Who has the Right to Urban Green Areas? Environmental Justice in a Brazilian Metropolis

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ABSTRACT

Urban green areas are essential for the quality of life of people living in large cities. In Brazil, 84.7% of the population lives in cities; however, studies assessing urban tree cover distribution and population's accessibility to such spaces are scarce. We aim at assessing urban green areas' distribution and accessibility in Rio de Janeiro City, according to places where people live in and to dominant economic classes in each neighborhood. In order to do so, 123 public areas larger than 5,000 m² were selected to the study, as well as the city's tree cover network. It was mainly done to analyze both tree vegetation distribution and afforestation rate *per capita* in each neighborhood in the city, and the profile of the population that has the greatest accessibility to herein selected green areas. In addition, the main aim of the present study is to analyze the likely contributions from tree cover to mitigate mean temperature increase in the city's neighborhoods. Based on the results, the white population, and the one with the highest income *per capita*, live in neighborhoods with milder temperatures, greater tree cover and closer to the selected areas. They potentially benefit more from ecosystem services than Black people and the low-income population. Finally, it is highlighted the need to find ways to achieve greater equity in the distribution of tree canopy coverage and accessibility to green areas.

Keywords: urban afforestation, urban forests, urban ecology, environmental urban history, environmental inequality.

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According to the United Nations, the world's urban population rate will increase from 54% to 66% between 2014 and 2050.[5] This rate is expected to be even higher in developing countries, such as Brazil, where 87% of the population lives in cities.[6] Currently, cities have proven to be unsustainable, regardless of their wealth, due to high atmospheric pollution, soil contamination and biodiversity loss rates, among others.[7] Solving these problems and improving the population's quality of life means adopting integrated policies for sustainable urban development.[8]

These policies must take into consideration green areas' strategic importance to achieve sustainable urban landscapes by providing local populations with better quality of life, based on their ecosystem services.[9] These green areas can significantly differ in size, vegetation cover, species' diversity, infrastructure, ease of access to and availability of services like squares, parks, corridors, community gardens, urban trees, riparian forests, lawns, among others. Moreover, they can offer four ecosystem service types, namely: regulation, habitat, provisions and cultural services.[10]

Populations' access to green areas has been related to reducing the incidence of several diseases. Thus, several studies have shown that regular contact to green areas can reduce childhood obesity and asthma cases[11], as well as mortality due to heart diseases[12], anxiety, stress and depression[13], since it has positive impact on psychological and social well-being factors.[14] Urban green areas are also essential to mitigate impacts

[5] ONU, World Urbanization Prospects: The 2014 Revision, 2015. https://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html (Accessed 20 April 2023).
[6] Maria José Andrade Núñez and T. Mitchell Aide, "Built up expansion between 2001 and 2011 in South America continues well beyond the cities", Environmental Research Letters 13 (2018): 1-6.
[7] Jennifer Wolch, "Green Urban Worlds", Annuals of the Association of American Geographers, 97 (2) (2007):373-384.
[8] ONU, World Urbanization Prospects: The 2014 Revision, 2015. https://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html (Accessed 20 April 2023).
[9] Anna Chiesura, "The role of urban parks for the sustainable city", Landscape and Urban Planning 68 (2004): 129-138.
[10] Rudolf S. Groot, Mateus A. Wilson and Roelof M. J. Boumans, "A typology for the classification, description and valuation of ecosystem functions, goods and services", Ecological Economics 41 (2002): 393-408.
[11] Susana Kay Cummins, Richard J. Jackson, "The built environment and children's health", Pediatric Clinics of North America 48 (5) (2001): 1241-1252.
[12] Christopher Coutts, Mark Horner and Timothy Chapin, "Using geographical information system to model the effects of green space accessibility on mortality in Florida", Geocarto International 25 (6) (2010): 471-484.
[13] Rachel Kaplan and Stephen Kaplan, "Adolescents and the Natural Environment: A Time Out?", in Peter H. Kahn-Jr, Stephen R. Kellert (eds.), Children and Nature – Psychological, Sociocultural, and Evolutionary Investigations (The MIT Press, Cambridge, Massachusetts, London, England, 2002), pp. 227-258; Daniel T. C. Cox et al., "Doses of Neighborhood Nature: The Benefits for Mental Health of Living with Nature", BioScience 67 (2) (2017): 147-155.
[14] WHO (World Health Organization), Urban green spaces and health, 2016. ttps://apps.who.int/iris/handle/10665/345751 (Accessed 20 April 2023); Nelson Grima et al., "The importance of urban natural areas and urban ecosystem services during the COVID-19 pandemic", PlosOne 15 (12) (2020): 1-13.

from climate change[15], since they help making cities more resilient to climate change, mitigating the impacts of rainstorms, flooding, heat islands' formation, desertification, fauna and flora species' loss and sea level rise.[16] In addition, access to public green spaces is one of the items in the United Nations Sustainable Development Goals (SDGs).[17]

Although the benefits provided by these areas for urban populations are globally acknowledged, their distribution can be uneven across cities.[18] Several studies developed in American and European cities, for example, have pointed towards the low availability of green areas in neighborhoods mainly occupied by minority or low-income groups.[19] Income, ethnic features, age and gender can influence green areas' distribution across the urban fabric.[20]

Studies carried out in six cities in the State of Illinois, USA, have shown that ethnic minority neighborhoods had less tree vegetation.[21] According to Wolch et al. (2005), neighborhoods with high concentration of Latinos in Los Angeles, State of California, USA, had 2 m² of green area per 1,000 inhabitants, but the institutional recommendation is for, at least, 33 m², on average. Areas with the highest rate of Black people have 6 m² of these areas, whereas neighborhoods with a non-Hispanic white majority had 128 m² of green area per 1,000 inhabitants.[22] Boone et al. (2009) carried

[15] Cecília Polacow Herzog and Lourdes Zunino Rosa, "Infraestrutura urbana: sustentabilidade e resiliência para a paisagem urbana", Revista Labverde (1) (2010): 92-115.
[16] Ibid; William Solecki and Peter J. Marcotullio, "Climate Change and Urban Biodiversity Vulnerability", in Thomas Elmqvist, Michail Fragkias, Julie Goodnes, Burak Güneralp, Peter J. Marcotullio, Robert I. McDonald, Susan Parnell, Maria Schewenius, Marte Sendstad, Karen C. Seto, Cathy Wilkinson (eds.), Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities (Springer Dordrecht Heidelberg New York London, 2013), pp. 485-504.
[17] ONU, World Urbanization Prospects: The 2014 Revision, 2015. https://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html (Accessed 20 April 2023).
[18] Jennifer R. Wolch, Jason Antony Byrne and Joshua Peter Newell, "Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'", Landscape and Urban Planning 125 (1) (2014): 234-244; Richieri Antonio Sartori et al., "Urban afforestation and favela: a study in a community of Rio de Janeiro, Brazil", Urban Forestry & Urban Greening 40 (2019): 84-92.
[19] Peter Groenewegen et al., "Vitamin G : effects of green space on health, well-being, and social safety", BMC Public Health 6 (149) (2006): 1-9; Dajun Dai, "Racial/ethnic and socioeconomic disparities in urban green space accessibility: where to intervene?", Landscape and Urban Planning 102 (4) (2011): 234-244; Sudipto Roy, Jason Byrne and Catherine Pickering, "A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones", Urban Forestry & Urban Greening 4 (11) (2012): 351-363; Jennifer R. Wolch, Jason Antony Byrne and Joshua Peter Newell, "Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'", Landscape and Urban Planning 125 (1) (2014): 234-244.
[20] M. Matthew McConnachie and Charlie M. Shackleton, "Public green space inequality in small towns in South America", Habitat International 34 (2) (2010): 244-248; Jennifer R. Wolch, Jason Antony Byrne and Joshua Peter Newell, "Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'", Landscape and Urban Planning 125 (1) (2014): 234-244; Viniece Jennings and Cassandra Johnson Gaither, "Approaching environmental health disparities and green spaces: an ecosystem services perspective", International Journal of Environmental Research and Public Health 12 (2015): 1952-1968.
[21] X. Zhou and J. Kim, "Social disparities in tree canopy and park accessibility: a case study of six cities in Illinois using GIS and remote sensing", Urban Forestry & Urban Greening, 12 (2013): 88-97.
[22] Jennifer R. Wolch, John P. Wilson and Jed Fehrenbach, "Parks and park funding in Los Angeles: an equity-mapping analysis", Urban Geography 26 (1) (2005): 4-35.

out a survey in Baltimore City, State of Maryland, USA, and pointed out that neighborhoods with the largest white populations have the largest green areas.[23] McConnachie and Shackleton (2010) conducted a research in South Africa and reached a conclusion similar to the aforementioned one.[24]

Studies on this topic remain scarce in Brazil, although it is particularly important for Brazilian cities, since the country is expected to have almost 90% of its population living in them, by 2050.[25] According to the United Nations, Rio de Janeiro, the second largest Brazilian city, will be the 23rd largest urban agglomeration in the world by 2050 due to the addition of 14 million people, to its metropolitan area.[26] The city's green fabric is covered by important fragments of Atlantic Forest, including a wide system of green areas and open spaces that encompass woods, tree-lined urban corridors, urban parks, historic parks, squares, public gardens, tree reserves, conservation units, among others.[27] Although not all green areas and open spaces are properly mapped, those that have already been recorded are unevenly distributed across the municipalities' 160 districts.[28] Rio de Janeiro, or any other city, must understand the disparities in the abundance, distribution and quality of urban green areas in order to better plan and promote environmental justice.[29]

It should be noted that urban environmental history, which can be understood as one of the lines of investigation within the broader field of environmental history, primarily focuses on the transformations of the relationships between societies, cities, and environments. It examines how human activities have influenced urban environments and how they have influenced them. It addresses issues such as land use

[23] Christopher G. Boone et al., "Parks and People: an environmental justice inquiry in Baltimore, Maryland", Annals of the Association of American Geographers 99 (4) (2009): 767-787.
[24] M. Matthew McConnachie and Charlie M. Shackleton, "Public green space inequality in small towns in South America", Habitat International 34 (2) (2010): 244-248.
[25] Marquiana de Freitas Vilas Boas Gomes, "Desigualdade socioambiental no espaço urbano de Guarapuava", RA'E GA (20) (2010): 95-105; Larissa de Lima Silva Elias, "Justiça Ambiental e distribuição de áreas verdes na cidade de Rio Claro – SP", (Trabalho de Conclusão de Curso, Universidade Estadual Paulista "Júlio de Mesquita Filho", 2012); ONU, World Urbanization Prospects: The 2014 Revision, 2015. https://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html (Accessed 20 April 2023).
[26] ONU, World Urbanization Prospects: The 2014 Revision, 2015. https://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html
[27] PDAU, Plano Diretor de Arborização Urbana da Cidade do Rio de Janeiro 2015. http://www.rio.rj.gov.br/dlstatic/10112/5560381/4146113/PDAUtotal5.pdf (Accessed 20 April 2023).
[28] Ibid.
[29] M. Matthew McConnachie and Charlie M. Shackleton, "Public green space inequality in small towns in South America", Habitat International 34 (2) (2010): 244-248.

and occupation from a historical perspective, urban planning, use of natural resources, climate change, environmental justice, environmental racism, and urban ecology.

In this regard, studies can be cited ranging from those that analyzed the quantity, distribution, and accessibility of parks in urban areas of Quito, considering the tripod: land value, poverty due to Unsatisfied Basic Needs, and ethnic self-identification, concluding that green areas are not evenly distributed[30] to the history of a plant and urban tree planting in a major city, such as the relationship between people and fig trees in Belo Horizonte throughout the 20th century.[31] Considering the spatial focus analyzed here, it is worth highlighting the issue of the struggle for access to and distribution of water, a vital resource for human survival, in colonial Rio de Janeiro[32], as well as the impacts and memories of floods in Rio de Janeiro in the second half of the 20th century[33] and environmental justice in a Rio de Janeiro favela and climate change.[34]

The aims of the present study were to assess inequalities in tree cover distribution across Rio de Janeiro City and population accessibility to urban green areas. We sought to analyze arboreal vegetation distribution and the rate of afforestation *per capita* in each neighborhood, as well as the profile of populations presenting the best accessibility to selected green areas, based on the selection of 123 public areas (larger than 5,000 m²) in the municipality and on its tree cover network. The goal was to analyze the likely contribution by tree cover to mitigate mean temperature increase in the city's neighborhoods.

[30] Nícolas Cuvi and Laura Catalina Gómez Vélez, "Los parques urbanos de Quito: distribución, accesibilidad y segregación espacial", Fronteiras: Journal of Social, Technological and Environment Science, 10 (2) (2021): 200-231.
[31] Regina Horta Duarte, "À sombra dos fícus: cidade e natureza em Belo Horizonte", Ambiente & Sociedade 10 (2) (2007): 25-44.
[32] Jorun Poettering, "Water and the struggle for public space: social negotiations in the usage of colonial Rio de Janeiro's waterworks", Brasiliana: Journal of Brazilian Studies 5 (2) (2017):154-170.
[33] Andréa Casa Nova Maia and Lise Sedrez, "Narrativas de um Dilúvio Carioca: memória e natureza na Grande Enchente de 1966", História Oral 2 (14) (2011): 221-254.
[34] Lise Sedrez and Roberta Biasillo, "Rooting Out Injustices from the Top: the multispecies alliance in Morro da Babilônia, Rio de Janeiro", Social Text 150 40 (1) (2022): 91-108.

METHODOLOGY

STUDY SITE

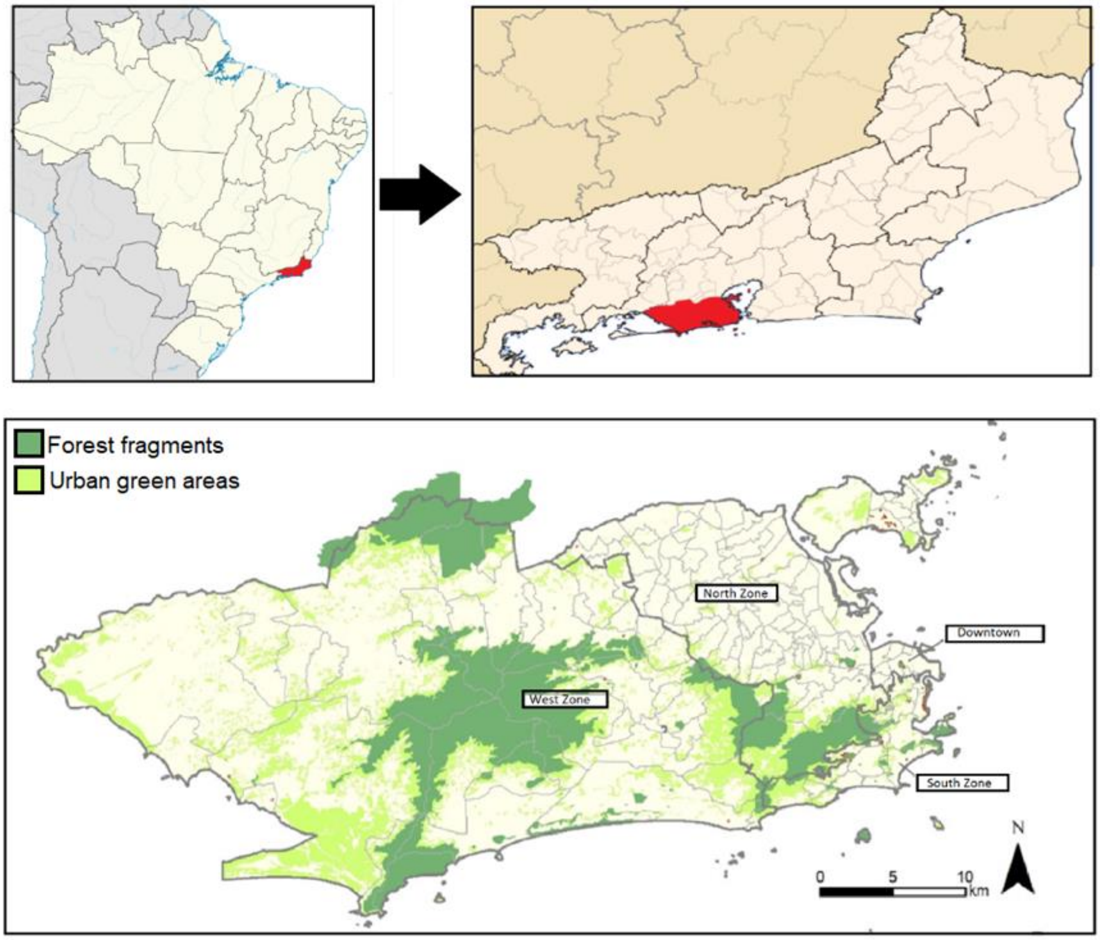
Rio de Janeiro City, Brazil was founded in 1565; its total area covers 1,200.177 km². It is considered the municipality with the highest demographic density in the country, with total population estimated at 6,775,561 people who are unevenly distributed across its territory.[35] In addition, approximately 25% of the municipality is forested.[36]

Only municipalities that match the definition of "European Common Indicators" were taken into consideration in the green areas' accessibility analysis. It includes parks, gardens and open areas (larger than 5,000 m²) open to the public.[37] Green areas were the ones previously identified by the City Hall as squares, conservation units and urban parks in compliance with European Common Indicator standards, if one takes into account that not all areas in Rio de Janeiro City are properly classified into these categories. An essential element for ecosystem services' provision was filtered according to the existence of tree cover by taking into consideration that some areas included in these criteria could still lack afforestation. In addition to be classified as squares, elements such as conservation units, urban parks, public space and having more than 5,000m² needed to be subjected to afforestation. Therefore, the total number of 123 green areas was taken into consideration (303 hectares, in total) in the current study. More specifically, 34 urban parks, 66 squares, 21 natural parks and 2 natural monuments were herein included (23 conservation units, in total) (Figure 1).

Study site included the entire arboreal vegetation of the city in the analysis of green areas' distribution across the municipality. In 2010, this phytophysiognomy accounted for 384 km² of urban land that was not evenly distributed over Rio de Janeiro's urban space.

[35] IBGE, Sinopse do censo demográfico 2010 (Brasil: Instituto Brasileiro de Geografia e Estatística, 2010). http://www.censo2010.ibge.gov.br/sinopse (Accessed 20 April 2023).
[36] Projeto MapBiomas, Coleção v. 7.1 da Série Anual de Mapas de Uso e Cobertura da Terra do Brasil. https://plataforma.brasil.mapbiomas.org/. (Accessed 20 April 2023).
[37] Ambiente Italia Research Institute. European Common Indicators: Towards a Local Sustainability Profile – Final Report, 2003. http://www.cityindicators.org/Deliverables/eci_final_report_12-4-2007-1024955.pdf (Accessed 20 April 2023).

Figure 1. Map of the green areas distributed by zones in the municipality of Rio de Janeiro. Caption: Dark green = Forest fragments; Light green = Area with recent tree cover, squares and parks.



Source: Cartographic elaboration by the authors.

Database

Urban land-use data were provided by Rio de Janeiro City Hall database, such as land locations and survey years: tree covers (2010), urban parks (2014), squares (2015) and conservation units (2017). Temperature data between 1984 and 2010 for each neighborhood was voluntarily provided by the Department of Geosciences of Federal Rural University of Rio de Janeiro.

Social data used in the present study were obtained from the last census carried out by the Brazilian Institute of Geography and Statistics (IBGE), in 2010. They were organized by the mesh of census sectors in the same year.[38] According to IBGE, in 2010,

[38] IBGE, Sinopse do censo demográfico 2010 (Brasil: Instituto Brasileiro de Geografia e Estatística, 2010). http://www.censo2010.ibge.gov.br/sinopse (Accessed 20 April 2023).

the white population in Rio de Janeiro municipality totaled 3,233,243 individuals; Black people were 723,432, Asian descendants individuals were 46,471, brown 2,305,442 and indigenous 6,756. Data were also collected from children aged 0 to 9 years, who, in that same year, totaled 759,548 individuals and elderly people over 60 years, it totaled 940,280.[39] Social and economic data, based on the populations' income per capita in each neighborhood, were provided by the 2010 Census base.

ANALYSES

Data on the distribution of tree cover in the city cover distribution in the city and on the 123 selected green areas (bigger than 5,000 m²), as well as populations' socioeconomic features, according to census sectors and neighborhoods. Spatial analyses were performed in ArcGis 10.4 software.

An analysis was carried out by dividing the wooded area in each neighborhood by its respective total area to better understand differences between the city's neighborhoods (in terms of presence of vegetation); thus, it was essential generating an individual tree cover rate for each neighborhood. We also sought to understand the ratio of wooded area *per capita* in each neighborhood. Accordingly, an investigation was performed by dividing the total area covered by tree vegetation by the total population in the neighborhood. A map depicting the city's neighborhoods was plotted for each new analysis.

A survey was carried out based on data from the City Hall of Rio de Janeiro to understand the association between tree cover and each racial ethnic group in the 2010 Census (Whites, Blacks, Browns, Asian-descendants and Indigenous peoples); according to which, rate of attendees in each group, based on neighborhood, and the respective tree cover rate were compared. The tree rate table based on the prevalent group was developed. Data on the rate of children and elderly people, and on income *per capita*, in the neighborhood in question, were the approached population variables.

Tree cover data were important to assess the likely contribution from this vegetation to mitigate temperature increase in the neighborhoods. In order to do so,

[39] Ibid.

tree vegetation rate in the neighborhoods was calculated. Subsequently, a graph was plotted by comparing this rate to the mean temperature in each neighborhood.

The profile of residents was assessed to better learn about accessibility in the 123 selected green areas. Three distance ranges were created for the herein selected areas, based on standards recommended by the European Commission and the American Environmental Protection Agency about the distance people should live from a green area, namely: 300 m, 500 m and 1,000 m.[40] These buffers were superimposed to municipality's census sectors to allow the calculation of White, Black, Asian-descendants and Brown populations, in addition to the population of elderly and children.

Multivariate analyses were carried out in the R software[41], Vegan package[42], to correlate population variables to both forest cover in the neighborhood and temperature. Discriminant analysis was performed in MASS package.[43] In addition, PCA was performed based on seven variables: Forest Coverage, Mean Temperature, Income, Number of White individuals, Number of Black individuals, Number of Children, and Number of Elderly Individuals. Initially, these was performed to better understand whether any of these variables were collinear. Finally, multiple logistic regression was performed to better understand the variables most closely related to forest cover.

Results

Comparison between neighborhoods based on tree vegetation and wooded area per capita

Urban green areas in Rio de Janeiro City are not homogeneously distributed among the city's neighborhoods (Figure 2). Afforestation rate in Northern Rio de Janeiro City ranged from 0.1% to 14%; this rate is lower than that recorded for the rest of the city. Neighborhoods in the Southern and Western zones recorded rates ranging from

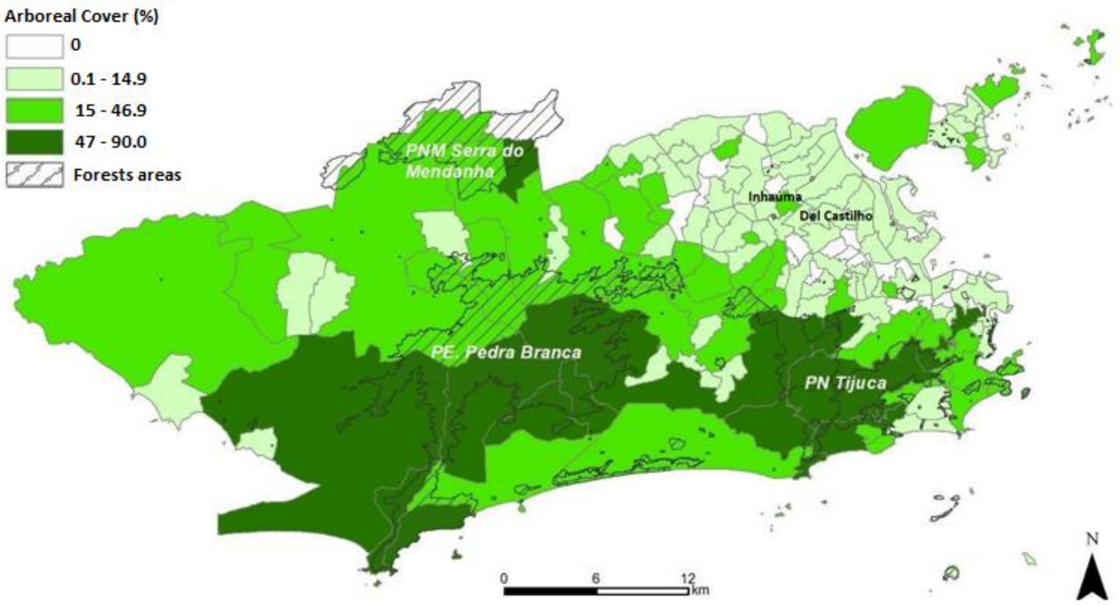
[40] Ambiente Italia Research Institute. European Common Indicators: Towards a Local Sustainability Profile – Final Report, 2003. http://www.cityindicators.org/Deliverables/eci_final_report_12-4-2007-1024955.pdf (Accessed 20 April 2023); Brian R. Pickard, Jessica Daniel, Megan Mehaffey, Laura E. Jackson, Anne Neale, "EnviroAtlas: a new geospatial tool to foster ecosystem services science and resource management", Ecosystems Services 14 (2015): 45-55.
[41] R Core Team. R: a language and environment for statistical computing, "R Foundation for Statistical Computing", Vienna, Austria. URL (2023).
[42] Jari. F. Oksanen, Guillaume Blanchet, Michael Friendly, Roeland Kindt, Pierre, Legendre, Dan McGlinn, Peter R. Minchin, R. B. O'Hara, Gavin Simpson, Peter Solymos, M. Henry, H. Stevens, Eduard Szoecs, Helene Wagner, "Vegan: Community Ecology Package", R package version 2.5-3. (2023).
[43] Brian D. Ripley, "Modern Applied Statistics with S" (Springer New York, 2002).

15% to 90%. In total, 22 (13%) of the 160 neighborhoods in the municipality do not have a tree-lined area highlighted in their tree cover map. These neighborhoods are mostly located in the Northern Zone of the city and are surrounded by neighborhoods with low arboreal vegetation distribution *per capita*. Grumari and Camorim neighborhoods, Western Rio de Janeiro City, account for 44,000 m² and 3,000 m² coverage *per capita*, respectively. They mainly stand out for this feature. Neighborhoods with the most arboreal vegetation *per capita* are found in this region (Figure 3). Areas presenting the highest tree cover rates (47%-90%) are directly associated with Rio de Janeiro City's two coastal massifs: Tijuca and Pedra Branca, whose territory is mostly circumscribed by Tijuca National Park (4,000 hectares) and Pedra Branca State Park (12,500 hectares), respectively – two of the largest urban forests in the world.[44]

The urban vegetation is of fundamental importance for maintaining health and social well-being.[45] However, it is portrayed as a social thermometer between richer and poorer areas, mainly reflecting social, ethnic, and gender differences in large metropolises.[46] This fact has been observed in the United States[47] , Japan[48], Brazil[49], and Europe [50].

[44] Gabriel Paes da Silva Sales and Rejan R. Guedes-Bruni, "New sources of biological data supporting environmental history of a tropical forest of south-eastern Brazil", HALAC – Historia Ambiental Latinoamericana y Caribeña 13 (2) (2023): 281-308.
[45] Bo-Xun Huang, Wen-Ying Li, Wen-Juan Ma, Hua Xiao, "Space Accessibility and Equity of Urban Green Space", *Land* , *12*, (2023), 766. https://doi.org/10.3390/land12040766; Rebecca Leigh Rutt and Natalie Marie Gulsrud. "Green justice in the city: A new agenda for urban green space research in Europe", Urban forestry & urban greening. 19 (2016): 123-127; Jennifer R Wolch, Jason Byrne and Joshua P. Newell, "Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'", Landscape and urban planning, 125 (2014): 234-244; Alessandro Rigolon, Matthew Browning and Viniece Jennings, "Inequities in the quality of urban park systems: An environmental justice investigation of cities in the United States", Landscape and urban planning, 178 (2018): 156-169.
[46] Charlotte Liotta, Yann Kervinio, Harold Levrel, Léa Tardieu, "Planning for environmental justice-reducing well-being inequalities through urban greening", Environmental Science & Policy,112 (2020): 47-60.
[47] Zbigniew J. Grabowski, Timon McPhearson and Steward T.A. Pickett . Transforming US urban green infrastructure planning to address equity. Landscape and Urban Planning. 2023. 229, 104591; Lauren E. Mullenbach, Sonja A. Wilhelm Stanis, Emily Piontek, Birgitta L. Baker and Andrew J. Mowen, "Centering environmental justice: Gentrification beliefs, attitudes, and support of parl development in a shrinking city", Landscape and Urban Planning, 216 (2021): 104253.
[48] Shinya Yasumoto, Tomoki Nakaya, and Andrew P. Jones, "Quantitative environmental equity analysis of perceived accessibility to urban parks in Osaka Prefecture, Japan", Applied Spatial Analysis and Policy, 14 (2021): 337-354.
[49] Richieri Antonio Sartori, Gustavo A. C. Martins, André S. Zau and Lucas S. C. Brasil, "Urban afforestation and favela: a study in a community of Rio de Janeiro, Brazil", Urban Forestry & Urban Greening 40 (2019): 84-92.
[50] Nadja Kabisch, Michael Strohbach, Dagmar Haase and Jakub Kronenberg, "Urban green space availability in European cities", Ecological indicators, 70 (2016): 586-596.

Figure 2. Percentage of tree cover by neighborhood in the city of Rio de Janeiro, RJ, Brazil. Highlights include the Serra do Mendanha Park (PNM Serra do Mendanha), Pedra Branca State Park (PE Pedra Branca), Tijuca National Park (PN Tijuca) and the neighborhoods of Zona Norte Inhaúma and Del Castilho

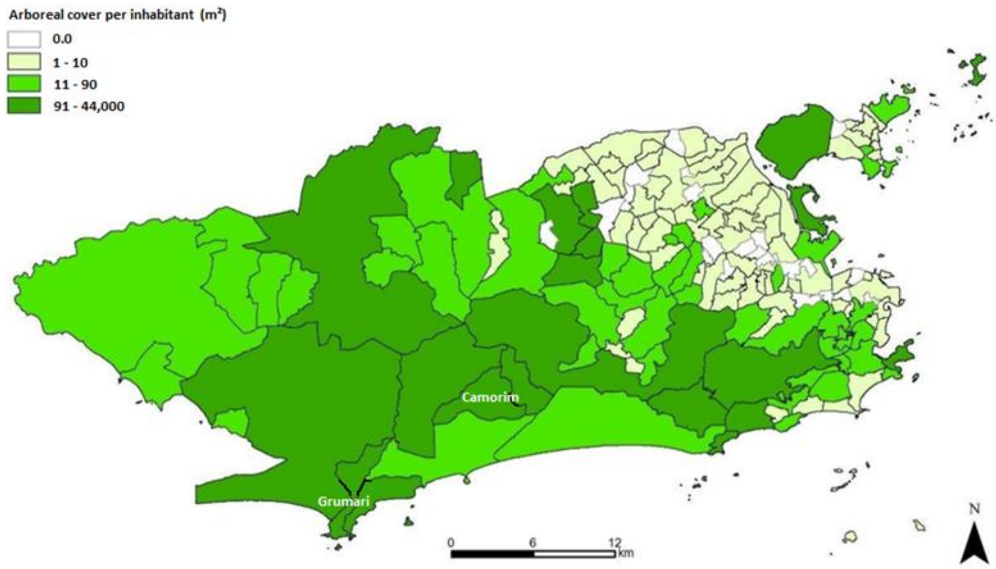


Source: Cartographic elaboration by the authors.

Green areas are considered essential for neighborhoods where there is more government involvement, such as wealthier neighborhoods or even private areas where parks and squares can be found within condominiums.[51] However, they are practically nonexistent in poorer neighborhoods[52] , indicating government neglect, as well as a lack of attention to other fundamental aspects like basic sanitation and security. This issue is crucial to consider green areas as a social interest, as they are favored in more affluent neighborhoods, highlighting a concrete concern for green spaces and revealing a significant elitism[53]. This is one of the main factors related to environmental injustice.[54]

[51] Bo-Xun Huang, Wen-Ying Li,Wen-Juan Ma and Hua Xiao, "Space Accessibility and Equity of Urban Green Space", *Land*, *12* (2023): 766. https://doi.org/10.3390/land12040766.
[52] Holger Sieg, V. Kerry Smith, H. Spencer Banzhaf, Randy Walsh, "Estimating the general equilibrium benefits of large changes in spatially delineated public goods" International Economic Review, 45 (2004): 1047–1077.
Jolanda Maas, Robert A Verheij, Peter P Groenewegen, Sjerp de Vries and Peter Spreeuwenberg, "Green space, urbanity, and health: How strong is the relation?", Journal of epidemiology & community health, 60 (2006): 587–592.
[53] L. J. Wang, "Spatial Analysis of the Equity of Urban Green Spaces—A Case Study of Taipei Metropolitan Area". Master's Thesis, National Taipei University, Taipei, TaiWan, 2020.
[54] Alessandro Rigolon, "A complex landscape of inequity in access to urban parks: A literature review", Landscape and urban planning, 153 (2016): 160-169.

Figure 3. Tree vegetation per inhabitant by neighborhood in the city of Rio de Janeiro, RJ, Brazil. The neighborhoods of the West Zone, Camorim and Grumari stand out.



Source: Cartographic elaboration by the authors.

Association between tree cover and prevalence of population by ethnicity in each neighborhood

In total, 20 (12.5%) of the 160 analyzed neighborhoods are mainly occupied (>75%) by white people and, comparatively, account for higher mean tree cover rate (24%). Blacks are found in all 160 neighborhoods, but they do not prevail in any of them. Tree cover rate is considerably lower (by 10 percentage points 14%) in neighborhoods where whites are the minority. The brown population prevails in 12 neighborhoods that account for mean tree cover rate of 21% (Table 1).

Table 1: Race/color ratio by neighborhoods and tree cover in the city of Rio de Janeiro.

Predominant color/race	Number of Neighborhoods	White	Black	Others	Average Tree Coverage
White					
>75%	20	611.219	27.060	101.672	24%
50%-75%	59	1.122,755	174.071	565.097	14%
<50%	81	1.499,269	522.301	1.691,900	14%
Black					
>75%	0	0	0	0	0
50%-75%	0	0	0	0	0
<50%	160	3.233,243	723.432	2.358,669	15%
Others					
>75%	0	0	0	0	0
50%-75%	12	274.174	107.684	400.323	21%
<50%	148	2.959,069	615.748	1,958,346	15%

Source: Elaboration by the authors

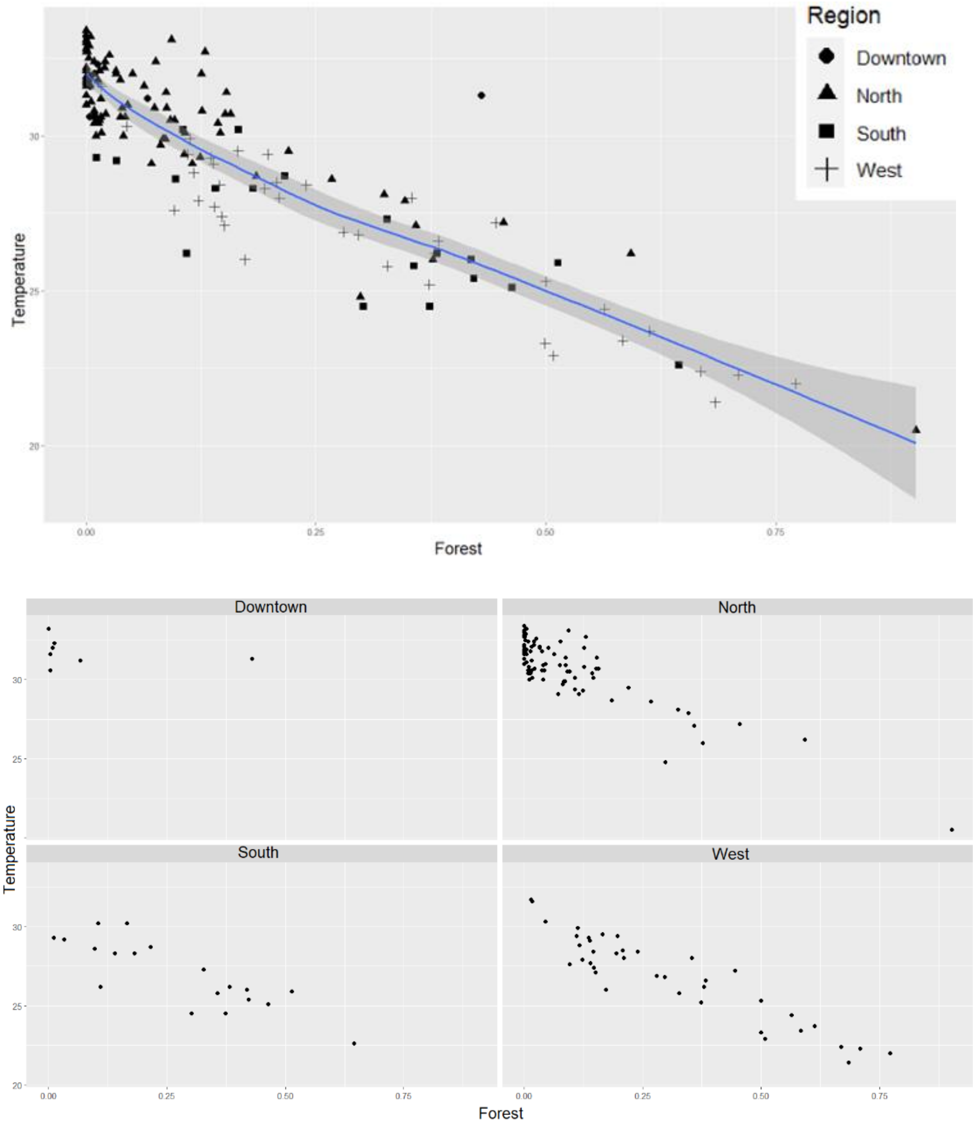
CONTRIBUTION BY TREE COVER TO MITIGATE TEMPERATURE INCREASE IN THE NEIGHBORHOODS

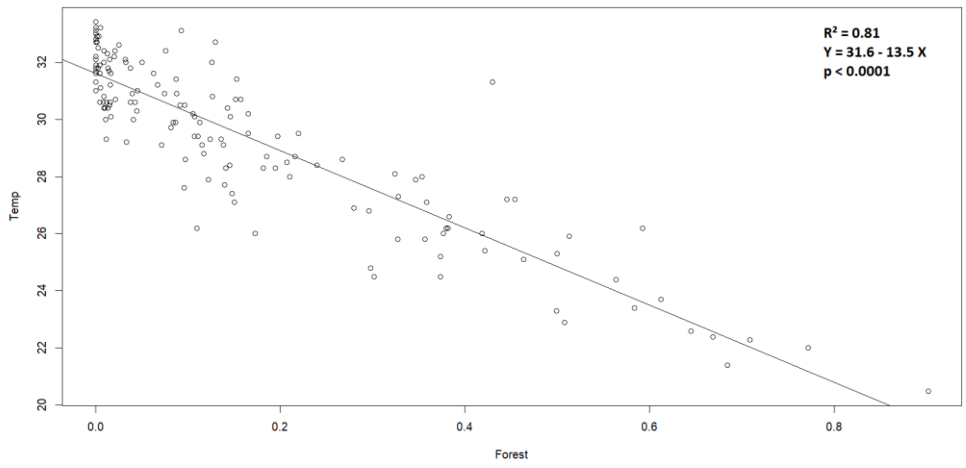
Neighborhoods that have higher green coverage rates also have lower mean temperature records. Those with the lowest rate of trees have higher temperatures, as shown in Figure 4. Alto da Boa Vista neighborhood accounts for the highest wooded area rate (90%); besides, this is the one with the lowest mean temperatures (23.5°C). Rocha neighborhood, on the other hand, is the one with the lowest wooded areas rate (9%) and with the highest mean temperature (33.5°C). Temperature and forest coverage are quite closely correlated to each other; this correlation is shown in Graph 4C, which presents R^2 value equal to 0.81 (this value is considered high) and p value < 0.0001.

Neighborhoods accounting for the highest mean temperature are also the ones with the lowest mean income *per capita* (Figure 5). The concentration of points on the upper left side of the graph shows the large number of neighborhoods that are in this very situation; Del Castilho is an example of it, due to its mean income *per capita* of R$ 428.00 and mean temperature close to 33°C. Lagoa neighborhood, Southern Zone of Rio de Janeiro City, on the other hand, illustrates a very different situation; it presents milder mean temperature (26°C) and mean income *per capita* of almost R$ 4,000.00. Figure 5C evidences reversed correlation between temperature and income (R^2 = 0.1), although this value is for a Spearman's correlation - it is significant at p= 4 *10-5.

Neighborhoods accounting for the highest mean income also show the lowest mean temperatures (Figure 6). Figure 6C depicts close correlation between temperature and income (R^2 = 0.05), although this value is low for a Spearman's correlation – it is significant at p= 4*10-3.

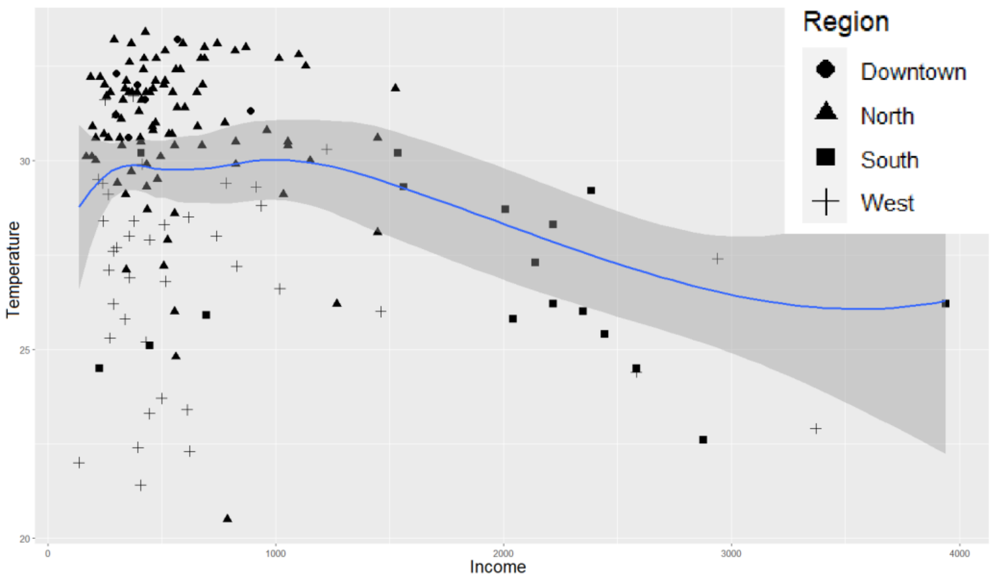
Figure 4. Average temperature and amount of green area by neighborhoods in the city of Rio de Janeiro. A) Dispersion data divided by zones; B) Trend on a Smooth chart; C) Trend of the distribution with a regression graph.

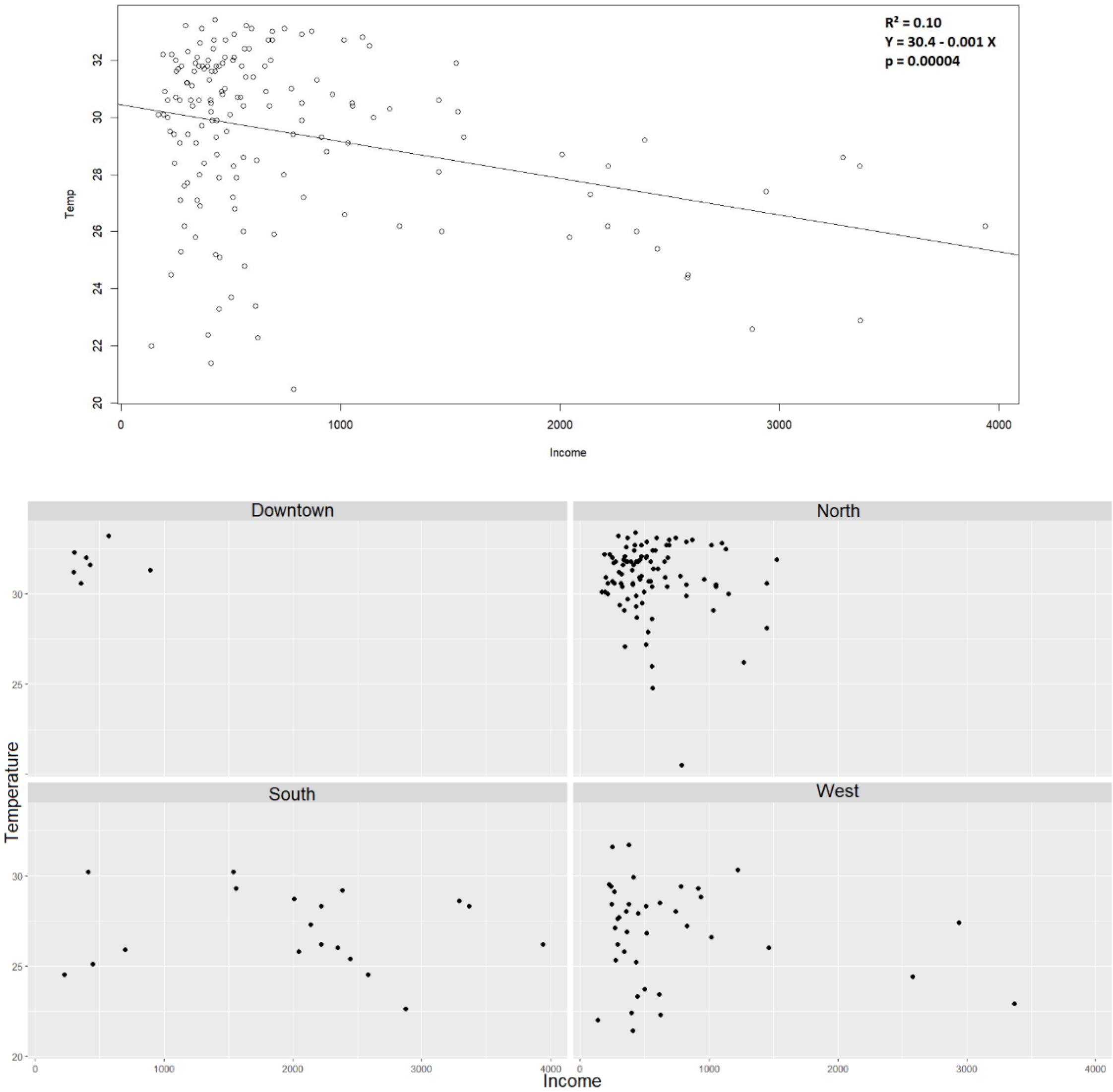




Source: Elaboration by the authors

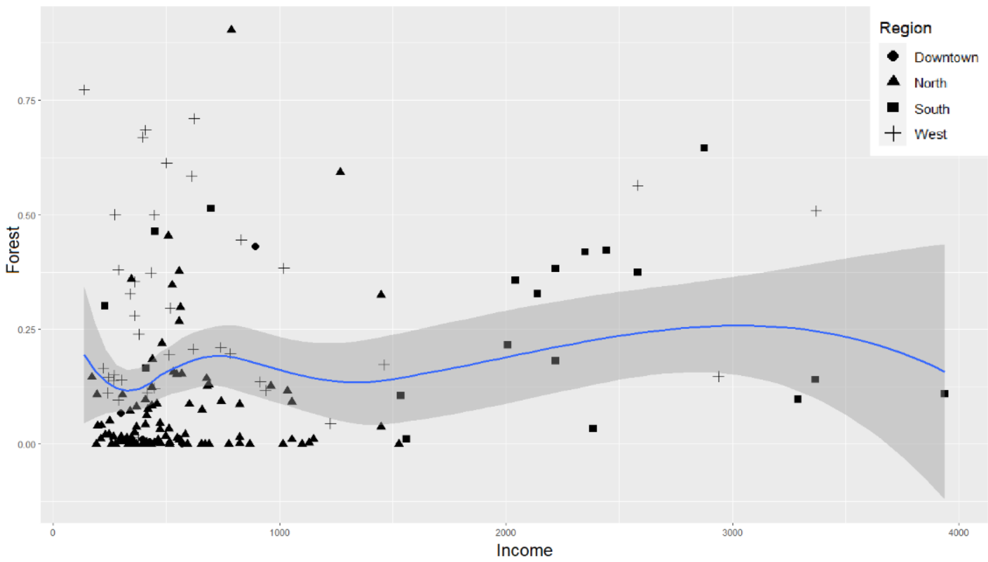
Figure 5. Average temperature and average income by neighborhood in the city of Rio de Janeiro (2019 data). A) Dispersion data divided by zones; B) Trend in a Smooth graph with all neighborhoods together; C) Trend distribution with a regression graph with all neighborhoods combined.

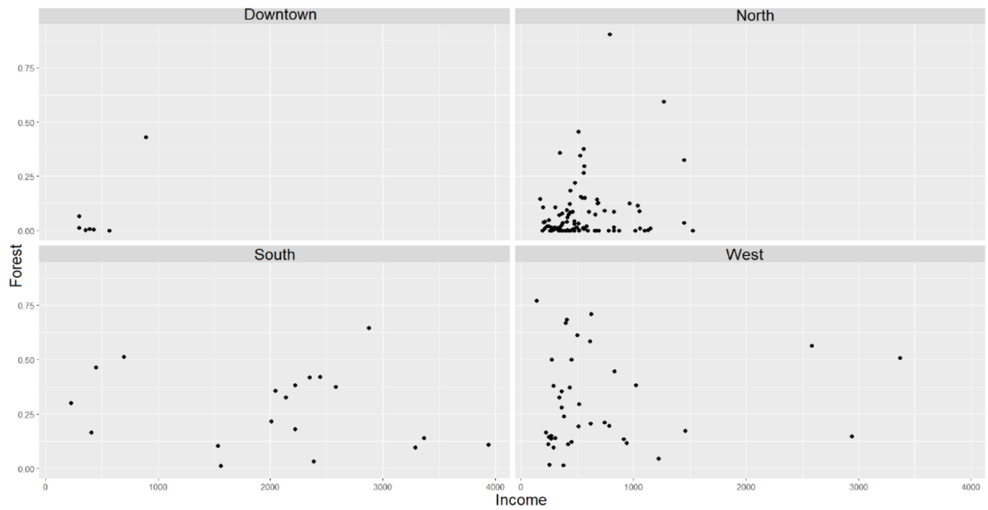


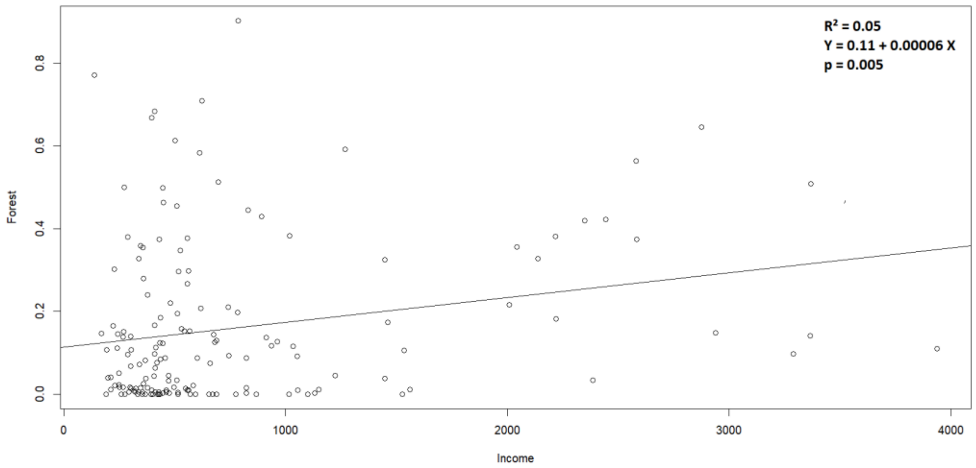


Source: Elaboration by the authors

Figure 6. Average income per neighborhood and amount of forest in the municipality of Rio de Janeiro (2019 data). In the first graph the dispersion data divided by zones, in the second graph the trend in a Smooth graph and in the third the trend of the distribution with a regression graph.







Source: Elaboration by the authors

Association between population and proximity to green areas (proximity) based on skin color and age group

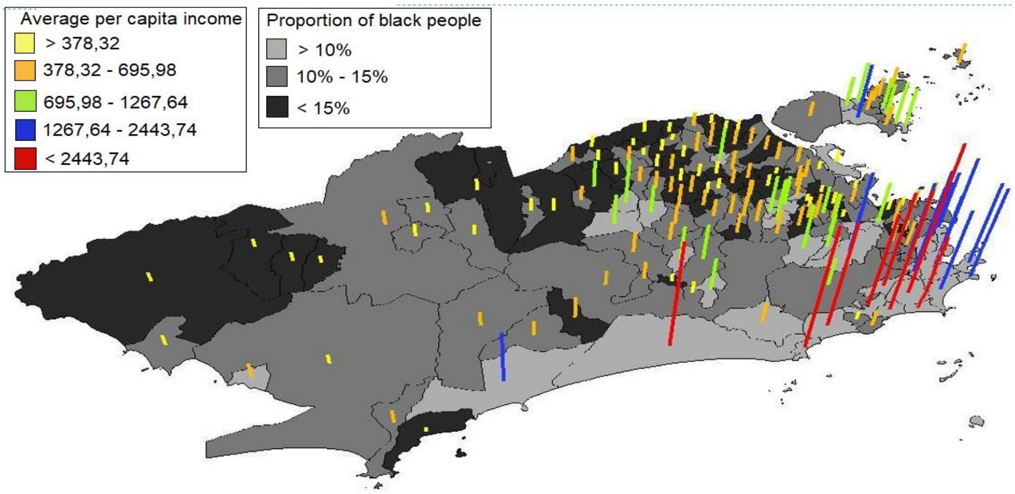
The population's skin-color profile changes as neighborhoods get farther from green areas. In total, 63% of the population is White, 27% is Brown and 8% is Black within a 300m radius. These rates change when the population within a 1,000 m range is calculated. The white population remains the majority within this 1,000 m radius, but its rate drops to 55% – decrease by 8%; brown color/race people, in their turn, represent 33% of the total population within this same radius – 6% more than within the 300m radius. The Black color/race population remains reasonably stable between the three aforementioned radius.

According to Figure 7, the concentration of elderly people increases from approximately 135,000 (17%) within the 300m radius to 205,000 (27%) within the 1,000m one - variation of 10 percentage points. Children under 9 years old totaled 74,370 (7%) within the 300m radius and 146,000 (15%) in the 1,000 m one; this finding represents variation of 8 percentage points.

Accordingly, all analyzed variables helped grouping data into three different groups. Data were separated into Southern, Western, and Central and Northern zones.

MANOVA was performed after the test, and it showed no statistical differences among any of the variables, between the Northern and Central zones.

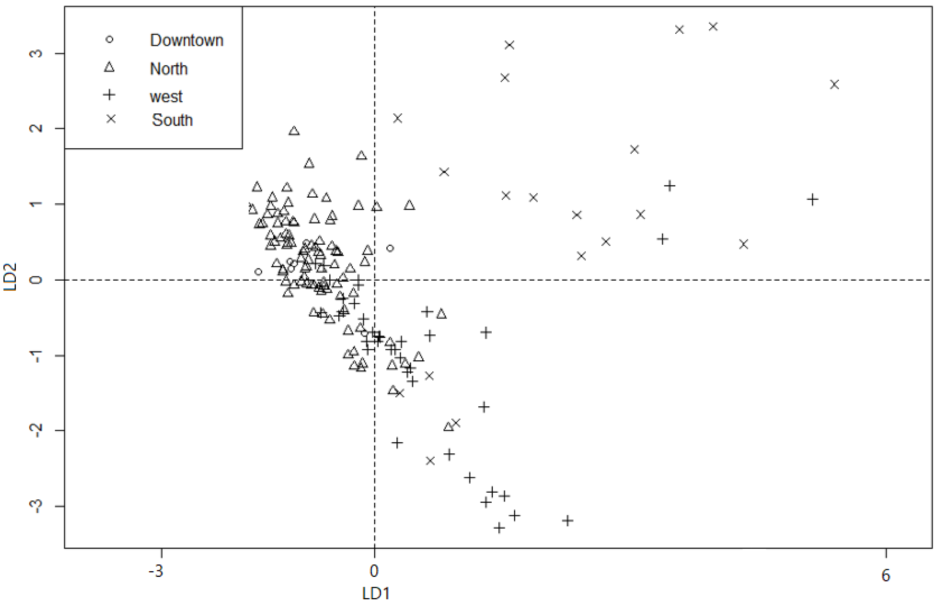
Figure 7. Distribution of the Black/Black population by neighborhoods and respective average per capita income.



Source: Cartographic elaboration by the authors.

The linear discriminant analysis (LDA) (Figure 8) showed evident separation between zones when all variables (color, age group, income *per capita*, forest cover and temperature) were taken into consideration. There were three partitions: one related to the Central and Northern zones, another comprised the Southern Zone and, finally, the last one encompassed the Western Zone. LDA was significant (p=2.2*10-16) at 0.73 on the first axis and 0.24 on the second one – it recorded 97% segregation between these two axes, which is a quite high value. MANOVA was performed based on the six adopted variables; all of them recorded significant results lower than p=0.05; in other words, they all led to data segregation and were gathered in three groups.

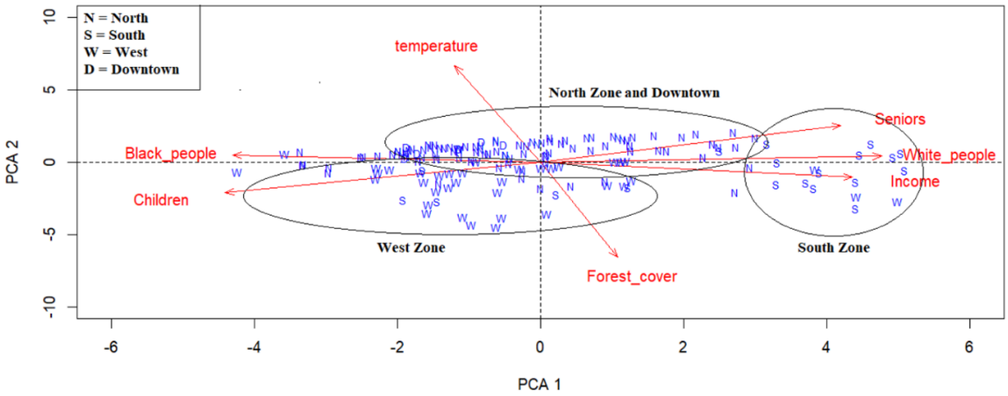
Figure 8. Discriminant analysis between population variables Ethnicity (White, Brown and Black), Age group (children and elderly), per capita income, forest cover and temperature of the neighborhoods analyzed in a research project in the city of Rio de Janeiro, RJ, Brazil.



Source: Elaboration by the authors

PCA (Figure 9) showed that variables related to elderly, Caucasians and higher income families match each other and mainly explain the Southern Zone points. Leblon, Humaitá and Flamengo neighborhoods are examples of upper-middle- and upper-class neighborhoods. Poorer neighborhoods, such as Mangueira and Santa Cruz, are on the opposite side; they are closely correlated to Afro-descendants and with larger number of children; their income rates are also different from that in the positive PC1. Temperature was on the opposite side of forest cover; they were both separated by PC2. Higher temperatures are mainly correlated to poorer neighborhoods and to less forest cover. The forest cover is related to neighborhoods in the Western and Southern zones, which are the wealthiest and most wooded neighborhoods in the assessed municipality. The two main axes explained 81% of the total, 56% for PC1 and 25% for PC2.

Figure 9. Principal component analysis between population variables (Whites, Blacks, children and elderly, per capita income), forest cover and temperature of the neighborhoods analyzed in a research project in the city of Rio de Janeiro, RJ, Brazil.



Source: Elaboration by the authors

Variables "children" and "elderly" were not significant for forest cover in the multiple logistic regression. Data were significant for all other variables (Table 2).

Table 2. Multiple logistic regression relating forest cover with the significant variables (whites, blacks, per capita income and temperature) of the analyzed neighborhoods in a research project in the city of Rio de Janeiro, RJ, Brazil.

VF	Df	Sum Sq	MeanSq	F (value)	Pr(>F)	
temp	1	4.018	4.018	821.013	< 0,000	***
income	1	0.021	0.021	4.246	0.041082	*
whites	1	0.064	0.064	13.017	0.000421	***
blacks	1	0.069	0.069	14.007	0.000259	***
residuals	149	0.729	0.005			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: Elaboration by the authors

Discussion

This study sought to assess both tree cover distribution throughout Rio de Janeiro City and the accessibility to 123 green areas in it. This assessment was based on selected green areas and on the city's tree network, and it associated them with the socioeconomic and environmental data available. Therefore, it seeks to contribute to the discussion on environmental justice in one of the largest Brazilian metropolises. The assumption of environmental justice is to break with the scheme of legal rationality founded on the equivalence of individual and private rights, leaving aside the principles of diversity, difference and alterity that legitimize the common rights of peoples to their biocultural heritage and the common goods of society, aiming to ensure a fair ecological distribution.[55]

The Northern Zone of the city stood out for having the lowest tree cover rate. These indicators were higher in the Western Zone and in a fraction of the Southern Zone; therefore, they may possibly be the places where urban afforestation benefits are more enjoyed. Assumingly, the presence of municipal parks and Tijuca National Park in the Southern Zone, and Pedra Branca State Park, in the Western Zone, have contributed to raise these indices. On the other hand, lack of conservation units similar to the aforementioned ones may have made these indices comparatively lower in the Northern Zone. In any case, the spatial fragmentation observed in the city can reduce its potential to provide ecosystem services to residents, since this scenario leaves the remaining vegetation susceptible to increased sunlight rates and to higher temperature, to humidity reduction and fauna and flora species' loss.[56] It is important to have municipal governments concretely developing actions to achieve the goals in the 2017-2020 strategic plan to reinforce the protection of wooded areas, mainly of those related to the environmental dimension, such as Goal 57: planting 127,000 trees in public places.[57]

With respect to the association between the prevalence of White, Black, Brown and indigenous people in each neighborhood, and the respective tree cover, results have shown that most neighborhoods accounting for white population prevalence present higher tree cover rates. This result corroborates studies conducted by McConnachie and Shackleton (2010), and Zhou and Kim (2013), who identified higher concentration of wooded areas, and higher tree cover rate *per capita*, in neighborhoods accounting for the largest number of white individuals in nine cities in South Africa, and six cities in the U.S.A, respectively.

[55] Pedro Enrique Villasana López, Anita Patricia Dörner Paris, Juan Guillermo Estay Sepúlveda, Germán Mauricio Moreno Leiva, Alessandro Monteverde Sanchez, "Zonas de Sacrificio y Justicia Ambientalen Chile. Una Mirada Crítica desde los Objetivos de Desarrollo Sostenible 2030", HALAC – Historia Ambiental Latinoamericana y Caribeña 10 (3) (2020): 342-365; Enrique Leff, "Racionalidad y Justicia Ambiental: La Elusiva Injusticia de la Vida", HALAC – Historia Ambiental Latinoamericana y Caribeña 11 (3) (2021): 19-38.
[56] INPE, Vulnerabilidade das megacidades brasileiras às mudanças climáticas: Região Metropolitana do Rio de Janeiro, 2021. http://megacidades.ccst.inpe.br/ (Accessed 20 April 2023).
[57] SMAC RIO DE JANEIRO, Plano Municipal de Conservação e Recuperação da Mata Atlântica do Rio de janeiro 2017. http://www.rio.rj.gov.br/dlstatic/10112/5362208/4140310/PMMARJCOMPLETObaixa.pdf (Accessed 20 April 2023).

Tree cover influence on mean temperature drop in neighborhoods corroborated results found by Martini et al. (2015) about the impact of forest remnants on mean air temperature decrease in Curitiba City (PR). According to them, areas with higher tree density tend to present lower temperatures, as observed in some neighborhoods in Rio de Janeiro City. It was possible observing that the poorest neighborhoods are mostly concentrated in the hottest neighborhoods' quadrant, when it comes to correlation between temperature and mean income *per capita* in the assessed neighborhoods. These neighborhoods can be on the top of the list for the implementation actions provided in goal 64 of the city's strategic plan, which aims at reducing greenhouse gas emissions by 20% - it can contribute to improve air quality and to reduce the heat.[58]

It was possible noticing that the population living closer to these areas (up to 300 m away from them), is mostly white, based on the analysis of the proximity of residents belonging to different ethnic/racial groups, and of those having different income *per capita* rates, to the 123 green areas. White individuals remain prevalent in distance range from 500 m to 1,000 m, but the income *per capita* drops down. These results meet those recorded by Wolch (2005) and Boone et al. (2009) in studies carried out in Los Angeles and Baltimore, USA, respectively. They concluded that the white population in these cities had considerably more access to urban parks than the Black one. This result also corroborates findings by Wen et al. (2013), who pointed out the fact that poverty levels and the concentration of ethnic minorities, such as Black, have positive association with living far from parks, as well as negative association with the rate of green areas in urban regions, in the United States.

Regarding the rate of children and elderly living close to green areas, based on the results, 7% of children and 17% of the elderly in Rio de Janeiro City live within a 300 m radius from the herein selected green areas. Arvidsen et al. (2022) have proven that proximity to green spaces can be associated with children's physical, mental and social health and well-being. Children prevalence increases by 8% within the 500 m – 1,000 m radius; elderly prevalence increases by 10%; they reach 15% and 27% respectively. In

[58] SMAC RIO DE JANEIRO, Plano Municipal de Conservação e Recuperação da Mata Atlântica do Rio de janeiro 2017. http://www.rio.rj.gov.br/dlstatic/10112/5362208/4140310/PMMARJCOMPLETObaixa.pdf (Accessed 20 April 2023).

other words, 85% of children and 73% of elderly people in Rio de Janeiro City live more than 1,000 meters away from a green area; therefore, they may not enjoy the benefits from these areas, so often. Although these two lanes (300 m, and 500 m, 1,000 m) are not equidistant, it likely explains the significant increase in the number of children and elderly in the last lane. Assumingly, this result could be minimized if the city had more green areas presenting the selection criteria features. Children or elderly who move to houses more than 300m away from a given green area would naturally enter another green area within this limit if the city would provide more spaces like this. The current 2017-2020 strategic plan can contribute for this target to be reached. If this plan is satisfactorily implemented, it would take two important actions in this regard, namely: recovering/requalifying 500 squares and implementing new urban parks, mainly in neighborhoods lacking green areas.[59]

FINAL REMARKS

The present research made it possible shining light on tree cover distribution in Rio de Janeiro City and on access to green areas in it. The study allowed better understanding the association among tree vegetation rate, wooded area *per capita*, and skin color/race population rates in each neighborhood, as well as afforestation influence on temperature. Although some methodological restrictions were observed, some observations were kept, including the raising hypotheses.

The adopted methodology was based on two parameters: a) 123 areas selected according to the following criteria - size, presence of trees and free access to them, in order to make a profile analysis of residents living closer to them; b) tree cover allowed comparing neighborhoods to their social features. Although the methods were different, results followed common sense about lack of green areas and with higher temperatures in Northern Rio de Janeiro City, with the presence of Blacks in this region, and with differences from the Southern and part of the Western zones of the city, where one finds more trees, relatively milder temperatures and the prevalence of white individuals.

[59] SMAC RIO DE JANEIRO, Plano Municipal de Conservação e Recuperação da Mata Atlântica do Rio de janeiro 2017. http://www.rio.rj.gov.br/dlstatic/10112/5362208/4140310/PMMARJCOMPLETObaixa.pdf (Accessed 20 April 2023).

It is imperative to implement afforestation actions and to create new green areas to provide greater equity in green areas and to broaden the access to their benefits, although this municipality's management instruments do not determine the minimum standard for afforestation or green areas *per capita*. However, tree planting actions and the implementation of squares and urban parks must be carried out, since these are actions defined in the 2017-2020 strategic plan of Rio de Janeiro City and in the Master Plan for Urban Arborization (PDAU). These actions can make accessibility easier for children and elderly individuals who live farther from the selected green areas.

It is worth remembering that these actions are essential to mitigate the impact of climate change on the metropolitan region of Rio de Janeiro. Overall, native fauna and flora species' loss, reduced water quality and quantity, and flooding, dengue and leptospirosis cases are expected to be observed in the city. The low-income population in Northern Rio de Janeiro City may suffer with these impacts in a more intense way, since it is known that this population is more vulnerable to climate change.

Finally, the analysis of urban "green" distribution based on the herein selected areas, and of the city's tree cover, is essential for public managers in cities like Rio de Janeiro. Results of this analysis allow decision makers to carry out urban planning focused on democratizing access to green areas and to their benefits, as well as on promoting urban resilience to the long-awaited climate changes. Accordingly, society's aspirations for both better quality of life and less environmental inequality are met at the same time.

References

Alessandro Rigolon, "A complex landscape of inequity in access to urban parks: A literature review", Landscape and urban planning, 153 (2016): 160-169.

Alessandro Rigolon, Matthew Browning and Viniece Jennings, "Inequities in the quality of urban park systems: An environmental justice investigation of cities in the United States", Landscape and urban planning, 178 (2018): 156-169.

Ambiente Italia Research Institute. European Common Indicators: Towards a Local Sustainability Profile – Final Report, 2003.

http://www.cityindicators.org/Deliverables/eci_final_report_12-4-2007-1024955.pdf (Accessed 20 April 2023).

Andréa Casa Nova Maia, Lise Sedrez, "Narrativas de um Dilúvio Carioca: memória e natureza na Grande Enchente de 1966", História Oral 2 (14) (2011): 221-254.

Angeline Martini, Daniela Biondi, Antonio Carlos Batista, Demóstenes Ferreira Silva-Filho, "Microclima em diferentes tipologias de floresta urbana", Revista da Sociedade Brasileira de Arborização Urbana 10 (4) (2015): 12-22.

Anna Chiesura, "The role of urban parks for the sustainable city", Landscape and Urban Planning 68 (2004): 129-138.

Brian R. Pickard, Jessica Daniel, Megan Mehaffey, Laura E. Jackson, Anne Neale, "EnviroAtlas: a new geospatial tool to foster ecosystem services science and resource management", Ecosystems Services 14 (2015): 45-55.

Bo-Xun Huang, Wen-Ying Li, Wen-Juan Ma, Hua Xiao, "Space Accessibility and Equity of Urban Green Space", Land, 12, (2023), 766. https://doi.org/10.3390/land12040766.

Brian D. Ripley, "Modern Applied Statistics with S" (Springer New York, 2002).

Cecília Polacow Herzog, Lourdes Zunino Rosa, "Infraestrutura urbana: sustentabilidade e resiliência para a paisagem urbana", Revista Labverde (1) (2010): 92-115.

Charlotte Liotta, Yann Kervinio, Harold Levrel, Léa Tardieu, "Planning for environmental justice-reducing well-being inequalities through urban greening", Environmental Science & Policy,112 (2020): 47-60.

Christopher Coutts, Mark Horner, Timothy Chapin, "Using geographical information system to model the effects of green space accessibility on mortality in Florida", Geocarto International 25 (6) (2010): 471-484.

Christopher G. Boone, Geoffrey L. Buckley, Morgan Grove, Chona Sister, "Parks and People: an environmental justice inquiry in Baltimore, Maryland", Annals of the Association of American Geographers 99 (4) (2009): 767-787.

Dajun Dai, "Racial/ethnic and socioeconomic disparities in urban green space accessibility: where to intervene?", Landscape and Urban Planning 102 (4) (2011): 234-244.

Daniel T. C. Cox, Danielle F. Shanahan, Hannah L. Hudson, Kate E. Plummer, Gavin M. Siriwardena, Richard A. Fuller, Karen Anderson, Steven Hancock, Kevin J. Gaston, "Doses of Neighborhood Nature: The Benefits for Mental Health of Living with Nature", BioScience 67 (2) (2017): 147-155.

Enrique Leff, "Racionalidad y Justicia Ambiental: La Elusiva Injusticia de la Vida", HALAC – Historia Ambiental Latinoamericana y Caribeña 11 (3) (2021): 19-38.

Gabriel Paes da Silva Sales and Rejan R. Guedes-Bruni, "New sources of biological data supporting environmental history of a tropical forest of south-eastern Brazil", HALAC – Historia Ambiental Latinoamericana y Caribeña 13 (2) (2023): 281-308.

Holger Sieg, V. Kerry Smith, H. Spencer Banzhaf, Randy Walsh, "Estimating the general equilibrium benefits of large changes in spatially delineated public goods" International Economic Review, 45 (2004): 1047–1077.

IBGE, Sinopse do censo demográfico 2010 (Brasil: Instituto Brasileiro de Geografia e Estatística, 2010). http://www.censo2010.ibge.gov.br/sinopse (Accessed 20 April 2023).

INPE, Vulnerabilidade das megacidades brasileiras às mudanças climáticas: Região Metropolitana do Rio de Janeiro, 2021. http://megacidades.ccst.inpe.br/ (Accessed 20 April 2023).

Jari. F. Oksanen, Guillaume Blanchet, Michael Friendly, Roeland Kindt, Pierre, Legendre, Dan McGlinn, Peter R. Minchin, R. B. O'Hara, Gavin Simpson, Peter Solymos, M. Henry, H. Stevens, Eduard Szoecs, Helene Wagner, "Vegan: Community Ecology Package", R package version 2.5-3. (2023).

J. Arvidsen, T. Schmidt, S. Præstholm, S. Andkjær, A. S. Olafsson, J. V. Nielsen and J. Schipperijn, "Demographic, social, and environmental factors predicting Danish children's greenspace use", Urban Forestry & Urban Greening 69 (2022): 1-8.

Jennifer R. Wolch, Jason Antony Byrne, Joshua Peter Newell, "Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'", Landscape and Urban Planning 125 (1) (2014): 234-244.

Jennifer R. Wolch, John P. Wilson, Jed Fehrenbach, "Parks and park funding in Los Angeles: an equity-mapping analysis", Urban Geography 26 (1) (2005): 4-35.

Jennifer Wolch, "Green Urban Worlds", Annuals of the Association of American Geographers, 97 (2) (2007):373-384.

Jolanda Maas, Robert A Verheij, Peter P Groenewegen, Sjerp de Vries and Peter Spreeuwenberg, "Green space, urbanity, and health: How strong is the relation?", Journal of epidemiology & community health, 60 (2006): 587–592.

Jorun Poettering, "Water and the struggle for public space: social negotiations in the usage of colonial Rio de Janeiro's waterworks", Brasiliana: Journal of Brazilian Studies 5 (2) (2017):154-170.

L. J. Wang, "Spatial Analysis of the Equity of Urban Green Spaces—A Case Study of Taipei Metropolitan Area". Master's Thesis, National Taipei University, Taipei, TaiWan, 2020.

Larissa de Lima Silva Elias, "Justiça Ambiental e distribuição de áreas verdes na cidade de Rio Claro – SP", (Trabalho de Conclusão de Curso, Universidade Estadual Paulista "Júlio de Mesquita Filho", (2012).

Lauren E. Mullenbach, Sonja A. Wilhelm Stanis, Emily Piontek, Birgitta L. Baker and Andrew J. Mowen, “Centering environmental justice: Gentrification beliefs, attitudes, and support of parl development in a shrinking city”, Landscape and Urban Planning, 216 (2021): 104253.

Lise Sedrez, Roberta Biasillo, “Rooting Out Injustices from the Top: the multispecies alliance in Morro da Babilônia, Rio de Janeiro”, Social Text 150 40 (1) (2022): 91-108.

M. Matthew McConnachie, Charlie M. Shackleton, “Public green space inequality in small towns in South America”, Habitat International 34 (2) (2010): 244-248.

Maria José Andrade Núñez, T. Mitchell Aide, “Built up expansion between 2001 and 2011 in South America continues well beyond the cities”, Environmental Research Letters 13 (2018): 1-6.

Marquiana de Freitas Vilas Boas Gomes, “Desigualdade socioambiental no espaço urbano de Guarapuava”, RA’E GA (20) (2010): 95-105.

Nadja Kabisch, Michael Strohbach, Dagmar Haase and Jakub Kronenberg, “Urban green space availability in European cities”, Ecological indicators, 70 (2016): 586-596.

Nelson Grima, Will Corcoran, Corinne Hill-James, Benjamin Langton, Haley Sommer, Brendan Fisher, “The importance of urban natural areas and urban ecosystem services during the COVID-19 pandemic”, PlosOne 15 (12) (2020): 1-13.

Nícolas Cuvi, Laura Catalina Gómez Vélez, “Los parques urbanos de Quito: distribución, accesibilidad y segregación espacial”, Fronteiras: Journal of Social, Technological and Environment Science, 10 (2) (2021): 200-231.

ONU, World Urbanization Prospects: The 2014 Revision, 2015. https://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html (Accessed 20 April 2023).

PDAU, Plano Diretor de Arborização Urbana da Cidade do Rio de Janeiro 2015. http://www.rio.rj.gov.br/dlstatic/10112/5560381/4146113/PDAUtotal5.pdf (Accessed 20 April 2023).

Pedro Enrique Villasana López, Anita Patricia Dörner Paris, Juan Guillermo Estay Sepúlveda, Germán Mauricio Moreno Leiva, Alessandro Monteverde Sanchez, “Zonas de Sacrificio y Justicia Ambientalen Chile. Una Mirada Crítica desde los Objetivos de Desarrollo Sostenible 2030”, HALAC – Historia Ambiental Latinoamericana y Caribeña 10 (3) (2020): 342-365.

Peter Groenewegen, Agnes van den Berg, Sjerp de Vries, Robert A. Verheij, “Vitamin G : effects of green space on health, well-being, and social safety”, BMC Public Health 6 (149) (2006): 1-9.

Projeto MapBiomas, Coleção v. 7.1 da Série Anual de Mapas de Uso e Cobertura da Terra do Brasil. https://plataforma.brasil.mapbiomas.org/. (Accessed 20 April 2023).

R Core Team. R: a language and environment for statistical computing, “R Foundation for Statistical Computing”, Vienna, Austria. URL (2023).

Rachel Kaplan, Stephen Kaplan, “Adolescents and the Natural Environment: A Time Out?”, in Peter H. Kahn-Jr, Stephen R. Kellert (eds.), Children and Nature – Psychological, Sociocultural, and Evolutionary Investigations (The MIT Press, Cambridge, Massachusetts, London, England, 2002), pp. 227-258.

Rebecca Leigh Rutt and Natalie Marie Gulsrud. “Green justice in the city: A new agenda for urban green space research in Europe”. Urban forestry & urban greening. 19 (2016): 123-127.

Regina Horta Duarte, “À sombra dos fícus: cidade e natureza em Belo Horizonte”, Ambiente & Sociedade 10 (2) (2007): 25-44.

Richieri Antonio Sartori, Gustavo Martins, André Scarambone Zaú, Lucas Santa Cruz Brasil, “Urban afforestation and favela: a study in a community of Rio de Janeiro, Brazil”, Urban Forestry & Urban Greening 40 (2019): 84-92.

Rudolf S. Groot, Mateus A. Wilson, Roelof M. J. Boumans, “A typology for the classification, description and valuation of ecosystem functions, goods and services”, Ecological Economics 41 (2002): 393-408.

Shinya Yasumoto, Tomoki Nakaya, and Andrew P. Jones, “Quantitative environmental equity analysis of perceived accessibility to urban parks in Osaka Prefecture, Japan”, Applied Spatial Analysis and Policy, 14 (2021): 337-354.

SMAC RIO DE JANEIRO, Plano Municipal de Conservação e Recuperação da Mata Atlântica do Rio de janeiro 2017. http://www.rio.rj.gov.br/dlstatic/10112/5362208/4140310/PMMARJCOMPLETObaixa.pdf (Accessed 20 April 2023).

Sudipto Roy, Jason Byrne, Catherine Pickering, “A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones”, Urban Forestry & Urban Greening 4 (11) (2012): 351-363.

Susana Kay Cummins, Richard J. Jackson, “The built environment and children’s health”, Pediatric Clinics of North America 48 (5) (2001): 1241-1252.

Viniece Jennings, Cassandra Johnson Gaither, “Approaching environmental health disparities and green spaces: an ecosystem services perspective”, International Journal of Environmental Research and Public Health 12 (2015): 1952-1968.

W. N. Venables, B. D. Ripley, Modern Applied Statistics with S (Springer New York, 2002).

Wenming Nie, Xingyou Zhang, Carmen D. Harris, James Holt, Janet B. Croft, “Spatial disparities in the distribution of parks and green spaces in the USA”, Annals of Behavioral Medicine 45 (1) (2013): 18-27.

WHO (World Health Organization), Urban green spaces and health, 2016. https://apps.who.int/iris/handle/10665/345751 (Accessed 20 April 2023).

William Solecki, Peter J. Marcotullio, “Climate Change and Urban Biodiversity Vulnerability”, in Thomas Elmqvist, Michail Fragkias, Julie Goodnes, Burak Güneralp, Peter J. Marcotullio, Robert I. McDonald, Susan Parnell, Maria Schewenius, Marte Sendstad, Karen C. Seto, Cathy Wilkinson (eds.), Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities (Springer Dordrecht Heidelberg New York London, 2013), pp. 485-504.

X. Zhou, J. Kim, “Social disparities in tree canopy and park accessibility: a case study of six cities in Illinois using GIS and remote sensing”, Urban Forestry & Urban Greening, 12 (2013): 88-97.

Zbigniew J. Grabowski, Timon McPhearson and Steward T.A. Pickett . Transforming US urban green infrastructure planning to address equity. Landscape and Urban Planning. 2023. 229, 104591.

Quem tem Direito às Áreas Verdes Urbanas? Justiça Ambiental em uma Metrópole Brasileira

RESUMO

As áreas verdes urbanas são essenciais para a qualidade de vida das pessoas que vivem nas grandes cidades. No Brasil, 84,7% da população vive em cidades; no entanto, são escassos os estudos que avaliam a distribuição da arborização urbana e o acesso da população a esses espaços. Objetiva-se avaliar a distribuição e acessibilidade das áreas verdes urbanas na cidade do Rio de Janeiro, de acordo com os locais de moradia e as classes econômicas dominantes em cada bairro. Para tanto, foram selecionadas para o estudo 123 áreas públicas com área superior a 5.000 m², bem como a rede de cobertura arbórea da cidade. Isso foi feito para analisar a distribuição da vegetação arbórea e taxa de arborização *per capita* em cada bairro, bem como o perfil da população que tem maior acessibilidade às áreas verdes aqui selecionadas. Além disso, objetiva-se também analisar as prováveis contribuições da cobertura arbórea para mitigar o aumento da temperatura média nos bairros da cidade. Com base nos resultados, a população branca e de maior renda per capita vive em bairros com temperaturas mais amenas, maior arborização e mais próximos das áreas selecionadas. Eles potencialmente se beneficiam mais dos serviços ecossistêmicos do que as pessoas negras e a população de baixa renda. Por fim, destaca-se a necessidade de encontrar maneiras de alcançar maior equidade na distribuição da cobertura arbórea e na acessibilidade às áreas verdes.

Palavras-chave: arborização urbana, florestas urbanas, ecologia urbana, história ambiental urbana, desigualdade ambiental.

Recibido: 07/06/2023
Aprovado: 14/03/2024