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Mapping of Bovine Tuberculosis in Colombia, 2001-2019

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Abstract: Introduction: Bovine tuberculosis is a zoonotic disease of considerable impact, especially in livestock countries, which can cause human disease. Despite its importance, Colombia is a country in which few studies analyse its behaviour, and none develop maps using geographic information systems to characterise it. **Objective:** To describe the temporal-spatial distribution of bovine tuberculosis in Colombia between 2001 and 2019. **Methods:** Retrospective cross-sectional descriptive study, based on reports by the Colombian Agricultural Institute, of tuberculosis surveillance in cattle on farms in Colombia from 2001 to 2019. The data were converted into databases in Microsoft Access 365®, and multiple epidemiological maps were generated with the Kosmo RC1®3.0 software coupled to shape files of all the country's departments. **Results:** During the study period, 5,273 tuberculosis cases in bovines were identified in the different departments of Colombia (mean 278 cases/year). Regarding its temporal distribution, the number of cases varied from a maximum of 903 cases (17.12% of the total) in 2015 to a minimum of 0 between 2001 and 2004 and between 2017 and 2019 (between 2005 and 2016, the minimum was 46 cases, 0.87%). **Conclusions:** GIS is an essential tool for understanding the temporospatial behaviour of zoonotic diseases in Colombia, as is the case of bovine tuberculosis, with its potential implications for Human and One Health.

Keywords: tuberculosis; infection; cattle; GIS; geographic information systems; *Mycobacterium bovis*; One Health

1. Introduction

Bovine tuberculosis is caused by *Mycobacterium bovis*, a species that belongs to the Mycobacteriaceae family, and the *Mycobacterium tuberculosis* complex [1,2]. These bacteria are characterised by being acid-resistant bacilli and having walls rich in mycolic acid, which allows them to survive in various environmental conditions, including water, for extended periods [3].

Bovine tuberculosis is a zoonotic disease that can be transmitted between animals and humans. While cattle (bovines) are considered the primary reservoir for *Mycobacterium bovis*, other animals like goats, buffaloes, dogs, primates, ferrets, opossums, and even endangered species like the white

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rhinoceros can also be susceptible to infection [3,4]. In some cases, these animals can contract the disease from contact with infected cattle or contaminated environments [5].

On the other hand, Mycobacterium tuberculosis is the bacterium responsible for causing tuberculosis (TB) in humans [6–8]. It is closely related to *Mycobacterium bovis* and shares many similarities regarding disease presentation, transmission, and characteristics [9]. However, *Mycobacterium tuberculosis* is adapted to infect humans and is the primary causative agent of human tuberculosis [10].

While bovines and other animals can become infected with *Mycobacterium tuberculosis*, these infections are considered accidental and not a significant part of the bacterium's natural lifecycle. In the case of bovine tuberculosis, the primary concern is the transmission of *Mycobacterium bovis* from cattle to humans, either through consuming contaminated dairy products or direct contact with infected animals [11,12].

Efforts to control bovine tuberculosis often involve measures such as regular testing of cattle herds, culling of infected animals, and proper hygiene practices in livestock management to prevent transmission to humans. In humans, tuberculosis is a serious global health concern, and efforts to control its spread involve early diagnosis, proper treatment, and public health interventions to minimise its impact [13–16].

Different tests for diagnosing this pathology include immunological tests (e.g. intradermic reaction, tuberculin or BCG), microscopical detection of the fast-acid bacilli, cultures, and PCR, among others [17]. In Colombia, the most common is the tuberculin test, where the antigen, a mixture of proteins from the bacterium, is injected intradermally. In a time of 48 to 96 hours after application, the area is evaluated to identify some reaction, mainly if an increase in skin thickness is evidenced, which is called delayed hypersensitivity reaction; invitro tests of cell-mediated immunity can also diagnose it, commonly ELISA tests or ELISPOT using blood samples, serological tests such as ELISA and lateral flow immunochromatographic assays and search for bacteria of the *Mycobacterium tuberculosis* complex in tissue biopsies, exudates, secretions, excretions and sputum [18].

Sometimes, there is antibiotic treatment for domestic animals or zoos that are infected, but slaughter is carried out in the case of bovines. It is important to remember that it is a notifiable disease in Colombia and other countries. Its prevention and control are of great importance; constant disinfection of the facilities and regular review by veterinarians can help prevent the spread of tuberculosis in bovines [18].

Bovine tuberculosis is a significant veterinary and public health concern in many parts of the world, including Latin America. The epidemiology of bovine tuberculosis in Latin America can vary from country to country due to differences in livestock practices, veterinary infrastructure, socioeconomic factors, and wildlife reservoirs. Bovine tuberculosis is present in several countries across Latin America, with varying prevalence levels. Countries such as Mexico [19], Brazil [20], Argentina [21], Chile [22], and Uruguay [23] have reported cases of bovine tuberculosis [24,25]. Unfortunately, the number of studies published in Colombia about bovine tuberculosis is minimal [12,26–31], as well as of infectious diseases in bovines [32,33].

The present study aimed to describe the spatio-temporal distribution of bovine tuberculosis in Colombia from 2001 to 2019.

2. Methods

2.1. Type of Study

A quantitative, observational, descriptive, cross-sectional retrospective study on the incidence of tuberculosis in cattle (bovine) was done. The incidence rate was estimated per year by Colombian departments, and epidemiological maps of the diseases were developed between 2001 and 2019.

2.2. Data Source, GIS-Mapping and Statistical Analyses

In the study of secondary sources, the main instrument was the bulletins of the Colombian Agricultural Institute (ICA); there are sociodemographic characteristics and the disease diagnosis. In

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addition, the total number of cases and their regional location were taken, and the geographic characterisation of tuberculosis in bovines began. A case was defined as any bovine suspected of tuberculosis, with or without clinical findings, confirmed by the intradermoreaction test (tuberculin).

For the respective geographical characterisation, the free access software Kosmo 3.1 was used, which has tools preloaded from the geographical point of view; for this research, we worked with Oeste Bogotá (West Bogotá) (Magna SIRGAS) as a reference system (EPSG 21896). The mapping was carried out (at a scale of 1: 1,365,207) for which two types of layers were used; the first layer, the departments, will be added colours of greater and less intensity, defined by the layer of epidemiological data (the second layer), classified by ranges established by quartiles, which allow differentiating the areas with a higher incidence of the disease from those with a lower incidence (according to the technique of quartiles/quintiles of cases/100,000 inhabitants). Data were analysed at two levels: herds and individual animals.

Descriptive analyses were performed on Stata IC® version 14. The summary of cases per year and departments and the mean number of cases per year were calculated. As part of the time-series analyses, linear regression for the trend from 2005 to 2016 for the country was calculated with a 95% confidence level ($p<0.05$), estimating the coefficient of determination (r^2). Annual incidence rates were calculated as the number of tuberculosis cases in bovines divided by the estimated population of bovine animals per 100,000 bovines for 2016, as the census was available for that year.

2.3. Population and Sample

Colombia's total bovine population for 2019 was 27,234,027 [34]. The sample was taken from the census from the ICA databases, from which registered data were obtained from cases of diagnosis of tuberculosis in bovines in Colombia between 2001-2019. For 2016 to 2019, the annual number of bovines per department was obtained. For that period, the incidence rate of bovine tuberculosis was estimated by calculating the number of cases per 100,000 bovines per department per year.

Results

During the study period, 5,273 cases of tuberculosis in bovines were identified in the different departments of Colombia (mean 278 cases/year). Regarding its temporal distribution, the number of cases varied from a maximum of 903 cases (17.12% of the total) in 2015 to a minimum of 0 between 2001 and 2004 and between 2017 and 2019 (between 2005 and 2016, the minimum was 46 cases, 0.87%) (Figure 1). A linear regression analysis from 2005 to 2016 showed a statistically significant reduction in the annual national proportion of positive cases ($r^2=0.3627$, $p=0.0382$, $F=5.69$, root $MSE=0.37512$) (Figure 1).

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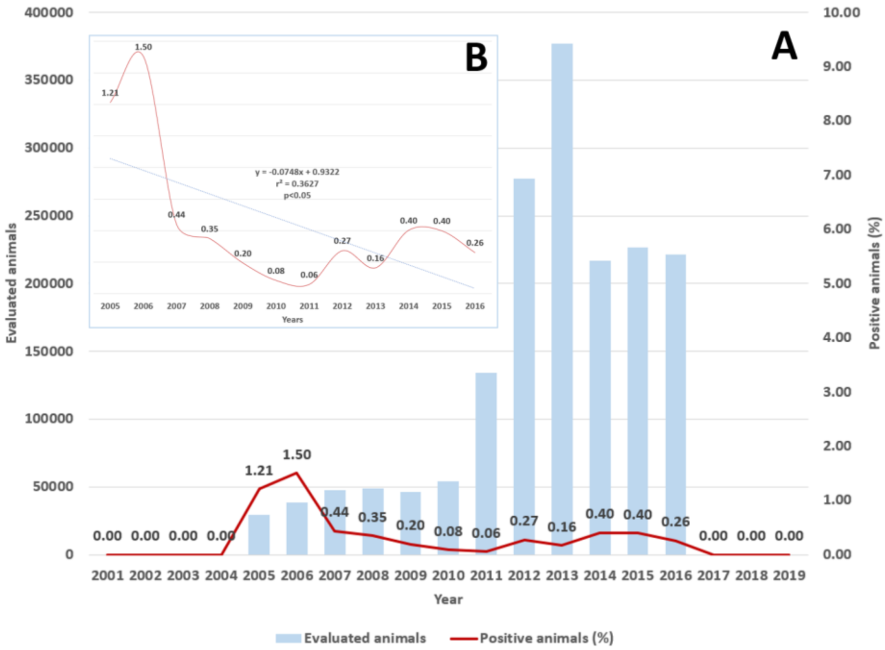

Figure 1. A. Bovine tuberculosis, the proportion of positive animals per year (%), and number of studied animals, Colombia, 2001-2019. B. Insert, linear trends for 2005-2016, showing statistically significant reduction (p<0.05).

During the study period, 1,286 herds were positive for bovine tuberculosis in the different departments of Colombia. Regarding its temporal distribution, the number of positive herds varied from a maximum of 206 positives (20.22% of the total) in 2012 to a minimum of 2 (0.16%) in 2001 and 2019. Between 2005 and 2016, the minimum was 16 positive herds, 1.24%) (Figure 2).

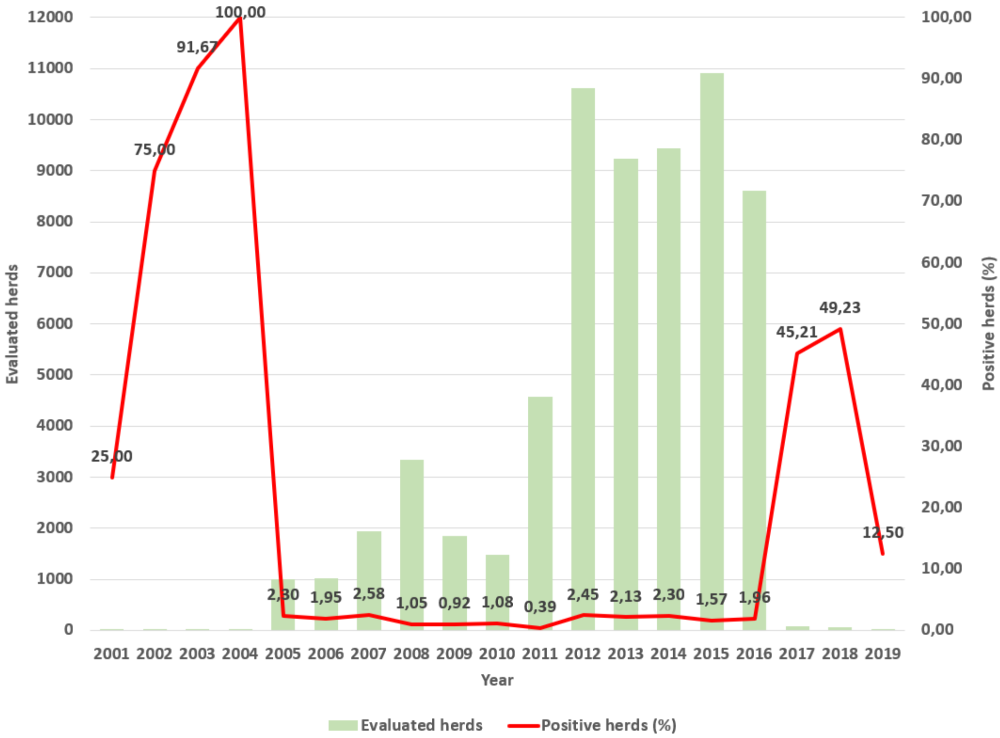

Figure 2. A. Bovine tuberculosis by herds, number of evaluated herds and proportion of positive herds per year (%), Colombia, 2001-2019.

A total of 20 epidemiological maps were generated (Figures 3–10) for the geographical distribution of the proportion of positive animals for bovine tuberculosis per department (Figures 3–6) and the proportion of positive herds for bovine tuberculosis per department (Figures 7–10).

Between 2001 and 2006, there were 941 cases of bovine tuberculosis among 68,278 with a positivity of 1.4%, but geographically focalised in three departments, Cundinamarca, Boyaca and Nariño, between 2005 and 2006 (Figure 3). From 2007 to 2012, a higher geographical distribution was observed, affecting multiple departments, but Santander in 2011 (12.8%) and Cauca in 2012 (6.5%) were the most affected (Figure 4).

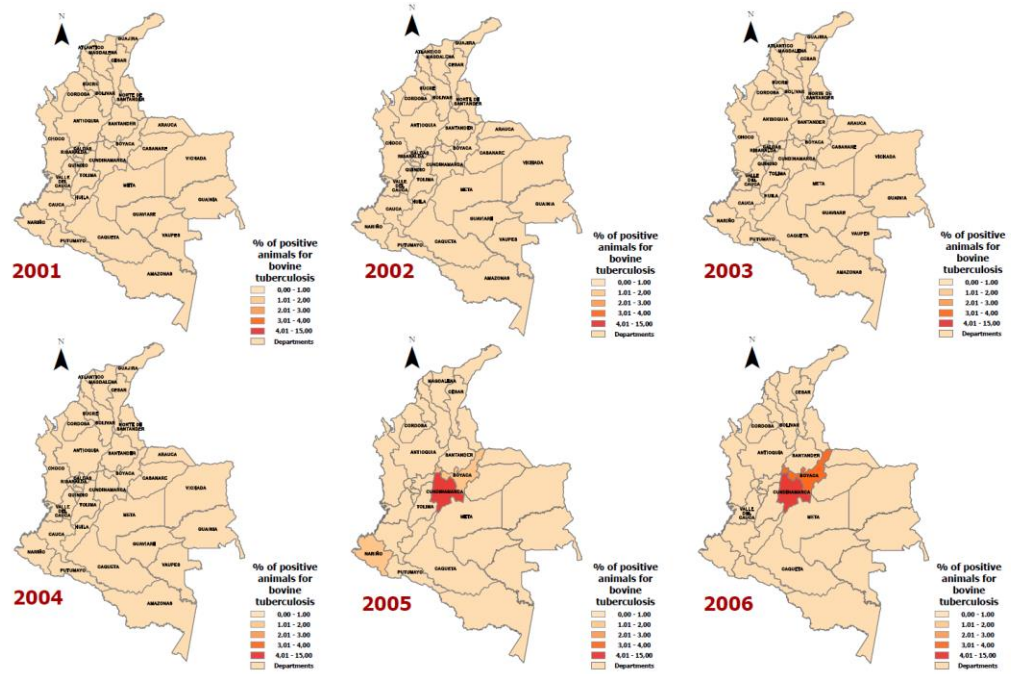

Figure 3. Proportion of positive animals for bovine tuberculosis in Colombia, 2001-2006.

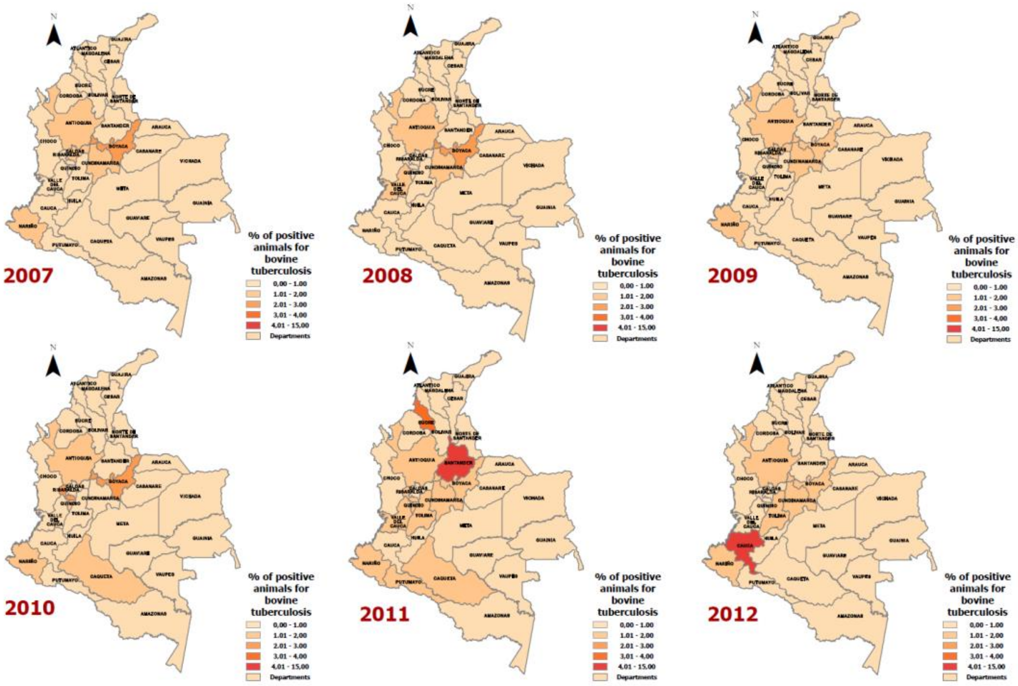

Figure 4. Proportion of positive animals for bovine tuberculosis in Colombia, 2007-2012.

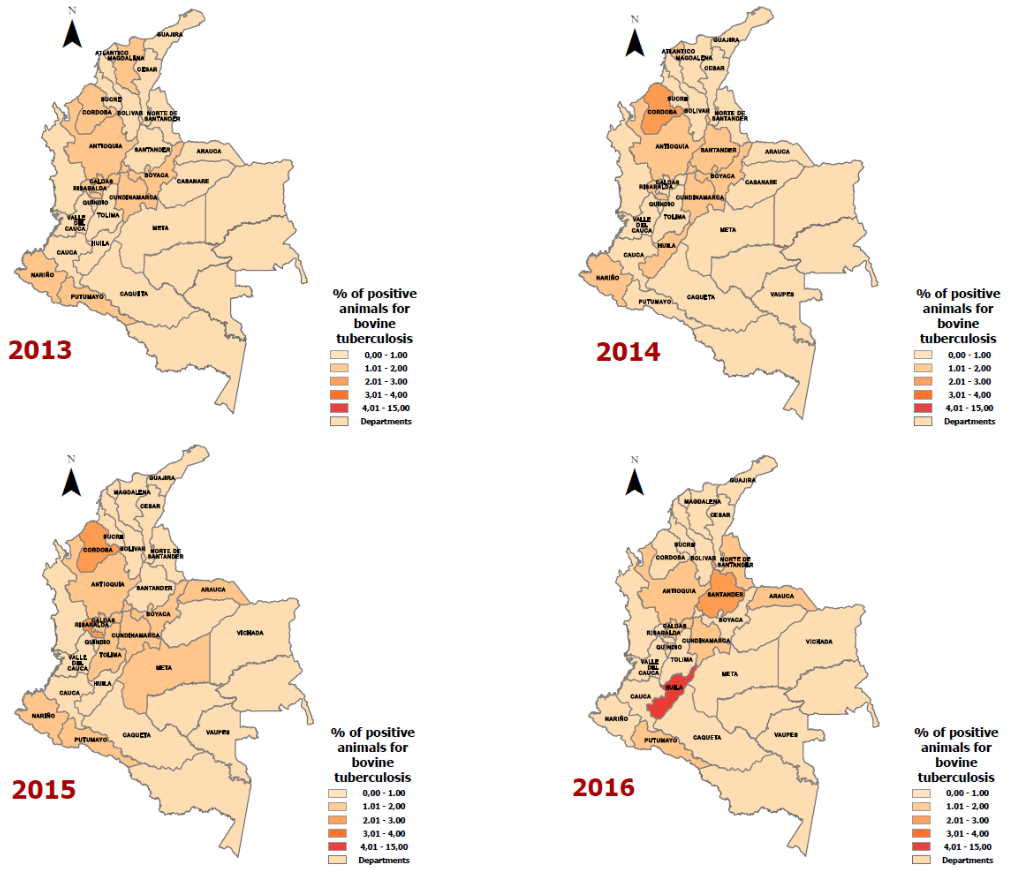

Figure 5. Proportion of positive animals for bovine tuberculosis in Colombia, 2013-2016.

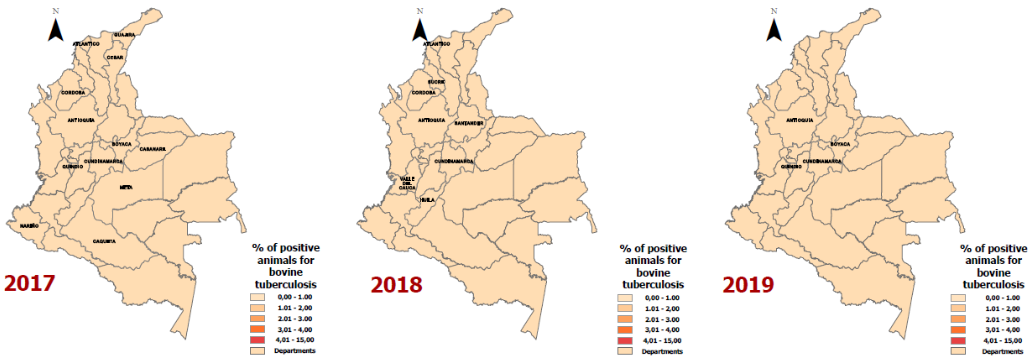

Figure 6. Proportion of positive animals for bovine tuberculosis in Colombia, 2017-2019.

From 2013 to 2016, Huila was the most affected department by bovine tuberculosis in 2016 (5.7%) (Figure 5). While in the last three years (2017-2019), no cases of bovine tuberculosis were observed in animals (Figure 6).

Between 2001 and 2006, a total of 69 herds were positive for bovine tuberculosis among 2,061 assessed (3.3%), but geographically focalised in four departments, Cundinamarca, Boyaca, Antioquia, and Nariño, especially in 2004 (Figure 7). From 2007 to 2012, a lower geographical distribution was observed. In Risaralda in 2010 (1/1), the department with the highest proportion of positive herds for bovine tuberculosis (Figure 8),

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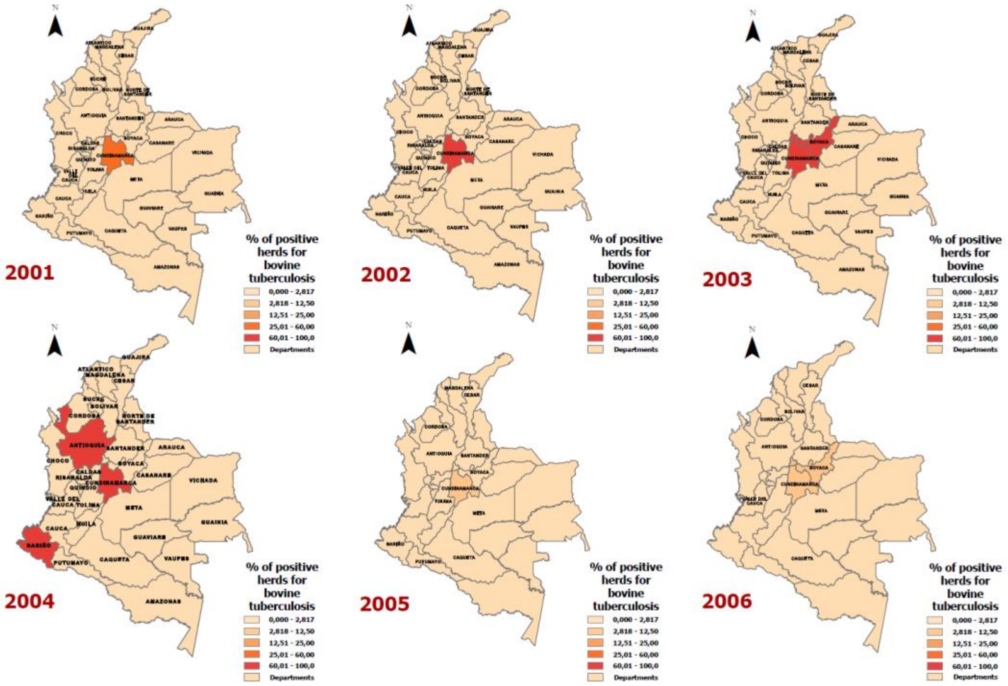

Figure 7. Proportion of positive herds for bovine tuberculosis in Colombia, 2001-2006.

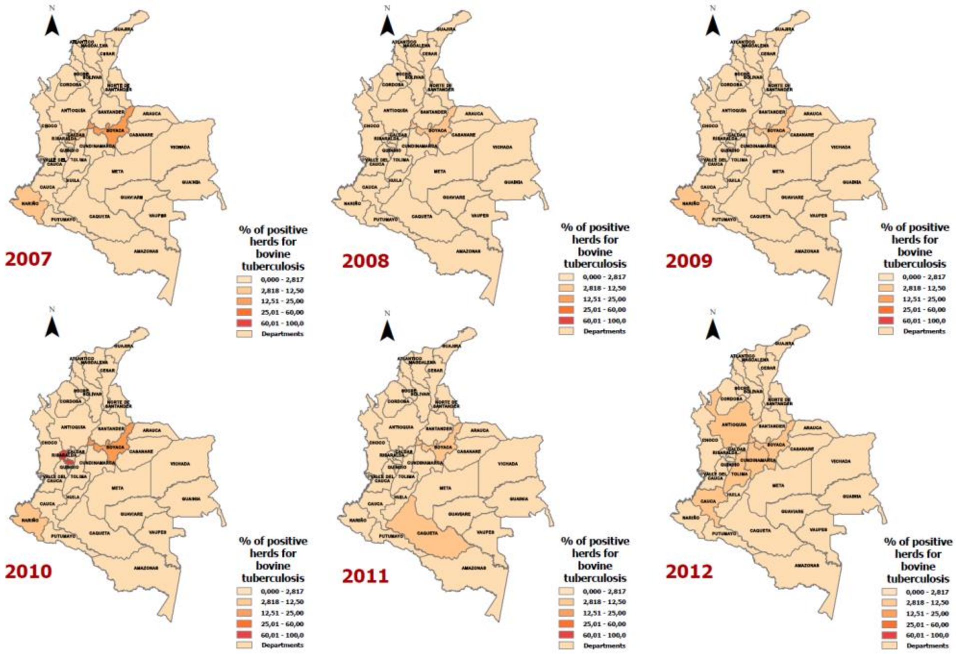

Figure 8. Proportion of positive herds for bovine tuberculosis in Colombia, 2007-2012.

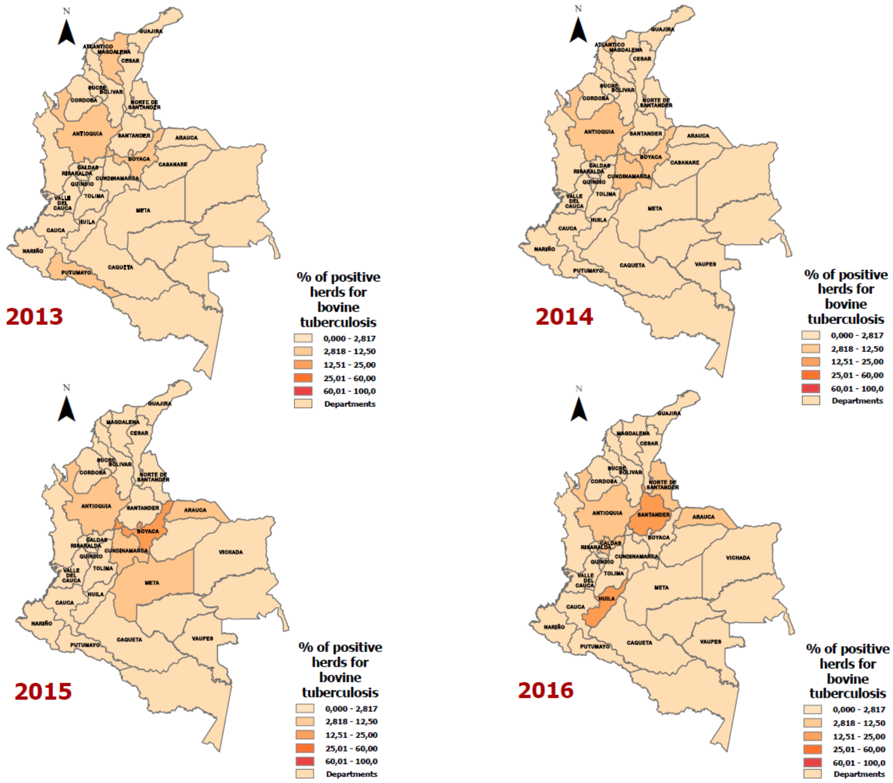

Figure 9. Proportion of positive herds for bovine tuberculosis in Colombia, 2013-2016.

From 2013 to 2016, different departments were positive at herds for bovine tuberculosis, especially Boyaca, Huila and Santander, in 2015 and 2016 (Figure 9). While in the last three years (2017-2019), the number of assessed herds was relatively low (154), but 67 of them were positive for bovine tuberculosis (43.5%), especially in Cundinamarca, Boyaca, Antioquia, Cordoba, Quindio, Atlantico, Guajira and Sucre, particularly in 2017 (Figure 10).

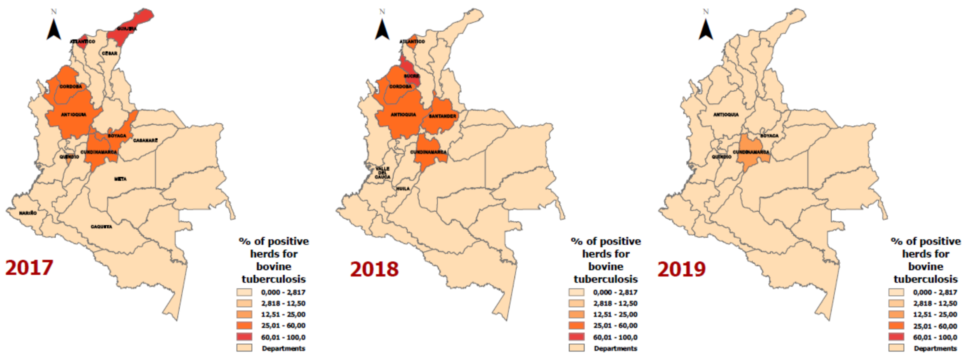

Figure 10. Proportion of positive herds for bovine tuberculosis in Colombia, 2017-2019.

Since 2016, data on the bovine census by departments has been available. With those data, the rate of cases of bovine tuberculosis per 100,000 animals was calculated (Table 1). No cases were reported at the individual level in 2017 and 2018. For 2016, the department with the highest rate of bovine tuberculosis was Putumayo (22.8 cases per 100,000 bovines) (Table 1), which reported 45 cases of bovine tuberculosis among 48,183 animals assessed (0.1%). Caldas, Huila and Cundinamarca also presented high rates of bovine tuberculosis in 2016 (>10 cases/100,000 animals) (Table 1).

Table 1. Rate of bovine tuberculosis (cases/100,000 animals) per department in 2016 in Colombia.

Year	Department	Positive Animals for Bovine Tuberculosis	Number of Animals according to the Bovine Census	Rate (Cases of bovine tuberculosis per 100,000 animals)
2016	Putumayo	45	197,611	22.8
2016	Caldas	60	370,345	16.2
2016	Huila	53	415,246	12.8
2016	Cundinamarca	138	1,256,535	11.0
2016	Antioquia	221	2,632,125	8.4
2016	Santander	55	1,412,313	3.9
2016	Norte de Santander	3	389,694	0.8
2016	Arauca	3	1,048,543	0.3

Discussion

Over almost two decades, more than 5,000 cases of bovine tuberculosis were reported in Colombia, with a mean of 278 cases per year. Then, although in apparent reduction, this represents a significant burden of animal disease and potential risk as a zoonotic condition for human health [9,35]. In other countries of the Latin American region, such as Brazil, launching and enhancing their National Programs for the Control and Eradication of Brucellosis and Tuberculosis contributes to reducing the prevalence of bovine brucellosis [35]. The program in Colombia for both diseases still needs to be improved to better control these bovine diseases [36].

In the present mapping study, Cundinamarca (Figures 3–10) and other departments have been significantly affected by bovine tuberculosis and should be the subject of further studies and activities of prevention and control of bovine tuberculosis. Although only available for 2016, the population rate of bovine tuberculosis among animals was highest in Putumayo (Table 1). Then, even more studies in this department should be considered because there are no published studies about bovine tuberculosis or bovine diseases.

Bovine tuberculosis is a zoonotic disease. The main transmission route of this condition for humans in Latin America, as in other parts of the world, is inhaling contaminated aerosols from infected animals. Close contact with infected animals, consumption of contaminated raw milk or dairy products, and exposure to contaminated environments can also lead to transmission in humans. Wildlife species, particularly in areas with close interaction between wildlife and domestic livestock, can serve as reservoirs of infection. Wild boars, deer, and possums have been identified in Latin America as potential wildlife hosts [37–39].

To improve disease control, livestock movement should be considered; both within and between countries can contribute to the spread of bovine tuberculosis. Transmission can occur in regions with significant cattle trade if infected animals are moved from one area to another without proper testing and quarantine measures [40–42].

Different countries in Latin America have implemented various control measures to combat bovine tuberculosis. These measures may include regular testing and surveillance of cattle herds, culling of infected animals, movement restrictions, and vaccination programs. However, the effectiveness of these measures can be influenced by factors such as funding availability, infrastructure, and stakeholder cooperation [43–45].

Bovine tuberculosis can have substantial economic implications for the livestock industry in Latin America. Infected animals can suffer reduced productivity, and control measures can burden farmers and governments economically. Additionally, trade restrictions on livestock and livestock products due to bovine tuberculosis concerns can impact international trade relationships [5,46].

Bovine tuberculosis is a zoonotic disease that can be transmitted between animals and humans. A One Health approach, which involves collaboration between veterinary and medical professionals, is crucial for addressing the disease's impact on animal and human health. Efforts to control bovine tuberculosis should include coordination among veterinary authorities, public health agencies, and other relevant stakeholders [47–49].

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Consent for publication: Not applicable.

Availability of data and materials: Available upon request.

Competing interests: None.

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Authors' contributions: DKBA conceived the idea of the study; DKBA and SDJD collected data; DKBA and AJRM analysed data; CL developed the GIS-based maps; DKBA and AJRM developed the first draft. All authors revised and contributed to subsequent versions. All authors approved the final submitted version.

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