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ARTIGO

MANGROVE PRESERVATION AND URBAN AIR POLLUTION IN ARACAJU, NORTHEAST BRAZIL

PRESERVAÇÃO DE MANGUEZAIS E POLUIÇÃO DO AR URBANO EM ARACAJU, NORDESTE DO BRASIL

ABSTRACT

According to WHO, in 2010 the air pollution was the main cause of over 200 thousand obits related to lung cancer. This paper aims to analyze the role of mangrove and their preservation on air pollution mitigation at Aracaju, northeast Brazil. The city was founded by the Sergipe River, few kilometers from the Atlantic Ocean, which configures it as an ideal site for mangrove development. Mobile measurements of CO were taken place in an urbanized area close to a mangrove area, providing an idea of the pollutant spatial dynamics. The benefits of the mangrove preservation were calculated using the ITree canopy v.7.1. The results reveal that the Mangrove preservation is responsible for over 4 tons of pollutants removal per year, a fact that can be related to the low levels of pollutions registered on the area during the measurements, helping to endorse the urban trees and mangrove areas preservation.

Palavras-chave: Urban trees, Urban Climate, Sergipe, Ecosystem services, Mobile air pollution measurements

RESUMO

Segundo a OMS, em 2010 a poluição do ar foi a principal causa de mais de 200 mil óbitos relacionados ao câncer de pulmão. Este trabalho tem como objetivo analisar o papel do manguezal e sua preservação na mitigação da poluição do ar em Aracaju, nordeste do Brasil. A cidade foi fundada junto ao rio Sergipe, a poucos quilômetros do Oceano Atlântico, o que a configura como um local ideal para o desenvolvimento de manguezais. Medições móveis de CO foram realizadas em uma área urbanizada próxima a uma área preservada de mangue, fornecendo uma ideia da dinâmica espacial do poluente. Os benefícios da preservação do manguezal foram calculados usando a plataforma ITree canopy v.7.1. Os resultados revelam que a preservação de manguezaisna área de estudo é responsável por mais de 4 toneladas de remoção de poluentes por ano, fato que pode estar relacionado aos baixos níveis de poluição registrados na área durante as medições, endossando a arborização urbana e a preservação de áreas de manguezais.

Keywords: Arborização urbana, Clima Urbano, Sergipe, Serviços Ecossistêmicos, Medições móveis de poluição do ar.

RESUMEN

Según la OMS, en 2010 la contaminación del aire fue la principal causa de más de 200 mil muertes relacionadas con el cáncer de pulmón. Este trabajo tiene como objetivo analizar el papel del manglar y su preservación en la mitigación de la contaminación del aire en Aracaju, noreste de Brasil. La ciudad fue fundada junto al río Sergipe, a pocos kilómetros del Océano Atlántico, lo que la configura como un lugar ideal para el desarrollo de manglares. Se realizaron mediciones móviles de CO en un área urbanizada próxima a un área preservada de manglar, proporcionando una idea de la dinámica espacial del contaminante. Los beneficios de la preservación del manglar fueron calculados usando la plataforma ITree canopy v.7.1. Los resultados revelan que la preservación de manglares en el área de estudio es responsable de más de 4 toneladas de remoción de contaminantes por año, hecho que puede estar relacionado con los bajos niveles de

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contaminación registrados en el área durante las mediciones, respaldando la arborización urbana y la preservación de áreas de manglares.

Palabras Clave: Arborización urbana, Clima Urbano, Sergipe, Servicios Ecosistémicos, Mediciones móviles de contaminación del aire.

INTRODUÇÃO

In September 2020, the Brazilian Ministry of the Environment revoked the resolution 303 from 2002, which had a fundamental role in the mangrove and “Restinga” preservations on the Brazilian coast. The resolution was reestablished by the Supreme Court by the end of the year but was sufficient to raise the discussion on the importance of the mangrove and “Restinga” preservations in Brazil.

Mangrove and “Restinga” are ecosystems that develop on specific conditions regarding water salinity, beeing found only by the coast. Due to their unique characteristics, the mangrove forests are interdital communities of trees, which grow only under specific salinization levels on estuaries (Pelage et al.,2019; Wilkie et al., 2003). The Brazilian coast has the second greatest mangrove area on the planet, consisting of estuaries from the Oiapoque river by the French Guyana border, until the southern coast of Santa Catarina state in the south of the country (Wilkie et al., 2003; Kjerfve,lacerda., 1993; Scheffer-Novelli, Cintron-Molero, 1993).

Mangrove is also known as the birthplace of many marine species such as crustaceans and other vertebrates. Also, the ecosystem has a unique function as a biological filter and as protection zones against coastal erosion, also playing a fundamental role in cultural activities such as traditional fishing, cultural landscape, and gastronomy (Brito, Bezerra, 2020; Pelage et al.,2019).

During the last three decades, however, the mangrove has been constantly reduced due to reasons such as harbor expansions, urban growth, and tourism activities. Brazilian coastal cities such as São Luis, Recife, Maceió, Aracaju (Northeast Brazil), Rio de Janeiro, Santos (Southeast Brazil), and Paranagua (Southern Brazil) among others, have experienced a massive reduction on its original mangrove areas directly related to their urban growth (Schaeffer-Novelli, 1989; Almeida, Ribeiro, 2009, 2009) .

Even in a well urbanized environment, the preservation of mangrove areas is necessary for several reasons such as a Urban Heat Island mitigation (Polocste et al.,2014; Grover, Singh, 2015); urban floods reductions (Munji et al.,2014) and air pollution reduction (Alemu et al., 2021).

The stomata of the leaves allowing the exchange of water vapor and CO2 through the processes of photosynthesis and evapotranspiration, absorb pollutants such as nitrogen dioxide, carbon monoxide, sulfur dioxide, and tropospheric ozone. In addition, the leaves are passive surfaces that clean particulate matter (PM10 and PM2.5) from the air (Baldocchi et al., 1987). Those characteristics justify the importance of its preservation; nevertheless, the current scenarios reveal a different reality.

Aracaju, the focus of this research, is the capital and biggest city of Sergipe state in northeast Brazil. The city was founded in the 19th century, by the Sergipe river, within a river harbor by its current city center. The discovery of petrol in the 1970s and the construction of oil refineries attracted a mass population, converging in an intense urban growth during this time. The population growth and the lack of planning made the urban area sprawl with no control, occupying the whole area of the river-mouth, including original mangrove forests (Almeida, Ribeiro, 2009; Loureiro, 1983; Nogueira, 2004).

Nowadays, most of the original mangroves have been suppressed, and the reminiscents are located in urban neighborhoods under constant pressure from the estate market (Almeida, Ribeiro, 2009).

Besides the mangrove suppression, the urban growth has also been increasing Aracaju's air pollution levels (Anjos, 2017). To endorse the importance of the mangrove preservations and discuss possibilities of air pollution mitigation, this research analyzed the benefits of this vegetation on air quality at Aracaju's urban core. Mobile measurements of Carbon monoxide were carried out at the city's most urbanized site, closed to a well-preserved mangrove area. CO is a primary pollutant generated by the incomplete combustion of carbon-containing compounds such as fossil fuels. The amount of CO emitted from these reactions is relative to the amount of CO2 generated. Therefore, the combustion of fossil fuels and wildfires are the most significant source of CO in outdoor air, which makes this pollutant a relevant parameter for air quality standards in urban environments (Zhou et al., 2017; Requia et al., 2015). Furthermore, recent studies have revealed a close relationship between CO concentrations and weather changes, pointing out the importance of studies concerning CO dynamics in different spatial scales (Castelhano et al., 2022). This also justifies the present study's relevance.

After the measurements, a spatial model was performed on ITree Canopy platform to estimate the benefits of the mangrove, as an urban forest, on the air pollution.

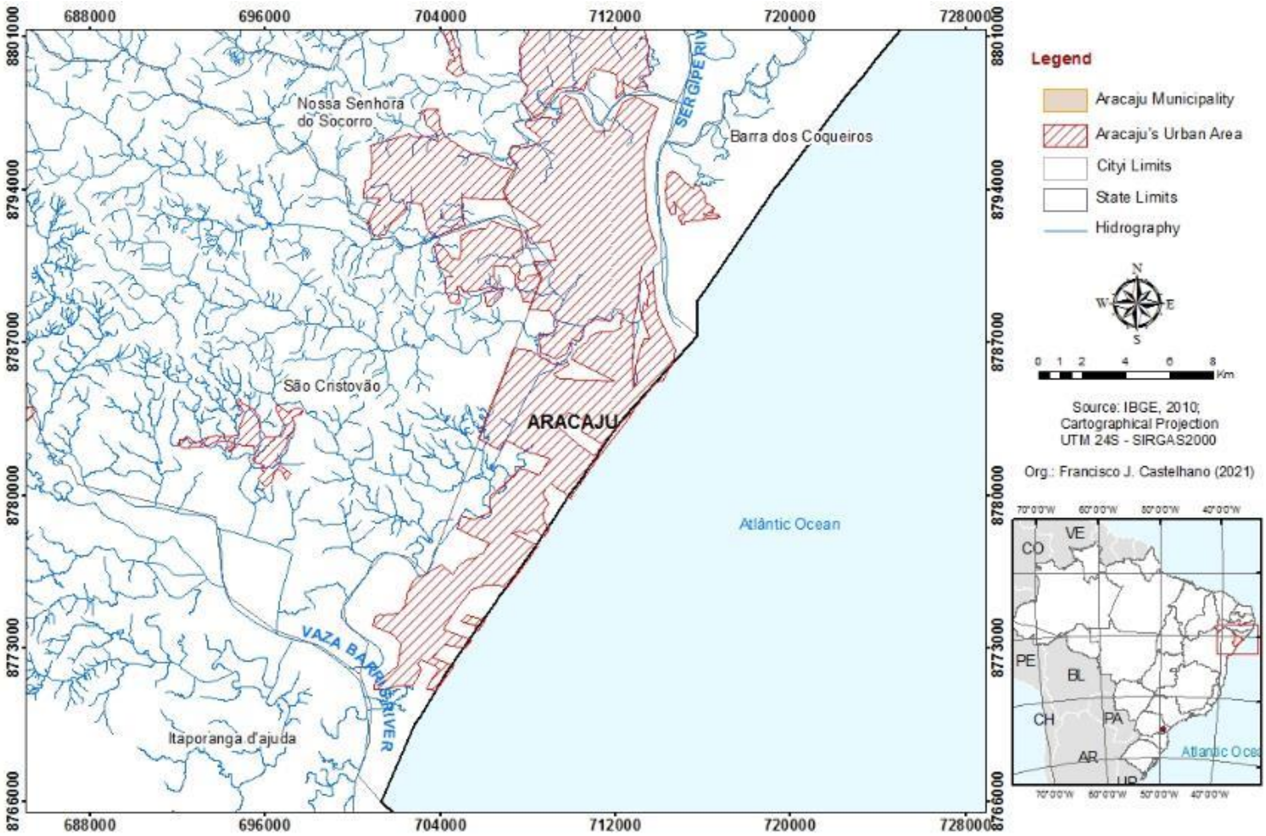
MATERIALS AND METHODS

Study Area

Aracaju is located in the northeast region of Brazil at 10º 55' 56'' south and 37º 04' 23'' west. The municipality is limited by the Sergipe by the north and the Vaza-Barris River by the south (Figure 1). Their estimated population is 664.098 inhabitants (IBGE, 2020) and their demographic density is an average of 3140 inhabitants/km².

The proximity to both rivers and the ocean is reflected on their geomorphology. Aracaju's topography has a low diversity, with the highest elevations reaching 100m above sea level. The landscape of Aracaju is characterized by a dense hydrographical network, leading to small water bodies and mangrove forests. Those natural characteristics also influence the local climate through the relative humidity levels, wind dynamics, and temperatures (Anjos, 2017).

Figure 1: Study Area Location



Source: (The authors).

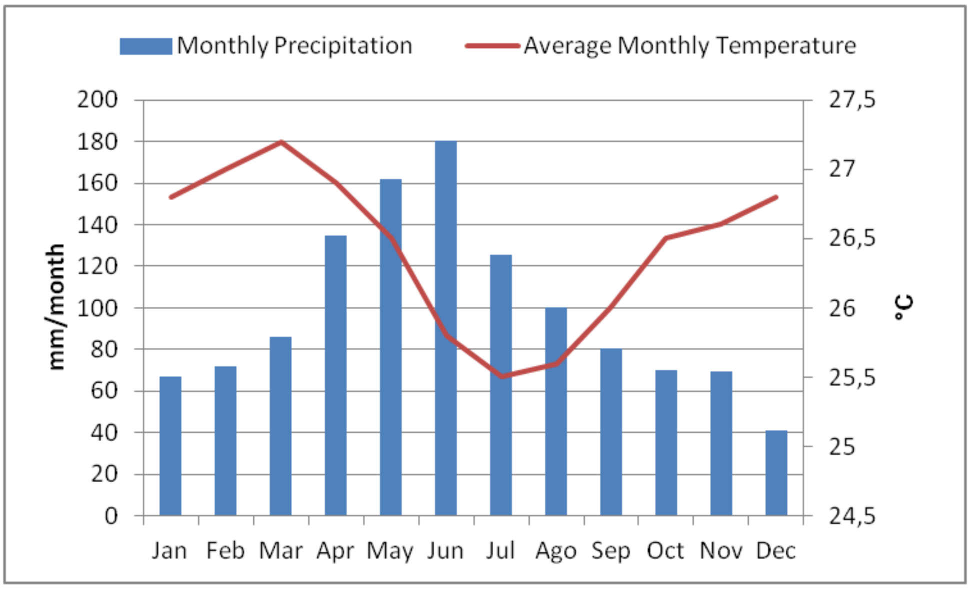
Aracaju's air quality is monitored by only one air quality measurements station, located in the industrial district of the city. This station is the only one in the state of Sergipe (IEMA, 2014).The monitoring started in 2008, collecting data on SO2, Smoke, and Particulate Matter (TSP). This station operates under manual conditions, which allows data collection only at daily scale. Such characteristics significantly limit the spatio-temporal analyzes.

The absence of a larger air quality monitoring network in Aracaju precludes further studies (Macedo, 2016). For instance, Aracaju's vehicle fleet, one of the main sources of atmospheric emissions, increased from 146,486 vehicles to 284,681, in the period from 2005 to 2016, should considerably impacts the air quality in the city, especially the NOx and fine particles pollution levels in the city.

Aracaju's climatic zone is classified as a tropical coast in the eastern northeast with one to three dry months. The climate is ruled by Atlantic atmospheric systems (tropical, equatorial, and polar), with intense influence from the Intertropical Convergence Zone (Danni-Oliveira, Mendonça, 2007; Pinto, 2002).

The main characteristics of the city climate are the rainfall distribution, with a dry season (September to March) and a rainy season (April to August), and high temperatures throughout the year (Fig. 2).

Figure 2: Aracaju's Average Climate Conditions– 1991-2020



Source: (INMET, 2021).

The annual average temperature in the municipality is 26.4 ° C. The city has its lowest temperature in July with 25.5 ° C while the hottest records are in March with an average of 27.2 ° C. This reveals a low atmospheric temperature amplitude throughout the year, of 1.7 ° C.

The annual average precipitation is 1189.1 mm. The least rainy month is December, with an average accumulated rainfall of 41.1 mm, while June is the the one with highest average values reaching 180.4 mm. The rainy period (April to August) concentrates about 60% of the annual precipitation in this period.

Air Pollution Measurements

In order to analyze the CO levels in Aracaju, mobile measurements were adopted. Mobile measurements are widely used by the Brazilian scientific climatology community, especially for the measurement of thermal data (Amorim, 2010; Alves, Specian, 2010, Maciel, 2011).

The mobile measurement follows specific precepts. For thermal field analysis, measurements are usually made with equipment linked to motorized vehicles, keeping a constant speed of 20 to 30km / h and at times predetermined by the World Meteorological Organization -00h, 06h, 12h, and 18h GMT (Valin Jr., 2019).

For the collection of pollution data, however, the literature has indicated a preference for the use of bicycles, for their ease of movement in congestion, absence of emissions, and reduced speed, which increase the accuracy of the data and enable the identification of pollutant hotspots (Elen et al., 2013, Castelhano,Pinto, 2022).

Such techniques were used in Curitiba (Cipoli et al., 2017; Castelhano, Pinto, 2020), southern Brazil, Aracaju's center (Castelhano e Pinto, 2022) and in the Danish cities of Aalborg and Haderslev (Schneiders, Skov, 2019). The data collection proposed in the present study is carried out with the aid of a bicycle, with the sensor at a height of 1.20m from the ground (Figure 3).

Figure 3 shows the sensor attached to the ARDUINO processor and the Neo6M GPS module used. Both sensor and GPS were coupled to a plastic container with a top opening so that the sensors are not exposed to direct frontal ventilation during the measurements. Sensor and GPS were powered by five-volt batteries and programmed to record data on a two-second time step. The CO sensor was calibrated and validated within historical data series from the official air quality monitoring stations located in Curitiba, South Brazil (Castelhano e Pinto, 2022).

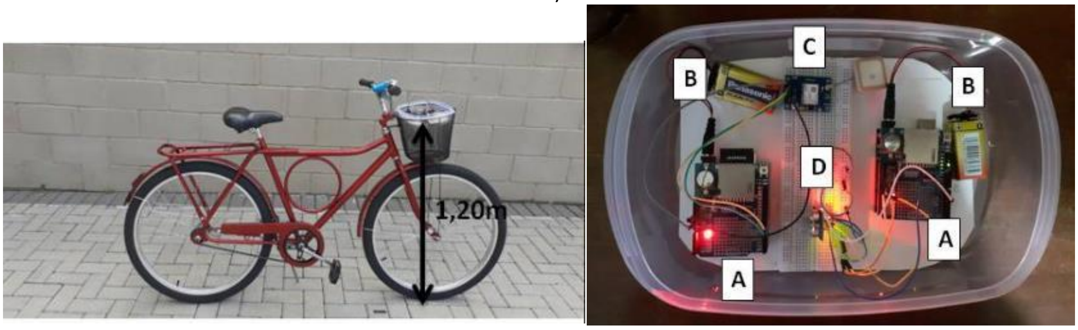
The MQ-135 sensor was chosen for the CO measurements and, programmed in an ARDUINO environment. This device is classified as a stable electrochemical sensor, which measures here carbon monoxide, among other gases, using the conductivity difference method (Kalra et al.,2016).

Electrochemical sensors are generally operated in an amperometric mode, in which the electrochemical reactions between the target gas, in this case, carbon monoxide, and an electrolyte produce an electric current depending on the gas concentration. Those devices generally consist of three electrodes, using SnO_2 as sensitive material (Rai, et al., 2017).

The target gas undergoes electrolysis (oxidation or reduction) at one electrode and generates an electric current balanced by the reaction at the counter electrode. The electric current measured concerning the reference corresponds to the gas concentration (Kalra et al.,2016).

Electrochemical sensors are usually recommended for indoor use due to their sensitivity to changes in temperature and air humidity. However, tests in electrochemical sensors were performed in outdoor environments, revealing a significant correlation with official measurement stations, demonstrating the possibility of outdoor usage (Rai, et al., 2017; Kalra et al.,2016), however, argue that electrochemical sensors should not be exposed to sudden changes in temperature and humidity without being recalibrated, suggesting the use in specific and short moments while the meteorological conditions remain constant.

Figure 3: Measurements Equipments on a bicycle : A: Arduino UNO processor; B: 5v Battery; C: GPS Neo6M; D: MQ-135 Sensor (The authors).



Source: (The authors).

Collecting Area

To analyze the influence of mangrove areas on CO levels, the boundaries of the data collecting were the Jardins neighborhood, a site where both intense urban characteristics and mangrove areas coexist, close to the city center (Figure 4). The starting point was the Godofredo Diniz Bridge, above Sergipe river, from where the Beira Mar avenue (Fig4a) was taken, next to the mangrove area by the River. This avenue connects the central region of the city with the southern portion of the municipality and which has the largest circulation of vehicles and is intensely occupied by high buildings. The route then follows to the Anisio Azevedo Avenue, by the end of the mangrove area, leaving the Sergipe River influence. From then on, the mobile measurements line follows the Acrisio Cruz Avenue (Fig 4c), finding a smaller mangrove area, from where takes its way back to the Sergipe River, thought the Jornalista Santos Santana Avenue (Fig 4b), passing by the Sementeira Municipal Park.

According to models generated by Anjos, Lopes & Alves (2018), the roads of the city of Aracaju, oriented in the east-west direction, tend to present lower concentrations of primary pollutants due to the effects of the sea breeze, especially in the afternoon and in the afternoon. This is the case of the Anisio Azevedo and Jornalista Santos Santana avenues.

To avoid sudden changes in climatic conditions, the measurements were performed only for a period between 40 and 50 minutes. The final measurement route extension was 4.7 kilometers, covered at an average speed of 7.5 km / h.

The measurements were carried out during three different days in February 2020: 12, 15, and 18, Wednesday, Saturday, and Tuesday respectively in order to measure on a weekend day to compare data from days with regular vehicle circulation. All the data measurements were performed at periods without the occurrence of precipitation, considering that such presence decreases the concentration of most primary pollutants, which would disfigure the hypothesis of the work and could affect the functioning of the equipment.

The measurements started at 3 pm, due to the low circulation of vehicles. This period is between the morning and afternoon peaks when the influence of urban morphology on air quality levels could be easily perceived (Castelhano, 2017). The collected data were statistically treated using the R software. The values above the 95th percentile threshold were considered as outliers and removed in the final analysis.

Figure 4: Mobile Measurements Route. A- Beira Mar Avenue; B-Jornalista Santos Santana Avenue; C- Acrisio Cruz Avenue

Source: (The authors).

Urban Trees and Air Pollution Modelling

In 2006, the American Forest Service developed the I-Tree, a platform with several tools (online, software, applications, reports) that allow the management and organization of urban green areas and, more that, to calculate the monetary value (annual and future income) linked to the types of benefits of the trees. The function/benefit generated by a tree depends on the existing green structure in an area, which, in turn, adds up to a compensatory value (Nowak et al., 2006).

This value depends on the natural characteristics of the tree, such as its size and type of leaf. The larger the area covered by trees, the greater the benefits that an environment can have. In this way, good management practices and decision-making related to urban planning, such as investments, places for planting, and selection of trees regarding climatic and environmental objectives can thus benefit from the use of the I-Tree.

Mangrove effects on Aracaju's air quality were quantified using I-Tree Canopy v.7.0 (Canopy). This tool integrates the ecological model I-Tree, assesses the benefits associated for removing pollutants from trees in a given area from the estimated tree cover, providing a monetary value resulting benefits (Nowak et al., 2006). The tool uses satellite imagery from Google Maps, placing random points to designate different classes of land use. In this particular experiment in Aracaju, we made a sample of 3,000 points in a buffer of 2 km surrounding the largest urban mangrove area of Aracaju (Figure 4a).The use of 3,000 points is is relatively large and consistent with the study area, as the greater the number of points, the smaller the margin of error in the estimate (Anjos et al., 2018; Richardson; Moskal, 2014).

Thus, the combined use of mobile measurements can, diagnose the CO distribution across the study area and evaluate the influence of the mangrove preservation on the pollutant levels.

RESULTS

CO MEASUREMENTS

Table 1 presents the average CO per day of measurement, as well as the average meteorological conditions of each day. It is noticed that the meteorological factors had few oscillations in all three days. No precipitation was registered during the measurement days. Wind Directions (ENE) and Relative Humidity were also considered similar in measurement days. The same happened to the temperature with less than 0, 2°C of average difference.

Table 1: Meteorological Data and CO Synthesis

Date	Weekday	Avg. Daily CO (PPM)	Max. Daily CO (PPM)	Avg. Daily Temp. (°C)	Max. Daily Temp. (°C)	Min. Daily Temp. (°C)	Avg. Daily Rel. Hum. (%)	Prec. (mm/24h)	Avg. Daily Wind Speed (m/s)	Wind Dir.
12/02/20	Wednesday	13,7	67,0	24,0	32,0	24,0	59,2	0	2,6	ENE
15/02/20	Saturday	0,13	0,52	24,3	31,9	24,3	60,7	0	2,4	ENE
18/02/20	Tuesday	2,1	17,7	24,2	31,8	24,2	60,5	0	3,1	ENE

Source: INMET and the authors (2021).

Concerning Wind speed, it was noticed and increase on the last day of measurements reaching up to 3.1 m/s as daily average.

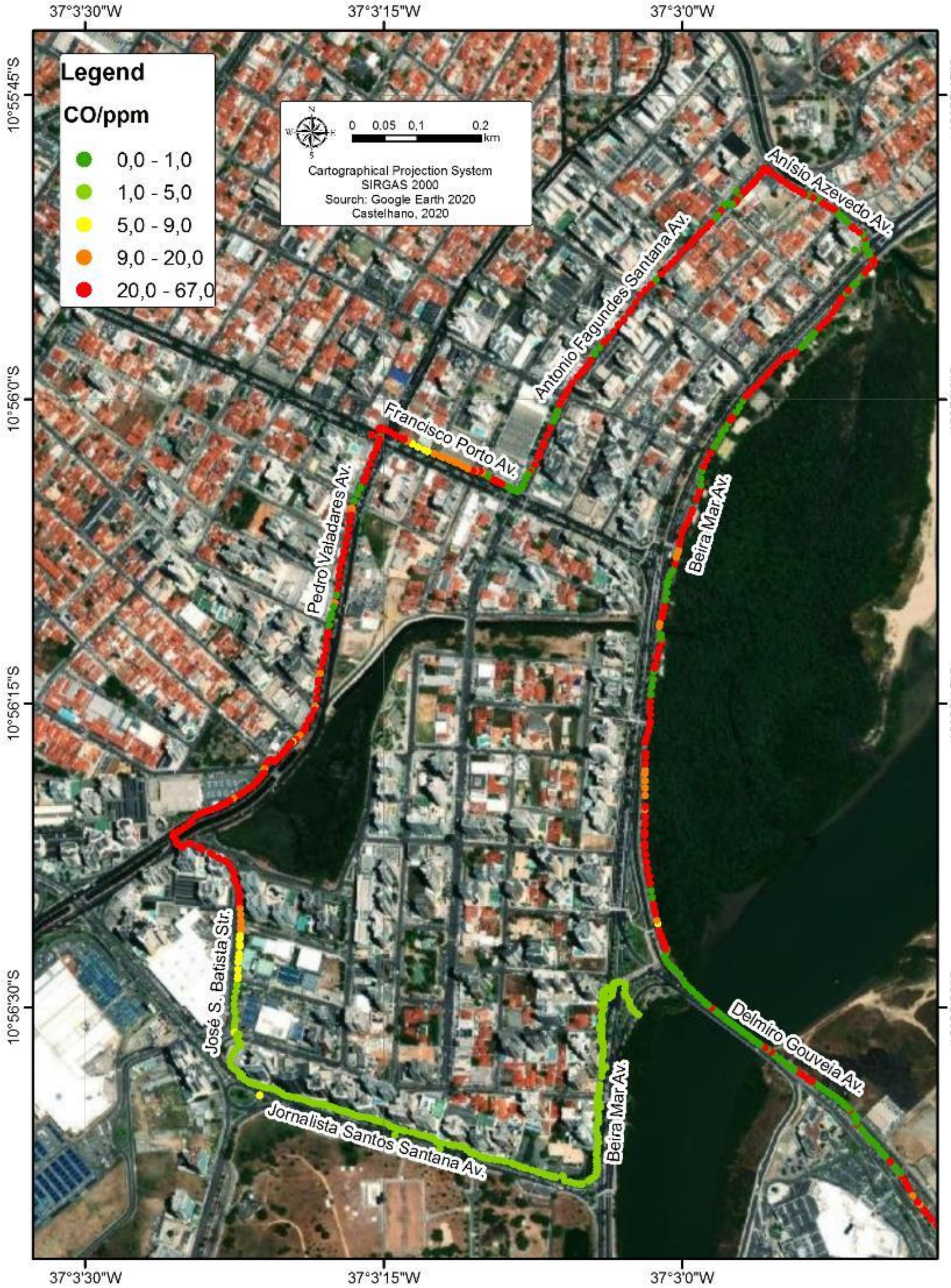
The CO measurements, however revealed intense differences comparing the measured days, and reveal a close interaction between the air pollution levels, and the urban functions of the study area.

By the first measurement day (12/02/2020 – Wednesday), the average CO on the study area was 13,7 PPM, with a peak of 67,0 PPM. The highest values during this day were collected mainly at Pedro Valadares Avenue, and Beira Mar Avenue. Figure 5 reveals the spatial pattern of the collecting, revealing an oscillation from 9 to 20 PPM at Beira Mar Avenue, and the lowest values registered at Jornalista Santos Santana Street and Francisco Porto Avenue. The Beira Mar Avenue is considered the main connection between the southern part of Aracaju, the most densely occupied, and the city center, also is where the biggest mangrove area of Aracaju is located.

The second day of measurements (15/02/2020 – Saturday) was the one when the lowest values of CO were registered. During Saturdays and Sundays, the commerce and services areas of the city center are usually closed, which makes the traffic levels get reduced. The traffic reduction was considered the main reason for the low CO levels registered. The average CO during this day was 0,13PPM, with a peak of 0,52PPM. Figure 6 reveals the spatial pattern observed on the second day of measurements. It is possible to notice, again, the highest values of the day on Beira Mar Avenue and Pedro Valadares Avenue.

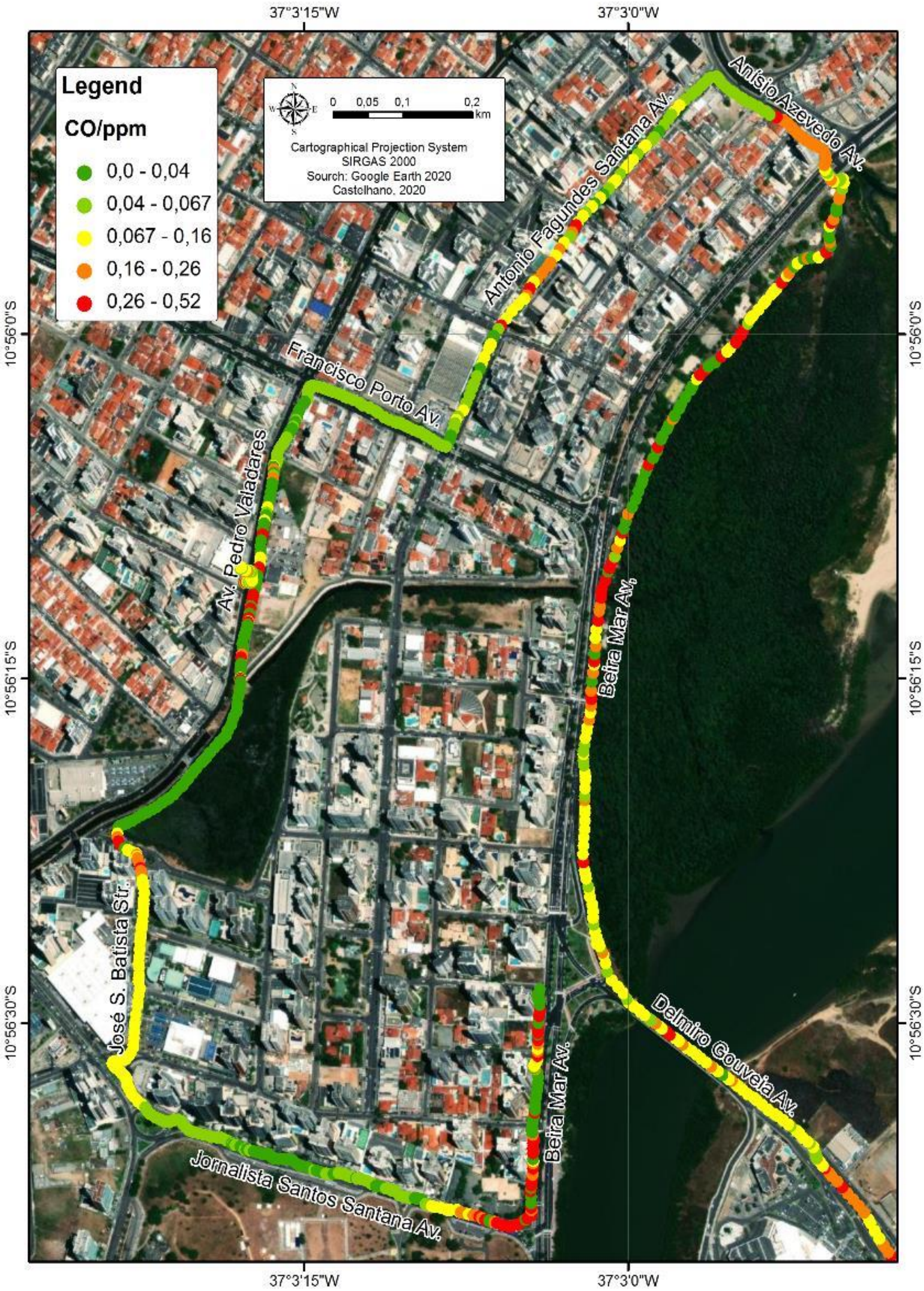
During the last day of measurements (18/02/2020 – Tuesday), high values of CO were again registered, with a peak of 17,7 PPM. However, the average CO was 2,1 PPM. Figure 7 reveals a more balanced spatial pattern, with subtle oscillations during the measurements and the highest values registered at Beira Mar Avenue.

Figure 5: CO Measurements 12/02/2020.



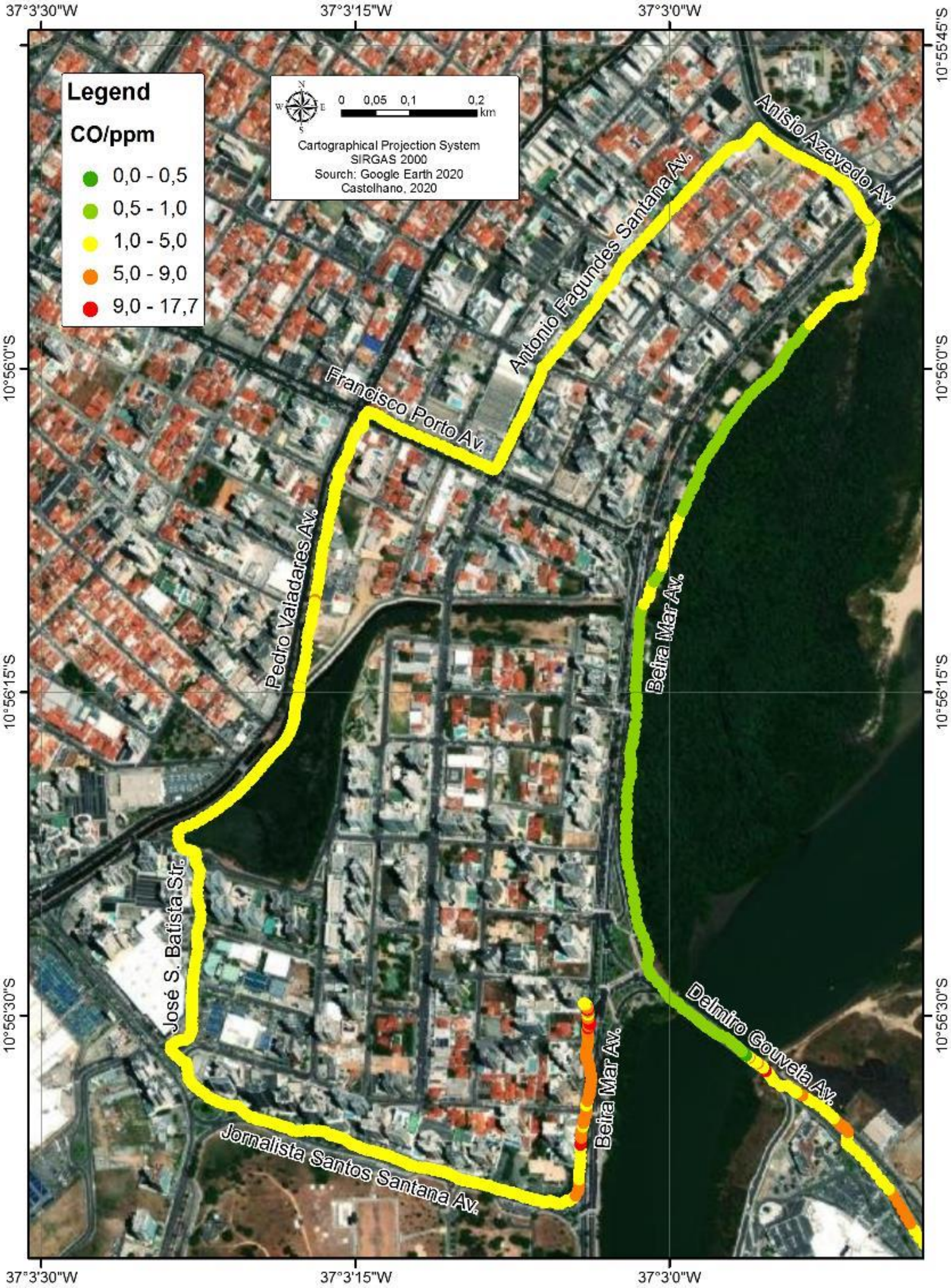
Source: (The authors).

Figure 6: CO Measurements 15/02/2020.



Source: (The authors).

Figure 7: CO Measurements 18/02/2020

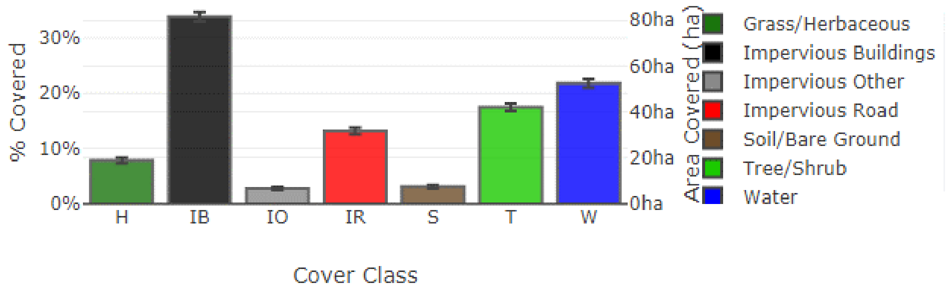


Source: (The authors).

MANGROVE ROLE ON ARACAJU'S AIR QUALITY

Figure 8 reveals the percentages of each land-use class at the buffer made by Itree Canopy at Jardins neighborhood where, in addition to the predominance of the built-up class (34%), 17% of it is covered by mangrove areas. Water cover was the second biggest area due to the Sergipe River presence, with 22%. 13% of the area is covered by impervious roads, and 8% with grass and other herbaceous species.

Figure 8: Land Use Areas – Jardins Neighborhood/ Aracaju



Source: (The authors).

Values above 30% of green areas are considered to be an indicator of a minimum environmental quality (Rocha, Nucci, 2018). At the study area, if both mangrove and grass areas are considered, there is a total of 25% of green areas. The spatial distribution of green areas and each land-use can be seen at figure 8.

Table 2 highlights the role of the green areas at Jardins Neighborhood, mainly due to the mangrove areas which represents 17% of the total area, on the air pollution reduction, suggesting that its preservation is not only necessary for its role on biodiversity protection but also, to urban issues such as air pollution. The ITree Canopy model reveals that, in ideal conditions, the mangrove area from Aracaju can remove 117 kg of Carbon monoxide per year. The highest impact of the mangrove maintenance however, is on ozone removal, with more than 2 tons per year.

Table 2: Tree Air Pollution Removal Estimation

Pollutant	Description	Amount (kg/year)
CO	Carbon Monoxide removed annually	117,34
NO_2	Nitrogen Dioxide removed annually	360,21
O_3	Ozone removed annually	2656,06
SO_2	Sulfur Dioxide removed annually	0,21
$PM_{2.5}$	Particulate Matter less than 2.5 microns removed annually	82,94

Source: the authors (2021).

DISCUSSION

The mobile data measurements technique proved to be of paramount importance in locating and mapping the spatial variability of air pollution in a simple way, prompting further research in different locations. Important to notice that measuring other pollutants such as PM or NOx would be of prime importance

Low-cost sensors can be easily reproduced which facilitates the acquisition of data from areas that are still little explored, such as those in developing countries, due to the high costs of obtaining equipment.

The CO measurements reveal a spatial pattern at Jardins Neighborhood in Aracaju. Both Beira Mar and Pedro Valadares Avenues, characterized as important connections from the city center to the southern parts of Aracaju, were the places where the highest CO were registered in our measurements. The presence of mangrove areas, most intense at Beira Mar avenue, apparently, did not affect directly the spatial patterns of CO.

The Jornalista Santos Silva Avenue, however, registered the lower levels of the pollutant. This can be explained by the street orientation, east-west, which is faced to the winds predominant direction (Anjos et al., 2018).

Also, on this avenue, is located, Sementeira Park. Sementeira Park concentrates the grass/herbaceous areas of the study area, which also contributes to the air pollution removal by wind circulation.

The intense differences between CO levels during weekdays reveal also, the influence of urban functions. The lower traffic during weekends represented a significant drop in the pollutant level.

Oke (2006) characterizes urban climate as a three-dimensional phenomenon to which temporal, horizontal, and vertical scales must be defined. Therefore, the types of instruments to be used, location and even quantity of these instruments must be defined considering such analysis scales intended in the study to be carried out.

Horizontal scales applied to Urban Climate studies, such as this one, are listed in Mesoscale, Local Scale, and Microscale. His proposal of “layers” or vertical scales of climate analysis proposes the city understood in two different scales, the Urban Boundary Layer (Urban Boundary Layer), which comprises the atmosphere altered by the urban effect on a mesoscale, and the Urban Canopy Layer (Urban Coverage Layer) attesting to changes on a micro and intra-urban scale

Our Itree model results revealed that the mangrove areas are playing a significant role in air pollution removal; however, our mobile measurements data suggests that the removal of CO only affects the urban boundary layer of the atmosphere and not the Urban Canopy Layer, which is affected more intensely by the traffic nearby.

Recent literature reinforces this role (Alemu, 2021), which should contribute to the discussion on the Brazilian environmental policies about mangrove protection.

CONCLUSIONS

The purpose of this article thus sought to carry out a geographic analysis of a complex and multifactorial socio-environmental problem whose origin and development are proved to be inseparable from the paradoxes, contradictions, and disagreements present in the way in which capitalist urban spaces are produced.

The exploratory research revealed a scenario of poor air quality in the Jardins Neighborhood in Aracaju, with CO values that exceed the legal minimum daily limits of 9 PPM established by WHO in several locations.

he solution to these problems involves new values and changes at both individual and society levels. Stakeholder's actions should be based, above all, on reducing emissions from mobile sources, that is, cars, thus providing new forms of urban mobility whose impacts are smaller compared to private automotive transport. This involves investments in public transport and other modes such as cycling.

The ITree Canopy, however, highlights that the air pollution reduction can also be achieved by the preservation and expansion of trees, as well as the resulting ecosystem services, which are unequivocally an effective measure to combat also global warming and its impact on cities.

Using the ITree Canopy model, it was demonstrated that the adequate inclusion of 9% of areas covered by trees removed 16.8 kg of annual PM10 in Aracaju roads and that it would be necessary to add at least 20% of trees to reach the limit of good air quality (50 µg/m3), considering the maximum observed 120 µg/m3 (Anjos et al., 2018). Same research suggested that the strategy of adding trees, especially at the level of congested roads, constitutes a convenient economic and environmental strategy for public management to improve air quality in cities and also, mitigating climate change since the trees also remove Green House gases.

Cities play an important role in global climate change as they account for more than 70% of greenhouse gas emissions, mainly related to the transport system aby burning fossil fuels. Originating from the burning of fossil fuels, CO2 is not a pollutant in the conventional sense, as non-toxic concentrations, if inhaled, do not directly harm human health, however, it is situated as the most important greenhouse gas that has contributed to the current anthropogenic global warming (IPCC, 2013). Thus, climate change mitigation and adaptation policies necessarily involve our ability to reduce their emissions at source.

Simple and pragmatic analyzes are unable to encompass the complexity of the air pollution issue, as its understanding also involves our daily habits as individuals, political, cultural and also economic issues. At this point is important to highlight the differential of carrying out a geographical approach to the phenomenon of air quality, given the ability of such science to aggregate those factors under the aegis of geographical space.

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REFERENCES

ALEMU, J B., RICHARDS, D.R., GAW, LEON Y.F., MASOUDI, M., NATHAN, Y., FRIESS,D. A., Identifying spatial patterns and interactions among multiple ecosystem services in an urban mangrove landscape, **Ecological Indicators**, v. 121, p 07-42, 2021.

ALMEIDA, F.C., RIBEIRO, A. S., A esfera pública e a devastação dos manguezais aracajuanos, **Revista Eletrônica do Prodema**,São Cristovão, Vol..3, No.1, p.23-41, 2009.
ALVES, E. D. L.; SPECIAN V., Estudo do Comportamento Termohigrométrico em Ambiente Urbano: Estudo de Caso em Iporá-GO, **Revista Brasileira de Geografia Física**, Recife, v. 3, n.2, p.87 – 95, 2010.

AMORIM, MC. C. T., Climatologia e gestão do espaço urbano, **Mercator - Revista de Geografia da UFC**, Fortaleza, v..9, No.1, p.71 – 90,2010.

ANJOS, M.W.. 2017, **Orientações climáticas para o planejamento urbano numa cidade costeira do nordeste do Brasil: Aracaju-SE**, Tese (Doutorado em Geografia) - Universidade de Lisboa, Lisboa, 2017.

ANJOS, M.W.; LOPES, A.; ALVES, E.D., Uso dos modelos CAL3QHC e I-Tree Canopy na avaliação da qualidade do ar em Aracaju: estimativas das concentrações de PM10 nas vias de tráfego intenso de automóveis, **Geousp: espaço e tempo**, São Paulo,v. 22, p.707-728,2018.

BALDOCCHI, D.D.; HICKS, B.B.; CAMARA, P., A canopy stomatal resistance model for gaseous deposition to vegetated surfaces". **Atmospheric Environment**,v. 21, p. 91-101,1987

BRITO, V., BEZERRA, D., Áreas de preservação permanente: análise legislativa e da ocupação de manguezais na ilha do Maranhão, **Revista Direito Ambiental e sociedade**, Caxias do Sul, v. 10,n. 1, p. 237-264,2020.

CASTELHANO,F.J., Considerações Acerca da Poluição do Ar e Circulação de Veículos na Região Central de Curitiba/PR. **GEOGRAFIA (LONDRINA)**, v. 26, p. 116, 2017

CASTELHANO, F.J.; PINTO, J.E.S.S, Urban morphology and air quality in curitiba, paraná southern braziL. In: XXXIIIème Colloque de l'Association Internationale de Climatologie, 2020, Rennes. Actes du XXXIIIème Colloque de l'Association Internationale de Climatologie. Rennes, v. 1. p. 139-144, 2020.

CASTELHANO F.J, PEDROSO A.C., COBELO I., BORGE R., ROIG H.L., ADAMS M., AMINI H., KOUTRAKIS P., RÉQUIA W.J., The impact of long-term weather changes on air quality in Brazil. **Atmospheric Environment**, v.283:119182, 2022

CIPOLI, Y.A.; TARGINO, A.C.L., TOLOTO; M.O., Distribuição espacial de poluentes atmosféricos no centro de Curitiba (PR), in: Seminário De Iniciação Científica E Tecnológica Da Utfpr, 2017, Londrina,Paper presented at XXIII Seminário de Iniciação Cientifica e Tecnológica da UTFPR, Londrina, p.1-7, 2017.

DANNI-OLIVEIRA, I.M., MENDONÇA, F.A., **Climatologia: Noções Básicas e Climas do Brasil**, São Paulo: Oficina de Textos, 2007.

ELEN, B..; PETERS, J..; POPPEL, M..V.; BLEUX, N., THEUNIS, J., REGGENTE, M.; STANDAERT, A.,The aeroflex: a bicycle for mobile air quality measurements,**Sensors**, v.13, n.1, pages 221– 240,2013.

GROVER, A, SINGH, R,B., Analysis of Urban Heat Island (UHI) in Relation to Normalized Difference Vegetation Index (NDVI): A Comparative Study of Delhi and Mumbai, **Environments**, v.. 2, n. 2,p.125-138,2015.
IBGE – Instituto Brasileiro De Geografia E Estatística, **Estimativas da população residente para os municípios e para as unidades da federação brasileiros com data de referência em 1º de julho de 2020**, IBGE,Rio de Janeiro, 13 p, 2020.

IEMA – Instituto Energia e Meio Ambiente, **Primeiro Diagnóstico da Rede de Monitoramento da Qualidade do Ar no Brasil**, São Paulo: IEMA Press, São Paulo, 277 p., 2014.

INMET – Instituto Nacional De Meteorologia,2021, **Banco de Dados Meteorológicos do INMET**, Avalaible at: https://bdmep.inmet.gov.br/.

IPCC – International Panel on Climate Change , **The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,** edited by: Stocker, T. F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., and Midgley, P. M., United Kingdom and New York: Cambridge University Press, Cambridge,2013.

KALRA, V.; CHAITANYA,B.; SIMMARPREET, D.R; CHOPRA, S., Influence of Temperature and Humidity on the Output Resistance Ratio of the MQ-135 Sensor”, **International Journal of Advanced Research in Computer Science and Software Engineering**, v.6, n.4, p.423-429,2016.

KJERFVE, B., LACERDA, L. D., Mangroves of Brazil. **Mangrove Ecosystems Technical Reports**, v.13,n. 2, p. 245–272, 1993.

LOUREIRO, K..A.S., 1983, **A trajetória Urbana de Aracaju, em tempo de interferir**, Aracaju: INEP, 115 p.,1983.

MACEDO, M..F.M., **Avaliação da Poluição Atmosférica Veícular com o Modelo AeroMod em Avenida de Aracaju-SE**, Dissertação - Universidade Federal de Sergipe, São Cristovão, 2016.

MACIEL, C.R., Análise da relação entre características do ambiente urbano e comportamento de variáveis microclimáticas: Estudo de caso em Cuiabá-MT, Dissertação (Mestrado em Física Ambiental) -Universidade Federal de Mato Grosso,Cuiabá, 2011.

MAYNARD, A., Avenida Beira Mar, Bairro 13 de Julho, em Aracaju, 2016 avaliable at : http://bemvindoasergipe.blogspot.com/2016/02/avenida-beira-mar-bairro-13-de-julho-em_17.html.

MUNJI, C.A., BELE, M.Y., IDINOBA, M.E., SONWA, D.J., Floods and mangrove forests, friends or foes? Perceptions of relationships and risks in Cameroon coastal mangroves, Estuarine, **Coastal and Shelf Science**, v. 140, n.1, p.67-75, 2014.

NOGUEIRA, A.D., **Análise Sintático-Espacial Das Transformações Urbanas De Aracaju (1855 – 2003)**, Tese (Doutorado em Arquitetura e Urbanismo) - Universidade Federal da Bahia, Salvador,2004.

NOWAK, D.J., CRANE, D.E., STEVENS, J.C., Air pollution removal by urban trees and shrubs in the United States, **Urban forestry urban greening**, v. 4, n. 3,p.115-123, 2006.

OKE,T., I**nitial Guidance to Obtain Representative Meteorological Observations At Urban Sites**, WMO, 2006

PELAGE, L., DOMALAIN, G., LIRA, A.S., TRAVASSOS, P., FREDOU, T., Coastal Land Use in Northeast Brazil: Mangrove Coverage Evolution Over Three Decades, **Tropical Conservation Science**, v.12, p.1-15, 2019.

PINTO, J.E. S. DE S., O clima local de Aracaju-SE. in Sant’anna Neto. João Lima (editor.). **Os climas das cidades brasileiras**,UNESP, Presidente Prudente, p. 46-60,2002.

PLOCOSTE, T., JACOBY-KOALY,J., MOLINIÉ,R.H., Evidence of the effect of an urban heat island on air quality near a landfill, **Urban Climate**, v. 10, p.745-757,2014.

RAI, A.C., KUMAR, P; PILLA, F; SKOULOUDIS, AN.; SABATINO, SD.; RATIFF, C; YASAR, A; RICKERBY, D, End-user perspective of low-cost sensors for outdoor air pollution monitoring, **Science of the Total Environment**, v.607-608, n.31, p. 691-705, 2017.

RÉQUIA, W. J., KOUTRAKIS, P. & ROIG, H. L. Spatial distribution of vehicle emission inventories in the Federal District, Brazil. **Atmospheric Environment** 112, 32–39, 2015.

RICHARDSON, J. J.; MOSKAL, L. M. Uncertainty in urban forest canopy assessment: Lessons from Seattle, WA, USA. **Urban Forestry & Urban Greening**, v. 13, p. 152-157, 2014

ROCHA, M.F., NUCCI, J.C., Índices de vegetação e competitividade entre cidades, São Paulo, **GeoUSP**, v.22, n.3, p.641-655,2018.

SCHAEFFER-NOVELLI, Y., Perfil dos ecossistemas litorâneos brasileiros, com especial ênfase sobre o sistema manguezal, São Paulo, **Publicação especial do instituto de oceanografia da USP**, n.7, p.1-16, 1989

SCHAEFFER-NOVELLI, Y., CINTRON-MOLERO, G., Manguezais brasileiros: Uma síntese sobre aspectos históricos (séculos XVI a XIX), zonação, estrutura e impactos ambientais. In: III Simpósio de Ecossistemas da Costa Brasileira,São Paulo, 1993.

SCHNEIDERS, E, SKOV, M.B., 2019, CyclAir: A Bike Mounted Prototype for Real-Time Visualization of CO2 Levels While Cycling, In: INTERACT 2019: The 17th IFIP TC.,2019, Paphos, p. 678-687, 2019.

VALIN JR, M. O., **Análise de abrigos termo-higrométricos alternativos para transectos móveis**,Dissertação, (Mestrado em Física Ambiental), Universidade Federal de Mato Grosso, Cuiabá,118 p., 2019.

WILKIE, M. L., FORTUNE, S, 2003, Status and trends of mangrove extent worldwide,**Rome Forest Resources Assessment Working Paper**, n. 63,2003

ZHOU, Y., MAO, H., DEMERJIAN, K., HOGREFE, C. & LIU, J. Regional and hemispheric influences on temporal variability in baseline carbon monoxide and ozone over the Northeast US. **Atmospheric Environment** 164, 309–324 (2017).