

# Brucellosis and tuberculosis in cattle in South America

## *Brucelose e tuberculose bovinas na América do Sul*

José Soares FERREIRA NETO<sup>1</sup>

<sup>1</sup> Universidade de São Paulo, Faculdade de Medicina Veterinária e Zootecnia,  
Departamento de Medicina Veterinária Preventiva e Saúde Animal, São Paulo – SP, Brazil

### Abstract

In general, European and North American countries, as well as Australia and New Zealand, have already eradicated or reached good levels of control of brucellosis and tuberculosis in cattle. In the rest of the world, however, the epidemiological situation of these two diseases is frequently poorly understood. In this review article, quantified data on these diseases in the South American countries are presented. Initially, the aspects that led the continent to host 25% of the world cattle population are presented, in addition to the aspects that placed the continent at a prominent position in the international meat market. Subsequently the continent was divided into three country groups, considering the size of the cattle population and how well the epidemiological situation of brucellosis and tuberculosis in cattle is quantified. It is argued that countries that do not generate high-quality quantitative epidemiological data on these diseases have serious limitations in outlining and managing control or eradication strategies. Thus, for successful outcomes, at least methodologies to estimate the prevalence of infected herds should be employed.

**Keywords:** Bovine brucellosis. Bovine tuberculosis. South America. Epidemiological situation.

### Resumo

De maneira geral, os países da Europa e da América do Norte, além da Austrália e da Nova Zelândia, já erradicaram ou atingiram bons níveis de controle da brucelose e da tuberculose bovinas. Entretanto, no restante do mundo, raramente a situação epidemiológica dessas duas doenças é adequadamente conhecida. Neste artigo de revisão são apresentados dados de quantificação dessas importantes enfermidades nos países da América do Sul. Inicialmente são apresentadas as características que concorreram para que atualmente o continente tenha 25% do efetivo bovino mundial e uma posição de destaque no mercado internacional de carnes. Os países foram então alocados em três grupos, levando em consideração o tamanho da população bovina e a qualidade da quantificação referente à situação epidemiológica da brucelose e da tuberculose bovinas. Argumenta-se que países que não geram dados epidemiológicos quantitativos de alta qualidade em relação a essas doenças têm sérias limitações para traçar estratégias eficazes de combate e são incapazes de realizar a gestão dos processos. Conclui-se que os países que desejam ser exitosos no combate à brucelose e tuberculose bovinas deveriam ao menos utilizar metodologias para estimar a prevalência de focos.

**Palavras-chave:** Brucelose bovina. Tuberculose bovina. América do Sul. Situação epidemiológica.

### Correspondence to:

José Soares Ferreira Neto  
Universidade de São Paulo, Faculdade de Medicina Veterinária  
e Zootecnia  
Av. Prof. Dr. Orlando Marques de Paiva, 87 – Cidade Universitária  
CEP 05508-270, São Paulo, SP, Brazil  
e-mail: jsoares@vps.fmvz.usp.br

Received: 29/11/2017

Approved: 28/2/2018

### Characterization of South America

South America holds 12% of the land area and 6% of the world's human population. The continent is composed of twelve sovereign countries and a French overseas region, as well as island territories in the southern Caribbean and

Atlantic. In the Venezuelan Caribbean is the sovereign state of Trinidad Tobago and the islands Aruba, Bonaire and Curaçao, Dutch possessions; in the South Atlantic, the Falklands, South Georgia and the South Sandwich Islands, all British possessions.

The majority of South American countries speak Spanish. Portuguese is spoken only in Brazil and French only in French Guiana. English is spoken in Guiana, Trinidad Tobago, and the insular British possessions. Dutch is spoken in Suriname and in insular Dutch possessions.

Geographically, the continent has a long mountain chain (the Andes) and a desert region (the Atacama Desert) to the west, a dense rainforest in the north, a marshland

in its middle portion that represents a continental drain (Pantanal/Chaco), and plains and plateau regions of equatorial, tropical, subtropical, and temperate climates, very conducive to agriculture and livestock. South

America holds approximately a quarter of the world's cattle population. Furthermore, 75% of these animals are found in only two countries, Brazil and Argentina (Table 1, Figure 1).

Table 1 – Geographic area and data on human and cattle population in South American countries

	Country	Area (Km <sup>2</sup> )	Human population*	Cattle population <sup>#</sup>	%	cattle / human
1	Brazil	8.514.877	202.241.714	211.764.292	60,78	1,05
2	Argentina	2.766.890	40.482.000	51.095.000	14,66	1,26
3	Colombia	1.141.748	46.920.000	23.141.388	6,64	0,49
4	Venezuela	916.445	31.648.930	14.500.000	4,16	0,46
5	Paraguay	406.750	6.831.306	13.376.456	3,84	1,96
6	Uruguay	176.220	3.477.780	11.500.000	3,30	3,31
7	Bolivia	1.098.580	9.863.000	8.847.434	2,54	0,90
8	Peru	1.285.220	29.132.013	5.556.188	1,59	0,19
9	Ecuador	283.560	14.573.101	5.134.122	1,47	0,35
10	Chile	756.950	16.928.873	3.305.365	0,95	0,20
11	Guyana	214.999	772.298	112.900	0,03	0,15
12	Suriname	163.270	472.000	46.060	0,01	0,10
13	Trinidad and Tobago	5.131	1.349.667	34.500	0,01	0,03
14	French Guiana (France)	91.000	221.500	18.370	0,01	0,08
15	Falkland Islands (UK)	12.173	3.140	4.300	0,00	1,37
16	Aruba, Bonaire, Curaçao (Netherlands)	931	260.675		0,00	
17	South Georgia, South Sandwich Islands (UK)	3.093	30		0,00	
TOTAL		17.837.837	405.178.027	348.436.375	100,0	

Source: \*Cook (2015); <sup>#</sup>Wikipedia Contributors (2018)

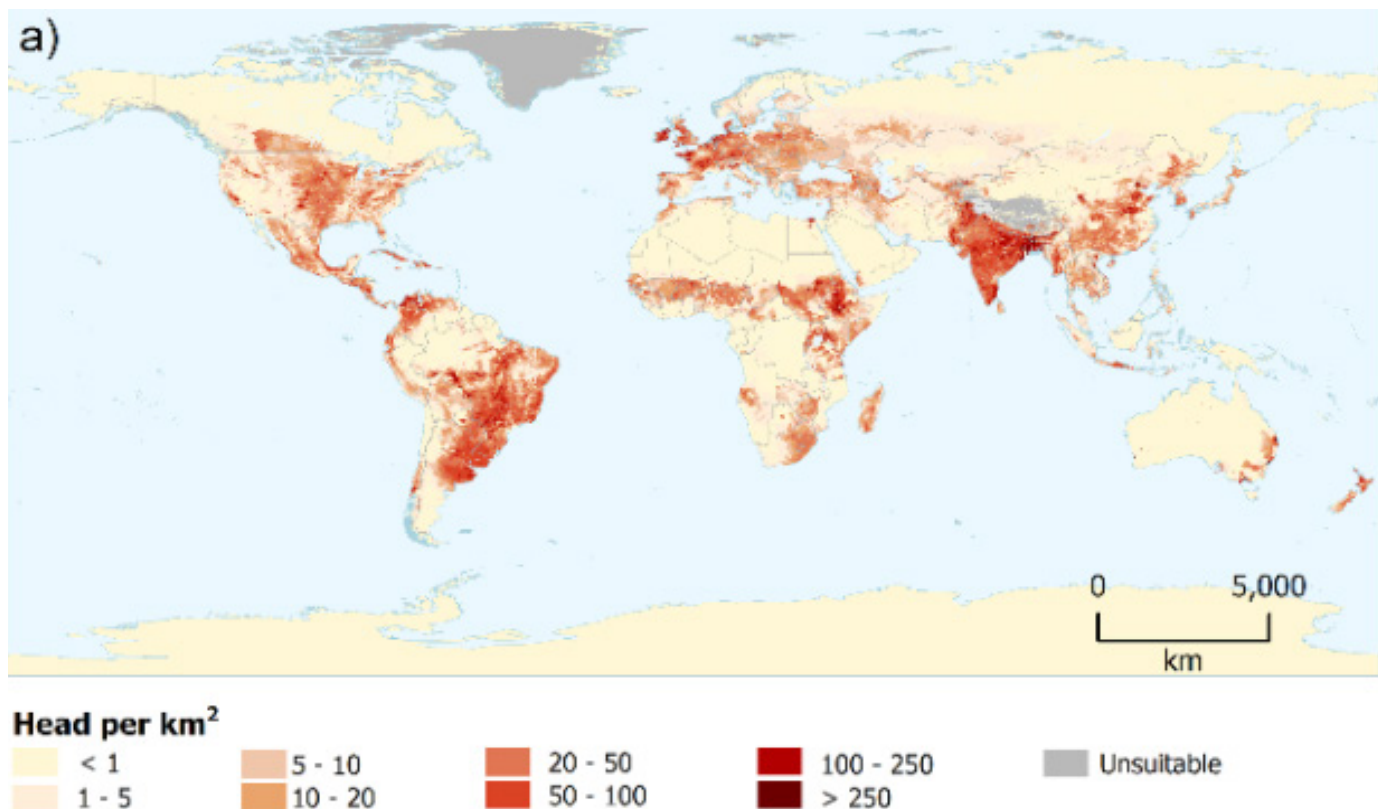


Figure 1 – Global distribution of cattle. Source: Robinson et al. (2014)

This enormous cattle population, combined with the existence of vast areas free from foot-and-mouth disease (FMD) and a negligible risk for bovine spongiform encephalopathy (BSE) (Figures 2 and 3), contributed to the economy of several South American countries, particularly Brazil, Uruguay, Paraguay, and Argentina, which stood out as meat exporters in the world market.

### Conducting review and organizing information

The information contained in this article were extracted exclusively from a survey spanning the last sixteen years in the following data sources: PubMed, ScienceDirect, Scopus, SciELO, Wiley Online Library, Google Scholar, Google Search.

It must be pointed out that the official veterinary services of these countries were not contacted to obtain

information on the epidemiological situation or strategies of combating brucellosis and tuberculosis in cattle.

After an extensive search in the bibliographical material, the information on the epidemiological situation of these diseases was separated into three blocks of countries:

- 1) Countries with very small cattle populations: Guiana, Suriname, French Guiana, Trinidad and Tobago, Aruba, Bonaire, Curacao, Falkland Islands, South Georgia, and South Sandwich Islands;
- 2) Countries where the epidemiological situation of brucellosis and tuberculosis in cattle is not properly characterized: Venezuela, Colombia, Ecuador, Peru, Bolivia, and Paraguay;
- 3) Countries where the epidemiological situation of brucellosis and tuberculosis in cattle is properly characterized: Chile, Uruguay, Argentina, and Brazil.

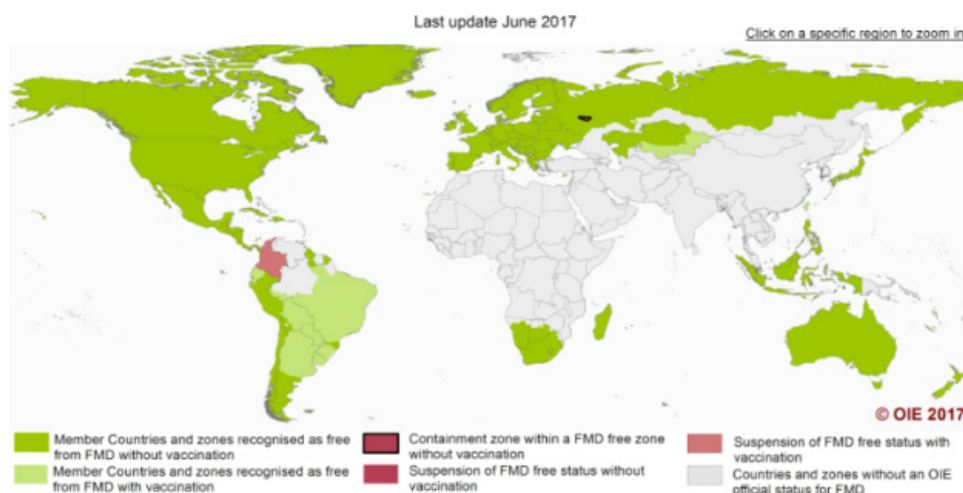


Figure 2 – Official foot-and-mouth disease (FMD) risk status map of the World Organisation for Animal Health (OIE) member countries

Source: World Organisation for Animal Health (2017)

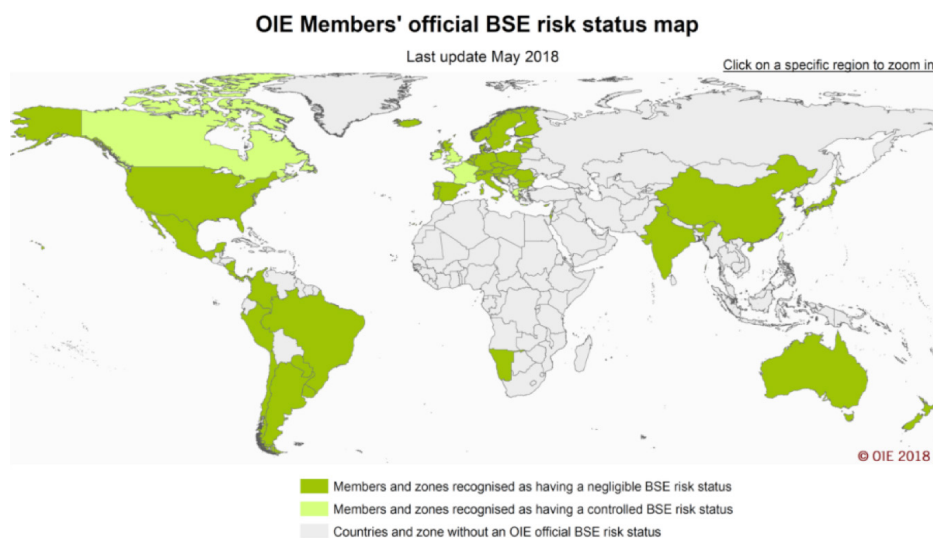


Figure 3 – Official bovine spongiform encephalopathy (BSE) risk status map of the World Organisation for Animal Health (OIE) member countries

Source: World Organisation for Animal Health (2018)

## Situation of brucellosis and tuberculosis in cattle in countries with very small cattle populations

The cattle populations of Guiana, Suriname, French Guiana, Trinidad and Tobago, Aruba, Bonaire, Curacao, Falkland Islands, South Georgia and South Sandwich Islands amount to a little more than 216,000 heads, which represent 0.06% of the cattle population in South America (Table 2). The

OIE online database, *Handistatus II*, provides data on the last occurrence, as well as the strategies adopted for brucellosis and tuberculosis, but only to Suriname, Trinidad and Tobago, French Guiana, and Falklands Islands (Table 2). There seems to be no cattle population in Aruba, Bonaire, Curacao, South Georgia, and South Sandwich Islands. No data were found on the occurrence of disease in Guiana (Table 2).

Table 2 – Data on bovine brucellosis and tuberculosis in South American countries with very small cattle populations

Country	Cattle population	% of South America	Bovine brucellosis							
			last occurrence	vaccination prohibited	precautions at the borders	surveillance	screening	movement control inside the country	stamping out	zoning
Guyana	112.900	0,032	–	–	–	–	–	–	–	–
Suriname	46.060	0,013	never	x	x	x				
Trinidad and Tobago	34.500	0,010	2.014	x	x	x				
French Guiana (FR)	18.370	0,005	1.995	x	x	x	x	x	x	x
Falkland Islands (UK)	4.300	0,001	never	x	x	x				
Aruba, Bonaire, Curaçao (NE)	– *	–	–	–	–	–	–	–	–	–
S. Georgia, S.Sandwich Islands (UK)	–	–	–	–	–	–	–	–	–	–
Total	216.130	0,062								

Country	Cattle population	% of South America	Bovine tuberculosis							
			last occurrence	precautions at the borders	general surveillance	screening	movement control inside the country	stamping out	zoning	
Guyana	112.900	0,032	–	–	–	–	–	–	–	–
Suriname	46.060	0,013	1.997	x	x					
Trinidad and Tobago	34.500	0,010	1.996	x	x	x				
French Guiana (FR)	18.370	0,005	2.013	x	x		x	x		
Falkland Islands (UK)	4.300	0,001	never	x	x					
Aruba, Bonaire, Curaçao (NE)	– *	–	–	–	–	–	–	–	–	–
S. Georgia, S.Sandwich Islands (UK)	–	–	–	–	–	–	–	–	–	–
Total	216.130	0,062								

\* information not available

Source: World Organisation for Animal Health (2014)

In conclusion, in addition to their extremely small cattle populations, the occurrence of brucellosis and tuberculosis in cattle in these countries and territories seems to be sporadic.

## Countries where the epidemiological situation of brucellosis and tuberculosis in cattle is not properly characterized

This group is composed of six countries, namely Venezuela, Colombia, Ecuador, Peru, Bolivia, and Paraguay,

which account for 20% of the cattle population in South America (Table 1).

The information available shows that there are no nationwide data about the situation of the diseases in all states and regions. With rare exceptions, small-sized studies, with little or no details on sample design and covering a small geographic region, are occasionally found. The results, for both diseases, almost always indicate significant differences in their prevalence between regions and/or between periods of time. The detailed situation of each country is described below.

## Venezuela

Studies on cattle brucellosis in Venezuela are summarized in table 3. The results show striking regional differences in the prevalence of animals and the prevalence data of infected herds only for locations in the state of Lara.

Table 4 provides a historical series of official data on the epidemiological situation of bovine tuberculosis, with significant numbers of properties and animals tested annually. However, the nearly 12-fold increase in the prevalence of animals from 1995 to 2001 confirms the inaccuracy of these data, considering that tuberculosis is a chronic disease of slow spread.

Table 3 – Studies on the epidemiological situation of bovine brucellosis in Venezuela

Author	Year	Location	Test	Herds		Animals	
				Tested	% Positive	Tested	% Positive
Vargas, 2002, reporting different authors	prior to 2002	many regions	ELISA, CFT, agglutination Tests				0,8 to 10,5
D'Pool et al., 2004	1999	La Cañada de Urdaneta municipality	C-ELISA + 2ME			384	9,1
Mosquera et al., 2009	2006/07	Buria County, Simón Planas municipality, Lara state	Ring Test (milk)	134	15,20		
Maldonado et al., 2010	2007	Lara state	ELISA (milk)	258	13,14		

Table 4 – Historical series of official data on the situation of bovine tuberculosis in Venezuela

Year	Herds			Animals		
	Tested	Positive	% Positive	Tested	Positive	% Positive
1995	3.716	93	2,50	1.060.967	218	0,021
1996	3.962	84	2,12	1.140.565	343	0,030
1997	2.861	74	2,59	729.560	326	0,045
2000	3.892	131	3,37	920.625	556	0,060
2001	1.982	119	6,00	340.883	845	0,248
2002	1.301	105	8,07	480.002	732	0,152
2003	2.708	133	4,91	779.847	325	0,042
2004	1.958	69	3,52	447.260	314	0,070
2005	1.250	45	3,60	276.988	435	0,157
2006	1.483	67	4,52	342.215	362	0,106

Source: data have been reported by Rivera and Giménez (2010)

## Colombia

Official data from the Colombian Agricultural Institute (ICA) indicated a 22% prevalence of infected herds and 5% prevalence of animals in 2006 (Table 5). Even though neither recent data nor accurate information on the situation of brucellosis in the whole Colombian territory have been found, the ICA website reports information on a free herd and free zone accreditation program (Figure 4, Table 6). Figure 4 shows two areas declared free of cattle brucellosis (in yellow): one area is located in the north of the country, including regions of the states of Santander and Boyacá, and another area is represented by the archipelago of San Andre and Providence. Table 6 summarizes the

number of properties accredited as free in Colombian states, highlighting Plan Nariño, Cundinamarca, and Antioquia, which accredited 55%, 17%, and 11% of their herds, respectively.

Regarding bovine tuberculosis, although the ICA site states that the prevalence is less than 1%, 3.1% of the 7,951 animals tested by tuberculin between 2005 and 2009 were positive, mainly in the states of San Andrés, César, Cundinamarca and Antioquia (WARD, 2010). Notwithstanding the inconsistent data on the disease situation in Colombia, the country has been promoting a free herd accreditation program, the results of which are listed in table 6.

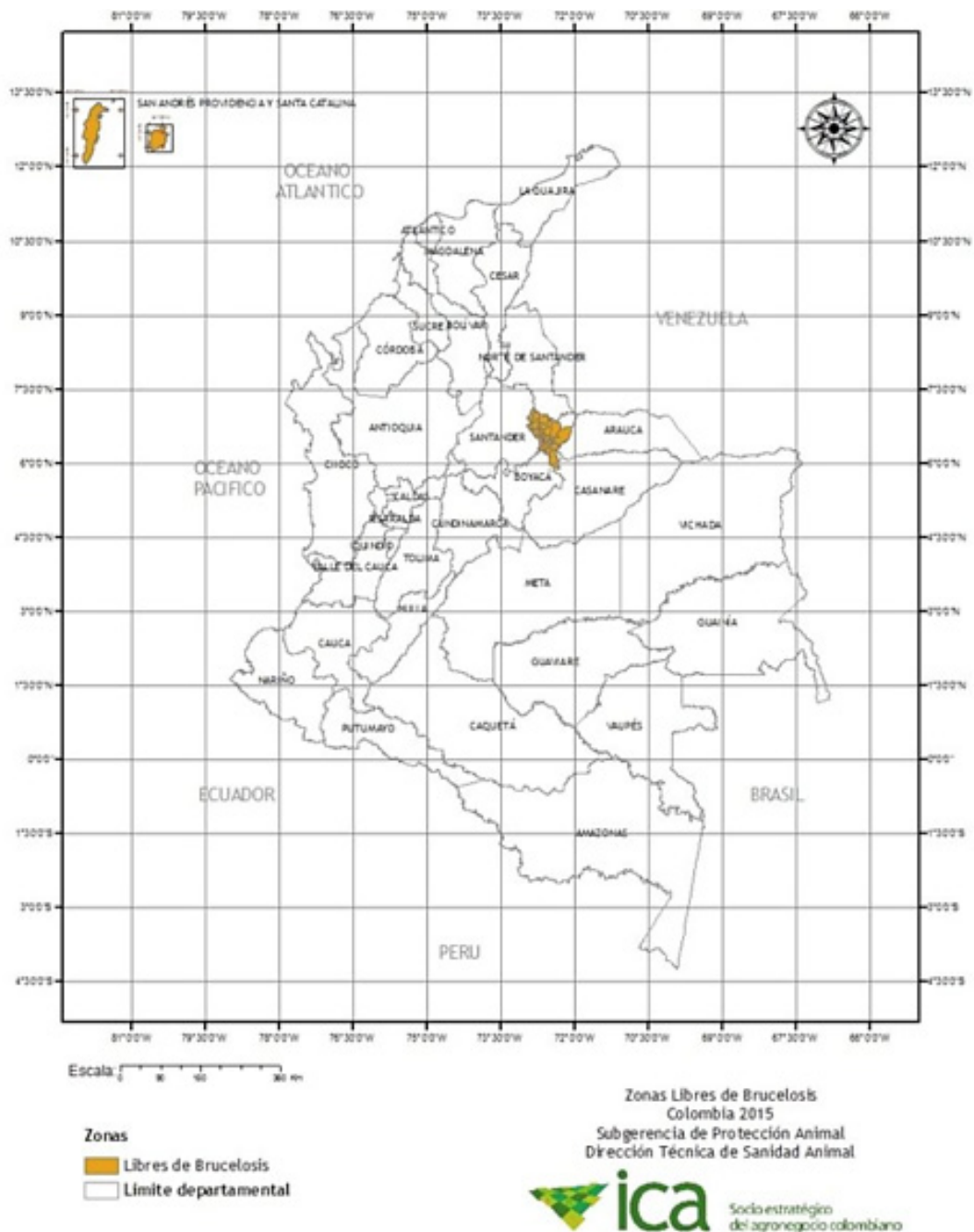


Figure 4 – Bovine brucellosis-free zones declared by the Colombian Agricultural Institute

Source: Colombia (2016)

Table 5 – Reports on the epidemiological situation of bovine brucellosis in Colombia

Author	Year	Location	Test	Tested Herds	% Positive	Tested Animals	% Positive
Aricapa et al., 2008	2001-2002	Caldas	RBT + CFT			2.434	0,6
ICA apud Tique et al., 2009	2006	national	?	3.976	22,0	226.941	5,0
Tique et al., 2009	2006-2008	Córdoba	RBT / ELISA	4.922	12,7	29.969	3,71
Giraldo et al., 2014	?	Caquetá and Putumayo	RBT + C-ELISA	7			11,9 (buffaloes) 5,3 (bovines)
Giraldo et al., 2014	?	Caquetá and Putumayo	RBT + C-ELISA	7			11.9 (buffaloes) 5.3 (bovines)

Table 6 – Number of official brucellosis-free herds (up to December 2016) and official tuberculosis-free herds (up to 2010) in the Colombian states

State	Brucellosis *	Tuberculosis **	State	Brucellosis *	Tuberculosis **
Amazonas	-	7	Huila	106	27
Antioquia	3.297	1.022	La Guajira	9	-
Arauca	35	-	Magdalena	8	-
Atlántico	17	10	Meta	15	19
Bolivar	17	-	Nariño	10.452	99
Boyacá	658	51	Norte de Santander	143	5
Caldas	213	58	Putumayo	375	38
Caquetá	384	47	Quindío	39	765
Casanare	194	41	Risaralda	154	80
Cauca	169	15	San Andres	-	-
Cesar	43	9	Santander	119	158
Chocó	-	-	Sucre	29	4
Córdoba	86	18	Tolima	98	365
Cundinamarca	2.181	838	Valle del Cauca	98	29
Guainía	1	-	Vaupués	4	-
Guaviare	52	-	Vichada	-	-
subtotal	7.347	2.116	subtotal	11.649	1.589
<b>Grand Total</b>				<b>18.996</b>	<b>3.705</b>

Source: Colombia (2010\*\*;2016\*)

## Ecuador

Recent studies on the prevalence of brucellosis-infected herds in Ecuador indicated major regional differences, suggesting that the disease occurs throughout the country, but in a rather heterogeneous way (Table 7).

Pérez et al. (2011) reviewed the situation of cattle tuberculosis in Ecuador, and the data are summarized

in figures 5 and 6. The data from several authors listed in the tables revealed that the disease is more prevalent in properties where milk is produced, especially in the provinces of Pichincha and Imbabura. However, although the studies did not provide a comprehensive view of all the national territory, they suggested the existence of large regional differences.

Table 7 – Studies of the epidemiological situation of bovine brucellosis in Ecuador

Author	Year	Location	Test	Heds		Animals	
				Tested	% Positive	Tested	% Positive
Aguayo et al., 2015	2014 - 2015	Manabí	RBT + C-ELISA	163	10,43%	2.317	1,99%
Poulsen et al., 2014	2011 - 2013	Northern	RBT card test	101	-	2.561	5,50%
different thesis apud Poulsen et al., 2014		different regions	serology	[1 - 9,7%] to [24 - 48%]			

Reference	Year	Location		Test used	Herd size <sup>a</sup>	No. of Herds	Positive cattle/ No. of animals	(%)
		Province	Canton					
Acosta & Parreño (16)	1977	Tungurahua	Píllaro	SITT <sup>b</sup> & CITT <sup>c</sup>	NA <sup>d</sup>	20	7/2 132	0.33
Andino-Ashqui (18)	2001	Pichincha	Cayambe	SITT & CITT	Large	2	5/178	2.81
		Imbabura	Otavalo		Large	1	24/329	7.29
		Carchi	Espejo		Large	2	11/516	2.13
		Pichincha	Cayambe		NA	26	14/3 006	0.47
Cano & Chulde (22)	2002	Pichincha	Mejía	SITT & CITT	Large	13	152/3 089	4.92
Burbano & León (20)	2002	Carchi	Espejo, Tulcán	SITT & CITT	NA	NA	52/3 011	1.73
			Montufar, Huaca					
Bedón & Verdesoto (19)	2003	Imbabura	Ibarra, Otavalo	SITT & CITT	Large	13	73/3 005	2.43
Alemán, et al. (17)	2003	Tungurahua	Píllaro, Mocha	SITT & CITT	NA	24	49/4 012	1.22
Proaño-Pérez, et al. (14)	2006	Pichincha	Mejía	SITT & CITT	Large	15	26/327	7.95
Proaño-Pérez, et al. (15)	2007	Pichincha	Mejía	CITT	Large	13	142/1 644	8.63
Proaño-Pérez, et al. (15)	2008	Pichincha	Mejía	CITT	Large	13	122/1 446	8.43

<sup>a</sup> > 70 bovines = large.<sup>b</sup> Simple intradermal tuberculin test.<sup>c</sup> Comparative intradermal tuberculin test.<sup>d</sup> Not available.

Figure 5 – Prevalence of bovine tuberculosis in dairy cattle according to previous studies – Ecuador – 1977-2008

Source: Peréz et al. (2011)

Reference	Year	Location		Test used	Herd size <sup>a</sup>	No. of Herds	Positive cattle/ No. of animals	(%)
		Province	Canton					
Cañizares (26)	1977	Guayas	Guayaquil	SITT <sup>b</sup>	NA <sup>c</sup>	NA	33/975	3.38
Maretti (27)	1981	Galápagos	San Cristóbal	SITT	NA	NA	0/1 000	0.00
Lojan (28)	1982	El Oro	Santa Rosa	SITT	NA	NA	4/1 465	0.27
Aguirre (29)	1984	El Oro	Pasaje	SITT	NA	NA	0/500	0.00
Torres, et al. (30)	1996	Santo Domingo	Santo Domingo	SITT	Large	1	21/4 888	0.43
Gutierrez (31)	1997	Guayas	El Triunfo	SITT	NA	NA	0/300	0.00
Muñoz (32)	1998	Los Rios	Ventanas	SITT	NA	NA	0/320	0.00
Villamar (33)	2000	Manabí	Paján	SITT	NA	NA	0/300	0.00
Moncada (34)	2003	Guayas	Naranjal	SITT	NA	NA	14/250	5.60
Avellan (35)	2003	Guayas	Bucay	SITT	NA	NA	2/200	1.00
Arevalo & Zamora (36)	2004	Santo Domingo	Santo Domingo	SITT & CITT <sup>d</sup>	Large	37	20/4 029	0.50

<sup>a</sup> > 70 bovinos = large.  
<sup>b</sup> Simple intradermal tuberculin test.  
<sup>c</sup> Not available.  
<sup>d</sup> Comparative intradermal tuberculin test.

Figure 6 – Prevalence of bovine tuberculosis in beef cattle according to previous studies – Ecuador – 1977-2008

Source: Pérez et al. (2011)

## Peru

In Peru, studies on the epidemiological situation of bovine brucellosis suggested large regional prevalence differences (Table 8).

Regarding cattle tuberculosis, a national study performed in 1965 reported a high prevalence of animals, which seems to have decreased over the years. The most recent data indicated important regional differences in the prevalence of animals (Table 9).

Table 8 – Prevalence of bovine brucellosis in Peru according to different studies

Author	Year	Location	Test	Tested Animals	% Positive
Huget T. et al., 2005		Canta, Lima	RBT + CFT	486	0,21 [0,09 - 0,60]
Ventocilla G. et al., 2009	2004	Tama-Junín	RBT	344	0
Cardenas, 2000 apud Zavala et al., 2011		Tambopata-Madre de Dios		2.561	5,4
Meza et al., 2010	2007	Puerto Inca	RBT	3.221	0,031 [0 - 0,114]
Zavala et al., 2011	2007	Codo del Pozuzo, Huánuco	RBT + CFT	5.439	0,02 [0 - 0,06]

Table 9 – Prevalence of bovine tuberculosis in Peru according to different studies

Author	Year	Location	Test	Tested Animals	% Positive
Castagnino, 1968 apud Sánchez; Rosadio, 2002	1965	national	CFT		18.1
Senasa, 1999 apud Sánchez; Rosadio, 2002		Junín	CFT	1.798	0.17
Senasa, 2000 apud Sánchez; Rosadio, 2002		Cajamarca	CFT	7.487	0.65
Senasa, 2000 apud Sánchez; Rosadio, 2002		Puno	CFT	1.901	0.21
Senasa, 2000 apud Sánchez; Rosadio, 2002		Arequipa	CFT	63.702	0.075
Senasa, 2000 apud Sánchez; Rosadio, 2002		Cusco	CFT	1.500	0
Sánchez; Rosadio, 2002		Parinacochas	CFT	461	0
Arcelles et al., 2005	2001-2002	Végueta	CFT	3.230	0.06
Flores et al., 2005		Canta, Lima	CFT	503	2.2

## Bolivia

In Bolivia, the studies on the epidemiological situation of brucellosis and tuberculosis in cattle are more frequent in the state of Santa Cruz, possibly because of its importance in cattle farming in the country (Table 10). The data

indicated moderate and high prevalence, with relevant regional differences.

Studies on tuberculosis show that the disease occurs in dairy and beef cattle and also suggest important regional differences (Table 11).



Table 10 – Studies on the epidemiological situation of bovine brucellosis in Bolivia

Author	Year	State	Province	Herds		Animals	
				Tested	% Positive	Tested	% Positive
Segovia, R. W. *	2000	Tarija	Arce			400	0,5
Revollo, Q. J. E. *	2001	Cochabamba	Quillacollo				11,72
Choque, C. M. *	2001	Chuquisaca	Azurduy			400	0
Sandoval, J. S. *	2001	Santa Cruz	Ichilo			1.182	1,69
Navarro, G. A. *	2001	Santa Cruz	Warnes			2.495	3,69
Escobar, F. A. N. *	2002	Cochabamba	Chapare-Carrasco			1.250	0,3
Zambrana, M. P.W. *	2003	Santa Cruz	Chapare			1.098	1,64
Manrique, 2005	2005	Santa Cruz	Andrés Ibáñez, Warnes, Sara, Ñulfo de Chávez	19	36,8	2.642	2,27
Melean, 2005	2005	Santa Cruz	Andrés Ibáñez, Warnes, Obispo Santiesteban, Sara	85	9,41	881	1,24

Table 11 – Studies on the epidemiological situation of bovine tuberculosis in Bolivia

Author	Year	Location	Test	Tested Animals	% Positive
Ortiz, 2001	1997	beef cattle from Santa Cruz state	gama interferon	300	0,33
Fedeple apud Marín, 2005	1998	beef cattle from Santa Cruz state	TT	6.094	2,8
Fedeple apud Marín, 2005	1999	dairy cattle from Santa Cruz state	TT	8.575	1,4
Fedeple apud Marín, 2005	2000	dairy cattle from Santa Cruz state	TT	17.232	2,2
Marín, 2005	2005	Cantón Los Chacos, Warnes province, Santa Cruz state	CFT + CCT	1.691	0,83

## Paraguay

In Paraguay, the National Animal Health Service (Senacsa) data on the occurrence of cattle brucellosis, published by Baumgarten (2002), suggested a relatively stable animal prevalence and a decline in the prevalence

of infected herds from 1979 to 2000 (Table 12). However, no recent data were found.

Regarding bovine tuberculosis, Kantor and Ritacco (2006) reported that 0.7% of 11,000 animals tested in 2002 were positive for tuberculin.

Table 12 – Official data on bovine brucellosis in Paraguay

Year	Animals			Herds		
	Tested	Positive	(%)	Tested	Positive	(%)
1979	11.633	331	2,8	151	52	34,4
1980	62.893	988	1,6	1.719	302	17,6
1981	91.998	1.165	1,3	2.115	450	21,3
1982	83.678	1.131	1,4	2.206	359	16,3
1983	63.292	894	1,4	1.892	255	13,5
1984	71.082	2.529	3,6	1.741	367	21,1
1985	49.641	2.056	4,1	1.298	374	28,8
1986	48.043	2.237	4,7	1.516	389	25,7
1987	51.350	1.721	3,4	1.586	349	22
1988	46.221	1.222	2,6	1.761	240	13,6
1989	34.469	794	2,3	1.414	200	14,1
1990	44.240	1.282	2,9	2.250	224	10
1991	63.026	1.355	2,1	3.069	285	9,3
1992	51.765	1.263	2,4	2.330	214	9,2
1993	52.825	1.835	3,5	2.533	238	9,4
1994	78.746	2.646	3,4	4.676	336	7,2
1995	42.639	998	2,3	1.907	172	9
1996	58.502	1.057	1,8	3.405	177	5,2
1997	62.726	1.785	2,8	3.384	238	7
1998	66.321	1.453	2,2	3.698	222	6
1999	48.444	1.193	2,5	3.228	229	7,1
2000	43.637	1.786	4,1	2.839	185	6,5
Total	1.227.171	31.721		50.718	5.857	

Source: Servicio Nacional de Salud Animal, Paraguay (Senacsa) apud Baumgarten (2002)

## Countries where the epidemiological situation of brucellosis and tuberculosis in cattle is properly characterized

This group is composed of four countries: Chile, Uruguay, Argentina, and Brazil, which amount to nearly 80% of the cattle population in South America (Table 1). The detailed situation in each country is described below.

### Chile

On its website, the Chilean Agricultural and Livestock Service (SAG) regularly publishes detailed reports of its program for the eradication of cattle brucellosis. The latest report covered the year 2015 (SAG, 2016). The country is divided into four regions in relation to the epidemiological situation: the area of absence of the disease in the desert region of the North and, going towards the South, the area of sporadic occurrence, the endemic area and the free zone. Chile operates a system of surveillance for the detection of infected herds in order to convert them into free herds based on five components: (1) detection of antibodies in milk; (2) detection of antibodies in the serum of animals in slaughterhouses; (3) serologic tests in animals of cattle fairs; (4) investigation of complaints/notifications of abortion syndrome; and (5) investigation of all positive serological results reported by official and private services.

In 2015, the surveillance activities for the detection of brucellosis-infected herds in Chile involved the detection of antibodies in milk at 3,957 properties and investigation of abortion syndrome in 116 farms. In addition, 128,553 animals were tested in slaughterhouses, 374,117 animals at cattle fairs, and 7,884 animals directly at properties. All efforts resulted in the detection of 31 new infected herds in that year. Figure 7 depicts the performance of the eradication program in Chile from 2006 to 2015.

The SAG performed an extensive data analysis of the occurrence of bovine tuberculosis between 2000 and 2014, involving 9.4% of the farms and 23% of the cattle population of the country in order to characterize the epidemiological situation of the disease. These data, available on the institution website (SAG, 2014), indicated that the disease is primarily more prevalent in regions of Atacama, Coquimbo, Valparaíso, Metropolitan, Biobío, Los Lagos, and Magallanes. In addition, the proportion of infected herds increases according to the size of the herd (Table 13). The result of this study was the foundation for improving the sanitary management of the problem, which was initiated in late 2011 with the launch of the Chilean National Program to combat bovine tuberculosis.

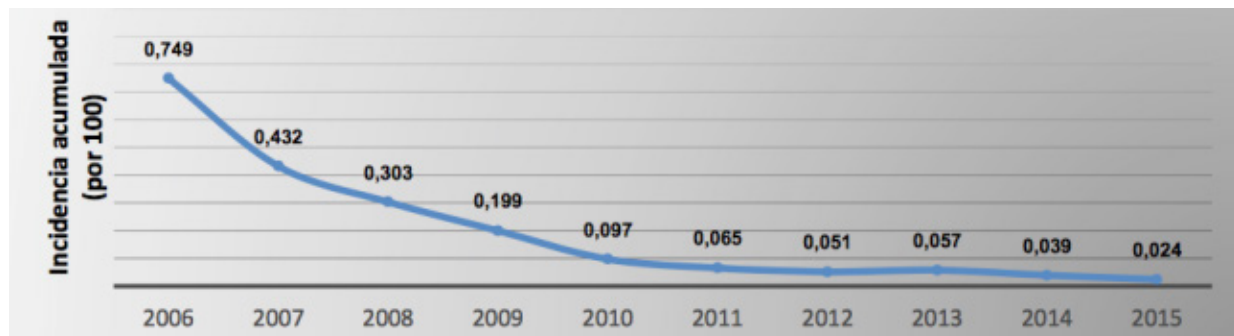


Figure 7 – Incidence of bovine brucellosis-infected herds in Chile from 2006 to 2015

Source: SAG (2016)

Table 13 – Proportion of bovine tuberculosis-infected herds according to the herd size in Chile – 2000-2014

Herd Size (N. Cattle)	Tested Herds	Infected Herds	Proportion (%)
< 5	2.596	204	7,9
5 to 10	2.017	26	1,3
11 to 30	3.262	137	4,2
31 to 100	1.983	193	9,7
101 to 300	1.178	192	16,3
> 300	697	207	29,7
Total	11.733	959	8,2

Source: adapted from SAG (2014)

## Uruguay

The prevalence of infected herds and positive animals for bovine brucellosis in Uruguay was estimated at 0.7% and 0.04%, respectively (GARIN, 2011). Regarding bovine tuberculosis, the same author reported 0.01% of carcasses with suggestive lesions being condemned at slaughterhouses.

An interesting report on the situation of brucellosis and tuberculosis in cattle in the country, prepared by the General Directorate of Livestock Services (Dirección General de Servicios Ganaderos), is available on the website

of the Uruguayan Ministry of Livestock, Agriculture and Fisheries (URUGUAY, 2015).

Approximately 1.8 million samples were processed in the brucellosis surveillance system routine in 2015. These led to the identification of 1,188 infected animals and the detection of 99 new infected herds. Figure 8 depicts a historical series of the incidence of infected herds by brucellosis in Uruguay.

Table 14 shows the performance of the surveillance system for bovine tuberculosis, showing the state location of the new infected herds detected in Uruguay in 2015.

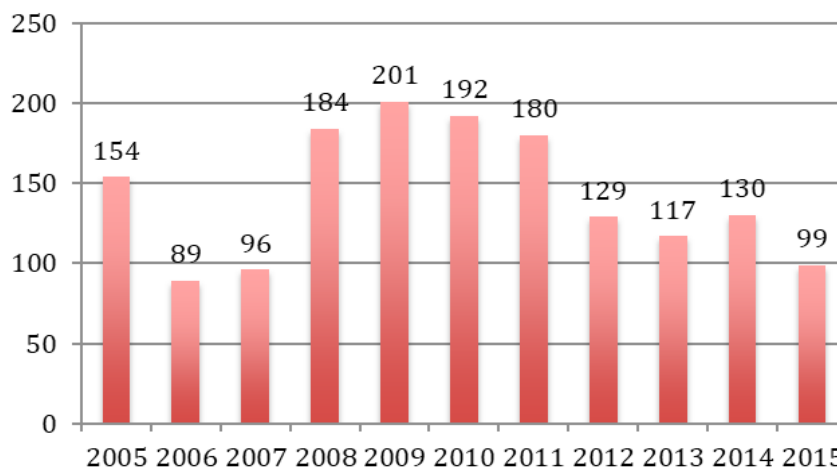


Figure 8 – Incidence of bovine brucellosis-infected herds in Uruguay from 2005 to 2015

Source: Uruguay (2015)

Table 14 – Incidence of bovine tuberculosis-infected herds in Uruguay in 2015 according to states

State	Number of Infected Herds Detected
Colonia	2
Durazno	3
Canelones	2
Florida	8
Paysandú	5
Rio Negro	2
Rocha	1
San José	2
Flores	1
Total	26

Source: Uruguay (2015)

## Argentina

In 2004, the Official Veterinary Service of Argentina (Senasa) performed a national study on the epidemiological situation of bovine brucellosis. In total, 18,471 adult females aged over 2 years, originating from 1,847 herds, were tested. The prevalence of infected herds was estimated at 12.5% (10.9-14.0%) and the prevalence of animals at 2.1% (1.9-2.4%)

(SOTA, 2006; AZNAR et al., 2014). Ten years later, Senasa published a report on a second nationwide study (30,508 animals from 810 herds were tested), which estimated the prevalence of infected herds at 12.35% (10.1-14.6%) and the prevalence of animals at 0.81% (0.56-1.05%) (SENASA, 2014). In conclusion, it was reported that there was a decrease only in the prevalence of animals, from 2.1% to 0.81%, between 2004

and 2014, whereas the prevalence of infected herds remained at around 12%. Table 15 and figure 9 depict data from the 2014 study (SENASA, 2014) indicating a heterogeneity in the prevalence of bovine brucellosis between provinces.

The indicator that Argentina uses to monitor the epidemiological situation of bovine tuberculosis is carcass

condemnation at slaughterhouses. Table 16 summarizes the frequency of these condemnations and indicates a decreasing trend since 1970 (TORRES, 2015). Table 17 shows that the disease is mainly concentrated in the provinces of La Pampa, Santa Fe, Buenos Aires and Cordoba (TORRES, 2015).

Table 15 – Prevalence of bovine brucellosis in Argentina, according to provinces

Province	Animals			Herds		
	Tested	Positive	Prevalence	Tested	Positive	Prevalence
Buenos Aires	10.265	105	1,02	263	39	14,83
Chaco	2.510	16	0,6	69	8	11,59
Córdoba	2.651	29	1,09	70	9	12,86
Corrientes	2.697	12	0,4	71	8	11,28
Entre Ríos	3.617	18	0,5	105	13	12,38
Formosa	1.290	17	1,32	37	5	13,55
La Pampa	1.709	4	0,23	42	3	7,14
Salta	719	3	0,42	23	3	13,04
San Luis	1.188	2	0,17	30	2	6,67
Santa Fe	2.993	37	1,24	78	7	8,97
Santiago del Estero	869	3	0,35	22	3	13,64
Total	30.508	246	0,81	810	100	12,35

Source: Senasa (2014)

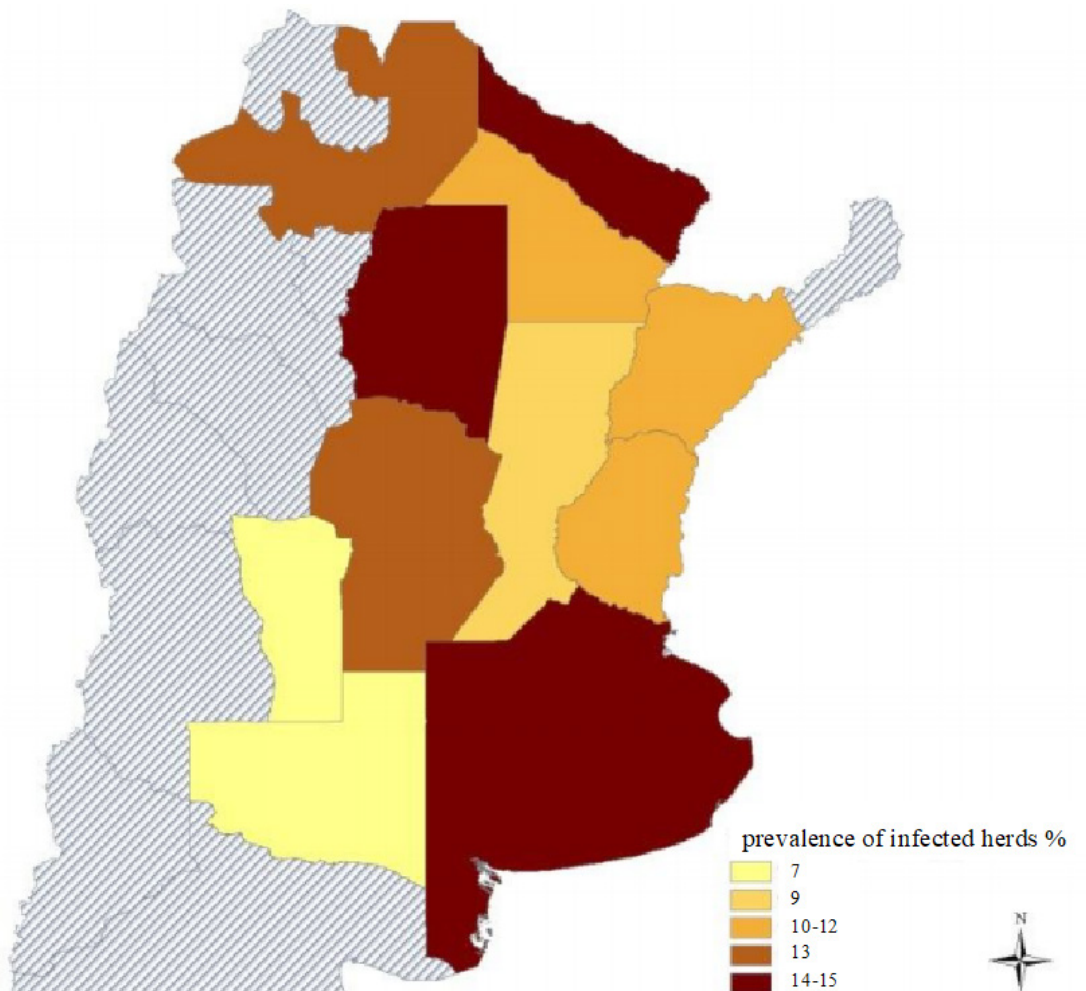


Figure 9 – Prevalence of bovine brucellosis-infected herd in Argentina, according to provinces

Source: Senasa (2014)

Table 16 – Frequency of cattle condemnation because of tuberculosis in slaughterhouses in Argentina from 1970 to 2015

Year	Slaughtered	Btb Condemned	%	Year	Slaughtered	Btb Condemned	%
1970	8.462.000	569.640	6,7	1993	10.283.000	306.322	3,1
1971	6.242.000	362.126	5,8	1994	10.266.393	281.873	2,7
1972	7.054.000	490.783	6,9	1995	10.100.398	223.688	2,2
1973	6.548.000	420.500	6,4	1996	10.550.624	204.004	1,9
1974	6.748.000	402.876	6	1997	10.787.815	211.009	1,9
1975	8.550.000	424.383	4,9	1998	9.480.492	170.002	1,8
1976	9.907.000	603.540	6	1999	10.432.710	162.000	1,6
1977	10.69.000	600.815	5,6	2000	10.729.451	146.990	1,4
1978	12.277.000	630.839	5,1	2001	9.777.846	135.000	1,3
1979	11.733.000	582.357	4,9	2002	9.494.021	133.326	1,4
1980	12.277.000	475.889	4,5	2003	10.246.477	124.000	1,2
1981	11.733.000	483.023	4,2	2004	12.017.667	147.201	1,2
1982	9.557.000	426.727	4,5	2005	12.018.251	140.840	1,2
1983	8.751.000	384.358	4,4	2006	11.205.407	114.717	1
1984	9.467.000	367.612	3,8	2007	12.375.477	124.998	1
1985	10.603.000	400.936	3,8	2008	12.205.828	110.579	0,9
1986	10.897.356	425.284	3,9	2009	13.483.515	116.798	0,9
1987	10.089.671	440.352	4,4	2010	9.692.930	91.838	0,9
1988	9.652.625	298.836	4,2	2011	9.034.220	57.808	0,6
1989	9.783.936	365.096	3,8	2012	9.258.541	28.106	0,3
1990	10.280.981	475.000	3,5	2013	10.140.582	36.965	0,4
1991	10.620.575	339.417	3,3	2014	9.984.170	32.110	0,3
1992	10.134.642	317.512	3,1	2015	12.428.614	24.909	0,2

Source: Torres (2015)

Table 17 – Frequency of herds with cattle condemned because of tuberculosis in slaughterhouses in Argentina, according to provinces

Provinces	Total of Herds	Infected Herds	%
Buenos Aires	60.322	2.268	3.7
Catamarca	5.322	5	0.09
Chaco	30.981	386	1.2
Chubut	2.717	0	0
Cordoba	24.776	907	3.6
Corrientes	28.704	108	0.4
Entrerios	37.461	392	1.04
Formosa	16.448	137	0.8
Jujuy	3.571	6	0.2
La Pampa	10.646	1516	14.2
La Rioja	3.791	1	0.02
Mendoza	4.237	11	0.3
Misiones	7.879	1	0.01
Neuquen	2.680	0	0
Rio Negro	4.442	29	0.6
Salta	15.026	32	0.21
San Juan	758	0	0
San Luis	9.330	79	0.8
Santa Cruz	425	1	0.2
Santa Fe	31.461	1751	5.6
Santiago del Estero	14.863	131	0.9
Tierra Fuego	64	0	0
Tucuman	3.552	16	0.5
Total	319.721	7.777	2.4

Source: Torres (2015)

**Brazil**

Brazil launched a national program of control and eradication of brucellosis and tuberculosis in cattle in 2001. Ever since, the country has been investigating the epidemiological situation of both diseases to define strategies and manage processes (LAGE et al., 2006). These investigations are performed through cross-sectional studies based on a partnership between the Department of Animal Health of the Ministry of Agriculture, Livestock and Food Supply, the official veterinary services of the states, and the Collaborating Center for Animal Health of the College of Veterinary Medicine and Animal Science of the University of São Paulo.

Regarding bovine brucellosis, 18 states have been investigated to date, which amount to 85% of the cattle population in Brazil, indicating significant differences within states (regional differences) and between states. The results indicated a prevalence of infected herds ranging from 0.32% (state of Santa Catarina) to 41.5% (state of Mato Grosso do Sul) (ALVES et al., 2009; AZEVEDO et al., 2009; CHATE et al., 2009;

DIAS et al., 2009a, 2009b; GONÇALVES et al., 2009a, 2009b; KLEIN-GUNNEWIEK et al., 2009; MARVULO et al., 2009; NEGREIROS et al., 2009; OGATA et al., 2009; ROCHA et al., 2009; SIKUSAWA et al., 2009; SILVA et al., 2009; VILLAR et al., 2009; BORBA et al., 2013; ALMEIDA et al., 2016; CLEMENTINO et al., 2016). Approximately ten years after the first study, eight states repeated the same investigation. Of these, seven studies aimed at verifying the effectiveness of their vaccination programs (ANZAI et al., 2016; BARDDAL et al., 2016; BAUMGARTEN et al., 2016; DIAS et al., 2016a; INLAMEA et al., 2016; LEAL FILHO et al., 2016; OLIVEIRA et al., 2016; SILVA et al., 2016b). In only four of these studies was it possible to verify the reduction of the disease prevalence following well-structured vaccination programs (Table 18).

Figure 10 depicts the results of the first studies conducted by the states, and figure 11 depicts the latest situation, including the decrease in prevalence achieved by four states because of effective implemented vaccination programs.

Table 18 – Reduction of the prevalence of bovine brucellosis-infected herds in Brazilian states as a consequence of effective vaccination programs

State	First Study			Second Study		
	Year	Prevalence (%)	IC95% (%)	Year	Prevalence (%)	IC95% (%)
Mato Grosso do Sul	1998	41,5	36,5 - 44,7	2009	30,6	27,4 - 34,0
Minas Gerais	2002	6,04	4,98 - 7,10	2011	3,59	2,76 - 4,42
Mato Grosso	2003	41,2	38,0 - 44,4	2014	24	21,3 - 26,8
Rondônia	2004	35,18	32,09 - 38,36	2014	12,3	10,3 - 14,6

Source: Ferreira Neto et al. (2016)

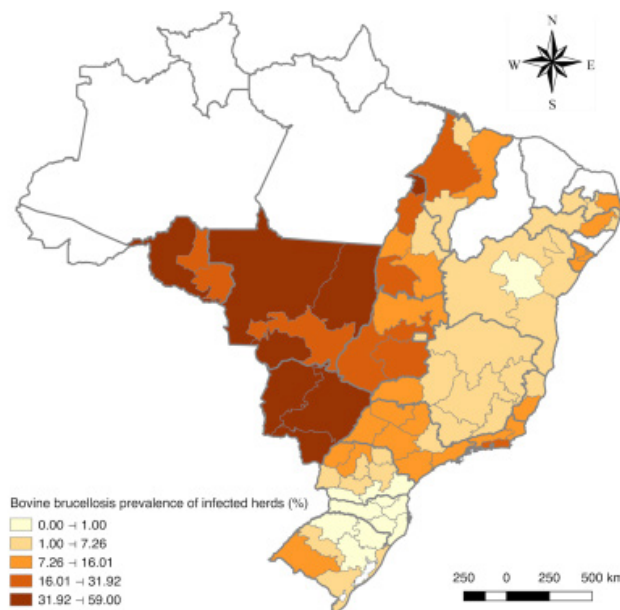


Figure 10 – First studies on the prevalence of bovine brucellosis-infected herds in Brazil

Source: Ferreira Neto et al. (2016)

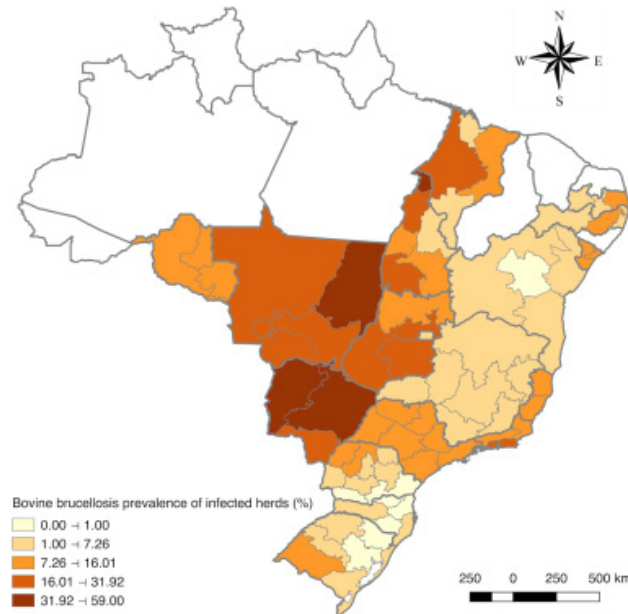


Figure 11 – Latest studies on the prevalence of herds infected with bovine brucellosis carried out in Brazilian states, showing the effect of the vaccination programs lowering the prevalence in some regions respect Figure 10

Source: Ferreira Neto et al. (2016)

In Brazil, the epidemiological situation of bovine tuberculosis is very well characterized in 75% of the cattle population. Transversal studies indicated a prevalence of infected herds varying from 0.36% (Distrito Federal) to 9% (state of São Paulo), and a prevalence of animals ranging from 0.035% to 1.3% in the same states. Furthermore, the disease was more prevalent in high-production dairy farms and the major risk factor was the introduction of animals without testing. Figure

12 indicates a higher prevalence in the state of Espírito Santo, north of São Paulo, south of Minas Gerais, and southern Goiás, coinciding with the milk-producing belt in Brazil (BAHIENSE et al., 2016; BARBIERI et al., 2016; DIAS et al., 2016b; FERREIRA NETO et al., 2016; GALVIS et al., 2016; GUEDES et al., 2016; LIMA et al., 2016; NÉSPOLI et al., 2016; QUEIROZ et al., 2016; RIBEIRO et al., 2016; ROCHA et al., 2016; SILVA et al., 2016a; VELOSO et al., 2016; VENDRAME et al., 2016).

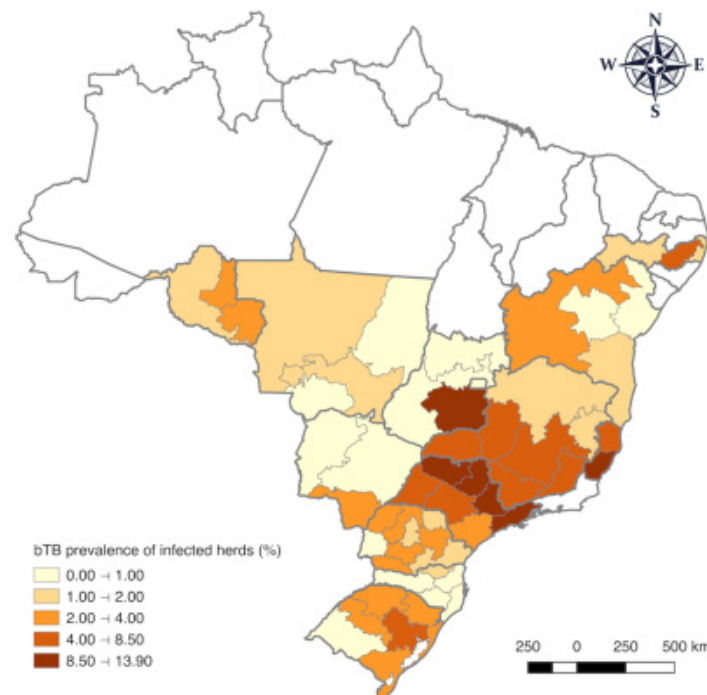


Figure 12 – Prevalence of bovine tuberculosis-infected herds in Brazil

Source: Ferreira Neto et al. (2016)

## Conclusions

For the epidemiological situation of both diseases, the main conclusions were condensed into topics.

### Brucellosis:

- the situation is heterogeneous among countries and most of them also feature internal heterogeneities;
- Chile and Uruguay are running eradication strategies. The countries have very low prevalence and the program information is well documented and easily accessible;
- Argentina has a moderate prevalence and information about the program is available;
- Colombia is developing a process of accreditation of free herds and free areas, and maintains updated information on the official websites, but the prevalence of the disease in the country is not well characterized;
- the epidemiological situation of the disease in Brazil is well described in 85% of cattle population, though it is very uneven amongst states and regions, and vaccination programs implemented by states have produced encouraging results;
- in other countries, the domestic situation is also heterogeneous and national studies are necessary to properly plan the disease control and eradication.

### Tuberculosis:

- the disease is associated with larger intensive dairy farms and the epidemiological situation among countries is quite different;
- Uruguay presents a very low prevalence and is running the eradication phase, with well-documented and available information;
- Chile and Argentina are running surveillance systems, but the prevalence is still high, especially in Chile and in certain regions of Argentina;
- Colombia is developing a process of accreditation of free herds, but the disease situation is not properly characterized in the country;
- the epidemiological situation of the disease in Brazil is well described in 75% of cattle population, with very low prevalence in beef production regions and higher in dairy basins;
- in other countries, the internal situation seems to be quite heterogeneous and national studies are essential to properly plan the disease control and eradication.

## Final remarks

The information on the epidemiological situation of brucellosis and tuberculosis in cattle has been presented herein because it is vital to successful control and eradication programs. Countries that do not generate high-quality quantitative epidemiological data on these diseases have serious limitations for outlining strategies. Moreover, they are unable to perform the management of processes, which is essential to measure the effectiveness of actions implemented so that they can be modified or corrected whenever necessary.

These data, basically represented by the prevalence of infected herds and animals, may be obtained by well-planned cross-sectional studies in order to capture regional heterogeneity, or by data generated from well-structured surveillance system routines. It must be pointed out that the prevalence of infected herds is the most relevant indicator, as the herds, properties, or farms, but not the animal, are the epidemiological units of interest to either control or eradicate brucellosis or tuberculosis in cattle.

Although bovine carcass condemnation because of tuberculosis at slaughterhouses is often used as an indicator of prevalence, it must be highlighted that it would be important to confirm the etiology the lesion in laboratory, preferably by isolation and identification of the *Mycobacterium bovis* (bTb), considering that the positive predictive value of the macroscopic inspection for the diagnosis of bovine tuberculosis tends to be low in accordance with the low prevalence that the disease usually presents in areas where extensive farming is predominant (GRISI-FILHO et al., 2011). Furthermore, illegal slaughtering represents a problem for the quantification of tuberculosis in cattle population, because it is conducted without official inspection and subsequent registration of the number of slaughtered and bTb condemned animals.

Regarding bovine brucellosis, which provides vaccines to reduce the prevalence at a low cost, the vaccination coverage is frequently used as an indicator of performance of the program. However, calculating it is not trivial, considering the difficulty of accurately estimating the vaccinateable population, as well as the vaccinated population (KURODA et al., 2016). A correct estimate of the vaccinateable population depends on high-quality cadastral data, and the vaccinated population is often overrated because fraud in the issuance of certificates of vaccination is not unusual. Thus, well planned cross-sectional studies, performed



at strategic moments, are an efficient way to verify if the vaccination produced the expected result, i.e., the decrease in prevalence.

The number of properties certified as free is also often used as a program performance indicator. Nonetheless, it is overrated as a management tool because it does not quantify the prevalence or incidence of infected herds, i.e., it does not provide knowledge on whether the implemented strategies result in a decrease in infected properties. Aggressive strategies of testing and euthanasia, which form the foundation of the accreditation of free herds, make much more sense when implemented in infected herds

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detected by surveillance systems, notably when fully or partially funded by the state.

To conclude, it is only possible to manage the programs for the control and eradication of brucellosis and tuberculosis in cattle if there are well defined and efficient mechanisms to quantify them in populations, using appropriate methodologies to estimate the prevalence of infected herds.

## Acknowledgments

The author thanks Dr. Cássia Yumi Ikuta for her assistance with the bibliographic research.

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