Sociodemographic and Economic Traits That Affect Malaria Prevalence in Sussundenga Village, Mozambique.

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1. Introduction

Malaria is a serious and sometimes fatal disease caused by a *Plasmodium* parasite that commonly infects *Anopheles* mosquitos which feeds on humans. Although malaria can be a deadly disease, infection and death can be prevented [1]. Almost half of the world's population lives in areas at risk of malaria transmission. Six countries account for more than half of all malaria cases worldwide and Mozambique is among them [2].

In Mozambique, a country in sub-Saharan Africa, with a population of over 30 million inhabitants, malaria is one of the leading causes of mortality and morbidity. In 2018, Mozambique recorded the third largest number of malaria cases in the world, that is, 5 % of all cases globally [3]. However, the country has made little progress in malaria control.

Indoor residual spraying (IRS), insecticide treated bed nets (ITNs), and parasitological diagnosis in health facilities using rapid diagnostic test (RDTs) with effective artemisinin combination therapy (ACT) are the malaria intervention currently being used in Mozambique [4]. While all of these interventions are available, their implementation varies greatly geographically. The entire country uses RDTs with ACT as the standard of care in public health facilities. IRS is only used in Maputo Province where incidence and prevalence are the lowest, and Zambézia Province where incidence and prevalence are the highest. ITNs are only available at antenatal clinics, indicated for pregnant women and children under 5.

Manica Province in central Mozambique has the second highest malaria incidence in the country. In the first quarter of 2020 1,039,283 cases with an incidence per 1000 inhabitants of 371 and test positivity in health facilities of 65 % were reported [5]. Sussundenga village, in Manica Province is one of most affected areas, with 31,397 malaria cases reported in 2019. Sussundenga village lies directly along the Zimbabwe border, making evaluation of malaria transmission and control policies integral for regional efforts.

Malaria infection risk, disease severity, and clinical outcome depend on environmental, socio-demographic, economic, and behavioral factors [6, 7]. An association between malaria prevalence and socioeconomic status has been well established in Mozambique and other endemic countries. The prevalence of malaria is 43% in urban areas and 58% in rural areas, throughout Mozambique. pregnant women with higher education tend to be more protected against malaria (54 %) compared to without an education (59%) and, children from higher income families (58 %) tend to be more protected against malaria compared to children from lower income families (43 %) [8].

The WHO Global Technical Strategy for Malaria (GTS), the Roll Back malaria advocacy plan, the Action and Investment to defeat Malaria 2016/2030 (AIM) and Sustainable Development Goals (SDGs) with target 3.3, all aims to reduce malaria cases, morbidity, and mortality by more than 90 % by 2030 [9].

While Mozambique has one of the highest incidences and prevalence of malaria in the region and it accounts for nearly half of childhood deaths, little is known about the epidemiology to inform appropriate and effective interventions [2]. This is one of two major barriers to expanding control measures in the country with the other being limited funding.

Malaria transmission is notoriously heterogeneous and all interventions don't work in all settings [10]. In Sussundenga Rural Municipality no studies on malaria are known and understanding the epidemiology of the disease is crucial for informing the implementation of the most appropriate and effective malaria interventions to achieve control.

Therefore, the objective of this study was to quantify and map the distribution of malaria parasite prevalence and model its relationship with sociodemographic and economic characteristics in Sussundenga Rural Municipality.

2. Methods

2.1. Study area.

The village of Sussundenga is a rural, agrarian community that shares a border with Zimbabwe, and is 45 kilometers from the provincial capital of Chimoio (Figure 1). Sussundenga has an estimated current population of 31,429 inhabitants, 47 % males and 53 % females, with an age distribution of 19.5 % from 0 to 4 years old, 29.9 % from 5- to 14-year-old, 20.5 % from 15 to 24 years old and 30.1 % with over 24 years old [11].

The climate is tropical with an average annual precipitation of 1200 mm. The rainy season occurs from November to April. The average minimum temperature is 6.3°C in the month of July and the average maximum temperature is 38.9°C in the month of January and the annual average is 21.2°C [12]. The village is divided administratively in 17 residential areas called "Bairros".

2.2. Data collection

GoogleEarth Pro™ satellite imagery was used to digitize and enumerate all household structures in the village of Sussundenga. A random sample of 125 households was taken; 100 households for enrollment in the study and 25 households as backup for refusals and errors in the digitizing process (misclassified non-household structures).

Coordinates of the households were extracted using a GPS device and maps of the selected households to conduct study visits. The study involved two visits to the selected households. The first was a notification visit where the study team introduced themselves to the head of the household and explained the objectives and procedures of the study. It is customary for the head of household to provide permission to the study team before any activities take place at the household involving other household members. Once the head of household gave permission, the study team conducted a household census with the head of household and begin the process of individual informed consent with the household residents, for all adult (18+ years) residents and parental permission and assent from minors.

After obtaining consent from the household residents, the study team informed participants when they will return the following day to conduct the study activities. The only eligibility requirement was that the residents live in household full time. [IRB protocol numbers]. Data collectors administered a questionnaire to collect basic demographics.

The study nurse collected current malaria specific symptoms by self-report and will took participant's temperature using a thermometer. They then collected a finger prick blood sample to administer a Rapid Diagnostic Test (RDT), RightSign Biotest [R], China. The results were recorded and, in the event, that a participant was positive for malaria, the study nurse referred them to the Sussundenga rural health center (RHC) for diagnosis confirmation and treatment. The questionnaire was conducted using tablet computers with the REDCap [Maker and country] mobile application. Data was stored in a secure REDCap server hosted by the University of Minnesota.

2.3. Data Analysis

This study was a cross-sectional community-based survey. The analyses were conducted on datasets downloaded from Research Electronic Data Capture (REDCap) to excel spread sheet. As variables, a binary variable as the dependent variable malaria presence, that is whether malaria was present (positive) to RDT or absent (negative) was used.

The explanatory variables were the following sociodemographic and economic traits: age, adult or child, age category, sex, previous malaria treatment, employment, cell phone ownership, education level, location (Bairro) and household size (Additional file 1). To avoid redundancy, collinearity test was performed and variables with over 4 of variance inflation factor (VIF) over 4 were dropped after investigation [13]. The malaria prevalence was calculated dividing positive cases of malaria by the study population tested at the time multiplied by 100.

$$Prevalence\ (\%) \frac{Persons\ having\ malaria}{Population\ during\ the\ period}\ x\ 100 \quad (1)$$

Point prevalence was calculated dividing the number of positive cases per "Bairro" dividing by the total population of the Bairro, multiplied by 100 [14].

$$Point\ Prevalence\ (\%) \frac{Persons\ malaria\ positive}{Population\ during\ the\ period}\ x\ 100 \quad (2)$$

Chi-square for proportion of age group and sex was tested. To establish the relationship between malaria prevalence and socio-demographic traits a simple logistic regression analysis was performed. In logistic regression, the canonical link function (logit) for the binominal distribution, of the unknown binomial probabilities are modeled as linear function of the risk factors:

$$X_i : g(Pi) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots \beta i x_i \quad (3)$$

Where:

$G(P_i)$ = link function

P_i = likelihood of response for the -ith factor

β_0 = intercept

β_1 = coefficient

x_1 = independent variable

The model sensitivity (probability of a positive test given that the patient has malaria) of the final model measures the proportion of positive that were correctly identified and was calculated as:

$$Sensitivity(\%) = \frac{Number\ of\ true\ malaria\ positive}{Number\ of\ true\ malaria\ positive + Number\ of\ false\ malaria\ negative)}\ x\ 100\ (4.1)$$

The model Specificity (probability of a negative test given that the patient is well) of the final model measures the proportion of negative case correctly identified and was calculated as:

$$Specificity(\%) = \frac{Number\ of\ true\ malaria\ positive}{Number\ of\ true\ malaria\ positive + Number\ of\ false\ malaria\ negative)}\ x\ 100\ (4.2)$$

Positive Predictive Value (PPV) that is, whether the screened people who tested positive do or do not actually have malaria was calculated as follows:

$$PPV(\%) = \frac{Number\ of\ true\ malaria\ positive}{Number\ of\ true\ malaria\ positive + Number\ of\ false\ malaria\ negative)}\ x\ 100\ (4.3)$$

Negative Predicted Value (NPV) that is the proportion of negative results in the diagnosis test that are true negative results as calculated as follows:

$$NPV(\%) = \frac{Number\ of\ true\ malaria\ negatives}{Number\ of\ true\ malaria\ negatives + Number\ of\ false\ malaria\ negative)}\ x\ 100\ (4.4)$$

To test the importance of the sociodemographic traits on malaria prevalence, and for the model development, logistic regression outcomes such as Scores statistic's, regression coefficient's, significance levels of variable coefficients and, overall classification accuracy were used [15]. All tests were carried out using SPSS IBM version 20 and Bioestat version 5. ArcGis version 10.7.1. was used for spatial mapping.

2.4. Ethical consideration

This study is part of the Malaria Risk, Prevention, and Health Seeking Behaviors in Sussundenga, Mozambique Project. All participants, or the guardians provided informed written assent and consent prior to participation. To carry out the study approval from the institutional Review (IRB) committee from the University of Minnesota and, from

Comissão Nacional de Bioética em Saúde (CNBS) from the Ministry of Health of Mozambique, approval number 560/CNBS/19 .

3. Results

3.1. Sample size and site, sex, age and, age group of participants.

One-hundred, twenty-five selected were visited but only 100 were used for the study. Two households refused to participate (1.6%), others were non-household structures (brick ovens, stores) or were abandoned. Three hundred eighty-six participants were interviewed but for the study 358 (93 %) were used. This was because, REDCAP only allowed the inclusion of 12 people per household and in the study, there were aggregates with more than 12 people, these were recorded in a separate notebook.

Seven out of the seventeen "Bairros" namenly Nhamezara, Chicueu, 25 de Junho 1 and 2, 7 de Abril, Unidade and Nhamarenza were covered by the study (Figure 1C). The area surveyed has 27,431 (87.3 %) of the total population of the village. There was an equal distribution of the enrolled participants among sex, 55 % were female and 45 % males, Chi-square = 0.081, P = 0.8872, DF = 1. No difference was found between female and male positive cases, 53 and 47 % respectively, Chi-square = 0.180, P = 07772, DF = 1.

The age of participants varied from 1 to 80 years old, with a median of 17 years and, an average of 21 standard deviation (SD) 16.2 years old. For the participants' education level (n = 302), 35.1% had no education or less than primary (5 grades), 47.4 % had primary or basic school (grades 5 to 10) and 17.5 % had secondary and higher education.

3.2. Malaria prevalence and its spatial distribution

Three hundred forty-two participants were tested for malaria and 108 tested positive for malaria ((31.6 %). Figure 2.A. presents the positive and negative malaria cases and figure 2B, the spatial distribution (point prevalence) of the malaria cases per Bairro. Bairro 7 de Abril (0.9 %) and Chicuei (0.51 %) had the highest malaria prevalence, Bairros 25 de Junho 1 (0.31 %), and Nhamezara (0.47 %) had a moderate prevalence and, Bairros Nhamarenza (0.18 %), Unidade (0.25 %) and 25 de Junho 2 (0.125 %) had the lowest malaria prevalence.

3.4. Malaria prevalence by age category

In terms of age group, 0 to 4 comprised 8.5 % of the participants while 5 to 14, 15 to 24 and over 24 were 32. 7, 28.5 and 30.4 % respectively. There was no difference between age group of the sample and the estimated by Instituto Nacional de Estatistica (INE), Chi-square = 6.09 = P = 0.1073, DF = 3. Figure 3 presents the positive results for age category. Half of the malaria positive cases occurred in age group 5 to 14. Comparing to the sample and INE percentage for the age group, around 40 % more than expected. Age group over 24 accounted for 17.6 % the cases, around 50 % less than expected. Age groups 0 to 4 and 15 to 24 presented 11.1 and 21.3 % respectively. There is a difference in positive malaria cases among groups, Chi-square = 17.527, P = 0.0075, Df = 6

3.5. Association between malaria infection and sociodemographic and economic traits.

After testing for collinearity, the following variables were removed from the model: population density and if the participant was an adult or child. The backward stepwise predictor selection into the logistic model carried out produced a series of models.

Table 1 presents the model summary and the Nagelkeke's R^2 is 0.149 which suggesting that the explained variation in malaria positive cases is approximately 15 %.

Table 2 presents the Hosmer and Lemeshow test, that test the model fitness and this model fit the data.

Table 3 presents the classification table of the final model, that is, the model capability to predict malaria positive cases, indicating a model accuracy of 72.3 % a modest improvement from the 0-step model. The sensitivity of the final model in classifying malaria positive cases is 91.8 % and specificity of the final model to classify malaria negative cases is 29.2 %, meaning that the final model is able to predict 83.4 % of malaria positive cases and 26 % of malaria negative cases.

Table 4 presents the variable in the equation, with the regression coefficients and their respective standard errors, the Wald test, the odd ratios and their confidence intervals. The model can be written:

Log(p/1-p) = -1.296 – 0.080 *sex* – 0.667 *mal-treat* - 0.242 *employment_paid* + 0.066 *phone* – 0.132 *education* + 0.629 *hh size* – 0.304 *age category* + 0.113 *bairro*.

The increase in malaria treatment history (b = -0.667), having paid employment (b = -0.242), increase in education level and age category (b= -0.132 and – 0.304) will decrease the probability of malaria positive cases in Sussundenga Village. The odds for malaria history (0.513), employment (0.785), level of education (0.876) and age category (0.738) indicates that and unit increase in these variables, the odds of malaria positive cases will decrease by 48 %, 21.5 %, 12.4 %, 26.2 % respectively.
Figure 3 presents the residuals graph and linearity can be assumed. The data were checked for outliers (normality) and in the residual normalized table (additional file 2) no values above 2.0 were found implying that there were no outliers.

4.0. Discussion

In this study, malaria prevalence was 31.6 % for Sussundenga Village, higher than the prevalence recorded in Chimoio city [16] of 20.1 % In the neighboring Zimbabwe, malaria prevalence was 19.5 % in Mutare and 50.9 % in Mutasa districts in 2016. [17] and in Zambia a study reported parasite prevalence between 0.7 and 1.8 % [18]. And 34 % in Malawi [19].

This study recorded the highest malaria prevalence 50. 0 % among age category 5 to 14 years old around 40 % more than expected from the sample and INE age categories. In Rwanda the odds of infection by malaria was reported to be 1.817 time more likely among age category 5 to 14 years, while the odds of infection were 57.3 % less likely among age category 25 to 34 years [20]. In Kenya studies indicated that highest malaria prevalence occurs in children between ages of 11 to 14 [21] while other study indicated age school children from 5 to 18 years as the category [22]. Similar results were also reported in Nigeria and Ghana [23, 24].

This finding differ from reports from Chimoio that reported 52 % of malaria cases in children under five [16] and Sussundenga district 47.5 % in Mozambique. The difference can be attributed to the fact that this study was carried out at community level while the other studies were carried out from health center data. This study also indicates that age group over 24 years presented 16 % of the infections, around 50 % less than expected from the sample and INE age categories and this can be probably due to acquired immunity.

In this study, there was a high variation in malaria cases and prevalence from "Bairro" to "Bairro". Malaria spatial distribution was also reported in other studied in Chimoio, Maputo and Beira in Mozambique [25, 26, 27], in Comoros, Zambia, and Madagascar in Africa [28, 29, 30] in Latin America [31] and in China [32]. Heterogeneity in spatial distribution in small settlement area is probably caused by land use, landscape due human activities in the settlement and the proximity of individuals to places with elevated vector presence [15].

The variables for population density and if a participant was an adult or child were removed from the model for redundancy. Age category and household size are good proxies for these variables. An association between malaria prevalence and socioeconomic status was established in Mozambique [8]. In this study it is suggested that approximately 15 % of the variation in positive malaria cases can be attributed to sociodemographic and economic traits. Previous study modelled the influence of climate on malaria occurrence in Chimoio and indicated that environmental traits accounted for malaria occurrence by 72.5 % [7], a study in Nigeria indicated 90 % f [33], and for Global Fund also 90 % [34], implying that non-environmental factors such as sociodemographic, economic, cultural and behavioral traits would be affected by remaining percentage, consistent with this result.
This study suggests that recent diagnosis and treatment for malaria infection reduces the odds of subsequent infection within the next month by 48 %. This reduction in odds is likely due to prophylactic effect of ACT. It provides protection usually 2 weeks to 1 month after completion. After repeated infections, the individual develops a certain degree of immunity [35]. Different result was reported in Angola where. women who had previous malaria during pregnancy also had a higher risk to contract malaria [36]. This is likely because pregnant women may take SP rather than ACT. Pregnant women are also at increased risk to malaria infection in general.

Having employment, the odds of malaria positive cases will decrease by 21.5 %. Employed person will have more capability of purchasing preventive malaria means and also Those employed are more likely to have better housing, which is protective. In India malaria cases decreased with an increasing monthly income [37]. This result contradicts findings in Indonesia that indicated that working participants were 1.2 times more likely to have malaria than those who were not [38]. This could be due to type of employment. Working outdoors can lead to increased risk.

In this study, the increase in level of education, the odds of malaria positive cases will decrease by 12.4 %. Previous study in Mozambique indicated that pregnant women with high levels of education tend to be more protected against malaria compared to non-educated [8]. Similar results were reported in Malawi [19]. In India and Indonesia studies did not find association between the education level and malaria occurrence [37,38]

Age category increase will decrease malaria positive cases by 26.2 %. This scenario is common in endemic settings with high transmission and is an is indicative of absence or ineffective control measures Similar results were reported in Vietnam and in Mozambique [6, 7]. These variables were also found significant predictors in studies in Nigeria, Ghana, Kenya, India and Indonesia [19, 24, 37,38]. When re-infected, patients present a mild form of the diseases without symptoms. Natural active immunity is established after ten or more *P. falciparum* infections, and there are sufficient to suppress symptoms and clinical signs [39].

The model capability to predict malaria positive cases (model accuracy), was 72.3 % in this study. Studies in Ghana reported 77.4 % [18]. The sensitivity of the final model in classifying malaria positive identifying cases was 91.8 % and the final model was able to predict 83.4 % (positive predictive value) meaning that the model is very effective in predicting malaria positive cases. Studies in Iran reported 81.8 % positive predictive value [40] and 52.72 % in Ghana [24].

5. Limitations of the study

Data collection for this study was conducted in December and January, rainy and wet season during the peak transmission season so would have probably the highest number of infections and results reflect this season and my not reflect malaria dynamics in dry season. The RightSign Biotest ^{R} test detects the protein antigen II rich in histidin of the *Pla*smodim falciparum and can last over a month in the blood and can detected positive cases in patients recently treated with malaria.

6. Conclusion

This study evaluated and estimated the sociodemographic and economic characteristics that affect malaria prevalence in Sussundenga Village, Mozambique. Recent diagnosis and treatment, having employment, level of education and age category can have lower odds of infection. The model accuracy was 72.3 % and positive predictive value of that the final model was able to predict 83.4 % implying that the model is robust. Targeting malaria control at community level can contributed better than waiting for cases at health centers and 5 to 14 years category should be addressed. This model indicates that 15 %

of malaria cases can be attributed to sociodemographic and economic traits while previous studied indicated that environmental conditions would contribute with around 75 % on malaria cases. Further studies are needed specially in dry season and in other areas of the district.

Declarations

Ethics of approval and consent to participate

This study is part of the Malaria Risk, Prevention, and Health Seeking Behaviors in Sussundenga, Mozambique Project. All participants, or the guardians provided informed written assent and consent prior to participation. To carry out the study approval from the institutional Review (IRB) committee from the University of Minnesota and, from Comissão Nacional de Bioética em Saúde (CNBS) from the Ministry of Health of Mozambique, approval number 560/CNBS/19.

Consent for publication

N/A

Availability of data and materials

Data are available as additional file 1.

Competing interests Competing

The authors declare that that have no any competing interests

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Authors contributions

JLF contributed in supervising the data collection process, writhing the manuscript and statistical analysis, DE contributed in English revision, AN contributed in confirmation and treatment of positive malaria cases, RM contributed in Mapping, AT contributed in data revision, AB and MB contributed in data collection and VM contributed in blood collection RDT test.

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Figures

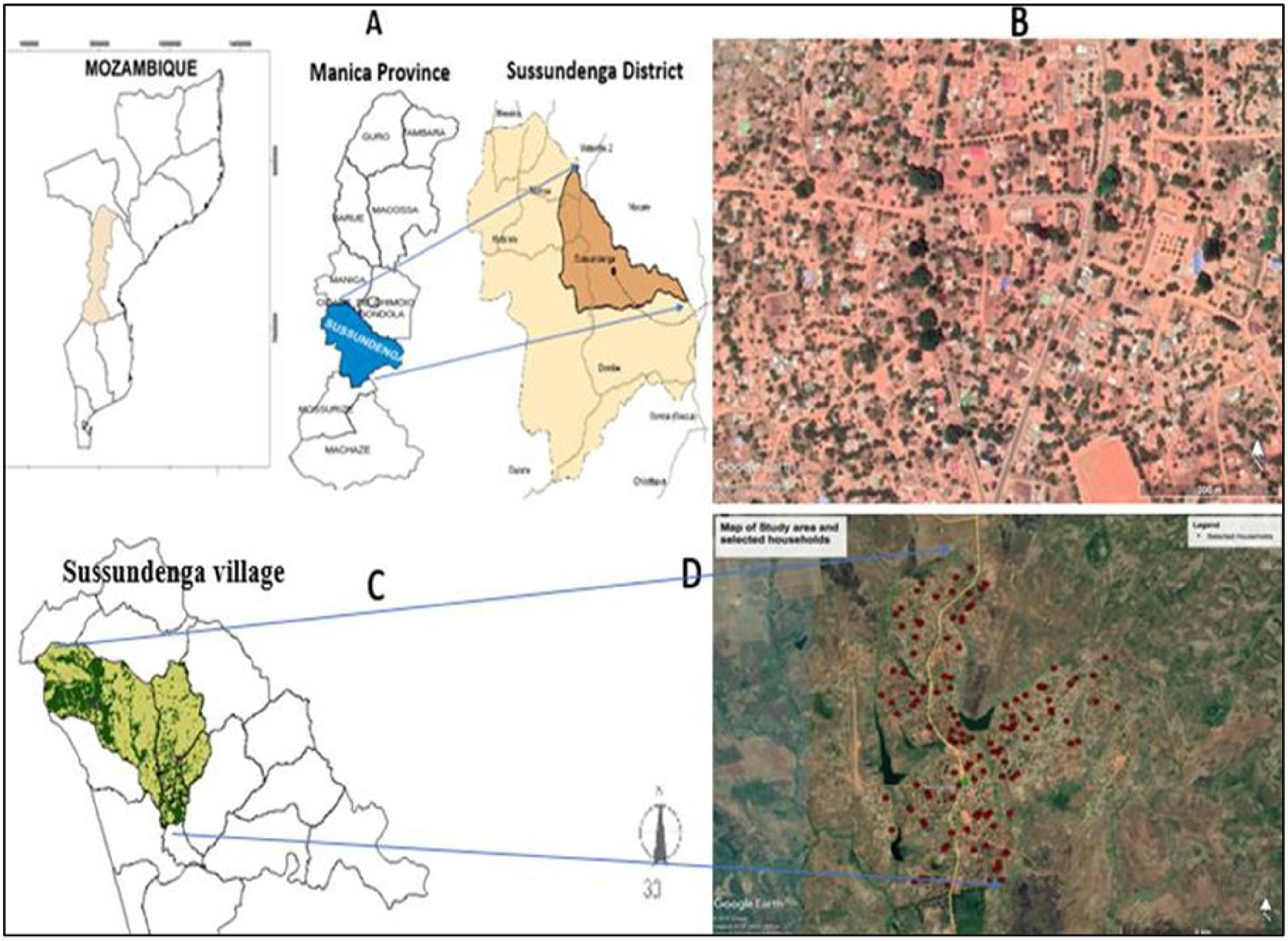

Figure 1

The village of Sussundenga is a rural, agrarian community that shares a border with Zimbabwe, and is 45 kilometers from the provincial capital of Chimoio (Figure 1). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

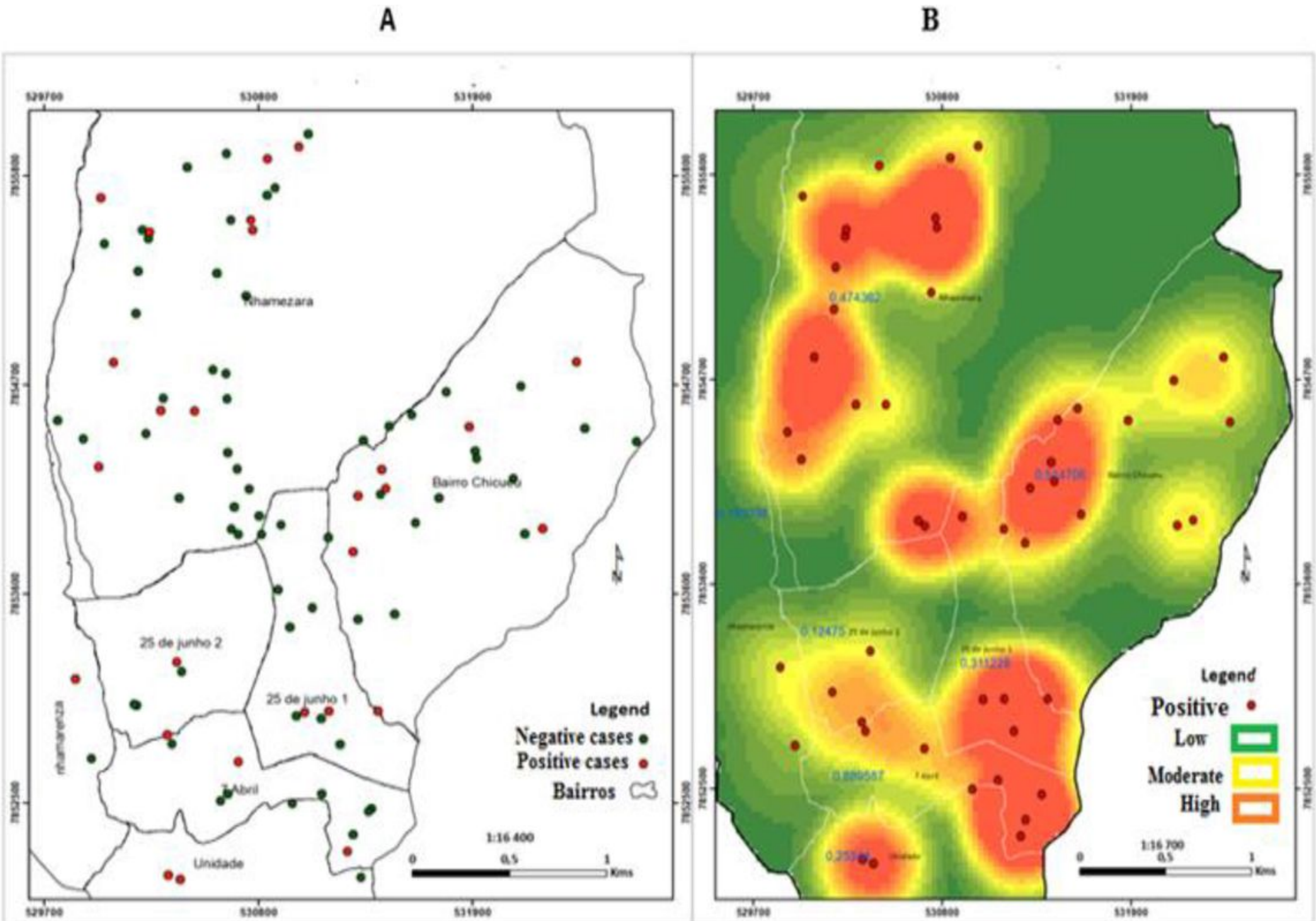

Figure 2

Three hundred forty-two participants were tested for malaria and 108 tested positive for malaria ((31.6 %). Figure 2.A. presents the positive and negative malaria cases and figure 2B, the spatial distribution (point prevalence) of the malaria cases per Bairro.

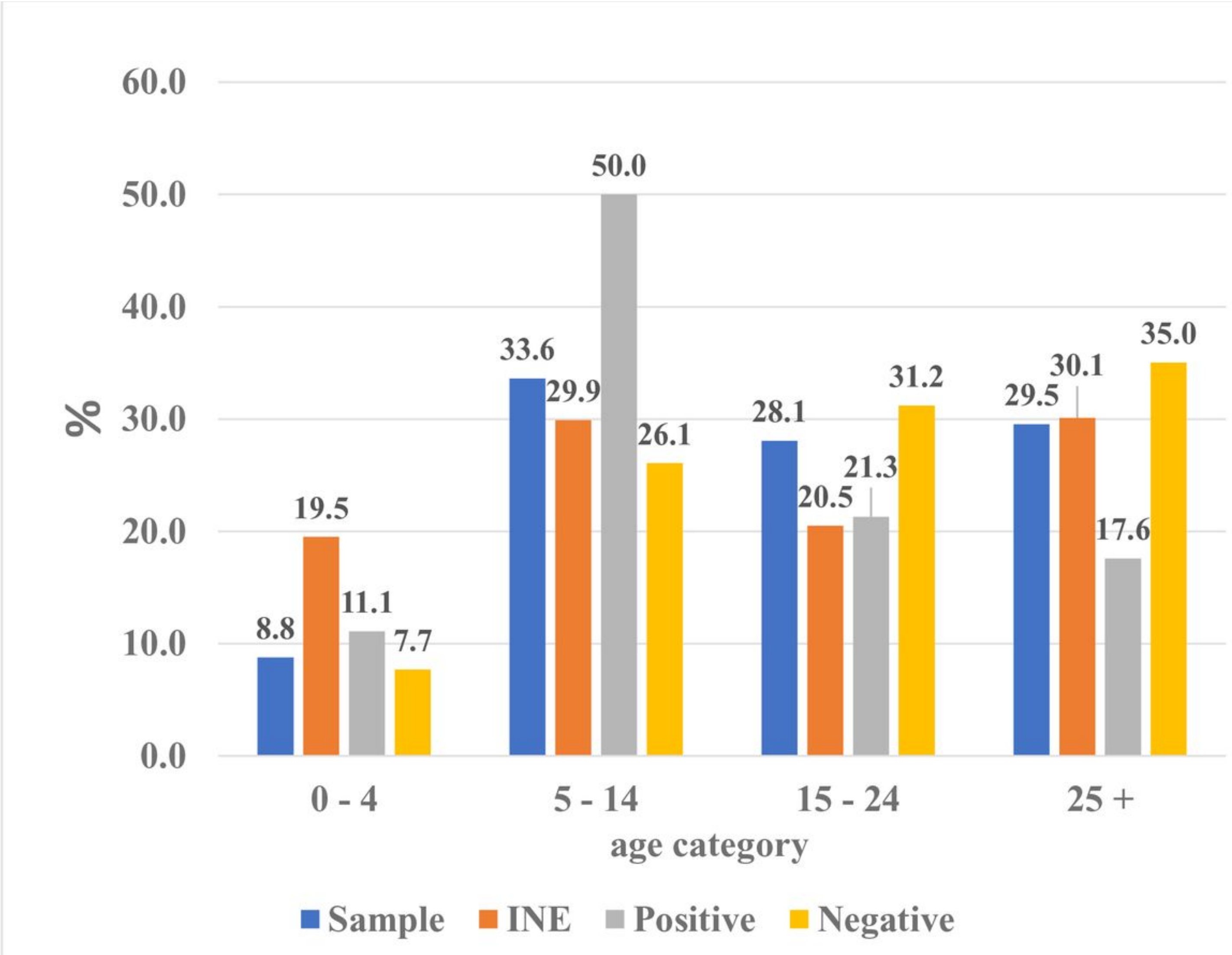

Figure 3

Figure 3 presents the residuals graph and linearity can be assumed. The data were checked for outliers (normality) and in the residual normalized table (additional file 2) no values above 2.0 were found implying that there were no outliers.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- 00752Table4.docx