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Food systems and community resilience: a case study of food deserts and centrality of Petrópolis (Rio de Janeiro, Brazil)

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Abstract. Urban and territorial planning play a crucial role in the performance and sustainability of agri-food systems, emphasizing local food production and consumption. This article, based on previous studies of Petrópolis, aims to reevaluate its urban centers, focusing on food and landscape aspects. Through a review of literature on healthy urbanism and agri-food systems, the study incorporates urban cartography developed in Quantum-GIS software, integrating Petrópolis' territorial and landscape features with comfortable walking and cycling distance. The rural-to-urban transect analysis reveals that rural spaces could be termed as the “periphery of the periphery.” To address decentralization and reduce segregation, comfortable walking and cycling radii—0.75 km in 15 minutes and 3.75 km in 15 minutes, respectively—suggest potential centralities. Implementing measures like expanding street markets and establishing individual points for local farmers to supply natural food can further support decentralization, benefiting public health and food security in vulnerable areas. This approach acknowledges the interdependence between urban and rural areas.

1. Introduction

The quality of life for individuals is significantly impacted by the environment in which they reside. Morphological and infrastructural characteristics have a crucial role in daily dynamics, influencing essential activities such as commuting to work, accessing food, healthcare, education, and leisure. Increasingly, the significance of essential services in neighborhood spaces has transcended temporal boundaries in urban discussions. The impacts of land use decisions are explored for many authors, not only urbanists, but also researchers in the area of health sciences. According to Jackson, Frumkin, and Frank [1], the process of urban sprawl has a detrimental impact on human life due to a decrease in physical activity. In this context, the urban health field seeks to examine the city as a tool for promoting quality of life. When urban planning allocates more space to roads and limits connectivity, it hinders people's access to essential services and activities. The authors also highlight the negative effects of urban sprawl on water and air quality in the formation of cities. Moreover, researchers emphasize the formation of heat islands above urbanized areas, which adversely affect human health [2, 1, 3], contributing to cardiovascular diseases, abrupt temperature variations, and other problems. A

paradigm of healthy urbanism aims to establish guidelines facilitating accessibility to daily activities and services through active transport, taking into account aspects of social inequalities and environmental justice. In this context, mixed-use development, housing policies, active mobility, and efficient public transit emerge as significant directions that encourage public space utilization, socialization, and physical activity [4, 1, 3].

From a sustainability standpoint, the emphasis placed on the appreciation of family farming, the preservation of rurality, and the promotion of local food production could be significant actions. In contrast with the agribusiness based on large estates, monoculture and export, it exerts a substantial impact on greenhouse gas emissions. According to the Greenhouse Gas Emissions and Removals Estimation System (SEEG) report, *agricultural activities and alterations in land and forest use* accounted for 73% of emissions in 2021 [5]. About the latter category, these emissions result from deforestation and the incineration of forest residues, reflecting changes in land and forest use driven by agribusiness activities, particularly those aimed at expanding livestock production areas. Furthermore, the production methods and technologies geared toward increasing production quantities are associated with the use of pesticides and chemical fertilizers, which detrimentally affect the environment and contribute to water, air, and soil contamination [6]. Recognizing the need to shift the paradigm of food production towards more ecological and environmentally friendly practices is crucial.

Additionally, the issue of food supply has been a focal point in territorial approaches, especially when identifying food deserts—areas with limited or no access to natural or minimally processed foods [7]. Based on Shaw's [8] research, the concept of food deserts acknowledges the multifaceted impacts on diet quality, encompassing environmental, social, economic, and cultural dimensions. According to the author, the term "food deserts" has gained prominence in newspaper reports, highlighting the decline in fresh food consumption juxtaposed with the rise in processed and ultra-processed food intake. This context has spurred an analysis of commuting patterns for food purchase and other factors tied to daily food consumption, including choices made by individuals. Shaw [8] notes the absence of a robust definition for food deserts, contributing to the conceptual ambiguity. However, the author emphasizes three factors crucial for analyzing these vulnerable areas that complement the understanding of these regions and differentiate the severity level for people in accessing nutritious food: 1) Ability: encompassing any factor that hinders access to food, including deficiencies, chronic problems, or local geography-related challenges; 2) Assets: pertaining to purchasing power, not only for food but also for other expenses and needs impacting overall income; 3) Attitude: in this perspective, issues related to the consumer's state of mind that influence consumption choices, such as time constraints for cooking or prejudices regarding certain options.

In the Beaulac, Kristjansson, and Cummins' [9] systematic review, the authors underscore the use of the term food deserts in many countries and highlight its association with the recognition of the disparities in food access. In 2017, the Ministry of Social Development (MDS) of Brazil enhanced the discussion about the thematic and promoted the first workshop dedicated to create a methodology to mapping the food deserts in the country. Both concept and methodology sought to be a basis to build public policies in favor of food security. Although the MDS' report [10] mentions a United States' methodology that considers the distance of more than 1.6 km between the residences and food commercial establishments to classify an area as food desert, the Brazilian report doesn't establish a metric. This article revisits earlier studies [11] that point areas facing challenges in accessing natural food, relying on MDS' report. It implies that the study doesn't establish a specific distance between residences and food commercial establishments to characterize a food desert, but instead considers the location of these establishments within the neighborhood boundaries.

The main article discusses the environmental impacts on people's food quality and presents a case-study in the Brazilian city of Petrópolis – RJ. It draws upon insights from previous studies that identify neighborhood with absence of food commercial establishments or having up to three of them. This identification relies on the categorization of these places in the National Classification of Economic Activity. These establishments are classified into three different types (natural food, mixed,

and ultra-processed), as explored by Rocha [11], which is revisited and incorporated into this research. Analyzing food deserts facilitates connections between contemporary urban problems, including socio-economic disparities, food insecurity, and the urban-rural dichotomy.

Within the framework of the 17 Sustainable Development Goals established by the United Nations Organization, food insecurity is interconnected with various issues, extending beyond the goal of “zero hunger”. These issues include “sustainable cities and communities”, “responsible production and consumption”, and “climate action”. An examination of the territory through agri-food systems allows for the recognition of interdependencies between urban and rural areas, stimulating the local economy and shortening supply chains. This approach could create opportunities to combat hunger and obesity while aligning people and nature with local capacities. Taking the case study of Petrópolis (Rio de Janeiro, Brazil) into consideration, local agricultural activities could serve as a key driver in promoting the connection between urban and rural areas, fostering sustainable food systems through the valorization of rurality.

This article revisits previous studies focused on the vulnerable neighborhoods of Petrópolis, aiming to furtherly analyze the quality of food supply in the city through the lens of active mobility and mixed-use perspectives. Against the background of centralized services and activities impacting daily commutes, the research employs landscape studies and cartography to explore the potential of decentralization. These methodologies aid in reimagining decentralization as a viable strategy to propose actions that contribute to territorial planning. Within this context, the appreciation of local family farming, consideration of geographical qualities, and the promotion of urban agriculture are fundamental principles for comprehending the intricate relationship between territory, food, and healthy cities.

2. Methods

This research revisits prior studies conducted within the context of the master's dissertation titled “Territory and Food: Access and Production of Food in Petrópolis City (RJ)” [11]. The dissertation investigates the food scenario in the first district of the city, identifying neighborhoods with disadvantage to purchase natural and minimally processed food. Furthermore, the theoretical framework seeks to examine the intricate relationship between territory, food, and sustainability. It concentrates on articles, literature, and academic productions published and made available on platforms such as Scholar Google and Scopus, particularly focusing on aspects such as short food supply chains and the territorialization of agri-food systems.

The Geographic Information System (GIS) complements the methodological process of this research through the geoprocessing software Quantum-GIS (QGIS). Considering the cartographies of the previous studies about Petrópolis, some layers such as the macro-zoning, the neighborhood planning, arterial and collector roads, public squares, and contour lines are essential to explore important possibilities in favor of food security. Complementing the analysis, research about walkability, active mobility, and landscape planning will help to reimagine the centrality in the first district of Petrópolis to benefit the fresh food supply and the local family farming.

3. Rurality and food deserts in Petrópolis: rescuing previous studies for a healthier city

Petrópolis is a historical city located in the state of Rio de Janeiro. Classified as a medium-sized city, Petrópolis is home to 278,881 inhabitants, with a demographic density of 352.50 inhabitants per square kilometer [12]. Its identity and perception are deeply associated with the imperial period, during which the monarch Dom Pedro II commissioned the German engineer Major Frederico Koeler to create an urban plan in 1843. Despite being recognized as the Imperial City, Petrópolis has a history of occupation dating back to the initial presence of indigenous people, followed by the Portuguese crown's movement of internalizing occupation [13]. In its earlier years, Petrópolis served as a support point and was part of the gold route leading to the present-day states of Minas Gerais and São Paulo. The Koeler plan, implemented in 1843, introduced significant features to the city's morphology and land occupation. Notable elements include the leading role of the watercourses in the urban layout,

tracing the roads by the riversides, something uncommon in Brazilian cities at this moment. Furthermore, the plan proposed the division of the territory into blocks with specific uses, encompassing agricultural activity. The historic center of Petrópolis still reflects the mixed-use characteristics outlined in Koeller's plan and remains a central destination for daily commuting related to essential activities.

As a part of the mountainous region of Rio de Janeiro, Petrópolis has a landscape characterized by the presence of mountain ranges, well-preserved vegetation, and rivers due to its settlement situated at the bottom of the valley. The city's territory is part of remnants of the Atlantic Forest, and it has numerous conservation units across its five districts. Despite being a region marked by environmental conservation efforts, Petrópolis faces challenges arising from inefficient habitation policies and concentrated land ownership. Both preservation areas and steep-sloped regions have experienced occupation for irregular constructions, primarily for residential purposes. This occupancy not only compromises the integrity of conservation areas but also poses risks due to susceptibility to flooding and mass movements, highlighting the presence of environmental injustice within the territory [14].

Considering economic aspects, tourism emerges as a crucial sector, alongside various activities within the tertiary sector, responsible for 47.3% of the municipal Gross Domestic Product (GDP). Despite the agricultural sector's relatively low contribution to the municipal GDP (only 0.5%) [15], the food production in cities within the mountainous region, including Petrópolis, significantly contributes to supplying the inhabitants of Rio de Janeiro state [16]. The limited involvement of agriculture in the GDP may be attributed to the devaluation of family farming, competition with large-scale producers, and inadequate remuneration in supply centers. The depreciation of rural areas is reflected in public investments primarily directed toward urban regions. Rural zones in Petrópolis and other cities often face pressure from urban expansion. Nevertheless, municipal legislation recognizes rural zones in the Macro Zoning Plan, besides the importance of family farming and rurality as forces to curtail urban expansion are outlined in the Master Plan. Analyzing these rural areas across all five districts, Figure 1 illustrates a concentration of agricultural establishments in these macro zones, with the Posse district gaining particular prominence. According to the 2017 Agricultural Census [17], out of Petrópolis' 768 agricultural establishments, 504 belong to family farming (65.6%), covering a total of 2,082 hectares, compared to 19,164 hectares of non-family farming (9.8% of the municipal agricultural area). Notably, leafy and cruciferous vegetables constitute the primary foods produced in these areas.

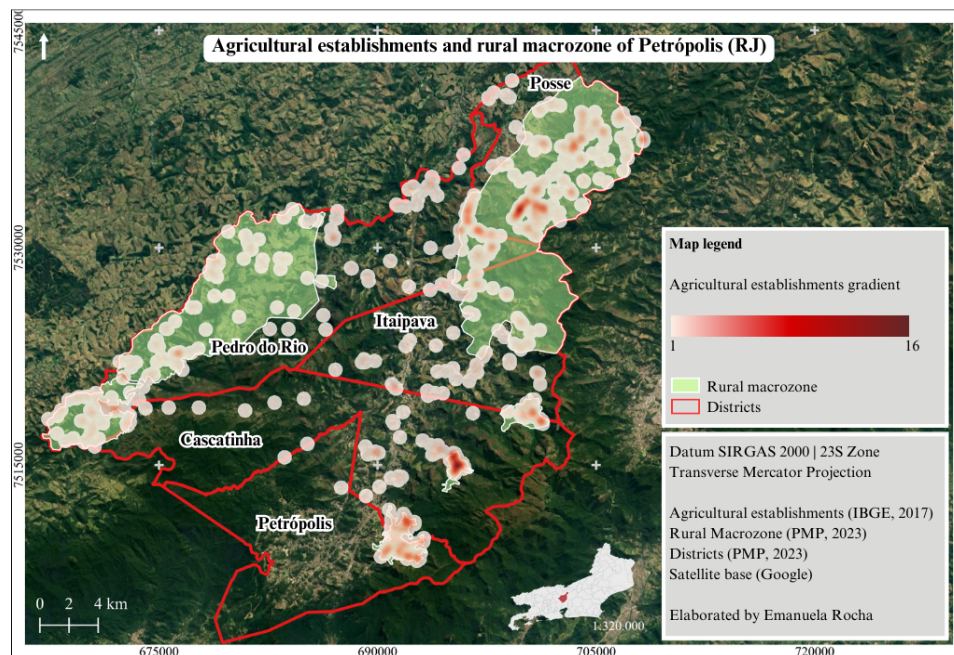


Figure 1. Agricultural establishments and rural macrozone of Petrópolis (RJ). Source: [11].

The locality of Caxambu, situated in the first district of Petrópolis, is approximately 7 km from the Historic Center and has been prominently featured in previous studies conducted by Rocha [11]. Rocha explains, through an interview with a leadership of Caxambu producers, that rural areas in Petrópolis face internal and external pressures that contribute to the challenging conditions faced by local producers. Among the internal factors, the impact of topography is notable, leading to difficulties in obtaining labor due to physical exhaustion in a low mechanized context, exacerbated by urban pressures. External factors include the absence of dedicated public policies for rural areas, considering the inadequacy of public infrastructure provided by the municipality in these regions. Additionally, the influence of middlemen in the street market context, coupled with the dominance of supermarkets in the food supply chain, further compounds the challenges faced by local producers. Rocha [11] underscores that, particularly in street markets, local producers and middlemen are often indistinguishable. Despite the appearance that consumption in these environments originates from local agriculture, the reality is that the majority of sellers are, in fact, middlemen. All these factors contribute to the commercialization of local food in other cities. There is a particular emphasis on Rio de Janeiro, Juiz de Fora, and some cities in the Baixada Fluminense, situated between Guanabara Bay and the mountainous region.

In an effort to identify vulnerable areas with limited access to fresh and minimally processed food in Petrópolis' first district, Rocha [11] conducted a mapping exercise of food commercial establishments, classifying them into three types: natural food (e.g., fruit and vegetable growers, butcher shops, and fishmongers), mixed (including hypermarkets, supermarkets, grocery stores, minimarkets, bakeries, restaurants, and food for home consumption), and ultra-processed (encompassing convenience stores, bars, snack bars, candy retailers, and canteens). According to Rocha's [11] mapping, there were a total of 2,457 commercial establishments, with 165 classified as natural food, 1,972 as mixed, and 320 as ultra-processed. To identify neighborhoods with limited access to nutritionally quality foods, Rocha [11] considered the presence of natural food and mixed establishments. Figure 2 illustrates neighborhoods without these commercial points (7), as well as those with up to three such establishments (18).

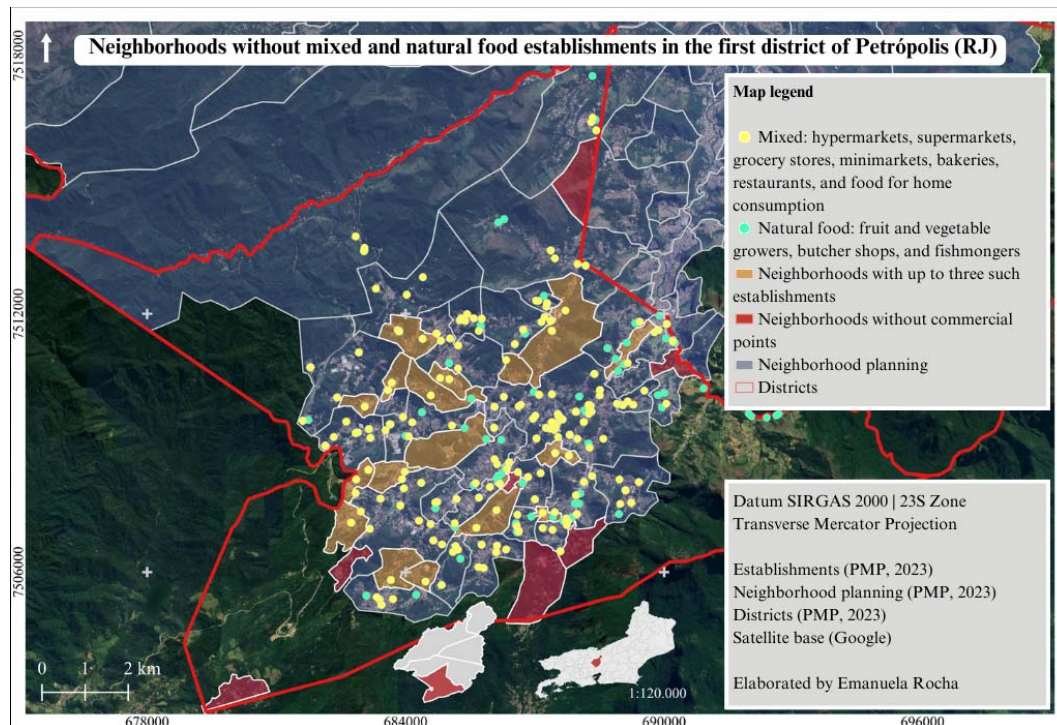


Figure 2. Neighborhoods without mixed and natural food establishments in the first district of Petrópolis (RJ).

Source: [11].

Highlighting the importance of valuing local agriculture in order to build more ecological agri-food systems, the author has emphasized the significance of strengthening the relation between producers and consumers, contrasting with the supermarket establishment's context. Consequently, she also mapped public squares due to their potential to create new food centralities through the expansion of street markets or the establishment of individual points for local food supply. To evaluate people's accessibility of street markets and squares from a walkability perspective, the previous study has utilized a metric of a 500 meters radius from these places [11, 18]. These mapping results are pivotal in guiding territorial planning strategies and the development of new centralities, which form the primary emphasis of this research. Now additional factors, including topography, structural roads, and metrics of active mobility from consolidated centralities will be considered to provide a comprehensive analysis.

4. New centralities as a territorial planning strategies: active mobility priority

For a city to encourage more active commuting, it is imperative that the residence's surroundings offer essential services and activities. It makes walking and cycling more useful in daily routine and tend to turn motor-vehicle displacements unnecessary. Besides, the provision of efficient public transit and safety infrastructure — such as well dimensioned and designed sidewalks and bike lanes—has a vital role in stimulate a modal shift by private motor vehicle users. Speck [4] acknowledges the significance of mixed-use in land occupation to promote a healthy city. The author emphasizes that incentivizing walkability is the most effective environmental and healthy public policy because of its substantial positive impacts on collective and individual health, economic aspects, and environmental preservation. Recognizing that urban morphology can influence daily habits, including the promotion of healthy patterns, Saldiva [3] explains that commuting routines through active transportation modes could be considered a health public policy aimed at reducing obesity levels and mitigating cardiovascular diseases, among other health benefits.

The planning concept of the 15-minute city encapsulates many of these perspectives as it advocates for urban planning dedicated to provide essential social functions (residential, work, commerce, healthcare, education, and leisure) within a fifteen-minute distance. This metric is linked to the idea of comfortable active displacement [19]. The discourse around this concept has gained prominence in recent years, particularly due to the COVID-19 pandemic, which has introduced elements such as lockdowns, social distancing, and concerns about contamination in public transportation into daily dynamics. Going further, the consequences of urban sprawl turn many city spaces and the life quality of the inhabitants vulnerable, highlighting the importance of being nearby to basic amenities [20].

Considering the prevalence of the binomial consolidated centralities and residential neighborhoods in many cities and their impact on people's daily commuting time, proposing decentralization based on active mobility and territorial dynamics requires careful consideration of comfortable velocities for walking and cycling, as well as the identification of potential areas in the city. To initiate this discussion, the Institute for Transportation and Development Policy [21] asserts that the principle of freedom of movement is directly linked to compliance with infrastructure variables. Regarding pedestrians, ITDP [21] highlights certain characteristics that urban planning should take into account, including easy direction changes, direct contact with surroundings, physical effort, and low speed. Additionally, for bicycles, several factors come into play, such a higher speed and the ability to cover longer distances, despite it is also a low-cost and no pollutant transport.

In order to evaluate the active transportation access to urban opportunities in Petrópolis first district, the average speed of 3 km/h for walking displacements [18] and 15 km/h for cycling displacements [22] were adopted to trace the 15 minutes radiuses from consolidated and potential centralities. Although many people use to walk faster than the settled speed, it aims to display, in one hand, a more realistic scenery of walking in a city with many steep streets as Petrópolis and, in other hand, seeks to include and benefit children, elderly and disability groups — which tend to move slowly—in urban planning decisions [23]. The lower cycling speed adopted also considers Petrópolis's slope challenges, besides embraces the rhythm of cargo bikes, which can gain space if supported by a

people-centered street design and planning. Figure 3 illustrates the radius from the Historic Center of Petrópolis, considering the distance results based on comfortable speeds within 15 minutes: 750 meters for walking and 3,750 meters for cycling displacements.

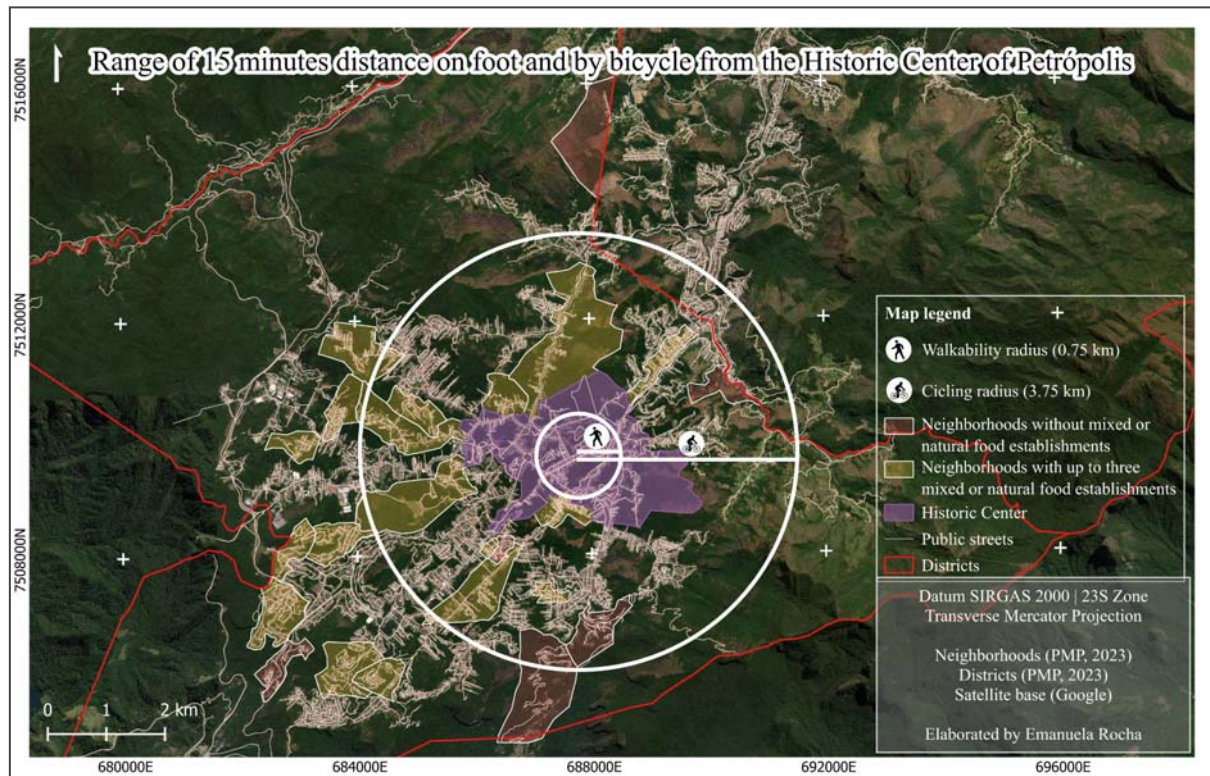


Figure 3. Range of 15 minutes distance on foot and by bicycle from the Historic Center of Petrópolis. Source: Authors.

By the map, it is notable that cycling could expand the accessibility of the historic center, including many peripheral neighborhoods in a 15-minute access range. It's important to highlight that many of these neighborhoods have just a few places in which it is possible to buy natural food, or even do not have any opportunity for it in its own limits. Considering the city's expensive bus fare (which impacts almost 20% of a minimum wage income) [24], making cycling a widely adopted transport mode could be significant for the increasing population health.

Examining the infrastructure of other neighborhoods in the first district, Bingen and Quitandinha emerge as potential centralities in their surroundings, marked by the presence of commercial establishments, structuring road system, and connections to other neighborhoods, some of which are vulnerable in terms of food access (Figure 4). In the context of Petrópolis, addressing food supply involves leveraging the rural areas within the city to enhance food security through stronger connections between farmers and consumers, thereby promoting a short food supply chain. Aguiar, DelGrossi, and Thomé [25] assert that short circuits are linked to the social and solidarity economy, creating alternative food networks based on healthy food choices, as well as environmental and social preservation. They emphasize that expense reduction, support for regional and local development, and improvement in consumers' food quality are significant factors characterizing the integration of local family farmers into short circuits. In Petrópolis, policies aimed at strengthening this relationship could contribute to the autonomy of family farmers, foster interdependence between urban and rural areas, and instill a sense of belonging. Furthermore, such investments could align with more ecological agri-food systems, emphasizing diversification, agroecology, pluriactivity, and other sustainable practices.

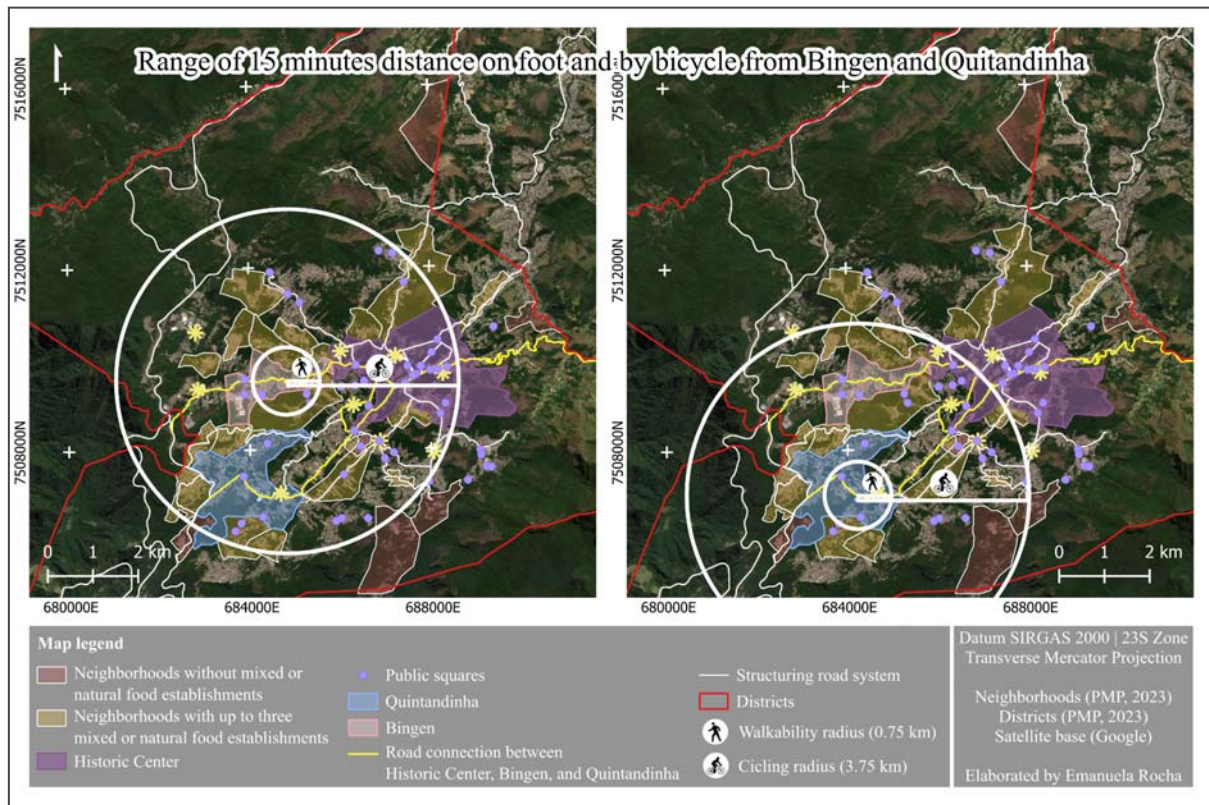


Figure 4. Range of 15 minutes distance of foot and by bicycle from Bingen and Quitandinha. Source: Authors.

The territorial planning approach that incorporates agri-food aspects enriches the discourse on the natural resources and cities vocations, providing opportunities for strategic interventions. Recognizing the potential of Bingen and Quitandinha to evolve into centralities, several considerations must enhance this analysis, including urban mobility—addressing access and accessibility issues—and public squares, which contribute to the discussion on public space appropriation, the expansion of free market network, and the creation of individual points for local food supply. In terms of urban mobility, Figure 5 emphasizes the main streets connecting the rural area of Caxambu to the Historic Center and to Bingen and Quitandinha. Considering the importance of cycling infrastructure for urban mobility and public health, it is crucial that urban planning takes into account their effectiveness and appropriation by the inhabitants. In order to potentiate a modal shift to bicycle in these regions, the city can implement existing bike lanes projects and adopt cycling infrastructure in flat streets in order to allow cyclists to avoid sloped paths, making bike commutes easier and more convenient. As highlighted by Paiva [14], a steep section in the route from the Historic Center to Quintandinha—which appears as a plateau in Figure 5’s second graph—could be avoided by cyclists if Washington Luiz Street receives a two-way segregated bike lane along a short section of just 700 meters long. Regarding the Historic Center to Caxambu connection, the rural-to-urban transect analysis can show the presence of vulnerable areas on the periphery of the Historic Center and the absence of initiatives to enhance rural areas, which could be characterized as the periphery of the periphery (Figure 6).

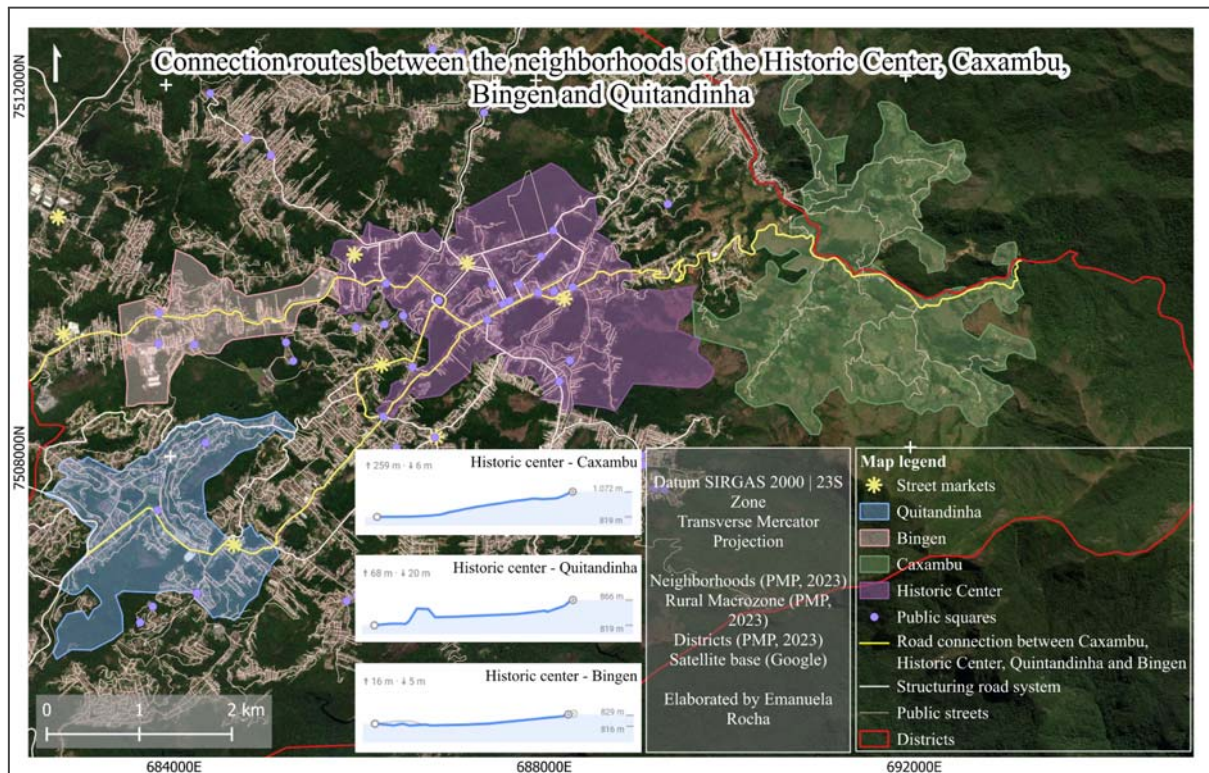


Figure 5. Connection routes between the neighborhoods of the Historic Center, Caxambu, Bingen and Quitandinha. Source: Authors.



Figure 6. Rural to urban transect: Caxambu to Historic Center. Source: Authors.

The mobility aspect is a consideration in the strategic planning that integrates both the interdependence between urban and rural areas and urban quality and health. The quality of road infrastructure is directly correlated with the dynamics of production flow. In Petrópolis, the road connecting Caxambu to the Historic Center has been a subject of prolonged concern due to daily commuting, the transportation of agricultural production inputs, and the distribution of products to other areas. In the context of decentralization analysis, infrastructure variables play a crucial role in promoting active mobility. Assessing the current state of streets, Figure 7 illustrates certain features of the roads linking the Historic Center to the Bingen and Quitandinha neighborhoods, such as the presence of sidewalks, although their low quality, and ample space for carriageways. This layout offers the potential to enhance sidewalks when expansion is required, along with the possibility of implementing cycling infrastructure. As occurs in many cities around the world, the on-street parking in many sections of these streets is a spacial issue to be faced by local authorities in order to implement cycling infrastructure.



Figure 7. Infrastructural characteristics of the analyzed routes. Source: Authors.

From the standpoint of food security and decentralization, the analysis highlights the potential of Bingen and Quitandinha to enhance access to natural food for residents in vulnerable areas. Public squares in these neighborhoods could host street markets on specific days of the week, while squares and other public space fractions located in vulnerable neighborhoods could be used for establishing individual points for the local farmers' natural food supply. Considering the existing dynamics of middlemen in Petrópolis' street markets, these initiatives could initiate municipal actions that value local farmers, providing them with opportunities and a prominent role in the food sales process.

5. Conclusions

Recognizing the importance of transitioning to more ecological approaches in food production and advocating for urban planning that aligns with environmental dynamics, this research considers the importance of the Petrópolis' agrarian sector fulfilled by family farming in supplying food to the city and the state. Through an examination of the local food scenario encompassing production to commercialization, this article has established connections between food production and consumption. The emphasis is placed on conducting a comprehensive analysis of the territory, with a focus on promoting rurality and ensuring food security.

It considers strategic and territorial approaches to Petrópolis, connecting essential aspects of contemporary cities, such as active mobility, food production, and sustainability. The valorization of rural areas is a significant consideration for rethinking the city in terms of territorial recognition, taking into account natural and vocational resources. Furthermore, this approach may be associated with actions in favor of food security and against social inequalities.

Looking ahead, the research following steps intend to explore urban voids, community gardens, and local food production initiatives in Petrópolis, expanding the scope of urban agriculture and the integration of food into the urban culture. Additionally, a gender perspective and an exploration of reproductive work will be subjects of future investigations to highlight the role of women in the context of food in both urban and rural areas of Petrópolis.

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