Spatial Structure and Urban Sprawl in the Metropolitan Region of Goiânia

Yordana Dias das Neves Naciff
Programa de Pós-graduação Projeto e Cidade, Faculdade de Artes Visuais, Universidade Federal de Goiás, Goiânia, GO, Brasil.
yordanad.neves@gmail.com

Erika Cristine Kneib
Programa de Pós-graduação Projeto e Cidade, Faculdade de Artes Visuais, Universidade Federal de Goiás, Goiânia, GO, Brasil.
erikakneib@ufg.br

Celene Cunha Monteiro Antunes Barreira
Universidade Federal de Goiás, Goiânia, GO, Brasil.
celenemonteiro05@gmail.com

Abstract

Cities are constantly changing the configuration of their urban and social spaces. As they grow, the various problems and challenges associated with organizing the territory stand out. The study and analysis of cities requires the understanding that they are an interdisciplinary and very complex subject of study. In Brazil, many cities and regions are experiencing scattered processes of rapid urbanization, creating large urban voids that affect the qualifying population density in the expanded regions. This process, known as urban sprawl, makes access to urban infrastructure more difficult and exacerbates social and spatial inequalities, be it in the municipality or in the metropolitan region. In this context, the choice of a metropolitan case study for this research - the metropolitan region of Goiania - takes into account the classification between the processes of metropolitanization and urban sprawl for the constitution of the urban spatial structure in this region consisting of 21 municipalities. The aim is, therefore, to develop a methodical procedure for the characterization and analysis of the dispersal processes in the spatial structure of the region. The research carried out is basic, exploratory, descriptive and based on a qualitative-quantitative analysis using a spatial autocorrelation analysis as a tool. The development of the analysis method, including the conception of an indicator of urban sprawl, which can be helpful in urban and metropolitan planning processes, stands out as the main results.

Keywords: spatial structure, sprawl, RMG, methodological procedure, indicator.

INTRODUCTION

Cities experiencing constant evolution always change the configuration of their urban and social spaces. Thus, issues inherent to territory organization exacerbate in the most diverse fields and urban activities as cities expand. Analyzing cities means understanding that they are an interdisciplinary object of study, as well as the largest, most contradictory and most complex structure made by man (FERREIRA, 2011).

Cities around the world, including the Brazilian ones, undergo fast and dispersed urbanization processes and create large urban voids capable of hindering the formation of a qualified demographic density in the expanded regions. Urban sprawl is the term used to name such a phenomenon. Urban fabric spreads out without control and leaves gaps within the urban spot. Consequently, it makes it hard to have access to urban infrastructure and worsens socio-spatial inequalities.

This urbanization type virtually takes place worldwide, since it generates metropoles in several territories by articulating and merging different urban centers around a core city (IPEA, 2011). Subsequently, cities merge into a “single city comprising several municipalities”, and it impairs the implementation of an integrated public management between the metropolis and the cities around it.

Based on this perspective, and given the different challenges faced by contemporary cities, urban sprawl reached a high urban and social impact scale. Population clusters featured by precariousness, as well as by scarce assistance and resources, emerged in urban territorial boundaries.

The process to select a metropolitan case study for the current research took into account the relevance established between ‘metropolization’ and urban sprawl processes accounting for building urban spatial structures. Thus, the decision to select

the Metropolitan Region of Goiânia (RMG - Região Metropolitana de Goiânia) as the object of study was based on the assumption that this territory clearly represents the formation of a fragmented urban spatial structure plenty of problems yet to be solved. RMG – which is located in Goiás State –covers 21 municipalities (Goiás, 2019) and comprises more than 2.5 million inhabitants (IBGE, 2018).

Therefore, the aim of the current study was to develop a methodological procedure to feature and analyze urban sprawl processes taking place in RMG spatial structure. It has adopted a basic, exploratory, descriptive approach mainly based on qualitative-quantitative analyses. Bibliographic research, case study, official and geo-referenced data were used as resources. The herein developed procedure has also used spatial autocorrelation analysis as tool.

The selection of the herein investigated topic was justified by the scarce number of studies about urban sprawl in the Metropolitan Region of Goiânia. The current research is expected to help better understanding urbanization and urban sprawl processes based on critical analyses and reflections on the herein assessed subject, as well as to contribute to future decision-making in urban planning processes, whether in Goiânia City or in municipalities belonging to RMG.

Therefore, the current article was structured in three different parts. Firstly, it presents the theoretical framework about the research topic, based on contexts and concepts of processes such as ‘metropolization’, urban sprawl and spatial structure. Next, it presents the herein adopted analysis method and, finally, it applies the methodological procedure, namely: the analysis and featuring of urban sprawl in the spatial structure of the Metropolitan Region of Goiânia.

The present research has successfully developed an analysis procedure, which comprised an urban sprawl indicator capable of helping urban and metropolitan

planning processes. The feasibility and potential of the aforementioned procedure became clear at the time it was applied to the Metropolitan Region of Goiânia.

THEORETICAL FRAMEWORK

This item aimed at summarizing the main concepts supporting the present study - i.e., 'metropolization', urban sprawl and spatial structure – in order to build a line of perception coherent with its aims and structure. It was done to select and build the theoretical framework necessary to develop the applications and analyses to be carried out in subsequent sections. Therefore, the current chapter has used bibliographic and documental research as methodology for content formulation purposes based on a qualitative approach.

The 'Metropolization' Process

From the 1950s onwards, the Brazilian urbanization process was intensified by internal migrations that have massively displaced the population from the countryside to the cities (ROMANELLI and ABIKO, 2011). Brazilian cities started growing without control, surpassed their administrative limits and merged their core, or urban areas, with other municipalities around them (PIRES, 2018).

Milton Santos (2018) has pointed out that the urbanization process in Brazil in the late 20th century was virtually observed nationwide and often spread through macro-urbanization and 'metropolization processes'. Intermediate cities have emerged alongside local cities, both based on a widespread growth model, due to the capitalist production mode and to real estate speculation (SANTOS, 2018).

Such an extensive urban expansion has generated the so-called "metropolization", which consists in articulating, and in the conurbation of, several urban centers around a core city (IPEA, 2011); this process results in a large city formed by several municipalities. Thus, 'metropolization' is a remarkably complex urbanization stage that constantly undergoes socio-spatial changes. According to Dias and Lopes (2014), this

process results from a true “metamorphosis” in the structure, shape and function of cities, presenting dynamic and central features.

Based on Moura (2012), Brazilian urban occupation expansion processes are based on the “dispersed city” archetype. Thus, creating new urban settlements close to large cities generates a new city type “with diffuse, selective, more dispersed and fragmented morphology” (MOURA, 2012, p.7). It comprises “urban-regional arrangements” that work as spatial units formed by urban centers, as well as by their interstitial urban and rural areas - which are important topics in discussions about urban sprawl.

Urban Sprawl

The North American urban growth, observed between 1950 and 1970, was featured by migrations from urban to suburban areas, which happened in the attempt to escape the problems plaguing industrial cities. Urban sprawl was the term assigned to this phenomenon: it described a dispersed, segregated, automobile-oriented urbanization pattern that led to economic, social and environmental impacts (TCRP, 2002; LITMAN, 2015).

According to Glaeser and Kahn (2003), the logic of a sprawling metropolitan area lies on forming densely-populated and decentralized economic areas where extensive underused territories - named “urban voids” – emerge between people concentration zones and employment centers. Galster et al (2001) have described urban sprawl as the consequence or effect of some independent variable such as fragmented governance, poor planning or excluding urban zoning.

Nadalin and Igliori (2010, p.12) have also defined urban sprawl based on concepts such as concentration and density. According to them, polycentric cities are “decentralized, although they have densified sub-centers”. Based on Kneib (2014, p.29), metropolitan centralities cannot be separated from urban mobility. The aforementioned author has advocated that “urban territories are structured based on their set of centers

and sub-centers" and that transport systems are the actors involved in urban territory planning and structuring processes.

Therefore, urban sprawl depicts a fast and low-density urban expansion that takes place in a disorderly, dispersed and unsustainable manner. Consequently, it leads to underused territories, dispersion between job and household locations, automobile dependence and maintenance of socio-spatial segregation.

Spatial Structure

Urban spatial structure is defined as the cluster of "urban activities and functions, and the way they are spatially organized and articulated" (KNEIB, 2014, p.8). Although this definition is featured in different ways by several authors, it often points towards concepts such as distance and density, activity allocation, urban functions, travel patterns, infrastructure, centers and sub-centers (HARRIS, 2015; KNEIB, 2014).

Centralities – or the set of centers and sub-centers – are a constant aspect in references about urban spatial structures. The concept of polycentric city - or region - has been increasingly defended in urban and metropolitan planning processes, as spatial structure capable of proving balance and greater sustainability (KNEIB, 2014; KNEIB and PORTUGAL, 2017). Polycentrism has also gained room as method used to organize cities' growth; it also helps mitigating negative impacts associated with urban sprawling (UNITED NATIONS, 2016).

Rodrigue et al (2013) have listed two parameters to help better understanding the elements of cities. The first parameter refers to cities' infrastructure (urban shape), whereas the other refers to cargos and people's interactions with the urban shape (urban spatial structure). Similarly, it is possible establishing a parallel to the concepts of "stationary elements" and "flows", which are widely used by Milton Santos (2017). According to the aforementioned author, "stationary elements" enable taking actions to change places, whereas "flows" result from the application of these actions on "stationary elements".

The spatial structure of cities is also based on the road structure, whose high influence “on the use and occupation of urban land, [...] enables human displacement, as well as the exchange of information and goods” (CASTRO et al, 2015, p. 176). These road-urban interfaces are maintained by constant migrations and by the displacement of different population groups.

As previously mentioned about the Brazilian ‘metropolization’ and urban sprawling processes, spaces understood as metropolitan present complex spatial structure in several dimensions. According to Ribeiro and Silva (2018), when it comes to the metropolitan context, it would be more interesting to “pay less attention to ‘how much’ downtown and periphery areas have grown and more attention to ‘how’ they did it, since this process attributes higher analytical relevance to variables such as ‘distance’ and ‘density’” (RIBEIRO; SILVA, 2018, p. 107).

After having presented, in a syntactic manner, the initial approaches to ‘metropolization’, urban sprawling and spatial structuring processes - necessary to help better understanding these topics in a more general context - the next item presents the methodological aspects of the current study. This procedure is followed by the procedure application in the analyzed metropolitan region.

METHODOLOGICAL AND INSTRUMENTAL ASPECTS

The methodological procedure developed in the current research started by selecting two analysis variables used to synthetize the urban sprawl indicator. Firstly, thematic maps, statistical summaries (Boxplots[1]) and the spatial autocorrelation analysis of each investigated variable (Moran Index[2]) were presented. Subsequently,

1 Boxplots are graphs built based on measurements applied to the distribution of the set of values recorded for a given variable (NETO and KNEIB, 2016).

2 “The Moran index (I) is the most widespread statistics used to measure spatial autocorrelation based on the product of deviations from the mean. This index is a global measurement of spatial autocorrelation that indicates the spatial association degree observed in the dataset” (SILVA, 2016).

values observed for these variables were standardized based on the Z Score[3] operation in order to associate these two variables with each other (NACIFF, 2020).

Simple arithmetic mean was the operation used to associate the aforementioned variables. It is a central trend measurement widely used in statistics, whose value results from the sum of a collection of numbers, which is divided by the count of numbers in the collection. It is done by assuming that all variables are equally important.

After the arithmetic mean operation was over, an inferential model of spatial autocorrelation between these values was adopted to enable an exploratory analysis focused on identifying atypical locations (outliers) and spatial association patterns (clusters), as well as to generate an urban sprawl synthesis map.

Vector files in shapefile format and .xls tables were used to help plotting the aforementioned maps; these files were available in official databases, such as the Brazilian Institute of Geography and Statistics (IBGE - Instituto Brasileiro de Geografia e Estatística) and the State Geoinformation System of Goiás (SIEG - Sistema Estadual de Geoinformação de Goiás). Data were manipulated in the Geographic Information Systems (GIS) software to develop and plot the thematic maps.

Census sectors were the cartographic scale defined for the current analysis, since they represent the smallest territorial units. In addition, the availability of data about census tracts enabled better planning the comparative analyses to be applied to the two selected variables. Thus, this scale has shown great potential to help developing the proposed analysis. It is noteworthy that the herein used census data derived from the 2010 Demographic Census (IBGE, 2010) due to database availability limitations.

The methodological procedure developed for the current research was divided into three different stages, as shown in Fig.1.

3 Z Score or Standard Score indicates how far a given value (Standard Deviation) deviates from the mean (VILELA JÚNIOR, 2012).

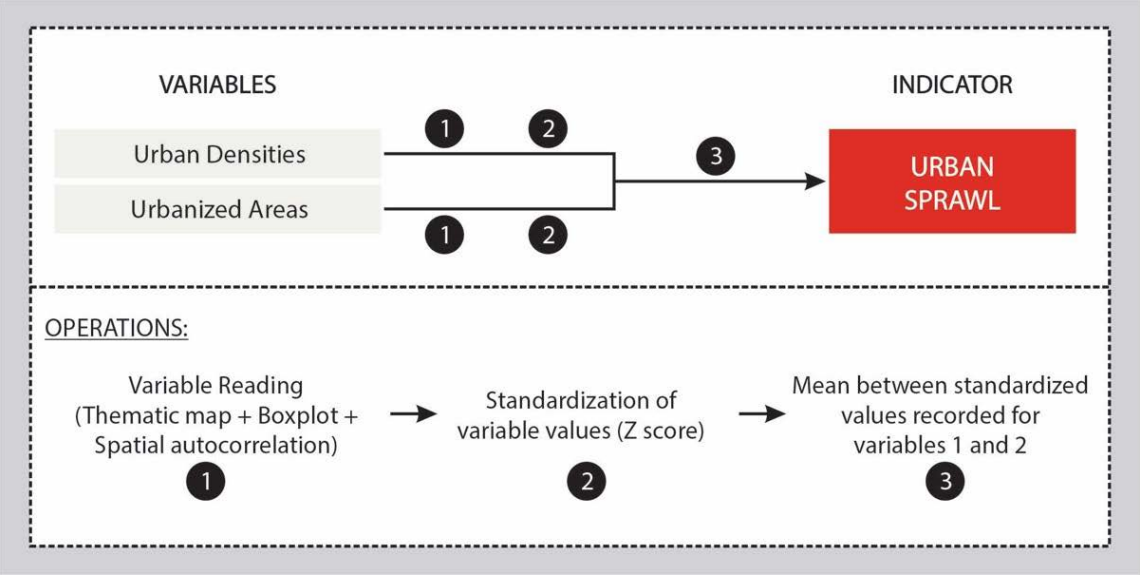

Figure 1 – Diagram depicting the methodological procedure developed for the current research. Source: Elaborated by the authors

ASSESSING SPATIAL STRUCTURE AND URBAN SPRAWL IN THE METROPOLITAN REGION OF GOIÂNIA

The Metropolitan Region of Goiânia, Goiás State, was the object of study herein selected for analysis and theoretical application purposes. Goiânia is the hub city in this region and, according to IBGE (2018), it is the 13th largest urban concentration in the country, since it holds 2,571,250 inhabitants who live in a territory encompassing 7,315.10 km². RMG concentrates a large part of the population, and of services available, in Goiás State. According to the IBGE (2018), its population density is close to 351.49 inhab. / km². Its current configuration - comprising 21 municipalities - was established in 2019, through the amendment of Complementary Law n. 139 (GOIÁS, 2019).

The region's spatial structure presents massive territorial heterogeneity, since the new centralities generated by the urban dynamics of Goiânia City feature considerable imbalance among networks forming RMG (KNEIB, 2016; GENTIL et al, 2016; GONZAGA, 2017).

RMG's spatial structure presents high polarization towards Goiânia City, a fact that makes the homogenized implementation of service network infrastructure,

urban equipment and public transport availability for the entire population unfeasible (UFG and SECIMA, 2017). Consequently, it opened room for spaces featured by high inequality levels, which are far from the ideal levels of dignified and balanced urban environments.

Urban sprawl features in the Metropolitan Region of Goiânia, and their association with spatial structure, can be better understood based on an investigation performed in the territory. In order to do so, two evaluation variables were selected: i) Urban densities; and ii) Urbanized areas.

Analysis Variable I - Urban Densities (Demographic Density)

The Metropolitan Region of Goiânia covers a territory of 7,481.84 km². Its total population comprises 2,571,250 inhabitants and its demographic density reaches approximately 343.66 inhabitants/km² (IPEA, 2015; GOIÁS, 2018; IBGE, 2018). Based on Fig. 2, the highest demographic densities are concentrated in the center of the territory. Municipalities such as Goiânia, Aparecida de Goiânia, Senador Canedo and Trindade account for approximately 90% of the population living in RMG.

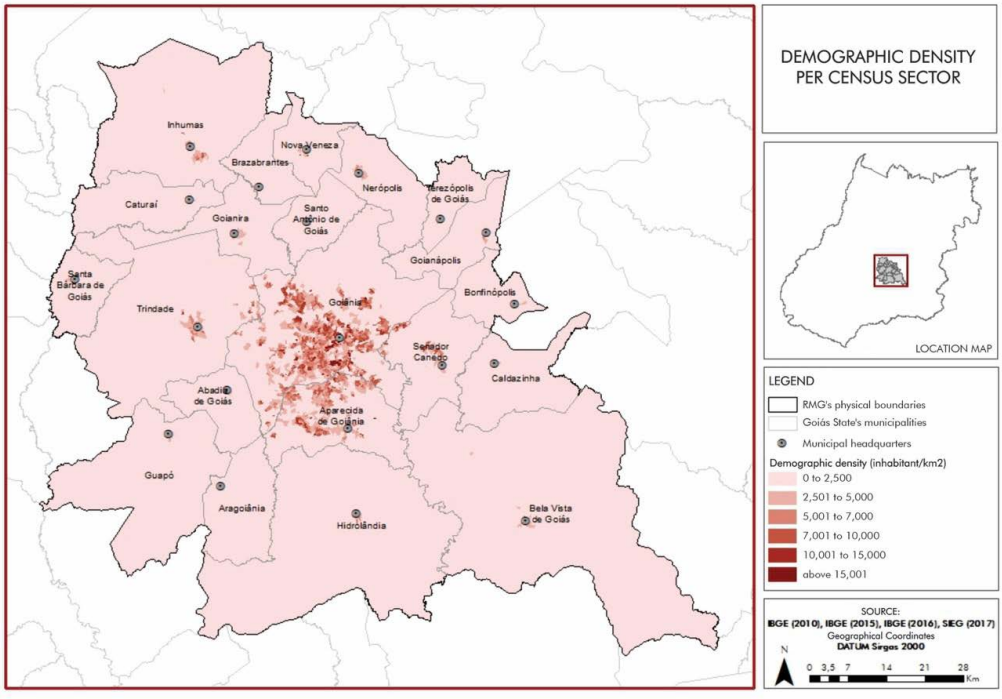

Figure 2 – Demographic density per census sector in the Metropolitan Region of Goiânia, 2010. Source: Elaborated by the authors.

The heterogeneity in population density distribution in GMR can be easily noticed in the spatial autocorrelation map, since it identifies concentration peaks in the observed values (Fig. 3). If one analyzes RMG as a single territory, it is possible noticing that the highest values (High-High Cluster) were observed in the center and headquarters of the investigated municipalities, whereas the lowest values (Low-Low Cluster) were observed for the most peripheral zones of this region. This information has evidenced the polarization taking place in the Metropolitan Region of Goiânia, due to discrepancies between high demographic density rates observed for central cities and low-density rates recorded for other cities in the region.

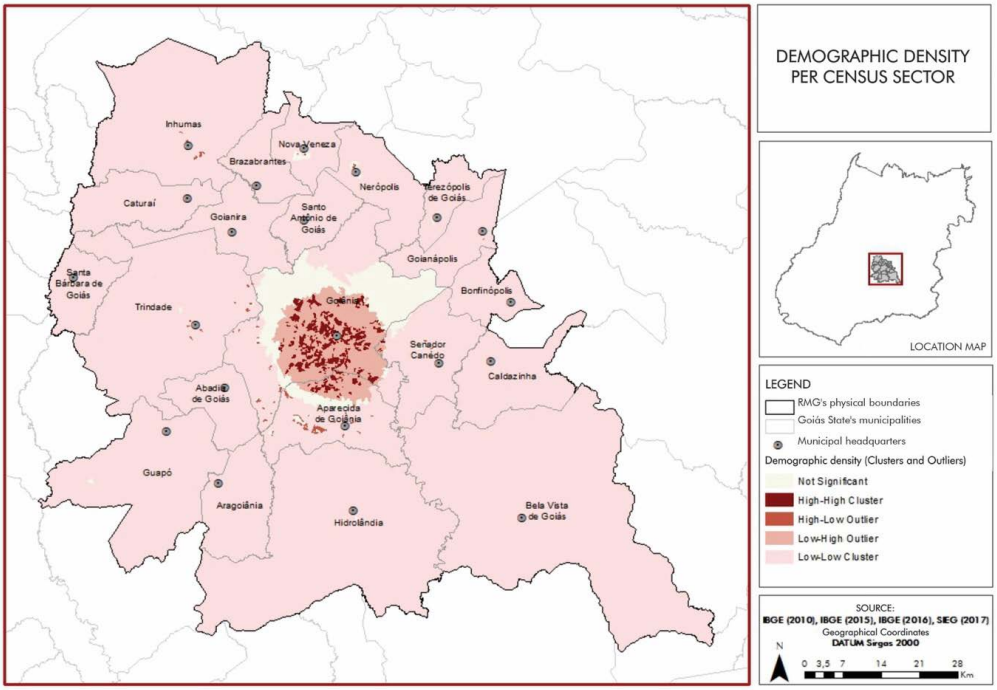

Figure 3 - Clusters and Outliers referring to demographic density in the Metropolitan Region of Goiânia, 2010. Source: Elaborated by the authors.

Analysis Variable II - Urbanized Areas

The variable used to analyze urbanized areas in a given territory enables observing the urbanization stage of a given zone by mapping urban spots via satellite images (IBGE, 2017). The current study has used the urban spot observed in the Metropolitan Region of Goiânia, in 2016, by the Institute of Social and Environmental Studies of Federal University of Goiás (IESA/UFG), to define urbanized areas in RMG (IESA, 2016). However, the urban spot was manipulated within the census sectors

in order to collect census data about this variable - this procedure resulted in the urbanized area-occupation rate per sector (Fig. 4).

The set of information resulting from the map of urbanized areas in RMG is analogous to results recorded for Variable I – Urban Densities. Areas presenting the highest urbanization rate were concentrated in municipalities such as Goiânia, Aparecida de Goiânia, Senador Canedo, and Trindade, as well as in all municipal headquarters. This analysis has also shown a linear occupation pattern, according to which, from 25.1% to 50% of the urbanization process mainly took place - in most cases - towards highways that give access to Goiânia City. These areas are susceptible to future urban conurbations.

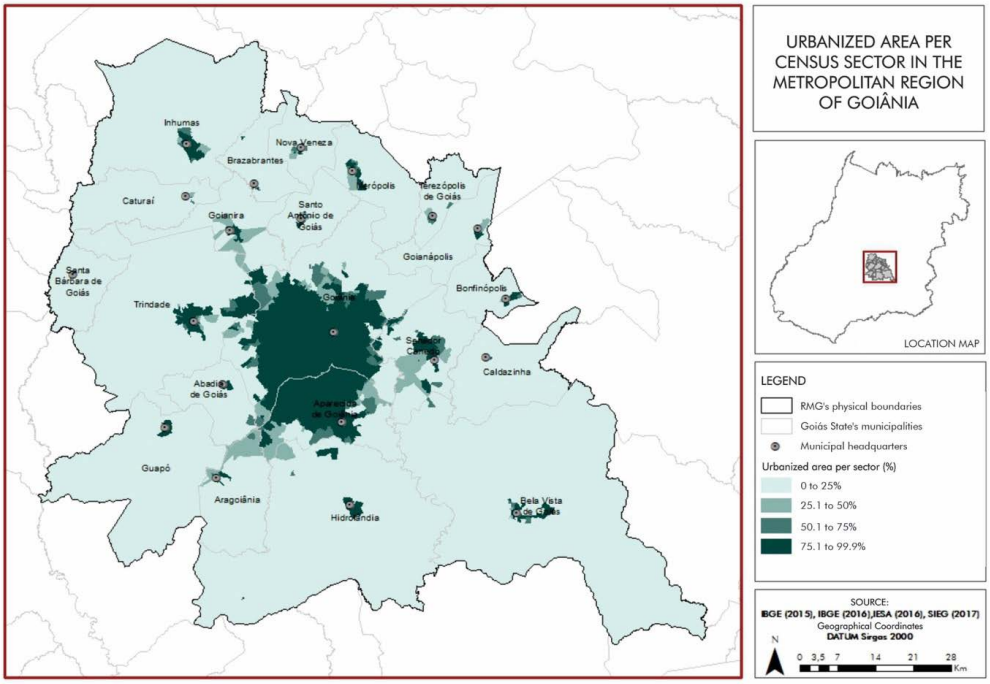

Figure 4 - Urbanized areas per census sector in the Metropolitan Region of Goiânia, 2016.
Source: Elaborated by the authors.

Urban sprawl gets even more evident if one takes into consideration the spatial autocorrelation of the investigated variable (Fig. 5). Sectors presenting high density of urbanized areas (High-High Cluster) are located in the center of the region; they are surrounded by low- and high-density values (Low-High Outlier). These low urbanization

density areas are located in expansion and conurbation zones in the heart of RMG, i.e., they are the most sprawled areas in the territory.

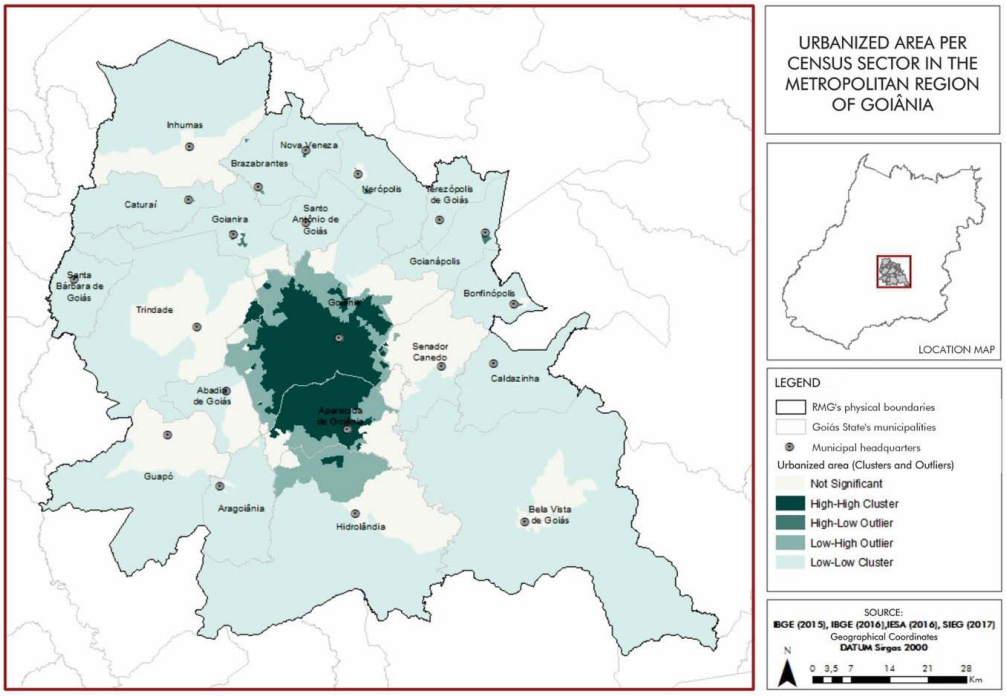

Figure 5 - Clusters and Outliers referring to urbanized areas in the Metropolitan Region of Goiânia, 2016.
Source: Elaborated by the authors.

Synthesis of variables - Urban Densities and Urbanized Areas (Standardized Mean)

Values recorded for the two selected variables analyzed in the current study were standardized based on the Z Score operation to enable joining them through arithmetic mean - which was calculated by dividing the sum of all values by the total number of values. Thus, it was possible obtaining a synthesis to build the urban sprawl indicator for the Metropolitan Region of Goiânia.

If one takes into consideration that urban sprawl leads to underused territories, dispersion between work and household locations, automobile dependence and maintenance of socio-spatial segregation, and the herein plotted synthesis maps enabled the spatial visualization of these sprawling areas and contributed to future studies about this urban system in RMG.

Based on variables “urban densities” and “urbanized areas”, the map showing urban sprawl in RMG (Fig. 6) has clearly pointed out the so-called central (High-high Cluster and High-low Outlier) and peripheral or segregated (Low-high Outlier and Low-low Cluster) areas. Spatial autocorrelation has confirmed what had been previously observed for each of the aforementioned variables. It was possible seeing the so-called “metropolitan core” and the urban expansion areas surrounding it and forming the most sprawling, fragmented and unsustainable regions in this territory. The aforementioned “metropolitan core” has also evidenced a spatial structure featured by the center-periphery dichotomy; it shapes a metropolitan region with high demographic concentration; based on the analyzed variables, it is featured as monocentric metropolitan region.

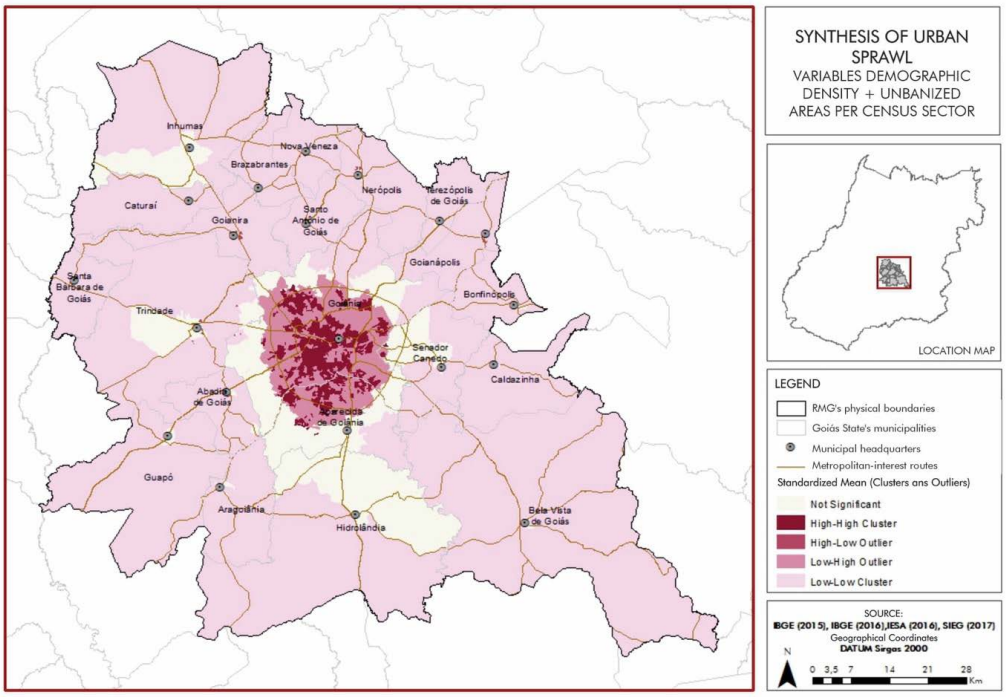

Figure 6 – Synthesis of variables (Clusters and Outliers) – Urban Densities and Urbanized Areas – Standardized Mean. Source: Elaborated by the authors.

FINAL CONSIDERATIONS

It is necessary acknowledging that urban expansion processes undergo continuous evolution, as well as that uncontrolled expansions have direct impact on the dynamics of urban life. The critical questioning of the urban planning developed in the

Metropolitan Region of Goiânia is applicable, since its urban expansion has produced unequal environments that led to negative social and environmental consequences.

The current research and the herein developed procedure enabled identifying and analyzing features of the urban sprawl observed in the Metropolitan Region of Goiânia. It was done based on variables, such as urban densities and urbanized areas, and on the development of an urban sprawl indicator that enabled reaching the herein proposed aim. Consequently, it was possible identifying and quantitatively analyzing how the spatial structure of this territory is shaped by pointing out the most segregated and disintegrated regions of the urban core, as well as its monocentric urban structure.

The incidence of high urban concentrations in the core of RMG, coexisting side by side with low density zones in the metropolitan territory, was confirmed. This outcome has confirmed the assumption that the spatial structure of RMG is featured by fragmentation and inequality. Urban sprawl often leads to unequal distribution of housing, income and service provision. In this case, it is necessary planning new centralities to help mitigating issues associated with urban segregation, as well as with territory organization and management in order to develop a better-balanced metropolitan region.

The current article resulted from investigative efforts to help better understanding the association between these two elements, based on the analysis of, and critical reflections on, the subject. In addition, it can be used to substantiate future decision-making about urban planning in Goiânia City and its region. Despite the specific focus – urban densities and urbanized areas – herein adopted to help better understanding the association between spatial structure and urban sprawl, future studies should apply a more comprehensive approach to these elements, by taking into consideration other variables, as well as the most recent data available in updated databases.

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