Qualitative Analysis of Urban Tree Arborization in the Streets of São Carlos (São Paulo/Brazil)

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ABSTRACT: Tree arborization in streets brings several advantages to the urban environment. In addition to their aesthetic function, urban trees cool local surface temperature, provide air humidity, ensure shelter and food for birds, reduce soil erosion while providing shade, all of which results in a more enjoyable urban landscape. Due to the city's dynamism and growth demands, urban streets often lack good tree coverage on the sidewalks or central plant beds along the streets. This paper conducts a qualitative study on tree arborization in seven public streets located in the urban area of São Carlos (São Paulo/Brazil). These streets were selected because of their high traffic flow. The methodology used in this research consists of an in loco qualitative analysis of urban trees using the Geographic Information System (GIS) to contextualize the road sections under study. The results showed the occurrence of species diversity, development stages, and the level of care and maintenance of trees along the streets assessed. The potential for inserting new arboreal specimens was also observed, which in terms of economic, visibility or luminosity factors, would cause no impairment.

Keywords *Urban trees, green infrastructure, public avenues, assessment.*

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1. INTRODUCTION

In a city, the avenues represent the arteries that connect the main points to neighborhoods and other locations. They are used by those who live there to walk or go to work, to transport the goods and resources produced, distributed and allocated in the city and to other municipalities. These are vital and strategic streets that interpret the care and the viewpoint of its people through its public space.

Most Brazilian cities, since the mid-1950s, due to market impositions and national industrial policy decisions to effectively and definitively establish cars as the main means of transportation nationwide, began projecting its avenues in order to sustain the volume of traffic. Urban tree arborization, little known when Brazilian cities were first formed, was mostly seen in private backyards and later in public spaces such as squares and parks. The urbanization process evidenced the need to associate the development of these areas with environmental conservation, contributing toward improving the quality of life of urban populations (Albertin *et al*., 2011). However, in the areas bordering the high traffic volume avenues, tree arborization is usually restricted to narrow sidewalks, or undersized plant beds along the streets. Generally in second place (although avenues are spaces that generate much heat and pollution), trees are moderately highlighted, not very representative and displaying low diversification given the diversity of the nation's flora and environmental landscape potential of urban tree arborization. The common citizens and public authorities were not galvanized with regard to its advantages.

When well planned, these roads can rely on a number of urban facilities, including afforestation. A well conducted street arborization in urban spaces provides, in addition to local beautification, humidity and cleaner air (Paiva & Gonçalves, 2002), a more shaded environment, shelter to birds, pleasant flower scents and mild temperatures.

Economically, the planting and maintenance of large trees that provide shade represents a better strategy than planting palm trees, which provide little shade and require more frequent care collecting its leaves. Over their life cycle, the dicotyledonous trees (palm trees are monocots species) require lower maintenance costs, live longer and provide many benefits when compared to medium or small trees (Geiger, 2004). However, this requires planting the individual trees in appropriate locations, with adequate spacing, lighting and sufficient space for their root and aerial development.

On the other hand, without proper planning to outline these streets, there may only be streets and sidewalks without any attention given to urban tree arborization, making this environment less gratifying for those who use it, either by car or on foot. Asphalt deformation, higher temperatures and less attractive streets are the disadvantages of a street with few or no trees. Other ecological problems can be mentioned as a result of poor planning regarding urban tree arborization, such as the loss of biodiversity caused by lack of shelter and food for the wildlife that remains in urban areas (Brun *et al.,* 2007). An inadequate selection of tree species can be problematic to pedestrians, because of their shoots (canopy) often at the height of pedestrians, or a root system that can break pavements, a potential danger that can injure people walking on these broken pavements. The purpose of this article is to conduct a critical tree arborization analysis of seven high

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traffic avenues in the urban area of São Carlos, a city located in the State of São Paulo (Brazil).

2. MATERIALS AND METHODS

The urban area of São Carlos, used as case study in this work, is located in the state of São Paulo. Seven high traffic volume streets were specifically selected: São Carlos Avenue, Trabalhador São Carlense Avenue, Francisco Pereira Lopes Avenue, Comendador Alfredo Maffei Avenue, Getúlio Vargas Avenue, Henrique Grégori Avenue and Teixeira de Barros Avenue. Figures 1 and 2 show the area and study object.

São Carlos is known as the Capital of Technology, it has two major public universities and many companies in the technology sector. According to the Brazilian Institute of Geography and Statistics, in 2015 its estimated population was of 241,389 inhabitants. Its total municipal area covers 1136.9 km², and its urban area is 85 km², or 7.5% of the municipal area (IBGE, 2016). According to the government of São Carlos, the current approximate estimate of light vehicles is of 176,000 units (São Carlos, 2016).

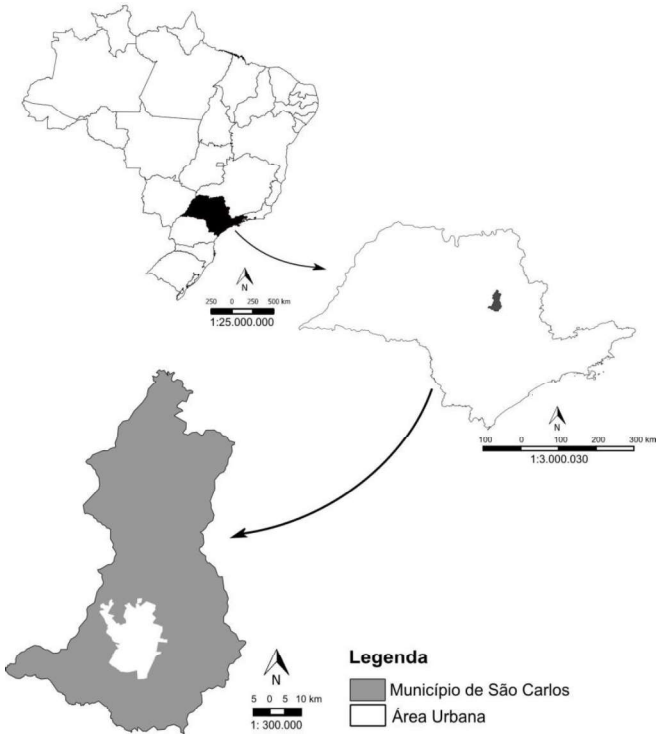

Figure 1. Overview of the location of the case study. Clockwise: political and administrative boundaries of Brazil, especially the state of São Paulo; location of São Carlos in the State of São Paulo; and the urban area of São Carlos.

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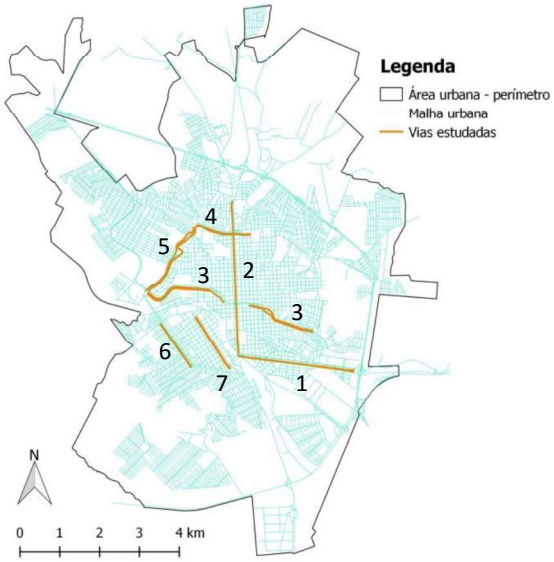

Figure 2. Urban area of São Carlos and its road network, especially the streets (avenues) studied: Getúlio Vargas (1); São Carlos (2); Alfredo Maffei (3); Trabalhador São Carlense (4); Francisco Pereira Lopes (5); Henrique Gregori (6); Dr. Teixeira Barros (7)

Direct *in loco* observation was carried out in all the avenues under study, recording their general characteristics as regards the existence, disposition, state of preservation and maintenance of tree species, as well as an assessment of the species selection for the location where they were planted. The Quantum GIS software (version 2.10.1), Geographic Information System (GIS) tool, was used to further understand and present the situation.

3. RESULTS AND DISCUSSION

Table 1 summarizes the information regarding the seven streets studied.

Table 1. Comparative analysis of the urban trees in the avenues studied.

Avenues analyzed	Length (m)	Average daily traffic flow	Arborization aspects
1. Getúlio Vargas	2.900	14.024	Cc (1,5m); Am; At; Ns; Md
2. São Carlos	3.900	7.041	Av; Ai; Ns; Md
3. Alfredo Maffei	4.000	11.383	Cc (4-35m); Av; At; Ns; Ch; Md
4. Trabalhador São Carlense	1.400	13.852	Cc (8-10m); Av; Ai; Ns; Ch; Md
5. Francisco Pereira Lopes	2.200	10.403	Av; At; Ns; Md; Ch; Md
6. Henrique Gregori	1.300	5.924	Cc (10m); Av; S; Ms
7. Dr. Teixeira de Barros	1.400	Ni	Cc (7m); Av; At; S; Ms

Source: São Carlos (2016). **Legend:** Ni – not informed; Cc – Central plant bed (in meters); Av – Varied arborization; Am – Monotonous arborization; At – Arborization along the street; Ai – Intermittent arborization; S – provides shade; Ns – Does not provide shade; Ms – Satisfactory maintenance; Md – Poor maintenance; Ch – Street along the water body.

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3.1 Street 1 assessed - Getúlio Vargas Avenue

Relevant aspects: This Avenue has a narrow plant bed with palm trees along its entire length (1.5 meters wide by 0.4 meters high). This street has no elaborate landscaping. Figure 3 shows the beginning of this avenue.

Problems encountered: The structure of the plant bed, 1.5 meters wide and 0.4 meters high, is an obstacle for pedestrian traffic. The sidewalks of this Avenue were not planned to include afforestation of dicotyledonous species. The sidewalk indentation between the retail establishments and the street has discrepancies, and with rare exceptions in some of these establishments there are trees of other species, all medium size, at most.

Figure 3. Partial view of Getúlio Vargas Avenue

3.2 Street 2 assessed - São Carlos Avenue

Relevant aspects: This is the main avenue of the city, given its connection with several other streets, although its traffic flow is not the highest (Table 1). This avenue has narrow sidewalks with streetlights and electric posts that are at times situated in the middle, demonstrating they were not adequately planned for pedestrian mobility. The urban trees along this street can be observed in the 8 squares positioned along both sides. However, this tree arborization serves the internal spaces more than the street. At the end of this avenue there are large-sized trees on the sidewalks, on both sides (Figure 4, second photo).

Problems encountered: This Avenue, with few exceptions, has trees due to the bordering squares. At the end of the street (near the cemetery) there is conflict with the electric wiring, the tree pruning performed that modified its design, bringing a different aesthetic to the canopies. These trees are in an undersized sidewalk for their size, evidencing its displacement in the direction of the street. In addition, in these examples a section is filled with cement, demonstrating inadequate care and maintenance. Except for the sidewalks of the squares, the other sidewalks located along this avenue were not planned for pedestrians, electric poles and trees.

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Figure 4. Two different sections of São Carlos Avenue. The first picture shows the urban trees of a square. The second photo (at the end of the avenue) shows the trees trimmed because of the electric wires.

3.3 Street 3 assessed - Alfredo Maffei Avenue

Relevant aspects: This Avenue shows a discontinuity in two sections, as seen in Figure 2. When referring to the first section, it is the one on the right. The avenue has a central plant bed, its width varies (4 to 35 meters) and the composition of the urban trees is varied. The green area segment accompanies the stream Córrego do Gregório. In the section where it passes through the city center, this stream is buffered. There was a vegetation recovery effort on the banks of the stream in the first stretch of the street (Figure 5). The avenue has a bike lane on one side of the street, but without any trees planned or aimed for this path. In the second stretch, walking paths and bicycle paths were built in the central plant bed which serve as a Permanent Preservation Area (Figure 5, on the right side), and there are also trash bins and cement benches. In this section, greater care was observed in the distribution and maintenance of the species, as well as the rest of the equipment.

Problems encountered: In both sections there are dead and vandalized species. Near the stream embankments there are no trees, with the occurrence of erosion and landslides during the rainfall periods. In some sections the pavement is raised due to undersized plant beds and tree species at more advanced development stages. The second section of this avenue, on the right, has pits (beds) on the sidewalks at every 20 meters for the inclusion of afforestation. However, few of these sites received plant species and many of the beds are cracked, which continues for the remaining sidewalk, prone to accidents for the pedestrians that circulate there.

Figure 5. Alfredo Maffei Avenue in the first and second section, respectively.

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3.4 Street 4 assessed - Trabalhador São Carlense Avenue

Relevant aspects: This Avenue follows the stream Córrego do Tijuco Preto, which was initially buffered. It has underutilized sections for afforestation (Figure 6) and the others with vegetation under development. There is no standard for local afforestation and its final section has more developed arboreal specimens (in greater numbers and variety), basically planted along the stream banks, consisting of a Permanent Preservation Area (APP).

Problems encountered: The first 160 meters of the Avenue, after the stream was unbuffered, could be afforested. However, this section only has grass as vegetation cover. Conflict with the electrical wiring was observed for some species.

Figure 6. Trabalhador São Carlense Avenue in the unbuffered section

3.5 Street 5 assessed - Francisco Pereira Lopes Avenue

Relevant aspects: Along most of the Avenue there is a bike path (Figure 7) in the central plant bed that accompanies the stream Monjolinho. There are several species in early development stages along this bed. However, there are some embankment sections that deteriorated from the rains and are eroding. The avenue, on one of its sides (stretch of about 600 meters) has a bush area of about 10 hectares (Environmental Preservation Area) belonging to the municipal government. At the end of this avenue there is a roundabout and the area is underutilized for planting tree species.

Problems encountered: There are landslips in some sections of the Monjolinho stream. There are many non-preserved species lacking maintenance (pruning), and also the occurrence of vandalism of small trees.

Figure 7. Francisco Pereira Lopes Avenue highlighting the bike path and landslip of the slope (photo on the right)

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3.6 Street 6 assessed - Henrique Gregori Avenue

Relevant aspects: This Avenue has a central plant bed (10 meters wide) with a walking path, bike path (Figure (Figure 8) and equipment such as trash bins, benches and light posts. The dispersed species provide shading along the walking path. There is species diversification at different development stages. In addition to the central plant bed, there are some species distributed (less frequently) along the external sidewalks.

Problems encountered: low maintenance was observed at this location due to lack of cleaning and acts of vandalism (broken trash bins). Although this section has tree arborization in many parts and there is a walking path, there are unfavorable points to practice exercises due to the level of car noise and gas emissions.

Figure 8. Central plant bed along Henrique Grégori Avenue.

3.7 Street 7 assessed - Dr. Teixeira Barros Avenue

Relevant aspects: A central plant bed of 7 meters, equipped with pavement at both ends and large individual trees in an advanced and uniform development stages planted in the center of this bed along its length. In sections of the street, the central bed has equipment such as benches. Aside from the central bed there are no species planted on the sidewalks (Figure 9).

Problems observed: Few flaws but it could receive new tree species.

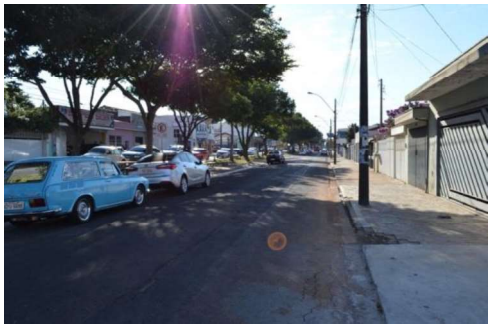

Figure 9. Dr. Teixeira de Barros Avenue and its central plant bed (on the left side)

3.8 Improvements in the qualitative aspect

Tree recovery could be performed at various points, as well as replacing dead or vandalized specimens.

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In general, the public sidewalks of the streets assessed were not designed to receive medium or large sized trees. Those that have tree arborization show poorly performed pruning, tabular roots breaking the cement pavements and undersized beds. The Building Code of São Carlos (São Carlos, 2011) states that the sidewalks should be built in a continuous plane. This City Law states that the circulation path (sidewalk) is an "*area of the main circulation path which must always guarantee an accessible physical path, a barrier-free path of travel, e.g., no elevated steps, pot holes* [...]". This document also states that the free circulation path should have a minimum width of 1.20m. Raised steps and pot holes were observed in several segments, as well as other types of discontinuities such as uneven and irregular pavements, posing risks to pedestrians. The width of the free circulation path, established by law, was also disregarded in several stretches. As they are narrow and sporadic, these paths are rarely in conditions – with few exceptions – to receive afforestation without any conflicts with urban constructions, electric wiring and other equipment that compose the sidewalks. In 2009 the Urban Afforestation Plan of São Carlos was instituted, which among other technical factors determines excavation specifications for individual trees along the public paths, determining minimum dimensions of 0.6m X 0.6m X 0.6m from the curb (São Carlos, 2009). In addition, other distance restrictions are determined in this decree in order to ensure that trees can fully develop, free of urban elements (traffic lights, drainage systems, bus stops, lighting poles and traffic signs, water and sewage networks), and subsequent trimmings resulting from a poor selection of species or technically flawed tree planting.

As the removal and replacement of trees is a non lucrative activity - except when at risk of collapse, pests or diseases that condemn the tree – the introduction of a new species occurs only when the tree has collapsed or expired. Therefore, selecting a greater tree variety is a strategy that emphasizes concern with the health of the urban forest, which can prevent verticalization in cases of disease or pest attacks.

There is significant difference between some of streets studied, such as 1 and 7 (Figures 3 and 9, respectively), considering the focus of this discussion addresses the central plant bed and its afforestation. Street 1, with palm trees planted along its length and a central plant bed of 1.5 meter wide (and 0.4 meters tall), obstructs pedestrian traffic and includes mostly monocots species, which despite their beauty, do not provide sufficient shade. Street 7, which has central plant beds that are 7-meter wide, and which predominantly includes varied dicotyledonous species, known as good shade providers. There is no difference in height between the level of the pavement and the trees planted, showing consideration for pedestrians. The width of the central beds, the mix of adult dicotyledonous species, the shading, spacing and positioning of trees in Street 7 are successful examples that could be replicated in new streets.

Table 1 exhibited maintenance deficiency in five streets (1, 2, 3, 4 and 5), and sporadic tree arborization in three streets. One of the streets (1) showed low species variability. Of the avenues assessed, five have central plant beds (1, 3, 4, 6 and 7), which showed these spaces have tree arborization. The average daily traffic flow was presented here to further the discussion regarding the need for afforestation in very busy streets, considering that plant species are responsible for partly sequestering the carbon gases emitted by motor vehicles.

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4. CONCLUSIONS

The afforestation observed in the avenues used as case study does not necessarily obey the strict criteria for species selection. Consequently, several trees already in advanced development stages are inadequate for the locations in which they were planted. However, they comprise the tree population and receive some maintenance, despite the fact these species are victims of poor tree trimming, undersized beds and are planted in inappropriate spaces.

In general, the assessed avenues have trees, although there are continuity gaps (quantitative aspect) and a lack of variety (qualitative aspect). The sidewalks, not designed to receive trees of any size, demonstrate a range of cases. While an effort in this direction by the local government can be perceived, street afforestation appears as only minimally satisfactory when there is afforestation in large squares or along long stretches of central plant beds.

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