



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



Researchers:

Amanda Lília Santos Leão¹, Rebeca Bezerra Praseres¹, Ana Luiza de Cássia Santos Raymundo¹, Luana Falcão Gonçalves¹, José Henrique Soares Lima¹, Isadora Manuela Vieira Juçá¹, Erick Henzo Botão Guimarães², Caio Vinícius Ferreira Pereira², Ana Clara Lafontaine Farias², Debora Marcelle², Mariane Rodrigues de Solsa², Wilson Roberto Caleb de Oliveira Balduin², Eduarda Resende Araújo²,

Teachers/ mentors:

Hilton Costa Louzeiro¹, João Paulo Tenório da Silva Santos¹, Núbia Fernanda Marinho Rodrigues¹, Ana Carolina Abraão Neri², Ulisses Denache Vieira Souza², Leidiane Caroline Lauthartte², Aline Bessa Veloso³, Aslei Andrade da Silva³, Geysa Adriana Corrêa Ribeiro¹

University College – COLUN / UFMA

Abstract

This study estimated carbon storage in urban trees on the Greater Island of São Luís (MA) using data from the GLOBE Observer application (Trees protocol). Height and diameter at breast height (DBH) were measured and used in allometric equations to calculate biomass and carbon per tree and for the total sample. Total carbon was approximately 28.8 tons (28,800 kg), with larger trees storing more carbon. A strong correlation between height and carbon ($r = 0.994$) highlights the importance of preserving mature trees. Continuous monitoring using GLOBE Observer provides valuable data to support urban planning and climate change mitigation.

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

Research Question

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?

Introduction

Urban centers are increasingly affected by climate change, with rising temperatures and more frequent extreme events intensifying thermal discomfort, public health risks, and environmental pressures, particularly in tropical cities such as São Luís (Araújo & Rangel, 2012; Santos, 2024; IPCC, 2023). Accelerated and poorly planned urbanization amplifies these impacts by reducing vegetation cover, altering the urban energy balance, and promoting urban heat island formation, especially under humid equatorial climates (Santamouris, 2020; Choudhury et al., 2020).

Urban trees play a central role in mitigating these effects by providing shading, enhancing evapotranspiration, improving air quality, and supporting rainwater infiltration. In addition, they sequester atmospheric carbon and store it in biomass, with carbon stocks strongly influenced by structural attributes such as height and diameter at breast height (DBH), as well as tree age and local environmental conditions (Nowak et al., 2002; Pregitzer et al., 2022). The removal of mature trees can therefore result in substantial and difficult-to-reverse losses in urban carbon stocks.

Given the scarcity of systematic studies on carbon storage in urban trees in Brazil, particularly in the North and Northeast regions, the generation of local data is essential to support urban and environmental planning in São Luís (Silva et al., 2019). In this context, the use of standardized protocols from the GLOBE Observer program enables the estimation of the carbon storage potential of urban trees on the Greater Island of São Luís and the evaluation of how structural attributes, such as height and DBH, influence carbon stocks, contributing to strategies for urban heat mitigation and green area conservation.

Research Methods

The study was conducted to estimate carbon storage in urban trees on the Greater Island of São Luís (MA, Brazil) between January 2025 and January 2026, using the GLOBE Trees protocol (Globe Program, 2021). This study area includes the municipalities of São Luís, São José de Ribamar, Pago do Lumiar, and Raposa, characterized by a humid tropical climate and intense urbanization (Araújo & Rangel, 2012) (Figure 1).

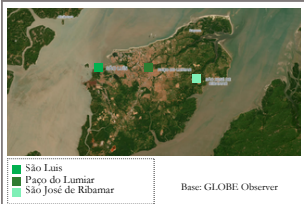


Figure 1 – Study area location: Greater Island of São Luís (MA). Source: GLOBE Observer.

High school students from the Technical Course in Environmental Studies, trained under the GLOBE Trees protocol, collected tree height, diameter at breast height (DBH), and location (Figure 2). Height was calculated using the GLOBE Observer app based on angle and distance, while DBH was measured from trunk circumference at 1.3 m above ground (Nowak et al., 2013; Silva et al., 2019).



Figure 2 – Measuring tree height and DBH (GLOBE Program). Source: Authors, 2026.

Aboveground biomass and carbon were estimated using the Trees Tool, with carbon calculated as 50% of biomass and converted to CO₂. The relationship with tree height was assessed using Pearson's r and R² (Pregitzer et al., 2022; Yin et al., 2022).

GLOBE BADGES

1. am a Data Scientist: The project performed quantitative analysis using GLOBE Observer data, applying statistical methods to interpret results and assess the relationship between tree height and stored carbon, addressing the research question and its implications.
2. am an Earth System Scientist: The study links urban tree growth and biomass (biosphere) to CO₂ storage and urban climate dynamics (atmosphere), highlighting the interdependence of Earth systems.
3. Make an Impact: The project promotes environmental education and community engagement by involving students in data collection and analysis, connecting local actions to global sustainability issues.

Results

Between January 2025 and January 2026, 428 urban trees (18 species) were analyzed on the Greater Island of São Luís, with an estimated total stock of 28.8 t of carbon, corresponding to 105.4 t of CO₂ equivalent, highlighting the role of urban trees as a carbon sink. A small number of species accounted for a large share of the total carbon stock: Mangifera indica, Licium tomentosum, and Ficus benjamina together contributed approximately 50% of the stored carbon (Table 1).

Species	Number of trees	Average carbon (kg/tree)	Total carbon (t)	CO ₂ equivalent (t)
Mango tree (<i>Mangifera indica</i>)	68	85.2	5,782	21,25
Oni (<i>Licania tomentosum</i>)	42	92.7	3,89	14,28
Ficus (<i>Ficus benjamina</i>)	35	78.4	2,74	10,06
Brazilwood (<i>Pithecellobium echinatum</i>)	28	105.3	2,95	10,83
Yellow leg (<i>Hibiscus thurberi</i>)	25	67.8	1,70	6,24

Table 1 – Species with the highest contribution to carbon storage in urban trees on the Greater Island of São Luís (MA). Source: Authors' elaboration based on GLOBE Observer data.

Carbon storage was strongly influenced by tree size. Smaller DBH classes contained more individuals, whereas larger trees stored more carbon per individual (Figure 3). A similar pattern was observed for tree height, with a progressive increase in mean carbon in higher classes (Table 2).

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

Table 2 – Statistics of stored carbon (kg/tree) by height class in urban trees. Source: Authors' elaboration based on GLOBE Observer data.

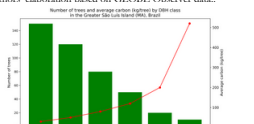


Figure 3 – Number of trees and Carbon (kg/tree) by DBH class on the Greater Island of São Luís (MA).

Source: Authors' elaboration based on GLOBE Observer data. Statistical analysis indicated a strong positive correlation between tree height and carbon stock ($r = 0.994$; $R^2 = 0.988$). Monthly variation showed continuous growth in accumulated carbon throughout the monitoring period (Figure 4).

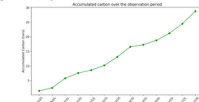


Figure 4 – Monthly evolution of accumulated carbon in urban trees. Source: Authors' elaboration based on GLOBE Observer data.

Discussion

The data confirm that taller and larger-diameter urban tree store disproportionately more carbon, reflecting the exponential relationship between tree size and biomass accumulation rather than ontogenetic maturity (Nowak et al., 2013; Pregitzer et al., 2022). Small increases in height of larger trees lead to substantial gains in biomass and carbon. Temporal increases in total carbon largely reflect sample expansion rather than individual growth, highlighting the need for cautious interpretation of citizen science time-series data. Similar patterns are reported globally and in Brazil, showing that mature urban trees, though fewer, dominate carbon stocks and can reach levels comparable to secondary forests (Nowak et al., 2002; Vieira et al., 2011). These findings reinforce the importance of prioritizing the conservation of mature trees in urban climate mitigation strategies. While planting new seedlings contributes to long-term forest expansion, preserving existing large trees ensures immediate carbon storage benefits and maintains ecological stability. In tropical cities like São Luís, where urban expansion is rapid, integrating nature-based solutions into urban planning is crucial to reduce socio-ecological vulnerability and enhance resilience (De Azevedo Júlio, 2025).

Furthermore, citizen science initiatives such as the GLOBE Observer provide reliable data for monitoring urban forests when sampling methods and dynamics are carefully considered. Participatory monitoring not only supports scientific research but also fosters environmental awareness and engagement among local communities. Overall, the results highlight the critical role of urban trees in tropical cities as carbon sinks and as central components of sustainable urban planning, reinforcing the need for continuous monitoring and strategic conservation actions.

Conclusions

The results highlight the role of urban trees in the Greater São Luís area as significant carbon sinks, contributing to local climate change mitigation. The GLOBE Trees protocol, through the GLOBE Observer app, proved effective for standardized data collection and for estimating biomass and carbon, emphasizing the value of citizen science in environmental monitoring. The data showed a consistent relationship between tree size and carbon storage, with larger trees storing substantially more carbon. Urban management strategies should prioritize the conservation of mature trees alongside the planting of new ones, supporting ecosystem services and informing effective climate mitigation policies.

Bibliography

- ARAÚJO, Rauldo Rodrigues; RANGEL, Ismael Eduardo; SPOSITO, J. Carlos; SILVA, Níbia Cavalcanti; S. A. P. 2012. **UFMA**.
 CHOUHURY, Md. Hossain; MAMUN, Md. Hossain; MAMUN, Md. Hossain et al. Urban tree species identification and carbon stock mapping for urban green planning and management. *Forests*, v. 11, n. 11, p. 2025, 2020.
 DE AZEVEDO JÚLIO, P. Estimativa de reservas aéreas e carbono total em comunidades vegetacionais em municípios do Maranhão. *Desenvolvimento*, v. 21, n. 67-68, p. 2020.
 GLOBE PROGRAM. GLOBE Observer. <https://www.globeobserver.org/>.
 GLOBE PROGRAM. GLOBE Observer. <https://www.globeobserver.org/>.
 NOWAK, D. J.; CHURCHILL, J. S.; STEVENS, J. C. Carbon storage and sequestration by trees in an urban and suburban setting in the United States. *Environmental Pollution*, v. 116, n. 3, p. 961-970, 2002.
 SANTAMOURIS, G. *Urban Heat Island Effect*. In: *Urban Heat Island Effect*. Springer, 2020.
 SANTAMOURIS, G. *Urban Heat Island Effect*. In: *Urban Heat Island Effect*. Springer, 2020.
 SANTAMOURIS, G. *Urban Heat Island Effect*. In: *Urban Heat Island Effect*. Springer, 2020.
 SANTAMOURIS, G. *Urban Heat Island Effect*. In: *Urban Heat Island Effect*. Springer, 2020.
 SILVA, N. B.; SILVA, R. B.; SILVA, R. B.; SILVA, R. B. et al. Carbon stock and sequestration in urban trees of São Luís. *Revista de Sociologia e Política*, v. 32, n. 1, p. 1-14, 2019.
 SILVA, N. B.; SILVA, R. B.; SILVA, R. B.; SILVA, R. B. et al. Carbon stock and sequestration in urban trees of São Luís. *Revista de Sociologia e Política*, v. 32, n. 1, p. 1-14, 2019.
 WANG, J.; WANG, J.; CHEN, J.; LI, Z., 2023. **UFMA**. Carbon sequestration in urban trees of São Luís. *Revista de Sociologia e Política*, v. 32, n. 1, p. 1-14, 2019.