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Original Research Article

Use of Mapping Technologies to Study the Spatial Distribution of Malaria Incidence in Vietnam

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ABSTRACT

Background: Malaria is one of the major public health issues globally. Malaria infection spreads through mosquito bites from infected female Anopheles mosquitoes. This study aims to apply mapping technologies to investigate the spatial distribution of malaria cases and incidence in Vietnam.

Materials and Methods: Malaria cases in 2019 were first collected from the websites of the Vietnam Ministry of Health (VMH). The incidence of malaria will be then computed. The histogram is employed to study the distribution of malaria cases and incidence. Mapping technologies is then used to study the spatial distribution of malaria cases and incidence. In addition, a scatter plot is also used to investigate the relationship between population density and the incidence of malaria. Finally, results and findings will be discussed and summarised.

Results: the study results showed that the highest rate of malaria infection was detected in Gia Lai, followed by Phu Yen, Dak Lak, and Binh Phuoc. Areas of high malaria infection rates were mainly concentrated in rural areas in the south-central region having with high vegetation coverage. Whereas, areas with no or low malaria infection rates were mainly concentrated in urban areas in the northeastern and southeastern regions of Vietnam. In addition, there was a negative correlation between population density and the incidence of malaria.

Conclusion: It can be concluded that the combination of histograms, mapping technologies and a scatter plot prove their effectiveness in the study of malaria. Findings in this study provide an insight into how to apply mapping technologies to study and prevent the spread of such an infectious disease as malaria.

Keywords: Spatial distribution, Malaria cases, Malaria incidence, Histogram, Scatter plot, Mapping technologies.

INTRODUCTION

Five Plasmodium species are responsible for the protozoan disease malaria, which is transmitted by female Anopheles mosquitoes. It has a significant negative influence on health and the economy and is one of the main causes of morbidity and mortality (1). The most prevalent and extensively dispersed parasites in Pakistan are four species, which include P. vivax and P. falciparum (2,3). Approximately half of the world's population resides in 87 countries and regions where malaria transmission is a concern, according to the World Malaria Report for 2021. An estimated 241 million medical episodes and 627,000 deaths were attributed to malaria in 2020 (4). Aside from that, it poses a serious threat to public health in humid and subtropical regions (5,6). Pakistan is one of the seven nations in the Eastern Mediterranean region that, according to the World Health Organization (WHO), bear 98% of the region's malarial burden. In Pakistan, 63 million people are at high risk of malaria, while 217 million are at moderate risk. There have been 800 recorded malaria deaths and 0.47 million cases as of 2020 (6). Mapping technologies have been widely applied in the study of infectious diseases. Infectious illness research has made extensive use of mapping tools. Techniques for mapping infectious diseases that are frequently employed are Internet Mapping

Technologies (IMTs). Software tools such as WebGIS, the Google Earth Engine (GEE) platform, Google and Baidu maps, and online features are examples of IMTs. The manner that geographic data is exchanged and seen is evolving as a result of these technologies. IMTs have thus been extensively employed in the COVID-19 battle. For example, an online interactive dashboard hosted by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University, Baltimore, MD, USA, was developed in response to this ongoing public health emergency to visually represent and track COVID-19 cases in real time (7). Public information on this rapidly evolving, epidemiologically intricate, and geographically unbounded process is largely provided through web-GIS maps (8). For the German city of Cologne, a WebGIS for the small-scale identification and investigation of COVID-19 (SARS-CoV-2) instances was created using voluntarily provided spatial data (9). When examining the tracking and mapping of coronavirus illness geographically The COVID-19/SARS-CoV-2 pandemic and related global events have been effectively tracked by several WebGIS-based mapping applications, including useful online/mobile GIS and mapping dashboards (10). A COVID-19 simulation visualization system has also been created and developed, and it is based on WebGIS (11). A Web GIS for COVID-19 (SARS-CoV-2) small-scale detection and analysis was created in Gemany using voluntarily provided geographic data for the city of Cologne (9). A WebGIS-based digital cartography application is being developed in Italy to help local people comprehend the spread of epidemics (12). During COVID-19 in Solapur City, Maharashtra, India, a user-interactive web-based geographic information system (WGS) webpage was created to facilitate decision-making and resource allocation (13).

Aside from GIS, the kinds of data that are accessible for mapping have a major role in the capacity to map a disease (14,15). Therefore, the quantity, spatial representativeness, and variability of such data heavily influence how accurate maps are (16). The most common point data types used in disease mapping are geo-referenced records of occurrence or prevalence. An accurate worldwide depiction of a disease's current endemicity is a significant accomplishment for infectious disease mapping, as it provides a wide range of operationally significant public health conclusions: for example, clinical burden (17,18) and basic reproductive number estimation (19,20) to inform national elimination feasibility assessment (21,22).

The past 20 years of continued malaria control efforts have resulted in the elimination of this disease in several provinces of Northern and Southern Vietnam (23). The National Malaria Control and Elimination Programme was formally launched by the Vietnamese government in 2011, with the goal of eradicating malaria nationwide by 2030 (24). However, such an ambitious goal faces several challenges that include forest malaria, seasonal population movements (internal and across international borders) and emerging drug resistance. The majority of malaria deaths (eight in 2012) and morbidity (18,387 confirmed cases in 2012) occur in 21 out of 58 provinces (=25% of total population), most of which are in Central and Central-Southern Vietnam in 2015 (24). In this study, we aim to use mapping technologies in the study of malaria cases and incidence in Vietnam. Malaria cases in 2019 were first collected from the websites of the Vietnam Ministry of Health. The incidence of malaria will be then computed. The histogram is employed to study the distribution of malaria cases and incidence. Mapping technologies is then used to study the spatial distribution of malaria cases and incidence. In addition, a scatter plot is also used to investigate the relationship between population density and the incidence of malaria. Finally, results and findings will be discussed and summarised.

MATERIALS & METHODS

Materials

The number of malaria cases reported in 2003 was 164,706, a striking 88% drop from the 1992 numbers. In a similar vein, there haven't been any recent reports of an epidemic or malaria mortality (25). While many countries struggle to control malaria, four countries, Brazil, Eritrea, India, and Vietnam, have successfully reduced malaria burden (25). After successfully reducing the malaria burden to pre-elimination levels over the past two decades, the national malaria programme in Vietnam has recently switched from control to elimination (24). To study the spatial distribution of malaria in Vietnam in recent years, in this study, datasets of malaria cases and population density in Vietnam in 2019 collected from website of the Vietnam Ministry of Health (VMH) were used to investigate the use of mapping technologies in the study of malaria cases and incidence in Vietnam.

Methods

Histograms

A histogram is a graph that uses rectangles to display the frequency of numerical data. The height of a rectangle (the vertical axis) represents the distribution frequency of a variable. A histogram measures the frequency at which specific values occur in the dataset in order to visually represent the distribution of a continuous numerical variable. A number line that has been divided into numerical ranges, or bins, is the x-axis in a histogram. A bar is drawn for each bin; the height of the bar indicates the number of data points that fall within that range, and the width of the bar indicates the bin's range. One of the key steps in the data exploration process is to comprehend the data distribution.

Although a histogram is used for quantitative data, it resembles a bar chart. The data must be arranged into class intervals in order to produce a histogram. Next, make a tally to display the frequency of the data into each interval, either relative or actual. The frequency in a given class divided by the total number of observations is the relative frequency. The bars match the height of the frequency (or relative frequency) and the width of the class interval.

Mapping technologies

A wide range of tools and methods are used to create, evaluate, and disseminate maps, and these are collectively referred to as mapping technologies. This can include Geographic Information Systems (GIS), software for enhancing or classifying digital photos, satellites of the Global Positioning System (GPS), and satellites used to gather high resolution and multispectral data. GIS software allows users to digitally store, retrieve, analyze, and display maps of all kinds. Azimuthal, conformal, and equal-area projections are the three different forms of map projections. The four qualities of a map projection - area, shape, distance, and direction - that each projection maintains and which it sacrifices distinguishes it from the others. To create a flat map, they are all using a cylinder or a cone. It is possible to modify and combine maps made with various projections or scales to generate new composite maps..

One of commonly used methods for projection is called Mercator. Mercator created his projection in space. The forward equations for the Space-oblique Mercator projection for the sphere are as follows (26):

$\frac{x}{\mathrm{R}} = \int_0^{\lambda'} \frac{H - S^2}{\sqrt{1+S^2}} d\lambda' - \frac{S}{\sqrt{1+S^2}} lntan\left(\frac{\pi}{4} + \frac{\varphi'}{2}\right)$	(1)
$\frac{y}{\mathrm{R}} = (H+1) \int_0^{\lambda'} \frac{S}{\sqrt{1+S^2}} d\lambda' + \frac{1}{\sqrt{1+S^2}} lntan\left(\frac{\pi}{4} + \frac{\varphi'}{2}\right)$	(2)
$S = \frac{P_2}{P_1} \sin(i) \cos(\lambda')$	(3)
$H = 1 - \frac{P_2}{P_1} \sin(i)$	(4)

Where: φ is geodetic (or geographic) latitude, λ is geodetic (or geographic) longitude, P_2 is the time required for revolution of satellite, P_1 is the length of Earth rotation, *i* is the angle of Earth rotation, is the radius of Earth, *x* and *y* are rectangular map coordinates (26).

Scatter plots

A scatter plot, also known as a scatter graph, scatter chart, scattergram, or scatter diagram, is a kind of plot or mathematical diagram that shows values for two variables, usually, for a collection of data using Cartesian coordinates (27). If the points are coded (color/shape/size), one more variable can be presented. The values of one variable that determines a point's position on the horizontal axis and the value of another variable that determines a point's position on the vertical axis are displayed together in the data display (28).

A scatter plot with a given confidence interval might indicate many types of correlations between variables. For example, population density would be on the y-axis, and the incidence of malaria would be on the x-axis. There are three types of correlations: null (uncorrelated), negative (falling), and positive (increasing). A positive correlation between the variables under investigation is shown if the pattern of the dots slopes from lower left to higher right. A negative association is indicated by a dot pattern that slopes from higher left to lower right, as shown in Figure 1. To examine the relationship between the variables, one can create a line of best fit, often known as a trendline.

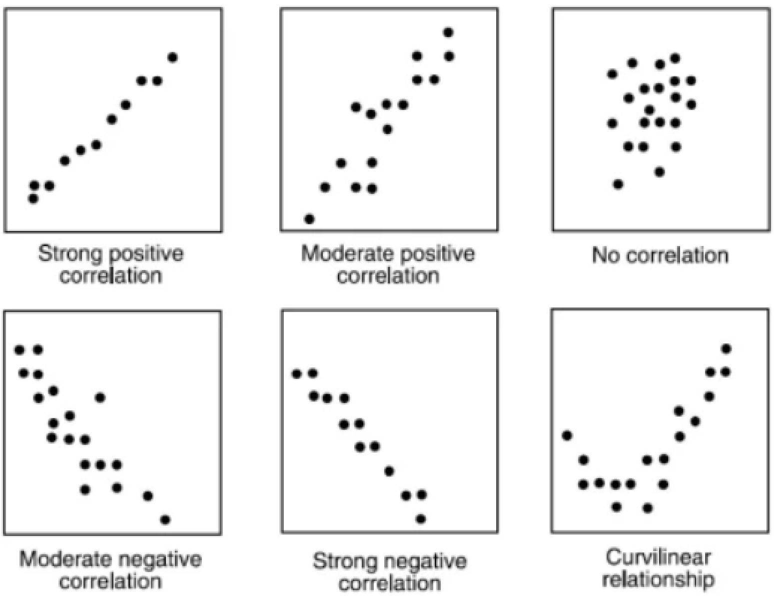


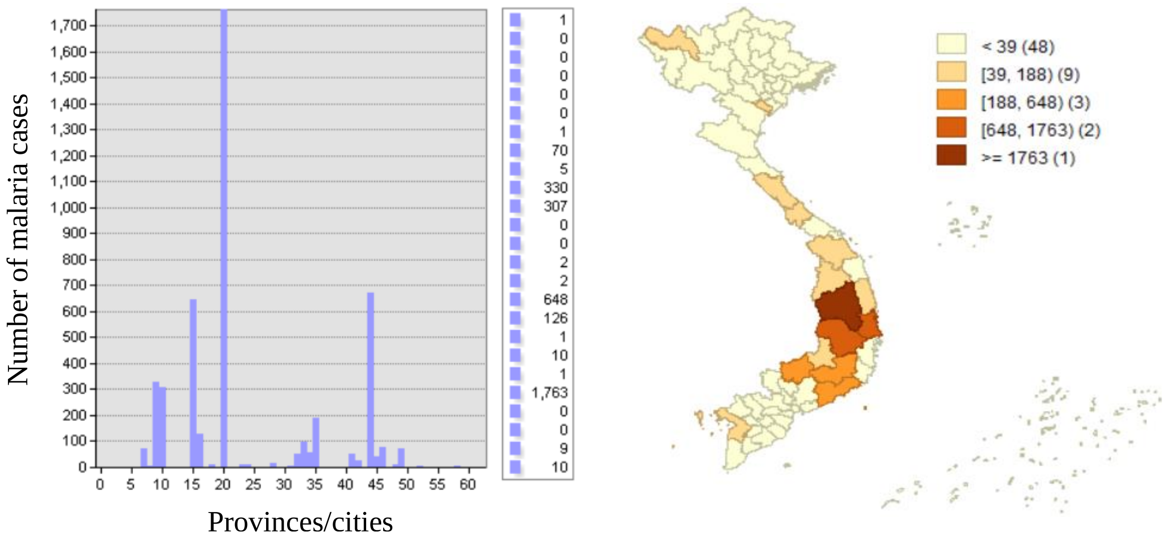
Figure 1. Different types of scatter plots.

RESULTS AND DISCUSSIONS

Spatial distribution of malaria cases

Data from the histogram in Figure 2-a shows the distribution of the number of malaria cases in Vietnam in 2019. The data in the histogram shows that a surprisingly large number of malaria infections was detected in many provinces/cities. The province having the largest number of malaria infected cases in 2019 was Gia Lai (1763 cases), followed by Phu Yen (673 cases), Dak Lak (648 cases), Binh Phuoc (330 cases), Binh Thuan (307 cases), Lam Dong (188 cases) and Dak Nong (126 cases), respectively. Some provinces/cities having low and very low numbers of malaria infected cases include Ben Tre, Thai Nguyen, Hai Phong, Dien Bien, Dong Thap, An Giang (01 case), and Tien Giang, Thanh Hoa, Cao Bang, Da Nang, and Quang Ninh (02 cases), and Kien Giang, Binh Duong (04 cases) and Tay Ninh (07 cases), Hanoi and Quang Ngai (09 cases). In addition, no new malaria cases were found in 27 provinces/cities in 2019 including Vinh Phuc, Ba Ria Vung Tau, Bac Giang, Bac Kan, Bac Lieu, Bac Ninh, Ha Nam, Yen Bai, Son La, Soc Trang, Thai Binh, Ca Mau, Can Tho, Ha Giang, Phu Tho, Ninh Binh, Nam Dinh, Lang Son, Lao Cao, Long An, Hai Duong, Hau Giang, Hoa Binh, Hung Yen, Tuyen Quang Tra Vinh, and Vinh Long.

The spatial distribution of new malaria cases in 2019 is shown in Figure 2-b. The number of malaria infections in 2019 was divided into five different levels: very low (0-39 cases), low (39-188 cases), medium (188-648 cases), high (648-1763 cases) and very high (>=1763 cases). Specifically as follows: a total of 68 provinces/cities had the number of new infections below 39 cases. New infections ranging from 39 to 188 cases were found in nine provinces/cities. The number of new infections ranging from 188 to 648 cases was detected in three provinces/cities. Meanwhile, only 03 provinces had a particularly high number of infections ranging from 648 to 1763 cases. The spatial distribution of malaria infections in the map in Figure 3 shows that areas having a large number of malaria infections were mainly concentrated in the provinces/cities of the south central region of Vietnam, especially in rural areas and places with high vegetation coverage. Meanwhile, areas with no or few new malaria cases were mainly concentrated in the northeastern and southeastern regions of Vietnam, especially in urban areas.



(a) (b)

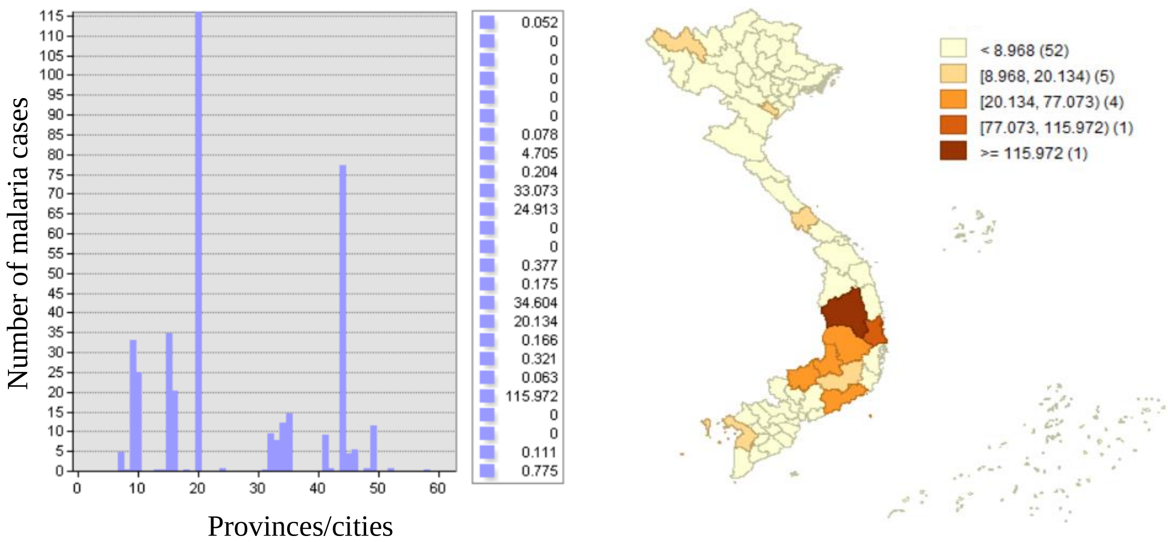
Figure 2. Histogram (a) and map (b) of malaria cases in Vietnam in 2019.

Spatial distribution of the incidence of malaria

The histogram in Figure 3-a shows the distribution of malaria incidence in Vietnam in 2019. The data in the histogram shows that many provinces/cities were found with a high and very high malaria infection rates. The highest rate of malaria infection was detected in Gia Lai province (115.9 cases/100,000 people), followed by Phu Yen (77.1 cases/100,000 people), Dak Lak (34.6 cases/100,000 people), Binh Phuoc (33.1 cases/100,000 people), Binh Thuan (24.9 cases/100,000 people), Dak Nong (20.1 cases/100,000 people) and Lam Dong (14.4 cases/100,000 people). Low and very low malaria infection rates were identified in several provinces such as Hai Phong (0.05 cases/100,000 people), An Giang (0.052 cases/100,000 people), Thanh Hoa (0.055 cases/100,000 people), Dong Thap (0.06 cases/100,000 people). 100,000 people), Thai Nguyen (0.077 cases/100,000 people). Wheareas, nearly half of Vietnam's provinces were found with no new malaria cases in 2019 including Vinh Phuc, Ba Ria Vung Tau, Bac Giang, Bac Kan, Bac Lieu, Bac Ninh, Ha Nam, Yen Bai, Son La, Soc Trang, Thai Binh, Ca Mau, Can Tho, Ha Giang, Phu Tho, Ninh Binh, Nam Dinh, Lang

Son, Lao Cao, Long An, Hai Duong, Hau Giang, Hoa Binh, Hung Yen, Tuyen Quang Tra Vinh , and Vinh Long.

The spatial distribution of the incidence of new malaria cases in 2019 is shown in Figure 3-b. The incidence of malaria in 2019 in Vietnam was divided into five different levels including very low (0-8.968 cases/100,000 people), low (8.968-20.134 cases/100,000 people), medium (20.134-77.073 cases/100,000 people), high (77.073-115.972 cases/100,000 people) and very high (>= 115.972 cases/100,000 people). Specifically as follows: a total of 52 provinces/cities was identified with an infection rate of below 8.968 cases/100,000 people. Five provinces/cities were found with new infection rates ranging from 8.968 cases to 20.134 cases/100,000 people. The four provinces were detected with infection rates ranging from 20.134 cases/100,000 people to 77.073 cases/100,000 people. Only two provinces were found with a particularly high and very high infection rate in the range of from 77.073 cases/100,000 people to 115.972 cases/100,000 people, and in the range of greater than 115.972 cases/100,000 people. The spatial distribution of malaria incidence in the map in Figure 4 shows that, similar to those obtained in Figure 3, areas with high malaria infection rates were mainly concentrated in the provinces/cities in the south central region, especially in rural areas having with high vegetation coverage. Meanwhile, areas with no or low malaria infection rates were mainly concentrated in the northeastern and southeastern regions of Vietnam, especially in urban areas.



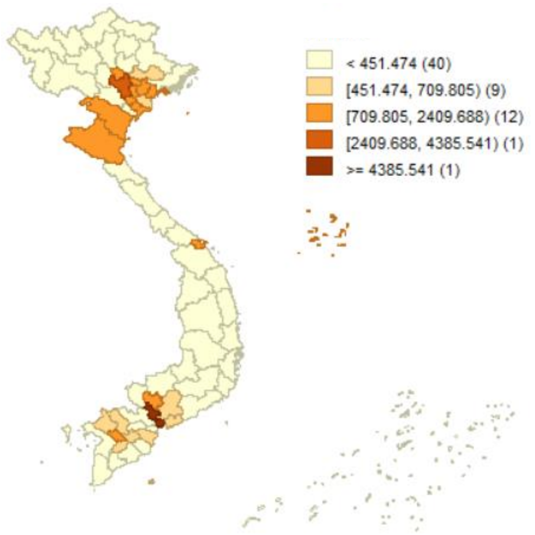
(a) (b)

Figure 3. Histogram (a) and map (b) of malaria incidence in Vietnam in 2019.

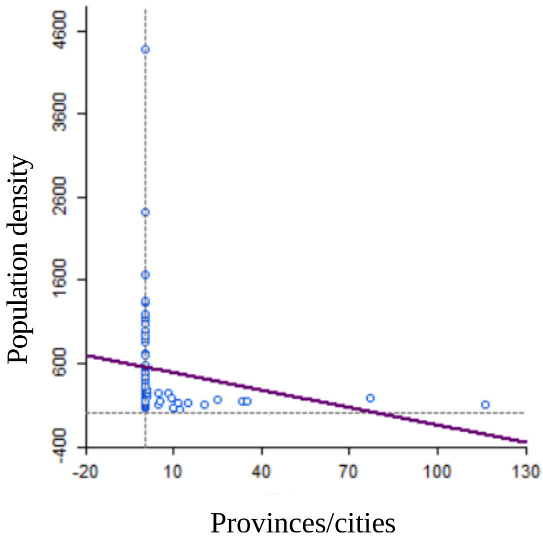
The relationship between population density and malaria incidence

Data from the map in Figure 4-a shows the spatial distribution of population density in Vietnam. Population density in 2019 was also divided into five different levels: very low (0-451,474 people/km^2 including 40 provinces/cities), low (451,474-709,805 including 09 provinces/cities), medium (709,805-2409,688 people/km^2 including 12 provinces/cities), high (2409,688-4385,541 people/km^2 including only one province) and very high (>= 4385,541 people/km^2 including only one province/city). The spatial distribution of Vietnam's population density in 2019 shows that high population density was mainly concentrated in the northeast and southeast regions. The provinces/cities having the largest population density in the northeast were Thai Binh (1185,737 people/km^2), Hai Duong (1137,094 people/km^2), Nam Dinh (1067,685 people/km^2), Ha Nam (992,565 people/km^2) and Vinh Phuc (934,909 people/km^2), and in the Eastern and Southern provinces such as Binh Duong (911,530 people/km^2), Can Tho (858,810 people/km^2) and Tien Giang (703,565). Meanwhile, low and very low population density was mainly distributed in the northwest and central provinces of Vietnam such as Lai Chau (51,010 people/km^2), Kon Tum (56,170 people/km^2), Dien Bien (63,064 people/km^2), Bac Kan (64,691 people/km^2), Cao Bang (79,235 people/km^2), Son La (88,696 people/km^2), and Lang Son (94,197 people/km^2).

Data from the scatter plot of population density against malaria incidence in Figure 7 shows the relationship between malaria incidence and population density. The horizontal axis in the scatter plot represents the incidence of malaria, whereas the vertical axis represents the population density of provinces/cities in Vietnam. The data in the scatter plot show that there was a negative correlation between population density and the incidence of malaria. This shows that the greater the population density, the lower the malaria infection rate and vice versa.



(a)



(b)

Figure 4. Map (a) of population density and a scatter plot (a) of population density against malaria incidence.

CONCLUSION

This study sets out to investigate the combination of histograms, mapping technologies and a scatter plot in the study of malaria cases and incidence in Vietnam. Malaria cases in 2019 were first collected from the websites of the Vietnam Ministry of Health (VMH). The incidence of malaria will be then computed based on the population density. The histogram is employed to study the distribution of malaria cases and incidence. Mapping technologies is then used to study the spatial distribution of malaria cases and incidence. In addition, a scatter plot is also used to investigate the relationship between population density and the incidence of malaria. Finally, results and findings will be discussed and summarised.

It was found that the highest rate of malaria infection was detected in Gia Lai province (115.9 cases/100,000 people), followed by Phu Yen (77.1 cases/100,000 people), Dak Lak (34.6 cases/100,000 people), Binh Phuoc (33.1 cases/100,000 people). Areas of high malaria infection rates were mainly concentrated in rural areas in the south central region having with high vegetation coverage. Whereas, areas with no or low malaria infection rates were mainly concentrated in urban areas in the northeastern and southeastern regions of Vietnam. In addition, there was a negative correlation between population density and the incidence of malaria. In the research of malaria incidence, it can be concluded that the use of scatter plots, mapping technologies, and histograms has proven to be helpful. The results of this study provide light on how mapping technology can be used to research and stop the spread of malaria.

Declaration by Authors

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Conflict of Interest: None

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