

## Research Article

# Spatial Distribution of Tuberculosis and Socioeconomic Inequalities in Cochabamba, Bolivia

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### Abstract

**Background:** Through their associations with the incidence of tuberculosis, socioeconomic variables contribute to the burden and the spread of the disease, especially in developing countries. Because there is no such data in Bolivia, we conducted an ecological study to evaluate the spatial distribution of tuberculosis and its relationship with socioeconomic determinants in the Department of Cochabamba.

**Methods:** Incidence of tuberculosis was computed from the 2016 data reported from the Tuberculosis Control Program and the socioeconomic indicators were retrieved from the Bolivian Population and Housing Census of the National Institute of Statistics conducted in 2012 at the municipality level. Incidence rates were standardized by age and were mapped to visualize the spatial distribution. Pearson correlation coefficients were used for associations.

**Results:** The spatial distribution of tuberculosis showed a high incidence in the Tropical Region with 163 cases/100,000. The Metropolitan Region showed a lower incidence of 52 cases/100,000 and the Valleys, Southern Cone and Andean Regions showed an ever lower incidence, with 26 cases/100,000. In the Tropical Region where there was a high incidence in all five municipalities, there was a negative correlation with school attendance ( $r=-0.46$ ) and a positive correlation with population density ( $r=0.62$ ). In the Metropolitan Region presented with medium incidences, a positive correlation with population density was observed ( $r=0.52$ ) across de 8 municipalities. In the joint analysis of the 34 municipalities of the Regions Andean, Southern Cone and Valleys having the lowest incidences, a quite low correlation was observed with all socioeconomic variables. In all regions, a moderate to highly positive correlation was observed with the variable “not be owner of its housing”: Tropical Region ( $r=0.65$ ), Metropolitan Region ( $r=0.82$ ) and Valleys, Southern Cone and Andean Regions ( $r=0.51$ ).

**Conclusions:** The pattern of the distribution of the incidence of tuberculosis showed a high incidence in all areas of the Tropical Region. Each of the 3 regions had its own socioeconomic variables associated with tuberculosis incidence but the variable “not be owner of its housing” was however positively associated with TB incidence in all regions.

**Keywords:** Tuberculosis; Space distribution; Socioeconomic determinants; Correlation

**Abbreviations:** TB: Tuberculosis; HIV/AIDS: Human Immunodeficiency Virus/ Acquired Immune Deficiency Syndrome

### Background

Tuberculosis is a neglected disease. It is the ninth leading cause of death in the world and the principal cause of death due to an infectious disease, including overcoming HIV/AIDS [1]. In 2016, an estimated 10.4 million people developed the disease and there were 1.3 million deaths. The majority of incident cases

occurred in developing countries. In the Americas' region in 2016, the incidence rate was 27 cases/100,000 inhabitants. However, in South America, Bolivia ranked second in the incidence of TB, with a rate of 114 cases/100,000 inhabitants [2]. In Cochabamba, the incidence of tuberculosis in 2016 was 60 cases/100,000 inhabitants, according to data from the Tuberculosis Control Program of the Bolivian Departmental Health Service.

The department of Cochabamba is located in the centre of Bolivia and shares borders with six out of eight departments in this country. It is the third largest department, and its estimated population in 2016 was 1,915,621 inhabitants [3]. About two third (68%) of this population live in urban areas and 32% in rural areas. Cochabamba is a department with great geographical contrasts and a great diversity of ecosystems. There are 47 municipalities grouped in five regions, each one having unique features [4].

The Bolivian health system is made up of three sectors: the public sector, the private sector and the social security sector. The levels of medical care are organized in a pyramid type model with first, second and third level of care. The Tuberculosis Control Program that carries out the free diagnosis and treatment of this disease is implemented in the public health system. In other words, any person with suspected pulmonary or extra pulmonary tuberculosis should be diagnosed and should begin treatment in the public health service network. Likewise, in Bolivia, all people after birth receive the BCG vaccine against tuberculosis, which is specially focused on avoiding serious cases of tuberculosis such as meningal tuberculosis.

In recent years, social policies oriented to the poor and rural areas were developed in Bolivia also, but in 2014 the moderate poverty that represents the people living on less than two dollars a day was 39%, the Gini coefficient was 0.47 [5] and the rural municipalities still had bad socioeconomic indicators [6]. Poverty, malnutrition, poor sanitation, high population density, acquired immunodeficiency syndrome and population aging are currently some of the factors involved in the spreading and severity of tuberculosis [7,8].

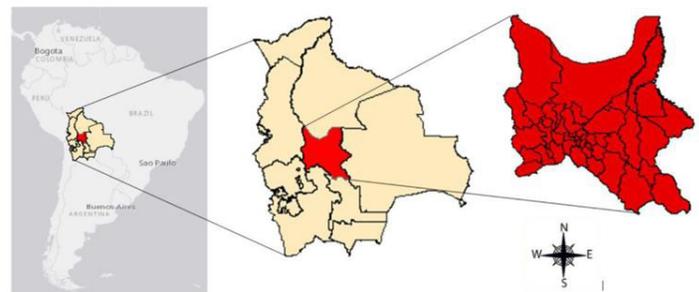
Besides the contact with patients with smear-positive tuberculosis, the probability for an individual to be infected and to develop the disease depends on several factors, such as socioeconomic conditions but also on the existence of comorbidities, particularly immunosuppressive ones like HIV [7]. Associations between incidence of tuberculosis and socioeconomic variables have been pointed in several studies, contributing to the heavy disease burden observed in the so-called developing countries [7,9-13]. The objective of the present study was to assess the spatial distribution of the incidence of tuberculosis and its socioeconomic determinants in Cochabamba, Bolivia.

## Material and Methods

An ecological study was conducted in Cochabamba to assess the association between the incidence of tuberculosis in 2016 and the socioeconomic indicators. These indicators were retrieved from the last census conducted in Bolivia, the Censo de Población y Vivienda (Population and Housing Census) in 2012. The data obtained from the census were aggregated at the municipal level, so the unit of analysis was the municipality.

## Settings

The Department of Cochabamba has a total area of 67,978 km<sup>2</sup> (Figure 1). It is divided into 16 provinces and in 47 municipalities, which are grouped into five regions: Tropic, Metropolitan, Andean, Southern Cone and Valleys.



**Figure 1:** Map of South America, Bolivia and the Department of Cochabamba with its 47 municipalities.

The Tropical Region has a warm and humid climate and it represents 64% of the territory of the Department. In the seventies and eighties of the last century, it was colonized by people from the Andean area, which sought better opportunities for life. A great part of its population work for the cultivation of the coca leaf because it generates better economic incomes, even if this production is destined to the illegal production of cocaine. Likewise, the Tropical Region has reached a very important development in recent years, thanks to the fact that it was prioritized by the government's policies, probably because the Bolivian president is originated from this region and he maintain up to now his title of President of the Federation of coca producers of the tropic of Cochabamba.

The Metropolitan Region has a temperate climate. It gathers the municipality of Cochabamba as the capital of the department, jointly with other seven adjacent municipalities to this great city. This region is characterized by a high population density. In the same way, it is an urbanized region, with high levels of coverage in primary and secondary education, and basic services.

The Andean and the Southern Cone Regions have high altitudes with very low temperatures and there are characterized

by a much dispersed population with a low to very low density. They also have high levels of poverty, with few natural resources, especially due to their arid and not very fertile lands. Finally, the Region of the Valleys is a region located between the Andean and the Southern cone regions characterized by an agricultural production from a very rich and fertile soil. These last three regions have mainly indigenous inhabitants who speak the native Quechua language.

### Data Sources

The incidence of tuberculosis in each municipality was estimated from the systematic registry of new cases in 2016, provided by the National Tuberculosis Control Program. The patients who were diagnosed and started treatment against tuberculosis were taken as tuberculosis cases. Incidence rates were standardized by age using the indirect method, and using the population of the department of Cochabamba as standard, with age groups defined as zero to 4 years, 5 to 9 years, 10 to 14 years, 15 to 19 years, 20 to 39 years, 40 to 49 years, 50 to 59 years, and 60 years or over. The resulting Standardized Incidence Rates were mapped to visualize the spatial distribution of the disease.

The socioeconomic data were collected from the population and housing census. Surveys are conducted with questionnaires to families regarding issues related to education, basic services, income levels and home ownership. Such surveys are conducted each 10 years at the national level in Bolivia, and the last one was in 2012.

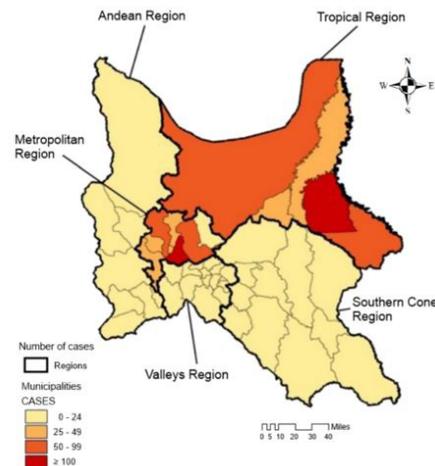
### Statistical analysis

To measure the magnitude of the relationship between the incidence of tuberculosis and socioeconomic variables, the Pearson correlation coefficient ( $r$ ) was calculated since both the dependent and the independent variables were continuous. We used the square root of the Standardized Incidence Rate as the dependent variable because incidences were very small proportions. Socioeconomic variables were standardized in Z-scores by subtracting the mean and dividing by the standard deviation. A correlation matrix was then constructed on these standardized variables. For the interpretation, values of  $r$  less than 0.40 and above -0.40 were not taken into account because of a low to very low correlation. The softwares SPSS 25.0 and ArcGis 10.4 were used for processing and analyzing data.

## Results

### Spatial distribution

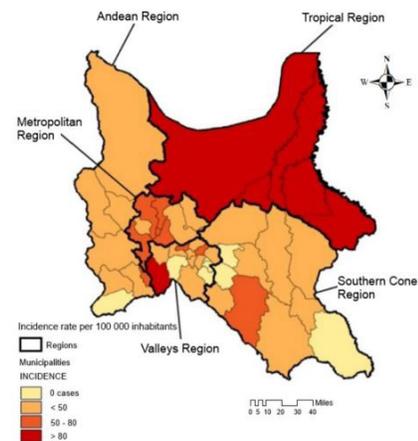
In 2016, 1150 new cases of tuberculosis were notified among the 1,915,621 people living in the Department of Cochabamba. Of this total, 87% occurred in the urban municipalities of the Tropical Region and the Metropolitan Region (Figure 2).



**Figure 2:** Spatial distribution of the number of new cases of tuberculosis in Cochabamba, Bolivia in 2016.

We observed municipalities without any cases, especially in the Regions of the Valleys, Southern Cone and Andean. In the municipality of Cochabamba within the Metropolitan Region, up to 373 new cases were registered the same year.

The global crude incidence rate during the year 2016 was 60 cases/100,000 inhabitants. The standardized rates were closed to the crude rates in all municipalities. Figure 3 shows the spatial distribution of the standardized incidence rate. After standardization, the rates showed values ranging from 0 cases in some municipalities of the Valleys, Andean and the Southern Cone regions without cases (Alalay, Bolivar, Cuchumuela, Pasorapa, Sacabamba, Tacachi, Tarata and Vacas), to 240.5 cases/100,000 people in the municipality of Puerto Villarroel within the Tropical Region.



**Figure 3:** Spatial distribution of the standardized incidence rate of tuberculosis per 100,000 populations in Cochabamba, 2016.

The visualization of the spatial pattern allowed to identify the Tropical Region as a hot spot, with five municipalities with the highest incidence rates: Villa Tunari (96.6 cases/100,000 inhabitants), Entre Rios (156.7 cases/100,000 inhabitants), Shinahota (161.2 cases/100,000 inhabitants), Chimore (162.2 cases/100,000 inhabitants) and Puerto Villarroel (240.5 cases/100,000). The municipality of Capinota (81.6 cases/100,000 inhabitants) within the Region of the Valleys had the sixth position in incidence.

Regions having municipalities with moderate incidence rates were the Metropolitan Region (Colcapirhua, Quillacollo, Sipe Sipe, Tiquipaya and Cochabamba), and even less for municipalities

in the Valleys Region (Punata and Tolata), Southern Cone Region (Mizque) and Andean Region (Sicaya).

The remaining municipalities, especially in the Valleys, Southern Cone and Andes regions, had a low incidence: Standardized Incidence Rate  $\leq 50$  cases/100,000 or even no cases.

### Socioeconomic characteristics

Table 1 shows the description of the socioeconomic variables by region. Regarding variables related to education, it can be observed that the highest percentage of illiteracy was found in the Andean Region with an average of  $16.7 \pm 4.0\%$  (mean  $\pm$  standard deviation). The lowest percentage of illiteracy was found in the Metropolitan Region with an average  $4.9 \pm 2.9\%$  (Figure 2).

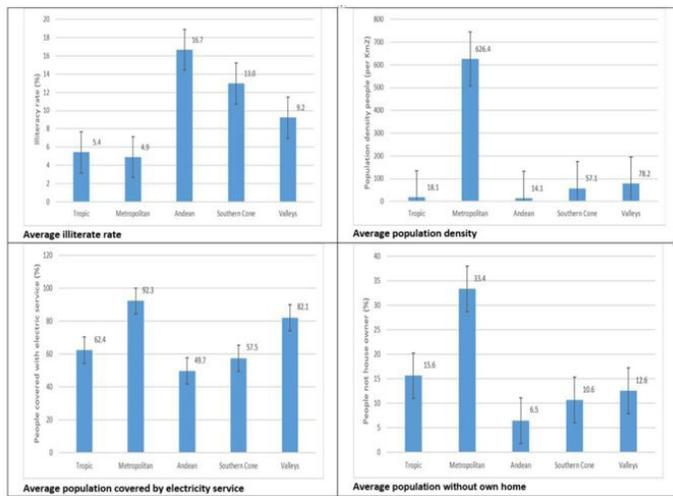
Variable	Tropical	Metropolitan	Valleys	Southern Cone	Andean
	n=5	n=8	n=15	n=11	n=8
Standardized incidence (cases/100000 p)					
Mean $\pm$ SD	163 $\pm$ 51	52 $\pm$ 14	28 $\pm$ 24	23 $\pm$ 20	26 $\pm$ 21
Median	161	55	27	29	21
Min-Max	97-241	28-71	0-87	0-53	0-64
Variables related to the field of education					
Illiteracy rate (%)					
Mean $\pm$ SD	5.4 $\pm$ 0.6	4.9 $\pm$ 2.9	9.2 $\pm$ 3.2	13 $\pm$ 4.2	16.7 $\pm$ 4
Median	5.7	3.8	8.7	12.1	16
Min-Max	4.4-5.9	2.4-11.1	5.1-17.2	7.1-20.6	10.1-23.9
School attendance rate (%)					
Mean $\pm$ SD	83 $\pm$ 0.7	89.2 $\pm$ 1.9	88.4 $\pm$ 3.5	82.6 $\pm$ 4.5	80.3 $\pm$ 3.3
Median	83.1	89.9	89.4	82.5	80.9
Min-Max	81.9-83.9	84.7-90.8	78-91.9	75.7-89.6	73.9-84.3
Variables related to the characteristics of the population					
Population density people (per Km <sup>2</sup> )					
Mean $\pm$ SD	18.1 $\pm$ 10.5	626.4 $\pm$ 917.7	78.2 $\pm$ 67.2	57.1 $\pm$ 116	14.1 $\pm$ 8.3
Median	18.1	189.3	64.6	10.2	15.6
Min-Max	6.9-31.3	18.1-2240	11.0-236.7	3.2-386.4	1.7-27
Average annual growth rate (%)					
Mean $\pm$ SD	2.7 $\pm$ 0.9	2.6 $\pm$ 1.1	0.9 $\pm$ 1.9	-0.4 $\pm$ 2	-0.3 – 2.2
Median	3.1	2.5	0.6	-0.7	-1.1
Min-Max	1.2-3.4	0.9-4.5	-2.1-5.5	-3.2-3.4	-2.5-4.6
People Speaking Local Language (%)					

Mean±SD	53.7±5.3	34.9±19.4	67.9±15.5	77.5±25.7	91.1 ±3.8
Median	54.3	29	70.9	88.3	92.9
Min-Max	46.2-60.9	17.2-75.3	42-90.9	6.9-92.9	85.7-95.2
Variables related to the coverage of basic services					
People covered with water service (%)					
Mean±SD	54.5±12.6	76.8±6.9	79.6±12.7	65.1±15.1	61.6± 17.5
Median	58.3	79.2	82.3	70.6	57.6
Min-Max	36.3-68.7	65.5-85.2	54.4-97.9	34.8-81.5	33.9-84.9
People covered with basic sanitation (%)					
Mean±SD	57.4±10.9	55.2±13.7	44.7±13.9	28.8±14.6	22.9±12.3
Median	53.6	59.7	46.1	25.5	23.1
Min-Max	44.6-72.5	32.9-71.1	20-69.7	9.5-53.6	5.9-43.8
People covered with electric service (%)					
Mean±SD	62.4±4.4	92.3±7.4	82.1±14.1	57.5±21.3	49.7±7.4
Median	64.1	93.8	86.2	62.3	50.1
Min-Max	54.7-65.4	76.1-99.4	52.5-96.6	14.7-80.9	37-58.9
People covered with service of garbage (%)					
Mean±SD	25.4±24.9	22.1±27	16.5±14.4	19.5±27.5	13.6±14.7
Median	11.9	13.8	15.5	11.8	9.4
Min-Max	8.2-66.2	0.1-71.6	0.1-42.7	0.1-63.9	0.3-44.2
Variables related to economic income					
Poor population (%)					
Mean±SD	70.2±4.9	39.1±17.2	58.2±16.2	82.5±9.5	92±4.5
Median	69	35.6	56.9	84.5	93
Min-Max	66.8-78.6	17.1-73.1	33.9-86.2	69-96.9	83.8-96.7
Non-salaried workers (%)					
Mean±SD	76.9±4.4	57.8±13	70.8±7.7	85.1±5.8	89.9±2.6
Median	76.4	54.2	69	88.1	90.2
Min-Max	71.5-83.6	10.5-45.5	45.3-87.4	74.9-92.2	84.5-92.7
People not house owner (%)					
Mean±SD	15.6±2.5	33.4±11.4	12.6±5.7	10.6± 6.7	6.5±4.2
Median	15.2	35.5	11.9	8.1	4.9
Min-Max	12.5-19.1	10.5-45.5	5.3-22.2	3.2-25.2	3-13.9

**Table 1:** Description of socioeconomic variables by region in Cochabamba, Bolivia, 2016.

The highest percentage of school attendance was observed in the Metropolitan area with an average of 89.2±1.9%. The lowest percentage of school attendance was observed in the Andean area with an average of 80.3%±2.2%. Such differences between Regions paralleled differences in illiteracy rates as illustrated on Figure 4.

Regarding characteristics of the population, the highest population density was found in the Metropolitan Region (626.4±917.7 inhabitants/km<sup>2</sup>); this region has very densely populated municipalities such as the municipality of Cochabamba together with municipalities with a low population density such as the municipality of Sacaba (Figure 4).



**Figure 4:** Socioeconomic variables in the five regions of the Department of Cochabamba, Bolivia. Average illiterate rate, Average population density, Average of the population covered by electricity service and Average of the population that does not have own house.

The highest growth rate was found in the Tropical Region with an average of 2.7% and the lowest growth rate was observed in the Andean Region with an average of -0.3%. The migration of the population remains constant from the Andean Region to the Tropical Region.

Andean region had the highest percentage of the population speaking a local native language with an average of 91.1±3.8%. The one with the lowest percentage was the Metropolitan Region with an average of 34.9±19.4%.

Regarding the variables related to the coverage of basic services, the highest percentage of population who had an electricity service coverage was in the Metropolitan Region with

an average of 92.29% and the lowest percentage was in the Andean Region with an average of 49.7% (Figure 4).

The highest percentage of population who had access to safe drinking water was in the Valley Region with an average of 79.6%, continuously and not far away was the Metropolitan Region with an average of 76.8%; the lowest percentage was found in the Andean Region with an average of 61.6%.

The largest percentage of the population covered by the basic sanitation services was in the Tropical Region with an average of 57.4% and immediately afterwards was the Metropolitan region with an average of 55.2%; the lowest percentage was found in the Andean Region with an average of 22.9%.

Garbage collection service coverage was the highest in the Tropical Region with an average of 25.4%, followed by the Metropolitan Region with an average of 22.1% and the lowest percentage was found in the Andean Region with an average of 13.6%.

Regarding variables related to the economic income, the highest percentage of house non owner people was observed in the Metropolitan Region with an average of 33.4% with a standard deviation of 11.4%, and the lowest percentage was in the Andean Region with an average of 6.5% and a standard deviation of 4.2% (Figure 4).

Andean Region had also the highest percentage of poor population with an average of 92% with a standard deviation of 4.5% and the lowest percentage was found in the Metropolitan Region with an average of 39.1% and a standard deviation of 17.2%.

Andean Region had also the highest percentage of non-salaried workers with an average of 89.9% with a standard deviation of 2.6%. The lowest percentage was found in the Metropolitan Region with an average of 57.8% and a standard deviation of 13%.

### Correlation analysis

Correlation analysis between the incidence of tuberculosis and the socioeconomic variables was computed within each region because characteristics of regions were quite different and scatter plots showed clear clusters of points, without a linear relationship. So, Tropical Region with high incidence, Metropolitan Region with a medium incidence, and the regions of the Valleys, the Southern Cone and the Andean, with low incidence and with similar characteristics, were grouped for the analysis of the socioeconomic indicators (Table 2).

		High Incidence	Median Incidence	Low Incidence
	All regions	Tropic	Metropolitan	Valleys, Andean and Southern cone
	n=47	n=5	n=8	n=34
Illiteracy rate	-0.40	0.11	-0.74	-0.01
School attendance rate	-0.04	-0.46	0.71	-0.03
Population density per Km <sup>2</sup>	0.06	0.62	0.52	-0.02
Average annual population growth rate	0.38	-0.61	0.56	0.17
People Speaking Local Language	-0.36	-0.44	-0.76	-0.09
People covered with basic sanitation	0.43	-0.36	0.16	0.30
People covered with electric service	0.06	0.85	0.81	0.18
People covered with drinking water service	-0.18	0.60	0.53	-0.01
People covered with service of garbage collection	0.23	0.81	0.07	0.08
Poor population	-0.21	-0.70	-0.81	-0.26
Non-salaried workers	-0.21	-0.66	-0.80	-0.16
People not house owner	0.39	0.65	0.82	0.51

r = Cross product correlation coefficient; no p-value because not a sampling design

**Table 2:** Correlation between standardized socioeconomic indicators and  $\sqrt{\text{incidence rate}}$  in the 47 municipalities of Cochabamba, Bolivia, 2016.

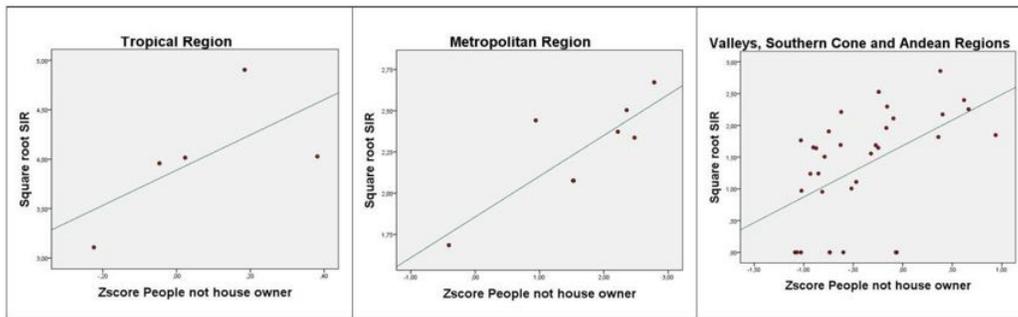
In the Tropical Region, the incidence of tuberculosis and school attendance were negatively correlated ( $r = -0.46$ ), showing that the lower the school attendance, the lower the incidence of tuberculosis. Positive correlation was observed ( $r = 0.62$ ) with the population density, the higher the population density, the higher the incidence of tuberculosis. We also observed a moderate positive correlation ( $r = 0.65$ ) with the fact that people didn't own a house; the greater the proportion of non-owner, the higher the incidence of tuberculosis.

In the Metropolitan Region, there was a positive correlation between the incidence of tuberculosis and population density ( $r = 0.52$ ). Incidence of tuberculosis was also increased in municipalities with more people. As in the Tropical Region a high positive correlation was observed with the proportion of people who were not house owner ( $r = 0.82$ ). Surprisingly, in the Metropolitan Region, there was a negative correlation between the incidence of tuberculosis and the variables that have to do with education and

basic services. Such correlating mean the lower the proportion of illiterate people and the greater the proportion of people attending school the higher the incidence of tuberculosis. Also, the greater the proportion of people with access to basic services, the higher the incidence of tuberculosis [14,15].

In the joint analysis of the regions of the Andes, the Southern Cone and the Valleys, a very low correlation between the incidence of tuberculosis and each variable was observed, except for the proportion of people who were not house owner, that showed a positive correlation ( $r = 0.51$ ). In this three regions, we also observed a higher incidence of tuberculosis where the proportion of people who were not house owner was lower.

Figure 5 shows a scatter plot of this relationship between the square root of the incidence of tuberculosis and the proportion of non-house owner in municipalities of each region.



**Figure 5:** Correlation between  $\sqrt{\text{standardized incidence rate}}$  and proportion of people non-house owner Tropical Region, Metropolitan Region and Regions of the Valleys, Southern Cone and Andean.

In the Metropolitan Region, all but one municipality had a proportion of non-house owner far above the mean of the Department. In the Tropical Region, three of the five municipalities were also above the departmental mean. Whereas in the Andean, Southern Cone and Valleys regions, only seven of the thirty-four municipalities had a proportion of non-house owners above the mean of the Department and the rest of municipalities were below.

In all regions there was an unexpected negative correlation with the two indicators related to the economic income. Incidences were higher in municipalities with less poor people and in municipalities with less non-salaried workers [16].

## Discussion

Each region of the Department of Cochabamba presents different values and characteristics regarding not only the incidence of tuberculosis but also regarding geography and per se socioeconomic variables.

Across the 47 municipalities, the incidence of tuberculosis varied from 0 to 162 cases/100,000 inhabitants but from 0 to 53 cases/100,000 in the Southern Cone Region, from 0 to 64 cases/100,000 in the Andean Region, from 0 to 82 cases/100,000 in the Region of the Valleys, from 28 to 71 cases/100,000 in the Metropolitan Region and from 97 to 162 cases/100,000 in the Tropical Region.

The distribution pattern of the incidence of tuberculosis highlighted a high incidence in the Tropical Region, a moderate incidence in the Metropolitan Region and a low incidence in the Valleys, Southern Cone and Andean Regions.

Such disparities were also reported in others studies carried out in Brazil, Rio de Janeiro [17], Victoria [18] and Campina Grande [11], however these studies were at the municipal level, using as unit of analysis the neighbourhoods, showing in many

cases also very high incidences.

With such disparities and also due to geographical and economic disparities between regions, global results at the Department level reflect different realities [19,20].

The studies noted above, as well as those reported by Munch [12] and Vendramini [13] were carried out in urban areas with high demographic density, showing a positive correlation as in our study in the Tropic Region and Metropolitan Region of the tuberculosis with population density [21].

It must be pointed out a possible underestimation of TB cases in own study. Several studies [11, 22] have reported an underestimation of incident cases linked to the poor organization of health services as well as the non-active detection of cases. The quality of the data of the Tuberculosis Control Program can be subject to variations as all health information systems in developing countries. Interpretations must therefore be careful. The relationship between the incidence of tuberculosis and socioeconomic variables was different across Regions.

However, the variable “not house owner” correlated positively with the incidence of tuberculosis in each Region. Camargo Sierra [15] also shows that this variable has a very important relationship with the economic situation of households, because people who do not have to their own home go to rental contracts in precarious conditions. According to Barcelo [16] these precarious houses are a space that works as a factor of anguish, causing multiple public health problems including tuberculosis. In the same way the precariousness of the houses is related to the overcrowding of people [7,12,18]. Therefore, a situation of overcrowding is associated with an increased risk of tuberculosis contamination, due to the greater likelihood of constant contact between people, as described by Munch [17]. The reliability of this variable is higher than indicators such as poverty or non-wage work; to be a house owner is an objective expression of quality of life.

Regarding the variables related to economic income, several studies [10,12,14] reported a relationship between the incidence of tuberculosis and economic income. These studies used variables such as annual income linked to minimum wages, income of heads of household and indicators adapted to living conditions.

In our study, none of the regions exhibited a coherent relationship between the incidence of tuberculosis and the variables related to economic income, such as the proportion of poor people or the proportion of non-salaried people. One explanation might be that these indicators used from the population and housing census, do not measure what is expected to be measured, for instance the informal economy or the barter economy are not certified in these indicators. Validity of the data may also be affected by an incorrect information provided by the interviewees, especially regarding their economic income; people are afraid of a possible intervention of the state in their resources.

## Conclusions

The pattern of the distribution of the incidence of tuberculosis showed a high incidence in all municipalities of the Tropical Region. Each region had its own socioeconomic variables associated with tuberculosis incidence. However, the variable “not having own housing” was common to all regions and was positively associated with TB incidence. The association between incidence of tuberculosis and a house owning highlights particularities of the country linked to informal or illegal economy that cannot be measured in an ecological study.

Therefore, in order to contribute to the control of tuberculosis, it would be important to carry out studies at individual levels, especially in the region where a high incidence was found, for investigating other possible factors related to the persistence of the disease [21].

This study also contributes to the Tuberculosis Control Program in providing information with respect to the spatial distribution of TB and its relationship with socioeconomic variables. In this way, it will be able to target and act in priority areas and establish epidemiological surveillance systems on a territorial basis that allows an adequate control of the disease.

## Funding

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## Availability of Data and Materials

The datasets used and analysed during the current study are

available from the corresponding author on reasonable request.

## Authors Contributions

MR was involved in the conception and design of the study, its implementation, analysis of the data, and interpretation of the findings. DI and AR participated in the drafting of the paper. JA was involved in the merging of data bases. WT participated to the analysis and the interpretation of data. All authors read and approved the final manuscript.

## Ethics Approval and Consent to Participate

The Committee of Research Ethics of the Faculty of Medicine of Universidad Mayor de San Simón approved the protocol of this study.

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