CAPÍTULO 1

MODELAGEM MATEMÁTICA E ESTATÍSTICA ESPACIAL APLICADAS AO ESTUDO DO DESMATAMENTO E DA MALÁRIA NA REGIÃO DA AMAZÔNIA OCIDENTAL, BRASIL

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RESUMO – O capítulo de livro é um estudo que tem como objetivo analisar o comportamento da dispersão espacial dos casos de desmatamento e malária no Distrito de União Bandeirantes, zona rural do município de Porto Velho, Rondônia, Amazônia Ocidental. Duas ferramentas de indicadores estatísticos foram usadas. O semivariograma e a krigagem. O método do semivariograma é a modelagem matemática e a estatística espacial que permitiu estudar a dispersão natural das variáveis, e o método da krigagem foi utilizado para analisar a variabilidade espacial dos indicadores existentes na área de estudo. O método de krigagem indicativa mostrou que a ocorrência de casos de malária está relacionada ao crescimento do desmatamento. Com o avanço do desmatamento em direção ao norte da área estudada, os casos de

malária aumentaram na mesma direção. Houve aumento dos casos de malária a leste da concentração populacional, convergindo com a área de avanço do desmatamento. Pode-se concluir que os métodos utilizados são eficientes para correlacionar e monitorar o desmatamento e a produção social da malária. Sugere-se que os gestores públicos desenvolvam meios para implementar uma estratégia de controle do desmatamento integrada à endemia da malária na zona rural, e neste caso específico, no Distrito de União Bandeirantes.
PALAVRAS-CHAVE: Modelagem Matemática. Estatística Espacial, Semiovariograma e krigagem, desmatamento, malária, Amazônia Ocidental.

MATHEMATICAL MODELING AND SPATIAL STATISTICS APPLIED TO THE STUDY OF DEFORESTATION AND MALARIA IN THE WESTERN AMAZON REGION, BRAZIL

ABSTRACT – The present study aimed to analyze the behavior of the spatial dispersion of deforestation and malaria cases in the District of União Bandeirantes, rural area of the municipality of Porto Velho, Rondônia, Western Amazon. Two statistical indicator tools were used. The semivariogram and kriging. The semivariogram method is the mathematical modeling and statistic spacial that allowed to study the natural dispersion of variables, and the kriging method was used to analyze the spatial variability of the existing indicators in the study area. The indicative kriging method showed that the occurrence of malaria cases is related to the growth of deforestation. With the advance of deforestation towards the north of the studied area, malaria cases increased in the same direction. There was an increase in malaria cases east of the population concentration, converging with the area of advance of deforestation. It can be concluded that the methods used are efficient to correlate and monitor deforestation and the social production of malaria. It is suggested that public managers should develop means to implement a deforestation control strategy integrated with the malaria endemic in the rural area, and in this specific case, in the District of União Bandeirantes.
KEYWORDS: Mathematical Modeling. Spatial Statistics, Semiovariogram and kriging, deforestation, malaria, Western Amazon

1 I INTRODUCTION

In the Amazon, felling and burning are common, especially in rural areas, causing an increase in the incidence of diseases, especially malaria, putting at risk the development of the region [1]. The Amazon Region - the largest area of tropical forest in the world, containing approximately a quarter of all tropical forests on the planet, is among the regions with the highest rates of deforestation. In the last three decades, it is estimated that the Amazon has lost approximately 17% of its native forest cover due to significant changes in land use patterns, through an intense process of human occupation, accompanied by national and international economic pressures.

In view of the occurrence of deforestation and the proliferation of malaria, we sought to study the risk factors and perspectives for the control of malaria and deforestation in the current District of União Bandeirantes, a rural area belonging to the Municipality of Porto Velho, Rondônia, Western Amazon, Brazil.

Studies in different populations and geographic regions contribute to the knowledge of malaria that does not necessarily apply to populations located in other areas of the world, subjected to plasmodium species with different genetic characteristics and different transmission conditions, as is the case of the Amazon.

Malaria, for example, is an infectious, febrile and acute disease, common in the states of the Amazon region. Its transmission occurs by the bite of mosquitoes of the genus Anopheles, contaminated with the protozoan of the genus Plasmodium.

Studies show that infectious diseases are prominent in human history as they constitute major public health problems. Malaria, cholera, typhoid, leprosy, plague, among others, have had a high incidence around the world over the past centuries. The improvement of the quality of life in the countries of the Northern Hemisphere, as well as the effects of the Industrial Revolution and, in particular, the phenomena of urbanization and technological acceleration, have restricted these diseases to the “poor areas” of the world, including the tropical zones.

In Brazil, an epidemiological picture is currently characterized by the coexistence of endemic diseases and the return of old infectious diseases. Diseases such as malaria, leishmaniasis, leprosy, tuberculosis, among others, also represented major health problems, particularly in the Amazon Region [2].

The factors that favor the transmission of malaria and hinder the application of traditional control measures were associated in the Amazon Basin Region. Among the first are: a) biological factors, such as the presence of high densities of mosquito vectors, a migrant population without naturally acquired immunity against the disease and the prevalence of strains of Plasmodium resistant to antimalarials for safe use in the field; b) geographical, such as the predominance of low altitude, high temperatures, high relative humidity, high rainfall and vegetation cover of the forest type, favorable to the proliferation of vectors; c) ecological, such as deforestation, keeping animals on which mosquitoes feed as an alternative to human food; construction of hydroelectric power plants and irrigation systems, increasing the number of mosquito breeding sites and d) social, such as the presence of numerous population groups living in houses with total or partial absence of side walls and work near or within forests, providing a very intense contact with the vector mosquito. And this association happens both with environmental changes and with the transmission of malaria mainly in the populations of rural settlements, due to changes and alterations in the environment called frontier malaria [3].

Some studies corroborate this picture, among them, “Malaria in Brazil: Epidemiological panorama in the last decade” by Barata [4]; “Risk of malaria transmission in the U.H.E of Porto Primavera-SP” by Bitencourt et al [5]; “Combating Malaria in Brazil: evolution, current situation and perspectives" by Marques and Cárdenas [6]; "Spatial Distribution of Deforestation in the Legal Amazon" by Alves [7]; "Anthropic land use and malaria in the North of Mato Grosso, 1992 to 1995" by Barbieri [8]; "Application of Spatial Analysis Methods in the Characterization of Health Risk Areas" by Carvalho [9].

The municipality of Porto Velho recorded 4,525 positive cases of malaria in 2021. As a reflection of the increase in cases in general, comparing the participation of special areas in the total of autochthonous cases of the State recorded in 2020 and the first half of 2021, the increase in the participation of malaria transmission in settlements, indigenous areas and mining was evidenced, despite the reduction in the participation of urban areas.

The large volume of rainfall recorded in the Amazonian winter favors the spread of tropical diseases such as malaria and dengue. In 2022, 7,199 cases of malaria were confirmed in the rural and urban areas of Porto Velho, a number that raises the alarm about the risks of contamination of the disease.

Regarding P. falciparum malaria and mixed malaria, in 2020 943 autochthonous cases were recorded and in 2021, from January to June, 233 cases, with a reduction of 42.6% in the number of autochthonous cases of this species. Of the total of 52 municipalities in the State, considering the cutoff from January 2020 to June 2021, only the municipalities of Porto Velho, Candeias do Jamari and Guajará-Mirim were responsible for 80.0% of the total of autochthonous cases of malaria in the State, being, in total, 41 municipalities (78.8%) of the State that had malaria transmission in the same period.

For P. falciparum malaria, the municipalities of Porto Velho and Candeias do Jamari were responsible for 80.0% of the burden of this parasitic species in the State. Among the municipalities with an increase in the number of cases, the capital Porto Velho represents the highest burden of the disease, reflected mainly by the territorial extension of the municipality, the structure of territorial occupation in the settlements, and the difficulty of adapting the diagnostic network for timely treatment of patients and interruption of the transmission cycle, as well as the continuity of vector control actions.

And in the current District of União Bandeirantes, since its beginning in 1999, malaria has been a health problem for the local population, due to the large area of forest degraded by deforestation, causing environmental damage and the social production of endemics.

Real estate speculation is practiced in the region and, through this activity, unscrupulous people take the opportunity to "sell landmarks" (fractions of public land), in open use in bad faith, deceiving people who, through ignorance, end up investing in the scarce economy in "invaded land", running the risk of losing the amounts invested. In addition, these people are subject to penalties, both from agrarian legislation and the Environmental Crimes Law.

With the absence of planning, on a preventive and conservationist basis, the illegal occupations that proliferate within the Bandeirantes Union District are plundering the forest, causing a vertiginous decline of forest species and, consequently, drastically reducing, the volumetric potential of economically marketable forests and the biodiversity of local flora and fauna. In addition, there is the inappropriate use of soil resources, causing a rapid reduction of the natural resources of the area, causing major social and political conflicts, as well as enormous damage to the environment.

The main endemic diseases in the Amazon are closely linked to the destruction of Amazonian ecosystems. These diseases are called focal diseases, which are rooted in the elements of fauna and flora. The dynamics of deforestation transform the circulation of microbial agents such as viruses, bacteria and parasites. The intensity of deforestation will have an impact on the ecosystem. Due to several biological, behavioral and geographic factors, this population of União Bandeirantes is exposed to a higher or lower incidence of malaria, with greater or lesser instability of transmission.

According to Moraes [10], the environment is not homogenized in a single target of actions, but merges as an inherent facet of every act of producing space. In this approach, nature and space do not only exchange in an appeal of complicity. In this approach, nature and space do not only exchange in an appeal of complicity. Natural space doesn't just exist to be explored, it's much more than that.

Man and nature coexist as synonyms. However, phenomena such as hunger, thirst and epidemics are injunctions aimed at what inhabits its core, which are the relationships maintained between man and the natural environment. Theme treated by Santos [11] in "For a New Geography", Santos [12] "Space and Method", Santos [13] "The Return of the Territory", Santos [14] "Health and environment in the process of development" and, Santos [15] "The Nature of Space: technique, reason and emotion".

It is perceived that this unplanned human-environment interaction generates a conflictual situation, especially about deforestation and endemic diseases. This is what Santos [14] called a hostile nature, due to its catastrophic effects, with damage to the physical and mental health of populations, when nature ceases to be a friend of man.

2 I METHOD

The theoretical basis of spatial statistics or geostatistics is centered on the theory of regionalized variables. One of the precursors of this method was Georges Matheron, who began with the work of Daniel Krige, who aimed to solve problems of estimating mineral reserves. According to Grip [16] because it is a probabilistic method, it uses a position of observations to understand the behavior of the variability of the observed values.

Thus, the concern of spatial statistics analysis is with natural phenomena. From the estimates of the regionalized variables, using some spatial characteristics of the sampling points of the discrete data set, evaluating the estimation errors, which establishes the degree of security in the predictions and the optimal sampling patterns, so that the maximum errors of the estimates are not exceeded.

Applied spatial statistics deals with problems related to regionalized variables. The variables present an apparent spatial continuity, with the characteristic of presenting values very close to two neighbors, which makes the different measures increasingly distant, in addition to presenting their own location, anisotropy and transition. In the behavior of regionalized variables there are two fundamental tools of statistical methods: semivariogram and kriging [17].

2.1 Semivariogram

The semivariogram is the mathematical modeling that allows to study the natural dispersion of the regionalized variable [18], which, according to Landim [19], this modeling demonstrates the degree of dependence between the samples. The regionalized variable has spatial continuity evidenced at the moment of inertia designated by the variogram.

The variogram is a basic tool to support kriging techniques, which allows quantitatively to represent the variation of a regionalized phenomenon in space [20]. This phenomenon is due to the distance and direction between pairs of observations, as shown in equation (1).

$$[z(x_i), z(x_i + h)] \tag{1}$$

The variogram is translated as follows, equation (2).

$$\gamma(h) = \frac{1}{2n(h)} \cdot \Sigma_{i=1}^{n(h)} \cdot [z(x_i + h) - z(x_i)]^2 \tag{2}$$

Where:

γ (h) is the semi-variance;

n(h) is the number of pairs of values of the variable considered in a given direction;

z(xi), z(xi+h) are values of the variable at two distinct points, separated by a predetermined and constant distance in one direction;

h is the preset distance interval;

½ is half the mean of the squared differences and represents the perpendicular distance of the two points from line 45 of the spatial dispersion diagram.

The semivariogram is usually called a variogram, and the format of this graph describes the degree of autocorrelation present in Figure 1.

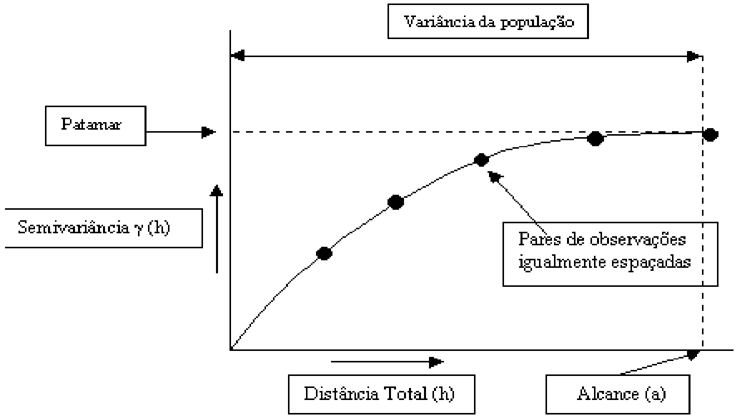

Figure 1 - Semi-variogram model

Source: author, 2023.

Where:

h: distance;

γ(h): semi-variance;

Range (a): indicates the distance where the samples no longer have spatial correlation, becoming random variation;

Level (C + C0): it is the value of the semivariogram corresponding to its range (a). Meaning that there is no longer any spatial dependence between the samples, hence null covariance.

C: is the contribution of the level.

C0: called the "nugget effect" reveals the discontinuities of the semivariogram for distances smaller than the shortest distance between samples. According to Isaaks and Srivastava [21], this discontinuity may be due to measurement errors. Making it impossible to assess whether the greatest contribution comes from measurement errors or from small-scale variability not captured by sampling.

In practice, variographic models are not known and must be adjusted by a theoretical model that represents the different regionalizations that occur in nature, which can be classified into two categories: non-platform model and

b) platform model.

According to Isaaks and Srivastava [21], these models are called isotropic. Models of the first type are referred to in geostatistics as transitive models. Since some of the transitives reach the level (C) asymptomatically. For these models, range (a) is arbitrarily defined as the distance corresponding to 95% threshold. The second type, on the other hand, does not reach the platform and continues to increase as the distance increases [22]. These models are used for modeling phenomena that have infinite dispersion capability.

According to Landim [19], in models with a platform, there are basically four theoretical functions that fit the empirical semivariogram models: linear, spherical, exponential and Gaussian. For Camargo et. al [22],

The semivariogram may or may not present structures of spatial variability in the study area, this can be seen by comparing the estimated semivariograms for the 0º, 45º, 90º and 135º directions. Therefore, this spatially dependent structure can occur in the same and in all directions, that is, in this case, h is considered as scalar, the phenomenon is called isotropic, otherwise, his considered as a vector and the phenomenon is called anisotropic.

Some natural phenomena are more likely to occur in anisotropic modeling, which can be geometric and zonal. The geometric anisotropy is adjusted in the same model, but there is variation in the range according to directions, with the maximum and minimum ranges being in orthogonal directions. In zonal anisotropy, there is more than one semivariogram model for the area [22].

The parameters found in the classic variogram models are related to scale, extension and continuity, where there is stability characterizing its form of spatial dependence, providing information necessary for the execution of kriging, allowing to find the optimal weights, related to the samples, still allowed estimate the unknown points [23].

2.2 Kriging

To obtain a more effective diagnosis of deforestation and malaria, the Kriging method was used to analyze the spatial variability of existing indicators in the area. According to Fuks [24] and Fuks et al [25], kriging is a stochastic spatial inference procedure, whose variographic analysis model provides a spatial covariance structure. It is an elaborate statistical technique that estimates a spatial covariance matrix that determines weights assigned to different samples.

A spatial dependence model is obtained, with the intention of predicting values at non-sampled points as well. This interpolator weights the neighbors of the point to be estimated, obeying the criteria of non-bias and minimum variance. There are several types of kriging: simple, ordinary, universal, indicative, among others.

Indicative Kriging basically consists of determining an average value in a non-sampled location. Other values can also be used as a basis for estimating values below or above a certain cut-off level [23]. This technique has the main advantage of being non-parametric, not requiring prior knowledge of the distribution for the random variable (VA).

Indication kriging allows estimating the VA distribution function, allowing the determination of uncertainties and the inference of attribute values in unsampled spatial locations. Unlike linear kriging, the indication kriging procedure models attributes with high spatial variability, without the need to ignore sampled data whose values are very far from a trend [26]; [27].

For Landim [17], the experimental semivariograms are achieve these goals, the first step in Indicative Kriging is to transform the original data into indicators, that is, transform the values that are above a certain cut-off level into zero (0) and those below into one (1):

$$I(v_c) = \begin{cases} 1, \cdots se \cdot \cdots v_j \leq v_c \\ 0, \cdots se \cdot \cdots v_j \leq v_c \end{cases} \quad (3)$$

And, therefore, the expected value of the VA per referral,

$$\mathrm{E}\{\ I\ (v_c)\ /(\mathrm{n})\} \quad (4)$$

provides an F* estimate of the fdc of at cutoff value and conditioned to the n sample data of the attribute v_ji

$$\mathrm{E}\{\ I\ (v_c)\ /(\mathrm{n})\} \quad (4)$$

$$1.\ \ Prob\{I(v_c = 1/(\mathrm{n})\} + 0.Prob\{I(v_c) = 0/(\mathrm{n}) =$$

$$1.\ \ Prob\{I(v_c = 1/(\mathrm{n})\} = \mathrm{F}^*\ (v_c\ /(\mathrm{n}))$$

According to Deutsch (1998), this technique allows the elaboration of the estimate by a kriging on the set of values per indication for the fdca of v_j at cutoff value v_c. calculated for certain cut-off levels and then the Indicative Kriging is applied, which provides maps of probability of occurrence. This aims to provide maps of occurrence of values, below and above the cut-off levels, providing the anomalies of the geoenvironmental research areas.

2.3 Study area.

The area chosen to carry out the study and assess deforestation, as well as the number of cases of malaria, is located in the region of the municipality of Porto Velho, on the Gleba Jorge Teixeira known as União Bandeirantes.

This is a colonization area monitored by the National Institute of Agrarian Reform (INCRA) in the vicinity of Highway BR-364, Km 9.5. It is an area of terra firme forest, which has a history of anthropogenic occupation. It is located 160 km from the city of Porto Velho.

The side roads (paths and small unpaved roads) of malaria incidence in the study area were, Line (road) 1, Line (road) November 15, Line (road) 2, Line (road) 4 – place, Line (road) 1º de Maio, Line (road) of Barraco Azul – place, Line (road) F, Line (road) P.O, Line (road) Triangle, Linhão- Rural camping, Line (road) Rio Contra-Povo, Travessão (road) 10- Rural camping, Travessão (road) 101 – place, Travessão (road) 4 - Rural camping, Travessão (road) 5 - Rural camping, Travessão (road) 6 - Rural camping, Travessão (road) 7 - Rural camping, Travessão (road) 8 - Rural camping, Travessão (road) 9 - Rural camping, Line (road) União Bandeirantes-Vila, Line (road) do Tucano, Line (road) do Pavão, Line (road) do Ferrugem, Line (road) Abacaxi.

In this study, 25 local samples were considered (rural roads, being the camps, agglomerations and places and the headquarters of the District) with an estimated population of 20,000 inhabitants and 1,400 cases of malaria.

2.4 Database

For the construction of the database of malaria incidence in Gleba União Bandeirante, in the period of 2 (two) years, data collected by the Epidemiological Surveillance and Information System - SIVEP were used, which were compiled into tables for analysis and identification of current patterns. The images of deforestation were compiled from the satellite image bank of the Secretariat of Environmental Development of Rondônia.

2.5 Variables

The cadastral data used in the study consist of the following variables: Number of inhabitants, places (lines or a kind of vicinal roads), total positive malaria, annual parasite index – IPA, annual falciparum index – API, falciparum malaria index, vivax malaria index, malaria index and malaria.

2.6 Statistical treatment

In the statistical treatment of the data, the geostatistical method of kriging was used as a tool for data analysis and geostatistical modeling to describe the spatial behavior of deforestation in Gleba União Bandeirantes, current District of União Bandeirantes – Municipality of Porto Velho, State of Rondônia, Western Amazon.

Descriptive statistics is often used in order to describe the data and synthesize the data series of the same nature, thus allowing a global view of the variation of this set, that is, descriptive measures help in the analysis of Dice’s behavior.

The statistical measure used as a parameter of behavior in this study was the median. This represented the best behavior as a measure that evaluated the incidence of deforestation and its possible correspondence with the number of malaria cases. This statistical parameter describes the measurement of the dataset as an evaluation that leaves 50% of the elements of the set [28].

This measure of tendency or central position describes the center of a distribution [29]. If the data set has discrepant elements, these should not be discarded, since these elements do not affect the set, when using the median as a measure of analysis [30].

3 I RESULTS AND DISCUSSION

Semivariogram Analysis

The first adjusted variographic model is the Gaussian (Figure 2), whose direction is

NE - SW. The parameters are: nugget effect (C0) = 20000, level is 1620,000 and range is 10500. This model describes the behavior of the deforestation variable. Thus, it resulted in the map of Figure 03.

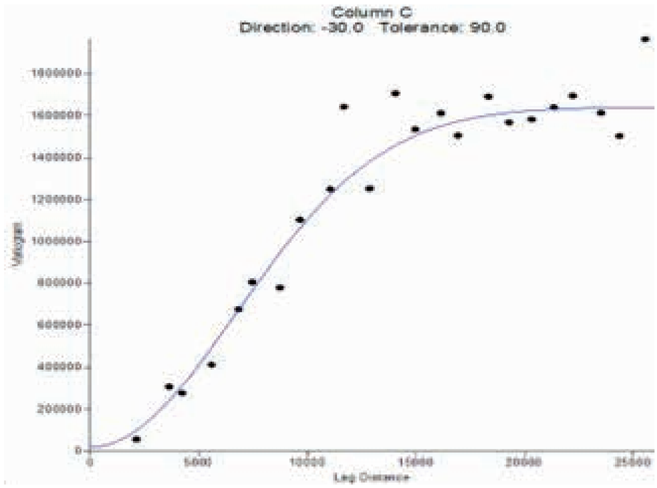

Figure 2. Experimental variogram of deforestation, adjusted for median (6560 ha).

Source: author, 2023.

For the map of deforestation (Figure 3), it is observed that it has a behavior of great part in the Central and North region of the Gleba União Bandeirantes. This means that the occurrence of deforestation was highly prevalent in this area. In the South and West parts, deforestation is much lower. However, it can be stated that the area has already been undergoing a process of exploration. In this territorial portion are located the Karipunas and Bom Futuro indigenous reserves and also the headquarters of the Jacy Paraná District, forming a deforestation control belt, thus reducing the rate of exploitation of the forest.

As expressed on the map, as the cut-off level approaches 0 (zero), deforestation is intense. The area of intense deforestation is represented cartographically by the red portion.

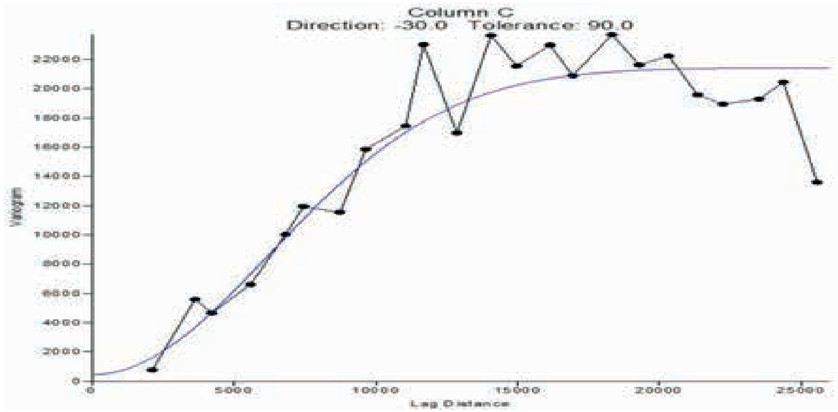

Figure.3: Probabilistic map of deforestation occurrence, median cut-off level (6560 ha).

Source: author, 2023.

The fitted variographic model (Figure 4) is a Gaussian whose direction is NE – SW. Its parameters are: nugget effect (C0) = 436, the threshold is 21000 and the range is 13000.

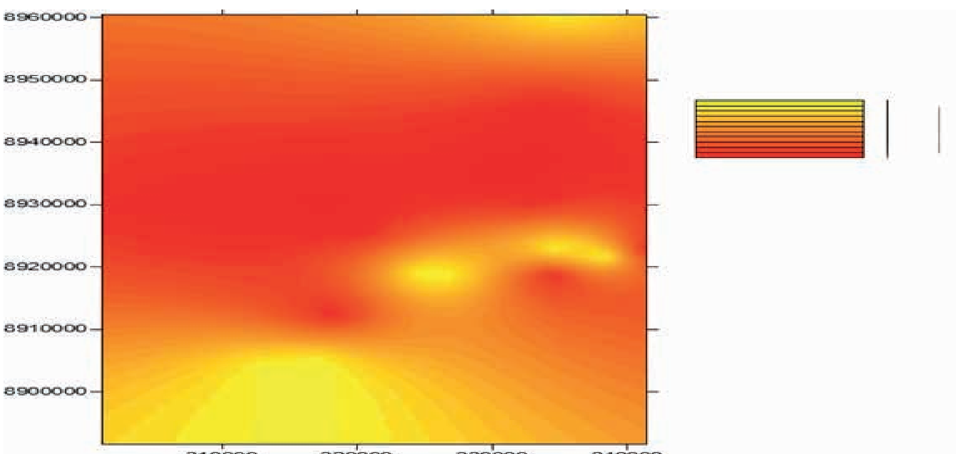

Figure.4: Experimental risk variogram for malaria cases, adjusted for median (1460 cases).

Source: author, 2023.

For the malaria risk map, it is observed that there was a great trend of occurrence of cases throughout the northern portion of the area (Figure 5).

The combined occurrence map, in which the occurrence of deforestation and malaria is observed, the growth of malaria cases occurs as deforestation advances to the North. This means that the increase in cases is due to human activity, leaving the population vulnerable to tropical endemics, especially malaria (Figure 5).

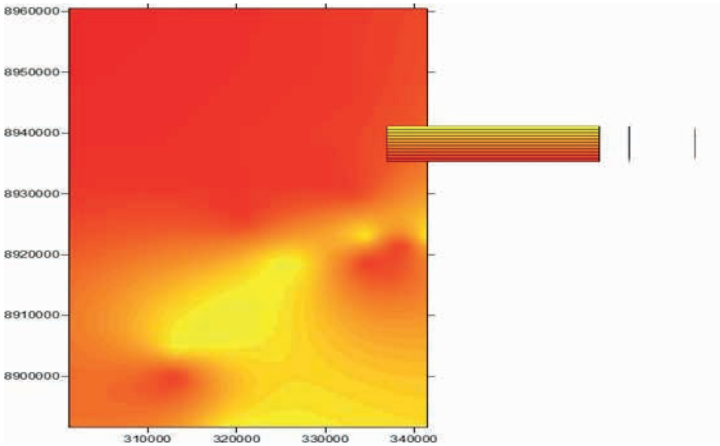

Figure.5: Map of probability of occurrence of malaria, median cut-off level (1460 cases).

Source: author, 2023.

The study by Paraguassu-Chaves [2] carried out in a subspace of the Western Amazon is another argument in favor of this interpretation. According to this author, the migrant population living in precarious housing conditions favors the expansion and development of an environment relevant to the social production of malaria.

4 I CONCLUSION

The present study was conducted in the current District of União Bandeirantes, a rural area of the municipality of Porto Velho, Rondônia, in which the rates of deforestation and incidence of malaria in the area were investigated.

For statistical analysis and modeling, the geostatistical methods of semivariogram and kriging were used, in which the behavior of the variables and their direction of growth of deforestation and malaria cases were observed. The indicative kriging method proved to be satisfactory because it presented the occurrence of malaria cases in line with the growth of deforestation. In fact, it was noticed that as deforestation advances towards the north of the studied area, malaria cases increase in the same direction.

The population in contact in the deforested region north of União Bandeirantes is vulnerable to contracting malaria. Similarly, there was an increase in malaria cases east of the population concentration studied, converging with the area of advance of deforestation. The illegal occupations (the invasions of public lands) that proliferate in the area of União Bandeirantes cause a significant rate of local deforestation, which harms not only the environment, but also the fragile population structure.

With the absence of planning and logistical guidance for the occupation of the area, the District of União Bandeirantes is on a dizzying path of decline of forest species and their biodiversity and the increase of endemic diseases such as malaria. It should also be considered that as long as the migrant population lives in precarious conditions of housing and basic sanitation, it will favor the emergence of an environment conducive to the emergence of endemics.

Finally, at the study site, malaria transmission accompanies the process of occupation of the territory. It is noteworthy that the incidence of malaria has a higher vector density in the periphery of Gleba, with a progressive reduction for the more central areas of the urban core.

Therefore, by identifying the areas in which the highest levels of autochthonous transmission are concentrated, the possibility of the particularized area being the object of necessary intervention measures increases, enabling the correct choice and direction of the control measures managed by the managers of the endemic control programs.

Thus, managers should develop means to implement a deforestation control strategy integrated with the malaria endemic in the area of the District of União Bandeirantes. This necessarily implies creating conditions for a coordinated multisectoral action, capable of addressing the local factors that make the transmission of malaria heterogeneous and complex and the increase in deforestation in the District of União Bandeirantes.

REFERENCES

1.Paraguassu-Chaves, C.A. Trindade, C.D. Aznar Filho, S. Almeida, F.M. Aznar, S.D., Trindade, C.A.D. de Souza, L.P.G. Guanabara, R. Dantas, L.R.M. Geostatistics Applied to the Study of Deforestation and Malaria in Rural Areas of Western Amazon. International Journal of Advanced Engineering Research and Science, 8(7)-2021.

2. Paraguassu-Chaves, C.A. Geografia médica ou da saúde – espaço e doença na Amazônia Ocidental. Porto Velho: EDUFRO, 2001.

3. Tauil, P. L. Avaliação de uma nova estratégia de controle da malária na amazônia brasileira. Universidade de Brasília, 2002. (tese de doutorado).

4. Barata, R.C.B. 1995. Malária no Brasil: Panorama epidemiológico na última década. Cadernos de Saúde Pública, 11(1): 128-136.

5. Bitencourt, M.D.; Mucci, L.F.; Gomes, A.C.; Natal, D.; Barata, J.M.S. & Paula, M.B., 1999. Risco de transmissão de malária na U.H.E de Porto Primavera-SP. (Estudo não publicado).

6. Marques, A.C.; Cárdenas. Combate à Malária no Brasil: evolução, situação atual e perspectivas. Revista da Sociedade Brasileira de Medicina Tropical 27 (Supl. III):91-108,1998.

7. Alves, D.S. Distribuição Espacial do Desflorestamento na Amazônia Legal. Análise dos dados do projeto PRODES do período 1991-1995, relatório preparado para a Secretária de Coordenação da Amazônia do Ministério do Meio Ambiente, São José dos Campos, Junho de 2000.

8. Barbieri, A.F. Uso antrópico da terra e malária no Norte de Mato Grosso, 1992 a 1995. Belo Horizonte: Cedeplar/UFMG, 2000. (Dissertação de Mestrado)

9. Carvalho, M. S. Aplicação de Métodos de Análise Espacial na Caracterização de Áreas de Risco à Saúde. Tese de Doutorado em Engenharia Biomédica, COPPE/UFRJ, 1997.

10. Moraes, A.C.R. Meio Ambiente e Ciências Humanas. Editora Hucitec. Niterói. 2007.

11. Santos, M. Por Uma Geografia Nova. São Paulo: Hucitec, 1978.

12. Santos, M. Espaço e Método. 4. ed. São Paulo: Nobel, 1997.

13. Santos, M. O Retorno do Território. In: SANTOS, Milton et al. (Org.). Território: Globalização e Fragmentação. 4. ed. São Paulo: Hucitec: Anpur, 1998. p. 15-20.

14. Santos, M. Saúde e ambiente no processo de desenvolvimento. Ciência e Saúde Coletiva, Rio de Janeiro, n. 1, v. 8, p. 309- 314, 2003.

15. Santos, M. A Natureza do Espaço: técnica, razão e emoção. 4. ed. São Paulo: Editora da Universidade de São Paulo, 2004.

16. Grip, A.H. Utilização de geoestatística para tratamento de dados de prospecção geoquímica. Revista Brasileira de Geociências, São Paulo, v.22, n.2, p. 248 – 251, 1992.

17. Landim, P.M.B. Análise Estatística de Dados Geológicos. 2. ed. São Paulo: Unesp, 2003.

18. Guerra, P.A.G. Geoestatística operacional. Brasília: Departamento Nacional de Produção Mineral. 145 p.1988.

19. Landim, P.M.B. Análise estatística de dados geológicos. São Paulo: Editora da UNESP. 1998.

20. Huijbregts, C.J. (1975) - Regionalized variables and quantitative analysis of spatial data. In: DAVIS, J.C. & MC CULLAGH, M.J. (ed.) Display and analysis of spatial data. John Wiley, p.38 - 53.

21. Isaaks, E.H. & Srivastava, R.M. (1989) – An Introduction to Applied Geostatistics: Oxford University Press, 561 p

22. Camargo, L.A.; Marques J.R.J.; Pereira, G.T. & Horvat, R.A. Variabilidade espacial de atributos mineralógicos de um Latossolo sob diferentes formas do relevo. I - Mineralogia da fração argila. R. Bras. Ci. Solo, 32:2269- 2277, 2008.

23. Landim, P. M. B.; Sturaro, J. R. Krigagem Indicativa Aplicada à Elaboração de Mapas Probabilísticos de Riscos. DGA, IGCE, UNESP/Rio Claro, Lab. Geomatemática, Texto Didático 06, 2002. 19 p. Disponível em http://www.rc.unesp.br/igce/aplicada/textodi.html. Acesso em: 10 set. 2019.

24. Fuks, S.D. 1998. Novos modelos para mapas derivados de informações de solos. In: ASSAD, E.D; SANO, E.E(Ed.) Sistemas de Informações Geográficas. 2. ed. Brasília: Serviço de Produção de Informação / Embrapa, cap. 19,p. 373-410.

25. Fuks, S.D.; Carvalho, M.S.; Câmara, G;. Monteiro, A.M.V. (ed.) Análise Espacial de Dados Geográficos. cap. 3, p.1-28, 2001.

26. Felgueiras, C.A.; Fuks, S. D.; Monteiro, A M. V.; Camargo, E.C.G. Inferências e estimativas de incertezas utilizando técnicas de krigagem não linear. 1999. Disponível em: <http://www.dpi.inpe.br/geopro/trabalhos/gisbrasil99/incertez as/2006>. Acesso em: 18 abr. 2019.

27. Felgueiras C.A. Modelagem Ambiental com Tratamento de Incertezas em Sistemas de Informação Geográfica: O Paradigma Geoestatístico por Indicação. Tese (Doutorado em Computação Aplicada) – Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Disponível em: em 2019.

28. Arango, H.G. (2001) Bioestatística: Teórica e Computacional. Rio de Janeiro: Guanabara Koogan.

29. Silveira Júnior, P.; Machado, A.A.; Zonta, E.P.; Silva, J. B. Curso de Estatística. v.1, Pelotas: Universidade Federal de Pelotas, 1989, 135p.

30. Triola, M.F. (1998) Introdução à Estatística. 7a ed. Rio de Janeiro: LTC.