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Spatial modeling of income inequality and population aging in Brazil

Modelagem espacial da desigualdade de renda e envelhecimento populacional no Brasil

Modelación espacial de la desigualdad de ingresos y el envejecimiento de la población en Brasil

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Abstract
Objective: To analyze the spatial dynamics of income inequality and its relationship with population aging in Brazil. Method: A population-based ecological study using spatial analysis techniques and data from the last two Brazilian Demographic Census. Spatial modeling presented the Global Moran Index (I) and Local Spatial Association Index (LISA) through spatial autocorrelation, and the correlation between income inequality, life expectancy, and aging rate. Results: We observed significant spatial autocorrelation of income inequality (I=0.284, I=0.462; p=0.001), life expectancy (I=0.560, I=0.352; p=0.001), and aging rate (I=0.663, I=0.646; p=0.001). Predominant clusters were found in the North, Northeast, and Southern regions of the country. Clusters from the North and Northeast regions were associated with higher inequalities and lower indicators of aging. There was an inverse spatial correlation between income inequality, life expectancy, and aging rate. Conclusion: Population aging in Brazil presents a non-random distribution revealing spatial correlations with income inequality. Given the social and economic disparities across Brazilian territory, spatial analysis proved to be a significant contribution to the formulation of public policies that respect locoregional peculiarities.
Keywords: Inequality; Social determinants of health; Aging; Geographic information systems; Spatial analysis.

Resumo
Objetivo: Analisar a dinâmica espacial da desigualdade de renda e sua relação com o envelhecimento populacional no Brasil. Método: Estudo ecológico de base populacional utilizando técnicas de análise espacial e dados dois últimos Censos Demográficos Brasileiros. A modelagem espacial apresentou o Índice de Moran Global (I) e o Índice de

Associação Espacial Local (LISA) através da autocorrelação espacial e correlação entre a desigualdade de renda, expectativa de vida e taxa de envelhecimento. Resultados: Observamos autocorrelação espacial significativa da desigualdade de renda (I=0,284; I=0,462; p=0,001), expectativa de vida (I=0,560; I=0,352; p=0,001) e taxa de envelhecimento (I=0,663; I=0,646; p=0,001). Os conglomerados predominantes foram encontrados nas regiões Norte, Nordeste e Sul do país. Os *clusters* das regiões Norte e Nordeste estiveram associados a maiores desigualdades e menores indicadores de envelhecimento. Houve uma correlação espacial inversa entre desigualdade de renda, expectativa de vida e taxa de envelhecimento. Conclusão: O envelhecimento populacional no Brasil apresenta uma distribuição não aleatória revelando correlações espaciais com a desigualdade de renda. Dadas as disparidades sociais e econômicas existentes no território brasileiro, a análise espacial mostrou-se um contributo significativo para a formulação de políticas públicas que respeitem as peculiaridades locorregionais.
Palavras-chave: Desigualdade; Determinantes sociais da saúde; Envelhecimento; Sistemas de informação geográfica; Análise espacial.

Resumen
Objetivo: Analizar la dinámica espacial de la desigualdad de ingresos y su relación con el envejecimiento de la población en Brasil. Método: Estudio ecológico de base poblacional utilizando técnicas de análisis espacial y datos de los dos últimos Censos Demográficos Brasileños. El modelado espacial presentó el Índice de Moran Global (I) y el Índice de Asociación Espacial Local (LISA) a través de la autocorrelación espacial y la correlación entre la desigualdad de ingresos, la esperanza de vida y la tasa de envejecimiento. Resultados: Observamos una autocorrelación espacial significativa de la desigualdad de ingresos (I=0,284, I=0,462; p=0,001), la esperanza de vida (I=0,560, I=0,352; p=0,001) y la tasa de envejecimiento (I=0,693, I=0,646; p=0,001). Los conglomerados predominantes se encuentran en las regiones Norte, Nordeste y Sur del país. Los conglomerados de las regiones Norte y Nordeste se asociaron con una mayor desigualdad y menores indicadores de envejecimiento. Hubo una correlación espacial inversa entre la desigualdad de ingresos, la esperanza de vida y la tasa de envejecimiento. Conclusión: El envejecimiento de la población en Brasil tiene una distribución no aleatoria que revela correlaciones espaciales con la desigualdad de ingresos. Dadas las disparidades sociales y económicas existentes en el territorio brasileño, el análisis espacial resultó ser una contribución significativa a la formulación de políticas públicas que respeten las peculiaridades locorregionales.
Palabras clave: Desigualdad; Determinantes sociales de la salud; Envejecimiento; Sistemas de información geográfica; Análisis espacial.

1. Introduction

According to the United Nations Human Development Report of 2018, Brazil is the ninth most unequal country in the world. Among the 189 countries analyzed, Brazil ranked 79th in the Human Development Index (HDI), but when the indicator was adjusted for inequality, it drops 17 positions and has the second-highest number of declines in rankings in this calculation (PNUD, 2018).

Studies on income distribution in Brazil show high levels of poverty and inequality (Maia, 2010; Medeiros, Souza & Castro, 2015), which reinforces the country as one of the most unequal nations globally (Maia, 2010; PNUD, 2018). This inequality has historical and regional roots which persist as a current issue for the country.

The relationship between socioeconomic factors and the determinants of population health has been widely investigated. Evidence shows that people living in less developed regions have the worst health indicators, with a direct relationship between economic growth and improvements in health conditions (Clarke et al., 2011; Kolahdooz et al., 2015; Sudharsanan, 2017). Therefore, it is possible to state that some of the effects of inequality are universal, regardless of the country examined.

People living in disadvantaged economic situations are more exposed to the risk of falling ill and dying, a situation that intensifies in vulnerable populations, such as the elderly (Feliciano, Moraes & Freitas, 2004). Several previous studies highlight the challenge created by the demographic and epidemiological transition for the elderly population regarding the need for more financial resources and improved infrastructure, as well as policy changes to help promote active aging (Carvalho & Rodrígues-Wong, 2008; Closs & Schwanke, 2012; Veras, 2009; Wong & Carvalho, 2006).

Child mortality is an important marker in studies that analyze the association between social inequalities and health

(Barata, 2009; Barreto, 2017; Oliveira et al., 2013). However, studies with indicators of population aging are scarce, especially those that use spatial analysis techniques.

Since a population's health can be estimated using demographic indicators, the economic disparities between populations and geographic regions may reflect the differences in factors related to population aging. This study aimed to analyze the spatial dynamics of income inequality and its relationship to indicators of population aging in Brazil.

2. Methodology

This study used a population-based ecological design with spatial analysis techniques and indicators of income inequality and aging in Brazil. Ecological design is a type of study whose the analysis unit is a group, that generally belongs to a delimited geographic area and combine data from large populations. This study aims to evaluate how social and environmental contexts may affect the populational health (Medronho, Bloch, Luiz & Werneck, 2008).

Brazil occupies an area of 8.51 million km², equivalent to almost 50% of South American territory and has a total population of 208.4 million people (IBGE, 2018). Brazil is the fifth-largest territorial area and the sixth-largest population worldwide. The 5.565 Brazilian municipalities, registered in 2010, were considered the units of analysis of the study. Data were obtained from the last two Brazilian Demographic Censuses (2000 and 2010) were also included.

The indicator of income inequality was represented by the Gini coefficient, which is a measure of the degree of income inequality in population distribution. The values range from zero (0), which represents perfect equality, to one (1), which represents maximum inequality, a higher concentration of income in a smaller number of people. Aging was measured by two types of indicators: health (life expectancy; LE) and demographic (aging rate; AR) factors. LE is the average number of expected years of life for a newborn in a given geographic area and year. AR is the ratio between the population over 65 and the total population, multiplied by 100, in a given geographic space, in the year examined (IPEA, 2017).

Spatial data from the Brazilian Demographic Censuses (2000 and 2010), were analyzed, and the resident population of Brazil was considered over the two respective years. The digital map of Brazil was acquired as a shapefile format from the SIRGAS 2000 (Geocentric Reference System for the Americas - 2000), updated in 2010.

The software used for spatial analysis and map creation was GeoDa (Spatial Analysis Laboratory, University of Illinois, Urbana-Champaign, USA), and QGis 2.18.3 (Creative Commons Attribution-Share Alike 3.0 license CC BY-SA, Las Palmas, California, USA).

The threshold for statistical significance was set at 5% ($p < 0.05$). The identification of spatial autocorrelation was obtained through the Moran Global Index (I) for income inequality and aging indicators in all Brazilian municipalities in both years. Positive values of I (between 0 and +1) indicate that there is a direct autocorrelation, and negative values (between 0 and -1) indicate an inverse autocorrelation.

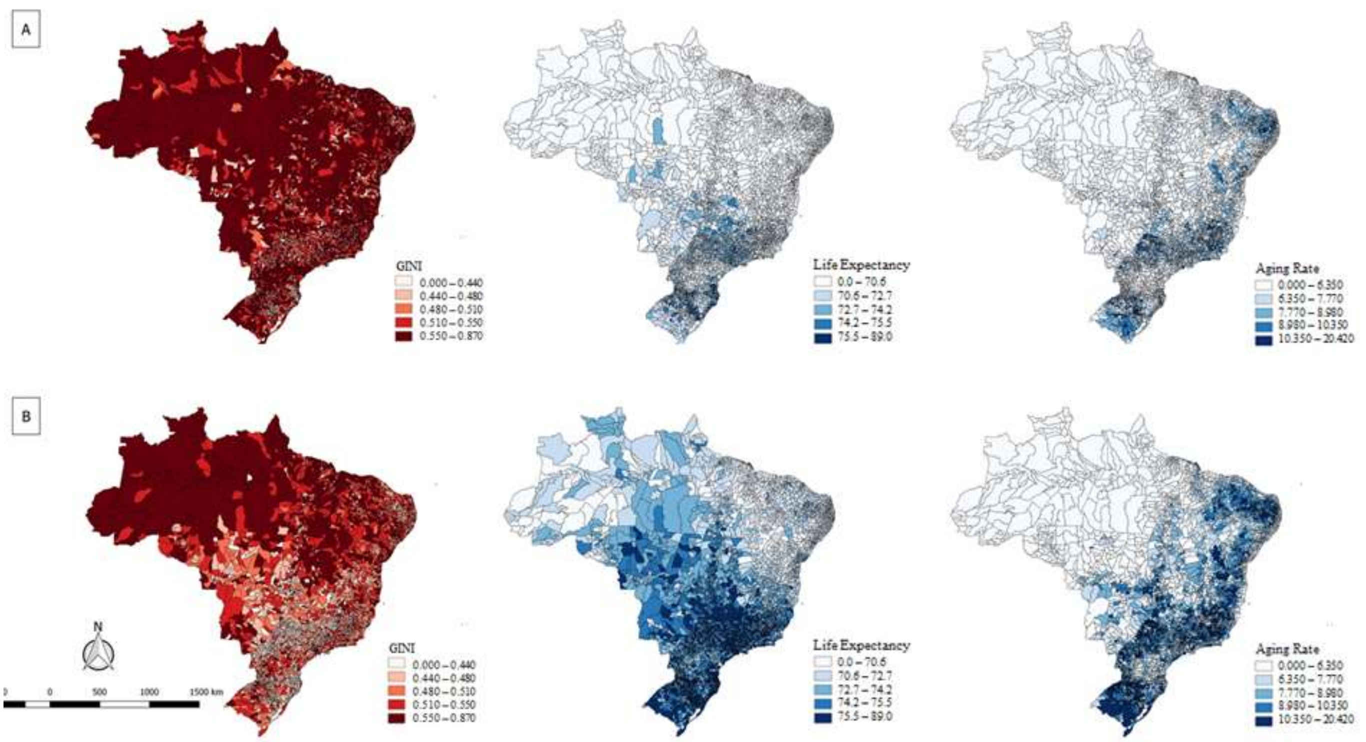
The Local Indicators of Spatial Association (LISA) was used to generate maps marking regions that present local autocorrelations that are significantly different from other regions, identifying clusters and outliers, classified by High-High and Low-Low when there was a positive correlation between these areas, and High-Low and Low-High when the correlation was inverse.

Bivariate analysis using LISA was performed to assess the spatial correlation between outcome variables (life expectancy and aging rate) and the independent variable (income inequality). Thus, the bivariate analysis contributes to the creation of clusters and significant spatial groupings between outcome variables and the independent variable.

3. Results

Figure 1 shows the geographical distribution of income inequality, life expectancy, and aging rate in Brazilian municipalities in 2000 (A) and 2010 (B). Regions with darker colors represent the indicators with the highest values.

Figure 1. Spatial distribution of Gini Index, life expectancy and aging rate. Brazil, 2000 (A) and 2010 (B).



Source: Authors.

In the income inequality maps (Figure 1), there is a uniform distribution pattern with 68.64% of the Brazilian municipalities that have an income inequality between 0.51 and 0.87 in 2000. In 2010, the areas with the highest income inequalities were located mainly throughout the North and Northeast. However, the overall percentage of Brazilian municipalities with income inequality between 0.51 and 0.87 decreased to 36.77%.

Analysis of LE revealed that in 2000, the indicator was below 71 years of age in virtually the entire North, Northeast, and Midwest, with higher LE in the South and Southeast. In 2010, LE increased by some Brazilian regions, especially the Southeast and South regions and some points of the Midwest region. The AR was largest in the coastal area of the country as well as in the South and Southeast regions in both years analyzed (Figure 1).

Table 1 presents the global spatial autocorrelation indices for income inequality, LE, and AR indicators across all the municipalities. There was significant spatial autocorrelation among all variables, indicating that the areas presented similar income inequalities, LE, and AR in the two years examined.

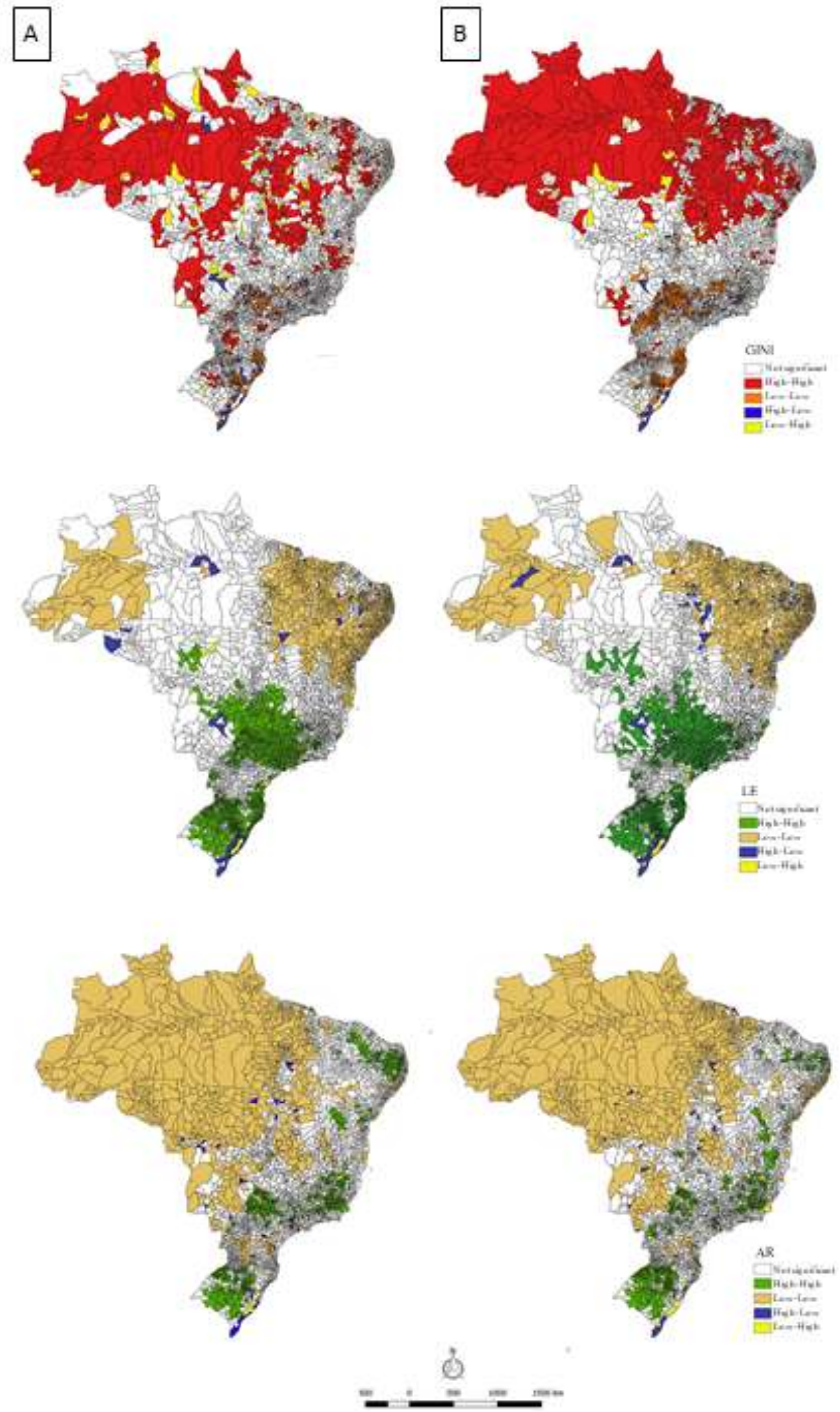
Table 1. Global Moran Index of Gini coefficient and aging indicators, Brazil, 2000 and 2010.

Indicators [I (p-value)]	2000	2010
Coeficiente de Gini	0,284123 (p = 0,001)	0,462326 (p = 0,001)
Life Expectancy	0,560501 (p = 0,001)	0,352758 (p = 0,001)
Aging Rate	0,663457 (p = 0,001)	0,646620 (p = 0,001)

*I – Moran Global Index. Source: Authors.

Figure 2 shows the Local Moran results for income inequality, LE, and AR variables. Income inequality shows High-High clusters in the North and Northeast regions, indicating that municipalities with higher income inequality are surrounded by areas with similar characteristics, with larger groupings in 2010. In 2000, 683 municipalities had High-High spatial groupings, and that number increased in 2010 (922). The Low-Low clusters were in the Southeast and South regions, involving 491 municipalities in 2000 and 749 in 2010, especially in the western portions of the South and Southeast.

Figure 2. Moran Map of Gini Index, life expectancy and aging rate. Brazil, 2000 e 2010.



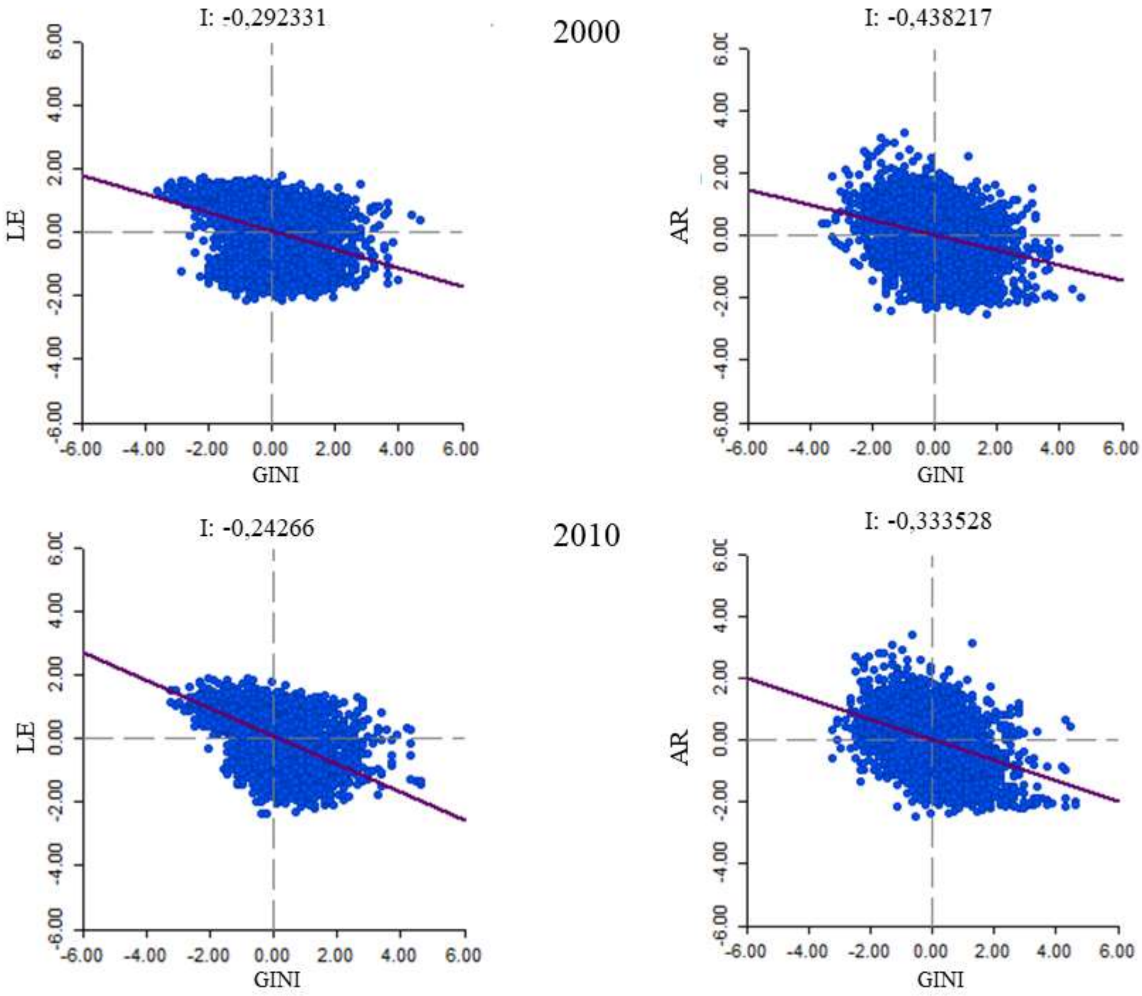
Source: Authors.

LE showed High-High clusters in the South and Southeast regions, comprising a total of 1.673 and 1.607 municipalities in 2000 and 2010, respectively. Low-Low clusters were evident in the western portion of the Northern region, and throughout the Northeast region, with 1.400 and 1.405 municipalities, respectively (Figure 2).

In the years 2000 and 2010 for AR, Low-Low clusters were identified throughout the North and in a small coastal strip of the Northeast, and small High-High clusters were identified in interior sections of the Northeast and the eastern portions of the Southeast and southern regions of the country (Figure 2).

Bivariate spatial analysis showed a negative Global Moran Index (I) in the scattering diagrams that identified significant inverse spatial correlations (Figure 3), demonstrating that the higher the Gini coefficient, the worse the LE and AR.

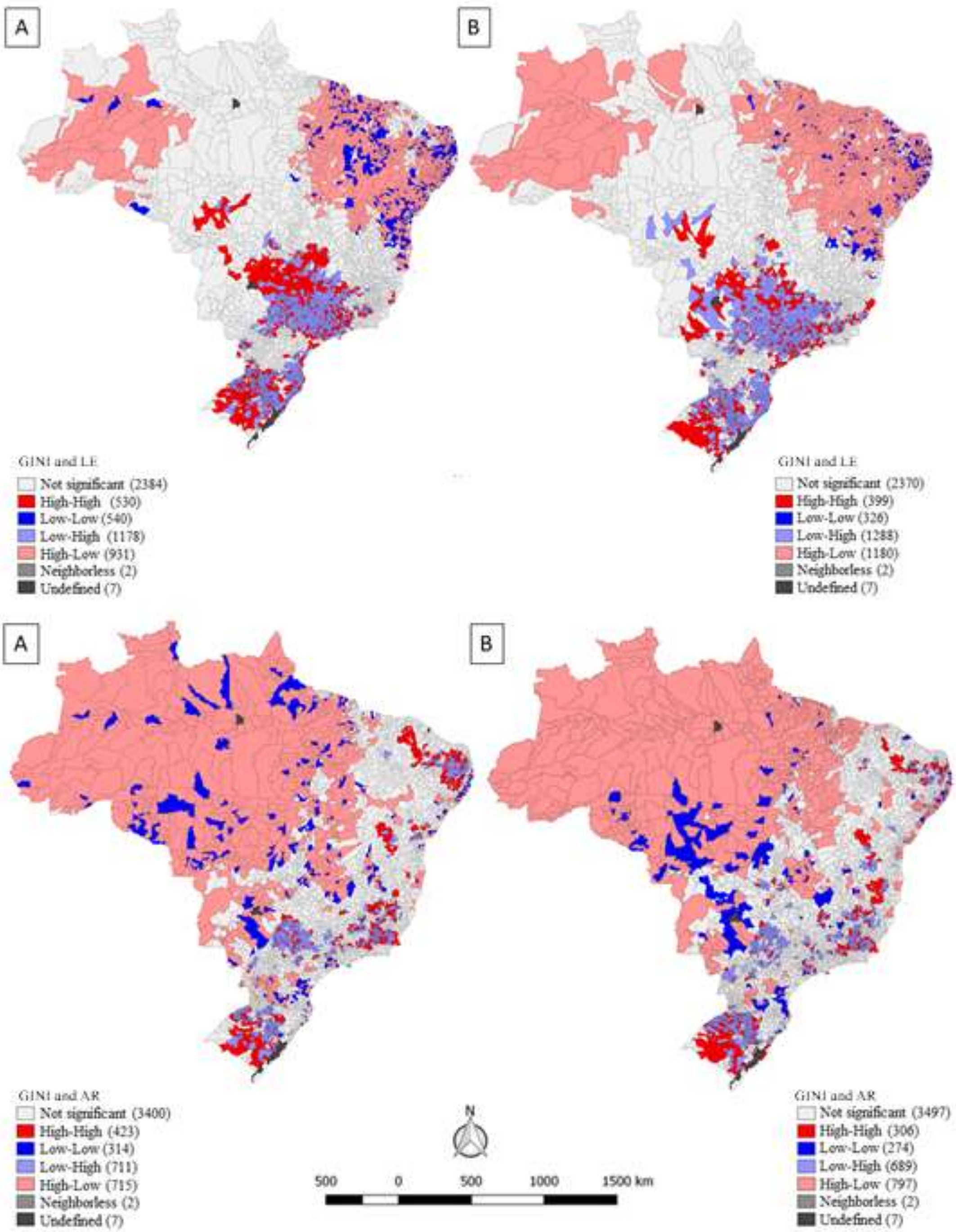
Figure 3. Scattering diagram of the association of income inequality with aging indicators, Brazil, 2000 and 2010.



Source: Authors.

In the Moran scattering diagram, the outcome variables are represented on the vertical axis and the independent variable on the horizontal axis. It is divided into four quadrants representing the High-High spatial associations in the first quadrant, Low-High in the second quadrant, Low-Low in the third quadrant, and High-Low in the fourth quadrant (Figure 4).

Figure 4. Moran bivariate map of the association of income inequality with aging indicators, Brazil, 2000 (A) and 2010 (B).



Source: Authors.

The spatial associations between the Gini coefficient to LE in both years appeared with the formation of High-Low clusters in the eastern portion of the North and throughout the Northeast of the country and Low-High clusters in the Southeast and South Associations of the Gini coefficient with High-Low AR appear throughout the northern region, and the far west and coastal regions of the Northeast. On the other hand, the Low-High clusters are in points of the Midwest, Southeast, and South, in both years.

4. Discussion

The spatial dynamics of income inequality, LE, and AR in Brazil are presented in a non-random way, with formation of clusters between Brazilian regions. There is heterogeneity in the income distribution and aging indicators, where Northern and Northeastern municipalities show greater income inequalities, and lower life expectancy, and aging ratios. The inverse relationship between income inequality and aging indicators reinforces that municipalities with higher income inequality have worse aging indicators. In 2010, income inequality increased the difference between Brazilian municipalities when compared to 2000.

Discussions about income inequalities around the world are complex, and Brazil has consistently been recognized as one of the countries with the highest income concentration (Barros & Goldbaum, 2018).

Historically, Brazil maintains large inequalities that resulted in social inequities and difficulties in accessing essential programs and services guaranteed by its Constitution. To solve this, public income transfer policies, such as the Bolsa Família (BF) and the benefit of continued rendering (BPC), were created to try to reduce these differences (Moraes, Pittham & Machado, 2018; Testa, Fronza, Petrini & Prates, 2013), but anyway it remains as one of the most unequal countries globally.

Some of the existing inequalities in Brazil need to be debated. The Northeast region has always presented poverty concentration (Heringer, 2002); this was attributed to the inability of the Brazilian State to reduce the disparities of this community. On the other hand, the Southeast and Southern regions received more European immigrants and were always characterized by being pillars of industrial and urban developments and were responsible for the highest indicators of human development nationally to date (Figueiredo, Netto-Júnior & Porto-Junior, 2007; Heringer, 2002).

Although our findings have shown that the level of inequality has decreased over time in different regions, the overall level of Brazilian inequality remains high and influences the results of aging, especially when discussing which factors may be associated with the inequalities of life expectancy (Guerra & Figoli, 2013).

In the year 2000, approximately 65% of the municipalities had an LE up to 70.6 years, which corresponds to the national average. In 2010, there is an extension of LE in some regions, especially the South, Southeast, and some areas in the Midwest, that presented higher LEs than the national average (73.8 years). We confirm that the highest LEs were found in the South and Southeast regions, where income inequality was lower. The lowest LEs were associated with the highest income inequality values and formed clusters in the eastern portion of the North and throughout the Northeast region.

LE is an indicator of the country's level of development by reflecting the whole set of favorable or unfavorable conditions (Guerra & Figoli, 2013). The relationship between income and LE is proven (Lin, Chen, Chien & Chan, 2012; Marmot, 2016; Mathers et al., 2015; Özdemir, Karabulut & Menteş, 2011; Wang et al., 2015), reinforcing the negative impact that income inequality has on LE. We highlight that low LE in the North and Northeast regions may be related to low education, and lower access and coverage of health services. However, the recent development of health policies has increased the access to services, especially for the poor, which is important for reducing social inequalities in the poor regions of Brazil (Andrade et al., 2013; Paim et al., 2011).

Demographic data, such as AR, indicates that Brazil is in the process of rapid demographic transition, but it does not occur simultaneously and homogeneously between Brazilian regions (Closs & Schwanke, 2012). In our study, AR has highest proportions on the coast, South, and Southeast regions. This identifies these regions as experiencing accelerated demographic transitions. The formation of clusters with high AR in the Eastern and Southeastern parts of the country can be explained by the better living conditions, and parts of the Northeastern interior that may be related to the migration phenomenon. The association between low-income inequality and high AR demonstrated in the Midwest, South, and Southeast regions show that socioeconomic status may have influenced the aging process.

Unlike the global scenario, the rise of the number of elderly people in Brazil is rapid, but it is occurring in an unfavorable social and economic context (Campos & Gonçalves, 2018; Miranda, Mendes & Silva, 2016). The challenge of the demographic and epidemiological transition for the elderly population is related to the demand for resource generation and improved infrastructure conditions, as well as the policy reforms to promote active aging (Carvalho & Rodríguez-Wong, 2008; Closs & Schwanke, 2012; Veras, 2009; Wong & Carvalho, 2006).

Social inequalities in the aging process of a community account for the regional variations found. However, little has been done to improve this disparity. Public policies must be introduced and government institutions – including health, education, and social care – must work cooperatively to achieve improved results compared to the past 20 years.

In 2018, Brazil implemented strict policies with the justification of fiscal balance (Schramm, Paes-Souza & Mendes, 2018). For the elderly population of Brazil, it may have deleterious and considerably serious effects compared to developed countries, since the social indicators and the public services provisions are below the level of developed countries. It may also imply a reduced investment in social protections, promotional policies, and access to health services, with different social groups being exposed asymmetrically to health risks (Santos & Vieira, 2018; Schramm, Paes-Souza & Mendes, 2018).

In discussions of social justice, the increase of protection networks for the elderly and the search for social protection for this population were highlighted as undisputed areas for improvement. This is supported by the approval of the BPC, a public policy to combat inequalities, which is constituted by income security mechanisms for adults over 65 years who live in households that do not exceed 1/4 per capita of the typical family income (Santos, 2011)

The influence of social determinants of health is widely reported in the literature, but the direct contribution of these factors to the health of a population is difficult to measure (Morteza et al., 2017), and accordingly, studies that emphasize the differences in mortality are more common. However, other ways of measuring the health of a population need to be explored, and for this reason, aging indicators are an essential element of future studies.

Given the geographic variations and the fact that data are aggregated, hypotheses cannot be extrapolated to the individual level. This should be considered in this study, because within each Brazilian municipality there is great variability in income and health. However, the analysis across the municipalities, which are the smallest administrative unit used by IBGE, and the two different years studied, showed a correlation between income inequality and aging. Because of this, it was possible to observe the changes that occurred over time and their influence on the population indicators.

5. Conclusion

The results found supported that income inequality has negative impacts on aging. Health issues are most evident among the underprivileged within a society, and this burden is greater in more unequal societies. While Brazil is in a demographic transition and is rapidly aging, the regional differences are still extensive. This situation provides challenges for the planning and execution of public policies that meet the locoregional peculiarities of a continental country. More studies are needed to assess racial and gender groups. Racial and gender divisions point to a clear relationship between social inequalities and greater health problems, especially through the exclusion to educational and work opportunities.

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