

# Spatial analysis of visceral leishmaniasis in the municipality of Rondonópolis, in the Brazilian State of Mato Grosso, from 2003 to 2012: human, canine and vector distribution in areas of disease transmission

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## ABSTRACT

**Introduction:** Visceral leishmaniasis (VL) is a zoonosis of great importance to public health and is considered a neglected disease by the World Health Organization. The disease has expanded and become more prevalent in urban areas in Brazil. **Methods:** Geospatial analyses were performed and thematic maps of the triad of the disease were produced for the study period (2003-2012) in the urban area of the municipality of Rondonópolis in the midwestern State of Mato Grosso (MT), Brazil. TerraView 4.2.2 software was used for the analyses. **Results:** A total of 87.9% of the 186 confirmed human cases of VL were cured. Children between the ages of 1 and 4 were the most affected. Registered deaths were predominant among adults aged 60 years or older. The urban area of the municipality consists of eight strata and 12 census districts include 237 neighborhoods. All sectors had confirmed cases of VL. During the study period, human cases of the disease were recorded in 90 neighborhoods. The 23 deaths from the disease were distributed in 21 neighborhoods. Sandflies carrying the parasite were captured in 192 out of 200 neighborhoods evaluated for the presence of the VL vector. The presence of dogs carrying the parasite was confirmed in, 140 out of 154 surveyed neighborhoods. **Conclusions:** The data demonstrated the endemic nature of VL, with a high percentage of infected children, a high distribution of canine infection, and a wide adaptation and dispersal of the vectors in the urban environment. These results, illustrate the process of urbanization of VL in the municipality of Rondonópolis, MT, Brazil.

**Keywords:** Visceral leishmaniasis. Epidemiology. Urbanization. Spatial analysis.

## INTRODUCTION

Visceral leishmaniasis (VL) is a disease of great importance to public health. Worldwide, an estimated 500,000 people are infected per year, and VL is responsible for 59,000 deaths<sup>(1)</sup> that result from approximately 12 million infected individuals<sup>(2)</sup>.

In Brazil, there were 48,358 confirmed cases of the disease over the past fourteen years (2000 to 2013)<sup>(3)</sup>, resulting in a mean incidence of 1.88 cases per 100,000 inhabitants<sup>(4)</sup>. The mean lethality rate was 6.65 during the same period, resulting in 3,151 deaths from VL<sup>(5)(6)</sup>.

In the midwestern Brazilian State of Mato Grosso (MT), 33.3% of the municipalities recorded cases of human visceral leishmaniasis (HVL) from 2001 to 2014. The City of Rondonópolis registered the highest number of reported cases in MT and was the only municipality classified as having intense transmission by the Federal Ministry of Health<sup>(7)</sup>.

The aim of this study was to georeference all cases of HVL in the municipality of Rondonópolis from 2003 to 2012. To classify areas at risk for active transmission of the disease, the spatial distribution of cases was verified in humans, dogs with a diagnosis of canine visceral leishmaniasis (CVL), and VL vectors (*Lutzomyia longipalpis*/*L. longipalpis* and *Lutzomyia cruzi*/*L. cruzi*) in the studied neighborhoods.

## METHODS

### Study type

This quantitative project was a descriptive, cross-sectional, epidemiological study based on data from confirmed cases of HVL collected from 2003 to 2012. The study was supported

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by secondary data from laboratory research that was focused on transmitters (vectors) and domestic reservoirs (dogs). The consolidation of the data combined with the use of geographic information systems (GISs) allowed for the construction of thematic maps of the triad of the disease and the identification of the spatial location of human cases of VL within the urban area.

### Study area

The municipality of Rondonópolis is part of the southeast mesoregion of MT and the microregion of Rondonópolis (Figure 1). Rondonópolis is located at latitude 16°28'15" South and longitude 54°38'08" west and is 215km from the state capital of Cuiabá; with an area of 4,159.12km<sup>2</sup>, it represents 0.48% of the total area of the state. The area is composed of 129.2km<sup>2</sup> of urban area and 4,029.92km<sup>2</sup> of rural area. Rondonópolis is bordered to the north by Juscimeira and Poxoréu; to the South by Itiquira; to the east by Pedra Preta, São José do Povo and Poxoréu; and to the west by Juscimeira and Santo Antônio do Leverger. The region has typical *Cerrado* vegetation, and the climate is hot, tropical and subhumid, with rains concentrated in the spring and summer. The mean annual precipitation is 1,500mm, and the mean temperature is 27°C. The urban area of

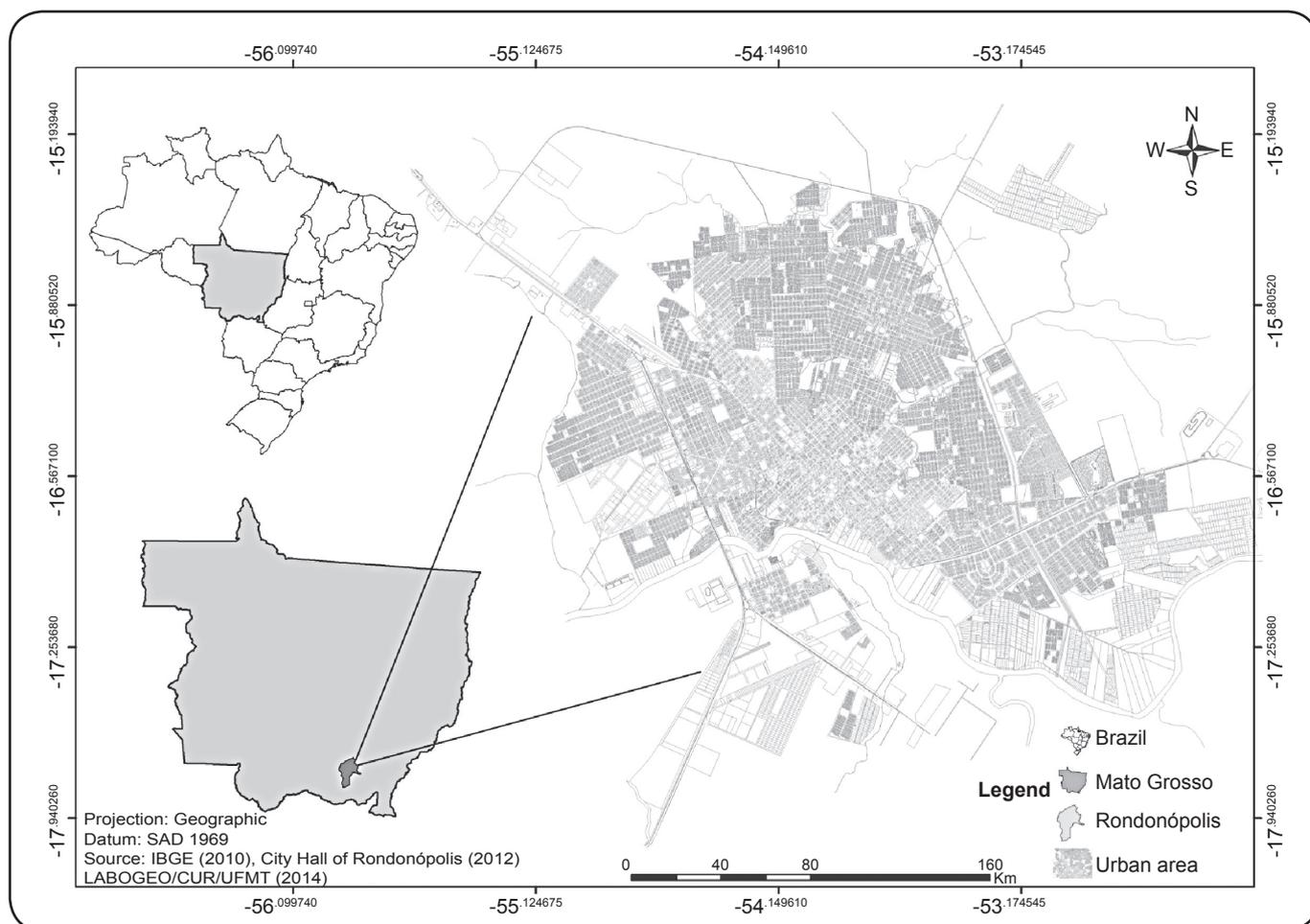
the city consists of 8 strata and 12 census districts that include 237 neighborhoods<sup>(8)</sup>.

### Study population

The study population was composed of 186 patients confirmed with HVL who were registered in the national disease notification system [*Sistema de Informação de Agravos de Notificação (SINAN-NET)*] during the period from 2003 to 2012. No cases were recorded in the municipality in 2004. In 2005 and 2006, only one case was recorded each year, but these cases were not autochthonous to Rondonópolis and were therefore not included in the study.

### Data collection

To georeference the data and to produce a location map, individual participants were preselected from the SINAN-NET records by their addresses. Secondary data on the canine reservoir and the presence of VL vectors were consolidated to produce thematic maps that classified the areas of risk and vulnerability to the transmission of the disease during the study period.



**FIGURE 1 - Location of the study area.** SAD: South American Datum; IBGE: *Instituto Brasileiro de Geografia e Estatística*; LABOGEO/CUR/UFMT: *Laboratório de Geoprocessamento/Campus Universitário de Rondonópolis/Universidade Federal de Mato Grosso*.

### Classification of risk areas for human visceral leishmaniasis

Information related to the spatial location of human cases, reservoirs and vectors was consolidated. With this information, thematic maps were produced to show the spatial distribution of human cases, classify risk areas and analyze areas of HVL vulnerability within the municipality. The definitions of transmission areas included in the Brazilian Ministry of Health's Visceral Leishmaniasis Control Program (VLCP)<sup>(9)</sup> were used for the classification of risk areas as follows: I) *Area with transmission*: area with transmission of human or canine VL. II) *Silent area or area without cases*: area with no record of autochthonous cases of canine or human VL. III) *Vulnerable area*: area with no autochthonous cases of human or canine VL but contiguous to an area with cases of VL; area also has intense migratory flow or shares a road axis of the area with cases of VL. IV) *Non-vulnerable area*: area that does not meet the criteria for being a vulnerable area. V) *Receptive area*: area with the presence of *L. longipalpis* and/or *L. cruzi*. VI) *Non-receptive area*: area where an entomological survey found the absence of *L. longipalpis* and/or *L. cruzi*.

### Data analysis

The sample households were georeferenced using a global positioning system (GPS) - Etrex-Garmin model, software version 3.50. The updated cartographic base was ceded in shape format by the Municipal Secretary of Infrastructure of the City of Rondonópolis. Geospatial analyses were performed and thematic maps were produced for the urban area of the municipality of Rondonópolis using the free software TerraView 4.2.2, a Geographic Information System (GIS) developed by the National Institute for Space Research.

Using this approach, spatialized information was produced on the disease triad, including neighborhoods with human cases, reservoirs and vectors. This approach allowed for classifications of risk areas according to the VLCP. This control program was adopted by the federal Ministry of Health with the aim of prioritizing actions in the areas of occurrence of the disease and surveillance in areas where the disease has not occurred.

### Ethical considerations

This study was evaluated by the Research Ethics Committee at Pontifical Catholic University in Goiás (number 229.558 - CAAE: 11135212.6.0000.0037). The research was initiated only after approval was received, and all principles and norms of Resolution 196/96 on research involving human subjects were followed.

## RESULTS

According to SINAN-NET records, 186 cases of HVL were confirmed during the study period; all of the cases were autochthonous. The cases had the following results: 1) 87.6% (n=163) of the cases were cured, and 2) 12.4% (n=23) of the cases resulted in death during the time period. The age group 60 years and older had the highest number of deaths, representing 43.5% (n=10) of the total.

The most affected age group was children aged 1 to 4 years; there were 54 (29%) cases in the sample, of which 52 were cured. The next most affected group was individuals aged 40 to 59 years, in which there were 34 (18.3%) cases, of which 25 were cured. The age group 20 to 39 years had 33 (17.7%) cases, of which 30 were cured.

No deaths were registered in the following age groups: less than 1 year, 18 (9.7%) cases; 5 to 9 years, 13 (7%) cases; and 10 to 19 years, 10 (5.4%) cases. The 10- to 19-year-old group recorded the lowest number of confirmed cases of the disease. The total number of cases in children younger than 10 years of age was 85 (45.7%), of which 83 were cured.

In all age groups affected by VL, cases were more prevalent in males, and there were more deaths among males compared to females. A total of 64% (n=119) of the cases occurred in males, and 60.9% (n=14) of the deaths recorded during the study period were males. People of African descent also predominated, corresponding to 64% of the individuals affected by the disease.

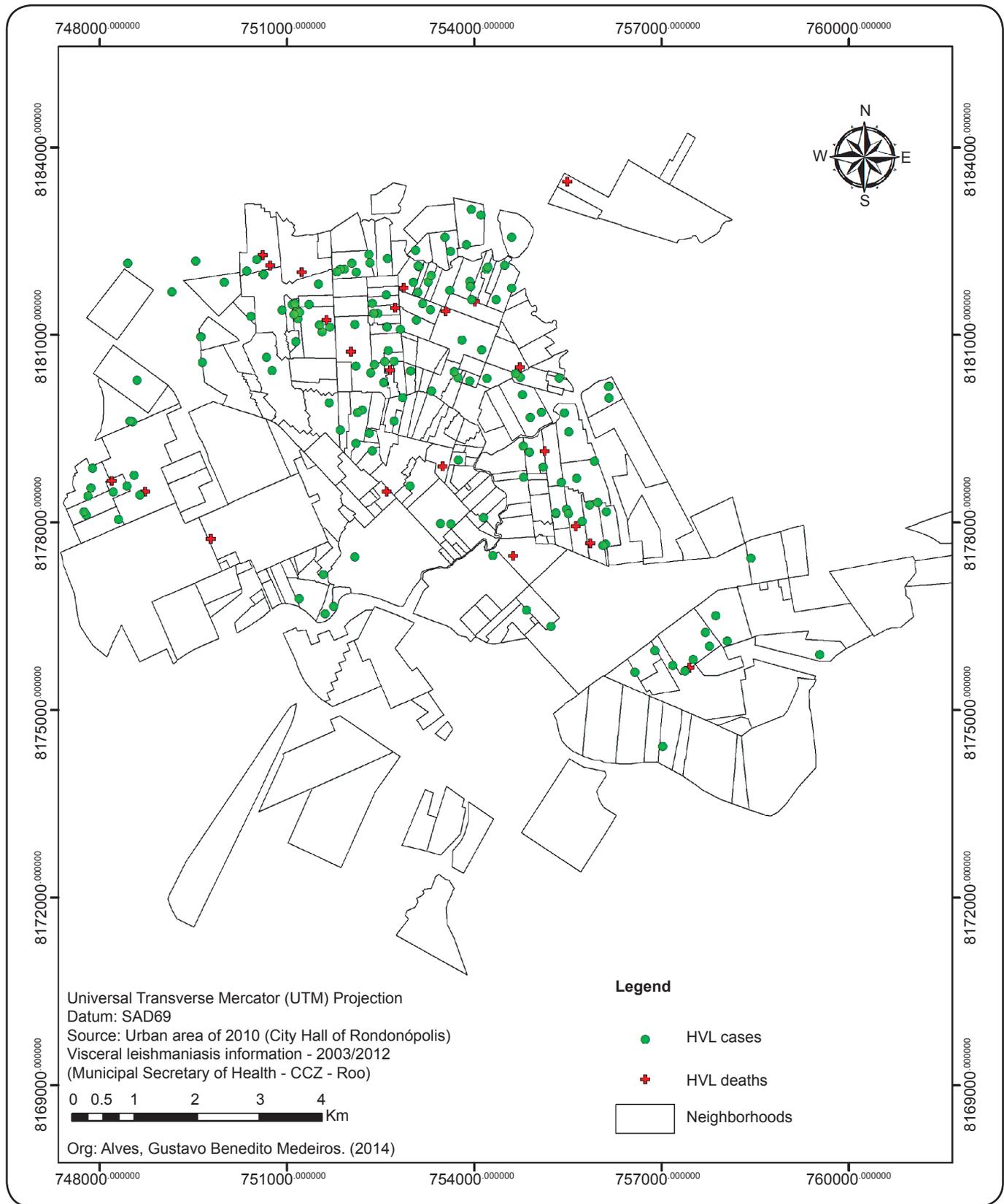
Visceral leishmaniasis is currently concentrated in the urban perimeter of the municipality of Rondonópolis. VL is widely distributed in the eight territorial strata and is present in all 12 census districts of the municipality. There were a total of 186 confirmed cases of HVL during the period 2003 to 2012. During this period, there were 23 deaths of patients diagnosed with HVL that were distributed in 21 neighborhoods. The neighborhoods Vila Operária and Núcleo Habitacional Marechal Rondon each registered two deaths.

The study georeferenced all cases of HVL during the period 2003 to 2012. **Figure 2** represents the georeferenced points of HVL cases within the urban perimeter. Human cases that were cured are represented by green circles on the spatialization map, and deaths are represented by red crosses.

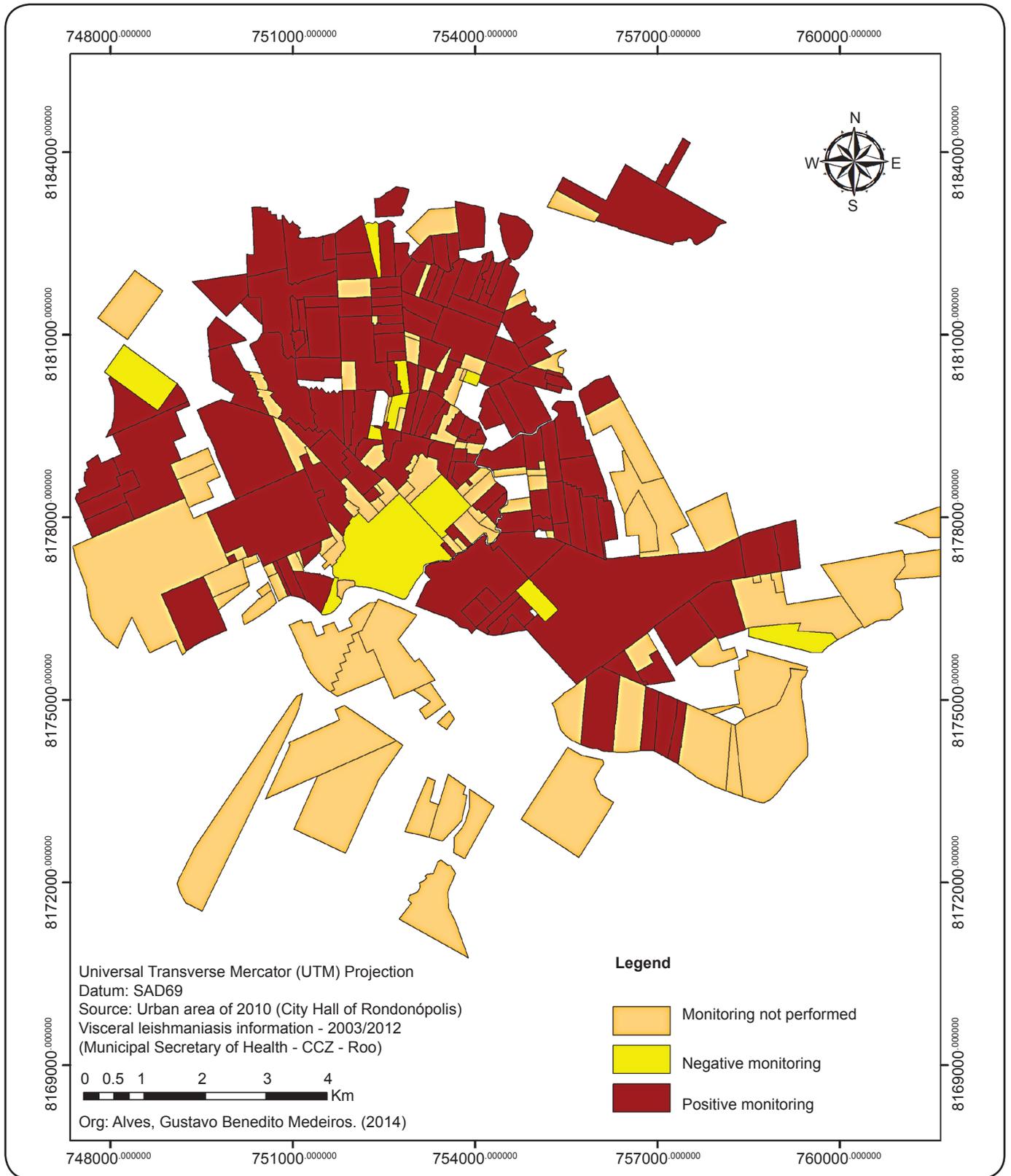
The most affected sectors were 4, 5 and 6, where 46.8% of the confirmed cases were located. CVL was detected in 140 neighborhoods, and a high prevalence of anti-leishmaniasis antibodies was detected. The year 2008 had the highest infection rate, reaching 48.5% (1,153/2,380).

Following the completion of data collection and the collection of the monthly surveillance spreadsheets from the Rondonópolis Center for Control of Zoonoses, the annual data regarding the canine reservoir during the study period were consolidated. During the period from January 2005 to December 2012, a survey of canine infection was conducted in 154 neighborhoods. Dogs with positive serology for CVL were observed in 140 neighborhoods, corresponding to 90.9% of the neighborhoods surveyed (**Figure 3**).

The species *L. longipalpis* was not identified or captured during the monitoring period (2009 to 2011). The last record of capture of *L. longipalpis* in Rondonópolis occurred in 2007. The two main vectors involved in the transmission of HVL in Rondonópolis, Brazil are *L. cruzi* and *L. longipalpis*. This information was obtained from entomological surveys performed from 2005 to 2012 by teams from the Rondonópolis Municipal Secretary of Health, the Rondonópolis Regional



**FIGURE 2 - Spatial distribution of georeferenced points of confirmed cases of human visceral leishmaniasis that were cured (green dots) or resulted in death (red crosses) located within the urban perimeter of the municipality of Rondonópolis, State of Mato Grosso, from 2003 to 2012.** SAD: South American Datum; CCZ – Roo: *Centro de Controle de Zoonoses de Rondonópolis*; HVL: human visceral leishmaniasis.



**FIGURE 3 - Distribution of neighborhoods with positive serology for canine visceral leishmaniasis within the urban perimeter of the municipality of Rondonópolis, State of Mato Grosso, from January 2005 to December 2012. SAD: South American Datum; CCZ – Roo: Centro de Controle de Zoonoses de Rondonópolis.**

Health Office, and the Central Health Office; the information was confirmed by the Entomology Laboratory of the Environmental Health Surveillance Coordination of the MT State Secretary of Health. During the study period, a total of 200 neighborhoods were surveyed for the presence of the main VL vectors; the presence of the vectors was confirmed in 192 neighborhoods, corresponding to 96% (Figure 4).

Figure 5 classifies the neighborhoods of Rondonópolis based on both the stratification of areas at risk for human and/or canine transmission and areas vulnerable for the occurrence of VL within the urban perimeter.

The spatial distribution of the disease in Rondonópolis displayed homogeneity with respect to the 186 human cases distributed in 90 positive neighborhoods/locations from a total of 237 locations in the municipality. The three census districts with the highest number of recorded cases of HVL were district 4 (30 cases), district 5 (30 cases) and district 6 (27 cases). These districts are located in the northern region of the city, where there is a high population density. Together, the three sectors accounted for 46.8% of the confirmed cases during the study period.

## DISCUSSION

The urbanization process of VL is one of the most remarkable and intriguing epidemiological transformations ever registered in Brazil. The processes that led to the urbanization of the disease are mostly unknown, but environmental changes associated with migration and unplanned urban occupation, precarious housing and sanitation conditions on the outskirts of urban areas, and malnutrition are some of the many factors involved in this phenomenon. The introduction of VL into large cities is an epidemiological reality that requires a new rationale for the surveillance and control of VL<sup>(10)</sup>.

In studies conducted by Mestre and Fontes and Botelho and Natal, the age group that was most affected by VL was also children under 10 years of age, and a predominance of males with VL was also observed<sup>(11)(12)</sup>. According to Borges, the risk of VL is 109.77-fold higher in children under 10 years of age compared to other age groups, and the risk is 2.57-fold higher in males than in females<sup>(13)</sup>.

In the present study, 119 out of 186 confirmed cases of the disease were male. Hormonal factors related to exposure to the vectors have been proposed to be responsible for the increased risk in males<sup>(14)</sup>. The predominance of males among cases was also observed in this study, thereby confirming the profile observed in other studies by other authors<sup>(15)(16)(17)(18)(19)(20)</sup>.

In Rondonópolis, the VL vectors were dispersed in 96% of the 200 neighborhoods surveyed. In entomological surveys in 2008, the predominant vector species for VL was *L. cruzi*. The number of males of this species was 5 times larger than the number of females, and this species was likely the agent that transmitted the disease in the city.

Entomological surveys in the municipality of Jaciara, MT, during a VL outbreak in 2003 found an abundance of the species *L. cruzi* and an absence of *L. longipalpis*. Deoxyribonucleic

acid (DNA) analysis showed infection of *L. cruzi* with *Leishmania chagasi*, suggesting the involvement of this species in transmitting VL in that municipality<sup>(21)</sup>.

The complete triad in the relationship among human cases, the positive reservoir (dogs) and vectors appeared simultaneously in 74 neighborhoods of the municipality of Rondonópolis, corresponding to 31.2% of the total neighborhoods. The presence of the complete human-vector-animal reservoir (positive dogs) population triad, which maintains the urban cycle of VL, is not the only determining factor in the occurrence of infection. According to the literature, factors such as the destruction of wild habitats, poor housing conditions and malnutrition also provide favorable conditions for the spread of VL<sup>(11)(22)</sup>.

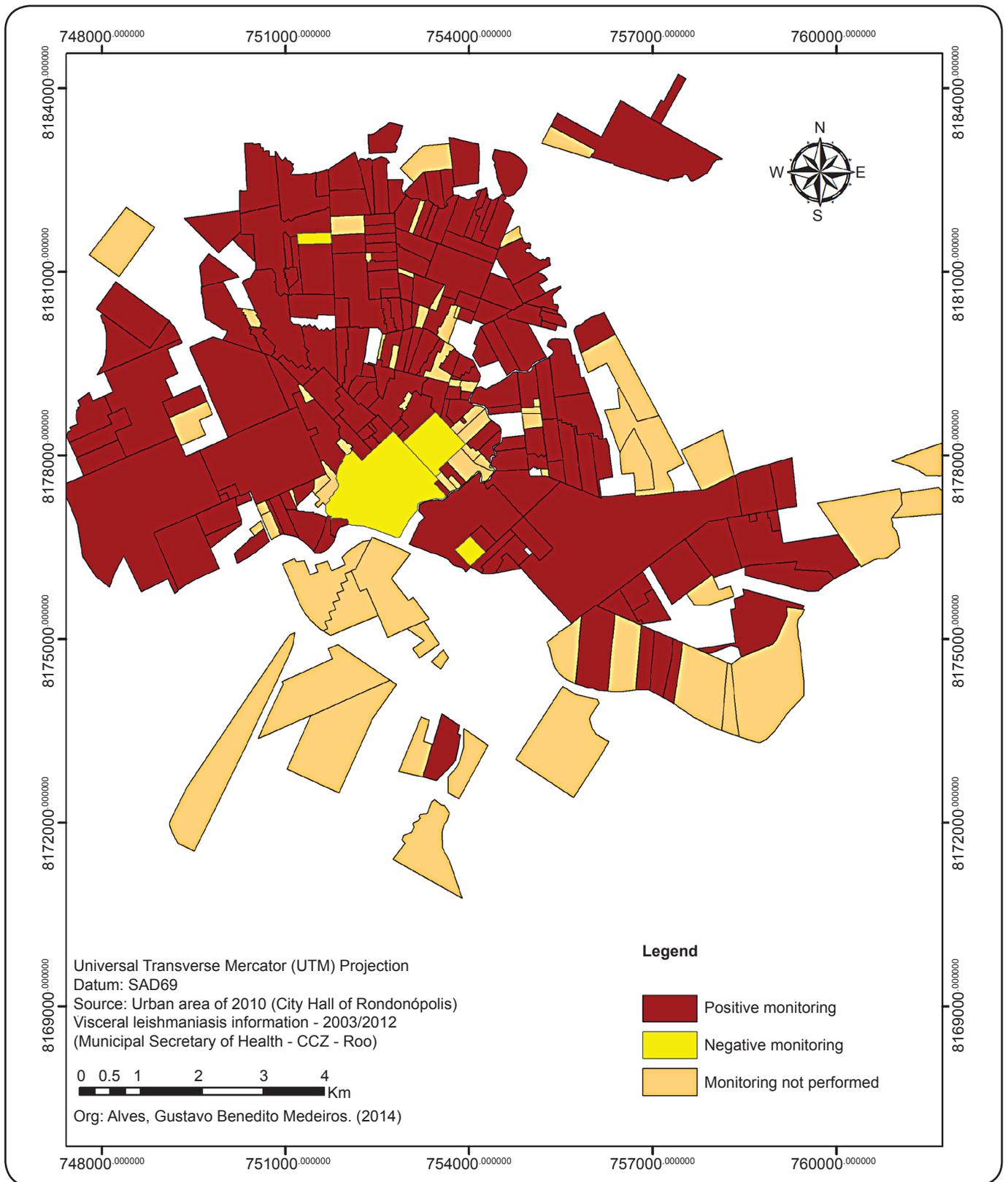
The pattern of the occurrence of VL in municipalities in the State of Mato Grosso clearly illustrates the process of urbanization of the disease. In recent decades, profound changes have occurred in the agrarian structure of Brazil that have resulted in the migration of large populations to urban centers<sup>(23)</sup>.

Using cases of HVL and the presence of infected canines and vectors, neighborhoods in Rondonópolis were classified according to their vulnerability to VL transmission. A total of 192 neighborhoods (corresponding to 96% of the surveyed areas) were considered receptive for the appearance of the VL vectors, while 8 neighborhoods (equivalent to 4% of the surveyed areas) were not receptive. Silent and vulnerable areas comprised the same percentage (38.8% each), together representing 92 neighborhoods within the urban perimeter. In this case, information about the surrounding areas that were positive for human or canine cases or shared an access road was used as a reference.

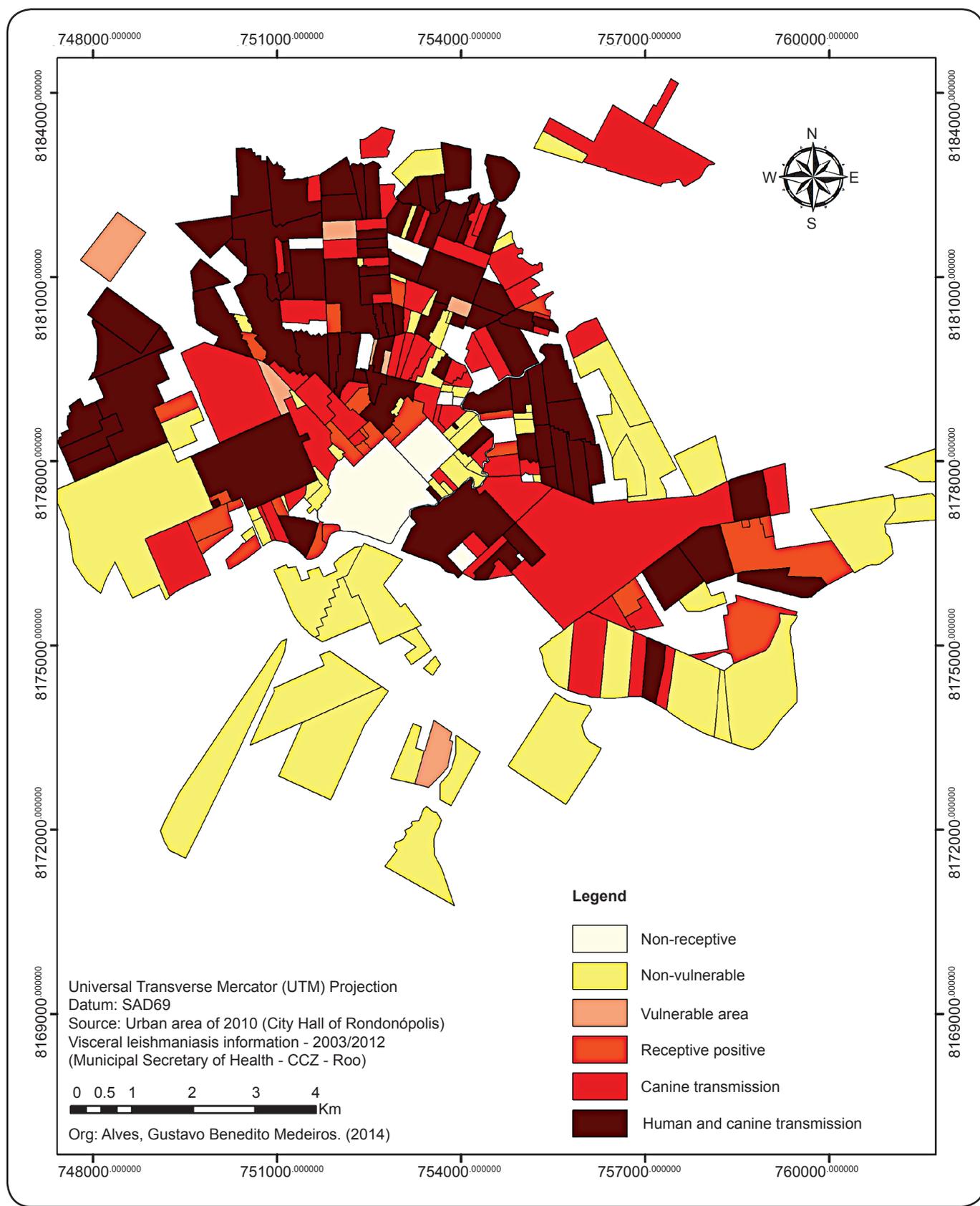
The thematic maps of the study showed a wide dispersion of human cases, positive reservoirs, and LV vectors in the urban area of the city; however, neither entomological studies nor canine surveys have been performed throughout the entire urban area of Rondonópolis, MT. The wide dispersion within the urban perimeter is especially notable during the study period. Previous studies in Brazil have suggested that CVL precedes cases of the disease in humans<sup>(17)(24)(25)</sup>.

Analysis of the available spatial data showed a wide distribution of the human strain of VL within the urban perimeter. The distribution was primarily in the northern region of the city and largely coincided with the areas with the highest population density. Georeferencing of all HVL cases within the urban perimeter enabled the construction of a thematic map that displayed the spatial location of patients who were cured or who died during the study period.

Our results demonstrate the feasibility of expanding the study prospectively to support the implementation of a Municipal GIS (GIS-VL). This approach can be used to assess the distribution of human cases, expand the environmental analysis of risk areas, and identify critical points of nosological risk of the disease in Rondonópolis. The results of such efforts can be used to support municipal planning and decision making to control the disease. The spatial distribution of data available on the triad of the disease (i.e., human cases, vectors and the animal reservoirs) in



**FIGURE 4 -** Distribution of neighborhoods with positive identification of the main visceral leishmaniasis vectors within the urban perimeter of the municipality of Rondonópolis, State of Mato Grosso, from January 2005 to December 2012. SAD: South American Datum; CCZ – Roo: *Centro de Controle de Zoonoses de Rondonópolis*.



**FIGURE 5 - Identification of neighborhoods within the transmission area in which the occurrence of human and/or canine cases and vulnerability for the transmission of visceral leishmaniasis were detected in the urban perimeter of Rondonópolis, State of Mato Grosso, from 2003 to 2012.** SAD: South American Datum; CCZ – Roo: *Centro de Controle de Zoonoses de Rondonópolis*.

the urban area of the municipality allowed for the construction of thematic maps with areas/neighborhoods classified according to their risk and vulnerability for HVL transmission.

In this study, a wide distribution of dogs with positive serology for CVL was observed, along with a high prevalence of anti-leishmaniasis antibodies in the processed samples (140 positive neighborhoods were mapped).

Visceral leishmaniasis vectors were distributed in 192 neighborhoods of the municipality during the study period, suggesting that *L. cruzi* was the predominant vector species. Based on these results, *L. cruzi* exhibits a high degree of adaptability and distribution in urban environments.

The data showed VL to be endemic, with the highest incidence of the disease coinciding with the areas with the highest population density; this finding clearly illustrates the process of expansion and urbanization of HVL. Several factors have created favorable conditions for HVL to become endemic in an urban environment, including the high distribution of canine infection, wide adaptation of the vectors to the urban environment, reduced investments in health, a discontinuous control measures, and the expansion of new housing construction projects on the outskirts of the city. These factors may increase the number of cases in the city in the near future.

## ACKNOWLEDGMENTS

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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