V!20
revista V!RUS
V!RUS journal
issn 2175-974x
ano 2020 year
semestre 01 semester
Julho 2020 July

MÉTODO PARA A CLASSIFICAÇÃO DA PERMEABILIDADE DE COPA DE ÁRVORES A METHOD TO CLASSIFY THE PERMEABILITY OF TREE CANOPIES

VIRGINIA NOGUEIRA DE VASCONCELLOS

Virginia Nogueira de Vasconcellos is an architect and urban planner, Master in Education and PhD in Architecture and Urbanism. She is a professor on the permanent staff of the undergraduate course at the School of Fine Arts at the Federal University of Rio de Janeiro, Brazil, and on the Graduate Program in Architecture at the same institution. virginia.vasconcellos@gmail.com

How to quote this text: Vasconcellos, V. M. N., 2020. A method to classify the permeability of tree canopies. Translated from Portuguese by Katia Arigone de Sá. *V!rus*, Sao Carlos, 20. [online] Available at: <http://www.nomads.usp.br/virus/virus20/?sec=4&item=13&lang=en>. [Accessed: 22 July 2020].

ARTICLE SUBMITTED ON MARCH 10, 2020

Abstract

This article presents a new way of organizing information and knowledge on trees for environmental comfort, setting actions to classify the permeability of their canopies. It aims to give support to professionals and researchers of the field through the calculation of the soil coverage percentage that the shade of canopies provides to urban hydrothermal comfort. Its relevance relies on considering that the percentage of light that passes between the leaves corresponds to the percentage of reduction of solar radiation that directly reflects upon the canopy. The method was developed at PROARQ-FAU-UFRJ and has been tested over various species in public areas. In the last year, we were able to adapt the method and test a new and faster way of calculating the "spaces between leaves". The process is based on the geometrization and photographic record of tree canopies and the calculation of the percentages of full and empty spaces by the MatLab program. The research has already classified four tree species and has been working on expanding the database with information on species used for urban landscape design in humid tropical climates. For future results, it intends to classify species from other Brazilian regions to facilitate the planning and specification of landscape design.

Keywords: Hydrothermal comfort, Urban landscaping, Environmental sustainability

1 Introduction

The native vegetation of a region is an important climatic indicator since plant species, their characteristics, and behavior, help to identify the local climate and vice versa. Its shape (plant architecture) is conditioned by the environment just as the environment takes advantage of the countless benefits generated by their species. Many exotic species have a great adaptation to distinct climatic situations different from their natural habitat, adjusting and collaborating with the anthropic environment. However, their insertion requires the knowledge and recognition of their main characteristics and behavior.

For landscape design studies, it is important to study each species, relating it to the characteristics of the built environment to verify its performance as to improve environmental comfort conditions, reduce energy consumption, and, consequently, enhance environmental sustainability. When dealing specifically with the role trees have in the built environment, we can observe various favorable contributions. Concerning environmental comfort, for example, trees are a fundamental element for the physical and mental well-being of the population. According to Olgyay (1963), the use of trees as a surrounding element of buildings precedes any aesthetic, protective, or entertainment usage. Trees represent a part of nature modified by men and, therefore, constitute a strong symbolic element.

We reaffirm that a tree is the main symbol of vegetation because of its size and shape, and its constitution as an element of a city's design. It identifies, organizes, and transforms the space, contributing to softening the climate and the harmful effects caused by the process of urbanization. It also brings man closer to the natural environment and plays countless roles in the everyday life of the city. Trees, with their canopies, control solar radiation by the obstruction, reflection, heat radiation, and filtering. They also help to control winds, since they can channel the beneficial winds and obstruct the unfavorable ones, increasing or reducing their natural flow, and even changing their direction. Regarding humidity control, trees modify the comfort levels because they absorb rainwater and return it to the atmosphere. Among many other benefits.

The structural composition of a tree is mainly established by its roots, trunk, and canopy. Each of these elements has vital functions for the development of the tree and has characteristics and specificities that differ from species to species. Hence, each one also has potential factors and adaptations for the built environment. Urban landscaping –defined as the group of trees planted in the city – seeks to elucidate and guide the appropriate specification for each situation, whether in parks, squares, or promenades. Depending on the extent of the project, the area available for planting, and/or physical obstacles of the environment, we can determine which species will bring the best results for the city's landscape planning. In any situation, this planning is essential.

The canopies, which combine different architectures, densities, and permeability, can guarantee a greater or lesser absorption of the incoming solar radiation. Although, there is no special focus on the performance of the canopy for urban hydrothermal comfort in the specialized literature.

In cities with a hot and humid tropical climate, protection against solar radiation is vital and the shading of trees should be available whenever possible. Vasconcellos (2006) recommends that urban free spaces, regardless of their use, have a guaranteed minimum percentage of 50% of their total area shaded by trees. It should be spread throughout their different areas, including those of circulation. The growing and rapid process of urbanization increasingly induces soil waterproofing, enhancing the risk of flooding. The occupation of slopes and riverbanks, which removes much of the vegetation, also strongly indicates that our forests and other plant formations are endangered and that their withdrawal causes problems to the city and society.

The re-establishment of the tree as an element of bioclimatic control, aiming at the proper specification of the species in different situations, is a relevant factor in the urban environmental comfort studies. It is crucial especially for the serious problems regarding climate change, which are already happening. Vegetation creates a harmonious environment between spaces that are natural and built, full and empty, and high and low. In this context, trees, bushes, and ground covers have many distinct characteristics but similar others concerning the bioclimatic control of spaces. The distribution of tree or shrub masses for wind and heat stroke (shading) control and/or the specification of lawns and ground covers, individually or associated, modify the microclimate and help to control human hydrothermal comfort: either by favoring the retention of natural humidity and soil permeability, or reducing the surface temperature or absorbing solar radiation, etc. (Vasconcelos and Barroso-Krause, 2011).

The understanding of how trees behave in the urban environment regarding environmental comfort is crucial for the planning and design processes of urban landscaping. In 2011, Vasconcellos and Barroso-Krause raised questions on the subject:

> But how does the tree behave in the urban environment and how can it help in the microclimatic control of the built spaces? How can vegetation be an inducing element of environmental quality? Which characteristics should be considered in the specification and location of trees to reduce energy consumption and establish design parameters focused on their sustainability? (Vasconcelos and Barroso-Krause, 2011, our translation).

These questions, which still concern us, are the basis of this work. Unveiling each of their parts, understanding their functioning for environmental comfort, is the premise of our investigations. Our concerns arise from the understanding of how the different levels of permeability of canopies can interfere in the attenuation of the solar radiation effects on the soil (and, above all, on people), contributing to the increase or decrease of air temperature and relative air humidity, fundamental variables for environmental hydrothermal comfort.

This work is about a new way of organizing information related to tree behavior, as an isolated element, to broaden the debate about the vegetation, environmental comfort, and landscaping. It intends to set the necessary actions to classify the permeability that a tree provides to the environment, minimizing incoming solar radiation and, consequently, reducing air temperature and glare. Its main objective is to give support to professionals and researchers of the field through the calculation of the soil coverage percentage that the shade of canopies provides to urban hydrothermal comfort and also to low-cost researches.

We did not find in specialized literature any systematic classification that assembles the percentage of permeability that each canopy (of each species itself) provides to minimize the negative effects of climate and incoming solar radiation based on its shading. In general, the studies on the behavior of vegetation in environmental hydrothermal comfort, especially about the reduction of solar radiation by afforestation, focus on qualitative experiments on tree clusters of parks, squares, and urban roads. They do not identify the characteristics of the species itself. They point out the contributions of tree clusters to the attenuation of solar radiation (and consequently air temperature) but do not examine the percentages of empty spaces inside the canopy. Among these studies, some articles, dissertations, and theses stand out. For example, the work of the research groups coordinated by Professors Lucila Labaki, at The University of Campinas (UNICAMP), Denise Duarte, at University of São Paulo (USP), and Virgínia Vasconcellos, at Federal University of Rio de Janeiro (UFRJ), in addition to others throughout Brazil and which are equally important to the research of this field.

It is important to emphasize that the reflections we make in this study are a new way of organizing the information and knowledge on trees for environmental comfort. We establish actions to classify the permeability of their canopies, contributing to ongoing researches and encouraging new studies, the absorption and dissemination of knowledge. It is also worth mentioning that this research is carried out in the Architecture Graduate Program at Faculty of Architecture and Urbanism at the Federal University of Rio de Janeiro – PROARQ-FAU-UFRJ – in the State of Rio de Janeiro, in southeastern Brazil. It was initially supported by CNPq (Brazilian National Council for Scientific and Technological Development), in 2008, which allowed the purchase of precision instruments, such as thermohydrometers, solar radiation sensors, anemometers, lux meters, and laser thermometers to measure surfaces temperature. Since 2018, we have the support of an undergraduate research intern, also through CNPq. In 2020, we will have the support of FAPERJ (Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro), also located in the State of Rio de Janeiro, to hire another intern.

Thus, after the investigation process of the permeability percentages of the canopies, we noticed a lack of information about this subject in the Architecture field. The subject is studies very closely by Plant Ecophysiology, which is "the science that studies all processes and vital plants responses regarding the changes of environmental factors" (Larcher, 2004, p. VI, our translation). It is an applied science used by Agronomy to predict the development and behavior of plants in agriculture and soil coverage.

Our initial concern, which has always focused on the contribution of trees to urban hydrothermal comfort, led us to seek new sources and, finally, develop a method to classify the permeability of canopies to the passage of light (and solar radiation). It is worth mentioning that the specialized literature dedicated to the selection of plant species in urban projects does not consider the percentages of solar radiation that passes through the canopies, classifying the trees as having small, medium, and high "density" according to their canopies.

This was the starting point of our work. According to Larcher (2004), we adapted and developed a method that systematically classifies the permeability of canopies. Simultaneously, we applied concepts, methodologies, and methods of spatial analysis and environmental comfort from Katzschner, Reinhold, and Lourenço (1999), Romero (2000), and Vasconcellos (2006), to test its applicability.

2 Theoretical references, the basis for the new method

Solar radiation is the main force that regulates the climate on the planet, decisively influencing all climatic scales in rural and urban areas. According to Givoni (1989), the incoming radiation over a rural area spreads over the vegetation and land surface. According to Larcher (2004), who worked on the distribution of solar radiation over the ground cover surface in forests (tree clusters),

The author also believes that the attenuation of radiation on the ground cover (he uses the term soil cover)

> a closed ground cover works as an assimilation system, in which the layers of leaves overlap and shade each other. At each depth of the ground cover, the radiation that gets through is gradually intercepted and used, being almost completely absorbed near the soil surface" (Larcher, 2004, p. 44, our translation).

depends on the leaves' density and arrangement, and the angle in which the radiation beats down on them. Larcher (2004) points out that we can obtain the leaf density quantitatively by its leaf area index (LAI). In other words, the LAI measures the number of leaves in m², per soil area (m²). Quoting Watson (1947), Larcher (2004) also points out that the cumulative LAI expresses "the whole leaf area surface per unit of soil surface" (Watson, 1947 apud Larcher, 2004, our translation). Consequently, we can characterize the interception of radiation on the ground cover by the space occupied by the leaves. By adapting the concept established by Larcher (2004) for the attenuation of solar radiation by the canopies isolated in the urban environment and understanding that it is influenced by the shape of the elements of the city, we can assume that the leaves of the canopy, whose permeability to light differs depending on their number of leaves, shapes, and overlaps, can also be influenced by the urban environment, such as shading of the surrounding buildings.

The main objective of the research is to design a faster method to classify the permeability percentages of the canopies. It is complemented by measurements with the use of instruments to classify their permeability and verify the behavior of the isolated species for environmental comfort. As a specific objective, we seek to verify the reduction degree of the incoming solar radiation that the canopies provide, contemplating the hydrothermal comfort of the population, especially in public leisure areas.

It is worth noting that Larcher (2004) works on the density of the canopy (and leaves) because he mathematically analyzes the overlapping of leaves on a given canopy. In our work, we replaced the term density with permeability since we work on the area and percentage of spaces between the leaves on the canopy.

3 The proposed method

The developed method is based on the concept of figure and background, and consists in calculating the "voids of light", that is, the spaces the leaves do not occupy in the images recorded by the researcher. The process relies on the photographic record of the canopies of three individual trees of the same species, from bottom to top, in at least three points (from where it is possible get their average values). The points are determined by the geometrization of the canopies and midpoints between the trunk and the intersection of the imaginary geometric on the canopy.

To classify the shape of the canopy, we decided to consider that the species, in general, can take circular or elliptical shapes. After the stage we called "geometrization of the canopy", we can to determine the midpoint for the photographic records. The images are then cropped and transformed into frames, in which we insert an orthogonal mesh of 10x10, totaling 100 spaces where the "empty and full spaces" are calculated. For empty spaces, we only consider the intervals that do not have any leaf.

How can we evaluate each canopy of different tree species? First, it was necessary to establish the desired permeability indices, that is, the intervals, to classify them by the percentages of empty spaces between the leaves. Another issue is that since a tree is a living element often modified by humans and which changes due to the environment, especially from wind, the records should consider more than one sample of each species and take into account the average of the occurrences as the average result of the analyzed species and not of each sample. After that, it was necessary to establish the methodological process itself, beginning with the species' choice, which need be fully-grown and have their original canopy structure (without any pruning or other drastic deformations).

Once we detected the lack of parameters that could properly define the percentages of light passage, we established the percentages from 5% to 39% for canopies that allow greater light permeability, species with thin canopies that obstruct a less amount of light; from 40% to 79% for species with light passage considered median; and above 80% of leaf obstruction for species considered to have a "dense" canopy.

To calculate the permeability percentages of the canopies, we took four species into account, one native and three exotic: *Licania tomentosa* (oiti, native), *Terminalia catappa* (almond tree, exotic) *Delonix regia* (flamboyant, exotic) e *Mangifera indica* (mango tree, exotic). We did not consider the species "origin" criterion since these species have a great adaptation to the Brazilian climatic and environmental conditions. All four species are widely used in landscaping, especially in the city of Rio de Janeiro, located in the southeast of Brazil. The main criteria for the selection prioritized the safety of the researchers, the architecture of the tree (fully-grown species, with good formation, and without drastic pruning), and its integration with the public landscaping system. However, for field measurements, which helps to compare the values measured with the classification process, we only used three species as the *Delonix regia* (flamboyant) fell due to a strong wind.

The first step was the photographic record of the species. This record allows us to register the architectural characteristics of the species: architecture (whole-body), the shape of the canopy, proportion between the height of the trunk and the canopy, and the color of the leaves. With the image of the tree, we proceed to the geometrization of its canopy, which corresponds to the insertion of a circle or ellipse in the largest possible portion of the canopy. We should emphasize that tree species have already been classified based on the structure of their canopies as round, oval, triangular, etc. (Salviati, 1993).

Our classification encompasses four basic models: round, vertical elliptical, horizontal elliptical, and triangular. Figure 1 shows the four used examples to present the geometrization of the canopies with the insertion of the circles that represent the structure of the trees and cover their canopies almost completely.

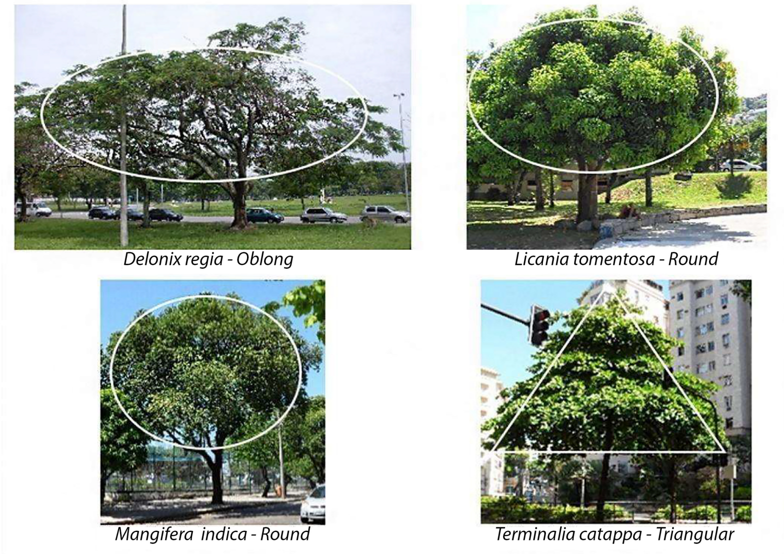

Fig. 1: Main formats of canopies adopted in the research and their respective geometrization Source: Research archive, 2011.

4 From the geometrization of tree canopies to the calculation of the empty spaces between leaves

The geometrization of the tree canopies is necessary to define the points from where the pictures will be taken and, later, the measuring points with the aid of instruments. We used two forms: the square and the rectangle, depending on the shape of the canopy. We inserted the squares and rectangles over the canopies. The intersection points on the edges of the square/rectangle canopy became the external point of the imaginary line that limits the space, while the other extreme was defined by the trunk of the tree. We took a minimum of 3 pictures in the center between these two points.

This procedure minimizes the interference of thick branches and the incidence of sunlight on the points. Still, to minimize the influence of the sun rays, the photos should be preferably taken around midnight. In Figure 2, we can observe the step-by-step process: the upper left photo shows the geometrization of the canopies; the lower left shows the process to define the points for photographic records and subsequent measurements; the right shows the photo edited in black and white with the orthogonal mesh for the calculation of the full and empty spaces.

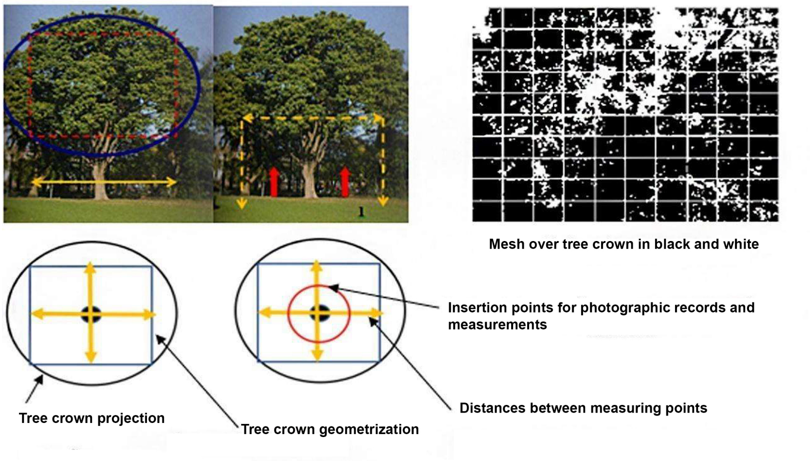

Fig. 2: Geometrization and definition of the points in the pictures and measurements, and insertion of the mesh for the calculation of empty and full spaces. Source: Research archive, 2011.

5 Working on the images: the step-by-step

Once in possession of the photographic records, we analyze the photos and selected the option that presents the least interference of the branches. We inserted an orthogonal mesh over the image and converted it to grayscale. It was necessary to change the image into grayscale to calculate the empty spaces. Figures 3 and 4 show, respectively, the photos of the canopies and the process of grayscale used in the images for the manual calculation process of the full and empty spaces.

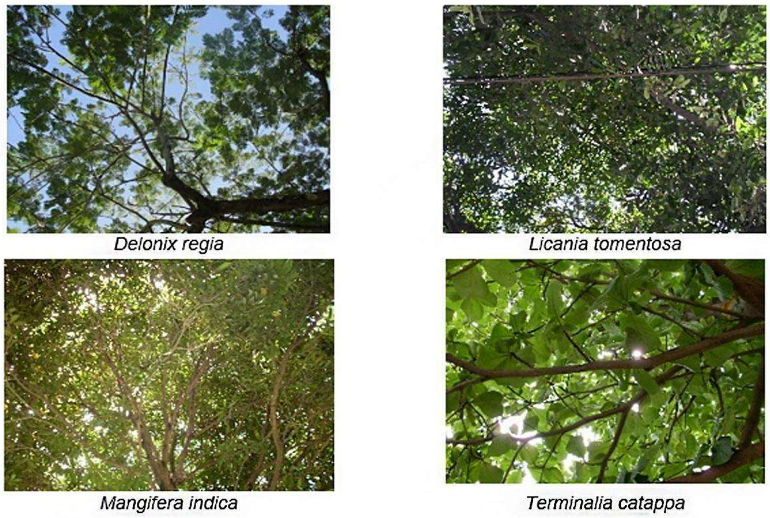

Fig. 3: Pictures of canopies. Source: Research archive, 2011.

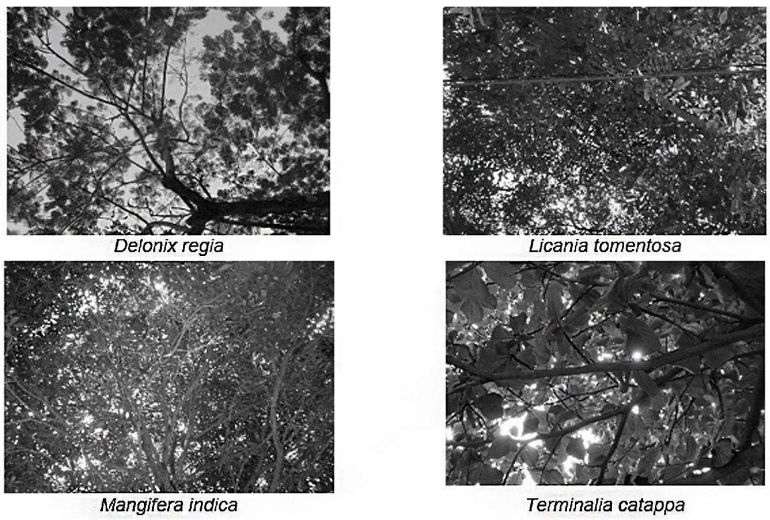

Fig. 4: Images edited on grayscale. Source: Research archive, 2011.

Initially, we calculated the points manually. In other words, we did an approximation of the sum of all the empty spaces on the orthogonal mesh. This sum corresponded to the percentage of empty spaces since it was measured on an orthogonal mesh of 10 x 10, totaling 100 equal small images. Figure 5 shows the mesh applied over the photograph of the *Mangifera indica*.

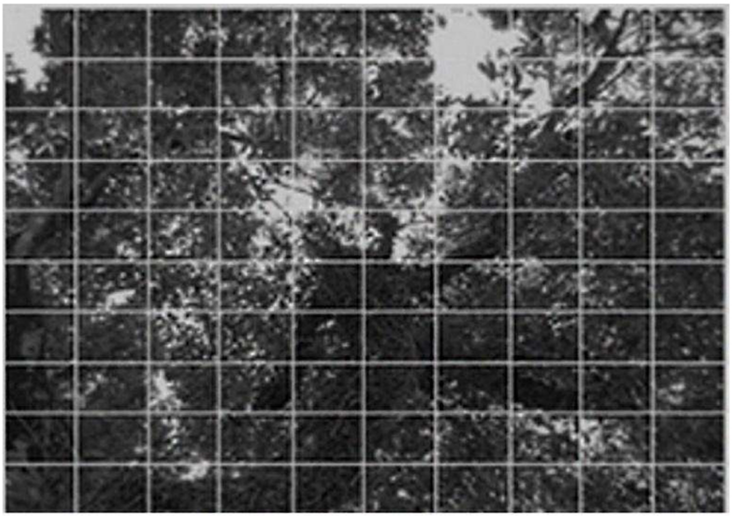

Fig. 5: Application of the mesh over the photo. Source: Research archive, 2011.

6 The application of the method

We carried out some studies to verify the results through the application of the method. One of the studies was the analysis of the reduction percentages of the incoming solar radiation on three tree species classified as having low permeability to the passage of light. In other words, three species that, according to the method's classification, allow little passage of light and, consequently, little incoming solar radiation.

Figure 6 shows the percentage values obtained by calculating the space by applying the mesh in three species: *Terminalia catappa* (almond tree), *Mangifera indica* (mango tree), and *Licania tomentosa* (oiti). It points out that almond trees block about 92.2% of the light, allowing only a percentage of 7.8% of light passage. Similarly, the mango tree absorbs about 94.1%, reducing to 5.9% the percentage of solar radiation that reaches the ground; and the oiti absorbs about 91.8%, allowing only 8.2% of solar radiation.

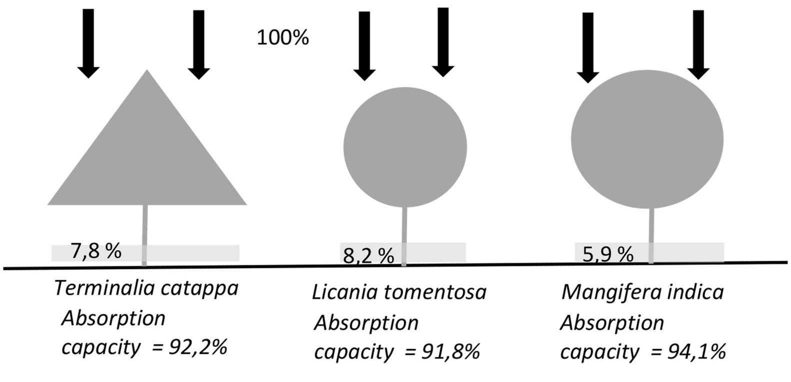

Fig. 6: Percentage of blockage and passage of light through the canopies in the analyzed species. Source: Research archive, 2011.

After the classification, the study was complemented by instrument measurements. The results presented in Table 1 represent the measuring averages and the percentages of blockage and passage of light in the canopy of the three species we measured. We measured the points under the canopies and points in the sun, close to each species (minimum distance necessary to avoid the shading of the point, which is determined by the species itself or elements of its immediate surroundings). We conducted four measurements at each point and produced the averages of the collected values. Two thermohydrometers, two solar radiation sensors, and two lux meters, properly calibrated were used. Measurements were taken at a distance of 1.80 m from the ground.

Table 1 also shows that there is a correlation between the percentages of permeability reduction and the other analyzed variables.

Species	% average of light blockage	% average of light passage	% average of solar radiation reduction	% average of temperature reduction	% average of relative humitdty addition	% averade of illuminance reduction
Terminalia catappa	92,2	7,8	88,5	7,6	10,4	90,8
Licania tomentosa	91,8	8,2	82,3	6,8	10	84,5
Magifera indica	94,1	5,9	89,7	4	8,1	92,4

Table 1: Average values obtained in the measurements with instruments. Source: Research archive, 2011.

7 Method revision

The method we developed has already tested some species found in open public spaces. Over the last year, we were able to test a new way of calculating the "empty spaces between leaves". This method speeded up the process since the manual calculation procedure greatly slowed the progress of the work down and its results could undergo a considerable change in the calculation of the empty spaces (percentage).

Currently, we work on the images using Matlab, a program that works with binary numbers and provides the percentages of full and empty spaces when we insert the photos. We heard about the program during a discussion in the Introduction to Scientific Research seminar at UFRJ. This fact reinforces the importance of publicizing studies and exchanging information between former and young researchers. It has also encouraged us to write this article.

Matlab for Windows[1] is a program developed for solving mathematical problems, which has also available a free version. Besides, it is the mechanism we are using to redo the calculations of the species already studied (for checking purposes). We are defining calculations for new species to expand our database. The program is easy to use, does not represent significant expenses to the research, and provides reliable results.

As main procedures for this new way of calculating the percentages of spaces between the leaves, we used the same method, geometrizing and taking photos at the midpoints between the intersection of the "geometrization" and the trunk, working on black and white images. It is not necessary to insert the mesh as the program already measures the empty spaces, providing the percentages previously obtained manually. The new step-by-step procedure accelerated our work. We can use any program to handle the image and change it into black and white. The second step is to import the photo into MatLab and type directly into the timelines, as shown in Figure 7.

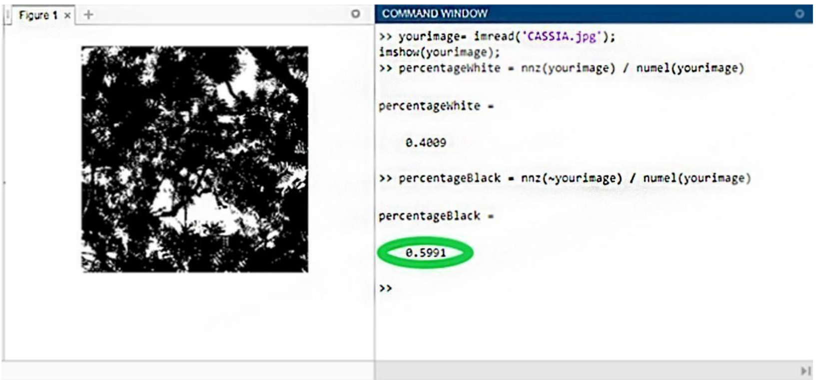

Fig. 7: Percentages of full and empty spaces in the canopy of a Cassia sp. Source: Documents of IT Service Catalogs, Matlab for Windows (2019), installation tutorial, 2019. Available at: https://www.ufrgs.br/documentacaoti/matlab-tutorial-de-instalacao/. Accessed in 4 Nov. 2019.

Aiming to improve the calculation of the full and empty spaces, we have certainly raised the research to greater level of practical and reliable results, speeding up the work and allowing the increase of the number of species classified according to the permeability of their canopies.

7 Final Considerations

The importance of urban landscaping planning is undeniable and it must be associated with urban planning as a whole. The issues of the city should be understood as a set of actions towards the same purposes – the city and its population.

OStudies on urban landscaping have focused on the species' specification and distribution, pest control, biodiversity, and even on the relationship between trees and environmental comfort, and the maintenance of native species to the climate adequacy. Nevertheless, these studies do not deal with the permeability degrees that their canopies provide, which causes variations in the passage of incoming solar radiation and, consequently, in the increase or decrease of temperature and relative humidity, important variables in the urban bioclimatic analysis. Given the importance of the adequate specification for environmental hydrothermal comfort, depending on the local climate, it is essential to understand trees' behavior, structure, and relevance. Thus, the search and/or adaptation of methods that allow the understanding of the importance of canopies to the reduction of the harmful effects of solar radiation is vital.

The method for the classification of the permeability of the canopies enables us to investigate, based on measurements that prove their results, the role of the permeability of the canopies for the reduction of the levels of incoming solar radiation. It is also possible to sort these levels of permeability and create a database with this information, which can be a convenient tool for the specification of landscaping in cities. The research has already classified four tree species and has been working to expand the database with information about the species used in urban landscaping, especially in humid tropical climates. In the future, we intend to classify species from other regions of the country.

The debates within the research group contributed to the considerations about the questions that permeate the discussion, enabling to encompass research, undergraduate, and graduate teaching, as well as to expand knowledge.

The proposed method is a practical and low-cost way to enable researches in the area. It differs from others because it correlates the permeability percentages of tree canopies individually for the reduction of solar radiation on the soil and, consequently, for the reduction of air temperature and the increase of urban hydrothermal comfort. We believe that the development of this procedure can contribute to the expansion of the knowledge about the vegetation characteristics, helping those who plan and specify urban landscaping, as well as fostering discussions about such issues.

Acknowledgements

This work was possible due to the support of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001. We thank CNPq and the Federal University of Rio de Janeiro, for granting the Introduction to Scientific Research (CNPq e UFRJ) and the Introduction to Artistic and Cultural scholarships (UFRJ).

To all the scholars and volunteers who were part of the research and who made the implementation and development of the presented method possible. To former scholar Antonio dos Santos Junior, whose dedication and contributions were of great importance at the beginning of this study. To students Gabrielle Procópio and Raquel Salvador for their help with imagery and MatLab program, enabling the completion of this article.

References

Katzschner, L., Reinhold, M., and Lourenço, L.D. 'Urban climate in the context of a sustainable development'. *Encontro Latino-Americano De Conforto Do Ambiente Construído.* Associação Nacional de Tecnologia do Ambiente Construído: Fortaleza, 1999.

Larcher, W., 2004. *Ecofisiologia vegetal*. São Carlos, São Paulo: RiMa.

Olgyay, V., 1963. *Design with climate: bioclimatic approach to architectural regionalism*. Princeton, New Jersey: Princeton University Press.

Romero, M. A. B., 2000. *Princípios Bioclimáticos para o Desenho Urbano*. São Paulo: Projeto Editores Associados. Ltda.

Salviati, E. J., 1993. Tipos vegetais aplicados ao paisagismo. *Paisagem e Ambiente*, 1993, (5), pp. 9-45.

Vasconcelos, V.M.N. de, Barroso-Krause, C; M. L. de. 'A amendoeira como aliada no conforto higrotérmico do ambiente construído – uma defesa pela reintrodução organizada da espécie na Cidade do Rio de Janeiro'. *XI Encontro Nacional De Conforto Do Ambiente Construído*. Associação Nacional de Tecnologia do Ambiente Construído: Buzios, Rio de Janeiro, 2011.

---

1 MATLAB – Windows – Tutorial de instalação. Available at: https://www.ufrgs.br/documentacaoti/matlab-tutorial-de-instalacao/. Accessed: 4 Nov. 2019.