Challenges in urban afforestation of the Amazon: exotic species and management

Desafios da arborização urbana na Amazônia: espécies exóticas e gestão

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ABSTRACT
This study was developed to evaluate the relationship among arboreal vegetation, physical structure, and the residents of Tabatinga, AM, Brazil, thus, providing additional information for future

afforestation projects. To evaluate the physical structure of tree insertion, a census with the residents of Avenida da Amizade was conducted, in which morphometric data of the trees and dimensions of sidewalks were collected; to assess the relationship with the population, 70 residents of different neighborhoods, age groups, and occupations were interviewed. Results indicated that the population recognizes that there are advantages in having tree-lined streets, but does not know exactly which advantages are these and does not act or feel responsible for the vegetation. The inventory showed that improvements in the parameters evaluated can make the relationship between the population and afforestation more harmonious and pleasant. For the implementation of an afforestation project, it is necessary to consider the tree and physical adaptations, and mainly, to involve the population.

Keywords: Dendrometry, Forest Inventory, Afforestation, Forest Policy and Law**.**

RESUMO

O trabalho foi realizado com o objetivo de estudar à relação da vegetação arbórea com a estrutura física e os moradores da cidade de Tabatinga, AM, consequentemente fornecer informações complementares para futuros projetos de arborização. Para avaliar a estrutura física de inserção das árvores foi conduzido um censo aos indivíduos presentes na Avenida da Amizade, onde foram coletados dados morfométricos das árvores e as dimensões das calçadas; para avaliar a relação com a população foram realizadas 70 entrevistas. Notou-se que a população reconhece as vantagens de se ter ruas arborizadas, porém ela não sabe quais vantagens, não atua em favor da conservação e não se sente responsável pela vegetação. O inventário apontou que melhorias nos parâmetros avaliados podem tornar mais harmonioso e agradável a relação da população com a arborização. Para a implantação de um projeto de arborização deve-se considerar as adequações arbóreas e físicas, e principalmente envolver a população.

Palavras-Chave: Dendrometria, Inventário Florestal, Arborização, Política e Legislação Florestal.

1 INTRODUCTION

Urban afforestation is important for people's quality of life, thus, requiring strategic planning to avoid problems that cause interference in urban elements (Roppa et al., 2007). However, when afforestation projects occur quickly and in a disorderly manner, they intensify conflicts between the population and areas with vegetation in the urban environment, causing a reduction in natural areas, which is one of the main causes of biodiversity reduction (Biondi and Lima Neto, 2011; Serret et al., 2014). The planting of new species, without the knowledge of their characteristics and the possibility of interaction with an existing afforestation, can cause discomfort and discontentment in the population (Coletto et al., 2008; Morita et al., 2020).

Aiming to maximize the benefits of urban afforestation and to optimize aesthetic and vital values, it is necessary that activities be well planned (Hoppen et al., 2014), through a survey of the conditions and possible conflicts in the present vegetation, in the infrastructure of the city, and in people's circulation, such as: sidewalks, electrical networks, sewage, road signs, and buildings (Roppa et al., 2007; Oliveira et al., 2016). Data related to the characteristics of the environment,

such as the conditions of sidewalks, are important to evaluate and plan afforestation (Bobrowski & Biondi, 2017).

The benefits of urban afforestation for society should be better studied, including improvements in the quality of life. For Serret et al. (2014), little has been studied about the impact of the urban matrix on biodiversity conservation, and studies that reconcile the perception of residents to the conditions of urban afforestation are scarce. In this context, the cities located on the western border of the Amazon are specific areas to be studied, due to peculiarities in the vegetal diversity of the Amazon rainforest and in the isolation of urban areas of other cities, due to difficulties in road transport.

The present work was developed in a systematic and integrated approach aiming to evaluate the relationship between tree vegetation, physical structure, and the residents of Tabatinga, AM, thus constituting another tool for the afforestation management projects of the city. Therefore, we expect to reduce the possible conflicts of afforestation with the population, suggesting alternatives to improve the quality of life of residents in urban environments.

2 MATERIAL AND METHODS

The research was carried out in the urban perimeter of Tabatinga, AM, located on the left bank of the Solimões/Amazon River, inside the Amazon rainforest (Euzébio, 2014). According to the IBGE census (2010), there are 36,371 residents in the urban area. The research site is located in the region called Open and Dense Ombrophilous Forest; its streets contain low density of trees, with greater expressiveness on the main street, called Avenida da Amizade (Silva et al., 2016), which is approximately 2.50 km long, with one central and two lateral beds (Fig. 1).

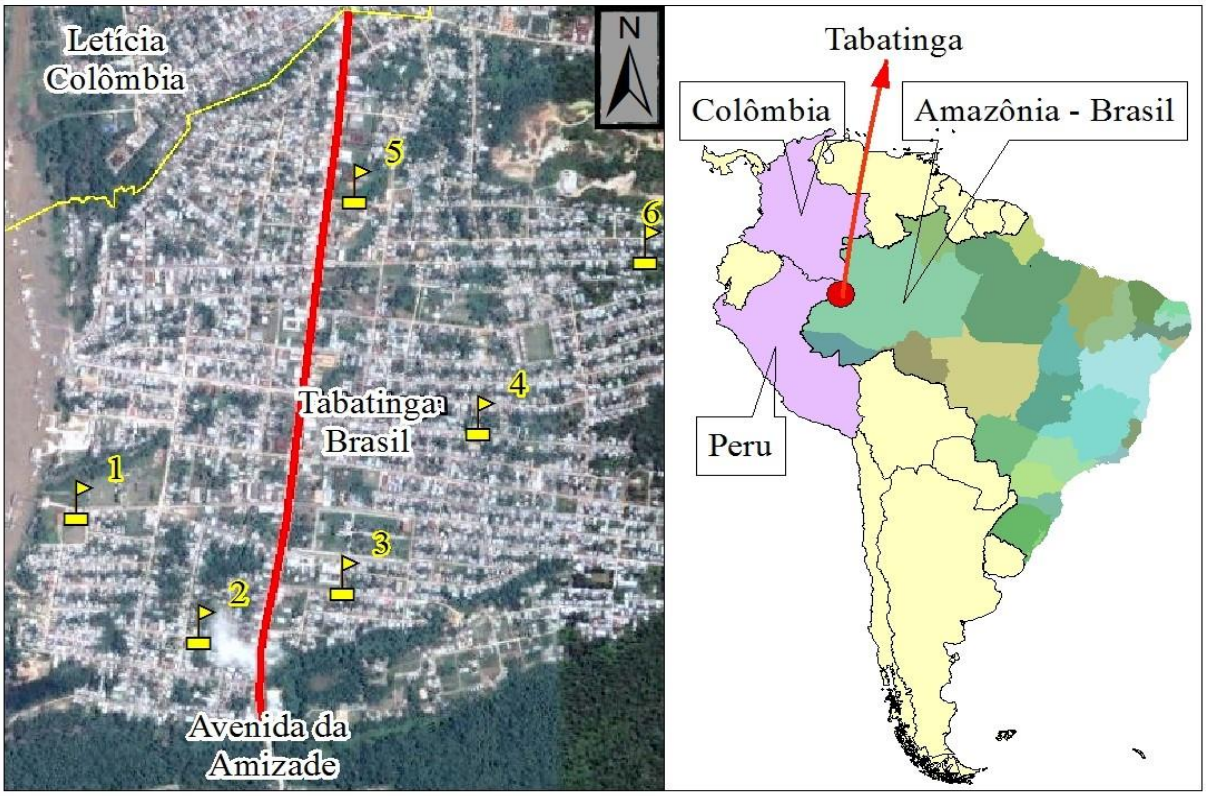

Fig. 1. Location of Avenida da Amizade and layout of interview locations in neighborhoods of Tabatinga, AM, 2013. Legend and number of respondents per neighborhood ( ): 1- Portobrás (20); 2- Brilhante (5); 3- Ibirapuera (12); 4- Comunicações (12); 5- Vila Verde (11); 6- Rui Barbosa (10).

This study used an integrated and systemic approach to assess the relationship between tree vegetation and the physical structure of the city and its adequacy with the residents of Tabatinga. It was considered that, in an urban environment, this relationship is not established in isolation, resulting in a complex structure (Andersson-Sköld et al., 2015). Therefore, the city was taken as a target for the discussion of afforestation characteristics that are recurrent in the state of Amazonas, also applying to other regions of Brazil. The methodological development included the following steps: qualitative-quantitative survey of the afforestation of the main avenue of Tabatinga and a survey with residents to assess their perception of afforestation.

The qualitative-quantitative survey was carried out in the form of a census (Biondi and Lima Neto, 2011), with 367 individuals (of shrub-tree size) present in the central bed and on the sidewalks of Avenida da Amizade between May and August 2018. For the perception assessment, 70 questionnaires were randomly applied to pedestrians who approached during the collection of morphometric data on the streets; the interviews were structured, with objective questions. The selection was random but it sought to cover individuals of different age groups, sex, and residence neighborhood (Fig. 1).

The collected morphometric data followed the recommendations of Oliveira & Tavares

(2012). The data were selected according to the relevance for this work and refer to the circumference of the base, height of the first bifurcation, projection of the average canopy diameter, trunk-sidewalk distance, distance from the canopy projection to the street, as well as the main damage found in the trees. The knowledge of the distance between the tree and the curb is important for planting with an adequate distance from the curb; data related to the canopy projection make it possible to observe the shading provided by the tree, as well as the possibility of its interference in urban equipment (Oliveira & Tavares, 2012).

3 RESULTS

The species identified in the census are listed in Table 1, containing 10 species in seven families, of which more than 80% were represented by only one species (*Ficus benjamina* L.), and the second species in number of individuals was *Dypsis lutescens* (H. Wendl.) Beentje & J. Dransf. Together, these two species reach almost 90% of the occupation of the study region with exotic species.

Table 1. Census conducted on individuals of shrub-tree size used in afforestation in Tabatinga, AM.

ID	Family	Scientific name	Common name	Origin	NI	%
1	Anacardiaceae	*Anacardium occidentale* L.	Cashew tree	N	3	0.82
2	Arecaceae	*Euterpe oleracea* Mart.	Açaí	N	5	1.36
		Coco nucifera L.	Coconut tree	N	5	1.36
		Elaeis guineensis Jacq.	Dendê (palm)	NA	7	1.91
		Dypsis lutescens (H. Wendl.) Beentje & J. Dransf.	Butterfly palm	E	30	8.17
6	Chrysobalanaceae	*Licania rigida* Benth	Oiticica	N	9	2.45
7	Combretaceae	*Terminalia catappa* L.	Country almond	NA	2	0.55
8	Fabaceae	*Erythrina indica* Picta	Indian coral tree	E	11	3.00
9	Moraceae	*Ficus benjamina L.*	Ficus tree	E	294	80.11
10	Sapotaceae	*Pouteria caimito* (Ruiz & Pav.) Radlk.	Abiu	N	1	0.27
				Total	**367**	**100.00**

Legend: ID = identification; N = native; E = exotic; Na = naturalized; NI = number of individuals.
Legenda: ID. = Identificação; N = Nativa; E = Exótica; Na = Naturalizada; NI = Número de indivíduos.

As for the qualitative-quantitative survey, the analysis of the circumference of the base showed that 62.94% of the tree individuals are between the 0.6-1.2 m range (Table 2). As the trees have continuous growth in diameter, it was considered that the concentration of individuals in the second class indicates the presence of young individuals, still in the maturation phase. By analyzing the height of the first bifurcation, we found that 48.5% of the individuals had a bifurcation between 0.5 and 1.0 m (Table 2), which can create conflicts of afforestation with pedestrians and cars.

Table 2. Quantitative data of the individuals that comprise the afforestation in Tabatinga, AM.

Circumference of the base (m)						
	Up to 0.6	0.6-1.2	1.2-2.0	2.0-2.6	> 2.6	SD
NI	36.00	231.00	90.00	5.00	5.00	0.42
%	9.81	62.95	24.52	1.36	1.36	
Height of the first bifurcation (m)						
	Up to 0.5	0.5-1.0	1.0-1.5	1.5-2.0	> 2.0	SD
NI	115.00	178.00	52.00	13.00	9.00	0.53
%	31.34	48.50	14.17	3.54	2.45	
Average canopy diameter (m)						
	Up to 2.5	2.5-3.8	3.8-5.1	5.1-5.9	> 6.4	SD
NI	21.00	72.00	166.00	85.00	23.00	0.88
%	5.72	19.62	45.23	23.16	6.27	
Canopy projection on the street (m)						
	Up to 1.5 m	1.5-2.5	2.5-3.5	3.5-4.5	> 4.5	SD
NI	203.00	54.00	41.00	25.00	44.00	1.72
%	55.31	14.72	11.17	6.81	11.99	
Distance from trunk to the sidewalk (m)						
	Up to 1.5	1.5-2.5	2.5-3.5	3.5-4.5	> 4.5	SD
NI	273.00	43.00	15.00	16.00	20.00	1.40
%	74.38	11.72	4.09	4.36	5.45	

NI - number of individuals; SD - standard deviation.

As for the canopy projection on the street, 55.31% is in the class up to 1.5 m; this pattern occurs because the beds support a large part of the projection of the trees; in addition, the canopies of trees of the central bed are often pruned. However, it was found that 11.99% exceeded the distance of 4.5 m, for which it is suggested pruning or cutting and replanting new species adapted to avoid further inconvenience. According to Bobrowski & Biondi (2017), this type of problem occurs due to the planting of species of inadequate sizes to the available urban space, to which the substitution for smaller species is recommended to avoid drastic pruning.

In the survey of damages, 70% of individuals showed some physical damage, that is, only 30% of the trees are healthy (Fig. 2). In the evaluation of plant health, 22.62% were found damaged by termites, ants, and other pathogens.

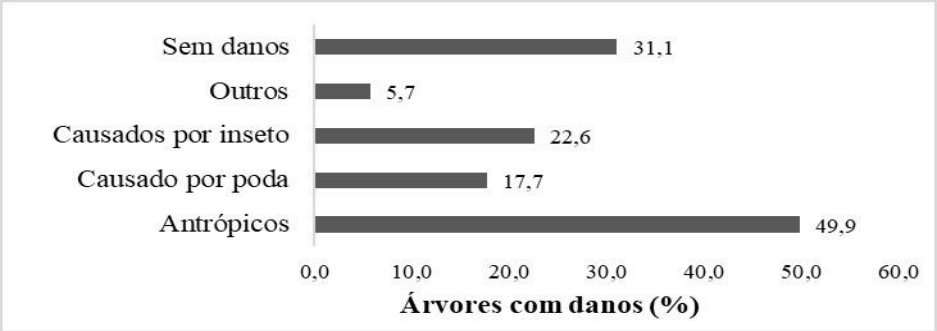

Figura 2. Damage found in the species inventoried in Tabatinga, AM.

The species morphological characteristics and the structural conditions of the planting site are essential for good afforestation. However, it is the population in general that lives daily with the benefits or problems of vegetation in urban environments. Therefore, we interviewed people interested in carrying out the research, in which 72.86% of respondents classified the afforestation as "good", and there was no bad classification (Table 3a).

Table 3. Analysis of residents' perception of urban afforestation in Tabatinga, AM.

Questions	Evaluation (%)	
a. How do you evaluate the afforestation in your city?	Good	Regular
	72.86	27.14
b. Do you think it is important to have a good afforestation?	No	Yes
	12.86	87.14
c. Do you see any advantage in having a tree-lined street?	No	Yes
	34.28	65.72
d. Do you see any disadvantage in having a tree-lined street?	No	Yes
	87.14	12.86
e. Have you ever had any problem with the trees on your street?	No	Yes
	84.28	15.72
f. Do you usually plant or care for trees?	No	Yes
	84.28	15.72
g. Does your neighborhood have any green areas?	No	Yes
	47.14	52.86
h. Are there neighbors in your neighborhood that take care of green areas?	No	Yes
	67.14	32.86

When asked about green areas in the neighborhood, 52.86% of respondents stated that they existed (Table 3g); however, it is known that there are only two public green areas; therefore, the fact that the city has borders in direct contact with the Amazon rainforest may have influenced their positive answer to this question. Despite the benefits of afforestation (65.72%), the residents are not accustomed to planting trees there.

4 DISCUSSION

For an area of approximately 2.5 km, the presence of only 10 species was considered low; however, the frequency of the species *Ficus benjamina* L. is worrisome since it is not recommended for urban afforestation due to the known aggressiveness of its roots that crack street and sidewalk pavements. At the time of the research, no visible ficus-related problems were found in relation to underground hydraulic networks, although there is a risk of perforating these installations. The second species in number of individuals (*Dypsis lutescens* (H. Wendl.) Beentje & J. Dransf.) does

not promote the improvement of the urban microclimate with its shadows and is present in more than 8% of the total percentage. Together, these two species reach almost 90% of the occupation of the study region with exotic species. Considering these percentages of occupation, we emphasize that there is no need for the use of exotic species in this region because there is a huge variety of natural or naturalized species, and in the present work, a little more than 10% of the species were found in these conditions.

Tabatinga is located on the banks of the Amazon River, inserted in the Amazon rainforest (Euzébio, 2014); therefore, it was expected that the city would reflect part of the local plant diversity. However, the afforestation in Tabatinga has low species diversity (Silva et al., 2016), which is not recommended for afforestation. Santamour Júnior (1990) recommended that no more than 10% of any species, 20% of any genus, or 30% of a single family should be included in urban afforestation.

As for the qualitative-quantitative survey, it was found that 48.5% of the individuals had their first bifurcation at a height between 0.5 and 1.0 m (Table 2), which can create afforestation conflicts with pedestrians and cars. Silva and Hasse et al. (2008) limited this data to a minimum height of 1.8 m, and Melo et al. (2007) considered that the ideal height to facilitate pedestrian traffic is 2.0 m. For new plantings, it is important to consider the minimum height of the first bifurcation for the acquisition of quality seedlings (Oliveira et al., 2016). The height of the first bifurcation indicates low quality of the seedlings used for planting (Oliveira et al., 2016), while the circumference of the base shows the presence of many young individuals. When assessing electrical wiring, road signs, and other aerial infrastructures, it may be necessary to perform formation pruning or even to cut and replant other species suitable for urban afforestation, so that in the future, these individuals will not cause problems.

The analysis of the treetops in urban roads indicated that the dimensions that provide greater shading without causing interference in buildings or wiring should be considered (Almeida & Rondon Neto, 2010). In this work, 45.23% of the inventoried individuals were found occupying a median interval for the parameter average canopy diameter; these dimensions are satisfactory, as they allow little interference on buildings, signs, or electrical wiring; however, the trees provide little shading, which negatively influences the local microclimate (Bobrowski & Biondi, 2017) and, therefore, social well-being.

In the variable distance from the trunk to the sidewalk, 75.39% of the individuals were in the smallest class, up to 1.5 m away, while 25.61% are more than 1.5 m away. The trees should be planted at an appropriate distance from the curb, so they can have free area for thickening of the trunk and growth of the root system. Nascimento & Guedes (2015) recommended that trees with deep roots should be chosen, as superficial roots result in damage to urban structures and can even

obstruct pipes.

In the evaluation of plant health, 22.62% of the trees were damaged by termites, ants, and other pathogens. This value can be justified by the poor use of pruning, low species diversity, and dominance of exotic species (Silva et al., 2016). One of the factors that explain the limited use of native species in urban afforestation is the lack of information about these species and their behavior in the urban environment (Biondi & Lima Neto, 2011). For Silva et al. (2016), it is necessary to invest in studies on new species aiming to increase diversity, especially of native species. Gerhardt et al. (2011), in studies conducted in Santo Cristo, RS, attributed the misuse of pruning, the high concentration of exotic species, and the lack of diversity as the causes of the high rate of damaged individuals (79.43%).

The damage caused by pruning was observed in 17.71% of the species found in the census; although it is a low value, these damages could be avoided if there was a training of professionals responsible for pruning. Pruning will always be an attack on the tree, which can affect its CO_2 assimilation; therefore, it must be done in a way to facilitate the healing of the cut, avoiding the entry of fungi and bacteria, responsible for the rotting of branches and trunks (Fini et al., 2015).

It was found that 50% of the trees showed anthropic damage in their structure, such as garbage inserted in the bifurcations, cuts, and drawings made in the bark. To minimize these situations, environmental education programs aimed at enhancing afforestation should be carried out. It is important to emphasize that the success of an afforestation program requires long-term and integrated actions between the public administration and the population. For this to happen, it is often necessary to establish policies focused on the environment, involving environmental education actions that can guide the community, always emphasizing the importance of well-structured afforestation, the incentive to adequate planting, and tree care.

Assessing the perception of residents, it was found that 72.86% of respondents rated afforestation as “good”, and there was no bad classification (Table 3a). It is believed that these results may have been influenced, in part, by the little information in relation to what would be an adequate or a really great urban afforestation or even to the presence of vegetation in the adjacent areas of the urban perimeter (Tabatinga is surrounded by the Amazon rainforest).

Afforestation is seen as important by 87.14% of respondents, and 65.71% perceive advantages in having tree-lined streets (Table 3b.c), corroborated by Bobrowski & Biondi (2017), Moser et al. (2016), Biondi & Lima Neto (2011) and Morita et al. (2020), for whom afforestation is extremely important in urban centers, being responsible for environmental and social benefits that help in the quality of life in cities and in the physical and mental health of the population. The responses show that the population recognizes an improvement in the quality of life from

afforestation and which characteristics of the landscape where they live can provide greater personal satisfaction to each individual and collectively.

Regarding the disadvantages, only 12.86% of the interviewees reported perceiving some disadvantage in having the tree-lined streets (Table 3d). This percentage is considerable and can be interpreted as a low level of awareness among the population regarding the importance of afforestation in the urban environment (Roppa et al., 2007). Recognizing the landscape where one lives and its benefits represents a greater level of awareness due to the complexity of the dynamism with which the landscape characteristics change over time and space.

As for the participation of residents in afforestation, 84.28% reported they do not plant trees and 67.14% were unaware of residents who cared for the vegetation in the study site (Table 3f, g), which shows that, despite the interviewees saying there are benefits with afforestation, they do not feel responsible for its maintenance. From these results it is possible to understand the little information accessed by the population interviewed and also the low participation in the management of urban afforestation, a fact that also leads to understand the level of 49.9% of anthropic damage found in the shrub-tree individuals (Figure 2).

The results point to the lack of information on the ideal conditions to maximize the benefits of afforestation. If, on the one hand, there is good acceptance of current vegetation conditions, the inventory showed that the parameters “height of the first bifurcation” and “distance from the trunk to the sidewalk” can cause conflicts with the population, thus constituting important tools for local afforestation planning and correct management. It is noted that a close look leads to believe in a certain degree of conformity of the population regarding the afforestation of Tabatinga, being important that they recognize the current situation of afforestation in their neighborhood, the aspects that need improvement, and the vegetation as an essential part of the city, aiming at a better quality of life.

It is believed that the introduction of species that can provide more ecological services and that are recognized by the population will motivate the participation of residents in the planning and maintenance of afforestation. The population’s contribution to the landscape is essential for improving the quality of works (Silva Filho et al., 2002), because without their participation and commitment, afforestation programs can become the target of vandalism, not achieving the expected results.

Given the above, it is essential that public agencies promote educational campaigns so that the population becomes aware of the importance of afforestation for the environment where they are inserted, thus enabling them to enjoy the benefits of adequate afforestation (Lacerda et al., 2010). For Shanahan et al. (2015), green areas inside cities can be a valuable tool for educational and

experimental opportunities, offering a contribution for biodiversity conservation.

An option for the involvement of the population may be the distribution of booklets or pamphlets with basic information on afforestation, which is an important initiative and tool for the restructuring of afforestation in many cities (Araújo et al., 2010). Environmental education and awareness work in primary schools tends to be very successful in the short term, in the sense that children speak to their parents and, especially, in the long term. Such works are effective when carried out continuously, preventing individuals from getting involved in degradation processes in the landscape.

5 CONCLUSION

There is a need for improvement in several structural parameters of urban afforestation that were evaluated in this research. There is great acceptance of the current conditions of the urban environment by the population, which exerts an opposite force to that improvement and can be observed by the lack of community involvement with afforestation projects in Tabatinga, AM. It becomes necessary to insert concepts of social responsibility and sustainable development, to promote harmonious and direct interaction between the population and vegetation, as well as the maintenance and conservation of public spaces. It is necessary to create environmental awareness and management projects so that the population is sensitized through environmental education and understands the benefits of an adequate urban afforestation to improve the landscape, aesthetics, and cultural quality of Tabatinga.

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