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Prioriority actions maps of municipal public services with geospace application

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ABSTRACT. Public services management is a fundamental role to public institutions, providing society with proper resources for a better quality of life. Local characteristics should be considered during public policies planning; however, generalizations are adopted to elaborate studies, overlooking these characteristics. Our objective was to apply a geostatistical analysis into the public services of Campo Mourão, Paraná State. The number of residents per census tracts lacking in water supply, sewage collection, waste collection, street lighting, electricity, and paving was found based on 2010 Census data. The spatial distribution of these data with the software ArcGIS 9.3 enabled the examination of these characteristics via the Cluster and Outlier method, through the Anselin Local Moran's I spatial analysis module, that identified hotspots and coldspots. As a result, it was found that Campo Mourão is satisfactorily supplied with electricity distribution services and waste collection with only 0.5% of absence in the census tracts. The sewage collection by the general network was the most absent service with 37% absence rate. Parque Industrial I and Jardim Isabel neighborhoods stood out as the most devoid of public services. The Cluster and Outlier Analysis is a subsidy tool for policy-making, which can increase efficiency when providing these services.

Keywords: public services; geostatistics; census; cluster; outlier.

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Introduction

The planning and management of public resources requires spatial analysis to support decision-making, regarding intervention in urban space or definition of policies that regulate the use and occupation of this space. Due to its ease in analyzing, visualizing and integrating data, the geographic information system becomes an important tool to support planning, management and resource allocation, highlighting two factors: efficient control (data accuracy with parameters) and corporate management of municipal secretariats through information sharing, joint actions and streamlining of management procedures (Stassun & Prado Filho, 2012).

It is a technology that increasingly expands its space utilization, and particularly increases in municipalities where your application can reach the most diverse areas. Some of them, such as: planning and land management, optimization of tax revenues, public facilities and service allocation, identification of target audience in public policies, environmental management, transportation system management, and communication. An example of application is to map occurrence of a disease transmitted by vectors. Determining the range of distribution of the disease in relation to the vector, it can be associated the sanitary conditions offered to the population in the radius of occurrence, among other characteristics that are associated to the vector. Thus, each agency can direct the appropriate actions to control and minimize the extent of the disease (Câmara, Monteiro, Fucks, & Carvalho, 2004).

The best way to guarantee this efficiency of analysis is to search for georeferenced information surveys, which have been required for its use in geostatistical analyzes. The demand for geospatial data in Brazil is supplied, in general, by the *Instituto Brasileiro de Geografia e Estatística* (IBGE), whose purpose is to provide information for public policies in the planning of investments in the public and private sector. It acts as the lead information provider agency in various segments of society. Equipped with the most complete form of demographic research, the IBGE elaborates the census, a statistical survey of the living conditions of the

population and socioeconomic characteristics throughout the Brazilian territory (*Instituto Brasileiro de Geografia e Estatística* [IBGE], 2011a).

Thus, this census works with a universe of variables; however, in the proposed analysis, it was used the data of essential public services for a better quality of life in the urban area. The services object of this paper are water supply, sewage system, waste collection, street lighting, electricity, and paving services in the city of Campo Mourão, State of Paraná, in 2010, the last census.

This paper aimed to highlight the census tracts that lacked public services in the municipality of Campo Mourão in the State of Paraná. Subsequently, maps of priority actions were generated from individual analyzes. So, in other words, a map of each public service was created in order to subsidize the decision-making based on local and reliable data about the municipality.

Material and methods

Characterization of the area

The municipality of Campo Mourão is in the Southern region of Brazil, placed in the Geographical Meso-Region of the Western Center of the State of Paraná. More precisely, it is 90 km away from the city of Maringá and 460 km from Curitiba, the state capital (Figure 1). Its urban area comprehends the city of Campo Mourão and the district of Piquirivaí, which is approximately 18 km far from the city.

The forest cover of the Campo Mourão comprises two phytophysiognomies of the Atlantic Forest – the Mixed Ombrophilous Forest and the Semideciduous Seasonal Forest – with enclaves the Brazilian Savanna. The expansion of intensive agriculture, agribusiness and urbanization are the main activities responsible for the reduction of natural areas (Ferreira et al., 2018; Ferreira, Bragion, Ferreira, Benedito, & Couto, 2019; Tomadon, Dettke, Caxambu, Ferreira, & Couto, 2019).

In 2010, the population of the municipality was of 87,194 inhabitants distributed in its 757,875 km^2 territory, resulting in a population density of 105 inhabitants km^{-2}. The Municipal Human Development Index (MHDI) was of 0.757. In addition, in 2010, the total male population was 42,013, and women were 45,181, of which 95% of them all lived in the urban area of Campo Mourão. Furthermore, most of the population considers themselves white and brown, and the smallest indigenous ethnicity (*Instituto Brasileiro de Geografia e Estatística* [IBGE], 2015).

The stipulated area of studying was delimited through the urban perimeter of the Municipality of Campo Mourão, which was subdivided by the IBGE census tracts in 2010 (Figure 1). Campo Mourão had 105 census tracts in its urban area, but the Piquirivaí district tract, 18 km away from its main urban area was not considered for the scope of the study, since it was inadequate for the geographic continuity necessary to develop the geostatistical analysis. In addition to this, the lack of data for the two census tracts in the Jardim Modelo neighborhood has justified their exclusion. Therefore, a total of 102 census tracts were analyzed considering the elimination tracts which lacks in information and the geography continuity in urban area (Figure 2).

2010 Census data

The data used were defined according to public health needs such as sanitation and basic resources, like electricity, available in the 2010 census database.

Among the public services, basic sanitation remains the most essential due to its relationship with health. Based on four pillars, basic sanitation includes potable water supply, sewage collection system, solid waste management, and rainwater drainage. Three of the four pillars were considered as the study scope to analyze the absence of these services in the census tracts of the municipality and to indicate places that stand out from the context of the universalization of service provision.

Among the three other services analyzed, electricity is the most important for the comfort and needs of modern society. Electric power has brought comfort and practicality to families; which is indispensable today mainly because of lighting, for the development of night activities and food conservation. In addition to indoor lighting, electricity is vital for providing street lighting, service that brings a security feeling to the population as it gives a field of vision of the neighborhood. Also, it is extremely valuable in helping drivers, providing vision of obstacles, people and other cars in circulation.

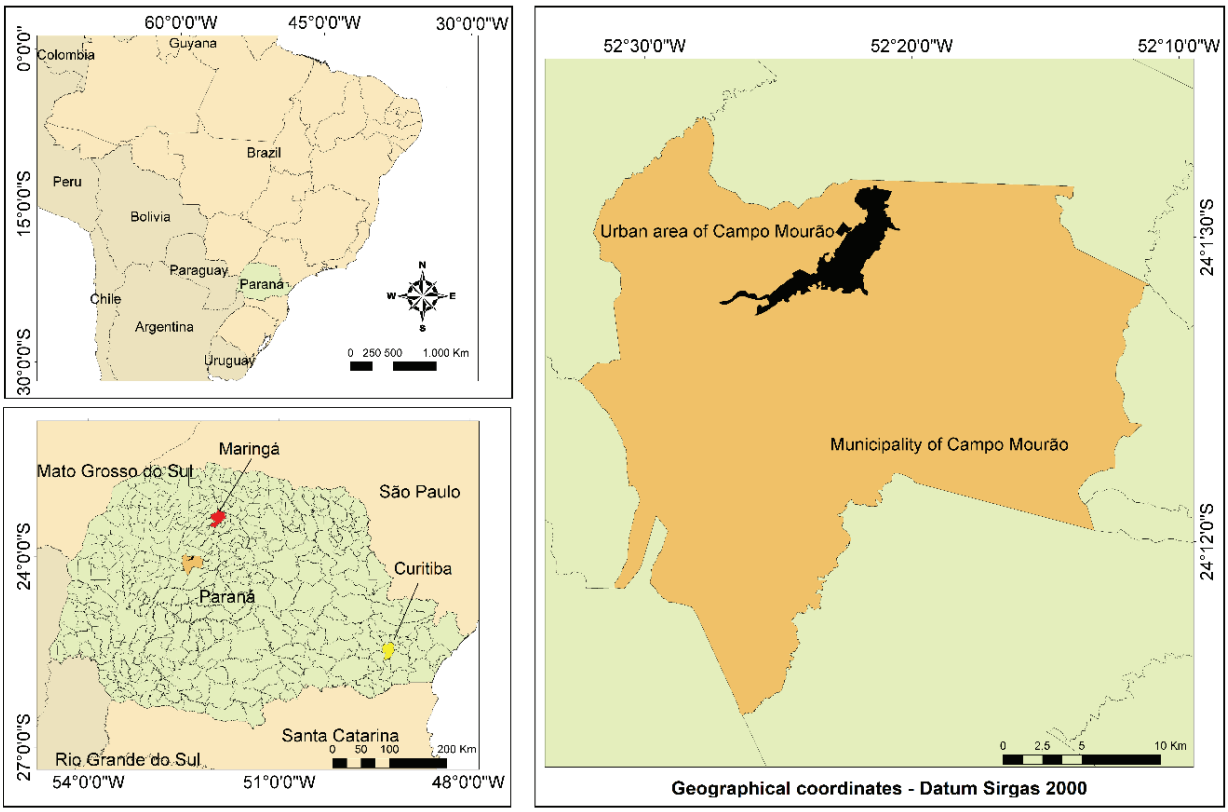

Figure 1. Location of the Municipality of Campo Mourão. Source: Cartographic Base: Digital urban census tracts network of the state of Paraná 2010 (*Instituto Brasileiro de Geografia e Estatística* [IBGE], 2010).

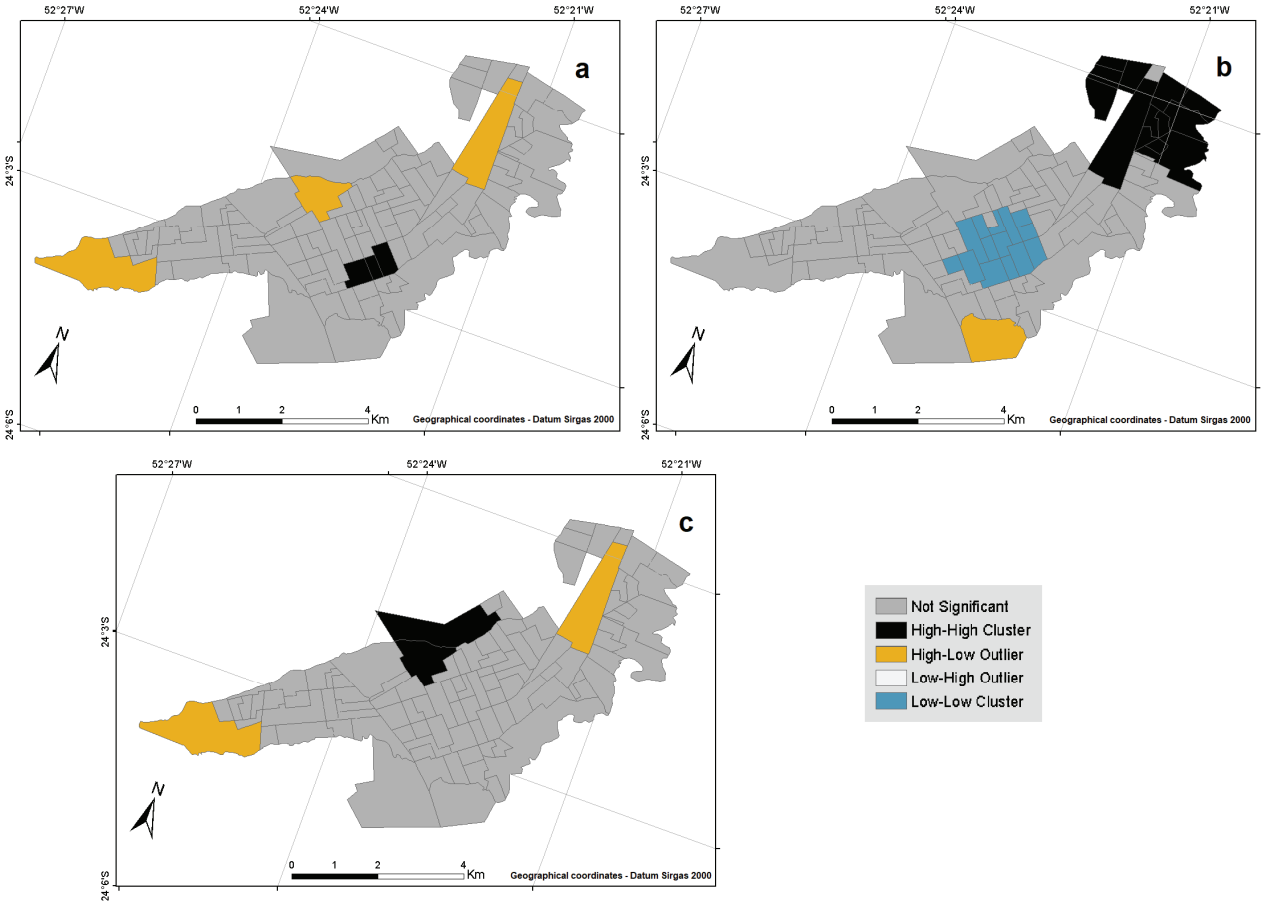

Figure 2. Cluster and outlier analysis of the absence of basic sanitation services a) water supply; b) sewage collection and c) solid waste management in Campo Mourão, State Paraná, based on the 2010 Census.

Finally, the pavement of the roads allows better displacement of vehicles and pedestrians, minimizes speeding and helps the locomotion of citizens who are subjected to the various physical barriers that the environment and man impose.

The development of this work was possible in a GIS environment through the manipulation of shapefiles of the census tracts. On Table 1, it shows the information used to the geostatistical analysis.

The public services data taken from the IBGE database were transformed from attendance to absence. In other words, instead of using the number of residents with the service present in their home or in their environment, it was used the number of those without it (Equation 1). The reason for such transformation was to facilitate the identification of the appropriate tracts (absence = 0) and inadequate ones (high values).

$$\partial_n = P_s - S_n \quad (1)$$

∂_n is the number of residents without service in the tract (absence); P_s is the total population in the census tract and S_n the number of residents who have the public service (census data).

Statistical analysis of clusters and outliers

The present study was developed in a GIS environment through ArcGis 9.3 software, using the geostatistical tools package Cluster and Outlier Analysis (Anselin Local Moran's I) (Anselin, 1995; Mitchell, 2005), which statistically evaluates the spatial distribution of the data of interest, classifying them into clusters or outliers (Equation 2).

$$I_i = \frac{Z_i - \acute{Z}}{\sigma^2} \sum_{j=1, j\neq i}^{n} \left[W_{ij}\left(Z_j - \acute{Z}\right)\right] \quad (2)$$

Z_i is the value of the variable Z in the location i; $\acute{Z}$ the average value of Z for n samples; $Z_j$represents the value of the variable Z in all other locations ($j \neq i$); σ^2 is the standard deviation of the variable Z; e W_{ij} is a weight value, which can be defined as the inverse of the distance between the locations$i$ and j. The weight W_{ij} can also be determined using a distance band. For samples within a distance band are given the same weight, while those outside the distance range is given the weight zero (Anselin, 1995).

The analysis of clusters and outliers was done individually for each public service. Through the local spatial auto-correlation tool discussed by Anselin (1995), it is possible to identify patterns of spatial groupings and circumstances that are not possible to group like the ones with extreme values, which can simply be interpreted as critical locations.

In ArcGis 9.3 software, the default output is a cluster/outlier map (COType). The analysis uses z-scores and p-value, which are statistical parameters of significance to accept or not the null hypothesis of spatial randomness. They indicate whether there is similarity (the spatial agglomeration of high or low values) or dissimilarity (outliers), which is more evident than the random distribution. A high and positive z-score means that its neighborhood has similar values, whether high or low. On the other hand, a low and negative z-score means a statistically value outside of the data curve, that is, the outliers that denotes places that differ from their neighborhood, whether in high or low values.

The COType representation will always indicate clusters and outliers, statistically significant for a confidence level at least of 95%, i.e. $p < 0.05$. Therefore, the spatial representation of COType output of the software uses a standard typology.

Table 1. Socioeconomic data and conditions of the inhabitants of Campo Mourão - PR in the 2010 Census. Source: *Instituto Brasileiro de Geografia e Estatística* (IBGE, 2011b).

Variables	Variable description
1. Water supply	Number of residents in permanent private houses with water supply from the general network
2. Sewage Collection	Number of residents in permanent private houses with bathrooms for the exclusive use of residents and sewage collection via general system or by rainwater drainage system
3. Solid waste management	Number of residents in permanent private houses with waste collected by public cleaning service
4. Electricity	Number of residents in permanent private houses with electricity provided by distribution company
5. Street lightning	Number of residents in permanent private houses, rented or assigned with street lightning
6. Paving of streets	Number of residents in permanent private houses, rented or assigned with paved streets

- HH (*High-High*): a statistically significant cluster of high values;
- LL (*Low-Low*): a statistically significant cluster of low values;
- HL (*High-Low*): high value outlier, surrounded by low values;
- LH (*Low-High*): low value outlier, surrounded by high values;
- Not significant: they do not fit in clusters nor in outliers, since they present varying levels as well as the values of the neighbors.

The positive high values of the Moran's I local index imply that the study site has either high or low cluster values. Clusters can be classified into high-value groupings (High-High HH) or low-value groupings (Low-Low LL). However, the negative values of the local Moran's I index indicate outliers, which can be high or low values, differing from their neighbors (Lalor & Zhang, 2001).

Thus, high-value clusters can be called 'regional hotspots', while low-value clusters are 'regional coldspots'. Furthermore, high-value outliers can also be called individual hotspots, and low-value outliers individual coldspots (Zhang, Luo, Xu, & Ledwith, 2008).

Results and discussion

The spatial representation of the patterns of cluster and outlier's statistical analysis for all variables was displayed in accordance with the data of the service absence. Therefore, higher values mean greater lack of service in the census tract.

The basic sanitation variables presented clusters with different characteristics among the neighborhoods (Figure 2). Most of the city was classified as not significant for the supply of potable water. However, of this study's 81,705 target residents, 1,069 residents, or 1.3% of them, had no water supply via the general network distribution of the Sanitation Company of Paraná (Sanepar). In the Central region of the city, it occurred a high-value cluster (HH, black region) with three census tracts grouped, indicating a high number, about 190 people, without this public service (Figure 2a).

It has also been found three high-value outliers (HL, yellow region) in different regions. Firstly, in a tract in the Great Lar Paraná region, in the Parque Industrial I neighborhood, which has stood out for having 125 residents without water supply service. The second one was near the Central region, in the Vila Rio Grande neighborhood and the third tract, located in the East Wing of the city, in the Jardim Isabel neighborhood (Figure 2a). Among the basic sanitation services, this is the best distributed to the population. In 2011, the average of the Southern region was of 99.1% of residents with service available, the largest in the country, whose average is 93% (*Departamento Intersindical de Estatística e Estudos Socioeconômicos* [Dieese], 2016).

The spatial representation for the sewage collection service through the general network obtained four COType typologies (Figure 2b). Notice that the collection of sewage refers to the exhaustion of it, whether it is treated or not before the final disposal, characterizing it as a service provided. The service is the most critical in the city, 30,277 residents did not have at their disposal the service, and this represents 37.05% of the studied residents. It places Campo Mourão above the average of the Southern region of the country, which in 2011 was 35% of residents served by this service (Dieese, 2016).

The Central region census tracts of Campo Mourão presented a 14 low-value tracts cluster (LL, blue region) (Figure 2b). Thus, in this region, it is evident how low is the number of residents who lack the service, which is expected for downtown tracts of the city. On the other hand, in the extreme south of the Central region, in the Araucária neighborhood, there was a high-value outlier (HL, yellow region). As it is an old neighborhood and on the suburb of the city, the tract counted on 98.4% of residents without infrastructure for the sewage collection. However, in 2014, the neighborhood received the sewage network, and today almost 100% of its area is served by this public service.

The municipality in the following years invested in expanding these public services in compliance with the law n. 11,445 (Brasil, 2007), which deals with the guidelines and basis for basic sanitation. This law has brought greater clarity on service concession contracts, the development of the Municipal Sanitation Basic Plans and the establishment of goals for investment in the sector (Albuquerque, 2011). The target set was that in 2023, through municipal plans, 95% of the population of the country would have sewage system.

In the East Wing, 12 census tracts were grouped, forming a high-value cluster (HH, black region). In this cluster, 34.65% of the inhabitants without sewage collection through the general network were evidenced.

The residents of Campo Mourão had an efficient public waste collection service, and only 409 residents did not have the service in their homes. Therefore, the number of people lacking this public service is minuscule in relation to the population surveyed, only 0.5% of the total (Figure 2c).

Again, the Parque Industrial I neighborhood, on the extreme left in Figure 2c, is highlighted with an outlier tract, as well as the Jardim Isabel to the right in Figure 2c (yellow regions). Both classified as high-value outliers, respectively 43 and 46 residents without waste collection service. In addition, a cluster was formed by two census tracts in Northern Central region of the city. They are Vila Rio Grande and Cidade Nova tracts, with a total of 113 inhabitants who lacked the waste collection service (Figure 2c, black region).

Some cities, for example Itu (SP), use more advanced systems to control solid waste such as sensors in buckets that allow monitoring the volume and characteristics of the deposited material, providing better management of the collection routes and the disposal points location (Monteiro & Nahas, 2018).

The company responsible for local electricity supply (*Companhia Paranaense de Energia* [Copel]) does not provide electricity to 332 residents, the equivalent of 0.4% of the target population. A very small percentage of the population does not have electricity supply by the distribution company, which may not characterize a severe problem.

There were only two significant tracts classified as high-value outliers (HL, yellow regions), the first, located in the Central region, in Vila Rio Grande neighborhood and the second in the East Wing, the Jardim Isabel (Figure 3a). Therefore, both have a high number of residents lacking the service and are surrounded by 102 non-significant value tracts, that is 98.04% of the census tracts investigated.

The municipality of Campo Mourão has shown to be provided with street lighting among the 81,705 inhabitants census tracts. in the urban area, while only 1,475 of them were devoid of streetlights, i.e. 1.8% of the residents (Figure 3b).

The suburb of the city stood out with two high-value outliers (HL, yellow regions). The first tract has its location in the Great Lar Paraná area, in Parque Industrial I neighborhood, a place of urban expansion with little infrastructure, which has few points of street lighting. There were 159 residents without street lighting registered in their vicinity amid the 234 total residents. In the second location, also in the suburb and urban expansion area (Vila Carola), none of its 192 residents had access to a spot of light in the surroundings of theirs houses in 2010.

The urban area of Campo Mourão presented 4,258 residents without paving in their homes' street. This represents 5.2% of the target population of this study (Figure 3c), yet the Central areas of the city were not significant. However, six census tracts evidenced a high number of residents in need of the service.

Bordering the Great Lar Paraná and the Central region of Campo Mourão (Figure 3c), the Jardim Damasco neighborhood had characterized as a high-value outlier (HL, yellow regions), with 283 of its 440 residents lacking paved ground on their homes' streets.

In the East Wing of the city, there were two high-value clusters (HH, black regions), formed by the neighborhoods Jardim Modelo, and part of Jardim Santa Cruz and Jardim Tropical. These are peripheral neighborhoods of urban sprawl, where there was little structure. However, there are two low-value outliers among the high values. They are areas of Jardim Santa Cruz and Jardim Tropical that there were less residents with pavement deficits. Moreover, it is difficult to determine the disparity in the absence of the paving service in neighboring tracts, but the most supplied tracts are younger neighborhoods.

By organizing the individual analysis of the services in a hot and cold spot analysis, it was observed that the surveyed urban area comprised of 102 census tracts, obtained 79 tracts where no hotspots of the absence of the public services were found (Figure 4). These are the best-ranked census tracts and are represented by the green color. The tracts in yellow were classified as HH or HL only in one occasion; in other words, a public service with high absence values, totalizing 15 areas. On the other hand, the tracts classified as high in two public services analysis were identified by a light orange color, and they are located in both Central regions: Vila Rio Grande neighborhood and also in the East Wing, embracing the Jardim Modelo, Jardim Santa Cruz and Jardim Tropical neighborhoods.

However, the most worrying census tracts were those in Parque Industrial I, represented in dark orange, which was indicated three times due to the high number of residents lacking public services. Finally, the most critical tract, which presented the worst performance in four of the six services analyzed was Jardim Isabel in red.

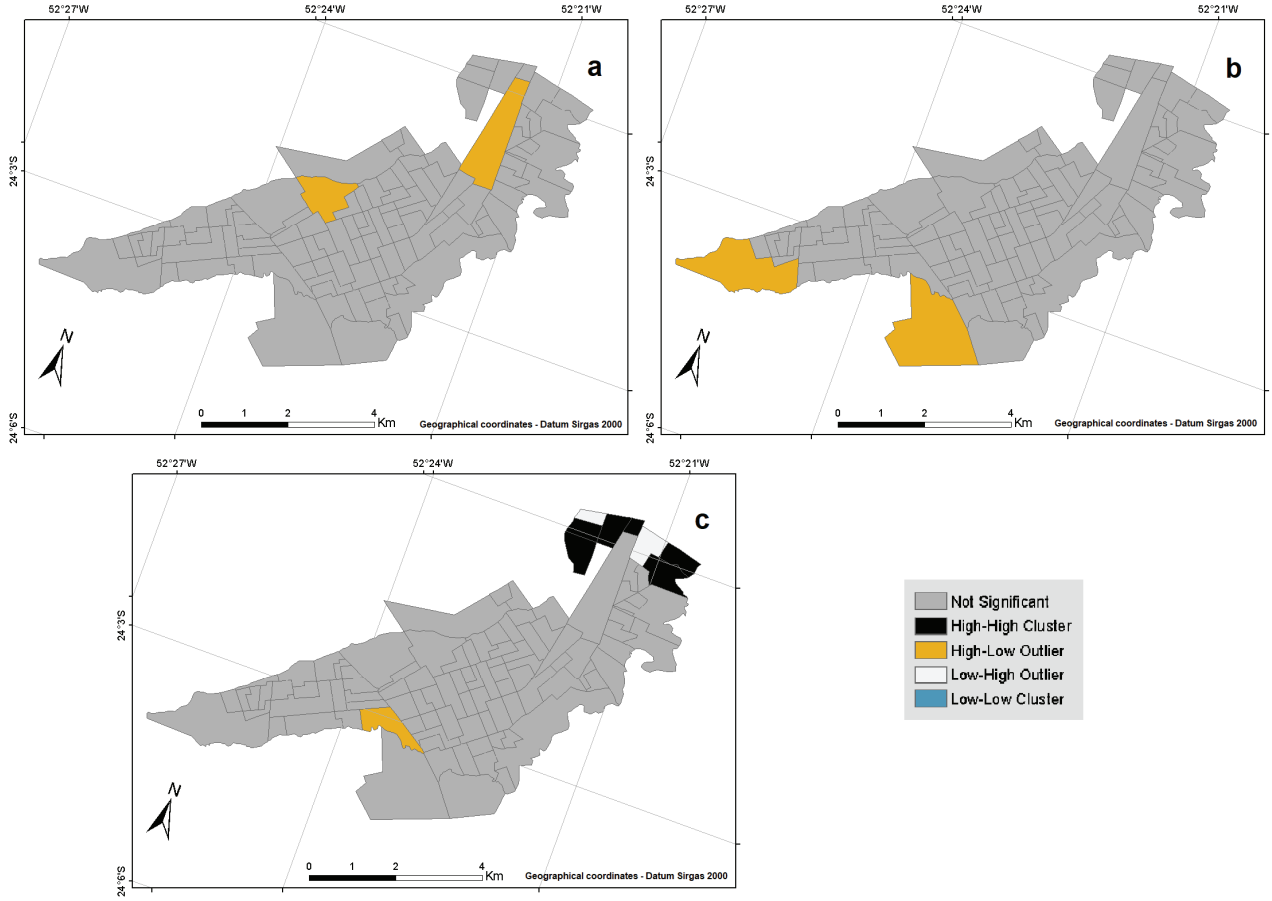

Figure 3. Cluster and outlier analysis of the absence of public service a) electricity; b) street lighting and c) paving in Campo Mourão, State Paraná, based on the 2010 Census.

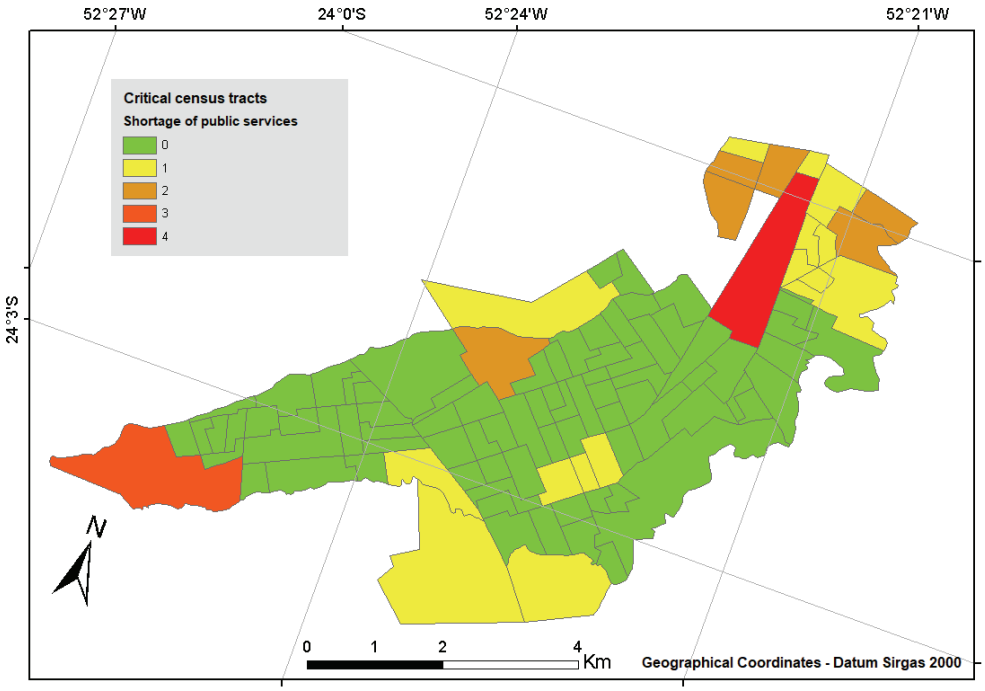

Figure 4. Classification of census tracts in Campo Mourão, State Paraná, according to the shortage of public services (water supply, electricity, sewerage system, public lighting, garbage collection and paving).

Thus, the most critical areas need targeted policies such as the expansion of the sewage system, which contributes to the removal of sewage from the proximity of residences and significantly reducing public health expenditures (Bay & Silva, 2011).

These highlighted points in this work are part of the actions that can be performed with the use of georeferenced information but, to guarantee a more effective action of this type of service, it is important to have a database with the most diverse possible information. In addition to this, creating channels of interaction with the population will allow needs to arrive more quickly to the knowledge of the public authorities. For example, a system that allows the population to notify the appearance of a hole in the asphalt and more, the georeferenced database pointing its exactly location, allowing quick decision in the maintenance (Monteiro & Nahas, 2018). It is also important that the municipal secretariats work in an integrated way, giving more agility in the decisions of maintenance operation of the city.

Conclusion

The Cluster and Outlier Analysis clearly pointed out the cold and hotspots, highlighting shortcomings of the targeted public services for Campo Mourão in 2010. Furthermore, aggregating all deficiencies, the critical census tracts were evidenced, regarding public services absence. This shows that the individual analysis of public services and subsequent integration can be a useful socioeconomic analysis tool. In the future, researches can deepen further investigations, exploring complementary statistical methods in ArcGis.

Therefore, statistical analyzes are tools that, when acting as a resource for public policy development, becomes basis for decision-making aimed at providing a higher quality of life to population.

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