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USE OF BIOINDICATOR IN THE ANALYSIS OF AIR QUALITY: A COMPARISON FOR THE NAPOLEÃO MOREIRA DA SILVA SQUARE IN MARINGÁ (PR) BETWEEN THE YEARS 2006 AND 2018

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Abstract: Green areas are key factors when it comes to quality of life and air quality, besides the aesthetic quality that brings to the city, offers better quality physical and mental health of the population, so using bioindicators in these areas as a source of instrument for air quality is of due importance. This paper presents an analysis of the Napoleão Moreira da Silva Square (Maringá - PR), specifically the lichens present on the tree trunks, as a bioindicator of air quality, making a comparison of the years 2006 and 2018. The Helmut Troppmair methodology was used, in which the quantification of the lichens makes it possible to infer the quality of the air at that location. The data obtained were studied both in the form of sectors, one representing each street, and in the square in general. Thus, it was possible to observe that the pollution presented differences in the sectors with greater presence of lichens in 2006, but in the general average, the data in relation to the classification proposed by Troppmair remained the same.
Keywords: Air quality, Lichens, Urban Green Areas.

INTRODUCTION

Currently, respiratory diseases are being aggravated by the air quality not being favorable, according to a report by Ferraz (2014), "in 16 years, air pollution will kill 256 thousand people in the state of São Paulo. One way to understand and analyze this air quality is in the use of bioindicators such as lichens.

In general, monitoring the air quality in cities is of utmost importance due to the increase in urban population, services, vehicles, which consequently increase the amount of gases and toxic particles in the atmosphere, causing the air quality to be compromised.

The objective of this work is to carry out a comparative study of the air quality of Napoleão Moreira da Silva Square in 2006 with the article by Sant'Ana et al "Analysis of the lichen cover in Napoleão Moreira da Silva Square. Maringá- PR" and in the present year 2018, seeking to know if the air quality has declined over the years, as a result of the increase in pollution, vehicle fleet and gases emitted in general.

For the development of this work, bibliographical and field researches were used, where the bibliographical research sought to conceptualize what green areas are and to define their importance for urbanization and for the population that consumes them. The field research was done by applying the methodology developed by Helmut Troppmair (1988) which aims to measure the higher or lower concentration of pollutants, their spatial and temporal variation and explain the causes or sources responsible by using bioindicators.

This paper is structured this way: In the first part, the concepts and definitions are presented then the delimitations of the city and the study area, bringing the history and uses of the Square over time, soon after it is brought with greater description the methodology applied and how it was used and finally the results obtained through the fields made and compared with those of the year 2006.

The importance that green areas have in urban areas and the knowledge about them become relevant tools for their management, in the case of the study area, which has an intense flow of people, hence the importance of studying the air quality in this square in the urban area of Maringa.

Regarding the importance of these areas to society, De Angelis and Loboda (2005, p.131) define

> [...] that the quality of urban life is directly linked to several factors that are gathered in the infrastructure, in the social-economic development and those linked to the environmental issue. In the case of the

> environment, the public green areas are essential elements for the well-being of the population, because they directly influence the physical and mental health of the population.

Finally, comparing the air quality in the years 2006 and 2018 for this location enables the instrumentalization of environmental planning aimed at the quality of life of people who consume this space.

De Mattos (2015) says that with the development of municipalities, it is evident that it becomes increasingly essential to monitor air pollution, taking into account studies and research that can contribute to mitigating measures of environmental pollution, and aiming at a better quality of life for the population.

Filho et al 2006, p. 65 says that

> Bioindication produces a snapshot of a given environmental situation, while biomonitoring allows the assessment of variations or trends in the environmental situation from several bioindication studies developed in space and/or time. The difference between bioindication and biomonitoring is thus analogous to that between a photograph and a film. [...] The survey of lichens carried out on the same trees at any time interval, allows us to estimate the progression or regression of pollution in certain areas, following the evolution of pollution within the space of time.

The studied square used to be called "Bosque de Essências" (Essence Woods). Soon after, by the first urbanistic plan, it became the 2nd bus station, functioning until the end of 1950, when it was transferred to Raposo Tavares Square. In 1957 by Law 32/1957 it was named Napoleão Moreira da Silva Square and in 1959 due to conflicts between the Mayor Américo Dias Ferraz and the CMNP managing director, all the trees were cut down. With this, the Improvement Company of the North of Paraná invited the architect José Augusto Belluci to design a new square, but only on the city's 15th anniversary was it inaugurated with the new project, when CMNP donated it to the City Hall. The last changes were in the year 2014, and the well-known Santa Claus house existed there until the year 2016.

As it is located near the central area of Maringá, with a large flow of people and automobiles, it suffers great influence from urbanization. Currently the square has great use by the elderly population where they use the benches with tables there for games, it also has some businesses such as ice cream parlor, rotating parking spot and cab stand and newsstand, having present a playground for children and a gym for the elderly.

It is assumed that the air quality in 2018 is lower than the analysis of the year 2006 given the installation of other structures in this area, the increase in the city's population and the holding of events in this space as well as the increase in the vehicle fleet in the municipality.

THEORETICAL REFERENCE

According to Park (1973 apud De Angelis and Loboda, 2005) the city cannot be seen merely as a physical mechanism, but rather as an artificial construction. It is involved in the vital processes of the people who compose it. It is a product of nature and particularly of human nature.

In the beginning the urban green had only the interest of pleasing visually, but as time went by it gained space in urban areas, and nowadays it is essential for any urban planning, always reflecting society's habits, becoming even more important due to its degradation and misuse.

Santos (1997 apud De Angelis e Loboda, 2005, p. 130), says that "the urban environment is increasingly an artificial environment, manufactured with remnants of primitive

nature increasingly covered by the works of men.

For Guzzo (1999 apud De Angelis and Loboda, 2005, p. 133-134), green areas have three main advantages:

> ecological, aesthetic, and social. The ecological contributions occur to the extent that the natural elements that make up these spaces minimize such impacts resulting from industrialization. The aesthetic function is based mainly on the role of integration between the built spaces and those destined for circulation. The social function is directly related to the provision of spaces for the population's leisure.

Green areas for Nucci (2008 apud Londe and Mendes, 2014, p. 265)

> are fundamental in the urban network, acting as an indicator of quality of life, for being closely linked to leisure and recreation of the population, and for being places of social interaction and manifestation of community life.

Still in relation to green areas Londe and Mendes, 2014 bring that their planning must be analyzed in the Master Plan, according to the criteria of development and urban expansion.

> [...]and in the urban life quality, the green areas besides giving improvements to the environment and the environmental balance; they contribute to the social development and bring benefits to the well-being, the physical and mental health of the population, by providing conditions for man to approach the natural environment, and have structural conditions that favor the practice of recreation and leisure activities. (p. 269)

Almeida et al, 2012 says that air pollution in the urban-industrial environment is an existing problem in recent centuries, being associated mainly with the burning of fossil fuels. (...) Among the millions of annual deaths that occur worldwide, 800,000 are due to respiratory and cardiovascular diseases caused by environmental pollution.

Regarding air quality, De Mattos (2015) addresses as a result of the interaction of a set of factors, among which are present: the concentration of emissions, topography and local weather conditions, which may or may not be favorable to the dispersion of pollutants.

In an interview to the newspaper: "O Estadão Ferraz" (2014) says that

> According to an unprecedented projection by the Health and Sustainability Institute, carried out by researchers from USP. The estimate foresees that at least 25% of the deaths, or 59 thousand, will occur in the São Paulo capital. The results indicate that, in the current scenario, pollution can kill up to six times more than AIDS or three times more than traffic accidents and breast cancer. The population at risk, that is, people who already suffer from circulatory, respiratory and heart diseases, will be the most affected, as well as children under 5 who have airway infections or pneumonia.

According to Troppmair (1989), the accelerated process of urbanization and the expansion of human activities contribute significantly to air pollution. This is characterized by the presence of materials or energies that can harm the use established for this natural resource. These pollutants are classified according to their state: solid, liquid, and gaseous. As the study focuses on air pollution in Napoleão Moreira da Silva Square, the state of the pollutant was gaseous.

Troppmair (1989) says that there are living beings, plants and animals, that are sensitive to pollution, due to this they are used as bioindicators, where their development, regression or even disappearance, being important for the analysis of the degree of air pollution. The species most commonly used as indicators are lichens, parsley, mango, soybean, and others, with lichens being the most widely used.

Honda and Vilegas 1998 say that

> lichens are symbiotic organisms composed of a mycobiont fungus with one or more photobiont algae. [...] In lichens, the algae constitute, with rare exceptions, a very small part of the thallus ranging from 5-10% of the mass or volume and are completely enveloped by the tissues of the fungus on the thallus. Therefore, the entire organization of the lichen thallus is due to the fungus. The algae may, or may not, be restricted to a special layer of the thallus and are entirely responsible for photosynthesis. [...] The presence of lichens in the most varied habitats and microhabitats depends on the availability of physical and climatic factors that provide the necessary conditions for their development. Thus, each region may present a lichen community with its own specific components in response to environmental conditions. (p. 110)

Filho et al 2006, brings that lichens in their formation, present several types of thallus, where each one has a different "habit" on the bark of the tree. The four main ones are: Crustaceous, being the most resistant to pollution, Fruity, the most sensitive, even disappearing where pollution is high, Filamentous and Dimorphic. In the case of the Crustaceans there are subtypes, being: endofloidal, endolytic, leprous, continuous, rickety, areolate, placoid, squamous, folious, or foliaceous.

Filho et al, 2006,

> An economical and efficient alternative to assess air quality is through plants, because they have specific responses to pollutants and can be used as bioindicators of pollution. Among the plant forms most commonly used for this purpose are lichens, mosses, and, to a lesser extent, some vascular plants. (p. 83)

Puckett, 1988 and Nimis 1990 (apud Filho et al, 2006 p.103) argue that lichens have characteristics that favor being used as environmental monitors because:

- They do not have protective layers, common in the leaves of phanerogamic plants, such as waxy layers and cuticles;
- Nutrient uptake is not normally from the substrate, which is only used for fixation;
- It has photosynthetic activity and exhibits year-round growth;
- Morphology does not vary considerably throughout the year;

Pilegaard (1977, apud Filho et al 2006 p. 106) still says that because they do not depend on a fixation system to absorb nutrients, also having a reduced, or absent, cuticle, they end up incorporating high levels of pollutants more easily.

CHARACTERIZATION OF THE STUDY AREA

The municipality of Maringá is located in the North Central region of Paraná, at 23º25' South latitude, is demarcated by the imaginary line of the Tropic of Capricorn and is at 51º57' West longitude (Figure 1), with altitude ranging from 470 to 600 meters and about 428 km away from the capital Curitiba. The total area is 487.052 km², already the estimated population in 2016 was 403,063 inhabitants (IBGE, 2016).

According to Sant'Ana et al, the climate of the municipality is humid subtropical, inserted in the domain of the SemidecidualSubmontane Seasonal Forest. The municipality has an area of 47,306 ha, in a watershed region between the Ivaí and Pirapó rivers, both tributaries of the left bank of the Paraná River.

The area of the square studied is located in the central area of the city, having a large circulation of cars and people. Its creation was given by law number 32/57 of May 4, 1957, changing over time its functions, many of these being detrimental to the preservation of its flora. The site "Maringá Histórica" was used to gather historical information about the square.

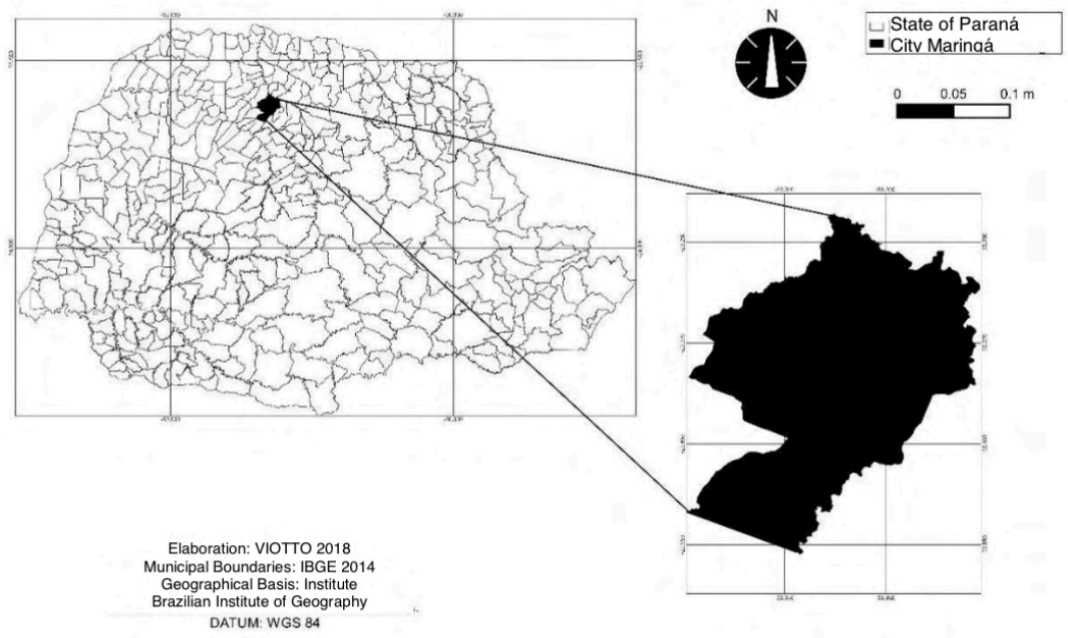


Figure 1. location map of the city of Maringá.

Source: Authoral.

Initially the square was called "Bosque das Essências" and also "Parque dos Eucaliptos" and received this name due to a stylized plantation of several native trees such as perobas, cedars, palmettos, marfins, alecrins, canjaranas, among others.

It has been owned by the Companhia Melhoramentos Norte do Paraná since the city's elevation to municipality. In 1947, with the new urban plan made for the city, the construction of Maringá's second bus station was started. Some former residents have recently reported that for a short period the two bus station structures functioned simultaneously, one in the "Old Maringá" and the other in the "New Maringá".

The second Bus Station Square functioned until the end of 1950 (Figure 2) when Mayor Américo Dias Ferraz started the work of making it temporary in front of Raposo Tavares Square and demolishing the boarding and alighting area of the Bus Station Square.

On May 4th 1957, the old Bus Station Square was named Napoleão Moreira da Silva Square by Law 32/1957, being the name intended to honor one of the first councilmen and presidents of the Maringá City Council who had died in a plane crash in the same year.

The third light fountain even had its works started at the Praça Napoleão Moreira da Silva, but, due to the crisis that took place at the end of Américo Dias Ferraz's administration, there was no conclusion.

Between 1958 and 1959 the managing director of the Companhia Melhoramentos do Norte do Paraná (CMNP), Hermann Moraes Barros, wrote several articles criticizing some of the administrative attitudes of the then mayor Américo Dias Ferraz. During the early morning of October 27, 1959, the then mayor ordered public servants to knock down that space that preserved perobas, palmettos, marfins, alecrins, canjaranas, among others

Figure 2. Second Road Square.

Source: Maringá Histórica.

Figure 3: Square after demolition.

Source: Maringá Histórica.

(Figure 3). When the day dawned, the whole population was taken by surprise.

After the political fight over the felling of the native trees, the Companhia Melhoramentos Norte do Paraná invited the architect José Augusto Bellucci to design a new square on the site and also gifted the municipality with the urbanization of the square, as well as donating the space to the City Hall. He designed the square with abstract geometric shapes and all the vegetation and landscaping was provided by the Horto Florestal, also owned by the Companhia de Melhoramentos Norte do Paraná (CMNP).

In the year of Maringá's 15th anniversary (May 10, 1962) Napoleão Moreira da Silva Square was inaugurated with the project of re-urbanization with the partnership works of the City Hall and the Companhia Melhoramentos Norte do Paraná, where it was donated by the latter to the City Hall.

Currently, Napoleão Moreira da Silva Square has most of the characteristics of Belluci's original project, with some reforms carried out from the end of the year 2014. The last cultural change in the square was in 2017, when the well-known Santa Claus house was transferred from the square to Praça Deputado Renato Celidônio, without much explanation as to the reason for the change.

According to Bovo, 2009 Napoleão Moreira da silva square is located between Avenida Brasil and Avenida Duque de Caxias and Rua Santos Dumont and Rua Basílio Saltchuk (Figure 5), in the geographical coordinates 23° 25'17" south latitude and 5° 51° 56'26" west longitude, at an altitude of 539 meters.

In this study we used the work of Sant'Ana, et al from 2006 for a comparison of the air quality of the Napoleão Moreira da Silva square, focusing on the use of lichens as bioindicators of air.

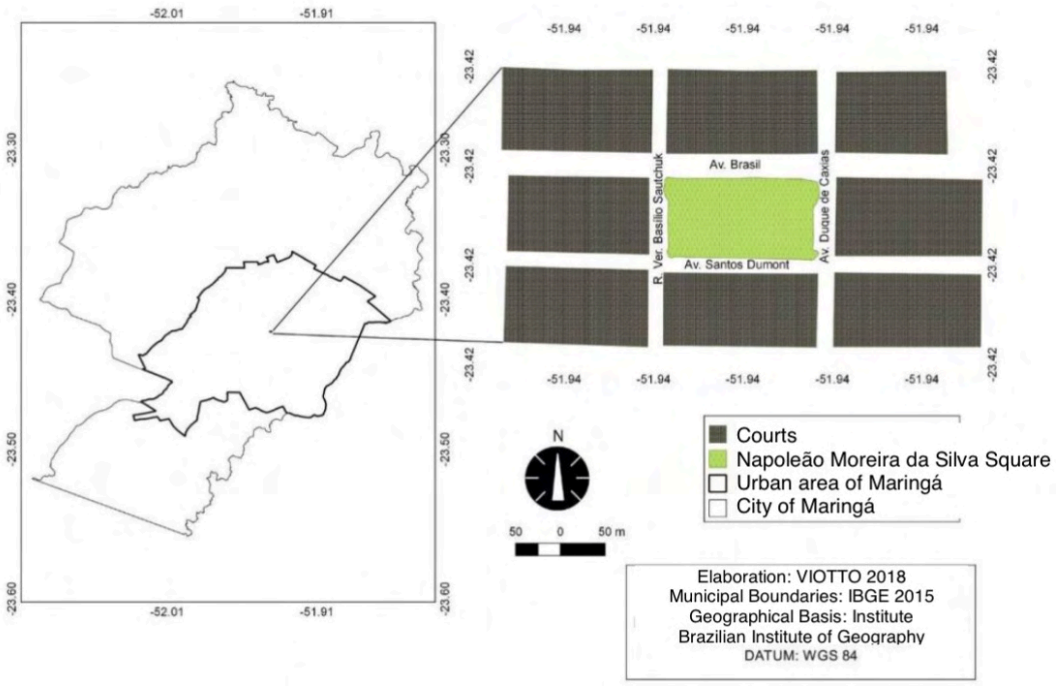


Figure 5. Study Area.

Source: Authoral.

METHODOLOGY

In this study the Troppmair methodology was used, making some adjustments in relation to data collection and analysis. In this study, we used the Troppmair methodology, making some adjustments in relation to the collection and analysis of data.

The measurement of lichens in front of the tree trunk is done by the side where the winds are predominant, because they bring the necessary moisture for the development of lichens, at a height of one to two meters, extends a grid square, approximately five by five centimeters, counting how many squares have the presence of lichens: For example: 27 squares or 27%.

The correction index must be applied, because lichen are difficult to attach to the trunk of some tree species, the percentage must be corrected. After measuring the lichen on the tree trunks, the correction is applied:

$$\%y = \frac{\%x * 100}{i}$$

Where,

%y = degree of coverage corrected for bark roughness;

%x = degree of coverage read on the trunk

i = correction index for the species under study.

After the result of the correction, it falls into the following classes:

- Class V: degree of coverage = 51 to 100%, normal zone, no pollution.
- Class IV: degree of coverage = 26 to 50%, external contested zone, low pollution.
- Class III: degree of coverage = 13 to 25%, intermediate contested zone, medium pollution.
- Class II: degree of coverage = 6 to 12%, inner contested zone, high pollution.
- Class I: degree of coverage = 0 to 5%, lichen desert, very heavy pollution.

For the study, the following materials were used: tracing paper 10x25cm, where ten squares were drawn, each 10x10 cm, to quantify the amount of lichens on the trees, in addition to obtaining the CAP (circumference at breast height) of each tree with the help of a tape measure.

According to Sant'Ana et al, in 2006 the first field was conducted in the month of August, where the average temperature was 20.8ºC and total rainfall of 27.6 mm³. Already in the second field in the month of January the ECPM recorded the average temperature of 25.3ºC, having its total precipitation of 271.5 mm³.

In the first field of the year 2018, made in the afternoon period of July 04, the average temperature according to the Agritempo website was 21.68°C and the total precipitation was 5.73mm. In the second, done in the morning of August 18, the average temperature recorded was 19°C with precipitation of 409.03 mm.

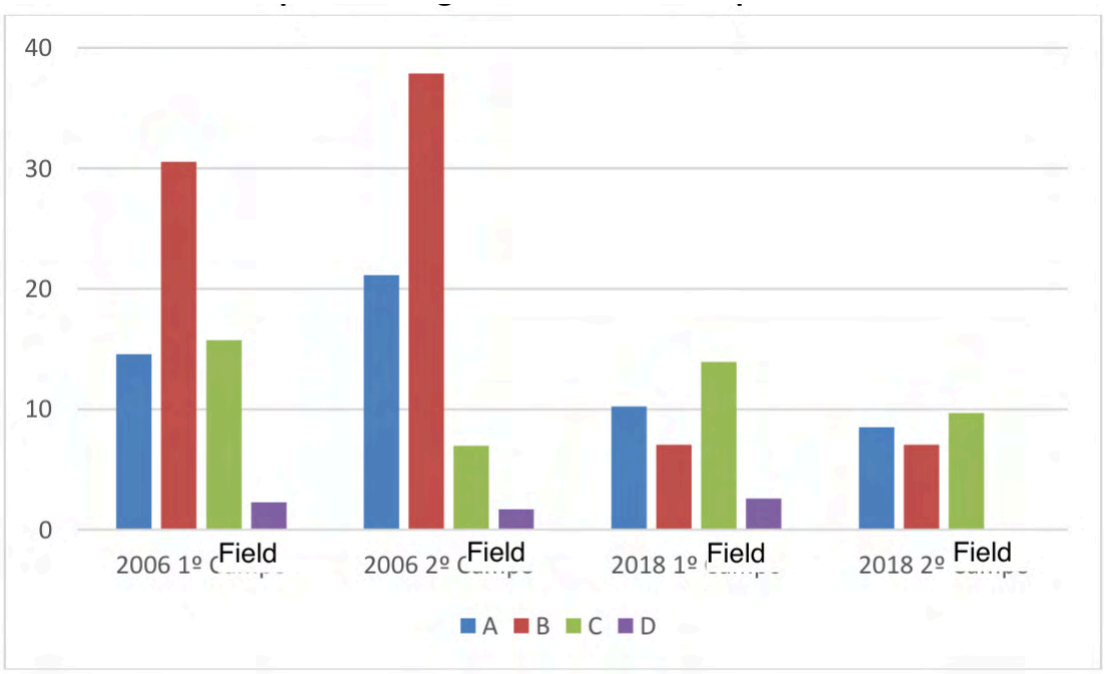
The species under study was Sibipiruna ("Caesalpiniapeltophoroides"), where its degree of correction according to Troppmair is 110.

After collecting the data, it was corrected using the correction formula, both for the data from the 2006 field where the data were just presented and not corrected (APPENDIX 1, 2, 3 and 4). Thus, the corrected data for the fields in their respective year (APPENDIX A, B, C, and D). Next, an average of all trees was made for the two years under comparison.

RESULTS AND DISCUSSION

With the averages analyzed and corrected as described above, a chart was organized for better analysis and spatialization of the data. First, the data was organized for each sector (Chart 1 and Figure 6) according to the fields and years analyzed.

Starting with sector A, which fits the corner of Basilio and Santos Dumont, in the two



Graph 1. Average number of lichens per sector.

Source: Author.

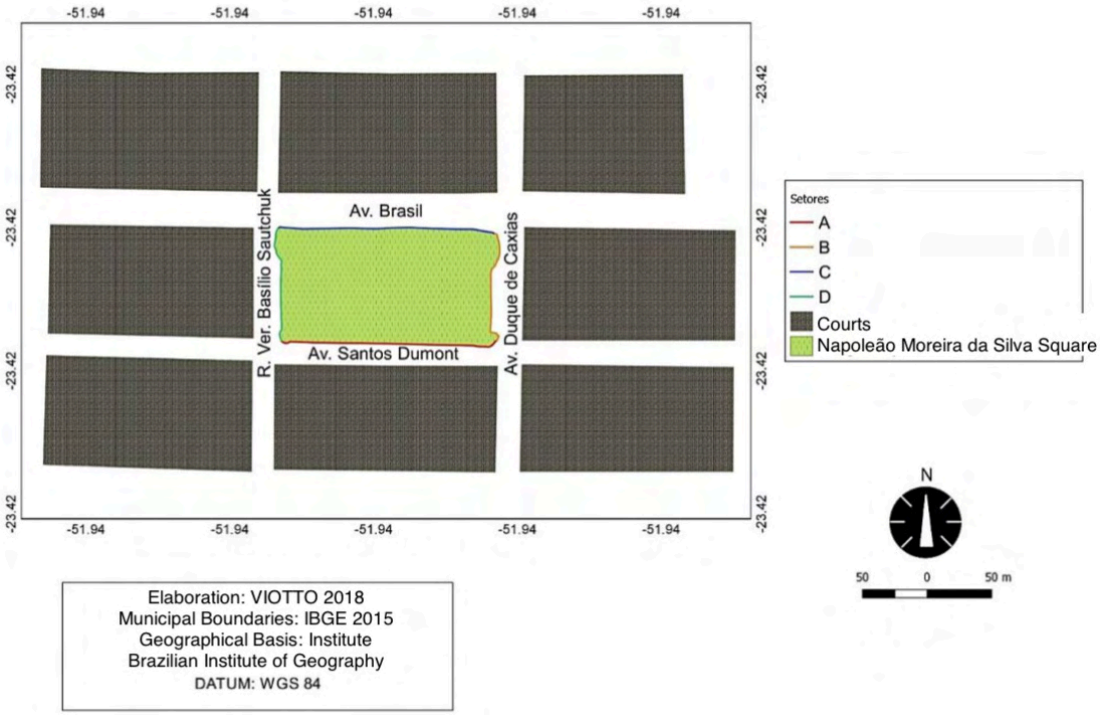


Figure 6: Map with respective sectors.

Source: Authoral.

fields of 2018 we can see that it is the second sector with the presence of lichens, having in the first field the average of 10.22% and in the second field the average was 8.52% presence of lichens, according to the categories of Troppmair the two collections fit in class II, internal contested zone, high pollution.

When we compare the same sector in the year 2006, in the first field appears as the third with presence of lichens, presenting 30.55% and in the second field its percentage increases to 37.87%, both being in Troppmair's class IV, external contested zone, low pollution.

In this sector we can analyze a sharp drop in values, dropping two classes of analysis, thus showing that the pollution from Napoleão Moreira da Silva Square to this street, had a decrease in air quality visibly. It is also noteworthy that some trees suffer from very serious damage, such as nail perforations (Figure 7) and loss of their first bark.

In relation to sector B, which is in Santos Dumont street with Duque de Caxias street in the 2006 fields was the sector that showed the highest concentration of lichens, the first scored 30.55% and the second field 37.87% the two fields fitting in class IV external contested zone, low pollution. In the year 2018, the first and second field showed the same presence of lichens 7.07% according to the classes fits in II internal contested zone, high pollution.

Analyzing the two years we see that the presence even dropped almost 30% of the presence of lichens, consequently the air quality decreased in the year 2018, in relation to Troppmair classification as well as sector A dropped two classes from the first to the second year of analysis.

Sector C which corresponds to the corner of Duque de Caxias and Av. Brazil, in the fields of 2006 were third with percentage, the first presented 15.75% of lichens, being in class III contested zone of the intermediate, medium pollution, the second had 6.96% of lichens present, fitting in class II according to Troppmair. In the year 2018, this sector presents itself with a higher index of percentage of lichens, the first field presenting 13.93% fitting in class III contested zone of the intermediate, medium pollution, already in the second had 9.69% being in class II.

In this sector the variation in the percentages of lichens was the one that presented the least difference from the first year of analysis to the second, with the field of August 2018 having a higher percentage than the one of January 2006. Regarding the classes was the only one that kept the same for the two years of study, some damage can be analyzed as piping between the tree roots, besides being used as a support. In this sector it is interesting to point out that right at the beginning of the collection in the year 2018 there was an empty hole where there was a tree removed compared to the first one surveyed in 2006.

The last sector to be analyzed is D, which is framed in the corner of Brasil Avenue and Basilio Saltchuk Street, presented the worst index of lichens in all the fields performed, in the 2006 the first field obtained 2.27%, and the second field had 1.70% the two results being in Troppmair class I. In the year 2018 the July field showed 2.59% and the being having null presence of lichens, being also in class I.

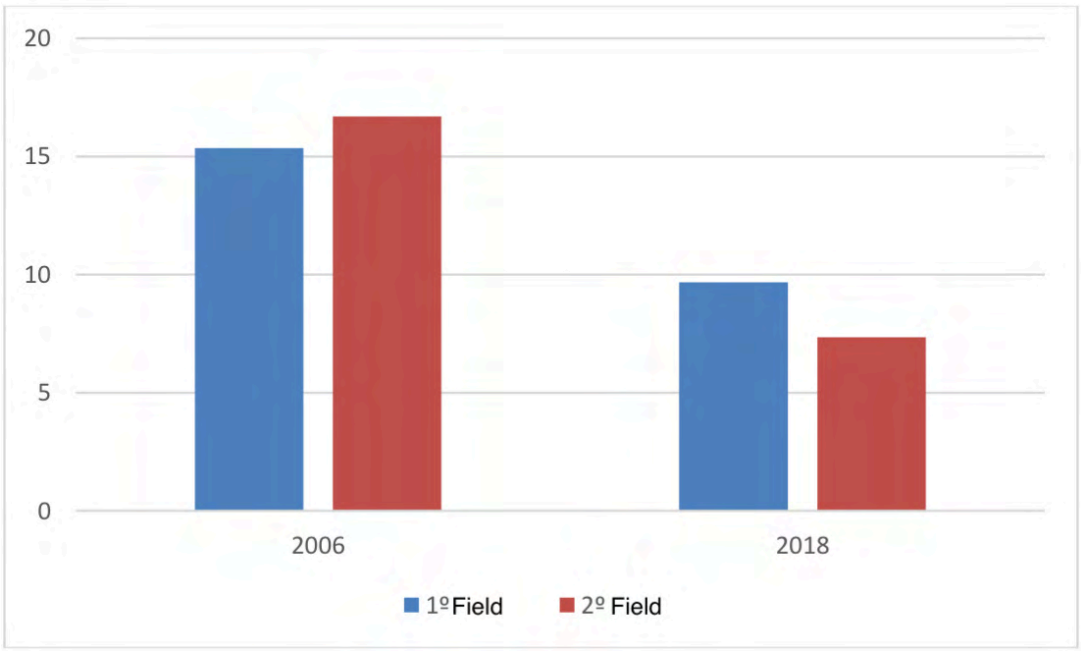
Sector D being compared to the two years of analysis had very low rates, but the only data from the year 2018 was higher than that observed in 2006. However, since one of the fields had no lichens, its quality is still lower because the 2006 fields had very few lichens.

After each sector a total spatialization was made for each field performed with the respective years (Graph 2).

In the first field of the year 2006 the average in total trees in Napoleon Square was 15.36%, while the second field showed 16.69% both indexes are classified in the internal contested zone, high pollution (class II). In the first field

Figure 7: Tree with nails and bark lesions.

Source: Authoral.



Graph 2. Analysis of the general average of Napoleão Moreira da Silva Square.

Source: Authoral.

of the year 2018 the percentage of lichens was 9.67%, the second had the index of 7.35% being also in Troppmair's class II.

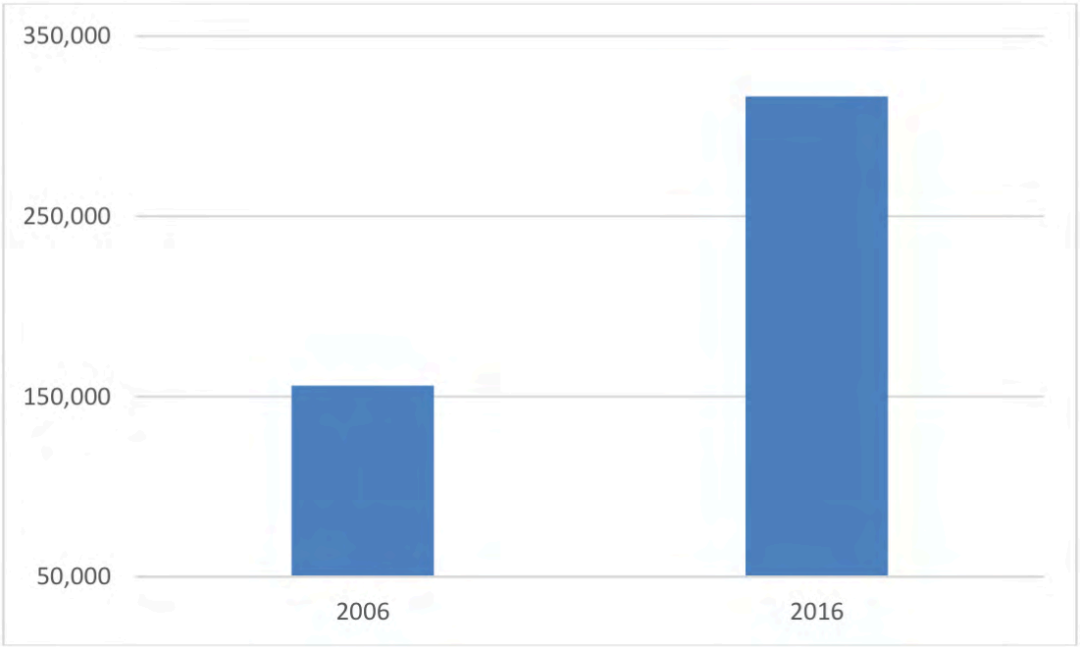
Based on these data, if we analyze by the Troppmair classes only, there was no increase or decrease in air quality, because the two years fall into the same class (internal contested zone, high pollution - II). However, according to the averages obtained in the first field alone we had a reduction of 8.01% in lichens and in the second, 7.02%, considering that these values are averages, the air quality does decrease on large scales.

A very important factor for this decreasing air quality is the vehicle fleet (Graph 3), where in 2006 according to the Brazilian Institute of Geography and Statistics (IBGE) was 155,924, for the last year dated 2016 had already increased to 316,493, being more than double the first year.

Due to the position of the square in the urban site (central zone), it is to be expected that the decrease in air quality in this square is symptomatic, as a result of the increase in more than 100% of the vehicle fleet between the years 2006 and 2016. This result could be further investigated in other studies that address the health of the residents who frequent this square more frequently, such as street vendors and the elderly who use this public space as a playground.

FINAL CONSIDERATIONS

The green areas for the cities are of due importance both for the city and for the population that consumes it, and must be analyzed separately, constituting not only the aesthetic beauty of the city but also for the existing air quality, some factors help the air to decrease its quality among them the increase in population. According to the IBGE demographic census of 2010, the population of the city of Maringá was 357,077 people, and the estimate for 2018 was 417,010



Graph 3. Vehicle fleet for the years 2006 and 2016.

Source: authoral.

people. Lichens are used as bioindicators and biomonitors for being able to monitor or analyze air quality because they are sensitive to pollution levels.

According to the results obtained and presented in relation to Napoleão Moreira da Silva Square, in its average by sectors surveyed, the one with the best index in the first field of the year 2006 was sector B, which according to Troppmair is an area with weak pollution. In the second field of the year the same sector continued to be the one with the greatest presence of lichens, also fitting in a weakly polluted area. The sector with the least lichens is sector D, for both fields, being an area with very strong pollution.

In 2018, the sector with the highest presence of lichens in the first field was sector C, with medium pollution; in the second field, this sector also had a higher presence of lichens in relation to the others, but with high pollution. In parallel, sector D had the worst index obtained, being in both fields as very strong pollution, in the second field the presence of these plants was null.

In relation to the sectors, they were not compatible with the sectors that present the largest presence of lichens, because in the first year of analysis it was the sector B, and in the second year it is the sector C. We can relate this to some damage already mentioned that these areas are suffering, as for example the installation of cab stands, allowing many cars to stay stopped for long times waiting for customers, which can be an aggravating factor for the pollution.

In the general analysis of the average of the sectors as a whole, we see that in 2006 there was a difference of 1.33% in lichens between the two fields, both being in the class of high pollution. In 2018, between the fields we had a difference of 2.32% of the bioindicator, but it is also classified as high pollution.

However, if we take only the Troppmair classification into account there would be no change in air pollution in Napoleão Moreira da Silva Square, but the difference data from one year to the other is clear the decrease in air quality. As seen in the hypothesis of the work, the quality of the square is lower than in 2006, one of the reasons being the increase of the fleet, and the increase of the population, causing more people to occupy the places, and consequently using and emitting more toxic particles into the air.

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