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Accessibility and sustainable use of Urban Green Areas as a factor for environmental preservation

Francisca Dalila Menezes Vasconcelos
Planning Analyst, PhD, City Council of Fortaleza, Brazil
menezes.dalila@gmail.com

Francisco Suetonio Bastos Mota
Professor, PhD, Federal University of Ceará, Brazil
suetonio@ufc.br

Larissa de Miranda Menescal
Professor, Master, Unichristus, Brazil
larissa.menescal@gmail.com

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ABSTRACT

The accessibility of Urban Green Areas (UGA) is widely studied in terms of parameters and metrics. The present work aims to analyze the relationship of accessibility and use of Urban Green Areas with the environmental preservation of these areas. To this end, a bibliographic survey of the existing indexes and indicators of accessibility of existing UGA was first carried out, resulting in 14 scientific papers analyzed. Then, three UGA of the city of Fortaleza were selected to analyze the relationship between accessibility and environmental preservation. It was found that areas without accessibility and sustainable use showed a higher degree of environmental degradation when compared to areas that had some kind of use or accessibility by residents.

KEYWORDS: Urban Green Areas (UGA). Environmental Equity. Environmental Urban Planning. Conservation Units.

1 INTRODUCTION

The present work studies the relationship of accessibility and use of Urban Green Areas with environmental preservation, by analyzing specific areas of the city of Fortaleza, Brazil's most dense capital city.

In the World Health Organization (WHO) publication "Urban green spaces: a brief for action", urban green space is defined as all urban land covered by vegetation of any type. This covers vegetation in public and private areas, regardless of size and function, and can also include small water bodies such as ponds, lakes, or streams (WHO, 2017). Also in the same publication, physical accessibility considers, as a general rule, that urban residents should have access to public green spaces of at least 0.5 to 1 hectare within a linear distance of 300 meters (about a 5-minute walk) from their homes.

In the context of urbanization in large capital cities, smaller green spaces are strongly influenced by the extensive built-up area around them, behaving as zones that are more susceptible to hazards (Bardhan *et al*., 2016). In addition to the built-up area, the road system and parking lots are susceptible components to disordered planning actions, such as partial plans developed in isolation without overall planning (Garcia-Garcia *et al*., 2020). This scenario constitutes an additional risk of the urban green area system, such as road building projects that fragment large natural spaces in cities.

Local society's relationship with urban green areas can be an important factor in promoting susceptibility. In other words, when a green space is not valued by local residents, it becomes more vulnerable to urban occupation or other use.

Bonnes *et al*. (2011) studied people's experiences regarding urban green areas, and the results point to two factors: (1) the first factor reflects positive evaluations of urban green areas, based on valuing the integration of human nature in the city; (2) the second factor reflects negative evaluations of urban green areas, based on an antagonistic view of human-nature relationships in the city. The authors concluded that positive attitudes toward urban green areas were more related to ecocentric worldviews and biosphere values, while negative attitudes toward urban green areas were more related to anthropocentric and apathetic worldviews and conservative values. People are not likely to recommend nature in the city to reduce other people's stress if they are not convinced that they can obtain the same benefits themselves.

Communicating and informing the population about the benefits of green areas can promote the preservation of these spaces, so that residents can understand the multiple benefits of green zones in the urban context. According to Rocha and Nucci (2018), city councils need to commit to making clear and complete data about the status of vegetation cover in cities available to the population.

There are several examples of ecologically relevant areas in the urban environment that have not been built upon or occupied due to the mobilization of the population. Moreover, by empowering the population for the sake of the natural environment, it is possible to reduce the risk of degradation and vulnerability.

We point out the change of management as a relevant factor of vulnerability of green spaces. In Brazil, the city council management changes every four years, and there may be discontinuity of projects and changes of priority actions, leaving it up to the new administration to continue the handling of urban green spaces. The possible mismatch between the priorities of the new administration and the actions in progress may harm the management of the green areas policy of the city under study.

The quantitative data of green spaces play the role of background for more complex studies on vegetation cover in cities. However, the accessibility and use of these spaces behave as more robust parameters for evaluation, studies and monitoring.

The results of this study can be an important reference to guide public policies and urban and environmental interventions to promote better quality of urban life and environmental preservation.

2 OBJECTIVES

2.1 Main objective

The central objective of this work is to evaluate the relationship between the accessibility of Urban Green Areas (UGA) and the preservation of these areas, through a case study of the city of Fortaleza, Ceará, Brazil.

2.2 Specific objectives

- Conducting a bibliographic survey of the existing Accessibility Indexes of Urban Green Areas, in order to verify if any of the indexes analyzes the relation accessibility versus preservation;
- Evaluating the accessibility of UGAs in a case study in the city of Fortaleza, CE.

3 METHODOLOGY

3.1 Bibliographic survey

The method of selection of the papers consisted of an interactive search on the *Google Scholar* and *Science Direct* platforms. The publication period of the selected papers was from

2014 to 2020. The keywords and combinations related to the research theme were in English and Portuguese languages, namely: indexes of urban green areas, indexes of accessibility of urban green areas, distribution, accessibility and proximity of urban green areas, visual and physical accessibility of urban green areas.

The papers were selected considering the following criteria: (1) Working with research related to urban green spaces with the themes: accessibility, connectivity, equity and planning; (2) Presenting indexes or indicators related to the themes of item 1; (3) Original scientific studies; (4) The relevance factor of the studies and the highest number of citations were taken into consideration, also including the most recent publication requirement.

Finally, 14 papers were selected to be studied in this research, organized in 6 (six) classes: (1) Quantification, Distribution and Accessibility; (2) Distribution and Proximity, (3) Physical Accessibility of the User to Urban Green Areas, (4) Accessibility and Usability, (5) Accessibility and Equity, and (6) Visual Accessibility.

The investigation of the existing publications on the theme allowed us to certify that no indexes worked directly with the analysis of the accessibility and the preservation conditions of the area. It was found that the existing indexes worked directly with metrics and parameters to estimate the accessibility of the UGA.

3.2 Selection of the study area

For the selection of the study areas the following order was adopted:

a. Survey of the regulated environmental areas of the city;
b. Categorization of the areas into Urban Municipal Parks, Conservation Units or other category applicable to the city under study;
c. Selection of the category to be studied, using the functionality of the area as a selection criterion;
d. Definition of which areas of the same category would be studied.

The city of Fortaleza has a diversity of protected environmental areas under federal, state, and municipal protection, including urban park areas, dunes, coastal tableland, water resources and their margins, remnants of native vegetation, and marine ecosystems.

The protection comes from the legislation in force. In several cases, the areas are overlapped or juxtaposed by different legislations. The territory presents the following regulated areas: Municipal Urban Parks (MUP), Conservation Units (CU), Municipal Urban and Environmental Macrozoning; the latter has in its scope the Environmental Protection Zone – 1, which deals with areas that protect urban water resources.

For the present work, three (3) Conservation Units of the AREI (Area of Relevant Ecological Interest) category were selected for verification of accessibility and its influence on environmental use and preservation.

3.3 Analysis of the selected areas

The analysis of the selected areas followed the steps below:

a. Identification of the access hubs;
b. Identification of the types of use, target audience, frequency of access, and surrounding roads;
c. Field visit and photographic record;
d. Survey of the history of previous anthropic events.

4 RESULTS

4.1 Available indexes and indicators on UGA accessibility

In order to identify and monitor the accessibility and equity of UGA, robust and easily applicable indexes are needed for cities with different profiles. Chart 1 presents the main indexes on distribution, equity, and visual and physical accessibility to urban green areas identified in the literature review, highlighting the methodological parameters and objectives of each index.

Chart 1- Available indexes of distribution, equity and accessibility of Urban Green Areas

Category	Model	References	Methodologies Applied
Quantification, distribution and accessibility	Weighted UGA Index	Thiloi *et al.* (2015). India.	• Uses the percentage of PC; • Classifies the types of green areas; • Estimates the proximity of green areas; Based on the percentage, each cell classify UGAs into four classes: low, moderate, high, and very high green quality on a scale of 0.25-1.
Distribution and Proximity	UGA Proximity Index	Li *et al.* (2014). China.	• The index values were calculated based on the proximity and adjacency of buildings to green spaces; Two districts were selected as study area to examine the relationships between the index and different urban environments.
User's physical accessibility to Urban Green Areas	UGA Accessibility	Cetin (2015). Turkey.	• Identifies potential points of accessibility to the UGA, according to the environmental functions of each area; Manual digitization was done in ArcGIS software, using 1:1000 implementation plans.
	Model of the physical accessibility network at street level.	Sarkar *et al.* (2015). London.	• 15,354 residents were interviewed in London. The travel diary of each user was obtained by geocoding individual walking behavior; • NDVI resolution of 0.5m was employed as a measure of greenspace; • Tree density was calculated with the number of street trees per square kilometer within 1 buffer from the participant's location; The urban network analysis technique called "Spatial Design Network Analysis" was used for modeling.
	Natural Space Index	Rugel *et al.* (2017).	• Models potential exposure based on the presence, form, accessibility and quality of UGAs and water resources; Uses public and private property as rating parameters.
	Set of Indicators	Grunewald *et al.* (2019). Germany.	• Investigate the provision of UGA: determines all UGA with recreational function and relates them to the number of inhabitants; • Uses impervious area as a parameter;

			• Uses the density of the built area as a parameter: it measures the number of inhabitants in relation to the occupied area; It estimates the degree of man-made changes.
Accessibility and usability	UGA from the user's perception	Heikinheimo *et al*. (2020). Finland.	• Uses social media data; • Sports tracking; • Mobile phone carrier data; Public participation geographic information data.
Accessibility and equity	Accessibility Index	Khalil (2014). Egypt.	• Quantification of green areas per capita; • Accessibility is measured by the percentage of the total population of the districts living within 300m, 500m and 15 minutes walking distance (± 1000m); Scanning of the UGAs based on the online *Bing* map.
	Accessibility to green areas	Gupta *et al*. (2016). India.	• Applies different network distance for each UGA hierarchy for high density urban centers; • Uses high-resolution images, under 1m, with a 5-day repetition; Parks and playgrounds were classified into different categories based on their size in terms of area.
	UGA accessibility for low-income population	Rahman e Zhang (2018). Bangladesh.	• Uses *Google Earth* data to measure accessibility levels with scores of distance over time from community areas to UGAs. Applies the Urban Green Space Index.
Visual accessibility	Green View Index	Li *et al*. (2015). New York.	• Calculates the green areas that a pedestrian can see by applying 300 random points; Uses *Google Street View* images in six directions and three vertical viewing angles for each sample location generated.
	Green View Index on the Soil	Yu *et al*. (2016). China.	• Creates observation points and platforms for each building floor; • Analyzes from the view of visible urban green space; The Index is applied via software.
	Index of the greenspace seen from the building	Wang *et al*. (2019). China.	• The Index is calculated for each floor of the building; Estimates the amount of vegetation seen from each floor of the building using satellite images and photographic record of the study area.
	Green View Index	Toikka *et al*. (2020). Helsinki.	• 360° panoramic *Google Street View* images of Summer months from 2009 to 2017 were used; • A total of 94,454 images were used; The spectral characteristics of green vegetation were analyzed using the modified Vegetation Index.

Note: UGAs = Urban Green Areas; PC = Plant Cover.
Source: Authors, 2021.

4.2 Case study: UGA of Fortaleza city, Ceará.

4.2.1 Selection of study areas

The Conservation Units (CU) are areas of unique environmental characteristics, protected by the National System of Conservation Units (NSCU), established by Federal Law 9,985/2000. The system is composed of federal, state and municipal Conservation Units, classified into twelve categories, which can be either Full Protection or Sustainable Use Areas.

According to Chart 2, in the city of Fortaleza 12 (twelve) Conservation Units are recognized. Of these, 3 (three) are Full Protection and 9 (nine) are Sustainable Use, which include two categories: 5 (five) Area of Relevant Ecological Interest (AREI) and 4 (four) Environmental Protection Area (EPA).

Chart 2 - Characterization of the Conservation Units, Fortaleza, Ceará (2021)

Use	Conservation Unit / Registry	Total area / in Fortaleza (ha)	Administrative Sphere / Coverage / Registration	Legal Act of Establishment
Areas of Sustainable Use	EPA Pacoti River	2914.93 / 249.09	State / Aquiraz, Eusébio and Fortaleza / SRCU and NRCU	Decree 25,778 of February 15, 2000.
	EPA estuary of Ceará River – Maranguapinho River	3892.44 / 594.57	State / Fortaleza, Maracanaú and Maranguape / SRCU and NRCU	Decree 25,413 of March 29, 1999. Extension - Decree 32,761 of July 16, 2018.
	EPA Dunas da Sabiaguaba	1009.74	Municipal /Fortaleza / UR	Decree 11,987 of February 20, 2006.
	AREI Sítio Curió	57.35	State / Fortaleza / SRCU and NRCU	Decree 28,333 of July 28, 2006.
	AREI Cambeba	11.01	State / Fortaleza / SRCU and NRCU	Decree 32,843 of October 30, 2018.
	AREI Matinha do Pici	42.62	Municipal / Fortaleza / UR	Law 10,463/2016.
	AREI Dunas do Cocó	15.72	Municipal / Fortaleza / UR	Law 9,502 de of October 7, 2009.
	AREI Prof. Abreu Matos	18.83	Municipal / Fortaleza / UR	Law 10,463/2016.
	EPA Maraponga Lagoon	31.39	Municipal / Fortaleza / SRCU	Municipal Decree 14,389 of April 24, 2019.
Full Protection Areas	Marine State Park Pedra da Risca do Meio	3716.02	State / Fortaleza / SRCU and NRCU	Law 12,717 of September 5, 1997.
	Cocó State Park	1571.29 / 1453.08	State / Fortaleza, Maracanaú, Itaitinga and Pacatuba / SRCU and NRCU	Decree 32,248 of June 7, 2017.
	Natural Municipal Park Dunas da Sabiaguaba	467.6	Municipal / Fortaleza / SRCU and NRCU	Decree 11,986 of February 20, 2006.

Note: NRCU = National Registry of Conservation Units; SRCU = State Registry of Conservation Units; UR = Unregistered.
Source: Authors, based on data from NRCU and SRCU, 2021.

Figure 1 shows the map of territorial distribution of the Conservation Units of Fortaleza. Table 2 and Figure 2 present the profile of the Conservation Units.

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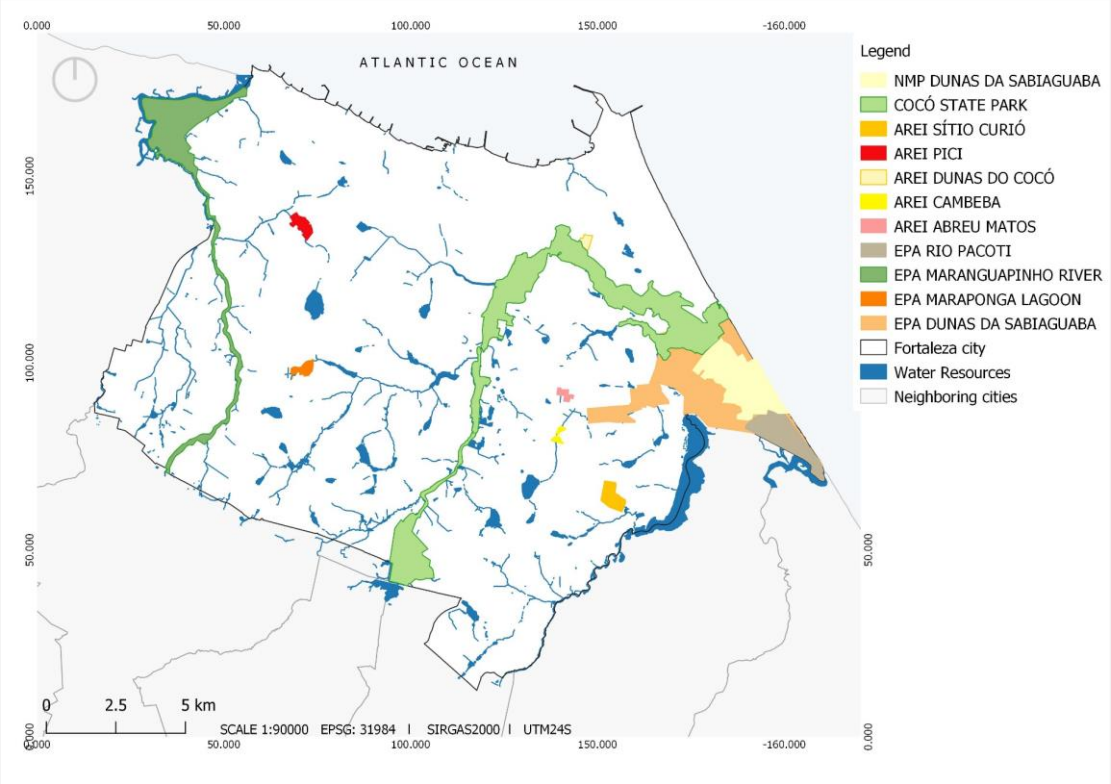
Figure 1 - Map of the Conservation Units existing in the city of Fortaleza, Ceará



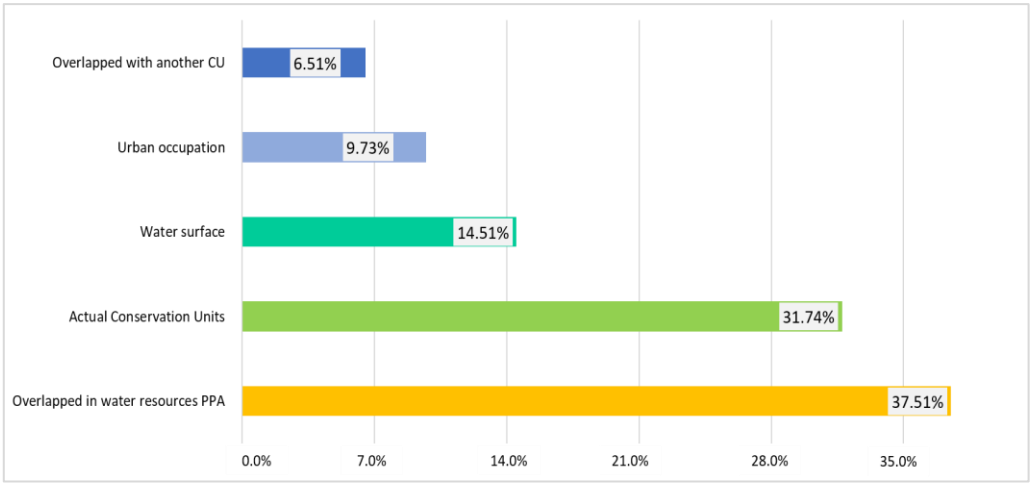
Source: Authors, based on data from NRCU and SRCU, 2021.

Table 1 - Profile of the Conservation Units of Fortaleza, Ceará (2021)

Profile of the Conservation Units	Area (hectare)
Total area of the CUs	10,032.92
Area of the portion inserted in Fortaleza	3,951.00
Area overlapping with another CU	257.42
Occupied area	384.59
Area overlapping in water resources PPA	1,482.35
Full Protection Area	1,920.68
Sustainable Use Area	2,030.32
Area under municipal management	1,585.9
Area under state management	2,365.1

Source: Authors, 2021.

Figure 2 - Profile chart of the Conservation Units, Fortaleza, Ceará (2020)



Source: Authors, 2021.

The AREI is a typology applied to smaller areas, with unique and relevant environmental characteristics, created by a specific law that determines its regular use. The EPA, in most cases, is a more extensive area of sustainable use, also created by its own legislation.

For the present work three AREI were selected (AREI Cambeba, AREI Abreu Matos and AREI Sítio Curió) as they present characteristics of Urban Green Areas, namely: 1) predominance of vegetation cover; 2) ecosystem services and maintenance of the local microclimate; 3) biodiversity and vegetation with functions of shelter for fauna and important environmental heritage of the city; 4) record of important remaining vegetation.

4.2.2 Evaluation of environmental areas regarding accessibility, use and preservation conditions

The AREI Sítio Curió is a forest fragment with ecosystemic, social, and local microclimate maintenance functions. There are two main entrance hubs with access to the ecological trail. Despite the urban occupation in the entrance, it is possible to observe the proximity to the Precabura Lagoon, which reinforces a context more connected to areas of protection of urban water resources (Figure 3).

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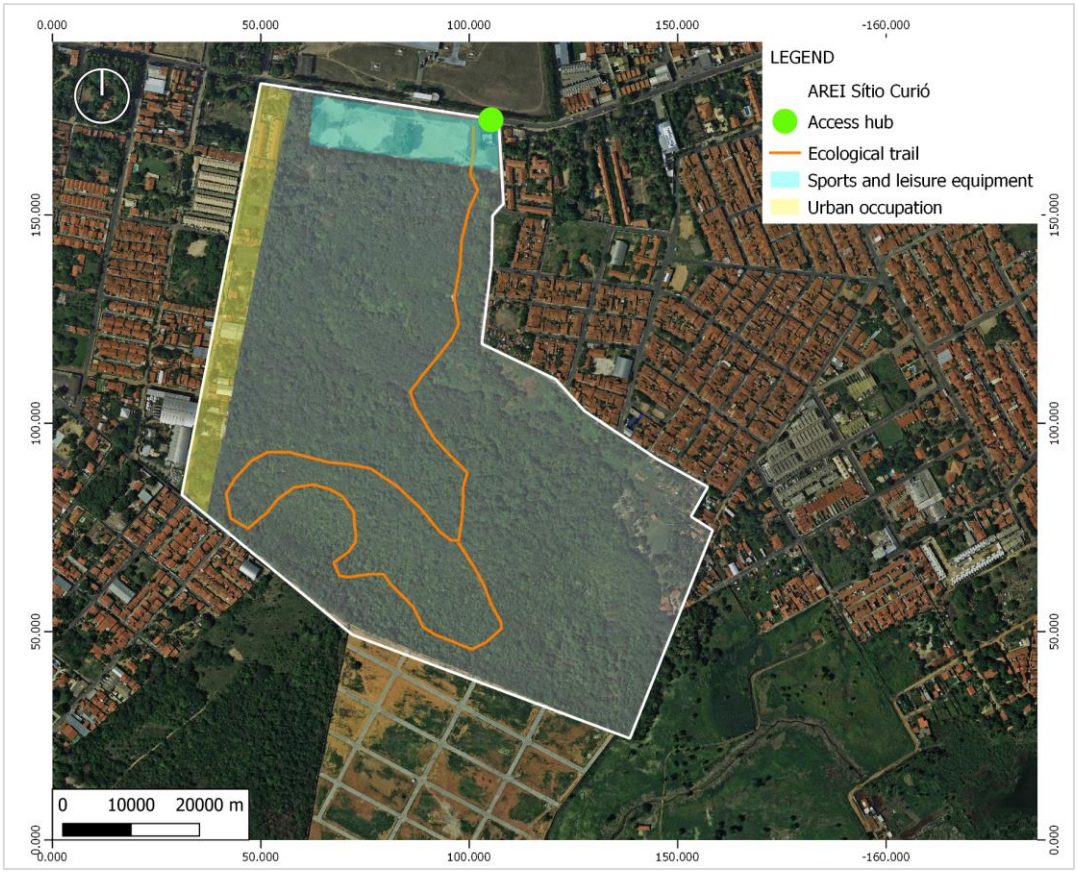
Figure 3 – AREI Sitio Curió, Fortaleza, Ceará (2021)



Source: Authors, 2021.

In 2020, the City Council of Fortaleza inserted in the surroundings of the AREI a sports and leisure equipment, the "Areninha do Sítio Curió", equipped with a soccer field that adds value and intensifies the use of the environmental area, thereby contributing to the relationship between the local community and the AREI. The ecological trail is an environmental education and sustainable use action that also positively reinforces the relationship between society and nature.

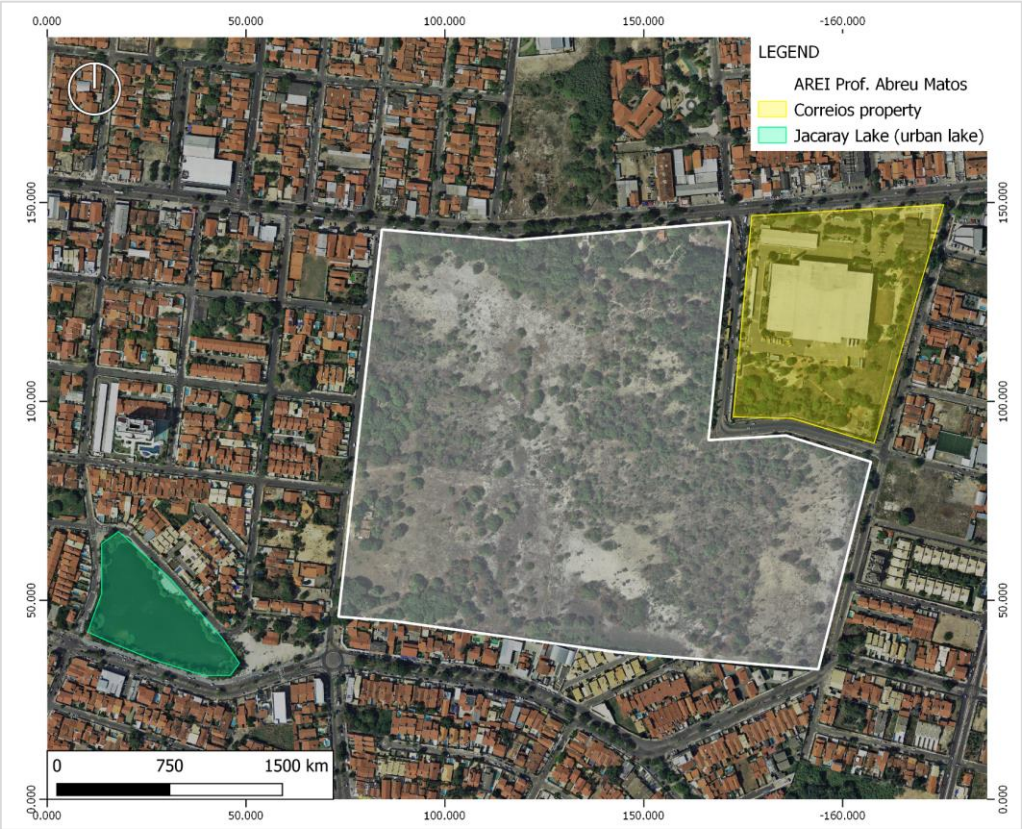
In the polygon of the AREI of Sítio Curió it is possible to observe the incidence of urban occupation on the frontage of José Bonfim Junior Street. Despite the identified occupation, the Conservation Unit presents good conditions for environmental preservation. However, it is necessary to inspect and monitor the unit's direct area of influence, in order to mitigate possible environmental impacts.

The second Conservation Unit analyzed was the AREI Prof. Abreu Matos, which does not present entrance hubs or accessibility to the public. The Conservation Unit is located in a densely urbanized area. The main frontage faces a collector road with heavy traffic at all times, especially during peak hours (Figure 4).

The integrity of the vegetation is compromised. It is possible that the pollution pulses coming from the direct and indirect area of influence contribute to these conditions. The Conservation Unit shelters a remnant fraction of *cerrado* vegetation. The area does not present connectivity with other natural components, such as water resources; this isolation possibly

compromises the integrity of the area. The lack of sustainable ecological use may be a threat to the integrity of the area in its current context.

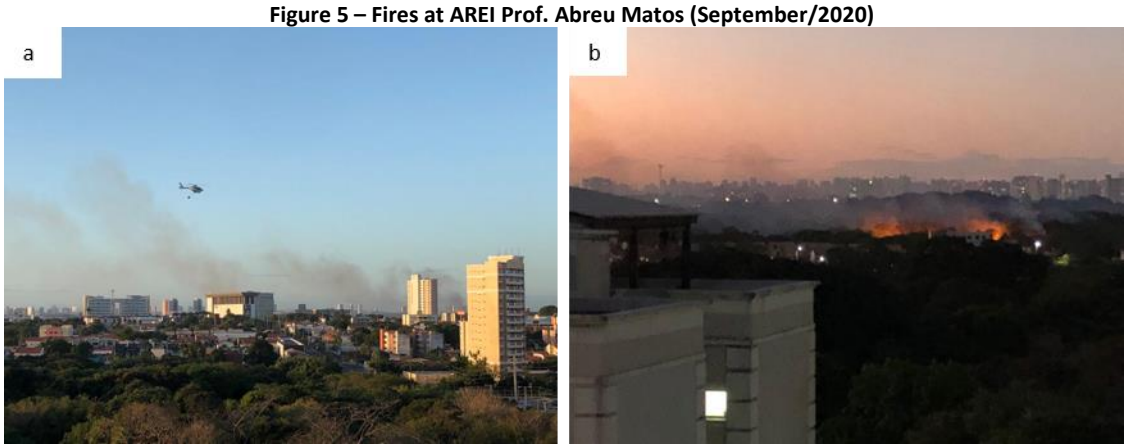
Figure 4 – AREI Prof. Abreu Matos, Fortaleza, Ceará (2021)



Source: Authors, 2021.

In September 2020, the AREI Prof. Abreu Matos suffered several episodes of fires that strongly threatened the integrity of the vegetation (Figure 5). The containment of the flames relied on the mobilization of environmentalists and citizens, along with the fire department; despite the efforts, the flames persisted for more than 24 hours. The causes of the fires were not disclosed.

Figure 5 – Fires at AREI Prof. Abreu Matos (September/2020)



Source: Authors, 2020.

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The AREI Cambeba, the third environmental area to be analyzed, is inserted in a location undergoing an intense occupation process and presents a peculiar situation: an administrative center of the state public management, i.e. buildings of the state public agencies, was built in its surroundings, turning it into an institutional area.

The area where the AREI is inserted presents three main access hubs, mainly for vehicles (Figure 6). Besides the administrative buildings, visitors carry out physical, sports and leisure activities in the vicinity of the environmental area.

Figure 6 – AREI Cambeba, Fortaleza, Ceará (2021)

Source: Authors, 2021.

During the field visits, the ambiance and harmonic coexistence of users with nature was verified. The amenities of the local microclimate were also verified during visits to the site. The specific use possibly offers more control over the occupation of the AREI. Monitoring is necessary to ensure that this coexistence is not detrimental to the integrity of the Conservation Unit.

5 CONCLUSION

In view of the results achieved, it is possible to point out the following evidences:

- The accessibility and use of Urban Green Areas are relevant factors for preserving these areas, avoiding inappropriate occupation and promoting a sense of belonging to the natural heritage by the resident population.

- The sustainable and controlled use of Urban Green Areas acts as an important factor in the relationship between society and nature.
- Further and more in-depth studies are needed addressing the concepts of environmental equity in the urban context, sustainable use without compromising the ecosystem function of the areas, and more detailed analysis in other urban contexts than the study area presented here.
- The identification of environmental areas with strategic positions for investments in the city can generate an attractiveness to guide the directions of urban development, promoting the concept of compact city, instead of sprawling city.
- The investment in interventions to stimulate the use of environmental areas can be considered as a strategy for environmental protection, besides promoting a better quality of life.
- Urbanistic instruments to encourage densification with the inclusion of social housing in the "safe" surroundings of the "environmental capital", equipped with (basic and leisure) infrastructure, can be a positive strategy of inclusion, reduction of inequality and expansion of opportunities.

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