International Journal of Trend in Research and Development, Volume 12(4), ISSN: 2394-9333
www.ijtrd.com

A Study of the Use of Geographical Information System (GIS) for the Identification of Malaria Patterns in a Community

[1]Abegunde Linda Olukemi, [2]Abdullahi Ayegba, [3]Abdullahi Yahaya Suleiman, [4]Desmond Wysenyuy, [5]Urukwe Ando and [6]Ndahi Aisha,
[1]Cooperative Information Network, National Space Research and Development Agency, Osun State, Nigeria,
[2]Engineering and Space Systems Department, National Space Research and Development Agency, Abuja, Nigeria,
[3]Policy, Planning and Research Department, National Space Research and Development Agency, Abuja, Nigeria,
[4]IAU North American Regional Office of Astronomy for Development, Associated Universities, USA,
[5]Independent Researcher, Taraba State, Nigeria, and
[6]Interplanetary Initiative, Arizona State University, USA.
[2]Department of Management of Information Technology, African University of Science and Technology, Abuja, Nigeria.

Abstract: The aim of this research work was to examine the use of Geographical Information System (GIS) in identifying the pattern of malaria in a community or particular location. The research method adopted for the work was the review research method. The research method adopted for the work was the review research method as well as the explanatory research method. From the result, it was observed that there are certain stages or processes that will be passed through to identify malaria patterns in a community using a Geographical Information System. These stages, according to the results, are data collection; data preprocessing, which involves cleaning, transforming, and formatting of the collected data; GIS mapping, which involves creating visual representations of the data; spatial analysis, which involves the analysis of the spatial relationships and patterns of malaria incidence and some factors; statistical modeling, which involves using statistical techniques to analyze the relationships between malaria incidence and some factors; and pattern identification, which involves analyzing the results of the spatial analysis and statistical modeling to identify patterns and trends in malaria incidence. It was also revealed by the result that the identification of malaria patterns in a community will be helpful in identifying factors causing malaria transmission in the community, effective resource allocation, and developing targeted strategies to address specific malaria transmission dynamics and risk factors, as well as improved health outcomes. We concluded that GIS plays a crucial role in identifying malaria patterns within a society or community.

Keywords: *Data, GIS, Malaria, Regression, Spatial analysis.*

I. INTRODUCTION

Geographical information system (GIS) has numerous applications, but its use in the health sector cannot be overemphasized. GIS can be used to show the location in a community affected by certain diseases or even show the locations where some vectors or factors responsible for certain illnesses are found. GIS can be used to study the pattern of variation or occurrences of certain diseases in a community. Although there are many diseases, malaria is very common in various parts of Africa. According to the WHO (2005), background malaria is a major public health problem in Africa, with over 200 million clinical episodes and nearly one million deaths occurring annually. As reported by Asnakew et al. (2009), in Ethiopia, malaria is the leading cause of morbidity and mortality. About 70% of the population (approximately 52 million people) is estimated to be at risk for malaria infection each year. Yakudima et al. (2024) reported that malaria is one of the leading causes of illness and death in developing countries. Despite growing international concern and efforts to provide effective treatment through the development and improvement of vector control mechanisms, malaria infection continues to remain a leading health problem in Africa, particularly south of the Sahara. According to Sweeney (1998), computerized spatial databases and GIS mapping software provide powerful tools for management and analysis of malaria control programs. These include practical operational maps to assist with resource allocation, analytical tools to facilitate program monitoring and evaluation, and sophisticated research projects to investigate various spatial aspects of malaria epidemiology. Climatic factors, particularly rainfall, temperature, and relative humidity, are known to have a strong influence on the biology of mosquitoes. GIS can be used to investigate associations between such environmental variables and the distribution of the different species responsible for malaria transmission (Sweeney, 1998). In view of the foregoing, it became imperative to examine how GIS can be used to identify malaria patterns in a community.

II. METHODOLOGY

The materials used for this work are secondary materials, which comprise the library materials and online research works that were carried out and published on the related research topic. In addition, this research was carried out using the review research method in addition to the explanatory research method. The review enabled the researchers to explain the discoveries of other authors in the related topics, while the explanatory research method was to enable the authors or researchers to provide some detailed information, when necessary, on the various points treated in the course of the work.

III. RESULTS AND DISCUSSION

A. The use of geographical information system (GIS) for the identification of malaria patterns in a community

GIS, as a tool, can be used in different aspects of healthcare sectors. In this work, the study of the use of GIS to identify the pattern of malaria in a community will be discussed. This involves the various stages followed to achieve this aim. The stages or processes of identifying malaria patterns in a community using GIS are as follows:

Stage 1: Data Collection

Data collection is a critical stage in identifying malaria patterns in a community using GIS. This stage involves gathering relevant data from various sources to support the analysis. The types of data collected include

1. Malaria Case Data: The data required in this case are the number of malaria cases reported in the community over a specific period, the geographic locations of malaria cases, such as households, villages, or towns, and the age, sex, and other demographic characteristics of individuals affected by malaria. This information can be gotten from hospitals, clinics, and other healthcare facilities.

2. Environmental Data: The data collected for this are average temperature data for the study area, which can influence mosquito breeding and malaria transmission, Rainfall data, which can impact mosquito breeding sites and malaria transmission; slope; elevation; nearness to river or water bodies; and information on land use patterns, such as agricultural areas, forests, and urban areas, which can influence mosquito habitats. This information can be gotten from government agencies, such as ministries of health and environment, who are in charge of environmental data. It can also be gotten from satellite imagery and remote sensing technologies. According to Diriba et al. (2024), numerous scholars have incorporated temperature as a primary factor in mapping malaria hazard zones, adding that malaria incidence and transmission typically occur in environments with higher temperatures. The classification of temperature values depends on the connection between temperature and malaria occurrence. Abdulahi et al. (2020), thus, higher temperature values were assigned the highest rank, and vice versa. Slope, another topographic factor potentially influencing the formation of mosquito larval habitats, represents the rate of land elevation change over a given distance, impacting the stability of aquatic habitats (Moha et al., 2019). Proximity to rivers Water bodies play a significant role in malaria transmission. They act as breeding grounds for mosquitoes that carry the malaria parasite (Manoharan et al., 2020). Therefore, the presence and proximity of water sources are important indicators of malaria risk.

In the views of Sarkar et al. (2019), rainfall patterns highly influence the distribution of malaria. As such, during periods of heavy rainfall, breeding sites may be disrupted due to excessive water, which can flush away mosquito eggs and larvae, reducing mosquito populations and consequently lowering malaria incidence. Regions with moderate rainfall and low variability are likelier to have stable breeding habitats than areas with frequent and intense rainfall. The use of vegetation density in this research was related to the best breeding and living place of the Anopheles sp. mosquito. The denser vegetation will increase the convenience of a mosquito to grow and breed, whereas the low vegetation density will reduce the convenience of a mosquito to grow (Adhina et al., 2018).

3. Socioeconomic Data: The data collected for this are population density, which is the number of people per unit area, which can impact malaria transmission; the poverty rate, which is the percentage of the population living below the poverty line, which can influence access to healthcare and malaria prevention measures; and the information on healthcare facilities and services available in the community. Government agencies, the National Population Commission, and others in charge of socioeconomic data or information. According to Dechasa et al. (2024), population density is a known vulnerability factor for malaria, and it has been shown from research that densely populated areas tend to have higher malaria incidence rates (Moha et al., 2019). Furthermore, they opined that healthcare facilities in a specific area are crucial for patient treatment, raising awareness, and implementing preventive measures (Abdulahi et al., 2020). This was corroborated by Mihiretie (2022), stating that individuals residing close to healthcare facilities are at an advantage compared to those living farther away.

Stage 2: Data Preprocessing

This stage involves cleaning, transforming, and formatting the collected data to ensure it is suitable for GIS analysis. The steps involved in data preprocessing include:

1. Data Cleaning and Validation: This implies identifying and correctinging errors in the data, such as inconsistencies in formatting or invalid values, and verifying the accuracy and completeness of the data. According to Danoedoro (2012), remote sensing imagery's geometrymust have errors; such errors can arise because of the movement of satellites, earth rotation, the movement of the sensornsor scanning mirror, and also earth curvature. Therefore, geometric correction, which, which process of image quality improvement in order to produce ready-to-use imagery for specific applications, is necessary. In addition, radiometric correction is also performed to improve the visual quality of the image as well as correct the errors of pixel values that do not match the actual object reflectance. These are for satellite imagery, as numerical data like numbers are cleaned in different ways, such as removing outliers, etc. (Adhina et al., 2018)

2. Data Formatting and Transformation: This involves putting the data in standard formats to ensure consistency across different datasets and transforming data into a suitable format for GIS analysis, such as converting data from Excel to a GIS-compatible format.

3. Geocoding and Spatial Reference: This involves assigning geographic coordinates (latitude and longitude) to malaria cases and environmental data as well as ensuring that all data is referenced to a common spatial reference system. This is followed by the verification of the quality and accuracy of the data as well as ensuring that the data is consistent across different datasets.

Stage 3: GIS Mapping

This stage involves creating visual representations of the data to understand the spatial relationships and patterns. The steps involved in GIS mapping include:

1. Creating Thematic Maps and Environmental Factor Maps: This involves creating Malaria Incidence Maps to visualize the distribution of malaria cases in the community. Also, there will be the creation of environmental factor maps, which will help to visualize environmental factors, such as temperature, rainfall, and land use patterns.

2. Mapping Environmental and Socioeconomic Factors: This involves the creation of maps of environmental factors that influence malaria transmission, such as mosquito breeding sites and vegetation, and the map of socioeconomic factors that influence malaria transmission, such as population density and poverty rates.

3. Visualizing Spatial Relationships: This involves identifying the spatial patterns and relationships between malaria incidence and environmental/socioeconomic factors and identifying areas with high malaria incidence or clusters of cases. The various maps that can be created here are the slope map, distance to river map, altitude map, rainfall map, land use map (Adhina et al., 2018), health facilities map, and malaria cases map.

Stage 4: Spatial Analysis

This involves analyzing the spatial relationships and patterns of malaria incidence and environmental/socioeconomic factors. The steps involved in spatial analysis include:

1. Spatial Autocorrelation Analysis: This involves analyzing the degree to which malaria incidence or environmental/socioeconomic factors are correlated with each other in space and identifying patterns of spatial autocorrelation, such as clustering or dispersion.
2. Identifying Clusters or Hotspots: This involves the use of statistical techniques to identify areas with high concentrations of malaria cases or environmental/socioeconomic factors, as well as hotspot identification, or identifying areas with statistically significant clusters of malaria cases or environmental/socioeconomic factors.
3. Analyzing Relationships between Malaria Incidence and Environmental/Socioeconomic Factors: This involves the analysis of the relationships between malaria incidence and environmental/socioeconomic factors, controlling for spatial autocorrelation, and identifying environmental/socioeconomic factors that are significant predictors of malaria incidence.

Stage 5: Statistical Modeling

This stage involves using statistical techniques to analyze the relationships between malaria incidence and environmental/socioeconomic factors. The steps involved in statistical modeling include:

1. Regression Analysis: This involves the use of regression analysis to model the relationships between malaria incidence and environmental/socioeconomic factors, as well as identifying environmental/socioeconomic factors that are significant predictors of malaria incidence.
2. Developing Predictive Models: This involves developing predictive models to forecast malaria incidence based on environmental/socioeconomic factors.
3. Validating Model Performance: This involves the evaluation of the performance of the statistical models using metrics such as accuracy, sensitivity, and specificity, which is followed by model refining, which helps to refine the models based on the evaluation results to improve their performance.

Stage 6: Pattern Identification

This stage involves analyzing the results of the spatial analysis and statistical modeling to identify patterns and trends in malaria incidence. The steps involved in pattern identification include:

1. Identifying Areas of High Malaria Risk: This involves identifying areas with high malaria incidence or clusters of cases and identifying environmental/socioeconomic factors that contribute to high malaria risk in these areas; Determining Spatial Patterns and Trends which involves identifying spatial patterns in malaria incidence, such as clustering or dispersion, as well as identifying trends in malaria incidence over time, such as seasonal or annual patterns; Analyzing relationships between variables, which involves analyzing the relationships between malaria incidence and environmental/socioeconomic factors, as well as identifying correlations between variables, such as the relationship between rainfall and malaria incidence.

B. Importance of malaria pattern identification

3.2.1 Understanding Malaria Transmission Factors: There are various factors that cause malaria or encourage the impact of malaria in the society, such as nearness to a body of water, rainfall, etc. When the pattern of material is identified, it will make it easy to understand some possible factors causing it at that location. In other words, pattern identification helps to understand the underlying factors driving malaria transmission in the community.

3.2.2 Interventions: Pattern identification enables targeted interventions and resource allocation to areas with high malaria risk. Sometimes, mosquito nets are distributed freely in some localities. These could be as a result of the research work or the known feature of the location. In addition, knowing the pattern of the malaria will enable proper distribution of needed intervention such as boreholes, fumigation, etc.

3.2.3 Helps in Public Health Policy: The result or data gotten from the pattern of the Maria effect in a community or location provides valuable insights for public health policy and decision-making, enabling effective malaria control and prevention strategies.

3.2.4. Guiding Resource Allocation: It is the responsibility of every government to take good care of her citizens, especially in the areas of healthcare. This can be done through the allocation of some resources, which are dependent on some factors like population, age, land use, areas with high risk of malaria, etc.

3.2.5 Effective Malaria Control: There cannot be a proper or sufficient way of controlling malaria in a location without having the data of malaria prevalence or occurrences in the location. The determination of the pattern of malaria in a location will enable effective control of the malaria.

3.2.6 Improved Health Outcomes: There are some communities in some areas that do not have good health care facilities. And there are some that have, but the distance between the healthcare facilities and the people is very far, thereby making it difficult or impossible in some cases for the people to access these facilities even if they are suffering from malaria or any other ailment. The result of the malaria pattern done with GIS will provide a clear visual result of the state of things in the location, and this in some cases will lead to facelifting of the existing healthcare facilities as well as the building of new ones that will be close to the people. This will help to contribute to improved health outcomes and reduced malaria burden in the community.

CONCLUSION

This research was carried out to study the Geographical Information System (GIS) in identifying the pattern of malaria in a community or particular location. The research method adopted the use of the review research method as well as the explanatory research method. The result shows that there are certain stages or processes that are required in order to identify malaria patterns in a community using Geographical Information System (GIS). These stages, according to the results, are data collection; data preprocessing, which involves cleaning, transforming, and formatting of the collected data; GIS mapping, which involves creating visual representations of the data; spatial analysis, which involves the analysis of the spatial relationships and patterns of malaria incidence and some factors; statistical modeling, which involves using statistical techniques to analyze the relationships between malaria incidence and some factors; and pattern identification,

which involves analyzing the results of the spatial analysis and statistical modeling to identify patterns and trends in malaria incidence. It was also revealed by the result that the identification of malaria patterns in a community will be helpful in identifying factors causing malaria transmission in the community, effective resource allocation, and developing targeted strategies to address specific malaria transmission dynamics and risk factors, as well as improved health outcomes. It can be concluded that GIS is very important in the identification of malaria patterns in the society or community.

References

[1] Abdulahi A, Wudad A, Abajihad M, Mohammed F. Malaria hazard and risk analysis using GIS and remote sensing in Korahey zone of Somali Regional State, Eastern Ethiopia. Am Sci Res J Eng Technol Sci. 2020;68(1):1

[2] AdhinaAzdahHanifati, Anggi Permata, Dian Mustofa, Dita Eko Wulandari, Intan DewiRatnasari, Nabila Anggita Ekafitri, YusronHidayat Ridho and Prima Widayani (2018): Application of Remote Sensing and GIS for Malaria Disease Susceptibility Area Mapping in Padang Cermin Sub-District, District of Pesawaran, Lampung Province. IOP Conf. Series: Earth and Environmental Science 165, 012012 doi :10.1088/1755-1315/165/1/012012.

[3] Asnakew K Yeshiwondim, Sucharita Gopal, Afework T Hailemariam, Dereje O Dengela and Hrishikesh P Patel (2009): Spatial analysis of malaria incidence at the village level in areas with unstable transmission in Ethiopia. International Journal of Health Geographics. 8:5, pp 1 – 11

[4] DanoedoroProjo (2012): Pengantar Penginderaan Jauh Digital (Yogyakarta: Penerbit Andi)

[5] Dechasa Diriba, Shankar Karuppannan, Teferi Regasa4 and MelionKasahun (2024): Spatial analysis and mapping of malaria risk areas using geospatial technology in the case of Nekemte City, western Ethiopia. International Journal of Health Geographics (2024) 23(27), 1 - 17.

[6] Manoharan DR, Alemu M, Legesse B, Abajihad M. Malaria Hazard and risk analysis using geospatial techniques in the case of selected woredas of Jimma Zone, Oromia Region, Ethiopia. Earth Syst Environ. 2020. https:// doi.org/10.1007/s41748-020-00170-w

[7] Mihiretie AA. (2022): Assessment of malaria risk using GIS and multi criteria: the case study of East Gojjam Zone. Ethiopia Int J Environ Geoinform (IJEGEO). 9(1):74–78.

[8] Moha A, Maru M, Megento T. (2019): Assessment of malaria hazard, vulnerability, and risks in Dire Dawa City Administration of eastern Ethiopia using GIS and remote sensing. Appl Geomatics. https://doi.org/10.1007/ s12518-019-00276-5.

[9] WHO/UNICEF: The world malaria report 2005. Geneva: World Health Organization; 2005.

[10] Sarkar S, Singh P, Lingala MAL, Verma P, Dhiman RC. (2019): Malaria risk map for India based on climate, ecology and geographical modelling. Geospat Health. https://doi.org/10.4081/gh.2019.767

[11] Sweeney A.W. (1998): The Application of GIS in Malaria Control Programs. Proceedings of the Spatial Information Research Centre's 10th Colloquium. University of Otago, New Zealand.

[12] Yakudima I.I., Adamu Y.M., Samat N., Mohammed M.U., Abdulkarim I.I. and Hassan N.I. (2024): Geospatial Analysis of Malaria Prevalence among Children Under Five Years in Jigawa State, North West, Nigeria. fr. J. Biomed. Res. Vol. 27, No.2 (May) 202, 243 – 251.