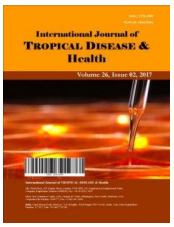

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Mansonic Schistosomiasis in the Brazilian Southeast: Spatial Analysis in Minas Gerais

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: Mansonic schistosomiasis is a parasitosis whose evolution is related to Brazilian history, linked to the migration currents from the Northeast, reaching the Brazilian Southeast, particularly the state of Minas Gerais.
Materials and Methods: with a view to the possible identification of clusters, the data concerning the incidence of schistosomiasis were subject to exploratory spatial analysis.
Results: The Global Moran index indicated the existence of clusters in the state. The Local Moran Index identified three clusters, one in the Northeast of Minas Gerais (Jequitinhonha, Mucuri), another in the Central-South of Rio Doceand the third cluster in the region Vertentes/Zona da Mata.
Discussion: In Minas Gerais, schistosomiasis occurs in specific areas. In addition, there exists a spatial correlation between the occurrence of the parasitosis and variables such as altitude and discharge of sanitary sewage in river/lake.
Conclusion: Schistosomiasis does not occur randomly, but in environments that somehow favour its occurrence. On the other hand, environmental factors like altitude and sanitary sewage in rivers are related to these clusters.

Keywords: Schistosomiasis; spatial analysis; ecological Studies.

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1. INTRODUCTION

The evolution of mansonic schistosomiasis in Brazil is related to the roots of Brazilian history. It is almost a consensus that the introduction of this disease in Brazil goes back to the period of slavery, to which the emergence of some diseases was ascribed. Despite the clear lack of support, this theory rests on the logic that characterized the country in the 18th and 19th centuries, with the arrival of the blacks from the African continent where mansonic schistosomiasis is endemic [1].

One of the important characteristics of schistosomiasis in Brazil is the fact that it affects poor and rural communities, whose populations depend on agriculture and fishing. Another noteworthy factor is the greater susceptibility of women who do housework in infected water, activities like washing clothes being considered a risk factor [2].

In the State of Minas Gerais, epidemiological studies on schistosomiasis still in the 1950's demonstrated that, at the time, the disease had spread across most of the territory, but not homogeneously. In the study, the highest rates were found in the region of Vale do Mucuri. In other regions like the North, cases of the disease also existed, is more scarce in the South of Minas and in the Triângulo Mineiro [3].

More recent epidemiological surveys have demonstrated little change, as the disease is not present in some regions of the state, while others show a large number of schistosomiasis reports [4].

Due to these different rates among regions in the state of Minas Gerais, it is feasible to consider that schistosomiasis is determined by environmental factors that limit its geographical occurrence. The occurrence of schistosomiasis in one city can result from the geographical correlations, whose distributions permits identifying the relation of spatial dependence among cities [5].

Another important fact is that the distribution of schistosomiasis is sometimes restricted in space due to environmental factors, where maps can demonstrate the interaction with the environment [6].

The use of geographical information systems can permit a more solid analysis, with a view to identifying the relation between environmental factors and the occurrence of schistosomiasis. The Exploratory Analysis of Spatial Data can identify clusters that demonstrate spatial autocorrelation.

2. MATERIALS AND METHODS

2.1 Study Area

The state of Minas Gerais has an estimated population of 20 million inhabitants in 2015, within an area of 586 thousand km², including 853 cities [7]. Data from the Ministry of Health based on the *Sistema Nacional de Agravos* (National Disease System) show reports of mansonic schistosomiasis in 482 cities between 2007 and 2014 [8].

2.2 Disease and Secondary Data

The spatial distribution of the incidence of mansonic schistosomiasis in Minas Gerais was analyzed based on the notifications between 2007 and 2014. The number of notifications per 100 thousand inhabitants was considered in a given geographical space, in this specific case each city in the state of Minas Gerais.

To calculate the rate (notifications/population), the data from the Brazilian Institute of Geography and Statistics (IBGE) on estimated populations in Brazilian cities were adopted to estimate the population, available on the website of the institution [9].

2.3 Statistical Analysis

The Global Moran Index was used to assess the spatial correlation. In this case, the null hypothesis should be equal to zero. Positive indices (between 0 and +1) indicate a direct correlation, while negative data (between 0 and –1) indicate an inverse correlation. The statistical validity was determined by the estimated significance, using the pseudo-significance tests for 999 permutations, which permits the determination of a p-value. The Moran scatter diagram was also elaborated, indicating the Global Moran Index.

The diagram was constructed based on standard values (values of attributes subtracted from their average and divided by the standard deviation), consisting of a two-dimensional graph of z (standard values) by wz (mean of neighbours) and divided into quadrants.

The Local Moran I Index (Local Indicators of Spatial Association - LISA) was determined for the exploratory analysis of the spatial data. Based on this index, the spatial correlation and clusters can be identified, as well as areas considered to be outliers.

Terraview ®, version 4.22 and GeoDa®, the version1.67 software was used for spatial analysis and the cartographic bases used were obtained on the IBGE website.

3. RESULTS

Based on the notifications, initially, choropleth maps were constructed, considering the mean notifications between 2007 and 2014 (Fig. 1). The classes are presented by quantiles. Part of the state of Minas Gerais presented no significant notifications, mainly in the South and Triângulo regions. Instead, the notifications are concentrated in the East and North of the state.
In the East, the mean incidence extends in an unbroken band between the regions of Jequitinhonha, Vale do Mucuri, Rio Doce, reaching the zona da Mata, crossing the Metropolitan region.

The existence of spatial autocorrelation of the variable: Mean incidence of schistosomiasis/100 thousand inhabitants was determined by means of the Global Moran Index. The I index = 0.343385 was significant (p=<0.01) for 999 permutations, (pseudo-significance test) (Fig. 2), which permits affirming that there is a spatial autocorrelation between the cities with notifications of mansonic schistosomiasis.

To identify the local clusters between 2007 and 2014, using the Local Indicators of Spatial Association (LISA), the Lisa Map and the Moran Map were elaborated.

After evidencing the existence of significant clusters, the next step was to determine the Moran Map with a view to identifying the association pattern.

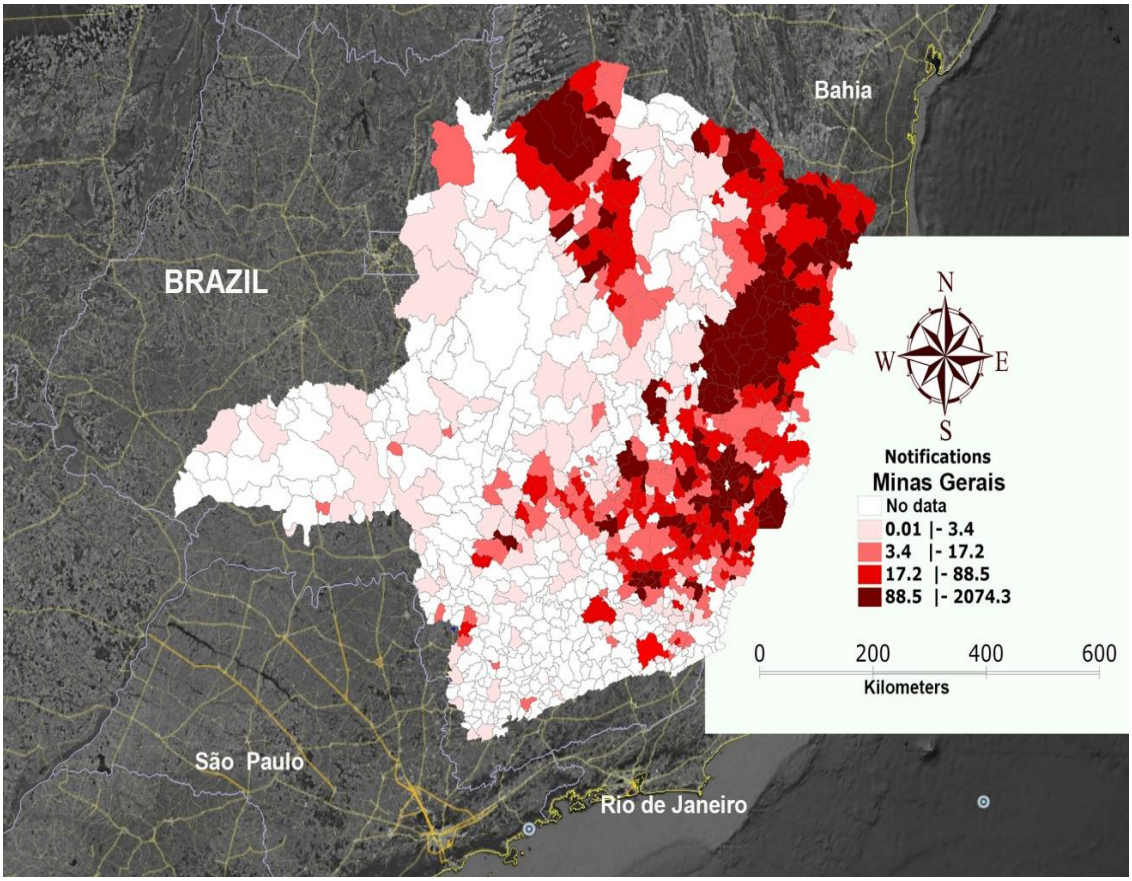

Fig. 1. Mean incidence of schistosomiasis/100 thousand inhabitants of schistosomiasis in Minas Gerais between 2007 and 2014

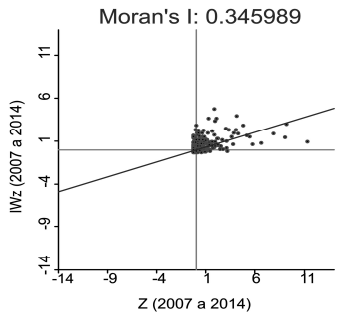

Fig. 2. Moran scatters diagram based on mean notifications of mansonic schistosomiasis per 100 thousand inhabitants between 2007 and 2014

Fig. 3 presents the Moran Map of the mean notifications of schistosomiasis between 2007 and 2014. The regions in white presented no significant autocorrelation. The regions with spatial autocorrelation with low means and low values are displayed in yellow (Q2). These regions are found in most of the South/Southeast, Triângulo Mineiro, Northwest and Central, while there are regions with autocorrelation (low – low) in other mesoregions of the state.

In the same Figure, the red colour (Q1) indicates the regions with spatial autocorrelation and high values and means. These regions are mainly located in the region of Jequitinhonha and Vale do Mucuri. The borders between the metropolitan region and North show small regions with high-high autocorrelation.

Some cities, in pink (Q4), presented low values in regions with a high average. No regions were identified in Q3, that is, high values close to the low average.

On the Moran Map, in Q1, three clusters were identified: one in the region Mucuri, Jequitinhonha and Norte do Rio Doce (identified in the table below as Northeast of Minas Gerais); the second in the South of the Rio Doce region (identified in the table as *Rio Doce*), and the third cluster more to the South (identified as Vertentes/*Zona da Mata*).The clusters and their respective cities are displayed in Table 1.

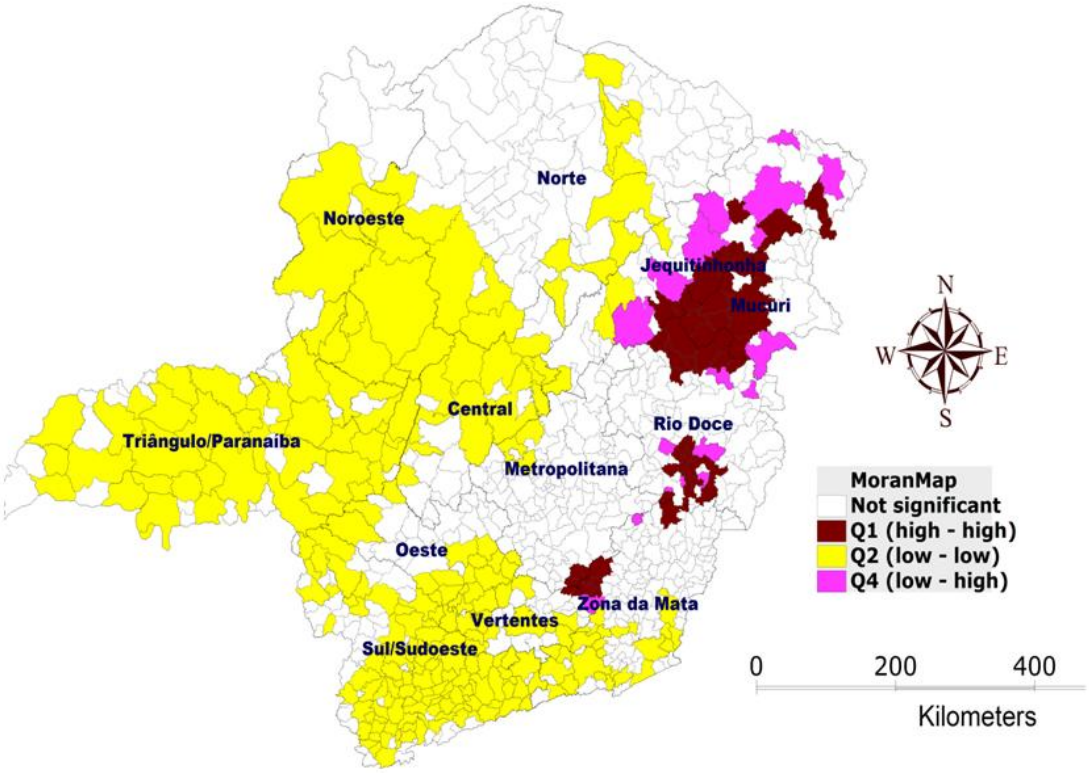

Fig. 3. Moran Map of mean notifications of mansonic schistosomiasis in Minas Gerais between 2007 and 2014

Table 1. Clusters of cities with notifications of schistosomiasis with spatial autocorrelation according to Local Moran Index – high means in regions with high means (Q1)

Northeast of minas gerais			Rio Doce	Vertentes/Zona da Mata
Água Boa	Itaobim	Poté	Bugre	Capela Nova
Angelândia	Joaíma	Rubim	Caratinga	Caranaíba
Campanário	Ladainha	S.M. Suaçuí	Córrego Novo	Catas Altas da Noruega
Capelinha	Malacacheta	S. J. Safira	Dom Cavati	Cipotânea
Caraí	Novo Cruzeiro	S. Seb. Maranhão	Iapu	Itaverava
Franciscópolis	N. Orie. Minas	Setubinha	Inhapim	Lamim
Frei Gaspar	Padre Paraíso	Teófilo Otoni	Raul Soares	Piranga
Itaipé	Palmópolis	Virgolândia	S.J.Oriente	Rio Espera
Itambacuri	Pescador		Sobrália	Santana dos Montes
			Ubaporanga	Senhora de Oliveira

Table 1 contains 46 cities, 26 in the Northeast of Minas Gerais and 10 in each of the other two, Rio Doce and Vertentes/Zona da Mata. The identification of the three areas can be compared with some environmental characteristics of the state of Minas Gerais.

The three clusters identified as Q1 (high values and high means) are displayed in Fig. 4b, where one circle marks the cluster located in the Northeast of Minas Gerais (Jequitinhonha/Mucuri) and the second circle the other two clusters, located in the region Rio DoceandVertentes/Zona da Mata.

Fig. 4a displays the altitude of the cities in Minas Gerais according to IBGE data [10]. The cities with the lowest altitude are found in the East.

Fig. 4c displays the percentage of homes in the cities whose sewage is cast into rivers, lakes or the sea, according to data from the 2010 IBGE census [11].

In the other two clusters, called Rio Doce and Vertentes/Zona da Mata, the regions whose cities cast the sewage untreated into rivers and lakes coincide (Fig. 4c).

With a view to confirming this relation between the variables and presence of the clusters, Moran's I coefficients were determined in the bivariate analysis, considering a mean incidence factor of schistosomiasis between 2007 and 2014 per 100 thousand inhabitants and each of the variables altitude and sewage in lakes and rivers, using the software GeoDa®.

The results of the Bivariate Moran Indices demonstrated discrete but significant correlations and were: mean schistosomiasis in cities in function of altitude I=-0.185656 (p=<0.01), and mean schistosomiasis in cities with sewage cast in river or lake I=0.0894692 (p =< 0.01).

The results indicate the presence of spatial autocorrelation between the mean schistosomiasis (2007-2014)/100 thousand inhabitants, altitude and sewage in rivers and lakes.

4. DISCUSSION

The geographical distribution of schistosomiasis in Minas Gerais maintains the distribution for many years. In 1950, Pellon[3], demonstrated at that time that the highest occurrence was found in the East of Minas Gerais with 48.7% of all cases, followed by the North of the state with almost 17%.

The spatial distribution of schistosomiasis demonstrates the strong spatial dependence of the disease in the state of Minas Gerais.In some regions, like the Triângulo Mineiro/Paranaíba, Northwest and South/Southwest, there are cities with low notification rates of schistosomiasis and autocorrelation, that is, regions with practically no schistosomiasis cases.

On the other hand, there are clusters in the region, Jequitinhonha and Rio Doce, with a large number of notifications of schistosomiasis and spatial autocorrelation (Fig. 3).

The local spatial autocorrelation permitted the identification of three clusters, located in the Northeast of the state of Minas Gerais, but the absence of Q3 clusters from the Moran Map demonstrates that there are no regions in the state with high autocorrelation and case numbers, close to other regions without notifications. This leads to the belief that the occurrence of schistosomiasis is restricted to specific regions.

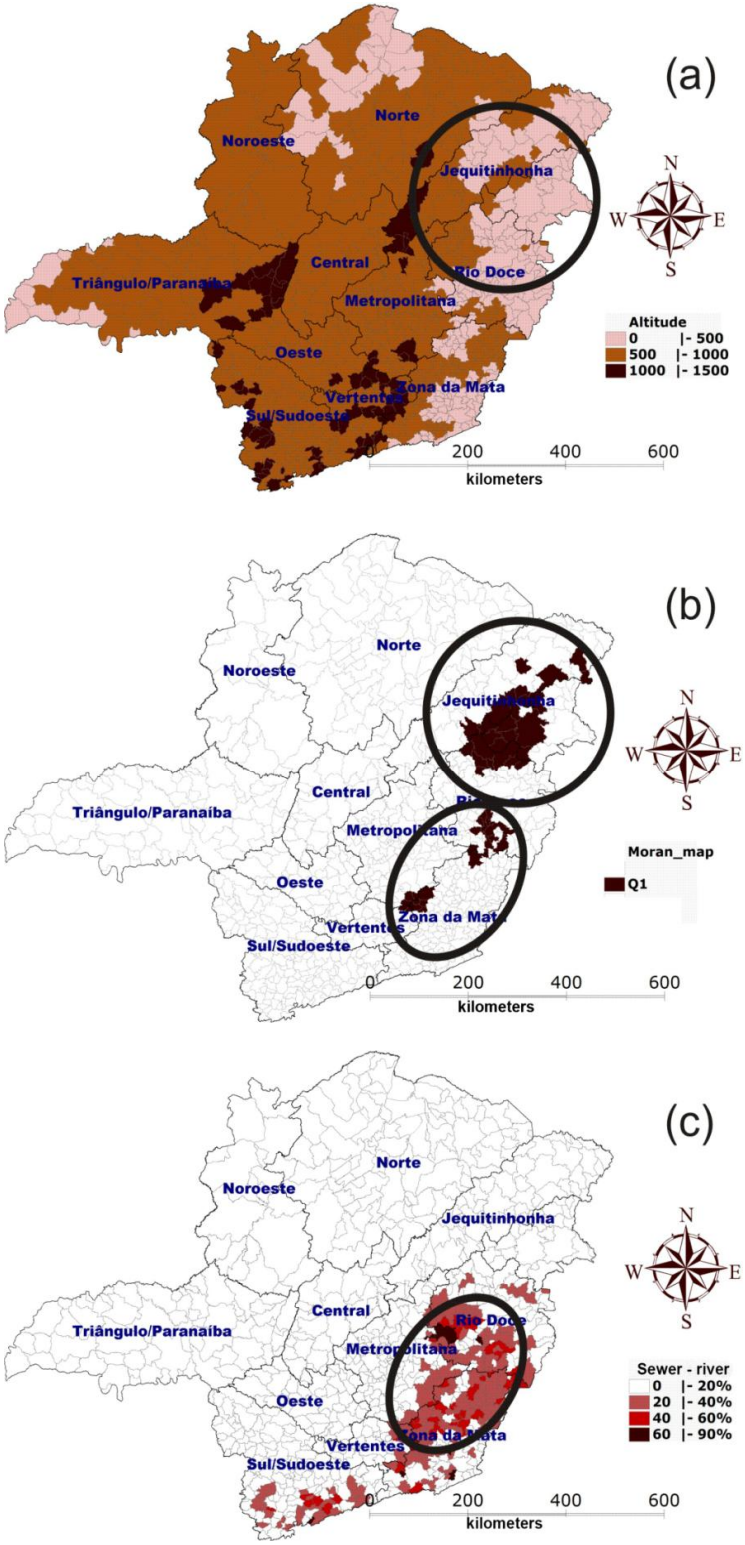

Fig. 4. The Comparative map of the state of Minas Gerais. The first map (a) presents the altitude of the cities in meters, the second (b) the clusters of cities with spatial autocorrelation, the third (c) the percentage of homes in the city with sewage into rivers and lakes

Therefore, a positive spatial association exists, that is, there are cities with high schistosomiasis rates surrounded by cities with the same characteristic.

The bivariate analysis demonstrated the correlation between schistosomiasis and two factors, the first being altitude.

Considering that the bivariate Moran's I is intended to reveal whether the mean indices of one cluster are related with another cluster in neighboring regions, in the first situation: Altitude and Schistosomiasis, it was negative, that is, the clusters of cities with high mean schistosomiasis rates are close to clusters of cities with low mean altitude levels. In the second situation: schistosomiasis and sewage in rivers and lakes, the cities with high mean schistosomiasis indices are close to clusters of cities with high means for sewage in rivers and lakes.

This information seems to be in line with some past studies, also developed in Brazil, where a relation was observed, for example, between low altitude, with a consequent possibility of a flood, and the incidence of schistosomiasis in the interior of the state of Pernambuco [12].

Schistosomiasis can be transmitted at high altitudes on the African continent, due to the existence of lakes at great altitude. Even in these conditions, however, the distribution of *Schistosoma mansoni*is more common at low altitudes [13].

The second factor considered was sewage disposal in rivers and lakes. In Brazil, in hyperendemic regions of schistosomiasis, factors like the inexistence of tap water, sewage collection and absence of treatment are very frequent [14]. That seems to be the case where regions with high rates of schistosomiasis in Minas Gerais are close to regions with high rates of sewage disposal in rivers and lakes.

5. CONCLUSION

A range of factors is correlated with the incidence of mansonic schistosomiasis in Minas Gerais. First of all, it does not happen at random, but there are clusters.

In addition, the spatial correlation with factors like altitude and sewage disposal in rivers and lakes demonstrate that there are preponderant environmental factors in schistosomiasis.

On the other hand, the prevention measures adopted have not been sufficient to eradicate schistosomiasis, perhaps because they do not consider important factors, such as environmental aspects. The bottleneck of strategies based on fighting transmissions and treatment is exactly related to issues that are always identified.

A paradigm change in the fight against schistosomiasis is needed, in which two factors could be characterized here. On the one hand, clusters can be identified, as schistosomiasis does not happen at random, but is contained in environments that somehow favor its occurrence. On the other hand, environmental factors like altitude and sewage disposal in rivers are related to these clusters. .

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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