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Spatial analysis on the risk of bovine cysticercosis occurrence in the state of Espírito Santo, Brazil

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ABSTRACT

A map of the risk of bovine cysticercosis occurrence was developed for the state of Espírito Santo, Brazil, and it was based in a mathematic model based on following variables: inadequate sewage, bovine population by county, use and occupation of the land and flood risks in GIS environ by means of the ArcGIS/ArcINFO 10.1 program. The work aims to spatially analyze the risk of bovine cysticercosis occurrence in the state of Espírito Santo, by means of risk factors related to cysticercosis and compare with the prevalence obtained from slaughterhouses in the same area. The map of risk showed areas high risk and very high risk located mainly in Ecoporanga, Linhares, counties, where the prevalence from slaughterhouses are low, and in two counties of south macro-region, Presidente Kennedy and Itapemirim, where prevalence from slaughterhouses are higher.

1. Introduction

Bovine cysticercosis is a zoonotic parasite caused by the larval stage of the *Taenia saginata*. It is found in areas holding poor sewage structures and population with low sanitation conscience. Pasture contamination is direct or indirectly caused by humans who eliminate proglottids with eggs in their feces, favoring the occurrence of such parasite (Abunna et al., 2008; Asaava et al., 2009; Nieto et al., 2012) as well as by the free access cattle have to contaminated surface water (rivers, lakes, canals) and flooded pastures (Boone et al., 2007; Allepuz et al., 2009).

Environmental data were incorporated to the geographic information system (GISs) and can be used by healthcare programs, including those regarding bovine cysticercosis (Dutra et al., 2012)(Dutra et al., 2012). Recently, some authors used GISs in their cysticercosis studies throughout the world, Allepuz et al. (2009) in Catalunha, Spain and Boone et al. (2007) in Belgium. In Brazil, Bavia et al. (2012), mapped the distribution of clusters of risk of bovine cysticercosis in Bahia. Dutra et al. (2012) and Guimarães-Peixoto et al. (2012) had mapped the distribution of the parasite, being the first in Brazil and the second one in the state of Paraná. In the state of Espírito Santo, Nieto et al. (2012), had mapped the distribution of the parasite in Colatina County, in the north of the state.

All these studies had mapped the distribution of cysticercosis, however, areas holding higher concentration of cases do not represent the higher risks areas, showing the need of renewing the approaches used to study the parasite (Bavia et al., 2012).

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The use of a tool enables the development of a transparent, repeatable and flexible decision process, which can be useful in certain animal health response situations including the increased prevalence of bovine cysticercosis. Thus, the current work aims to spatially analyze the risk of bovine cysticercosis occurrence in the state of Espírito Santo, by means of risk factors related to cysticercosis.

2. Materials and methods

2.1. Characterizing the studied area

The state of Espírito Santo has 78 counties and along with the states of Minas Gerais, Rio de Janeiro and São Paulo form the Southeast Region of Brazil. It is located between parallels 17°53′29″ to 21°18′03″ south latitude and the meridians 39°41′18″ to 41°52′45″ longitude west of Greenwich (Toledo et al., 2009).

2.2. The determining factors to the occurrence of bovine cysticercosis in the state of Espírito Santo

Literature available in scientific articles was firstly consulted in specialized electronic indexers, in order to elaborate the bovine cysticercosis occurrence risk map for the 78 counties in the state of Espírito Santo. Based on such index, all the variables involved with the development of the *T. saginata* cycle were selected in accordance to bovine contamination with *Cysticercus bovis* (Abunna et al., 2008; Asaava et al., 2009; Boone et al., 2007; Allepuz et al., 2009; Bavia et al., 2012; Guimarães-Peixoto et al., 2012; European Food Safety Authority (EFSA), 2004; Dorny and Praet, 2007; Calvo-Artavia et al., 2013a).

The data base was set in *Microsoft Excel* (2010) and the selected variables were: inadequate sewerage, bovine population per county, use and occupation of land and flood risk.

2.3. Inadequate sewerage and Bovine population per county

The assemblage of the themed map "inadequate sewerage" (IS) was done based on population data provided by "Instituto Brasileiro de Geografia e Estatística — IBGE (Brazilian Institute of Geography and Statistics)". They came from universe results regarding population features and domains of the 2010 Census.

It was used a description provided by IBGE about the kind of inadequate sewerage per house in order to characterize IS, featuring houses that have rudimentary cesspools or those in which toilets were directly linked to rivers/lakes, to the sea or to a ditch as holding inadequate sewerage. Houses in which the toilet did not meet any of the descriptions proposed by IBGE or that had no bathroom or toilet were also included.

It was used data referring to the bovine population in the state of Espírito Santo in order to assemble the themed map "bovine population per county" (BPC). They were also provided by IBGE and came from the County Livestock Production, Livestock Census 2011.

Thus, the Excel table grades — provided by IBGE — were combined in order to create an IS themed map. IS and BPC data were imported to and analyzed in *ArcGIS/ArcINFO* 10.1 software, and were added to the mesh of census, which generated an IS map in a vector format.

2.4. Flood risk and use and occupation of land

The map of use and occupation of land (UOL) is available at the "Sistema Integrado de Bases Geoespaciais do Estado do Espírito Santo (GEOBAES). Aiming to generate a Flood risk map (FR) for the state of Espírito Santo, the following variables were used: steepness, altitude and use and occupation of land. The maps were re-categorized and the classes classified as less important were: steepness from 0 to 3%, altitude from 0 to 83 m and use of land in mangrove areas, oceans, rivers and flooded areas.

After setting the statistical weights, it was used the function "*raster calculation*" in order to generate the statistical model "Flood risk" represented by:

$$FR = a1 * DEC + a2 * MDE + a3 * UOL \quad (1)$$

where FR = Flood risk; DEC = slope; MDE: MDE (altitude); UOL: Use and occupation of land; a1, a2, and a3: constants of model.

Right after data standardization and filtration, the standards were: (R1) for low risk, (R2) for medium risk, (R3) for high risk and (R4) for very high risk.

2.5. Statistical analysis and the generation of cartographic data

The conversion function in raster format was applied to IS, BPC and UOL vector images. After such stage, it was applied the spatial re-categorization function, dividing IS and BPC variables into ten statistically equal classes that gain weight from 1 to 10 according to the importance of the classes to the occurrence of the disease. FR and UOL variables were re-categorized in classes, based in weights from 0 to 10, according to their importance to the occurrence of the disease.

The AHP method suggested by Saaty (1977) was used to represent the risk conditions in a realistic way. The decision matrix was applied and the Saaty fundamental scale was also used. The matrix elaboration method used a comparison scale which has

linearly defined the hierarchy of importance among factors previously defined. It was done by getting to the acceptable reason of consistency of 0.0334.

It was used the "raster calculator" function in order to generate the statistical model after setting the statistical weight to each polygonal vector class. The Bovine Cysticercosis occurrence risk (BCOR) is represented by:

$$BCOR = a1 * IS + a2 * BPC + a3 * UOL + a4 * FR \quad (2)$$

where BCOR: Bovine cysticercosis occurrence risk; IS: inadequate sewerage; BPC bovine population per county; UOL: use and occupation of land; FR: flood risk; a1, a2, a2, and a4: constants of model.

Right after data standardization and filtration, low, medium, high risk and very high risk standards were obtained as shown in the methodological flowchart represented in Fig. 1.

2.6. Prevalence data

Prevalence data of bovine cysticercosis were obtained from the Serviço de Inspeção Federal (SIF) and Estadual (SIE) of the state of Espírito Santo in the period 2009–2012 and compared separating the average prevalences by region of location of state slaughterhouses.

3. Results

The themed map resulting from the selected risk variables is found in Fig. 2 and Table 1 shows the prevalence data of bovine cysticercosis in the state of Espírito Santo in the period 2009–2012. Bovine cysticercosis occurrence risk in the state of Espírito Santo was generated (Fig. 3) as a result of the mathematical model. According to the proportion of land in the state of Espírito Santo, more than half of the analyzed territory (55.6%) is located in medium risk areas. High and very high risk do not reach 12% of the total studied area.

The percentage of counties, among the 78 analyzed ones, presents high and very high, medium and low risk areas in more than 50% of their territory, representing 1.28% (1 county), 57.69% (45) and 41.03% (32) respectively.

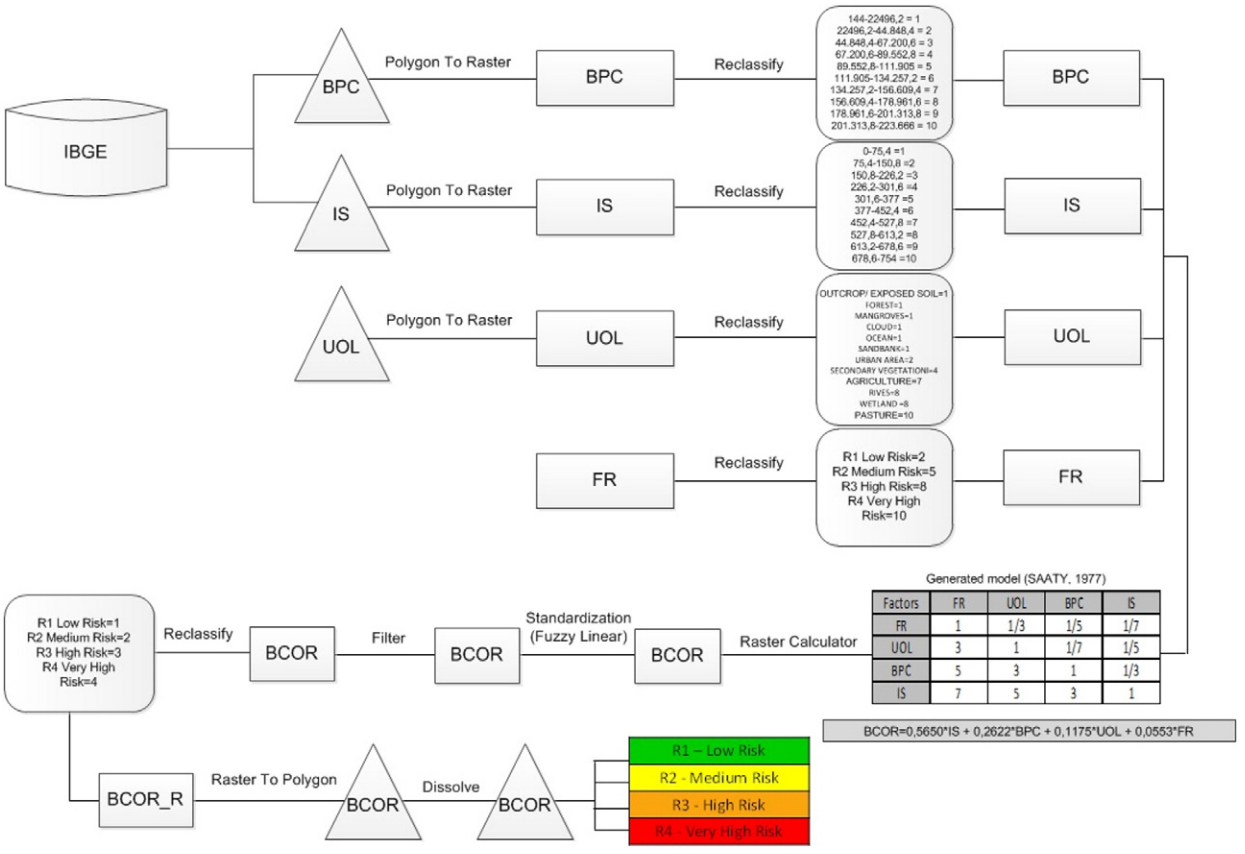

Fig. 1. Flowchart statement on the steps taken to generate maps of bovine cysticercosis occurrence risk in the state of Espírito Santo.

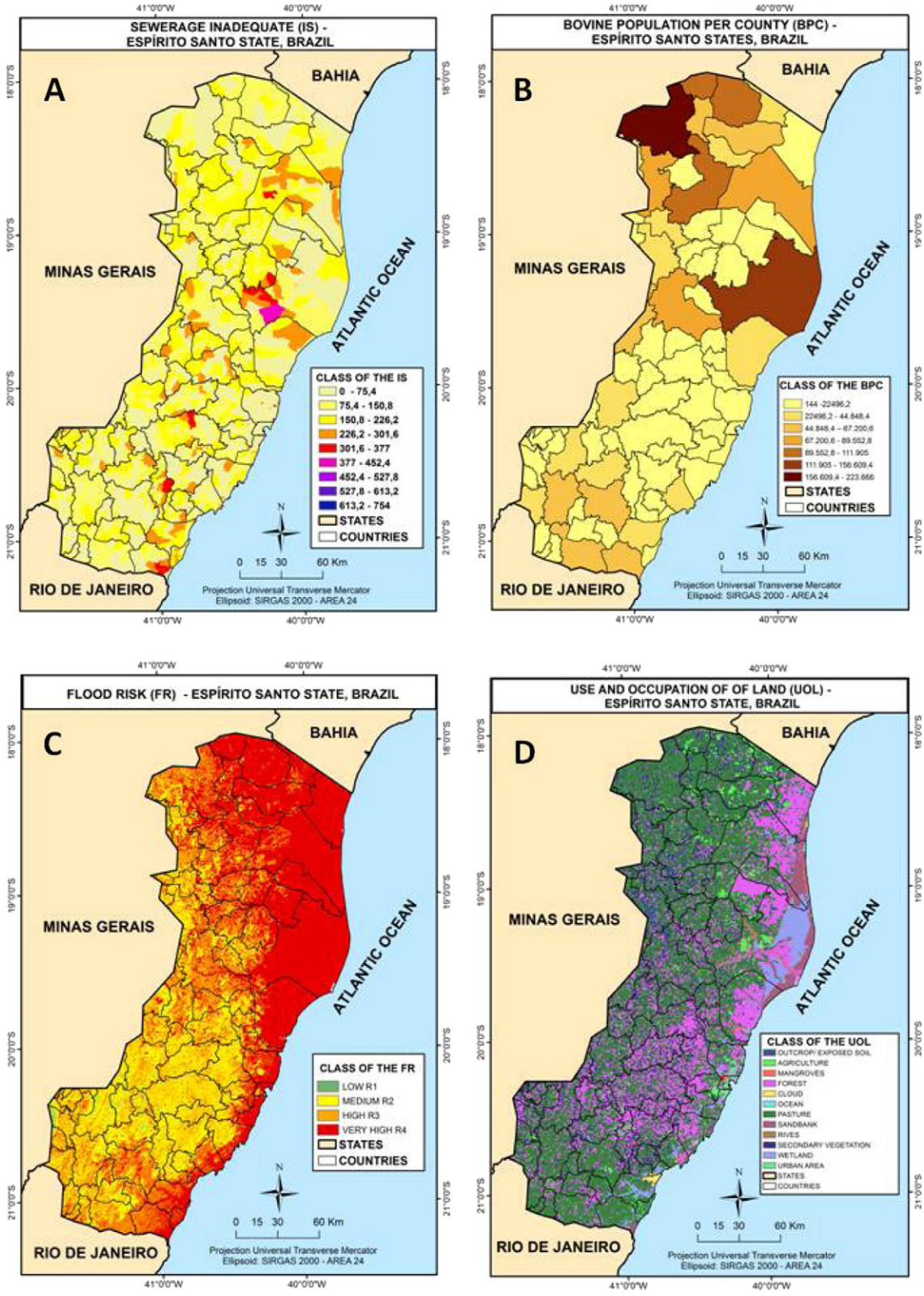

Fig. 2. Maps used in assembling the database. A: Inadequate sewerage; B: bovine population per county; C: flood risk; D: use and occupation of land.

Among the studied counties it is possible highlighting: Linhares and Ecoporanga. They hold respectively 6.59% and 1.21% of areas with very high risk. Ecoporanga is the county presenting higher percentage of high and very high risk in its territory, once they represent 90.1% of it.

Regarding the presence of high risk areas in the counties, 37 (47.44%) out of the 78 analyzed ones have some percentage in such category, but in the majority of them, such areas do not reach 1%. The counties of Ecopanga (88.89%), Linhares (37.24%), Nova Venécia (28.92%), Presidente Kennedy (26.17%), São Mateus (25.57%), Itapemirim (18.42%), Mucurici (16.10%), Colatina (12.65%), and Barra de São Francisco (10.55%) are those that present higher percentages of high risk areas.

Regarding areas presenting medium risk, 45 (57.69%) counties present more than 50% of the territory in such class. Among the 32 counties that present more than 50% of low risk areas, it is possible highlighting Vitória and Venda Nova do Imigrante. They have approximately 100% of their territories covered by low risk areas.

Bovine cysticercosis prevalence in the state of Espírito Santo is between 0 and 3.22% (Table 1). Ecoporanga and Linhares municipalities were with medium low prevalence of cysticercosis in the period 2009 to 2012, with rates of 0.23% in Linhares and 0.007% in the slaughterhouse located in Montanha, the closest to Ecoporanga. Atilio Vivacqua slaughterhouse, south of the state, showed the highest prevalence, with an average of prevalence of 3.22%. In one of the slaughterhouses located in Colatina, the prevalence was on average 0.86%, the second highest in the slaughterhouses of the state.

4. Discussion

Inadequate sewerage, bovine population per county, use and occupation of land and flood risk variables showed up as potential risk items to measure bovine cysticercosis occurrence.

Firstly, inadequate sewerages were selected due to regions presenting precarious sewage structure and low socio-economic and cultural level. As per many authors, pasture contamination by human excrement is one of the main factors linked to the transmission of *T. saginata* eggs (Abunna et al., 2008; Asaava et al., 2009; Boone et al., 2007; Allepuz et al., 2009; Bavia et al., 2012; Guimarães-Peixoto et al., 2012; European Food Safety Authority (EFSA), 2004; Dorny and Praet, 2007; Calvo-Artavia et al., 2013a).

Bovine population per county was used because cattle host *C. bovis* and also because some authors relate higher bovine populations to the high number of slaughtering with positive animals (Dutra et al., 2012; Bavia et al., 2012).

The use and occupation of land is justified by the importance of pastures as a risk factor to the cysticercosis context (Calvo-Artavia et al., 2013b). In Brazil, the majority of bovines are fatted with pasture in semi-extensive or extensive systems (Dutra et al., 2012) and there is a low prevalence of association to animals' feedlots (Allepuz et al., 2009).

Flood risks within properties are also described as important environmental risk factors regarding the detection of parasites in bovines (Boone et al., 2007), once *T. saginata* eggs can contaminate the water and the pasture of properties located by areas geographically exposed to floods, even if such properties have good water sources (European Food Safety Authority (EFSA), 2004).

By taking a close look over all the analyzed territory, it is possible stating that 55.61% of it stays on medium risk areas and 57.69% of all counties have more than 50% of their territories in such category. Thus, even in these areas, control actions and bovine cysticercosis prophylaxis must be adopted once such parasite is an important public health and economic interest issue (Boone et al., 2007)(Boone et al., 2007).

In the state of Espírito Santo, the percentage of houses with adequate sewerage system is higher in urban areas than it is in the rural ones, but such percentage has increased in the rural areas. It went from 0.6% in 2001 up to 5.4% in 2009 (Instituto Jones dos Santos Neves (IJSN), 2011). It is worth saying that such rural zone sewerage systems were inadequately set, once its proximity to

Table 1
Prevalence of bovine cysticercosis in Espírito Santo, Brazil from 2009 to 2012.

Region	County[a]	2009	2010	2011	2012	Average prevalence
North macro-region	Montanha	0.00	0.00	0.02	0.01	**0.01**
Central macro-region	Colatina[b]	0.19	0.18	0.00	2.67	**0.76**
	São Gabriel da Palha	0.58	0.26	0.20	0.00	**0.26**
	São Domingos do Norte	0.02	0.02	0.00	0.05	**0.02**
	Linhares	0.42	0.17	0.10	0.23	**0.23**
	Colatina[b]	0.05	0.00	0.00	0.35	**0.10**
	Colatina[b]	0.83	0.78	0.88	1.00	**0.86**
	Media	**0.35**	**0.24**	**0.20**	**0.72**	**0.37**
Metropolitan macro-region	Cariacica	0.83	0.78	0.88	1.00	**0.86**
South macro-region	Atilio Vivacqua	1.89	1.85	2.18	7.00	**3.23**
	Anchieta[c]	1.01	0.09	0.00	0.00	**0.28**
	Muniz Freire	0.15	0.15	0.10	0.11	**0.13**
	Anchieta[c]	0.69	0.69	0.41	0.03	**0.45**
	Cachoeiro de Itapemirim	—[d]	—[d]	—[d]	0.0741	**0007**
	Media	**0.75**	**0.55**	**0.54**	**1.44**	**1.02**

[a] County where the slaughterhouse is located.
[b] Three different slaughterhouses in the same county.
[c] Two different slaughterhouses in the same county.
[d] Closed slaughterhouse.

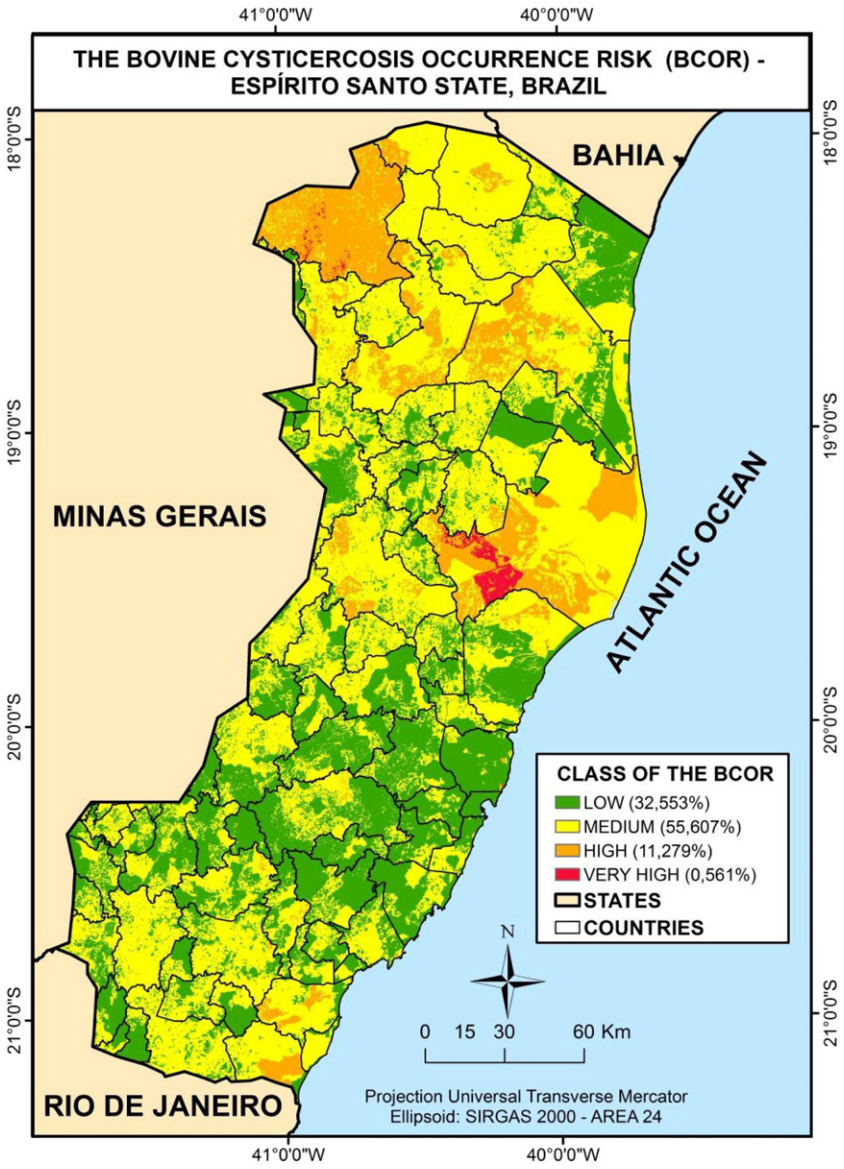

Fig. 3. The bovine cysticercosis occurrence risk (BCOR) in Espírito Santo State, Brazil.

pasture areas means a potential factor to the contamination of the cattle with cysticercosis (Asaava et al., 2009), because lack of adequate sewerage leads hygienic-sanitary features that favor the dissemination and the maintenance of taeniasis–cysticercosis complex life cycle.

The importance given to high and very high risk areas found in the state of Espírito Santo cannot be forgotten, although such areas represent less than 12% of the analyzed territory. This is because bovine cysticercosis is a zoonotic disease and the prevalence in the state of Espírito Santo is considered moderate to World Health Organization. Furthermore, Santos (1993) reports that the prevalence in the country is higher than the data published, confirming the low sensitivity of postmortem diagnosis.

The majority of the counties that have presented high percentages of high risk areas are located in the north of the state. In Ecoporanga and Linhares — north and central macro-region, respectively — low risk areas were found in less than 1% of the territory. Such counties are underlined by high and very high risk areas and are the ones that have larger bovine production as well as larger dairy production in the state, according to IBGE (Instituto Brasileiro de Geografia e Estatística (IBGE), 2011). The awareness of high dairy production in these two counties, along with the fact that they present higher percentages of high and very high risk areas call the attention to bovine meat and pinpoint the need for much more rigorous inspections in these areas than in another counties, once, according to Dorny et al. (2000), Dorny and Praet (2007) and Allepuz et al. (2009) the prevalence of bovine cysticercosis is higher in dairy cattle than it is in beef cattle, due to the time that it takes to slaughter dairy cattle. However, Ecoporanga and Linhares municipalities were with medium low prevalence of cysticercosis in the period 2009 to 2012.

Presidente Kennedy and Itapemirim counties, both located in the south of the state, present percentage indexes of 26.17% and 18.42% for high risk areas, respectively. Theses counties present large parts of their territories holding inadequate sewerage, flood risk and large pasture areas, showing that the association of factors led to high and very high risk areas. Normally, the animals from these counties are slaughtered in Atilio Vivacqua slaughterhouse, where the average of prevalence is 3.23% and that index reached 7% in 2012. In other counties in the same region to high and very high risk areas reach 3% of the territory.

Colatina county presented 12.65% of high risk areas. In a recent work performed by Nieto et al. (2012) in the micro-region of Colatina, 43.5% of properties were positive, highlighting that Colatina held 73.4% of all cysticercosis' cases. In one of the slaughterhouses located in Colatina, the prevalence was the second highest in the slaughterhouses of the state. According to the authors, in the other studied counties the number of cases was smaller as well as there was the prevalence of low and medium risk areas. Even though, no taeniasis host was found. It indicates that cysticercosis sources in these particular counties' properties can come from external sources such as rivers/brooks, people visitation or yet, from animals that are bought in other previously infected areas.

According to the visual comparison done with the map assembled by Dutra et al. (2012), the region that holds the larger areas of high and very high risk is the same one in which counties present larger numbers of bovine cysticercosis cases. Such information is based on data from slaughterhouses that undergo federal inspection. In this study the slaughterhouses inspected by the state and federal institution were divided into macro-regions, and Table 1 shows the prevalences in the counties where the slaughterhouses are located. Whereas the abattoirs slaughter animals from the municipality and neighbor counties, it can be inferred that in the north macro-region, where they are located area of high and very high favorability in Ecoporanga, the prevalence is lower (0.0073%) than in relation to the central macro-region (0.37%), which also features high and very high areas of favorability, such as Linhares. Already in the south macro-region, where the mean prevalence rates are higher, there is also high favorability area in some counties.

An inspection system based on bovine risks of hosting cysticercosis was suggested in Denmark by Calvo-Artavia et al. (Calvo-Artavia et al., 2013a; Calvo-Artavia et al., 2013b; Calvo-Artavia et al., 2013c). Animals considered as under high risk were the older and female ones as well as those that had access to contaminated pastures or water sources. But, the presence of only one of the factors was already seen as a risk to find animals with cysticercosis (Calvo-Artavia et al., 2013b).

Due to free trade and transportation of animals set by cattle ranchers, data provided by the slaughterhouses do not reflect the true origin of the animals. Besides, previously infected animals can be bought by ranchers (Nieto et al., 2012), what makes it difficult to be aware of the real origins of the animal and where it was infected.

Based on such context, strong actions must be taken throughout the inspection done over beef cattle that come from regions in the state that present high and very high risk — even in counties in which such areas do not reach 1% of the territory, once as per some authors, the prevalence of bovine cysticercosis can be underestimated by the inspection procedures in place nowadays (Eichenberger et al., 2011) and, so, stronger actions during inspections can positively influence the taeniasis–cysticercosis control in the region.

Besides, studies aiming to analyze the influence of environmental, economic, socio-cultural, and hygienic-sanitary factors from the animal exploitation system in the state and countywide help developing control and preventions actions, once there is a multiplicity of factors linked to the parasites' transmission chain (Bavia et al., 2012). And still, studies on the prevalence of taeniasis by *T. saginata* are essential, because bovine cysticercosis occurrence areas are an indication of human taeniasis, once animals get infected by the ingestion of *T. saginata* eggs from human feces (Ungar and Germano, 1992).

It is important to recognize that the decisions informal voting are most often used in responding to an emerging disease. One of the inherent advantages of the new approach is that a decision-supporting tool provides appropriate facilities for modeling, both for environmental and non-environmental factors that are involved in the epidemiology of the disease. In the case of cysticercosis, future model approach may indicate future prevalences of the disease, contributing to prophylactic point control measures.

5. Conclusion

The spatial analysis of bovine cysticercosis occurrence risk showed that there are many counties in the north and south of the state of Espírito Santo presenting high and very high risk areas due to the development of bovine cysticercosis.

In the north of the state of Espírito Santo the high and very high risk areas are larger.

The risk of bovine cysticercosis occurrence in Espírito Santo might help the development and management of taeniasis–cysticercosis complex control programs in a more effective way.

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