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Risk Areas for the Insertion of Infectious Agents The Implementation of Geoprocessing in Epidemiology

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Abstract— The current study aimed at determining risk areas for the insertion of infectious agents by means of geoprocessing techniques. The study was conducted in the cities of Paço do Lumiar, Raposa, São José de Ribamar and São Luís, which are part of the Microregion of Urban Agglomeration in the State of Maranhão. In order to determine these risk areas, a geographic database was developed from the collection, storage and processing of data, using alphanumeric data (information from the questionnaire and data obtained from the State protection agency) and geographic data (georeferenced maps obtained from the protection agency and field research data from a GPS device). With this work, it was possible to identify and map risk areas by the determination of 35 points and 181 livestock properties at higher epidemiological risk. The identification, rating and mapping of these areas will help implementing a more efficient epidemiological surveillance system and show the importance of using geoprocessing in epidemiology.

Index Terms— Epidemiological Surveillance, Geotechnologies Infirmities, Maranhão.

I. Introduction

Diseases of Compulsory Notification (DCN) represent a group of diseases of health relevance to animal health and they are rated based on socioeconomic significance and public health significance. After several revisions, the World Organization for Animal Health [1] has included 119 infirmities on the DCN list. In this category, there are infectious and parasitic diseases, which affect several animal species. The emergence of diseases among livestock causes economic losses and serious social issues. The affected countries suffer heavy losses due to the decrease and devaluation of animal-origin products and by limitations imposed by international markets, thus hindering the development of such countries [2]. The concern with the emergence of "new" infectious diseases, the re-emergence of other diseases and the bioterrorism may compromise the livestock production system and jeopardize public health. This fact has caused the need for reviewing and updating the ruling epidemiological protection and surveillance systems, and for making investments for the implementation of national and state health programs and those for animal inspection [3].

Veterinary epidemiological surveillance is understood a group of elements and activities employed with four objectives: (i) preventing the insertion of infection and contamination sources, (ii) detecting these sources when they settle in a territory, (iii) immediately notifying their location to the official veterinary authorities and, (iv) coordinating the immediate reaction leading to the total eradication of a threat to livestock or to the control of outbreaks and, the restoration of the free status of the affected zones or compartments, depending on the involved species and production system [4].

As for the monitoring and evaluation activities in epidemiological surveillance, it is important to define and identify areas for the insertion of infectious agents [2,5]. With respect to animal health, the risk areas may be defined by the identification of places (points) and livestock properties at higher epidemiological risk. The places and surrounding areas in which susceptible animals are at higher risk of having contact with other animals or animal-origin products that may carry pathogenic microorganisms are considered risk points for the insertion of infectious agents. And, the livestock properties at higher epidemiological risk are rural properties located in the surroundings of the risk points (radius of 3 km) [4,6]. The identification of risk areas and their conditioning factors is essential to an efficient control of the manifestation of diseases and to the planning of inspection activities [5]. The model and method for the veterinary epidemiological assessment and monitoring currently in use do not allow the spatial location of the occurrence of the disease or a quick prognosis indicating the risk areas or areas of greater intervention urgency [7].

Nowadays, Geotechnologies are powerful tools for supporting the decision in the spatial distribution of health technologies. The geoprocessing applied to public health issues allows mapping the diseases and evaluating the risk areas [8,9]. In this context, the current study aimed at determining risk areas for the insertion of infectious agents by means of geoprocessing techniques.

II. MATERIAL AND METHODS

A. Study Area

The study area included the Island of São Luís – MA, which is formed by the cities of Paço do Lumiar (Area= 124,753 Km^2; Location: 44.1°S e 2.53ºW), Raposa (Area= 64,353 km^2; Location: 44.1°S e 2.42°W), São José de Ribamar (Area= 388,369 km^2; Location: 44.05°S e 2.56°W) and São Luís (Area= 834,780 km^2;

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Location: 44.3°S e 2.52°W), thus totaling 1.412.255 km^2 of the studied area [10]. The four cities hold together an approximate population of 7.168.146 inhabitants and they represent the metropolitan region of the State where the highest level of socioeconomic development can be seen. The economy is based on service provision, industrial and agricultural activities, and there is the predominance of the dynamic and expansive dairy farming and the semi-intensive livestock of beef cattle, concentrated in small and medium producers with approximately 345 rural properties [6, 10].

The delimitation of the study area was performed by means of intentional non-probabilistic sampling. The choice of the location as a research sample due to existing epidemiological conditions that can enable the insertion of infectious agents.

B. Risk Areas

The determination of risk areas followed the procedures referred by the Standardized Operating Procedures (SOP) of the State Agency for Agricultural Protection of Maranhão - AGED [6].

The following variables were considered as risk points for each city: the presence of slaughterhouses, dairies, cheese factories, dumps and landfills, salting places, tanneries, venues with agglomerations of animals, drover roads, airports, bus stations, train stations and, pontoons and vessels.

As for the identification of livestock properties at higher epidemiological risk, the study took under consideration their proximity to the identified risk points (radius of 3Km) besides the existence of the following variables: places on the margins of drover roads, intense traffic of animals susceptible to infectious and contagious diseases, places that lend facilities, participate in collective vaccinations, offer ranch, rent pastures, located at the border with other States, with livestock properties within rural settlements, indigenous tribes or any other situation in which the livestock production system needs special veterinary attention.

The evaluation of risk points and risk properties was characterized by the data collection from the State protection agency (AGED) and by the application of a questionnaire to rural producers. As for the rating of risk points, a *Check List*-type questionnaire was used (Appendix 1) and the variables were analyzed through questions, considering the following aspects: (i) only one answer was considered for each question; (ii) a predetermined value was assigned to each answer (1 to 3); (iii) the questions were grouped according to the risk of vulnerability (subtotal X) and receptivity (subtotal Y), with percentage weights of importance for the (re)insertion and dissemination of infectious agents between 60% and 40%, respectively; (iv) after all the questions were answered, the values assigned to the answers were summed in order to obtain the subtotals (X and Y); (v) the subtotals were used to perform the calculation of the Risk Index (RI),using the following mathematical formula:

$$IR = \frac{0.6 \text{ x Subtotal X}}{\text{Number of analyzed variables}} + \frac{0.4 \text{ x Subtotal Y}}{\text{Number of analyzed variables}}$$

At the end of the evaluation and calculation of RI, a rating was given to each potential risk point, namely, High risk ($3.00 \leq RI \geq 2.41$), Medium risk ($2.40 \leq RI \geq 1.61$) and Low risk ($1.60 \leq RI \geq 1.00$).

C. Geographic Database

A geographic database was developed from the collection (GPS5 Device model Garmin® and Trex Vista HCx), storage and processing of data (GPS TrackMaker® v. 13.0) in order to prepare the current descriptive study. The following data were analyzed to create the geographic database:

- Alphanumeric data: the data in paper corresponding to the surveys performed in the points and properties of the study area and the data obtained from AGED-MA;
- Geographic data:

a) Georeferenced maps obtained from AGED [11]. This database, besides presenting registered rural properties, counted on information about the capillarity of the services offered by this agency, effective cattle herd, surveillance index in the properties and cities that were used to relate the evaluated points to the geographic location.

b) Field research data from a GPS device to check whether the geographic data from the obtained maps were compatible with the reality and, to georeference the points and properties, i.e., to correctly situate each address in a point.

III. RESULTS

Table 1 shows 35 risk points identified for the insertion of infectious agents and their rating per studied city. Of the identified risk points, 51.43% (n=18) were rated as of low risk, 25.71% (n=9) as medium risk and 22.86% (n=8) as high risk.

Table 1: Identification and rating of risk points for the insertion of infectious agents in the cities of Paço do Lumiar, São José de Ribamar and São Luiz, Maranhão, Brazil

Cities	Risk point	Quantity	Risk Rating
Paço do Lumiar	Agglomerations/Park	1	Low
	Airport	1	Low
	Meat and Bone meal factory	1	High
	Dairies	1	Low
	Dump/ Landfills	1	Medium
Raposa	Agglomerations	1	Low
	Drover Roads	1	Medium
	Ports	1	Low
São José de Ribamar	Agglomerations	3	Low
	Dairies	1	Low
	Dumps/ Landfills	1	Medium
São Luiz	Airports	1	Low
	Agglomerations	4	Low
	Drover Roads	2	Medium
	Dumps/ Landfills	2	Medium
	Slaughterhouses	4	High
	Ports/Pontoons/Vessels	4	Low
	Train stations	1	Medium
	Bus stations	1	Medium
	Salting places	3	High

It was possible to identify 181 properties at higher epidemiological risk in the study area. This percentage represents 52.46% (181/345) of the total properties in the region.

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One possible use of geoprocessing, in the current study, concerned the identification of areas of epidemiological risk, represented by the spatial distribution of risk points and risk properties (Fig. 1, 2, 3, e 4).

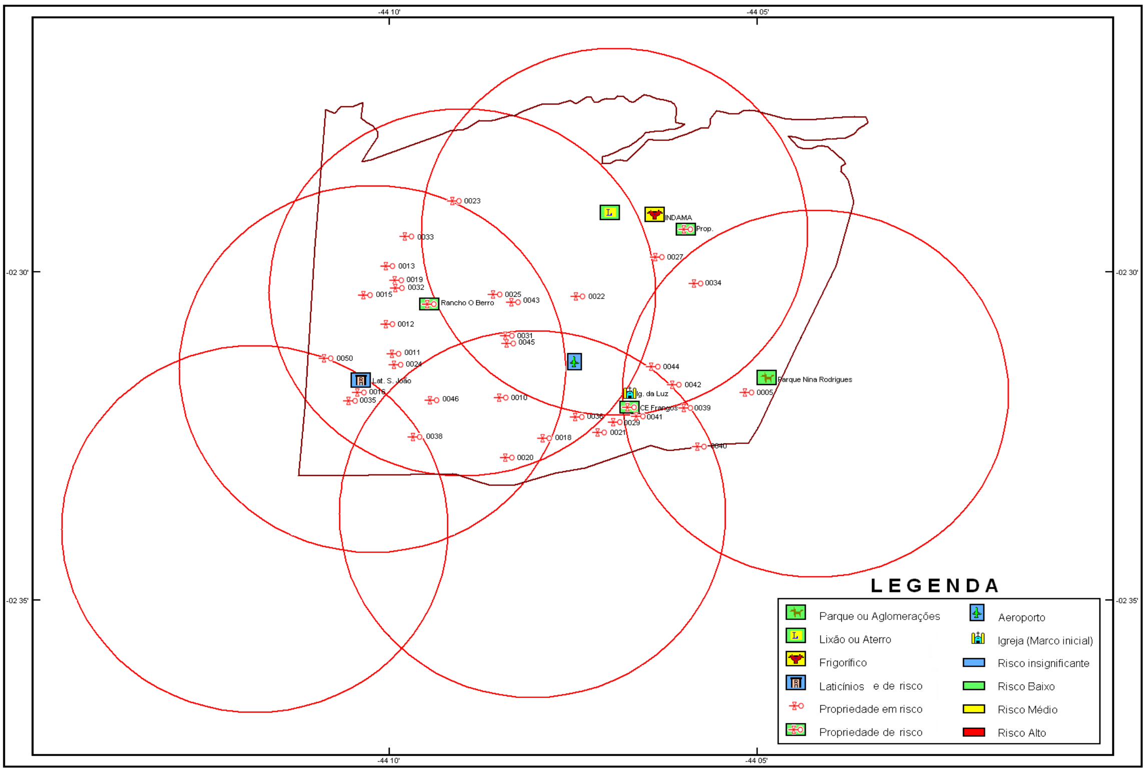

Fig. 1: Areas of epidemiological risk for the insertion of infectious agents in the city of Paço do Lumiar - MA, Brazil.

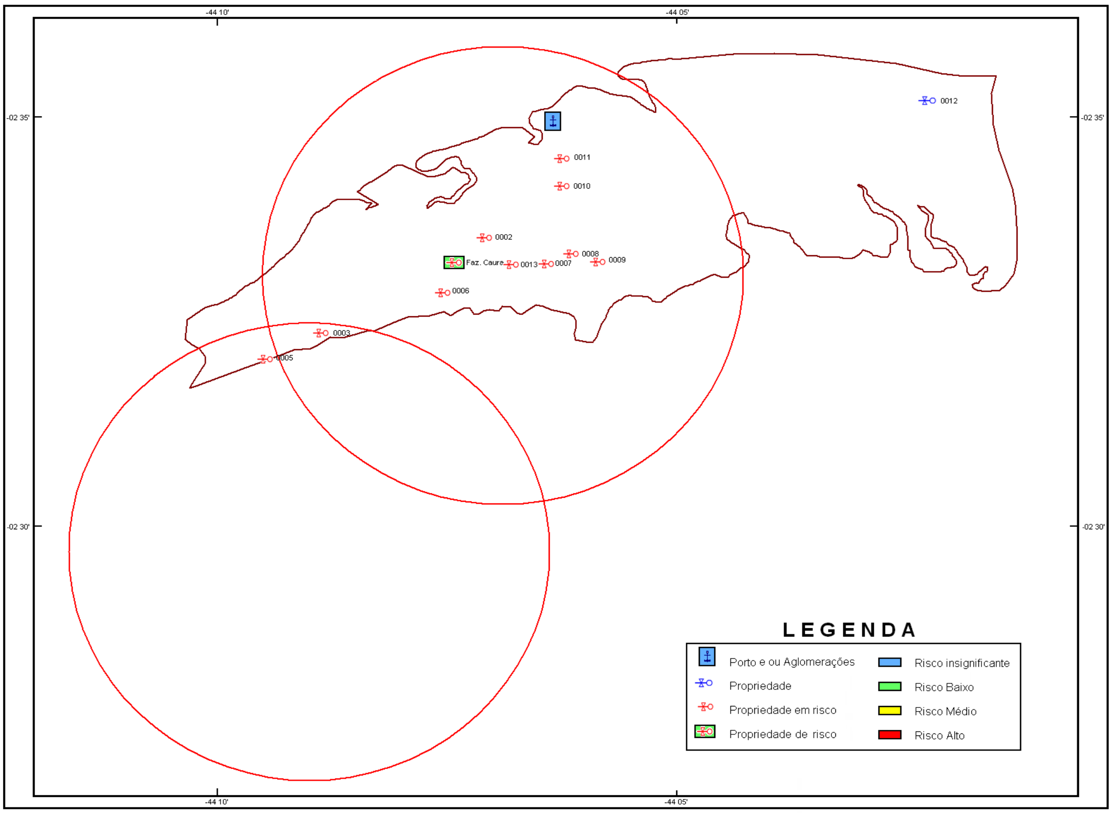

Fig. 2: Areas of epidemiological risk for the insertion of infectious agents in the city of Raposa - MA, Brazil, 2012.

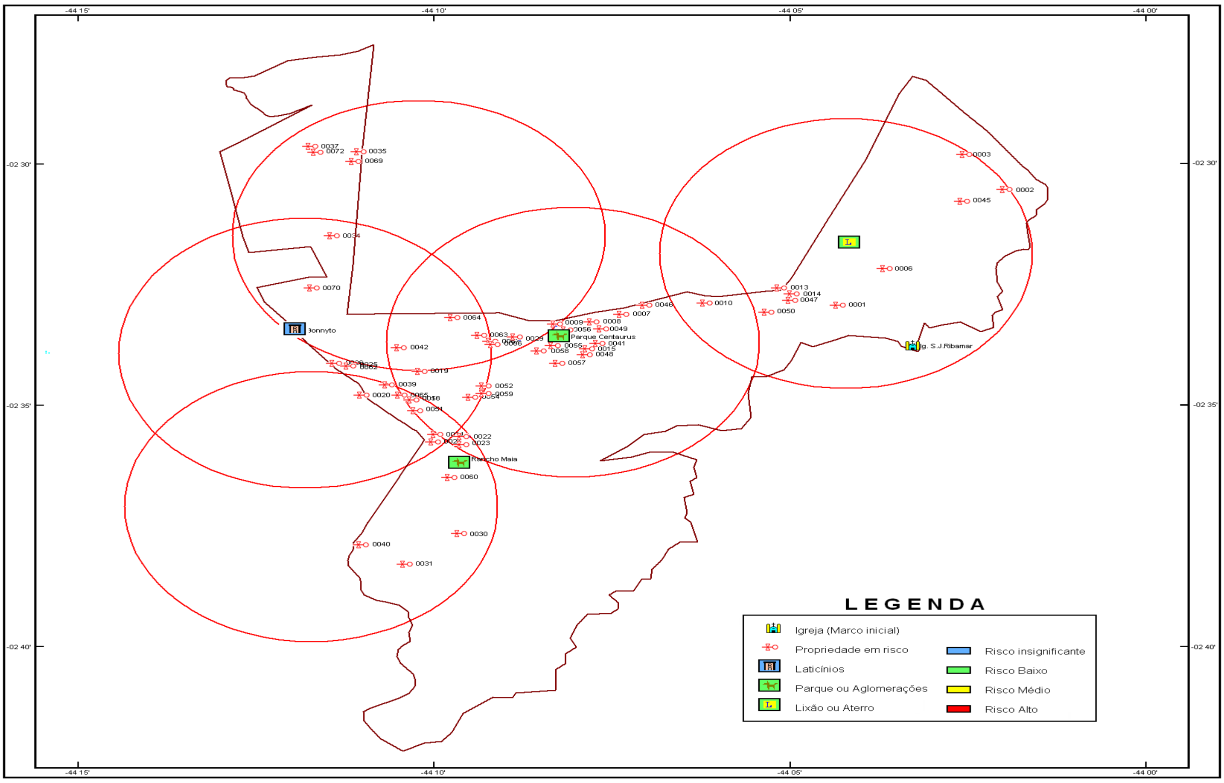

Fig. 3: Areas of epidemiological risk for the insertion of infectious agents in the city of São José de Ribamar - MA, Brazil, 2012.

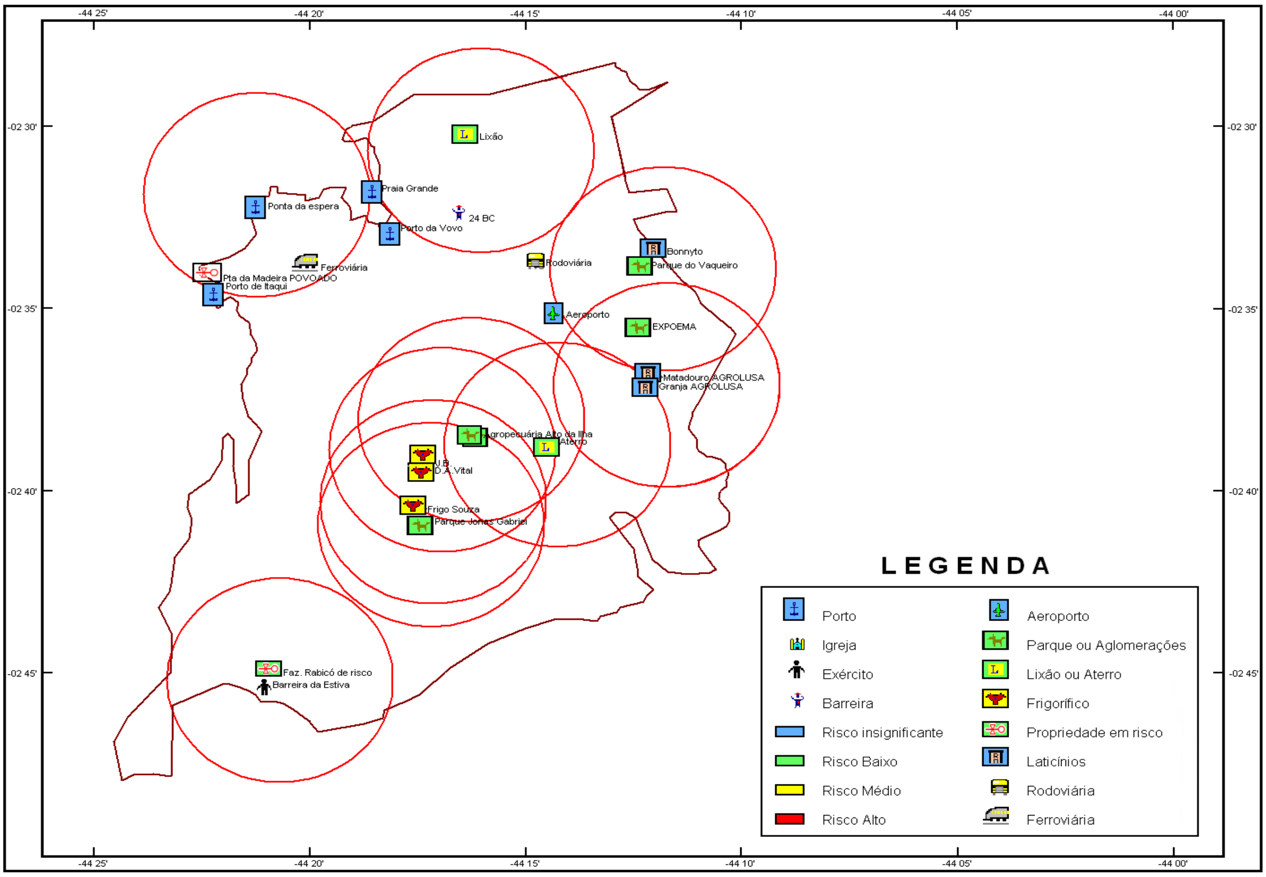

Fig. 4: Areas of epidemiological risk for the insertion of infectious agents in the city of São Luiz - MA, Brazil.

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IV. DISCUSSION

All risk points identified in the study present epidemiological importance, regardless of rating, because it is not static and may change over time. According to the Ministry of Agriculture, Livestock, and Supply - MAPA [4], monthly inspections should be performed in the risk points rated as high, medium and low risk with a minimum of three, two and one time, respectively, according to the risk rating.

The Itaqui port is located in the study area and it is internationally known for having the largest tidal ranges, excellent navigability due to the natural depth of access (27 meters), as well as the width of its channel. The studied location has the largest airport of the State and operates regional, national and international flights. It also holds the largest bus and train stations of the State. The rating of these points range from low (port, airport) to medium risk (bus and train stations). In these locations, despite the heavy traffic of people, there is a small traffic of animals and products of animal and vegetal origin (semen, food etc.). These aspects have influenced the rating.

In the city of São Luís - MA, four slaughterhouses slaughter animals coming from all Maranhão State as well as from other States. Together, these establishments account for most of the meat sold in the region. The high-risk rating of these establishments occurred due to the following reasons: (i) proximity with rural properties containing animals susceptible to infectious diseases; (ii) for receiving animals for slaughter from regions rated as having a high epidemiological risk equivalent or lower than that of Maranhão (free from FMD with vaccinations in 2014), with vaccination against FMD > 80% and ≤ 90%, and without registration of other infectious infirmities; (iii) they slaughter cattle or pigs and, eventually small ruminants, although they do not have a slaughter line for the last two species; (iv) absence of a rendering plant; (v) inadequate cleaning of facilities; (vi) little restriction of the traffic of animals and people in the establishment area and (vii) little recording and reporting of infirmities observed in the *ante-* and *post-mortem* inspections. Slaughterhouses were not identified in the other cities of the study.

In this location, there is one meat and bone meal factory, which receives slaughter wastes from four slaughterhouses and three salting places. Deficiency in receiving and processing this material, as well as the proximity to rural properties resulted in a high-risk rating of the meat and bone meal factory. The variables that guided the rating of salting places as of high risk were the inadequate conditions of leather treatment, leakage and wrong disposal of waste as well as the presence of animals and people in such places.

Dairy products under municipal and state inspection were also observed in the study area, with internal and intra-municipal marketing, and all had low-risk rating.

The study area still presents the biggest animal exhibition State park that stands out in the national scenario, and in which animals from different States participate in the exhibitions. Other places of animal agglomerations were also identified, although smaller; these places were rated as of low risk. The variables that have influenced this rating were: (i) holding the event in predetermined periods; (ii) little or no proximity with properties containing animals susceptible to infectious diseases; (iii) animals coming from regions rated as having an epidemiological risk higher or equivalent to that of Maranhão; (iv) presence of monitoring by the State protection agency; (v) presence of the technician responsible for the event.

There were five dumps and four drover roads in the studied location, all rated as of medium risk. As for the dumps, the presence of animals and people, the existence of animal slaughter waste, leachate leakage, proximity to rural properties and ineffective waste treatment have determined the rating. On the other hand, as for the drover roads, the medium-risk rating was determined due to the heavy flow of animals, the existence of other risk points and rural properties in their path, in addition to the flow of walking animals.

In epidemiology, the identification of points of insertion of infectious agents, such as ports, airports, exhibition parks, among others that are considered areas of agglomerations of people and animals, is important for the implementation of inspection actions [4,6].

The increasing demand for animal-origin food, due to the increment of livestock industries, and the habit of keeping wild animals at home constitute a factor that increases the chances of occurrence of zoonotic diseases. On the other hand, the bus, train, sea, and air means of transportation favor the dissemination of pathogens by the accidental conduction of vertebrates (reservoirs) or invertebrates (vectors) from an enzootic region to a harmless one. Similarly, the marketing (import or export) or displacement of animals to fairs or exhibitions raise the probability of transmitting these agents [12].

Regarding the properties at higher epidemiological risk identified in the study, the monitoring should be more intensive, since they are more prone to the insertion of infectious agents that can compromise the success of any animal defense system and negatively affect the animals' health status.

The presence of infectious agents may be higher and more frequent in the risk areas identified in the study. Thus, identifying these areas is essential when considering the need for surveillance in the face of health emergencies, because knowing the geographic pattern of the diseases can provide information about the etiology and pathophysiology of certain morbid events, and many diseases have a well-defined geographic pattern.

The analysis of the spatial distribution of diseases is interesting to epidemiology for a long time. With the advances of computational techniques and new methodologies developed to this end, geoprocessing has become an important epidemiological research tool [13].

The tools for manipulating geographic data are of great importance in supporting veterinary emergency activities. The State veterinary services should invest on the training of their employees and on the acquisition of specialized programs in Geographic Information Systems (GIS). All veterinary units should have maps of the geographic area of work printed in appropriate scales, including information on geopolitical boundaries, roads, river systems, location of the rural properties, towns, villages, indigenous tribes, rural settlements, protected areas or areas under environmental protection, forest reserves, among other elements relevant to health intervention activities [14].

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V. CONCLUSION

Based on the results obtained in the current study, it can be concluded that:

1. The geoprocessing techniques herein used were important tools for the identification of risk areas in the studied area;
2. The current study contributes to the animal protection service by spatially determining risk areas for the implementation of infectious agents, thus allowing faster and more efficient health interventions.

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