Trees and their impact on Carbon Storage and Surface Temperature, a comparative study

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Abstract

Urban trees contribute to carbon storage and temperature regulation. This study compares carbon storage at two university campuses (UNCo, Argentina; UTT, USA), an urban planted forest, a park, and a native Araucaria forest, while analyzing the impact of canopy cover on surface temperature and differences between ground-based and satellite-derived tree height measurements. Tree height and circumference were measured using GLOBE Observer, while biomass and carbon storage were estimated through allometric equations. Surface temperature was recorded seasonally under different canopy cover conditions on sunny and cloudy days using an infrared thermometer. ICESat-2 and GEDI satellite data were compared with ground-based tree height measurements. Results show a negative correlation between canopy cover and surface temperature, especially in spring and summer, when trees reduce solar radiation. Araucaria forests store more carbon per tree, but the highest carbon stock per square meter is found in an urban eucalyptus-dominated park. While UTT trees were taller, UNCo had higher carbon stock per square meter, likely due to tree density differences. These findings underscore the importance of urban and peri-urban forests in temperature regulation and carbon sequestration.
Keywords: Urban trees, carbon storage, surface temperature, canopy cover, remote sensing

Research Questions

- How much carbon do urban trees store on the UN Comahue and UT Tyler campuses?
- How do carbon stock per square meter and tree biomass vary between the campuses?
- Are there differences in height and carbon storage between native forests, urban forests, parks, and campuses?
- How do trees and cloud cover influence surface temperature moderation?
- Are there differences between field and satellite tree height measurements?

Introduction & Review of Literature

Greenhouse gas emissions are a major global challenge (Baek et al., 2022). Urban areas contribute significantly to carbon emissions, making mitigation strategies essential. Urban trees play a key role in carbon sequestration, reducing greenhouse gases and improving environmental quality through CO_2 absorption, air purification, and microclimate regulation (Nowak et al., 2013).

Despite their benefits, urban trees' carbon storage potential remains underestimated due to limited data (Lee et al., 2019). This study estimates carbon storage in urban trees across different environments and assesses their impact on temperature. Data on tree height, temperature, and land cover are collected using GLOBE Program protocols and applications (GLOBE Program, 2024). Study sites include the University of Comahue (Argentina), the University of Texas at Tyler (USA), a planted forest in Plottier, and an araucaria forest in Lanín National Park.

Understanding urban trees' role in carbon sequestration and temperature moderation is crucial for sustainable urban planning. Additionally, non-urban forests contribute indirectly to climate regulation and biodiversity conservation, benefiting urban ecosystems (Wilson et al., 2022).

Research Methods

This study, part of the 100K Strong in The Americas initiative, analyzed tree carbon storage and surface temperature on university campuses in Argentina and the U.S.

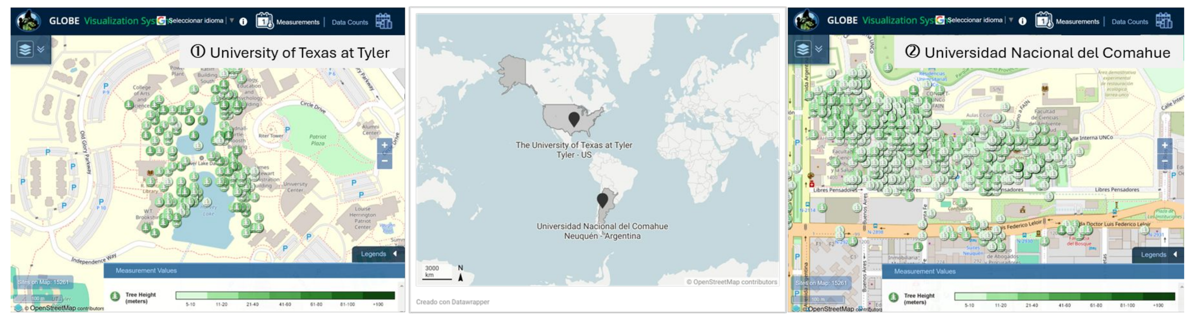

Figure 1: Location of the National University of Comahue (Argentina) and University of Texas at Tyler (United States). Main sampling sites.

Data collection followed GLOBE Program protocols (GLOBE Program, 2024):

- Biosphere protocols: Tree height and circumference (Biometry), Carbon Cycle, and Land Cover Classification.
- Atmosphere protocols: Surface Temperature and Clouds.

Tree height, land cover and cloud data were recorded using the GLOBE Observer App. To quantify the surface temperature throughout the seasons of the year and in different weather conditions (sunny and cloudy days), a digital infrared thermometer was used.
Tree height was measured manually and compared with ICESat-2 and GEDI LiDAR (Enterkine et al., 2022; Campbell, 2021). Land cover and cloud data were recorded using the GLOBE Observer Land Cover and GLOBE Observer Clouds applications. Surface temperature was measured with an infrared thermometer under different conditions (sunny/cloudy), complemented by satellite imagery (Landsat, Sentinel) and climate classification (Köppen-Geiger).

Carbon biomass was estimated using DBH:

$$DBH\ (cm) = Circumference\ (cm) \div \pi$$

Biomass was calculated with Jenkins et al.'s (2003) model:

$$Biomass = \exp(B_0 + B_1 \ln(DBH))$$

For Araucaria araucana, coefficients from Kutchartt et al. (2021) were used. Carbon storage was estimated as:

$$Biomass\ (g/m^2) \times 50\% = Carbon\ storage\ (gC/m^2)$$

Study Sites

Universidad Nacional del Comahue (Argentina): Urban campus in Neuquén (BWk climate). Sample: 792 exotic trees (pines, cypresses, elms, poplars, etc.).
Plottier Canals (Argentina): Implanted forest along Limay River and Park (BWk climate). Sample: 92 trees (poplars, acacia, eucalyptus).
Araucaria Forest (Argentina): Lanín National Park (Csb climate). Sample: 205 Araucaria araucana and native species.
University of Texas at Tyler (U.S.): Campus with a Cfa (humid subtropical) climate. Sample: 192 trees.

Results

Changes in Land Cover (2017-2023)
Argentina – Cities of Plottier and Neuquén
Sentinel images show urban expansion, with Plottier growing along the Limay River and Neuquén expanding north and northwest. From 2017 to 2023, urbanization increased by 6% and tree cover decreased by 0.2%.
United States – City of Tyler
In the United States, Sentinel data show that Tyler experienced a 4% increase in built-up areas and a 2% expansion of agricultural land between 2017 and 2023, while tree cover decreased by 0.9%.

Table 1. Comparative Table of Biomass and Carbon Storage

Location	Elevation (MASL)	Avg Tree Height (m)	Max Tree Height (m)	Avg Tree Circumference (cm)	Max Tree Circumference (cm)	Total Biomass (g/total area)	Total Carbon Storage (g C/total area)	Biomass (g/m²)	Carbon Storage (g C/m²)
Universidad Nacional del Comahue	315	11	37	91	381	427,327,256	213,663,628	4,936	2,468
Plottier Forest	281	18	37	105	418	9,961,449	4,980,724	388,054	194,027
Plottier Park	280	19	30	171	546	78,413,945	39,206,973	11,913	5,956
Araucaria Forest	979	13	30	195	657	626,854,613	313,427,306	3,404	1,702
University of Texas at Tyler	179	17	42	133	288	161,616,777	80,808,388	2,670	1,335

Surface Temperature and Tree Cover Impact
Surface temperature measurements across different seasons highlight significant variations. While overcast autumn and clear winter days showed minimal differences between air and land temperatures, spring and summer recorded much higher surface temperatures, with summer peaks reaching 69°C in areas lacking tree cover. This emphasizes the role of vegetation in temperature regulation.
Comparisons across four study sections revealed that tree coverage significantly reduced surface temperatures, particularly in summer, where shaded areas remained around 35°C compared to 69°C in exposed zones. Additionally, a sunny vs. cloudy day analysis showed that tree cover had a greater cooling effect on sunny days, reducing surface temperatures by over 30°C.
Building structures also contributed to moderating surface temperatures, particularly in urban sections.

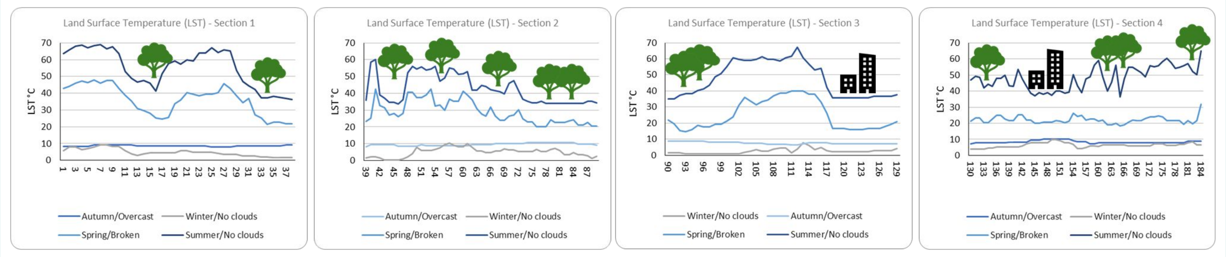

Figure 2: Impact of tree cover on surface temperature

Tree Height Comparison: In-Field vs. Satellite Measurements
Tree height measurements were compared using in-field data from GLOBE Observer and satellite sources like ICESAT-2, GEDI, and Landsat ARD. At Universidad Nacional del Comahue, ICESAT-2 recorded a tree height of 8.12 m, while in-field measurements averaged 7.3 ± 0.6 m. GEDI data for the UNCo sector estimated tree heights at 5.5 ± 1 m, significantly lower than the in-field average of 11.3 ± 5.5 m. In Plottier, in-field measurements averaged 17.8 ± 7.5 m, while GEDI recorded 8.5 ± 1 m, with a maximum of 12 m.

Discussion

This study highlights the variability of carbon storage across different environments. While the Plottier Park, with large eucalyptus trees, showed the highest carbon storage per square meter, the native Araucaria forest stored more carbon per individual tree, likely due to its older age. The UNCo campus exhibited smaller tree diameters, leading to lower carbon storage per tree compared to urban parks and native forests. These results emphasize the crucial role of urban and peri-urban trees in carbon capture and long-term ecosystem sustainability.
In terms of surface temperature regulation, a strong negative correlation was observed between canopy cover and temperature. Areas with dense vegetation experienced significantly lower surface temperatures, particularly during sunny days in spring and summer. Tree shade effectively reduced solar radiation exposure, mitigating the urban heat island effect.
Tree height measurements showed discrepancies between field and satellite data, mainly due to limited satellite coverage and the time gap between GEDI data collection (2019) and field measurements (2024). ICESAT-2 provided limited data, reinforcing the need for improved tree height estimation models. Despite these limitations, carbon storage estimates align with previous urban forestry studies, highlighting the reliability of ground-based measurements following GLOBE protocols.
When comparing carbon storage in the evaluated areas of both university campuses, it is observed that, although the trees at the University of Texas at Tyler are taller on average, the campus of the National University of Comahue presents a higher carbon storage per square meter. This difference could be due to a higher density of trees.

Conclusions

- Tree height and circumference show no significant differences across sites.
- Trees help reduce surface temperatures by providing shade and releasing water vapor, mitigating the urban heat island effect.
- In semiarid regions like Neuquén, trees are essential for cooling, emphasizing the need for urban green space conservation.
- Native and planted forests store more carbon and regulate climate better than urban plantations due to their higher density and tree size.
- Using GLOBE Observer, ICESat-2, and GEDI improves carbon storage estimates.
- Geographic and temporal limitations affect comparisons between field and satellite-based tree height measurements.

Bibliography

Baek, K. Y., Kim, H. G., Kil, S. H., & Yoon, E. J. (2022). Estimating CO_2 storage and absorption of trees in urban parks: Case study of Daejeon-si, Republic of Korea. Sensors and Materials, 34(12), 4615–4628.

GLOBE Program (2024d). The GLOBE Teacher's Guide. Atmosphere and biosphere protocols. https://www.globe.gov/do-globe/globe-protocols

Lee, L. S., & Jim, C. Y. (2019). Urban woodland on intensive green roof improved outdoor thermal comfort in subtropical summer. International Journal of Biometeorology, 63, 895-909.

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

Wilson, S. J., Juno, E., Pool, J. R., Ray, S., Phillips, M., Francisco, S., & McCallum, S. (2022). Better forests, better cities. Report. Washington, DC: World Resources Institute.

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