Analysis of CO_2 Capture by Cashew Trees in Dom Nivaldo Monte Park, Natal

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ABSTRACT

This study aimed to measure the amount of carbon absorbed by the biomass of cashew trees present in the afforestation of Parque da Cidade Dom Nivaldo Monte, in Natal-RN. The methodology involved data collection through the GLOBE Program, an international science and environmental education initiative that engages students, teachers, scientists, and citizens in environmental data collection and scientific research. The measurements conducted within the program contributed to understanding the role of plants in carbon storage and their relevance in reducing atmospheric pollutant emissions associated with the greenhouse effect. The amount of sequestered carbon was calculated based on the measurements of DBH (Diameter at Breast Height) and tree height, using an allometric equation. The results highlighted the significant contribution of the afforestation in Parque da Cidade Dom Nivaldo Monte to the improvement of environmental quality in Natal-RN.

Keywords: Carbon sequestration; GLOBE Program; Atlantic Forest and Caatinga vegetation; Environmental preservation.

1. Introduction

In Rio Grande do Norte, the first Conservation Unit (UC) was established on November 27, 1977, by State Decree No. 7,237. This unit corresponds to the Parque Estadual Dunas de Natal, widely known as "Parque das Dunas," which encompasses an area of 1,172 hectares. According to the Instituto de Desenvolvimento Sustentável e Meio Ambiente do Rio Grande do Norte (IDEMA, 2013), the park is part of the Brazilian Atlantic Forest Biosphere Reserve, which in 1994 was officially recognized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as the largest urban park on dunes in the country. Within the municipality of Natal, the Parque Municipal Dom Nivaldo Monte, better known as Parque da Cidade, created by Municipal Decree No. 87,078/2006, constitutes the first Conservation Unit classified under the management category of "Strict Protection Unit."

The Parque da Cidade Dom Nivaldo Monte plays a relevant role for the city of Natal for several reasons. A significant contribution to biodiversity conservation is observed, as the park shelters a wide variety of plant and animal species, including endemic species and species regionally threatened with extinction. In addition, environmental education activities are promoted, encouraging the population to protect the natural environment.

Moreover, ecological and interpretive trails are offered, providing visitors with direct contact with nature and strengthening environmental awareness. Its protection and use as a source of scientific research are considered fundamental to regional sustainable development, as they ensure environmental and cultural integrity.

Another remarkable characteristic lies in its strategic location, integrating two neighborhoods—Candelária and Cidade Nova—with distinct socioeconomic and environmental profiles. The park is also situated over one of the main aquifers of the city, thereby contributing to its preservation.

In this context, the Parque da Cidade Dom Nivaldo Monte is understood to present significant potential for research on carbon sequestration and the mitigation of the

greenhouse effect, given the diversity of its vegetation, which includes endemic species from both the Atlantic Forest and the Caatinga biomes.

Tree species such as the cashew tree (Anacardium occidentale), the purple jatobá (Hymenaea rubriflora), and the Brazilwood (Paubrasilia echinata), for example, play a fundamental role in capturing atmospheric CO_2, storing carbon in their biomass and contributing to the reduction of greenhouse gas emission impacts. The study of carbon allocation in these ecosystems may provide essential data for the development of environmental preservation strategies and climate change mitigation, thus turning the park into a natural laboratory for scientific analyses focused on sustainability.

Within this framework, carbon, considered one of the most abundant elements on the planet, plays an essential role in global climate regulation. It is primarily absorbed by trees and tropical forests, which act as important natural reservoirs, reducing the concentration of carbon dioxide in the atmosphere. Furthermore, carbon is present in several planetary compartments, such as soil, atmosphere, oceans, and the Earth's crust, integrating natural cycles that contribute to mitigating the effects of global warming and the greenhouse effect.

In this regard, Foote (1856 apud Jackson, 2018, p. 106) had already indicated, in her studies on the greenhouse effect, that an atmosphere rich in carbon dioxide would result in elevated temperatures on Earth. Therefore, if at any moment in its history the composition of the air had presented a higher concentration of this gas than that currently observed, an increase in temperature would inevitably have occurred, along with an increase in atmospheric weight due to the intrinsic properties of the gas itself.

To support this investigation, the article presents, in the Theoretical Framework, a review of the importance of Conservation Units for urban sustainability, in addition to discussing fundamental concepts related to carbon sequestration, tree biomass, and climate change. The research methodology is detailed in the Methods section, which describes the procedures adopted for data collection in the Parque da Cidade, including the stages of tree measurement and the calculations used to estimate biomass and stored carbon.

The results obtained are presented and analyzed in the Data Analysis/Results section, where the quantities of biomass and sequestered carbon are discussed, as well as comparisons with CO_2 emission indices. The implementation of QR codes for the identification of the analyzed trees is also addressed, allowing greater accessibility and transparency of the collected data. Finally, in the Conclusion, the main contributions of the research are highlighted, reinforcing the importance of environmental preservation and the use of educational technologies in the monitoring of urban ecosystems.

This study therefore reinforces the relevance of the Parque da Cidade Dom Nivaldo Monte as a space for research and environmental education, while also demonstrating how local initiatives can contribute to climate change mitigation and to the promotion of sustainable practices in society.

2. Theoretical Framework

he preservation of natural ecosystems in urban areas plays a fundamental role in reducing the environmental impacts generated by the disorderly growth of cities. In this context,

Conservation Units (CUs) emerge as essential strategies for biodiversity protection and climate balance. The Dom Nivaldo Monte Municipal Park, the first Full Protection Unit in Natal, Rio Grande do Norte, exemplifies the relevance of such areas by sheltering remnants of the Atlantic Forest, one of the most threatened biomes in Brazil.

In addition to its ecological importance, the park provides, as previously mentioned, a favorable environment for conducting scientific studies focused on carbon sequestration and the reduction of greenhouse gas emissions. Accordingly, this section presents a conceptual review of the role of Conservation Units in environmental sustainability, the processes of carbon capture and storage by vegetation, and the impacts of climate change on the daily lives of the population.

According to Rebouças, Grilo, and Araújo (2015), the Dom Nivaldo Monte Municipal Park is the first Full Protection Unit in Natal–RN and plays a fundamental role in biodiversity conservation. In the area where the park is located, there is an important remnant of the Atlantic Forest ecosystem. According to information from the SOS Atlantic Forest Foundation, only about 7% of the original forest cover remains in Brazil, and it is highly fragmented due to sugarcane cultivation, subsistence agriculture, and urban areas. The park was designed by architect Oscar Niemeyer and includes a main entrance structure known as the "East Entrance Gateway," which provides access for pedestrians and vehicles, as shown in Figure 1.

Figure 1 – *Pórtico Leste. Source: SEMURB (2008)*

Based on records from the 2020 Management Plan of the Municipal Natural Park, the park, in addition to containing an important natural area in the heart of Natal, presents significant biological diversity and serves as a space for contemplation, recreation, sports practice in contact with nature, scientific research, and environmental education. It plays an important role in protecting the underground water source. Its vegetation is recognized

as a remnant of the Atlantic Forest, associated with some species characteristic of the Cerrado and the Caatinga, which positively influence the city's microclimate.

According to studies by Medeiros and Ayrthon (2016), the park is a habitat for at least 269 species belonging to 71 families and distributed across 201 genera, including five species classified as threatened with extinction. In addition, information from the Flora do Brasil 2020 website indicates that 51 of these species were recently recorded as new occurrences for the state of Rio Grande do Norte, contributing to the knowledge of local biodiversity.

Full Protection Units are governed by restrictive rules regarding their use, including specific guidelines for public visitation and scientific research, which must comply with the regulations established in the Management Plan and by park administration (Brazil, 2000). However, the implementation of this system alone has not been sufficient to ensure the effective conservation of green areas, especially in urban regions. In this sense, the incorporation of educational activities, such as Environmental Education (EE), emerges as an essential complement to promote awareness and active participation of society in environmental preservation (Diegues, 2001).

In this regard, according to Pereira et al. (2020), Environmental Education is an instrument that contributes to the conservation of the park and has fulfilled its role at the Dom Nivaldo Monte Park. Moreover, investment in disseminating information about the park's activities is desirable in order to attract a larger audience to initiatives focused on Environmental Education.

It is also important to highlight that the increase in CO_2 levels represents one of the main factors responsible for climate change. In this context, human activities such as the burning of fossil fuels, industrial emissions, mining, and wildfires intensify this problem by releasing large quantities of greenhouse gases into the atmosphere, making it more difficult to mitigate environmental impacts.

Among these activities, wildfires—mostly caused by human actions—significantly reduce the planet's vegetation cover. This loss compromises plants' capacity to capture carbon and release oxygen, disrupting ecological balance and exacerbating global warming (Cardoso, 2021).

Therefore, understanding the mechanisms by which terrestrial ecosystems store and transfer carbon to the atmosphere is fundamental for the analysis of climate change. In this sense, biomass is frequently studied as a carbon reservoir, as it represents the total amount of living matter present in a given area.

Since all organisms contain water in their composition and this proportion varies among species, biomass is calculated based on dry mass, which corresponds to the weight of biological material after complete removal of water. In the case of plants, this process is carried out in laboratories through drying plant material in specialized ovens. The total biomass of a region is determined by summing the dry biomass of all individuals present, and it can be applied at different scales, such as vegetation areas, biomes, or even specific environments, such as classrooms (Roquette, 2018).

To enable comparisons between different locations, scientists use standardized measurements expressed in units such as grams per square meter (g/m^2) or kilograms per

square meter (kg/m²). Knowledge of ecosystem biomass is essential for several fields, including agriculture, forest exploitation, and biodiversity management.

Accordingly, in order to quantify biomass and estimate the amount of carbon sequestered by trees in the Dom Nivaldo Monte City Park, this study adopted a methodological approach based on field data collection and the application of allometric equations. The following section details the procedures adopted for sample selection, the techniques used to measure Diameter at Breast Height (DBH), and the methodology employed for biomass and stored carbon calculations.

3. Metodology

The research was conducted in a Conservation Unit (CU) located within the urban area of Natal. The area is known as the Parque Natural Municipal Dom Nivaldo Monte, more commonly referred to as Parque da Cidade, and is situated between the neighborhoods of Candelária, Cidade Nova, and Pitimbu. The corresponding geographic coordinates are 5.851133° S and 35.228015° W. Currently, the park covers an area of 148.68 hectares and is classified as a Full Protection Conservation Unit under municipal management, as shown in Figure 2.

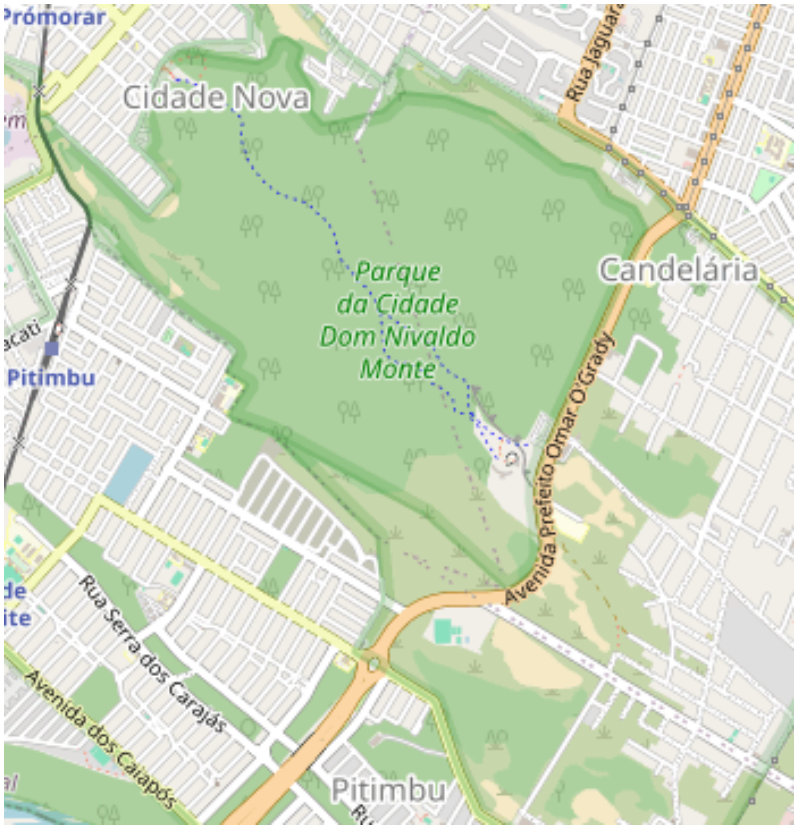

Figure 2. *Parque da Cidade Dom Nivaldo Monte*. Fonte: (GLOBE Observer)

For the implementation of the research and data collection at the Parque Natural Municipal Dom Nivaldo Monte (Parque da Cidade), the following procedures were required:

(a) submission of an official letter addressed to the Park Manager requesting authorization to conduct the research project;
(b) submission of the required forms—including research registration, researcher registration, supervisor registration, as well as the Research Project prepared in accordance with ABNT standards—to the Environmental Management Sector, followed by an in-person meeting with the management of the Conservation Unit to clarify questions and procedures.
After completion of all bureaucratic procedures, written authorization was obtained to conduct the scientific research within the Conservation Unit. For the collection of tree biometric data, the following materials were used: a flexible measuring tape, tree circumference data sheets, a pen or pencil, and personal protective equipment (boots, safety glasses, and protective clothing). Using the flexible measuring tape, measurements were taken from ground level at the base of the tree up to a height of 1.35 m above the ground, a standard measurement referred to as Diameter at Breast Height (DBH). In addition, the GLOBE Observer Trees protocol, installed on a smartphone, was used for the collection of tree-related data.

4. Data Analysis / Results

The study was conducted in a small area of the Parque Natural Municipal Dom Nivaldo Monte, located within the Environmental Protection subzone, designated as Environmental Protection Zone 1 (ZPA-1), along Avenida Omar O'Grady, situated in the urban area of the municipality of Natal, encompassing the South and West Administrative Regions (Figure 4). ZPA-1 includes portions of the neighborhoods of Candelária, Pitimbu, and Cidade Nova. The selection of this area was motivated by the higher concentration of cashew trees present at this site.

Figure 4. *Tree data collection area. Source: GLOBE Observer.*

The collection of tree biometric data (Figure 5) was carried out on twenty-two trees within the Parque da Cidade. The values obtained from the tree measurements were applied to an allometric equation (Equation 1) to estimate the amount of carbon dioxide sequestered by each cashew tree.

In this equation, *M* represents the aboveground tree biomass (dry weight; kg), *D* corresponds to the Diameter at Breast Height (DBH; cm), and the coefficients "0.1184" and "2.53" are parameters commonly used for aboveground biomass estimation in trees.

Equação Alométrica	$M = 0{,}1184\ DAP^{2{,}53}$

Figure 5 **.** *Tree data collection area. Source: author.*

Tabela 1. Diameters at breast height (DBH, in centimeters), tree height (H, in meters), biomass (M, in grams), carbon content (C, in grams), and carbon dioxide amount (CO_2, in grams), data collected at Parque da Cidade. (Source: authors).

ÁRVORES	CAP	DAP	H	M	C (g)	CO_2 (g)
1	54	17,19745223	6,15	158,1524431	79,07622154	316,3048862
2	41	13,05732484	4,35	78,78850325	39,39425163	157,5770065
3	44	14,01273885	4,84	94,20088095	47,10044048	188,4017619
4	46	14,79068411	5,16	107,9995645	53,99978227	215,9991291
5	100	31,84713376	6,74	751,8300719	375,915036	1503,660144
6	36	11,46496815	5,36	56,69764491	28,34882246	113,3952898
7	108	34,39490446	8,46	913,4437196	456,7218598	1826,887439
8	23	7,324840764	4,41	18,25118713	9,125593564	36,50237425
9	62	19,74522293	4,16	224,3213796	112,1606898	448,6427591
10	20	6,369426752	3,88	12,81520571	6,407602854	25,63041141
11	35	11,14649682	2,3	52,79731596	26,39865798	105,5946319
12	28	8,917197452	4,06	30,02130122	15,01065061	60,04260244
13	70	22,29299363	6,49	304,9423438	152,4711719	609,8846876
14	56	17,8343949	5,85	173,3945333	86,69726664	346,7890666
15	85	27,07006369	5,68	498,3673415	249,1836707	996,7346829
16	70	22,29299363	5,31	304,9423438	152,4711719	609,8846876
17	77	24,52229299	3,53	388,0978416	194,0489208	776,1956832
18	17,5	5,573248408	2,98	9,141257778	4,570628889	18,28251556
19	157	50,0000000	3,85	2353,671309	1176,835654	4707,342618
20	69	21,97452229	6	294,0410009	147,0205004	588,0820017
21	46	14,64968153	4,01	105,4136878	52,70684389	210,8273756
22	69	21,97452229	6,02	294,0410009	147,0205004	588,0820017
	Total =				**3612,685939**	**14450,74376**
	Árvores estudadas =		**22**			

According to data from the GLOBE Platform, for every 4 grams of CO_2 (carbon dioxide), there is, on average, 1 gram of C (carbon). One (1) liter of gasoline generates approximately 2,430 grams of CO_2. Based on the biomass data of the cashew trees

collected in Parque da Cidade, this amount of biomass is equivalent to approximately 6 liters of gasoline.

In addition to the calculation of biomass and carbon content, QR codes were generated containing data for each tree registered in the park. The QR codes were printed on adhesive material and affixed to identification plates. These plates were attached to the tree trunks using nails, nylon ties, and coated steel wires. The QR codes provide information related to tree height, spatial location, estimated age, amount of sequestered CO_2, scientific name, and the contribution of each tree to the maintenance of animal and plant biodiversity within Parque da Cidade. This information is highly relevant for individuals who use and visit the park.

Figura 6. *QR code with information on each collected tree. Source: own elaboration.*

5. Conclusion

At the conclusion of this research, it was determined that the use of the GLOBE Program Protocols and the GLOBE Observer application effectively contributes to the study of carbon sinks, demonstrating the importance of environmental preservation in mitigating the impacts of climate change and promoting environmental awareness within the community. Furthermore, evidence of the importance of species such as the cashew tree in capturing carbon dioxide (CO_2), and consequently in reducing greenhouse gas concentrations in the atmosphere, reinforces the transformative role of education in shaping citizens who are conscious of and committed to environmental preservation and sustainable development.

Finally, the partnership between the State Center for Professional Education Professor João Faustino Ferreira Neto and the Dom Nivaldo Monte City Park highlighted the relevance of such initiatives for the development of sustainable practices aimed at balancing the relationship between urban and natural environments.

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