280.0	89.13	4949.42	4,949,419.26	2,474,709.63
28	AspenAlder	161.0	51.25	1321.15	1,321,154.14	660,577.07
29	AspenAlder	147.0	46.79	1063.31	1,063,306.46	531,653.23
30	AspenAlder	243.0	77.35	3528.98	3,528,975.67	1,764,487.83
31	AspenAlder	79.0	25.15	241.54	241,539.83	120,769.91

32	MixedHardwood	489.0	155.65	23290.38	23,290,377.49	11,645,188.75
33	MixedHardwood	182.0	57.93	2000.62	2,000,623.05	1,000,311.52
34	MixedHardwood	328.0	104.41	8638.75	8,638,745.24	4,319,372.62
35	AspenAlder	353.0	112.36	8603.91	8,603,913.98	4,301,956.99
36	AspenAlder	479.0	152.47	17827.03	17,827,027.74	8,913,513.87
37	AspenAlder	273.0	86.90	4659.20	4,659,202.22	2,329,601.11
38	MixedHardwood	324.0	103.13	8379.47	8,379,469.20	4,189,734.60
39	MixedHardwood	204.0	64.94	2656.10	2,656,100.46	1,328,050.23
40	SoftMapleBirch	272.0	86.58	5645.32	5,645,318.03	2,822,659.02
41	SoftMapleBirch	212.0	67.48	3131.17	3,131,168.53	1,565,584.26
42	MapleOak	168.0	53.48	2150.71	2,150,706.41	1,075,353.21
43	MixedHardwood	179.0	56.98	1919.72	1,919,722.60	959,861.30
44	Pine	143.0	45.52	863.62	863,615.45	431,807.73
45	Pine	100.0	31.83	361.49	361,487.00	180,743.50

## Trees processed in 2025

Tree #	Species Group	Circumference/ CBH (cm)	Diameter/ DBH (cm)	Total Aboveground Biomass (kg)	Aboveground Biomass (g)	Aboveground Carbon Storage (g C)
#	Group	Circ	Day	TotAboveBio	TotAboveBio-g	Coal
1	AspenAlder	272.0	86.58	4618.57	4,618,572.59	2,309,286.29
2	AspenAlder	246.0	78.30	3633.85	3,633,849.95	1,816,924.98
3	AspenAlder	28.0	8.91	20.32	20,316.75	10,158.38
4	AspenAlder	103.0	32.79	454.95	454,946.97	227,473.48
5	SoftMapleBirch	85.0	27.06	360.54	360,543.94	180,271.97
6	MixedHardwood	132.0	42.02	901.00	900,996.98	450,498.49
7	MapleOak	175.0	55.70	2375.40	2,375,398.59	1,187,699.29
8	SoftMapleBirch	205.0	65.25	2892.13	2,892,134.96	1,446,067.48
9	AspenAlder	165.0	52.52	1400.85	1,400,848.28	700,424.14
10	AspenAlder	152.0	48.38	1151.67	1,151,670.55	575,835.28
11	MixedHardwood	27.0	8.59	17.50	17,501.28	8,750.64
12	MixedHardwood	71.0	22.60	193.14	193,142.61	96,571.30

13	SoftMapleBirch	347.0	110.45	10042.06	10,042,058.32	5,021,029.16
14	MixedHardwood	200.0	63.66	2528.63	2,528,633.98	1,264,316.99
15	MixedHardwood	176.0	56.02	1840.81	1,840,808.82	920,404.41
16	MixedHardwood	61.0	19.42	132.48	132,478.26	66,239.13
17	MixedHardwood	40.0	12.73	46.45	46,450.88	23,225.44
18	SoftMapleBirch	195.0	62.07	2569.51	2,569,510.27	1,284,755.13
19	MixedHardwood	184.0	58.57	2055.67	2,055,668.30	1,027,834.15
20	MapleOak	94.0	29.92	523.26	523,264.29	261,632.14
21	MixedHardwood	113.0	35.97	612.49	612,489.00	306,244.50
22	MixedHardwood	85.0	27.06	301.99	301,988.13	150,994.07
23	SoftMapleBirch	94.0	29.92	457.44	457,440.05	228,720.02
24	SoftMapleBirch	113.0	35.97	707.01	707,009.62	353,504.81
25	SoftMapleBirch	85.0	27.06	360.54	360,543.94	180,271.97
26	MixedHardwood	23.0	7.32	11.75	11,752.47	5,876.23
27	SoftMapleBirch	30.0	9.55	30.71	30,706.41	15,353.20
28	SoftMapleBirch	271.0	86.26	5596.35	5,596,353.87	2,798,176.94
29	Pine	195.0	62.07	1837.80	1,837,798.79	918,899.40
30	Pine	164.0	52.20	1205.64	1,205,635.35	602,817.67
31	SoftMapleBirch	355.0	113.00	10598.26	10,598,260.16	5,299,130.08
32	MixedHardwood	104.0	33.10	498.40	498,402.57	249,201.29
33	MixedHardwood	51.0	16.23	84.92	84,923.62	42,461.81
34	MixedHardwood	101.0	32.15	463.46	463,457.71	231,728.85
35	SoftMapleBirch	97.0	30.88	492.72	492,723.56	246,361.78
36	MixedHardwood	40.0	12.73	46.45	46,450.88	23,225.44
37	MixedHardwood	304.0	96.77	7153.10	7,153,103.70	3,576,551.85
38	MixedHardwood	93.0	29.60	377.58	377,576.87	188,788.43
39	SoftMapleBirch	222.0	70.66	3491.80	3,491,796.44	1,745,898.22
40	MixedHardwood	54.0	17.19	97.88	97,876.38	48,938.19
41	MixedHardwood	50.0	15.92	80.85	80,848.13	40,424.07
42	MixedHardwood	64.0	20.37	149.25	149,253.99	74,626.99
43	MixedHardwood	45.0	14.32	62.23	62,234.51	31,117.25
44	MixedHardwood	44.0	14.01	58.86	58,856.26	29,428.13
45	MixedHardwood	91.0	28.97	357.73	357,731.57	178,865.79
46	AspenAlder	230.0	73.21	3094.98	3,094,981.07	1,547,490.53
47	MixedHardwood	104.0	33.10	498.40	498,402.57	249,201.29

48	MixedHardwood	79.0	25.15	251.79	251,787.90	125,893.95
49	MixedHardwood	150.0	47.75	1237.66	1,237,657.90	618,828.95
50	MixedHardwood	365.0	116.18	11265.03	11,265,028.76	5,632,514.38
51	MixedHardwood	316.0	100.59	7875.01	7,875,005.14	3,937,502.57
52	MixedHardwood	190.0	60.48	2226.19	2,226,191.62	1,113,095.81
53	MixedHardwood	479.0	152.47	22125.40	22,125,404.72	11,062,702.36
54	MixedHardwood	91.0	28.97	357.73	357,731.57	178,865.79
55	MixedHardwood	88.0	28.01	329.16	329,155.18	164,577.59
56	MixedHardwood	27.0	8.59	17.50	17,501.28	8,750.64
57	MixedHardwood	35.0	11.14	33,34	33,340.41	16,670.21
58	AspenAlder	477.0	151.83	17649.89	17,649,889.30	8,824,944.65
59	MixedHardwood	104.0	33.10	498.40	498,402.57	249,201.29

## ANNEX 3

### Acknowledgments

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