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Epidemiological profile of malaria in a rural community in the Amazon, Mato Grosso State, Brazil, 2011

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Abstract

Background More than 95% of malaria transmission in Brazil occurs in the Legal Amazon Region, which in 2010 recorded around 333,429 cases reported in the Epidemiological Surveillance Information System-Malaria (Sivep_malaria), presenting an annual parasitic incidence (IPA) of 13.1 cases/1000 inhabitants.

Methods This was a descriptive study that measured the community prevalence of *Plasmodium* infection and its relationship with land use in Três Fronteiras District, Colniza Municipality, Mato Grosso State. Data were collected during household visits in July 2011, with blood collection from finger pricks for the preparation of thick smear slides, and completion of a standardized case notification form. A georeferenced database was analysed, with land use evaluated as categorical variables. A kernel density map was built to show the density of cases and their location.

Results Of the 621 respondents, 68(11%) had *Plasmodium* infection: 39 (57.4%) with *Plasmodium vivax*, 27(39.7%) with *Plasmodium falciparum* and two (2.9%) with mixed infections. Among infected individuals, 49 (72.1%) were men. Cases of malaria were distributed over the district, with greater occurrence of cases per household in open areas close to the mining company and artisanal mining sites. There was a greater density of cases located in the gold mining region.

Conclusion Transmission of malaria in Três Fronteiras District has a heterogeneous distribution. Individuals residing in mining and timber extraction sites have increased occurrence of *Plasmodium* infection.

Keywords Malaria, Spatial analysis, Epidemiology

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Background

Malaria is considered a serious public health problem worldwide, and is responsible for the greatest increase in morbidity and mortality in tropical and subtropical countries. It is caused by protozoa of the *Plasmodium* genus, and in the Americas is largely spread by the bite of the female *Anopheles darlingi* mosquito vector [1].

According to the World Health Organization (WHO), around 241 million cases of malaria were reported in 2020 in 85 endemic countries, 6.2% higher than the 2019 data. Estimates show that 3.4 billion people are at risk of malaria worldwide [2]. In Brazil, 99% of locally acquired malaria cases occur in the region known as the Legal Amazon, which includes the states of Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Rondônia, Roraima and Tocantins, and comprises 807 municipalities of different areas and population sizes [3].

The state of Mato Grosso, although hyperendemic for malaria in the 1980's and the beginning of the 1990's, has presented significant reduction of transmission in recent years. There was a reduction of 86.1% in the number of malaria cases between 2000 and 2011. This was the largest proportional reduction in incidence of any state in Legal Amazon Region during this period [4].

In Brazil, between 2000 and 2011, the malaria diagnostic network carried out more than 2 million tests a year. In 2011, the malaria diagnostic network in the Amazon Region carried out a total of 2,565,616 tests. The states with the highest incidence were Acre, Amazonas, Amapá, Maranhão and Mato Grosso. In the municipality of Colniza-MT, between 2003 and 2009, 65,994 blood tests were carried out, of which 28.6% (18,903) were positive for malaria. The highest number of cases occurred in 2005, with 3,988 cases of the disease. Cases were detected in every month, with the highest number in June 2005 (842 cases) [5]. This spatial pattern changed in subsequent years, with progressive targeting of transmission in the Northwest region of the state, in particular the microregion of Aripuanã, located in the extreme northwest of Mato Grosso, bordering the states of Rondônia and Amazônia [6].

In 2010, 61% of the 2,365 cases of malaria recorded in Mato Grosso were transmitted in only one municipality, Colniza, in the Aripuanã microregion. Almost half (45%) of them occurred in the district of Três Fronteiras, where a rural community of logging and sawmill workers live and which is also the site of cassiterite and gold mining. The district is bordered by two Amazonian states (Rondônia and Amazônia) and is located approximately 300 km from the municipality capital. Poor infrastructure, low-skilled human resources and scarce health service are hallmarks of this population. In 2015, 509 cases

of malaria were reported in Três Fronteiras, which represented 54% of all malaria cases in Mato Grosso.

Several potential factors were found to contribute to the persistence of malaria transmission in areas such as Três Fronteiras. Living in areas close to potential anopheline breeding sites in mining areas and in areas of dense vegetation were considered to be the main risk factors for the occurrence of malaria in the northwestern region of Mato Grosso where there are sites with characteristics similar to those found in the district of Três Fronteiras [7]. The entry of people coming from non-endemic (non-immune) locations into areas of dense vegetation of the region in order to deforest them likely contributes to high transmission in this area [8]. The high mobility of its population, the high vector density, the large number of breeding sites for *Anopheles* vectors and a high rate of participation in activities like mining and timber extraction are also relevant factors [9].

Use of geographic information systems as computational tools to combine environmental variables with information on malaria occurrence for spatial analysis of malaria risk stratification in specific regions is important, as the spread of the disease is closely related to malaria prevalence location and environment [6–8, 10–12]. Georeferencing allows identification of the populations at greatest risk and thus can allow for case tracking measures to intervene in time [13]. A study conducted in a settlement of farmers' families in a city in the northwest of Mato Grosso showed a relationship between the spatial configuration of environmental changes and the risk of falling ill due to malaria [14].

In Brazil, mining areas are still of great epidemiological importance for the disease, and registered a significant increase in the number of cases in recent years. In 2020, 14,086 autochthonous cases were recorded in these areas, while in 2021, 20,468 cases were recorded, representing an increase of 45.3%. In mining areas, 3569 (17.4%) cases were due to *P. falciparum* and mixed malaria. In Mato Grosso, the increase was 66.7% in this time period. The states that imported the most malaria cases in the Amazon region in 2021 were Tocantins, Maranhão and Rondônia, and those that exported the most were Mato Grosso and Pará [15].

The objective of this study was to analyse the epidemiological profile of malaria in a rural community in the northwestern region of Mato Grosso, emphasizing its spatial pattern of occurrence.

Methods

Study area

The municipality of Colniza is composed of a rural area and an urban area. Additionally, it contains smaller areas called districts without political autonomy. The study was

conducted in the District of Três Fronteiras (DTF), Colniza Municipality, in the northwestern region of Mato Grosso, located on the border with the state of Rondônia and Amazônia, and 1530 km distant from the state’s capital city of Cuiabá (Fig. 1). Coverage of the health service in the FTD is scarce, with only one health clinic that performs malaria testing and basic nursing care. The community of DTF has no basic sanitation, electricity, or access to mobile phones or landlines. In the rainy period, there is limited access to the DTF, due to the precarious state of the roads between the district and neighbouring cities. Its main economic activities are cassiterite mining, gold prospecting and timber exploitation [16].

The estimated population of DTF is 2000 people. However, there is a high rate of migration of people from the three states due to economic activities. Immigration is highest during the dry season, while during the rainy period, many workers move to Machadinho, Rondônia, one of the larger cities in the region [16].

For the analysis of the geographical distribution of malaria cases, the DTF was divided into three areas: the mining company area (cassiterite and gold mining), the logging and sawmill area, and the village area. The mining company area contains the São Francisco, Fazenda Comil and Igarapé Grande artisanal mining sites. The logging and sawmill area includes areas with logging, sawmills and rolling mills. The village comprises the Village of Três Fronteiras, in addition to the households located on the *Rodovia do Estanho* road, from BR 174 through Lagoa das Conchas and Vila T (Fig. 1).

Study design

This was a descriptive study that measured the prevalence of *Plasmodium* infection and explored its association with land use and in DTF in July 2011. The prevalence of infection was obtained by screening all (100%) permanent inhabitants of DTF by microscopy. Sociodemographic, clinical and exposure data were collected by interview. Individuals present only for seasonal work were excluded.

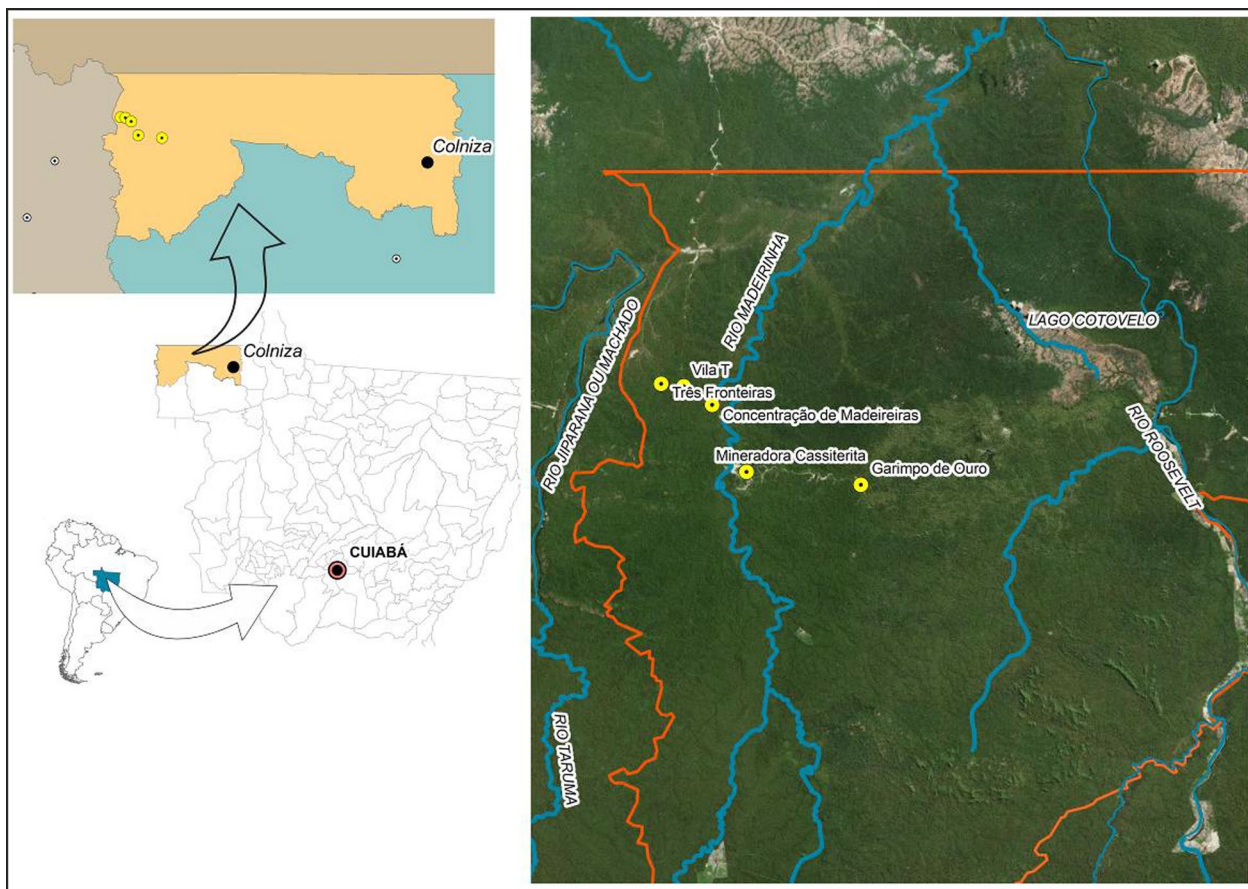


Fig. 1 Map of the District of Três Fronteiras, Colniza Municipality, Mato Grosso, Brazil

Table 1 Characteristics of the individuals infected by *Plasmodium*, identified by microscopy in the population from the District of Três Fronteiras, Colniza, MT, 2011, stratifying by to place of residence

Variable	Place of residence						Total	
	Village		Mining company area		Timber and Sawmills area		N	%
	n	%	n	%	n	%		
Gender								
Male	7	58.3	33	78.6	9	64.3	49	72.1
Female	5	41.7	9	21.4	5	35.7	19	27.9
Age group								
1–9	2	16.7	2	4.8	2	14.3	6	8.8
10–14	1	8.3	–	–	3	21.4	4	5.9
15–19	1	8.3	3	7.1	–	–	4	5.9
20–39	7	58.3	22	52.4	8	57.1	37	54.4
40–59	–	–	14	33.3	1	7.1	15	22.1
>60	1	8.3	1	2.4	–	–	2	2.9
Education								
None	2	16.7	7	16.7	4	28.6	13	19.1
Elementary school	9	75.0	28	66.7	7	50.0	44	64.7
High school	1	8.3	6	14.3	3	21.4	10	14.7
College	–	–	1	2.4	–	–	1	1.5
Exam result								
<i>P. falciparum</i>	3	25.0	21	50.0	3	21.4	27	39.7
<i>P. vivax</i>	9	75.0	19	45.2	11	78.6	39	57.4
Mixed infection	–	–	2	4.8	–	–	2	2.9
Symptoms								
Yes	6	50.0	23	54.8	10	71.4	39	57.4
No	6	50.0	19	45.2	4	28.6	29	42.6

Table 2 Distribution of Prevalence of *Plasmodium* Infection in the District of Três Fronteiras, Colniza, Mato Grosso, according to microscopy, 2011

Areas	Population	Cases	Prevalence (%)
Village	261	12	4.6
Mining company area	240	42	17.5
Timber and sawmills area	120	14	11.7
Total	621	68	11.0

Data collection

Epidemiological data

Data collection took place in July 2011 and was carried out by a group composed of health professionals from the Health Surveillance Department of the State Health Secretariat of Mato Grosso, the Municipality of Colniza and the District of Três Fronteiras.

After obtaining consent of voluntary participation, the case notification form from the official system of epidemiological surveillance of malaria was filled out, and

an interview was performed to obtain demographic, socioeconomic and exposure data for each participant. Each individual residing in the household underwent a finger-prick, a thick smear was prepared, and the slide was tested for *Plasmodium* infection by optical microscopy. Individuals permanently residing in the area, having signed the terms of free and informed consent of the project, and not on anti-malarial drugs were eligible for inclusion.

Slides were stained and examined by microscopists from DTF and forwarded for review at the Central Laboratory of the Health State Department of Mato Grosso. Individuals with a positive result in the first microscopic examination received treatment as recommended by the Ministry of Health, within a maximum of 24 h after blood collection.

The total of the individuals participating in the microscopy screening was used as the denominator for the calculation of the prevalence of *Plasmodium* infection in each locality of the DTF. Epidata 3.1 was used for the construction of the database and for data analysis.

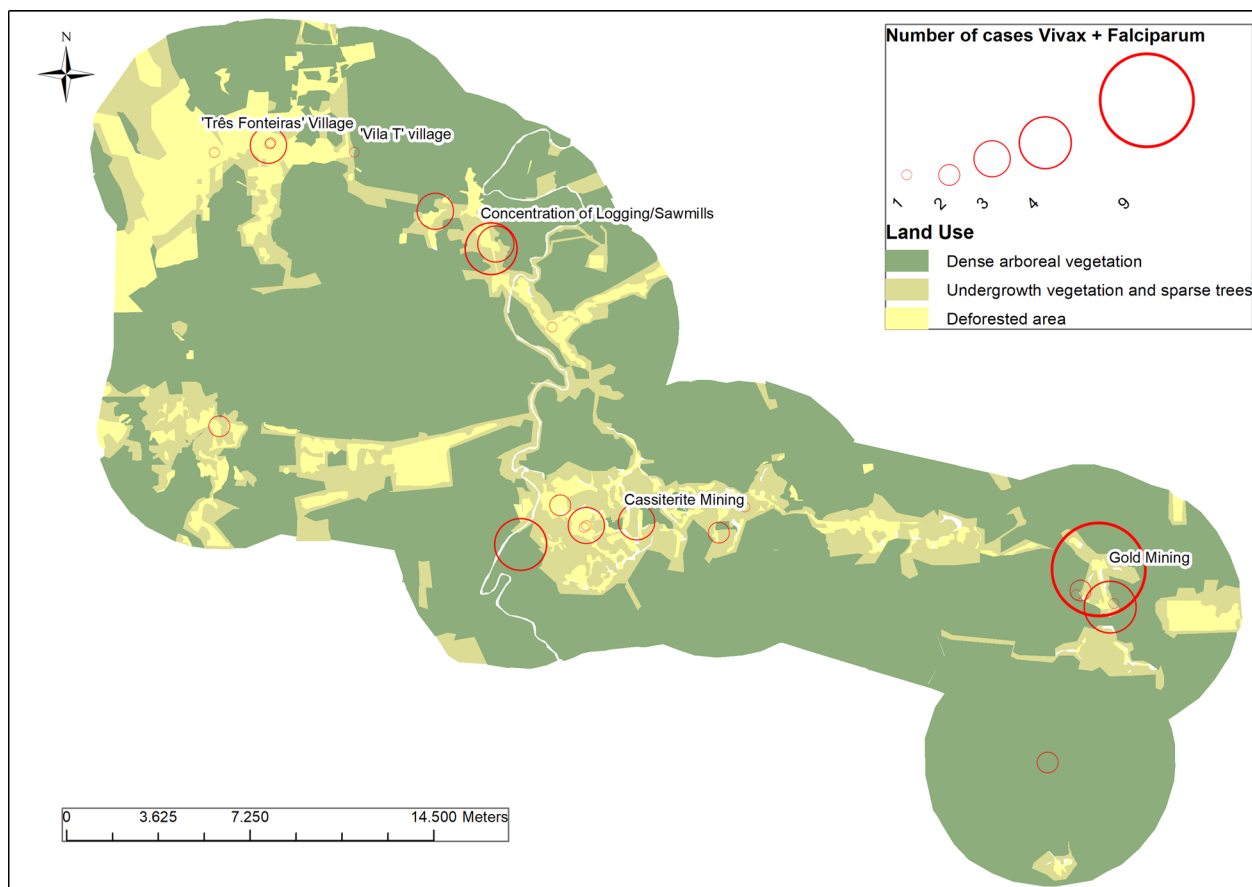


Fig. 2 Map of distribution of malaria cases according to land use in the District of Distrito Três Fronteiras, city of Colniza, Mato Grosso, 2011

Data on spatial distribution of malaria cases

Geographic coordinates of the households were collected using a Garmin eTrex 10. The geographic coordinates obtained were later linked with the questionnaires containing the epidemiological data. For the construction of a georeferenced database, ArcGIS 10.1 software (ESRI, California, USA) was used. Geographical points of each household were superimposed on a map of land use, built based on visual classification [14] of a TM-Landsat 5 multispectral image in 2011, obtained in the catalog of images of the *Instituto Nacional de Pesquisas Espaciais* (National Institute of Space Research).

Information on land use was obtained according to the classification described by De Oliveira et al. [7] dense tree vegetation was defined as the predominance of forest formations with no signs of anthropogenic interference (deforestation); deforested area was defined as the predominance of open areas for villages, pastures, mining and/or mining; and undergrowth and sparse trees were defined as the predominance of natural vegetation in the regeneration phase and the presence of isolated trees. Based on this classification, a map of the distribution of

malaria cases by location was constructed, incorporating information on land use.

Using TerraView version 3.14 (www.dpi.inpe.br/terra-view), a kernel density map was built to visualize the density of cases and their location. In order to identify the areas with the highest prevalence, the maps were built according to the methodology in the software [17].

The degree of smoothing was controlled by adopting a bandwidth of 30 m. Six individuals had to be excluded from the study because the geographical coordinates of their homes were not collected.

Ethical considerations

This study was approved by the Research Ethics Committee under protocol no. 982/CEP-HUJM/2010.

Results

Of the 621 individuals residing in the DTF who participated in the microscopy screening, 434 (69.9%) were men; 70.% were between 20 and 59 years of age. In terms

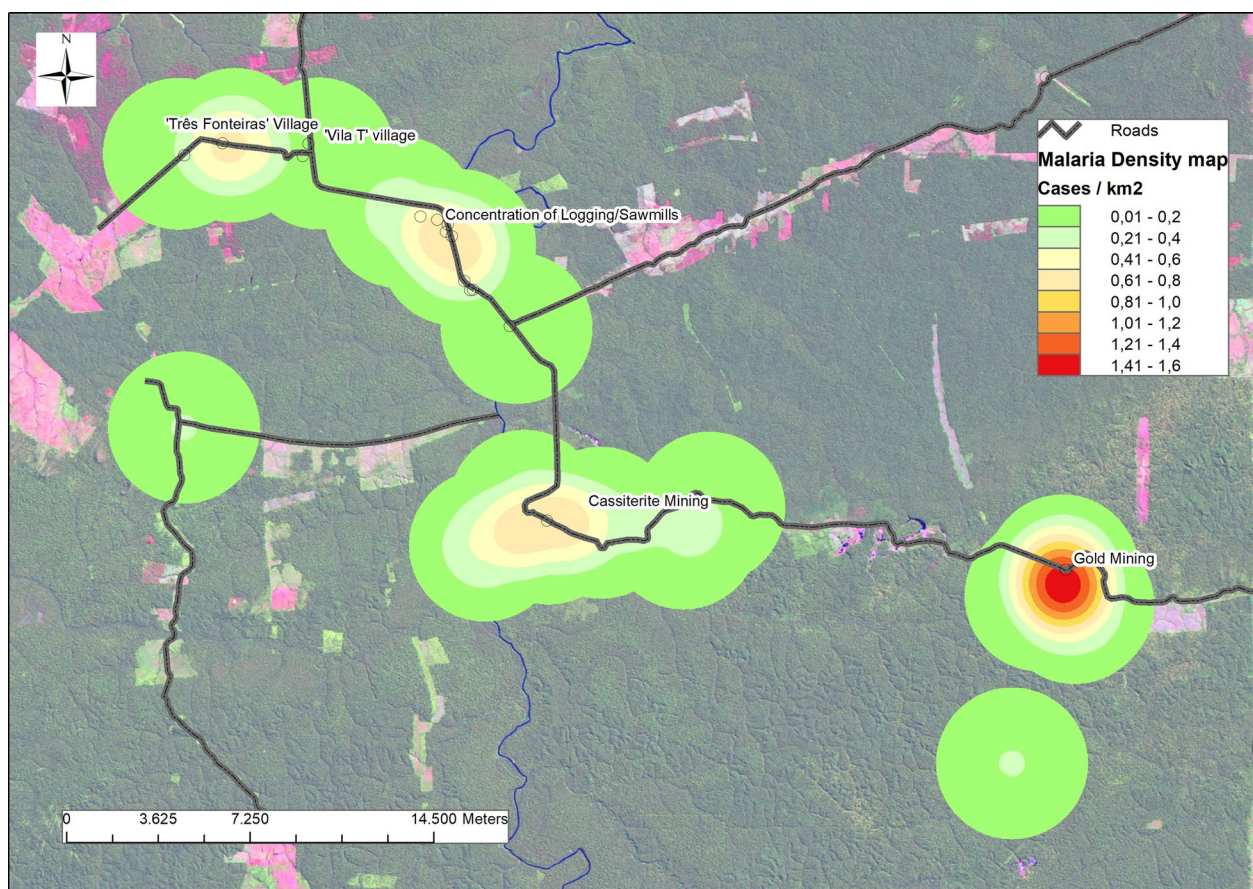


Fig. 3 Kernel density map of malaria cases in the District of Três Fronteiras, city of Colniza, Mato Grosso, 2011

of education, 63.6% had only a basic education (or an 19.2% were without any degree of instruction).

Of the total number of respondents, 68 (11%) were infected with *Plasmodium*: 39 (57.4%) with *Plasmodium vivax*, 27 (39.7%) with *Plasmodium falciparum* and two (2.9%) with mixed infection. Among those infected, 49 (72.1%) were men, and 76.5% were between 20 and 59 years of age. Their educational profile was similar to that of the general population. Any type of clinical manifestation was reported by 39 (57.4%) infected individuals, while the remaining 29 (42.6%) were asymptomatic at the time of interview (Table 1). The mining company area had the highest prevalence of infection (17.5%), followed by the timber and sawmills area (11.7%) (Table 2).

By overlaying the distribution of infected individuals on the map of land use showed that presence of cases across the area of DTE, with greater occurrence in open areas, close to the mining company and artisanal mining areas, followed by the existing timber and sawmills areas.

Of the total DTF area of 72,565.64 hectares, 55,014.85 hectares, were classified as dense arboreal vegetation (75.8%), 7,611.70 hectares were classified as deforested area (10.5%) and 9,939.09 were classified as undergrowth vegetation and sparse trees (13.7%). Amongst infected individuals, 85.3% resided in either deforested areas or in areas with sparse and undergrowth vegetation, and 69.1% resided in deforested areas (Fig. 2). Hot spots identified on the kernel map occurred in areas with gold mining, in which deforested areas and undergrowth vegetation and spares trees (Fig. 3).

The highest rate (45.2%) of asymptomatic infection was observed in the mining area, where there was a diversity of flora with some deforested areas (Fig. 4).

Discussion

In recent years, *P. vivax* infection has become predominant in the Amazon region, where only 16.3% of infections are caused by *P. falciparum* [18–20]. While this

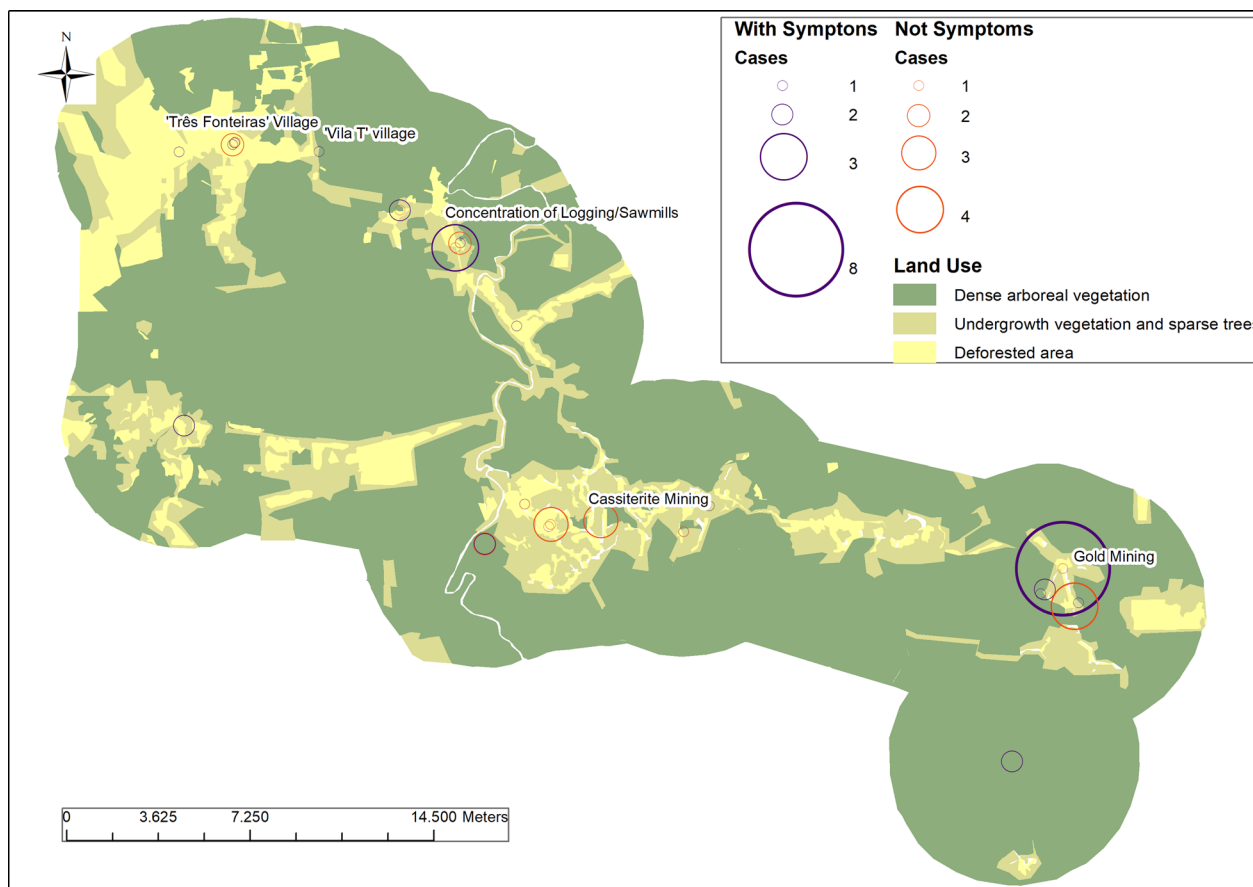


Fig. 4 Map of distribution of symptomatic and asymptomatic individuals infected by *Plasmodium* as assessed by microscopy, according to the type of land use in the District of Três Fronteiras, Colniza, Mato Grosso, 2011

shift in prevalence has contributed to an overall reduction in the number of malaria infections [21], there is still a high prevalence in rural areas due to geographical factors and lack of resources and infrastructure [22].

In addition, the prevalence of malaria in floating populations, such as migrants, refugees, seasonal workers and people on the move, presents significant challenges in controlling and preventing the disease due to constant movement, which can lead to exposure to different geographical areas with different levels of malaria transmission. This increases the risk of infection, especially in areas where the disease is not endemic [23].

The persistence of malaria transmission in the region was characterized in a study carried out in the municipality of Colniza in the period from 2003 to 2009, where the majority of the 18,903 cases were autochthonous (90.5%), predominantly in men (71.4%), in the age group of 15 to 59 years (74.4%), with 4 to 7 years of studies (19.5%) and an average age of 27.7 years. In the species breakdown, 77.7% of cases were *P. vivax* and 21.6% were *P. falciparum* [5].

Based on the data from the 2011 study reported here, the community prevalence of infection by *Plasmodium* spp was 11%, which would characterize the region as mesoendemic for malaria in this period.

Individuals who reported being symptomatic at time of blood collection were concentrated in the mining and logging areas. However, in these areas, there were also substantial numbers of asymptomatic individuals. As a method of contributing to the eradication of malaria, in addition to the active detection of cases, research indicates that investigations may be more effective as an intervention strategy because they can identify asymptomatic individuals, thus reducing transmission [24, 25].

Prevalence in the study area was more common in cassiterite and gold mining locations, which could possibly be related to work activities, since individuals work in endemic areas and do not use preventive measures, thus favouring the transmission of the disease. With respect to the type of land use, the study area showed higher prevalence of malaria carriage in deforested areas and/or areas with undergrowth vegetation and sparse trees, consistent

with the evidence that deforestation for timber extraction and other activities contributes to the occurrence of disease transmission [26].

These scenarios, in which anthropic environmental modification contributes to the occurrence of cases, matches the finding of this research, in which the highest prevalence of malaria occurred in mining areas. Furthermore, other studies conducted in areas with similar characteristics that found that the prevalence of malaria appeared with the creation of mining camps and was higher in houses near the prospecting zone [27].

The distance of these areas from major health centres may be one of the factors contributing to the concentration of cases, since the delay in seeking care and obtaining diagnosis to start treatment increases the duration of the period during which an individual can transmit the infection, generating a high number of new cases [28].

Previous research carried out in Mato Grosso also found evidence between the occurrence of cases of malaria and prospecting activities, reinforcing the analyses made in this state by other authors [5]. The proportion of miners with undiagnosed malaria contributes to the collective transmission of the disease, causing a concentration of cases that can evolve into outbreaks [29]. Population-wide blood microscopy screening presents great challenges, as it requires trained individuals to identify the parasite and correctly dispense drugs when diagnosing infected individuals, and it is necessary to have an effective strategy to prevent and control *Plasmodium* infection [30].

Conclusion

Community prevalence of malaria infection in the District of Três Fronteiras has a heterogeneous spatial distribution throughout the district. Individuals residing in mining, prospecting and timber extraction areas have a higher occurrence of *Plasmodium* infection.

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Author contributions

CJFF ensured the financing of fieldwork, with resources from PRONEX/Rede Malária (Malaria Network)/CNPq/FAPEMAT. ECO, ESS and PAFJ contributed to the study design, acquisition and interpretation of data, statistical analysis, and writing of the manuscript. ESS, MAS and CJFF participated in the study concept, coordination and critical review of the manuscript. ACPT, MCPL and ERFL participated in the writing and critical review of the manuscript. All authors have read and approved the final manuscript.

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Availability of data and materials

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee under protocol no. 982/CEP-HUJM/2010.

Competing interests

The authors declare that there are no conflicts of interests.

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