CARBON STOCK IN URBAN TREES OF SÃO LUÍS ESTIMATED VIA GLOBE OBSERVER

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RESUMO

This study estimated the carbon stock in urban trees on the Greater Island of São Luís (MA), based on data collected between January 2025 and January 2026 using the GLOBE Observer application (Trees protocol). Project participants recorded biometric measurements in the field, such height and diameter at breast height (DBH). The application used these variables in standardized allometric equations to calculate aboveground biomass and, subsequently, the carbon stored per tree and in the total sample. The estimated total carbon reached approximately 28.8 tons (28,800 kg), and the results show that trees with greater height and diameter tend to concentrate higher volumes of carbon. Statistical analysis resulted in a correlation between height and stored carbon (r = 0.994), reinforcing that the preservation of individuals with greater structural size and biomass can generate storage gains when compared to young individuals. It is concluded that continuous monitoring initiatives, with participatory tools such as GLOBE Observer, produce valuable information to support urban management and planning actions, especially in cities with tropical climates such as São Luís, where urban forestry plays a relevant role in mitigating the effects of climate change.

Keywords: Urban forestry; Carbon stock; Biomass; GLOBE Observer

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INTRODUCTION

Urban centers have been experiencing the effects of climate change with increasing intensity. In cities like São Luís, the increase in average temperature and the greater frequency of extreme weather events compromise thermal comfort and public health, in addition to aggravating existing environmental problems (Santos, 2024; Araújo and Rangel, 2012). This reality makes the search for local adaptation and mitigation strategies urgent. According to the Intergovernmental Panel on Climate Change, urban centers concentrate both a large part of greenhouse gas emissions and a significant portion of the population vulnerable to the impacts of global warming (IPCC, 2023).

The urbanization process, when it occurs in an accelerated and poorly planned manner, tends to intensify these effects (Choudhury et al., 2020). The replacement of natural areas with buildings, paved roads, and impermeable surfaces reduces the presence of vegetation and alters the city's energy balance, favoring the formation of urban heat islands (Araújo and Rangel, 2012). This phenomenon results in higher temperatures in urbanized areas compared to adjacent rural areas, increasing thermal discomfort and raising the demand for electricity to cool environments (Santamouris, 2020; Santos, 2024).

In tropical regions like São Luís, these impacts are enhanced by the humid equatorial climate, characterized by high temperatures, high humidity, and intense solar radiation throughout almost the entire year (Araújo and Rangel, 2012). Under these conditions, the loss of vegetation cover can significantly worsen heat islands, especially in neighborhoods with less green space (Nowak et al., 2013; Choudhury et al., 2020). The combination of a naturally warm climate and increasing urbanization makes environmental monitoring an urgent necessity to understand how the natural elements still present in the city influence the urban microclimate.

Urban trees offer multiple environmental benefits that help mitigate the impacts of warming in cities. The presence of trees promotes shading, evapotranspiration, and reduction of air temperature, in addition to contributing to improved air quality and rainwater infiltration (Choudhury et al., 2020). Another aspect of great relevance is the ability of trees to absorb carbon dioxide from the atmosphere during growth and store it in biomass over time. This storage occurs both in the aerial part and in the root system, varying according to the size, age, and environmental conditions in which the tree develops (Nowak et al., 2002).

Studies conducted in different cities around the world indicate that large urban trees concentrate significantly larger amounts of carbon when compared to young or small individuals. This means that the removal of adult trees can result in significant losses in the urban carbon stock, which are difficult to compensate for in the short term by planting new seedlings (Pregitzer et al., 2022). In this sense, understanding the structure of urban trees and monitoring their growth over time becomes important for guiding conservation and management strategies.

In Brazil, despite growing attention to the issue of climate change, studies that systematically quantify carbon storage in urban trees are still limited, especially in cities in the North and Northeast (Silva et al, 2019). In São Luís, urban expansion in recent decades has led to the replacement of green areas with new developments, reinforcing the need to produce local information to assist urban and environmental planning. Monitoring urban trees allows us to identify which species and which individuals concentrate the greatest amount of biomass and carbon, as well as revealing inequalities in the distribution of trees among different neighborhoods of the city.

In recent years, digital tools and citizen science initiatives have expanded the possibilities for environmental monitoring on a local scale. The GLOBE (Global Learning and Observations to Benefit the Environment) program, coordinated by NASA in partnership with scientific and educational institutions, offers standardized protocols that allow the collection of environmental data by students, teachers, and citizens (Globe Program, 2021). Through the GLOBE Observer application, it is possible to record biometric information of urban trees, such as height and diameter at breast height, generating data that can be used in scientific studies and educational actions (Bonney et al., 2009).

Recent research demonstrates that the data generated by GLOBE Observer has the potential to support environmental analyses at different scales, including the validation of remote sensing products and studies related to canopy structure and plant biomass (Lu; Popescu; Campbell, 2025). In urban contexts, this participatory approach contributes not only to expanding the available database, but also to strengthening scientific education and environmental awareness among the population involved.

In the context of São Luís, the use of GLOBE Observer to monitor urban trees represents an opportunity to integrate education, science, and environmental planning. By involving students in data collection and analysis, continuous monitoring of urban trees allows us to understand how tree growth relates to carbon storage and how this information can support decisions aimed at conserving existing green areas (Lu; Popescu; Campbell, 2025). In addition, temporal monitoring makes it possible to identify trends, such as gains or losses in biomass, associated with climatic, urban, or management factors.

From the above, this research is guided by the following question: What is the carbon storage potential of urban trees on the Greater Island of São Luís (MA), estimated from the Trees protocol of the GLOBE Observer program, and how do the structural characteristics of the trees (height and DBH) influence this stock?

The generation of local data contributes to filling existing gaps in the literature and offers technical support for public policies aimed at mitigating climate change, sustainable urban planning, and improving the quality of life of the population. Based on these findings, this study proposes to estimate carbon storage in urban trees on the Greater São Luís Island using data collected with the GLOBE Observer application, seeking to broaden the understanding of the relationship between urban afforestation, equatorial climate, and mitigation of the effects of urban warming.

MATERIALS AND METHODS

To estimate carbon storage in the urban tree cover of Greater São Luís Island, an observational approach was carried out based on monitoring trees in different neighborhoods. The data collection period extended from January 2025 to January 2026, using the protocols of the GLOBE Observer program, specifically the Trees protocol, which guides the standardized collection of biometric information in urban and natural trees (Globe Program, 2021).

The study area comprises Greater São Luís Island, located on the northern coast of the state of Maranhão, encompassing the municipalities of São Luís, São José de Ribamar, Paço do Lumiar, and Raposa. It is a coastal region with a humid tropical climate, high environmental diversity, and an intense urbanization process (Araújo and Rangel, 2012). The spatial distribution of the investigated area is presented in Figure 1, which illustrates the geographic location of the island and the municipalities that compose it.

Figure 1 – Location of the study area: Greater São Luís Island (MA).
Source: GLOBE Observer.

The observations were conducted by high school students, previously instructed on the use of the application and field procedures, ensuring greater consistency in the measurements. For each selected tree, data such as total height, diameter at breast height (DBH), and location were recorded. The choice of trees considered the visibility of the top of the crown, a necessary condition for the adequate estimation of height, according to the guidelines of the Trees protocol.

The height of the trees was obtained with the aid of the GLOBE Observer application, which calculates the measurement from the observer's viewing angle and the distance to the trunk. This method, based on trigonometry, reduces common errors in visual estimates and was applied by previously trained high school students. The application guides the observer's positioning and automatically performs the calculations, reducing errors associated with direct visual estimation and allowing for greater standardization of measurements in the field (Globe Program, 2021).

The diameter at breast height (DBH) was obtained from measuring the circumference of the trunk at 1.30 m from the ground, using a measuring tape. Subsequently, the circumference was converted to DBH using the mathematical relationship $DBH = CBH/\pi$, a procedure widely used in urban forest inventories (Nowak et al., 2013; Silva et al., 2019).

The aboveground biomass estimate was performed automatically by the Trees Tool, a tool integrated into the GLOBE Observer application. The application applies standardized allometric equations that relate structural variables of trees, such as DBH and height, to the accumulation of plant biomass. In general, these equations take the form Biomass = $B = a \cdot (DAP) b \cdot (H) c$, Where: B = aboveground biomass (kg or t), D = diameter at breast height (cm or m), H = total tree height (m), a, b, c = specific coefficients determined empirically for each species or group of species, biome or type of vegetation (Pregitzer et al., 2022).

Based on the estimated biomass, the application calculates the stored carbon, considering that approximately 50% of the dry biomass corresponds to carbon. To express the results in carbon dioxide equivalent (CO_2e), the conversion factor 44/12 was applied, which relates the molar masses of carbon and CO_2, according to the methodology adopted in urban carbon accounting studies (Yin et al., 2022).

To assess the relationship between tree height (m) and stored carbon (kg/tree), Pearson's correlation coefficient (r) was applied, which is indicated for continuous quantitative variables and to verify the intensity and direction of a linear association (ZAR, 2010). The calculations were performed based on the pairs of values obtained in the GLOBE Observer spreadsheet (n = number of trees sampled with both values available). The coefficient r was calculated by:

$$r = fracsum_{i=1}^{n}(H_i - barH)(C_i - barC)sqrtsum_{i=1}^{n}(H_i - barH)^2 sqrtsum_{i=1}^{n}(C_i barC)^2$$

where Hi represents the height of the i-th tree, Ci the corresponding stored carbon, and He and C are the sample means. Then, the coefficient of determination (R^2) was obtained using the following relationship:

$$R^2 = r^2$$

R^2 expresses the proportion of the variability in stored carbon that can be explained by the variation in height, assuming a linear association.

DATA AND RESULTS

From January 2025 to January 2026, 428 urban trees distributed across different neighborhoods of Greater São Luís Island were analyzed, identifying 18 tree species. Based on biometric data collected in the field and processed by the GLOBE Observer application (Trees Tool), a total carbon stock of approximately 28.8 tons (28,800 kg) was estimated, highlighting the contribution of urban afforestation to the removal of carbon dioxide from the atmosphere in a tropical urban environment.

Table 1 presents a general summary of the main indicators obtained in the study, including the number of trees analyzed, the total carbon stored, and the corresponding value in carbon dioxide equivalent (CO_2e). These results demonstrate that, even in urbanized areas, the existing tree population accumulates significant amounts of carbon over time.

Table 1 – General metrics of carbon storage in urban trees on the Greater São Luís Island (MA).

Indicator	Value
Trees analyzed	428 units
Species identified	18 different species
Total carbon stored	28.8 tons
Estimated CO_2 equivalent	105.4 tons

Source: Prepared by the authors using data from the GLOBE Observer.

Analysis of carbon storage by species revealed that a few species concentrate a significant portion of the total stock. As shown in Table 2, the species Mango (*Mangifera indica*), Oiti (*Licania tomentosa*), and Ficus (*Ficus benjamina*) stood out as the largest contributors, jointly accounting for approximately half of the total carbon stored in the sample set.

Table 2 – Species with the greatest contribution to carbon storage in urban trees of Greater São Luís Island (MA).

Species	Number of trees	Average carbon (kg/tree)	Total carbon (t)	CO_2 equivalent (t)
Mango tree (*Mangifera indica*)	68	85.2	5.79	21.25
Oiti (*Licania tomentosa*)	42	92.7	3.89	14.28
Ficus (*Ficus benjamina*)	35	78.4	2.74	10.06
Brazilwood (*Paubrasilia echinata*)	28	105.3	2.95	10.83
Yellow Ipê (*Handroanthus chrysotrichus*)	25	67.8	1.70	6.24

Source: Prepared by the authors using data from the GLOBE Observer.

The relationship between tree size and stored carbon was analyzed based on structural classes. Figure 2 and Table 3 show that the lower diameter at breast height (DBH) classes concentrate the largest number of individuals, while the upper classes, although less frequent, present significantly higher average carbon values. Trees with higher DBH stored substantially larger amounts of carbon than smaller individuals, reinforcing the importance of conserving trees with greater structural development in the urban environmen (Pires et al., 2023; Choudhury et al., 2020; Silva et al., 2019).

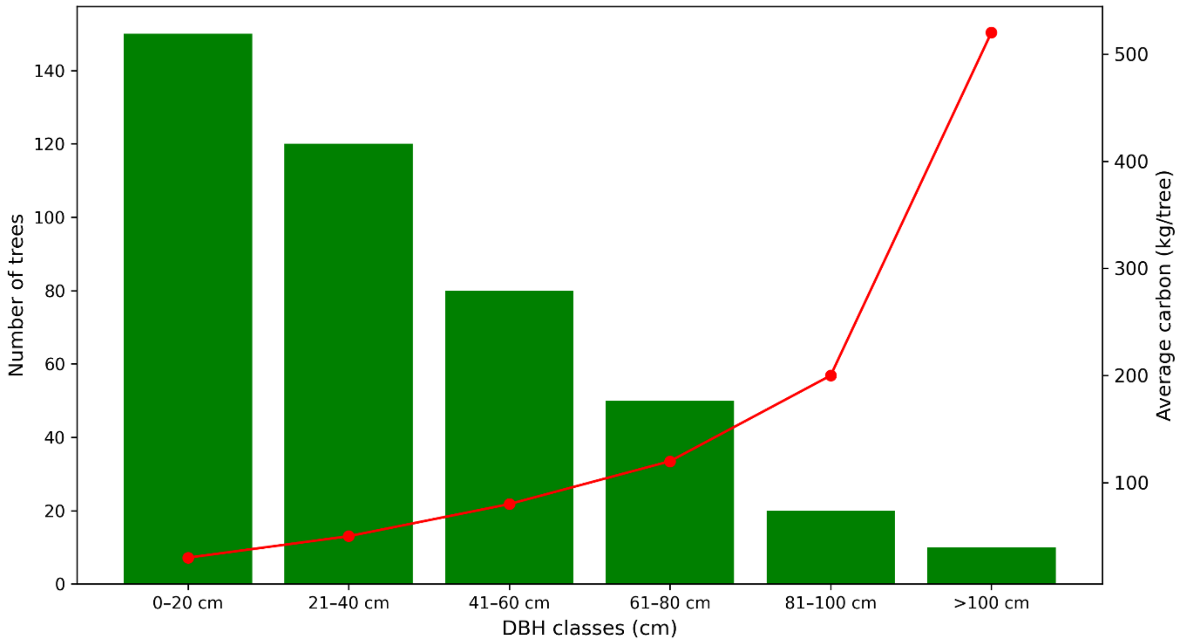

Figure 2 – Number of trees and average carbon (kg/tree) by DBH class in the Greater São Luís Island (MA).

Source: Prepared by the authors based on data from GLOBE Observer.

Table 3 – Statistics of stored carbon (kg/tree) by height class in urban trees

Height class (m)	n (trees)	Average carbon (kg/tree)	Minimum carbon (kg)	Maximum carbon (kg)
11–12.9	3	49.98	40.13	56.12
13–14.9	2	70.41	66.96	73.86
15–16.9	3	98.91	87.14	115.00
17–18.9	3	131.11	127.75	137.46
≥ 19.0	1	158.18	158.18	158.18

Source: Prepared by the authors using data from the GLOBE Observer.

In addition, Table 3 summarizes the relationship between height classes and stored carbon, showing a progressive increase in average carbon as tree height increases. Trees taller than 16 m showed substantially higher average carbon values, reaching peaks above 150 kg per individual in the highest height classes.

The statistical analysis confirmed this structural pattern, indicating a positive correlation between tree height and stored carbon ($r = 0.994$; $R^2 = 0.988$). This result demonstrates that much of the variation in stored carbon can be explained by the structural dimensions of the trees, especially their height, which reinforces the adequacy of the method adopted and the consistency of the data collected (Choudhury et al., 2020).

The monthly variation in accumulated carbon throughout the monitoring period is shown in Figure 3, which shows continuous growth in carbon stock, with more pronounced increases in the months associated with the rainy season. This behavior suggests a direct influence of local climatic conditions on tree growth and biomass accumulation, a pattern also observed in other studies conducted in tropical regions (Nowak et al., 2013).

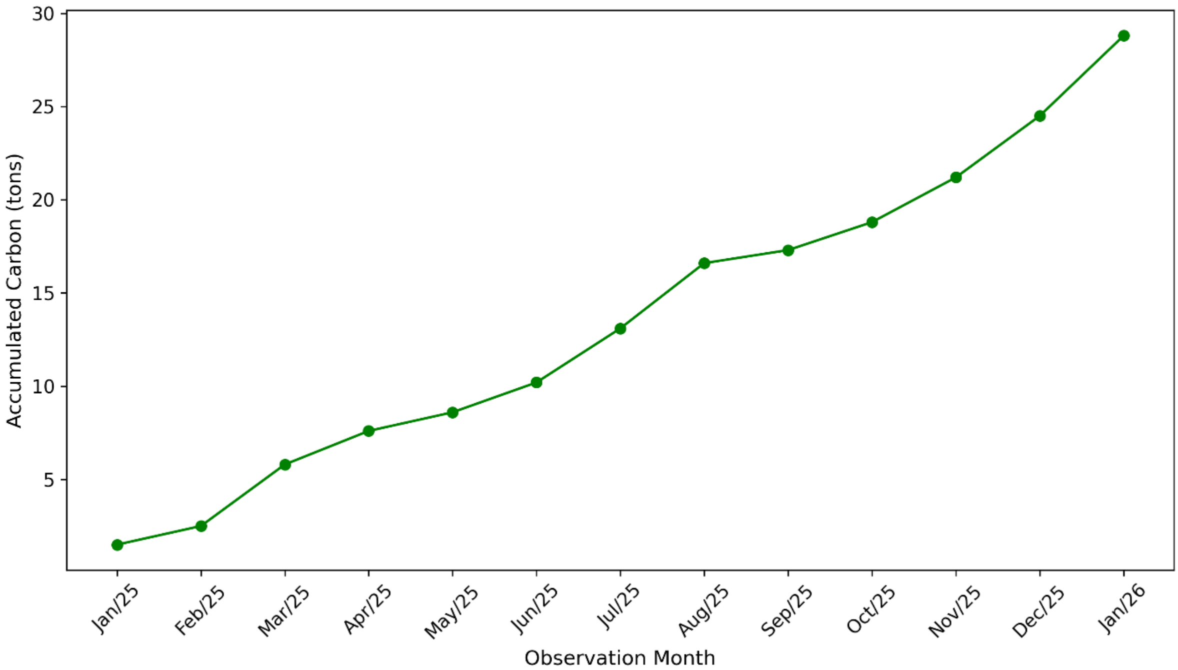

Figure 2 – Monthly evolution of carbon accumulated in urban trees.

Source: Prepared by the authors based on data from the GLOBE Observer.

Overall, the data obtained demonstrate that urban tree cover on the Greater São Luís Island plays a significant role as a carbon sink, even in a context of intense urbanization. The results reinforce the importance of management, conservation, and expansion strategies for wooded areas as essential components of public policies aimed at mitigating climate change in urban environments.

DISCUSSION

The data obtained confirm that trees with greater height and diameter store larger amounts of carbon, highlighting the central role of individuals with greater structural size in urban carbon stocks. This pattern is related to increased biomass accumulation rather than to ontogenetic maturity, since different species reach maturity at different heights. Such a relationship was expected, as increases in tree size generally reflect greater biomass volume, a pattern widely documented for urban forests (Nowak et al., 2013).

It is worth noting that the relationship between height and carbon is not linear, but tends to be exponential, something that is explained by the geometry of tree growth: as the tree gains height, the diameter of the trunk and crown expand more than proportionally. As a tree grows in height, the increase in the diameter of the trunk and crown occurs proportionally greater, resulting in accelerated volumetric growth. Since biomass is directly related to the volume of the trunk and branches, small variations in the height of large trees can represent significant increases in total biomass and, consequently, in stored carbon, regardless of the ontogenetic stage of the individual. This behavior is widely described in studies that use allometric equations to estimate forest biomass (Nowak et al., 2013; Pregitzer et al., 2022).

The temporal analysis of accumulated carbon over the monitoring period showed a more pronounced increase in the final months of the series. Although seasonal tree growth in tropical regions may partially contribute to this increase, it is unlikely that the observed increase over a short period of time is explained solely by biological growth (Pregitzer et al., 2022). Therefore, the growth in total carbon mainly reflects the expansion of the sample set, and not just the individual growth of the trees already monitored.

This aspect reinforces the importance of interpreting time series data obtained through citizen science with caution, considering not only ecological processes but also the dynamics of data collection. In this sense, the general pattern observed — higher concentration of carbon in large trees — remains valid regardless of sample expansion, as it is based on robust and biologically coherent structural relationships (Pregitzer et al., 2022).

In the literature, we find studies that confirm our findings and help to broaden the interpretation of the results in the urban context. Nowak, Crane, and Stevens (2002), for example, observed in cities in the United States that adult urban trees — although fewer in number — concentrate a large part of the total carbon stock, a pattern that resembles what we identified on the Greater Island of São Luís. Similarly, Pregitzer et al. (2022), when analyzing urban forests in New York, found that larger trees dominate the urban carbon stock, reinforcing the relevance of conserving mature individuals.

Studies conducted in Brazil show that well-developed urban trees maintained for a long time can achieve carbon stocks similar to those of secondary forests (Vieira et al., 2011; Pires et al., 2023). In parallel, research on urban expansion in the Global South warns that the disorderly occupation of the territory increases socio-ecological vulnerability and requires that nature-based solutions be integrated into city planning (De Azevedo Júlio, 2025). In this sense, the preservation and expansion of urban afforestation emerge not only as a climate mitigation measure, but also as a central strategy for building more resilient cities.

Based on the results obtained, it is clear that public policies aimed at climate mitigation in cities like São Luís need to go beyond planting new seedlings. It is urgent to prioritize the conservation of already mature trees, which accumulate more biomass and store a greater amount of carbon. The experience with GLOBE Observer also showed that citizen science tools can produce reliable data, provided that the dynamics of data collection and the composition of the sample are taken into account. Together, these findings help us to better understand the role of urban trees in tropical cities and reinforce the importance of ongoing monitoring as a basis for truly sustainable urban planning.

CONCLUSION

The results obtained reinforce the role of urban afforestation on the Greater Island of São Luís as a significant carbon sink, highlighting its contribution to mitigating climate change at the local level. The use of the Trees protocol of the GLOBE program, through the GLOBE Observer application, proved to be a viable tool for the standardized collection of biometric data and for the estimation of biomass and carbon, further highlighting the value of citizen science in environmental monitoring. The data demonstrated a consistent relationship between tree size and stored carbon, with a correlation between height and carbon stock—which confirms that larger trees accumulate considerably higher volumes. In light of these findings, urban management strategies should prioritize not only the planting of new trees, but, above all, the conservation of individuals with greater structural size and high biomass, which concentrate a disproportionate share of urban carbon of stocks combined with a planned expansion of afforestation. This approach proves to be of great value in enhancing ecosystem services and underpinning effective public policies for climate mitigation.

REFERENCES

ARAÚJO, Ronaldo Rodrigues; RANGEL, Mauricio Eduardo Salgado. Crescimento urbano e variações térmicas em São Luís-MA. **Revista Geonorte**, v. 3, n. 9, p. 308–318-308–318, 2012.

BONNEY, R.; COOPER, C. B.; DICKINSON, J.; KELLING, S.; PHILLIPS, T.; ROSENBERG, K. V.; SHIRK, J. Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience*, v. 59, n. 11, p. 977–984, 2009. DOI: https://doi.org/10.1525/bio.2009.59.11.9.

CHOUDHURY, Md Abdul Mueed et al. Urban tree species identification and carbon stock mapping for urban green planning and management. **Forests**, v. 11, n. 11, p. 1226, 2020.

DAVIES, H. J.; DOICK, K. J.; HUDSON, M. D.; SCHREIBER, J. The role of urban trees in regulating climate and reducing energy demand. *Urban Forestry & Urban Greening*, v. 78, p. 127770, 2023.

DE AZEVEDO JÚLIO, T. Dinâmicas da expansão urbana e implicações para a vulnerabilidade socioecológica no município de Maputo (Moçambique). *Revista Brasileira de Meio Ambiente & Sustentabilidade*, v. 5, n. 5, p. 51–74, 2025.

GLOBE PROGRAM. *GLOBE Observer: Trees Protocol*. Global Learning and Observations to Benefit the Environment, 2021. Disponível em: https://observer.globe.gov. Acesso em: 11 jan. 2026.

IPCC. *Climate Change 2023: Synthesis Report*. Geneva: Intergovernmental Panel on Climate Change, 2023.

LU, M.-K.; POPESCU, S. C.; CAMPBELL, B. A. Use of GLOBE Observer citizen science data to validate continental-scale canopy height maps derived from ICESat-2 and GEDI. *Frontiers in Environmental Science*, v. 13, 1635707, 2025. DOI: https://doi.org/10.3389/fenvs.2025.1635707.

NOWAK, D. J.; CRANE, D. E.; STEVENS, J. C. Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*, v. 116, n. 3, p. 381–389, 2002.

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., Lapoint, E. Carbon storage and sequestration by trees in urban and community areas of the United States. **Environmental pollution**, v. 178, p. 229-236, 2013.

PIRES, A. S.; VIEIRA, M.; SILVA, L. R.; FIDALGO, E. C. C. Quantifying the carbon stocks in urban trees: the Rio de Janeiro Botanical Garden as an important tropical carbon sink. *Journal of Zoological Botany and Gardening*, v. 5, n. 4, p. 1–17, 2023. DOI: https://doi.org/10.3390/jzbg5040039.

PREGITZER, C. C.; HANNA, C.; CHARLOP-POWERS, S. et al. Estimating carbon storage in urban forests. *Urban Ecosystems*, v. 25, p. 617–631, 2022. DOI: https://doi.org/10.1007/s11252-021-01173-9.

SANTAMOURIS, M. Recent progress on urban overheating and heat island research. *Energy and Buildings*, v. 207, p. 109482, 2020.

SANTOS, F. A. S. *Avaliação do estoque de carbono em áreas verdes na Ilha do Maranhão como base de políticas públicas para compensação da emissão de gases de efeito estufa*. 2024. 125 f. Dissertação (Mestrado em Desenvolvimento e Meio Ambiente) – Universidade Federal do Maranhão, São Luís, 2024.

SILVA, D. A.; WATZLAWICK, L. F.; DLUGOSZ, F. L.; SANTOS, J. C. Estoques de carbono e dióxido de carbono equivalente em árvores de rua de cidades brasileiras. *Revista da Sociedade Brasileira de Arborização Urbana*, v. 14, n. 2, p. 1–14, 2019. Disponível em: https://revistas.ufpr.br/revsbau/article/view/68565. Acesso em: 02 jan. 2026.

VIEIRA, M.; SCHUMACHER, M. V.; ARAÚJO, E. J. G. Carbon stock in an urban area afforested 50 years ago. *Revista Árvore*, v. 35, n. 6, p. 1211–1221, 2011. Disponível em: https://www.scielo.br/j/rarv/a/XvSqsS4svzWzdLrV6BrWrKy/. Acesso em: 04 jan. 2026.

YIN, L.; WANG, J.; CHEN, J.; LI, X.; ZHAO, X. Urban carbon accounting: an overview. *Urban Climate*, v. 44, p. 101195, 2022. DOI: https://doi.org/10.1016/j.uclim.2022.101195.

ZAR, Jerrold H. *Biostatistical analysis*. 5. ed. Upper Saddle River: Pearson Prentice Hall, 2010.

DESCRIÇÃO DOS DISTINTIVOS

This study is linked to the GLOBE program and aims to obtain badges related to participation in citizen science activities, systematic collection of environmental data, and application of standardized scientific protocols. These badges are intended to recognize the engagement of participants, as well as the quality and consistency of observations made throughout the project. Thus, in addition to the mandatory "I Am a GLOBE Researcher" badge, the following additional badges will be sought:

1. I am a Data Scientist: this is appropriate for this work, as the project carried out a consistent quantitative analysis from data collected with the GLOBE Observer and organized in its own database. Data processing and interpretation procedures were applied, and the study used statistical metrics to support inferences, such as the analysis of the relationship between height and stored carbon (with a strong correlation), demonstrating the use of data to answer the research question and discuss limitations and implications of the results;

2. I am an Earth System Scientist: This also applies to the project, since the research connects biosphere processes (growth and biomass of urban trees) to the atmosphere (removal and storage of CO_2) and to urban climate dynamics, such as mitigating heat islands and contributing to the reduction of greenhouse gases. The study shows that urban afforestation demonstrates an understanding of the dynamic and interdependent nature of Earth systems;

3. I Generate Impact: This is relevant because it establishes clear connections with global impacts, such as increased emissions and global warming. The initiative promotes environmental education and social engagement by involving students in data collection and analysis, raising community awareness and enhancing local sustainability actions.