

## PORTO ALEGRE'S URBAN PARKS: ACCESSIBILITY AND SOCIOECONOMIC EXCLUSION

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**ABSTRACT** – This article is a study on accessibility to urban parks in Porto Alegre, Rio Grande do Sul, Brazil, which aims to investigate how different social classes access these spaces. For this purpose, a methodology that considers travel times was used to determine the spatial accessibility of places/locations, considering the spatial distribution of nine urban parks and evaluating the performance of walking, cycling, and public transport. To calculate and determine accessibility considering the cost of travel in terms of time, the *RStudio* software was used through the  $\{r5r\}$  package. Spatial opportunity maps of socioeconomic groups were generated by crossing with the accessibility data previously calculated, with the income information per hexagon, the distribution of accessibility of the population of each income level was calculated, and the weighting of the accessibility level was made. The distribution of accessibility of people located in the origins of a certain income decile was obtained, generating graphs according to travel time (30, 60, 90, and 120 minutes). The analysis highlights significant inequality in access to urban parks in Porto Alegre. Accessibility on foot is the most restricted and unequal, benefiting mainly central areas and higher income classes. Although cycling increases the reach of parks compared to walking, it still faces significant inequalities. Public transportation emerges as the most equitable mode, offering the greatest coverage and potentially reducing disparities.

**Keywords:** Urban accessibility; urban parks; socio-spatial inequality; urban mobility.

**RESUMO** – PARQUES URBANOS DE PORTO ALEGRE: ACESSIBILIDADE E EXCLUSÃO SOCIOECONÔMICA. Este artigo é um estudo sobre a acessibilidade aos parques urbanos de Porto Alegre, Rio Grande do Sul, Brasil, que tem como objetivo investigar como diferentes classes sociais acessam esses espaços. Para tal, foi utilizada uma metodologia que considera os tempos de deslocamento para determinar a acessibilidade espacial dos locais, levando em conta a distribuição espacial de nove parques urbanos e avaliando o desempenho dos modos a pé, de bicicleta e de transporte público. Para calcular e determinar a acessibilidade considerando o custo do deslocamento em termos de tempo, foi utilizado o software *RStudio* por meio do pacote  $\{r5r\}$ . Mapas de oportunidade espacial dos grupos socioeconômicos foram gerados cruzando-se os dados de acessibilidade previamente calculados com as informações de renda por hexágono, calculando-se a distribuição da acessibilidade da população em cada nível de renda e ponderando-se o nível de acessibilidade. Obteve-se a distribuição da acessibilidade das pessoas localizadas nas origens de um determinado decil de renda, gerando-se gráficos conforme o tempo de viagem (30, 60, 90 e 120 minutos). A análise destaca uma desigualdade significativa no acesso aos parques urbanos de Porto Alegre. A acessibilidade a pé é a mais restrita e desigual, beneficiando principalmente áreas centrais e classes de maior renda. Embora o uso da bicicleta amplie o alcance aos parques em comparação com o deslocamento a pé, ainda persistem desigualdades significativas. O transporte público surge como o modo mais equitativo, oferecendo maior cobertura e potencialmente reduzindo disparidades.

**Palavras-chave:** Acessibilidade urbana; parques urbanos; desigualdade socioespacial; mobilidade urbana.

### HIGHLIGHTS

- Income-based inequality in park access in Porto Alegre.
- Public transport enables most equitable park access.
- City centre has best pedestrian/cycling infrastructure.
- Wealthier groups reach parks faster.
- Peripheral areas lack urban green spaces.

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## 1. INTRODUCTION

Urban parks play a crucial role in cities, especially in a context of growing environmental awareness, such as adaptation to climate change (Ramyar *et al.*, 2021) and the pursuit of urban quality of life (Markevych *et al.*, 2017; Mouratidis, 2021). These spaces are essential to improve the quality of life in cities and have become an increasingly important issue for urban planning (Mouratidis, 2021), as they provide people with physical, psychological, and social well-being (Buckley, 2020; Kim & Miller, 2019; Wan *et al.*, 2020).

In addition to promoting quality of life, urban parks play vital environmental roles, such as improving the urban climate (Ramyar *et al.*, 2021; Zhao *et al.*, 2024), filtering air (Kabisch *et al.*, 2024; Zhao *et al.*, 2024; Zhou *et al.*, 2024), and preserving biodiversity (Aronson *et al.*, 2017; Beninde *et al.*, 2015; Egerer *et al.*, 2024; Lepczyk *et al.*, 2017). These areas also foster social development by serving as inclusive spaces that promote social and community cohesion (Delshad, 2022; Jennings & Bamkole, 2019). Green spaces, in particular, have been shown to strengthen neighbourhood ties and trust, contributing to collective well-being and social resilience (Jennings & Bamkole, 2019). However, it is important to distinguish the effects of public open spaces in general, which facilitate social encounters regardless of vegetation (Francis *et al.*, 2012), from those of urban green spaces, which also provide restorative and environmental benefits that contribute to individual and collective well-being (Delshad, 2022; Kaplan & Kaplan, 1989). Additionally, urban parks function as places for environmental education (Lu *et al.*, 2024; Park *et al.*, 2021), recreation (Barbosa *et al.*, 2024), and health promotion (Barbosa *et al.*, 2024; Park *et al.*, 2021; Shanahan *et al.*, 2015).

As Tucci (2005) argues, urban parks emerge as a viable solution to balance the urbanization process with the need for environmental preservation. These spaces play an important function, not only in ecological conservation but also serve as accessible social arenas that foster everyday encounters, strengthen neighbourhood bonds, and enhance social cohesion and community wellbeing. (Egerer *et al.*, 2024).

In this context, the interaction of urban parks with their surroundings becomes fundamental, both for their effectiveness and relevance in cities (Patino *et al.*, 2023). However, as Jacobs (2011) argues, such interactions are not always positive since specific urban conditions, including mixed uses, active edges, and continuous presence, are essential for parks to function as vibrant and safe public spaces. These spaces influence and are influenced by environmental dynamics, directly impacting the social, aesthetic, and economic functions of urban areas, in addition to reflecting significant differences in access to these green areas (Delshad, 2022; Lu *et al.*, 2024; Park *et al.*, 2021; Patino *et al.*, 2023). The study by Patino *et al.* (2023) indicates that, in some cities, a higher socioeconomic level is associated with greater proximity to green areas, while in others, populations of middle socioeconomic status face the lowest access. Thus, planning parks in an integrated manner with their surroundings and adjacent infrastructure is essential to ensure their efficient use by the community (Jacobs, 2011).

Accessibility to parks is directly related/associated with the use of the park by the population. Comber *et al.* (2008) found that the distribution of access to green spaces is unequal among ethnic groups. Similarly, Dash and Chakraborty (2023, p. 64) identified that in one study in Bhubaneswar, India, public green spaces are larger in “least deprived communities”.

In this sense, the research aims to answer the following question: are the urban parks of Porto Alegre accessible to people of all social classes? The central hypothesis of this work is that the city’s urban parks are more accessible to higher-income populations, who, according to Rigolon (2016), have control over the city’s accessibility and can choose where they will be located and how the means of conveyance used. Therefore, the objective of this work is to investigate access to urban parks by the Porto Alegre population, analysing how different social classes access each city space. The accessibility method of capturing and processing information is a noteworthy contribution of this work, as it utilises the urban network used by the population on foot, bicycle, buses and trains, considering lines and stops, to calculate the space distribution of urban parks.

## 2. EVALUATED ACCESSIBILITY

Accessibility in urban planning links the urban network and transport system performance within a city’s spatial structure, influencing population, economic activities, and public services. Pereira and Herszenhut (2023) identify three core components: infrastructure, land use, and individual characteristics. This aligns with accessibility as the ease of reaching desired destinations (Geurs & Van Wee, 2004; Hansen, 1959). Infrastructure facilitates urban access. Quality transport services and infrastructure are crucial, including network connectivity, road efficiency, and high-capacity corridors (Ryan & McNally, 1995). Its efficient spatial-temporal integration is fundamental (Cervero & Kockelman, 1997).

Land use affects accessibility through the proximity of people to activities like schools and healthcare. Closer activities mean easier access. Mixed-use and denser areas generally boost accessibility by cutting travel distances and encouraging sustainable transport (Ewing & Cervero, 2010). Jacobs (2011) also highlighted how diverse land uses foster vibrant, accessible urban life.

Individual characteristics significantly impact accessibility. Mobility/cognitive impairments, age, gender, ethnicity, and income affect movement, transport use, and feelings of safety (Imrie, 2000). The United Nations (2006) stresses accessibility as a fundamental right, requiring barrier removal. In this context, Van Wee (2016) emphasize its social value for equity and inclusion.

Urban accessibility levels are determined by the interaction of these three components, which must be considered in an integrated manner to foster a more accessible and inclusive city.

### **3. ACCESSIBILITY AND SOCIO-SPATIAL EXCLUSION**

Understanding how these three components interact within the urban space is essential for analysing inequalities in access to parks and public spaces. Socio-spatial exclusion, as discussed by Carlos (2020), is not limited to the physical separation between social groups but rather concerns the structural form of city production based on capitalist logic, in which space is a commodity and access to it is determined by unequal power relations. For the author, urban segregation expresses a process in which certain groups are deprived of the conditions to enjoy and appropriate urban space, which implies restrictions on the use and right to the city. Thus, socio-spatial exclusion manifests itself not only in the physical distance between poor and rich areas but also in the unequal distribution of public facilities, leisure opportunities, and infrastructure.

Furthermore, it is important to examine how different social classes use and access these environments, considering the various factors that influence the appropriation and effective use of these spaces. As Macedo (1995, p. 49) states, “the solutions adopted are generally partial and rarely reach the entire population, and certainly very little those most in need”. In this study, accessibility is understood not only as a factor measured by travel time, but also as a social condition involving the population’s use and appropriation of parks.

As a result of these exclusions, an impoverished space emerges and becomes impoverished: materially, socially, politically, and culturally, showing that the space we live in is a space without citizens (Santos, 2011). This reality is aggravated by the fact that urban space produces inequality. For Rolnik (2015), the systematic exclusion of most of the population is a central element of the machinery of inequality in the city. In this sense, the dynamics of exclusion affect access to public spaces and perpetuate the marginalisation of the most vulnerable social classes, compromising their right to the city and leisure. As Oliveira and Neto (2020, p.7) argue, the right to the city should reclaim “the place of dwelling, of use value, of public spaces, of encounter, of and through simultaneities”, thinking of cities through their “horizontalities”, associating the places themselves with cultural issues. In the city of Porto Alegre, as throughout Brazil, public space is still thought of as urban residue, unoccupied land, a lack of capital investment, and a disregard for the cultural aspects of territories, perhaps even depriving people with lower incomes of the very concept of “place” as a neoliberal idea.

Inequality in access to public and leisure spaces becomes evident when we observe the search by the wealthiest classes for alternative solutions to the urban crisis. According to Macedo (1995), these classes have increasingly created private spaces that aim to meet emerging needs, resulting in the internalization of leisure in areas such as squares, parks, and private clubs, often within condominiums. This privatization of urban space leads to the exclusion of those who cannot pay for access to goods that should be public (Santos, 2011). Thus, urban life and the use of public spaces are transformed into a scenario where leisure becomes a consumer privilege, marginalizing those who do not have access to these facilities, since “those who cannot pay for the stadium, the swimming pool, the mountain, the fresh air, the water, are excluded from the enjoyment of these goods, which should be public because they are essential” (Santos, 2011, p. 64).

Open spaces for the lower classes are reduced and fragmented, limiting their use to basic activities, such as washing clothes or playing with small children (Macedo, 1995). This reflects the statement by Santos (2011, p. 63), who asks: “And the right to the environment? It is in the books and official speeches, but it is still a long way from being implemented”. This lack of access and the privatization of public spaces create an urban environment that not only ignores the needs of the population but also intensifies existing social inequalities, transforming the city into a space where the right to leisure is denied to the lower income. In this study, incomes were used in deciles, that is, dividing the total population into 10 intervals based on income, so the lowest incomes presented correspond, for example, to the poorest 10%.

#### 4. PORTO ALEGRE'S URBAN PARKS

Briefly, in the late 18<sup>th</sup> century, Porto Alegre's first squares were large open spaces for religious festivals, popular events, and food sales. During the 19<sup>th</sup> century, urban core expansion introduced sanitation improvements and effectively urbanized public spaces (Menegat & Almeida, 2004). This period marked initial concerns about organizing these spaces, resulting in significant transformations, high urbanization, and over 70 new squares (Menegat *et al.*, 1998). Following metropolitanization, maintaining a balance between greenspaces and population became particularly important (Menegat & Almeida, 2004).

Porto Alegre is one of Brazil's most forested capitals. Growing ecological awareness led to Brazil's first Municipal Department of the Environment in 1976. In 1979, the new Master Plan required 2% of new subdivisions for the city's park network (Menegat *et al.*, 1998). Porto Alegre officially has 11 urban parks (fig. 1) (Prefeitura Municipal de Porto Alegre, 2024).

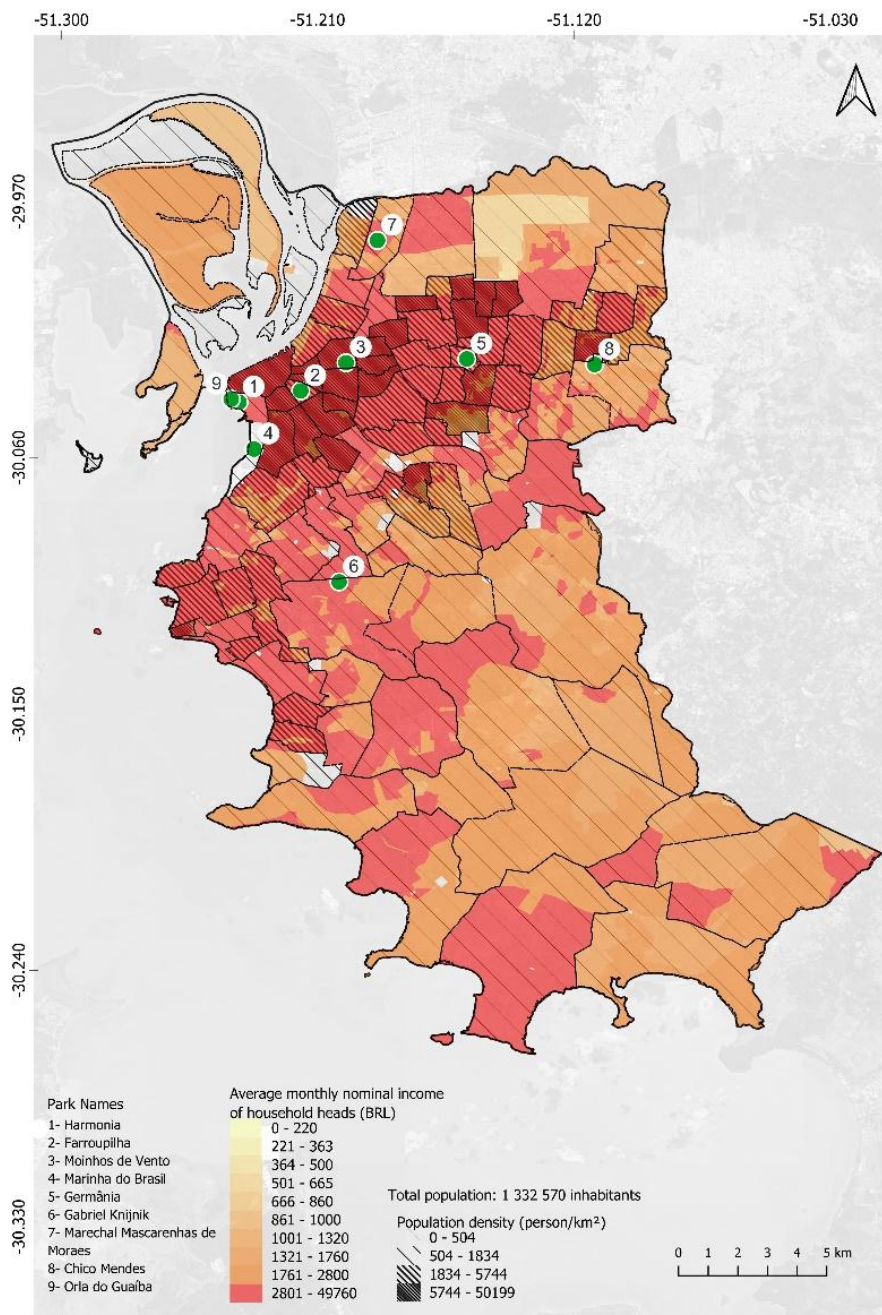


Fig. 1 – Urban parks, income, and population density in Porto Alegre, Brazil.

Fig. 1 – Parques urbanos, renda e densidade populacional em Porto Alegre, Brasil.

Source: IBGE; Google Satellite; Porto Alegre Municipal Government & OpenStreetMap

This study considers nine, as Orla do Guaíba sections 1 (Moacyr Scliar) and 3 (Jaime Lerner) were analysed together. Pontal Park was excluded due to its significantly smaller area. Park selection is justified by Dash and Chakraborty (2023, p. 63), stating “parks are considered a better indicator for Urban Green Spaces (UGS) due to their presence across all neighbourhoods”.

According to data from the Porto Alegre municipality (2022), the oldest of these parks is Farroupilha Park (Redenção, with 37.51ha), inaugurated in 1935. In the following decades, other important parks were established, such as Moinhos de Vento Park (Parcão, with 11.50ha) in 1972 and Marinha do Brasil Park (70.70ha) in 1978. In the 1980s, Harmonia Park (17.00ha) was inaugurated in 1981, and Marechal Mascarenhas de Moraes Park (18.30ha) in 1982.

The 1990s saw the creation of only one park, Chico Mendes Park (25.29ha), inaugurated in 1992. In the 21<sup>st</sup> century, new parks were created, such as Gabriel Knijnik Park (11.95ha) in 2004 and Germânia Park (15.11ha) in 2006. More recently, the city revitalized the Orla do Guaíba, with sections Moacyr Scliar in 2018 and Jaime Lerner in 2021 (sections 1 and 3, totalling 23.24ha). The parks in Porto Alegre vary in size, with some areas standing out for their vast expanses. Porto Alegre’s parks vary in size, some with vast expanses. According to Instituto Brasileiro de Geografia e Estatística (IBGE, 2019), Porto Alegre’s total territory is 495.390km<sup>2</sup>, with 214.91km<sup>2</sup> of urbanized area (43.4%). The parks’ combined area totals 233.50ha, only 1.09% of the urbanized area.

## 5. METHODOLOGY

Porto Alegre has a cycling network consisting of bike lanes and cycle paths, primarily concentrated in the central region, where the infrastructure is more developed. However, the city faces significant challenges due to disconnected segments in the southern and northern areas, limiting cyclist mobility and access to urbans outside the city centre (fig. 2).

The public transportation network is well distributed, with bus routes and stops covering the entire urbanized area, aligning with conventional bus corridors. Though one train line extends from central region northwards, connecting to other cities, the rail system primarily serves intermunicipal travel. Nonetheless, the proximity of bus stops facilitates intermodal connections between these transport modes.

For the development of Porto Alegre’s urban parks accessibility map, was adopted of Pereira and Herszenhut (2023) methodology, which uses travel times to assess the spatial accessibility of places. This approach assumes that all people in the same area have the same opportunities to access activities distributed throughout the city (Pereira & Herszenhut, 2023).

In this context, the spatial distribution of urban parks and the urban configuration are analysed, along with the efficiency of walking, cycling, and public transportation networks. However, this method does not consider individual characteristics when analysing spatial accessibility.

To calculate and determine accessibility regarding the cost of travel in terms of time, the *RStudio* software was used through the *{r5r}* package, which combines all this data into a multimodal transport network operated in routing trips between origin-destination matrix pairs and in calculating travel time.

According to Pereira and Herszenhut (2023), the calculation procedure involves three steps: (i) compilation and formatting of the data required for the analysis; (ii) calculation of accessibility levels; (iii) generation of the resulting data: maps of accessibility levels and graphs of income deciles x accessibility level. The data used for the analysis were obtained from different sources, processed in the *QGIS* software, and inserted into *RStudio* and are described in the table 1 below:

Table I – Source of data used.  
*Quadro I – Fonte dos dados utilizados.*

Data	Source
Street Network	Website <a href="https://export.hotosm.org/">https://export.hotosm.org/</a> from OpenStreetMap data
Public Transit Network	General Transit Feed Specification (GTFS) files – Access to Opportunity Project/Ipea
Topography	Raster data file – <a href="https://search.earthdata.nasa.gov/">https://search.earthdata.nasa.gov/</a>
Income Data	Information obtained through the <i>{aopdata}</i> package

Source: Authors

The file contains the geographic coordinates of the centroids of a regular hexagonal grid covering the entire city of Porto Alegre (Pereira & Herszenhut, 2023), along with data on the resident population.

These data, obtained from IBGE, were processed in *QGIS* and distributed across the hexagonal<sup>i</sup> grid. The dataset includes the insertion of centroids for each urban park analysed and the centroids of each hexagon, identified by a unique identifier (ID).

The table records, in addition to the ID, latitude, longitude, the presence or absence of a park, and the population. All these hexagonal<sup>ii</sup> centroids were used to compute the travel time matrix, independently of their direct relationship with urban parks.

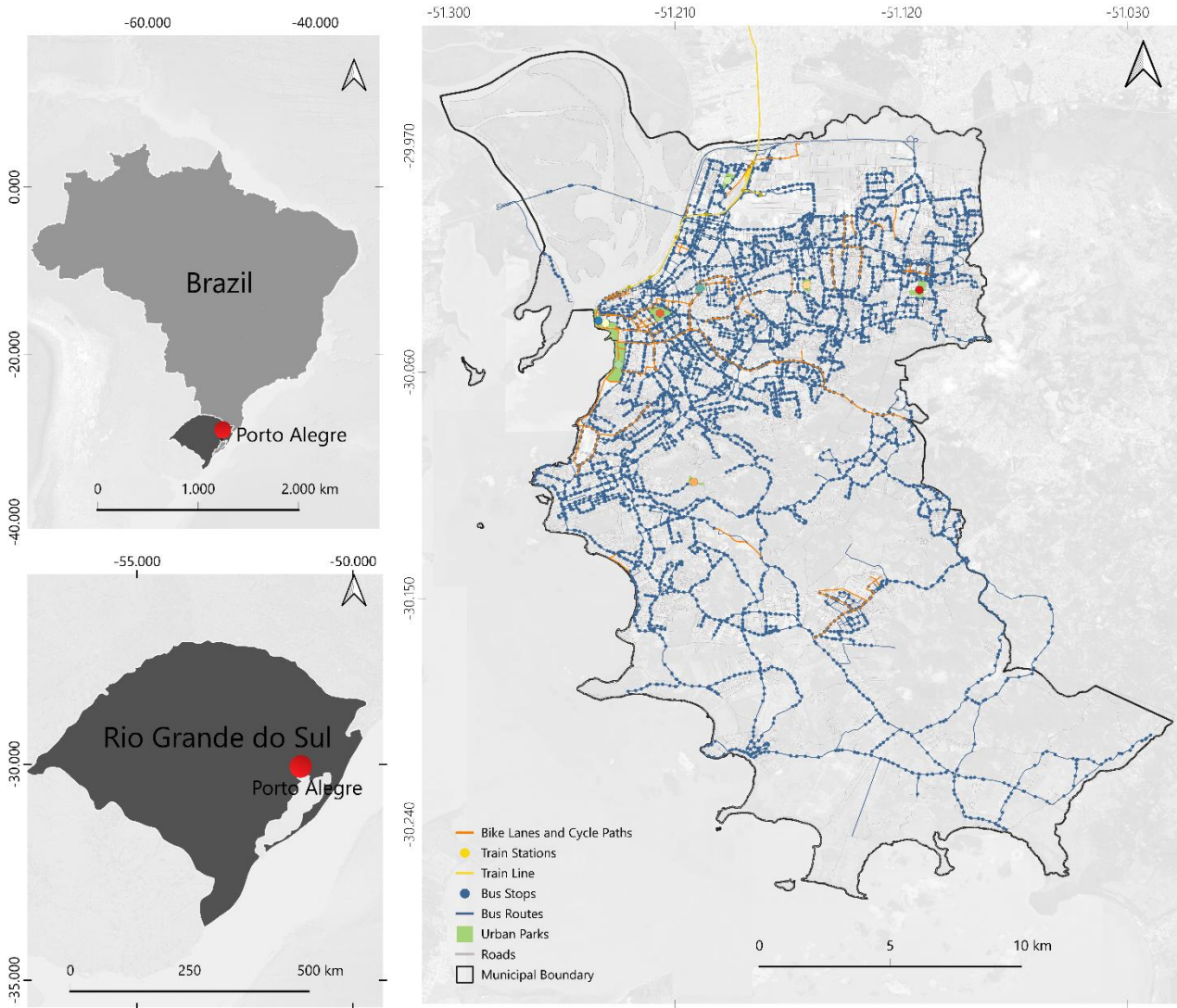


Fig. 2 – Cycling network infrastructure, public transport, and green areas in Porto Alegre/Brazil.

*Fig. 2 – Infraestrutura cicloviária, transporte público e áreas verdes em Porto Alegre/Brasil.*

Source: IBGE; Google Satellite; Porto Alegre Municipal Government & OpenStreetMap

The accessibility level calculations were conducted in two stages. First, the accessibility levels of Porto Alegre’s urban parks were estimated by computing a travel time cost matrix between multiple origins – the centroids of the hexagons covering the entire city – and the destinations, which are the urban parks.

The travel time matrix was computed using the `travel_time_matrix()` function, which defines origins and destinations. Regarding transport modes, walking was analysed using the WALK mode, cycling with the BICYCLE mode, and public transit with the TRANSIT mode.

The departure time was set to 14:00:00 on May 13, 2019, with maximum travel times of 30, 60, 90, and 120 minutes, as exemplified by Pereira and Herszenhut (2023).

This function aims to identify the fastest route from each origin to all possible destinations, considering the travel mode, departure time, and other user-defined parameters (Pereira & Herszenhut, 2023).

These thresholds were defined after preliminary tests using a 15-minute cutoff produced minimal accessibility results, particularly for public transport. The 30-minute interval was therefore adopted as the baseline, as it provided more meaningful spatial coverage and better reflected typical urban travel-time tolerances. Subsequent thresholds were established in continuous 30-minute increments (30-120 minutes) to ensure comparability across transport modes and to capture progressive changes in accessibility levels.

The selected intervals are consistent with those applied by Pereira (2019) in public transport accessibility analyses for Rio de Janeiro, supporting methodological comparability.

This approach also aligns with findings from El-Geneidy *et al.* (2016), who emphasize that cumulative accessibility is highly sensitive to the choice of time thresholds, and from Tomasiello *et al.* (2023), who recommend the use of multiple time intervals to reduce the arbitrariness of such selections.

Although a 120-minute threshold is uncommon for walking, it is commonly applied in public transport analyses, as in Pereira (2018).

Moreover, the inclusion of this upper limit allows illustrating that even at extended travel durations, portions of the population, especially in peripheral areas, remain without effective access to parks, revealing structural spatial inequalities in opportunity distribution.

In addition, as demonstrated in Domeneghini (2019), cyclists may cover considerable distances to reach urban parks, further justifying the use of broader time thresholds for comparative multimodal analyses.

This function aims to identify the fastest route from each origin to all possible destinations, considering the travel mode, departure time, and other user-defined parameters (Pereira & Herszenhut, 2023). For walking trips (WALK), the displacement calculation is based on the Euclidean distance between the origin and destination points, adjusted to the actual road network.

The algorithm employs a street network to determine the shortest path, considering the average walking speed. The default speed for the WALK mode in  $\{r5r\}$  is set at 3km/h. Furthermore, the package incorporates topography and street characteristics, such as sidewalks and crossings, to provide an accurate estimate of walking travel time (Pereira & Herszenhut, 2023).

For bicycle trips (BICYCLE),  $\{r5r\}$  employs a similar approach, identifying the most efficient route within the street network. The default speed for the BICYCLE mode is 12km/h. In addition to the road network,  $\{r5r\}$  considers bike lanes, elevation changes, and other cycling-specific infrastructure, ensuring that travel time is calculated based on real-world route conditions (Pereira & Herszenhut, 2023).

The travel time calculation for public transit (TRANSIT) in  $\{r5r\}$  is conducted using a door-to-door approach. For a TRANSIT trip, the total travel time consists of: (i) walking time to the nearest public transport stop, (ii) waiting time at the stop, (iii) in-vehicle travel time, and (iv) walking time from the drop-off stop to the destination (Pereira & Herszenhut, 2023).

For the second stage, accessibility levels were calculated using the `accessibility()` function from the  $\{r5r\}$  package, which evaluates the accessibility of different locations based on various criteria. This calculation required generating a cost (travel time) matrix that connects the origins and destinations, represented by the centroids of the hexagons.

Additionally, the transport modes (walking, cycling, and public transit) were specified, along with the points of interest for assessing accessibility levels (urban parks), the exact departure time (May 13, 2019, at 14:00:00), and the maximum travel time to be considered. Separate analyses were conducted for maximum travel times of 30, 60, 90, and 120 minutes, enabling a detailed evaluation of accessibility across different time intervals.

After completing the accessibility calculations, accessibility maps were generated based on travel times, incorporating origin and destination points represented by hexagons. The resulting maps were imported into the Geographic Information System (GIS) environment, highlighting the most accessible areas and presented in the results.

Similarly, spatial opportunity maps for socioeconomic groups were generated by intersecting previously calculated accessibility data. Income levels were determined using income decile data for each origin, classified through natural break intervals based on the average income of residents. With income data assigned to each hexagon, the distribution of accessibility across different income<sup>iii</sup> levels were analysed, and accessibility levels were weighted accordingly.

As a result, the accessibility distribution for individuals from origins within a given income decile was determined. The boxplots were produced using the `ggplot2` package in *R*. Graphs were generated for different travel time intervals (30, 60, 90, and 120 minutes) and transport modes (walking, cycling, and public transit), and are presented in the results.

The boxes represent the interquartile range (IQR), the central line indicates the median, and the whiskers extend to the most extreme values within  $1.5 \times \text{IQR}$ .

The dots correspond to statistical outliers automatically identified by the boxplot geometry, that is, values beyond  $1.5 \times \text{IQR}$ .

This representation highlights spatial units with exceptionally high or low accessibility values within each income decile, following the standard convention adopted in previous studies from the Access to Opportunities Project conducted by Instituto de Pesquisa Econômica Aplicada (IPEA) (Pereira *et al.*, 2019; Pereira *et al.*, 2021; Pereira & Herszenhut, 2023).

## 6. RESULTS

It was possible to conduct a comparative analysis of how accessibility patterns vary according to the mode of transport and how these variations reinforce or mitigate existing socio-spatial inequalities in the city. Thus, to understand who has better access to parks and through which modes of transport, income-based accessibility maps were produced for the entire city (figs. 3, 4, 5, and 6).

As expected, the results show that public transport provides the widest service coverage; however, higher-income populations are the most advantaged, particularly within shorter travel-time thresholds, as they tend to reside in more central areas. In contrast, lower-income populations require longer travel times to access parks.

Walking accessibility follows the same spatial logic, with its effective range concentrated in the city core and favouring higher-income groups. This pattern indicates that walking accessibility is selective, as it primarily benefits central areas – where the most accessible parks are located – while peripheral areas remain excluded or experience very limited access.

Parks with the highest levels of accessibility include Park Harmonia, the Orla do Guaíba and Farroupilha Park, reflecting areas with a higher density of accessible points.

Cycling presents a broader spatial reach than walking; however, due to the lack of connectivity between existing bicycle lane segments and the significant absence of cycling infrastructure in lower-income and peripheral areas, its effectiveness in providing access to parks is constrained.

This finding indicates that the increased spatial reach associated with cycling does not result in a significant redistribution of accessibility, which remains concentrated in central areas. Even with its wider coverage, the city core continues to exhibit the highest levels of accessibility, although other parks – such as Marinha do Brasil Park – also demonstrate good accessibility, particularly as travel time thresholds increase.

As travel time increases, all transport modes provide greater access; nevertheless, both walking and cycling remain largely restricted to the central area, offering limited access to peripheral neighbourhoods. The importance of public transport becomes evident as a key mechanism for integrating peripheral and central areas.

It should be noted, however, that the need to pay fares to access public transport may hinder or exclude a significant portion of the population from accessing parks. Overall, the accessibility pattern remains consistent, with central parks being the most accessible.

The central area features a higher concentration of urban parks located in proximity, including the Orla do Guaíba, Park Farroupilha, Park Marinha do Brasil, Park Harmonia, and Park Moinhos de Vento. In addition, the city's main public transport routes are also concentrated in this central area, facilitating park access for residents living there.

The relationship between public transport corridors and highly accessible parks reinforces existing centralities, suggesting that public transport infrastructure, rather than redistributing access, tends to amplify spatial advantages already embedded in the urban structure.

Overall, the accessibility maps and distributions indicate that parks are more accessible to higher-income populations. Conversely, lower-income residents must travel longer distances to reach parks. Xu *et al.* (2017) suggest that improvements in public transport can increase leisure opportunities for low-income populations.

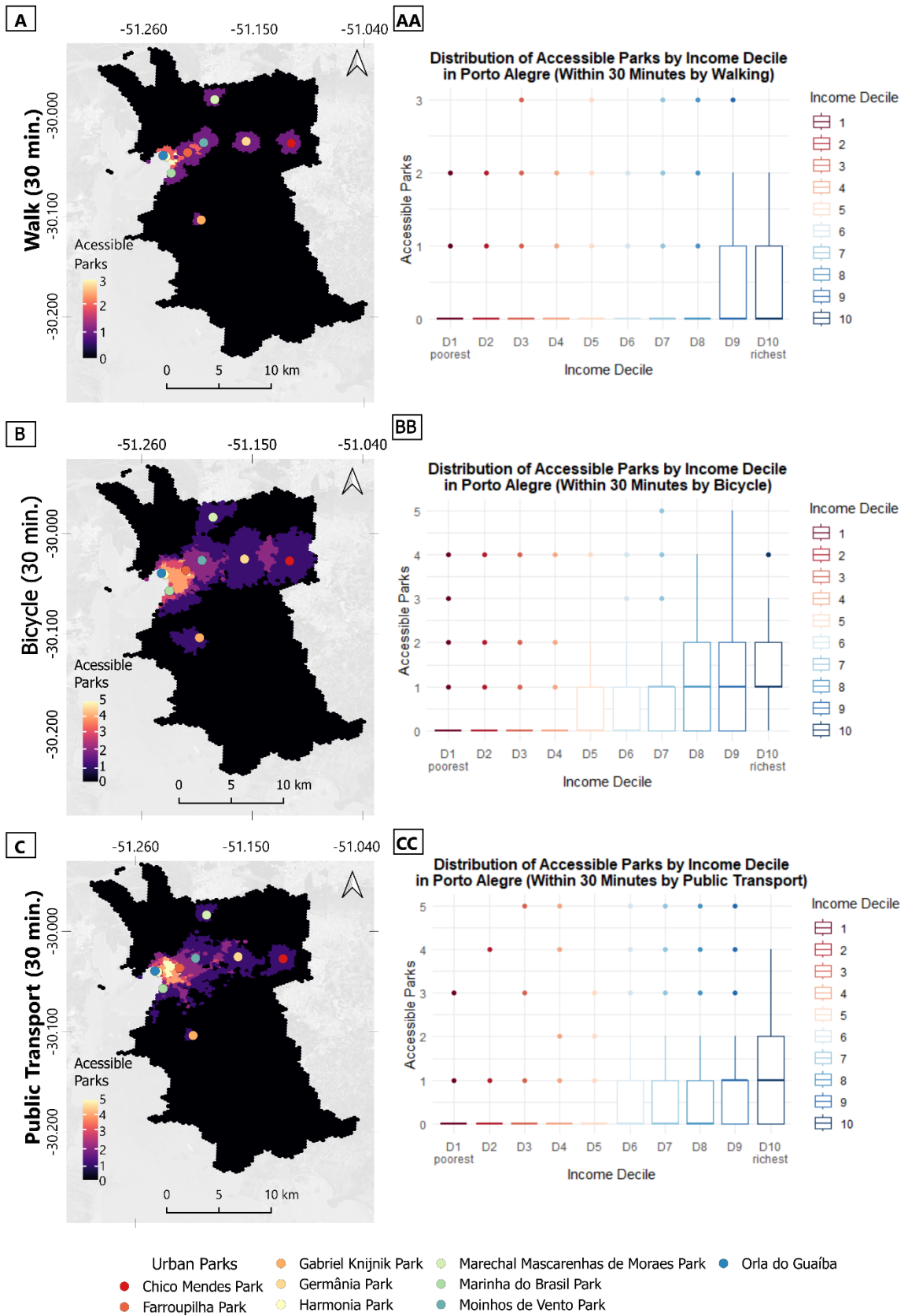


Fig. 3 – Accessibility of urban parks in Porto Alegre: distribution by income decile for walk, bicycle, and public transport within 30 minutes.

Fig. 3 – Acessibilidade a parques urbanos em Porto Alegre: distribuição por decil de renda para deslocamentos a pé, de bicicleta e por transporte público em 30 minutos.

Source: Authors

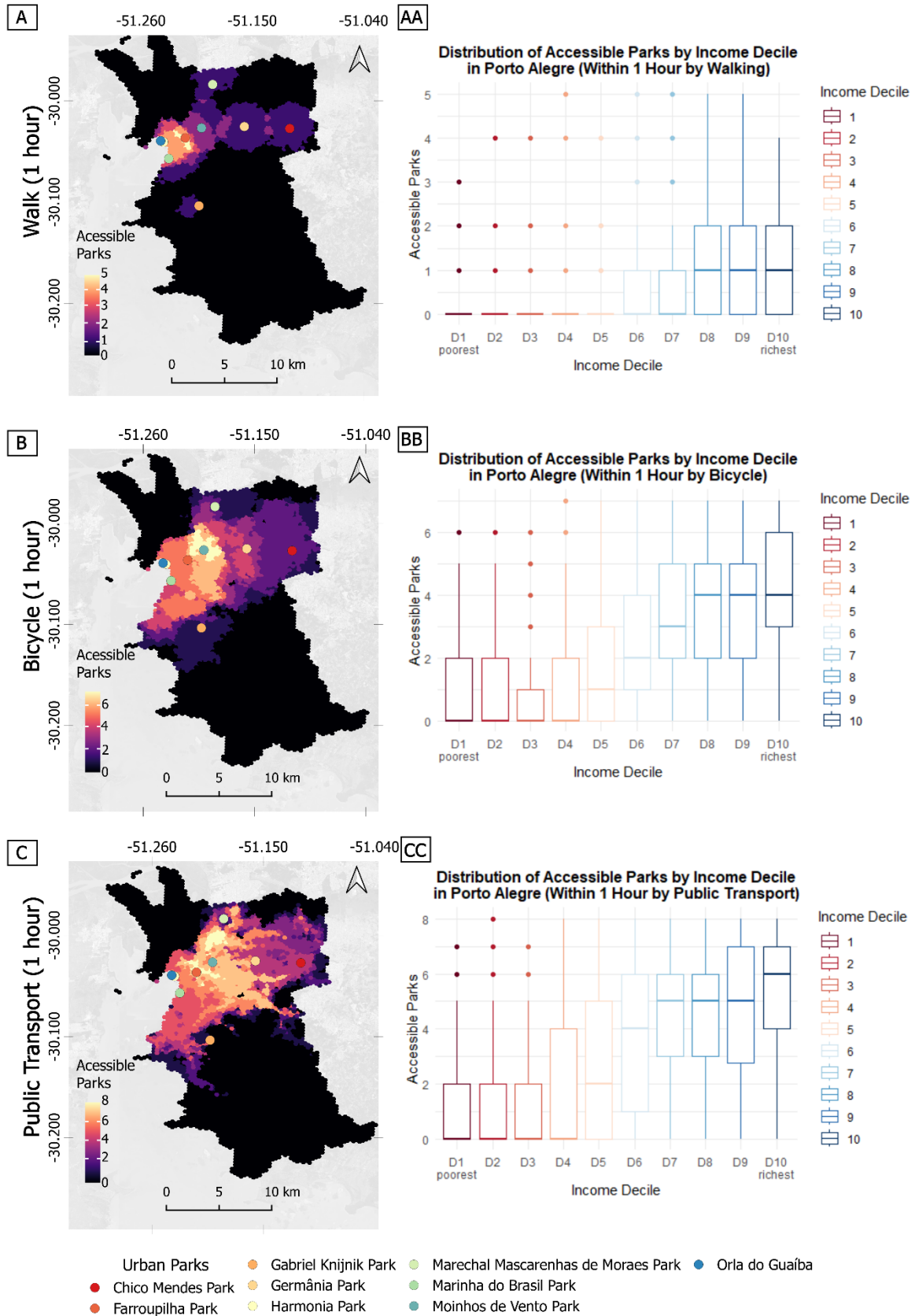


Fig. 4 – Accessibility of urban parks in Porto Alegre: distribution by income decile for walk, bicycle, and public transport within 1 hour.

Fig. 4 – Acessibilidade a parques urbanos em Porto Alegre: distribuição por decil de renda para deslocamentos a pé, de bicicleta e por transporte público em 1 hora.

Source: Authors

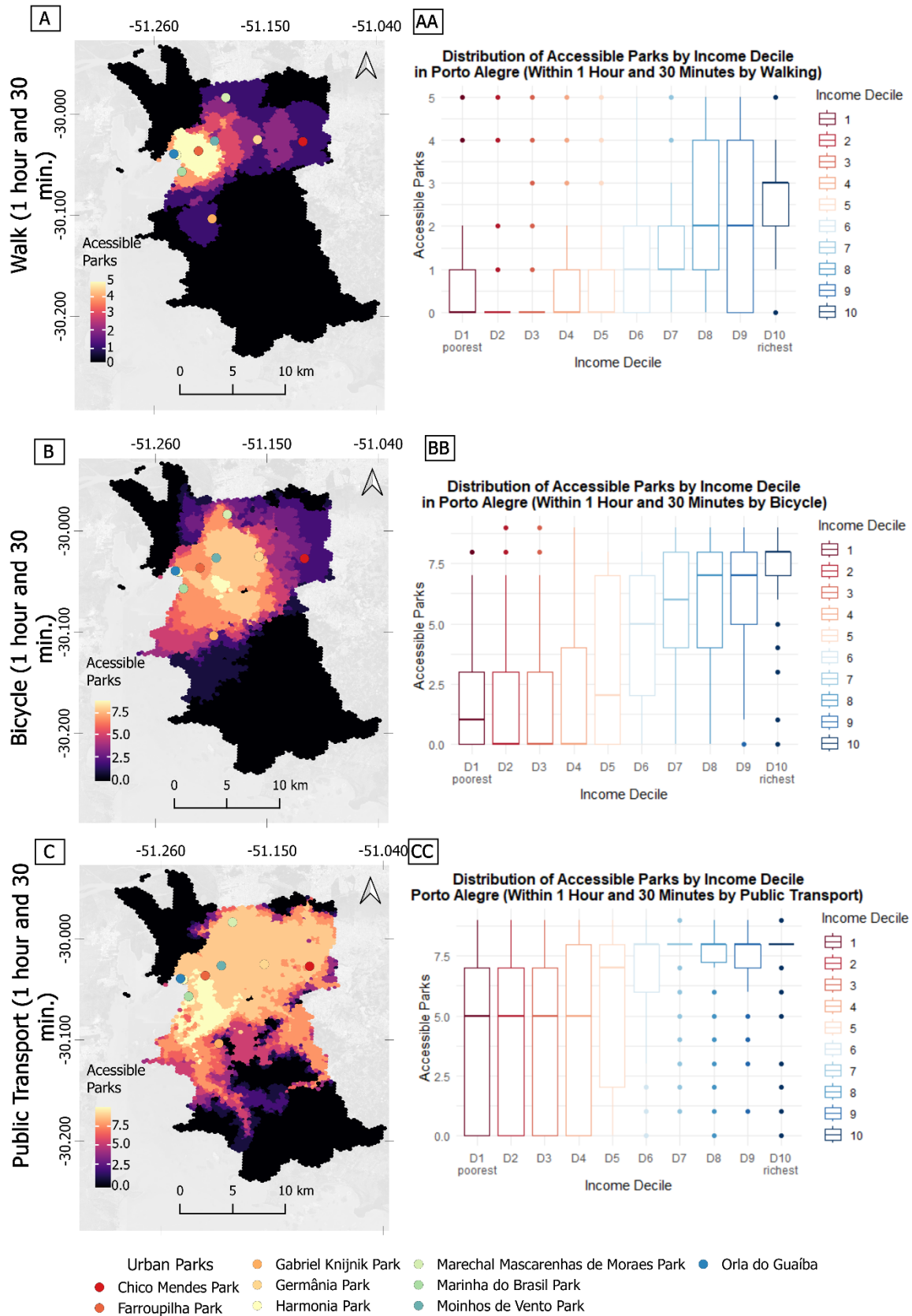


Fig. 5 – Accessibility of urban parks in Porto Alegre: distribution by income decile for walk, bicycle, and public transport within 1 hour and 30 minutes.

Fig. 5 – Acessibilidade a parques urbanos em Porto Alegre: distribuição por decil de renda para deslocamentos a pé, de bicicleta e por transporte público em 1 hora e 30 minutos.

Source: Authors

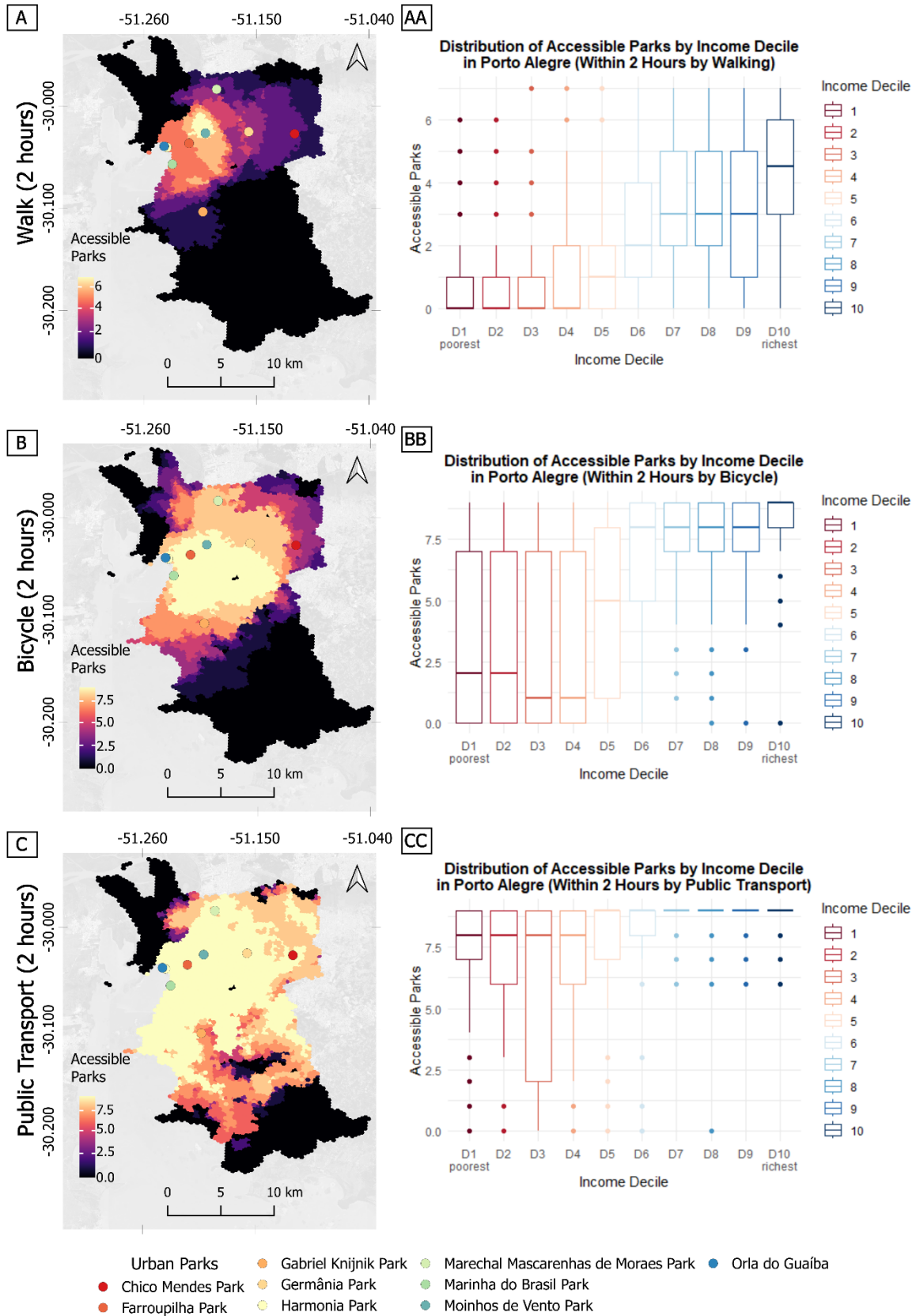


Fig. 6 – Accessibility of urban parks in Porto Alegre: distribution by income decile for walk, bicycle, and public transport within 2 hours.

Fig. 6 – Acessibilidade a parques urbanos em Porto Alegre: distribuição por decil de renda para deslocamentos a pé, de bicicleta e por transporte público em 2 horas.

Source: Authors

## 6.1. Socioeconomic gradients in accessibility

Regarding income deciles, the results across all figures indicate that higher-income groups are consistently the most privileged (deciles 9 and 10) in terms of access to parks, regardless of the transport mode considered. In contrast, lower-income deciles (such as D1, D2, and D3) only begin to experience improved accessibility at travel times of 90 minutes or more, and even then, with substantial gaps in the areas reached.

The analysis of park accessibility by walking reveals a strong concentration in higher-income areas, with particular emphasis on the highest income deciles (D9 and D10), which enjoy easy access to parks. In contrast, lower-income deciles (D1 to D4) face limited access to parks. Lower and middle deciles (D1 to D7) have access to, at most, one park. Accessibility improves substantially from D8 to D10, which have access to up to four parks, demonstrating a clear advantage for higher-income groups.

As travel time increases to 1 hour and 30 minutes, intermediate deciles (D6 and D7) begin to gain access to a greater number of parks; however, lower-income deciles (D1 to D5) continue to experience limited accessibility. At a travel time of 2 hours, the highest deciles (D8 to D10) maintain the best access, reaching up to six parks. Although extending travel time to 2 hours improves access for intermediate deciles, the lowest-income groups (D1 to D4) remain highly constrained. The persistence of this pattern indicates that, even with longer walking times, accessibility remains strongly conditioned by economic privilege.

Park accessibility by bicycle follows a pattern similar to that observed for walking. Higher-income deciles continue to have greater access to parks, reflecting the advantage of centrally located areas that are better equipped with cycling infrastructure. Intermediate-income deciles (D5 to D8) show an improvement relative to the lowest deciles; although they still face constraints, these groups achieve moderate levels of park access. Meanwhile, the highest-income deciles maintain superior accessibility, with access to up to six parks, indicating a slight improvement in equity when compared to walking.

As travel time increases, lower-income deciles experience a modest increase in park access, although higher-income deciles continue to hold the highest levels of accessibility, reaching up to 7.5 parks. Equity improves marginally in comparison to walking; however, the gap between higher and lower-income deciles remains substantial. This suggests that, while cycling provides broader spatial coverage, inequality persists, possibly due to disparities in cycling infrastructure and the spatial distribution of parks.

Park accessibility by bus follows a pattern similar to that observed in the previous modes. Higher-income deciles exhibit broader and superior access to parks, reflecting the more efficient coverage of public transport in central areas. In contrast, lower-income deciles continue to experience more restricted accessibility, highlighting the persistence of inequalities in access even when public transport is considered as a means of reaching parks.

All income deciles, except the lowest-income groups (D1 to D3), show considerable access to parks. Higher-income deciles retain an advantage, with access to up to eight parks; however, the gap between income groups is less pronounced. With a travel time of 1 hour and 30 minutes, nearly all deciles – including the lowest-income groups (D1 to D3) – achieve reasonable access to up to 7.5 parks. Differences across income deciles become less marked, indicating that public transport functions as a major equalizer in park accessibility. At a travel time of 120 minutes, lower-income groups gain access to up to eight parks, while the remaining income groups have access to all nine urban parks analysed. The 2-hour travel-time scenario represents the most equitable condition, with both the lowest- and highest-income deciles accessing up to 7.5 parks. Overall, the analysis demonstrates that accessibility via public transport is the most equitable among the transport modes examined.

## 6.2. Spatial patterns and centrality versus Income and Travel Mode

Regarding spatial patterns and urban centrality, the distribution of parks itself clearly reveals their concentration in more central areas, which directly influences population access – particularly for active transport modes such as walking and cycling – even when a 2-hour travel-time threshold is considered. This spatial configuration clearly produces “islands of exclusion” in the more peripheral parts of the city. Public transport partially mitigates, but does not eliminate, these gaps: the six new Orla lines operate exclusively on weekends and holidays (13:40-20:40), with a total of 37 trips and an aggregate headway of 20 minutes across the network. However, roughly 2 hours elapse between departures serving each neighbourhood. As an illustrative case, line O210 (Orla–Restinga Nova) serves the southern sector only during these limited hours (three departures per direction), thereby restricting southern residents to narrow temporal windows for reaching centrally located parks.

The analysis of the generated data, crossing interactions between transport modes, income, and urban space, indicates that inequalities in access to parks in Porto Alegre are produced by three interrelated factors: the location of parks, which are predominantly concentrated in the central area; the quality and availability of mobility infrastructure, which are better developed and more structured in the city core – such as cycling lanes and a higher number of bus routes; and the spatial distribution of the population itself, with lower-income deciles concentrated in peripheral areas.

Walking accessibility to parks is concentrated in the city core, and residents of peripheral areas – particularly in the southern and far northern portions of the city – are effectively excluded from the system, even when a 2-hour walking threshold is considered. Cycling expands spatial coverage; however, due to the lack of interconnected, continuous, and integrated cycling infrastructure, its reach is largely limited to the expanded central area and does not eliminate existing accessibility gaps. Peripheral areas, characterized by the absence of cycling infrastructure and steep slopes, prevent cycling from functioning as a moderator of spatial accessibility. Public transport, in contrast, represents the most inclusive mode among those analysed, provided that bus corridors and routes offer adequate coverage and frequency to connect green amenities to peripheral areas. Accessibility constraints arise primarily from reduced service frequency during weekends – when the population is more likely to use parks – and from fare costs.

Unfortunately, the creation of new parks in peripheral areas without simultaneous investment in supporting infrastructure is unlikely to produce meaningful outcomes, given that lower-income populations in Brazilian cities tend to be located in urban peripheries. An approach based on the creation of new peripheral centralities – where urban land values remain lower – combined with the implementation of parks, even of smaller size, and integrated with efficient and multimodal public transport, could contribute to addressing this issue.

The results reveal spatial patterns that reflect deeply embedded dynamics in the production of urban space in Porto Alegre. The concentration of high-income populations in central areas – historically favoured by investments in infrastructure, transport, and public facilities – reinforces the spatial advantages of these groups in terms of accessibility. In contrast, peripheral zones, which have long suffered from insufficient investment in public transport, continue to face structural barriers to accessing green spaces and mobility. Similar dynamics have been observed in other Latin American cities, where socio-spatial segregation and infrastructure inequality shape urban accessibility patterns (Patino *et al.*, 2023; Pereira *et al.*, 2019). Thus, the disparities identified are not merely statistical outcomes but reflect long-standing political and spatial processes embedded in the city's urban development.

The Brazilian context, as in many countries of the Global South, differs from that of other regions, particularly regarding public safety. Green areas located near remote and low-income regions are often informal or privately owned and lack adequate public security, posing potential risks to the population. Consequently, even when vegetated areas are located nearby, they cannot be considered suitable leisure spaces. For this reason, the present study was restricted to public parks that are formally regulated and managed by the government.

## 7. CONCLUSION

This work presents studies that demonstrate the importance of green areas, such as parks, in addressing sustainability issues and their impact on the population. However, it is known that not all residents have equal access to parks, with higher-income populations living in closer areas. Assuming that access to parks is necessary for their use, this work focused on discovering how access to Porto Alegre's parks occurs by bus, bicycle and on foot, and considering the population's income.

The maps and graphs clearly illustrate that, regardless of transportation mode, higher-income deciles consistently enjoy better urban park access. This suggests urban mobility infrastructure and park locations are intentionally structured to favour central areas, where resources and services are more concentrated. These regions provide a broader range of public transportation options and are closer to a denser park network, further enhancing accessibility for higher-income groups.

On the other hand, peripheral areas with concentrated low-income populations often face significant transportation infrastructure deficits, limiting urban park accessibility. This disparity not only restricts access to the benefits of green parks but also reinforces socioeconomic inequalities in cities. Spatial segregation, therefore, extends beyond access to services and employment opportunities; it also affects access to recreational and communal spaces, perpetuating a cycle of exclusion that negatively impacts the quality of life of the most vulnerable communities.

This inequality pattern in accessibility in public transportation access is supported by Pereira *et al.* (2019) and Pereira *et al.* (2021) studies, which examined unequal urban transport service access among social groups. These studies highlight that central areas, predominantly occupied by high-income individuals, have significantly better accessibility, while peripheral areas, home to low-income populations, face severe limitations. Similarly, Patino *et al.* (2023) emphasize in some cities, higher socioeconomic status links to green space proximity; in others, the opposite. In certain locations, populations with a middle socioeconomic status experience the least access to green environments.

These findings reinforce this study's conclusions, which revealed that low-income individuals face greater challenges in accessing urban parks due to their location in more distant areas with limited public transportation infrastructure. In contrast, higher-income residents living in central areas enjoy greater accessibility to urban parks, benefiting from more frequent and efficient public transport options.

In a sense, public transportation is not as comprehensive in integrating this population as green infrastructure is in more central areas. This situation appears to be replicated in other cities in the Global South, demonstrating the failure of public policies to integrate their low-income populations into the formal city. However, although improvements in transportation access for lower-income populations are necessary, perhaps the creation of parks in peripheral areas should also be considered.

Finally, it is acknowledged that the analysis presented relies exclusively on quantitative dimensions of spatial accessibility, without encompassing qualitative aspects of urban experience, such as perceptions of safety, environmental comfort, or perspectives associated with gender and race. Although these factors are fundamental for a broader understanding of access to public spaces, they fall beyond the scope of this study, however, they may constitute important directions for future research.

These disparities highlight the importance of public policies aimed at improving and expanding public transportation to promote more equitable access to green spaces and other urban resources. Investments in mobility infrastructure that accommodates pedestrians, cyclists, and public transport users are necessary for reducing inequalities in access to urban parks and enhancing the overall quality of life in the city.

Transportation planning – whether for public transit or cycling – plays a key role in expanding the range of park accessibility, enabling longer trips in less time. However, the creation and maintenance of well-equipped parks near low-income areas ensure better access for the population, fostering social interactions and community engagement (Xu *et al.*, 2017). A more inclusive and equitable urban planning approach can help ensure that all residents, regardless of income or location, can benefit from urban green spaces.


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## AUTHORS' CONTRIBUTIONS

**Jennifer Domeneghini:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft preparation, Writing – review and editing, Visualization. **Fábio Lúcio Lopes Zampieri:** Conceptualization, Data curation, Writing – original draft preparation, Writing – review and editing, Visualization, Supervision, Project administration. **Amanda Silveira Correa:** Writing – review and editing, Visualization.

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<sup>i</sup> Geodetic CRS (Coordinate Reference System) WGS 84 (World Geodetic System 1984) was used.

<sup>ii</sup> Each spatial unit (hexagon) covers approximately 0.11 km<sup>2</sup>, an area comparable to a city block (Pereira & Herszenhut, 2023). The data were provided by the Access to Opportunities Project at Ipea.

<sup>iii</sup> Income decile data are divided into ten intervals, each with a specific average income. The first decile ranges from 0 to 220 BRL, with an average of 109 BRL. The second decile spans from 220 to 363 BRL, averaging 294 BRL, while the third covers 363 to 500 BRL, with an average of 436 BRL. The fourth decile ranges from 500 to 665 BRL, with an average of 572 BRL, followed by the fifth, which spans 665 to 860 BRL, averaging 747 BRL. The sixth decile covers 860 to 1000 BRL, with an average of 950 BRL, and the seventh ranges from 1000 to 1320 BRL, averaging 1133 BRL. The eighth decile spans from 1320 to 1760 BRL, with an average of 1522 BRL, while the ninth ranges from 1760 to 2800 BRL, averaging 2184 BRL. Finally, the tenth decile covers incomes from 2800 to 116,667 BRL, with an average of 5994 BRL. Income decile classifications were obtained from: <https://blogdoibre.fgv.br/posts/distribuicao-de-renda-no-brasil-e-o-papel-dos-rendimentos-alem-do-trabalho-para-desigualdade>, accessed on July 16, 2024.