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Spatial Analysis Of Scorpion Accidents In Brazil: Its Relation To Climate And Urbanization

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Abstract: This essay has the objective of performing a spatial analysis and of identifying spatial pattern configurations of scorpion accidents, in order to assist in the implementation of projects and interventions for the prevention and control of areas infested by venomous animals. Between the data surveys and statistical data bank organizations we can quote the *Departamento de Informática do Sistema Único de Saúde* - DATASUS (Department of Informatics of the Unified Health System), agency of the *Secretaria de Gestão Estratégica e Participativa do Ministério da Saúde* (Office of Strategic and Participatory Management at the Ministry of Health), in the years of 2019 and 2020, for the Brazilian territory. The modeling and data collection were developed, and organized into a geographic database, exploratory data analysis, spatial analysis, as well as the production of thematic maps, with identified spatial patterns. As a result a systematized set of thematic maps was obtained which presents the distribution of scorpion-caused accidents. Finally, a geographic analysis was conducted in order to analyze the data and results found, as well as the information conveyed in terms of demographic factors. It was found then a certain concentration of cases, which can generate a relationship between tropical climates and with the distribution of urbanized areas.

Keywords: Spatial analysis, cartography, venomous animals, scorpion

1. Introduction

Cartography is the discipline dealing with the art, science and technology of making and using maps (ICA, 2003).

Spatial analysis is a technique which entails the understanding of anthropic and environmental phenomena from the identification of patterns and spatial relationships, which assists in the creation of hypotheses related to the studied data. This field of knowledge is widely used in studies in the areas of Cartography and Geography, for the reason that maps are a fundamental means of representing geographic information.

Geovisualization, for example, is a valuable tool in spatial analysis because it specializes in handling specific types of data derived from detailed maps. Quoting Kraak (2009), 'geovisualization is a vaguely delimited domain which addresses the visual exploration, analysis, synthesis and presentation of geospatial data, integrating approaches from various disciplines, including cartography with those of scientific visualization, image analysis, information visualization, data exploration analysis, visual analysis and geographic information science'.

From the spatial analysis and geovisualization we can study venomous animal related accidents, which are frequently documented in both literature and news. These incidents generally occur due to the urban densification in areas of native vegetation, the biological activities of the animals, the behavior of venomous species in urban environments and the activities carried out by the victims.

Venomous animals are classified, in Brazil, as animals that produce venom, popularly known as poison, and for their ability to release these toxic compounds to hunt or defend themselves. (MINISTÉRIO DA SAÚDE, 2018).

The importance of the accidents caused by venomous animals to public health can be expressed by the more than 100,000 accidents and almost 200 registered deaths per year, due to the different types of envenomation. Scorpion stings have been acquiring greater magnitude, corresponding to 30% of notifications in 2007, surpassing cases of snakebite in absolute numbers. (MANUAL DE CONTROLE DE ESCORPIÃO, 2009, p. 5)

The scorpion denomination is derived from latin scorpio/scorpionis; and as defined by the Manual de Controle de Escorpião (2009), the scorpion is a chelicerate arthropod, belonging to the phylum Arthropoda, class Arachnida (for having eight legs) and order Scorpiones.

It was reported by the *Secretaria de Saúde de Minas Gerais* (SES-MG) (2022), that between 2018 and 2022, 305 deaths were registered in the state of Minas Gerais involving venomous animals, of which 185 of those deaths were related to scorpions.

The scorpion related cases are of the utmost importance to the municipalities, because the constant rise in these types of occurrences presents a number of problems, specifically, to public health, which reflects an economic, public health and social issue. The control of these occurrences aligns with objective number 3 (Good Health and Well-Being) of the Sustainable Development Goals (SDGs). Therefore, spatial analysis contributes to identifying the primary locations of reported cases in the states and municipalities, enabling intervention planning, cost rationalization, efficient use of human resources and

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time, as well as guaranteeing greater efficacy in control actions.

In this essay, we strive to perform the analysis of the distribution of reported scorpion-related cases in the national territory. To that end data exploration and spatial analysis were employed. The area of study selected was the entire Brazilian territory due to its great extension and prevalence of a tropical climate which is characterized by its elevated temperature and regular precipitation, which favors the influence of certain vectors, such as the emergence of scorpions.

In the first stage, the required data was obtained, such as the cartographic databases containing administrative boundaries and seats of the municipalities, as well as the estimated population and the number of scorpion accident occurrences for the years of 2019 and 2020.

Firstly, the Brazilian municipal and state borders were obtained from the Brazilian Institute of Geography and Statistics which is named as *Instituto Brasileiro de Geografia e Estatística* (IBGE, 2022). Furthermore, in the SIDRA module of IBGE, the estimated population data was obtained.

The data collection referring to the scorpion accidents, in the years 2019 and 2020, was gathered through *Departamento de Informática do Sistema Único de Saúde* (DATASUS) which is an agency of the *Secretaria de Gestão Estratégica e Participativa do Ministério da Saúde*, which is responsible for collecting and providing access to health-related data.

The SINAN, which represents the *Sistema de Informação de Agravos de Notificação* (Notifiable Diseases Information System), being gradually implemented, starting from 1993, is primarily responsible for collection and storage of notifications and investigation of disease cases, as well as collecting and providing access to health-related data available in the database of SUS.

2. Exploratory data analysis

To FISCHER (2015), "the exploratory data analysis consists in the range of techniques used to summarize data properties, identify unusual or noteworthy properties in the data, detect patterns, detect errors and formulate hypotheses". In this kind of analysis, a summary and the organization of the collected data for the object of study takes place, in the form of charts, graphs or numerical measures and, from these searchthese searches for some regularity or pattern in the observations, i.ei.e., interpret the collected data.

Through data interpretation, it is possible to identify whether the collected data follows a model or not. To achieve this, the techniques used highlight the graphical visualization of the data in accentuate specific features and enable. The detection of patterns or discrepant values, relationships and other possible characteristics.

The analysis of the distribution of scorpion case notifications, in the Brazilian territory, was applied in a context of geovisualization due to being accomplished with different cartographic representations.

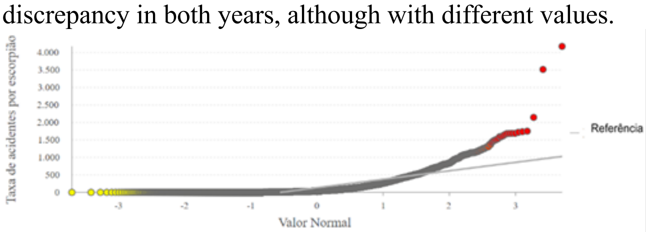
Initially, there was a collection and systematization of the data regarding the number of cases of scorpion accidents for the years 2019 and 2020 in the database of the DATASUS and the cartographic data of the IBGE. In this step exploratory data analysis was performed, to identify uncommon or interesting properties, detect patterns and errors and, finally, formulate hypotheses from the obtained results.

Two distinct procedures were applied to perform the evaluation, the Q-Q Plot Diagram, which was applied for the preliminary analysis; and ScatterPlot, which associates two quantitative variables.

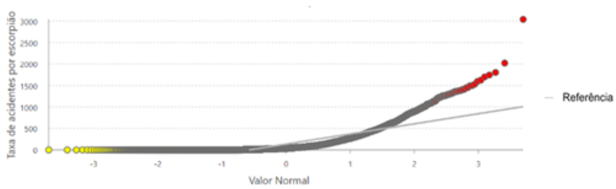
2.1 Q-Q Plot Diagram

The Q-QPlot diagram (Quantil-Quantil Plot), is used to perform a preliminary analysis and evaluation of the supposed normality of the data, by means of comparison of the cumulative distribution along the theoretical distribution of a dataset, generally with the normal distribution. In a QQ-Plot, the points that 'fall' along the straight line follow the theoretical distribution.

Observing the graphics for the years 2019 and 2020 (Figures 1a and 1b), it can be noted that the data does not show consistency, since they are far from the normal line, which is a reference line used to understand the consistency of the data. It is observed that there is a discrepancy in both years, although with different values.



a - 2019



b - 2020

Figure 1 - Q-Q Plot Diagram of the scorpion accident notification rate in 2019 e 2020.

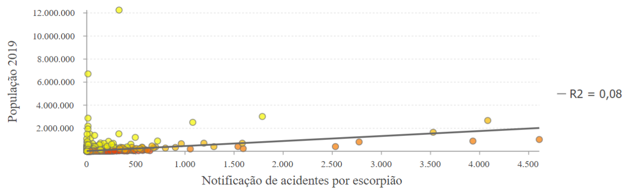
2.2 ScatterPlot

The ScatterPlot associates two quantitative variables, as it performs the relationship between two numerical variables. The representation of these relationships is made by means of points, with each point representing the value of one variable on the horizontal axis and the value of another variable on the vertical axis. Thus, it can be verified that there is a cause-and-effect relationship between the two variables. However, it does not mean that one variable causes an effect on the other, but only that there is a relationship which is possible to see the intensity of this relationship.

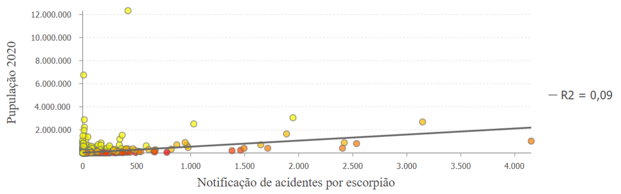
In addition, the graph represents a trend line that models the linear relationship between the horizontal and vertical axes, and the value of R^2 (coefficient of determination) that quantifies how well the sample data fits the model, which can vary from 0 to 100%, so they are relevant for linear relationships.

Therefore, Figures 2a and 2b show the relationship between the notifications of scorpion accidents in the municipalities of Brazil and the population of each municipality is shown. A concentration of points is observed in the lower left part of the graphs, meaning that there are many cities with a low population and a few notifications of accidents.

With this graphical representation, we observe that there are some outliers in the sample. In 2019, the outlier in the lower right corner corresponds to the city of Maceió, Alagoas state, with a population of 1,018,948 inhabitants and 4,608 scorpion accidents. The outlier in the upper left corner corresponds to the city of São Paulo, São Paulo state, with a population of 12,252,023 inhabitants and 329 notifications of scorpion accidents. The same occurs for the year 2020, with low changes in values. Thus, it is observed that municipalities with more inhabitants than others do not imply an increase in the number of scorpion accidents.



a - 2019



b - 2020

Figure 2. Relationship between population total (vertical) and number of incidents (horizontal)

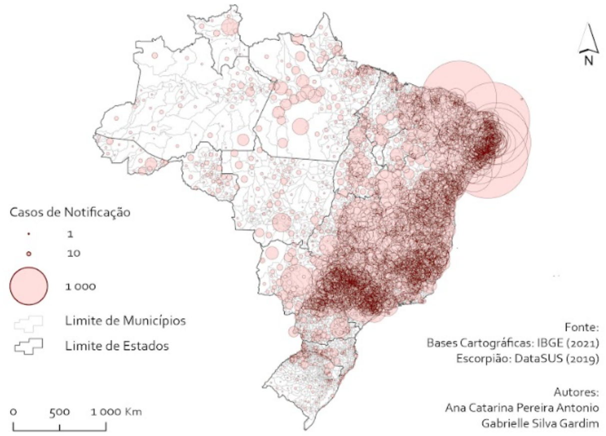
3. Cartographic products

To identify cores of cases from scorpion incidents, two Kernel density surfaces by gradient were generated (Figures 3, 4 and 5). The first step was to determine the type of spatial pattern presented by the data, and for this purpose, the nearest neighbor analysis was applied, which allowed us to verify that the type of spatial pattern of the phenomenon for 2019 (Ratio = 0.654; z-score = -44.98; p-value < 0.0001) and for 2020 (Ratio = 0.659; z-score = -44.28; p-value < 0.0001) are clustered. Both analyses were carried out by municipality seat that contained notifications in each of the years.

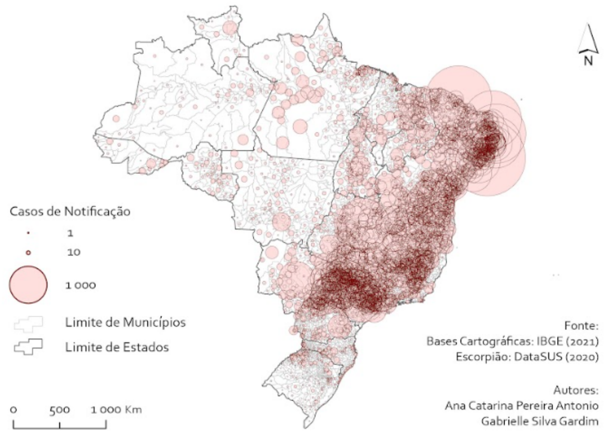
After analyzing the results in the graphs, it was possible to create thematic maps with the data of scorpion notification cases in Brazilian municipalities in 2019 and 2020 for the second stage. Proportional symbol maps, which represent the absolute number of cases per municipality (Figure 3a and 3b), showed better results for analysis, as well as the heat map (Figure 4a and 4b) and the Graduated symbol maps were used to represent classes for absolute numbers of cases per municipality (Figure 5a and 5b).

3.1 Proportional Symbols

In the proportional symbols map represented by quantitative data, the symbol size will be proportional to a specific single value, especially the number of reported cases of scorpion accidents in the municipalities of Brazil. Thus, in Maps A and B, we see that the highest number of cases is concentrated in the Southeast and Northeast regions of the country, especially in the coastal part of the Northeast region, as well as in Goiânia located in the Central-West.



a - 2019



b - 2020

Figure 3. Proportional Symbols, 2019 and 2020

3.2 Heat Map

In the heat map (Figure 4a and 4b), the selected color palette was a multi-part one that ranges from blue (low density) to purple, red, and yellow (high density), commonly used in geovisualization. In 2019, it is noticed that the densest part is located in a coastal portion of the Northeast region, followed by a second less dense nucleus in the state of São Paulo and a third weaker nucleus that goes through the states of Bahia and Minas Gerais. In 2020, something similar to the pattern of the previous year occurs, but the density increases in the state of São Paulo.

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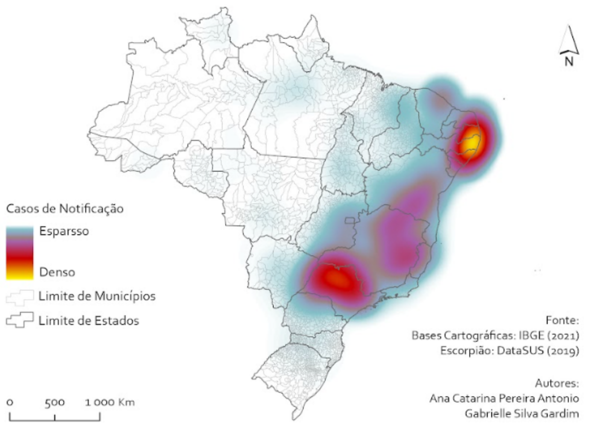
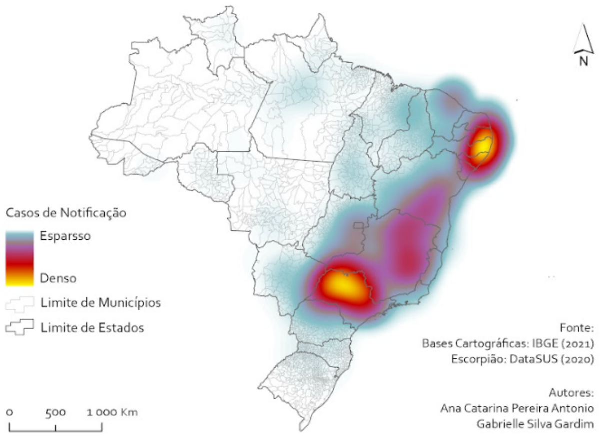


a - 2019

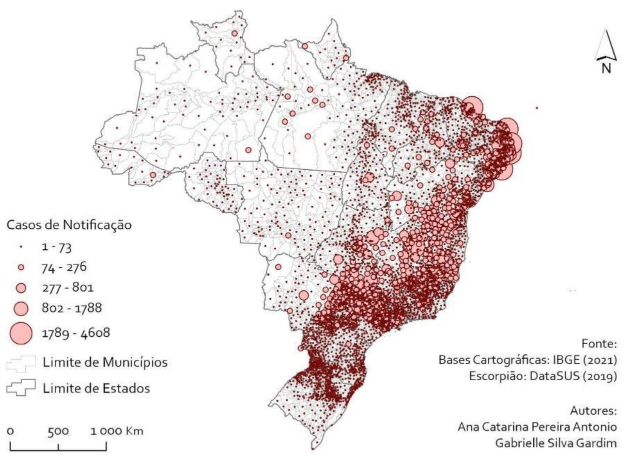


b - 2020

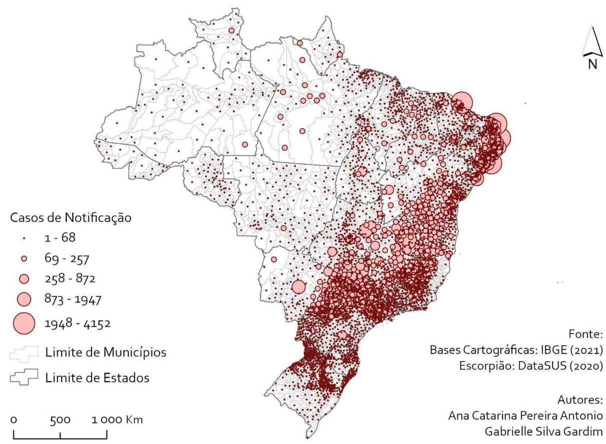
Figure 4. Kernel Density Surface 2019 and 2020

3.3 Graduated Symbol

Now, it is shown some thematic maps representing scorpion notification data in the Brazilian municipalities, in 2019 and 2020. Graduated symbol maps were used to represent classes for absolute numbers of cases per municipality (Figure 5a and 5b). Thus, we see that the highest number of cases is concentrated in the Southeast and Northeast regions of the country, especially in the coastal part of the Northeast region, as well as in Goiânia which is in the Central-West.



a - 2019



b - 2020

Figure 5. Graduated Symbol, 2019 and 2020

4. Climate predominance in the Brazilian climate

There are records of scorpions existing for over 400 million years. Scorpions have developed evolutionary and adaptive capacity to withstand major accidents and are capable of adapting to a variety of habitats. However, according to the *Manual de Controle de Escorpiões* (2009), most species prefer tropical and subtropical climates.

The national territory, on the other hand, has three types of climate: equatorial, tropical, and temperate (Figure 6), with the tropical climate varying according to the region and characterized mainly by high temperatures and less regular rainfall.

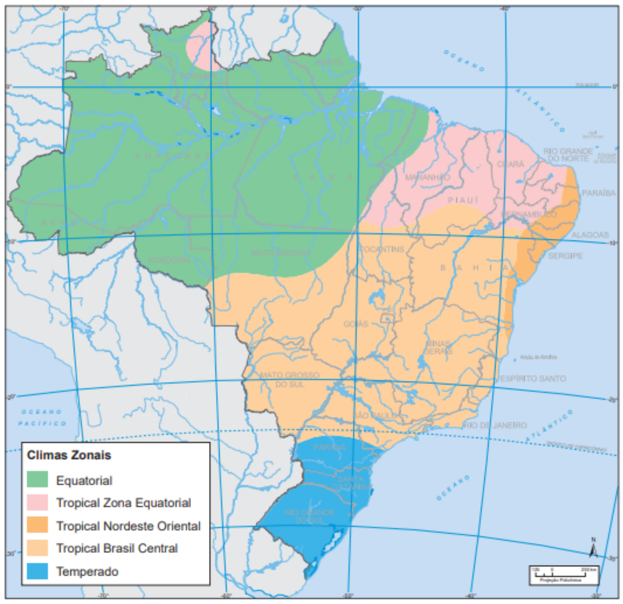


Figure 6. Climatic Diversity in Brazil. © IBGE 2002

The regions with the highest incidence of notified cases are characterized by the predominance of the tropical climate and the following biomes: Caatinga(Semi-Arid), Atlantic

Forest(Tropical Forest), and a small fraction of the Cerrado(Savannah) biome, as can be seen in Figure 7.

The Atlantic Forest occupies approximately 13% of the Brazilian territory. The Caatinga biome covers an area of approximately 10% of the national territory. In turn, the Cerrado biome, located in the Brazilian Central Plateau, covers approximately 24% of the territory.

Figure 7. Biomes of Brazil. © IBGE 2008

5. Distribution of urbanized areas

Recently, the *Instituto Brasileiro de Geografia e Estatística* (IBGE) produced a map on the distribution of urbanized areas in Brazil in 2019 (Figure 8). According to Guimarães (2022), the state of São Paulo holds 18.39% of the total urbanized areas in the national territory, while Amapá has the lowest percentage, with 0.33% of the total national territory. Coastal municipalities account for approximately 19% of the total urbanized areas in the country, as shown in Figure 8.

According to Guimarães (2022), the urban concentrations of São Paulo (SP), composed of 37 municipalities, and Rio de Janeiro (RJ), formed by 21 municipalities, have urbanized areas larger than 1,000 km², the first with 2,133.81 km² and the second with 1,693.80 km². Therefore, based on figure 8, the areas of highest urban concentration in the country are located near the coast, as well as the cases of scorpions.

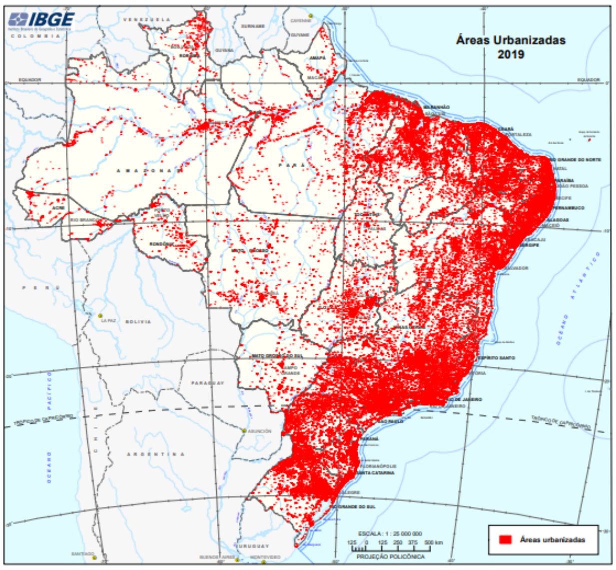


Figure 8. Distribution of urbanized areas in Brazil 2019. © IBGE 2022

6. Discussion and recommendations

The Exploratory Data Analysis was performed in order to examine the data prior to the application of statistical techniques, with a preliminary analysis of the data and its relationship with the variables. Overall, it was possible to observe that the data did not present a normal pattern, thus, the size of the municipalities does not directly influence the results regarding the number of cases. A smaller city may have more reported cases of scorpion accidents than a larger city, due to proportionality, therefore, we have a high frequency of low rates of scorpion accidents.

In Cartographic Products, in the proportional symbols map, it is possible to observe the areas with the highest concentration of notifications, and with heat maps, we can also visually observe the locations with the highest notifications, through the core of colors, which reduces as there are fewer notifications.

Finally, by analyzing the predominant climate of each region throughout the year, together with the data presented previously, it was possible to establish a correlation between the climate and scorpion cases. As observed, the regions with the highest incidence of scorpion accidents are the Northeast and Southeast, with the states of Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, São Paulo, Bahia, and Minas Gerais having the highest concentration, which are regions with a predominantly tropical climate throughout the year. The tropical climate varies according to the region, but it is generally characterized by high temperatures and irregular rainfall, favoring the emergence of scorpions inside homes. The same can be analyzed for the types of biomes, with the predominant ones for case concentration being the Caatinga, Atlantic Forest, and a small fraction of the Cerrado biome, and regarding population density, there are more cases in regions with a higher urban concentration.

The choice of the years 2019 and 2020 made it possible to identify the locations with the highest incidence of scorpion cases. Even though the analysis was performed over two years, a spatial pattern can be observed regarding the cases and their locations. By studying the determined years and considering the COVID-19 pandemic, the number of cases reported in 2020 was similar to that of 2019, as observed and analyzed in the maps and graphs. However, there may have been underreporting of cases due to the existing burden on the healthcare system in that year, which could influence the research outcome.

With the presented results, it is possible for health teams to carry out intervention projects in areas with higher indices, in order to preserve life and ensure good health and well-being for the resident population. This will enable the application of SDG goal 3.

Utilizing this study as a basis, a more comprehensive investigation is recommended for each of the regions, aimed at supporting scorpion combat and prevention campaigns.

7. References

ANSELIN, L., 1995. Local indicators of spatial association – LISA. Geographical analysis, 27(2), pp. 93-115.

BRASIL, MINISTÉRIO DA SAÚDE. 2018. Acidentes por animais peçonhentos: o que fazer e como evitar. Brasília: Ministério da Saúde.

Brasil, MINISTÉRIO DA SAÚDE. 2009. Secretaria de Vigilância em Saúde. Departamento de Vigilância Epidemiológica. Manual de controle de escorpiões/Ministério da Saúde, Secretaria de Vigilância em Saúde, Departamento de Vigilância Epidemiológica- Brasília:Ministério da Saúde.

Guimarães., C.A., 2022. Sudeste concentra mais de um terço das áreas urbanizadas do país.

FISCHER, M. M. 2015. Spatial Analysis in Geography. 2. ed. In: International Encyclopedia of the Social & Behavioral Sciences. pp-94-99.

IBGE. 2004. Mapa de biomas do Brasil: primeira aproximação. Rio de Janeiro. 1 mapa. Escala 1:5 000 000.

IBGE. 2002. Mapa de clima do Brasil. Rio de Janeiro. 1 mapa. Escala 1:5 000 000.

ICA. 2003. A Strategic Plan for the International Cartographic Association.

SES-MG. 2022. JORNALISMO: Saúde orienta como prevenir acidentes com animais peçonhentos. Minas Gerais, Abril de 2022.

United Nations. 2018. The 17 Goals.

Kraak, Menno-Jan. 2009. Geovisualização. In: International Encyclopedia of Human Geography. Elsevier. pp.468-480.

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