



Trends and Potential of Geographic Information Systems in Dengue Management: Bibliometric Analysis

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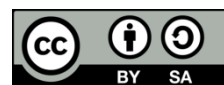
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ABSTRACT

Dengue fever remains a significant public health issue in many countries. Its high prevalence highlights the need for effective tools like Geographic Information Systems (GIS) to help predict and manage the spread of the disease. This study aims to examine and summarize the role of GIS in mapping and communicating dengue transmission patterns. A bibliometric approach was used to collect relevant literature from databases such as Google Scholar, Scopus, and PubMed. Out of 440 identified articles, only 11 met the inclusion criteria. Data extracted included publication years (2013–2023), journal titles, study designs, populations, interventions, outcomes, and reported benefits of GIS in dengue-related research. Qualitative analysis was conducted by organizing and presenting key findings. The results show that GIS is valuable in identifying current outbreak areas, detecting high-risk zones through spatial clustering, improving the accuracy of case predictions, and supporting ongoing surveillance efforts. Additionally, GIS contributes to more informed decision-making in dengue prevention and control programs. Overall, GIS plays an essential role in understanding disease dynamics, enhancing early warning systems, and guiding public health responses to dengue outbreaks.

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1. INTRODUCTION

Dengue fever remains one of the major public health problems, especially in tropical and subtropical regions [1]. The disease is an arbovirus infection caused by a virus from the Flaviviridae family, which consist of four serotypes (Dengue Virus 1, 2, 3, and 4) [2]. Dengue is recognized as a mosquito-borne disease with the highest rate of spread in the world, where approximately four billion people are considered to be at risk [3].

Globally, the World Health Organization report shows a significant increase in the spread of dengue fever worldwide, from 504,430 cases in 2000 to 5.2 million cases in 2019. In the Region of the Americas, 3.1 million cases were recorded, with more than 25,000 of them categorized as severe cases. Not only that high cases were also reported in Asia, such as Bangladesh (101,000), Malaysia (131,000), Philippines (420,000), and Vietnam (320,000) [4]. To improve surveillance and support the prediction of dengue fever epidemics, the utilization of Geographic Information Systems (GIS) is crucial.

Geographic Information Systems (GIS) serve as spatial data management platforms capable of integrating, storing, modifying, analyzing, and structuring geographical information. Commonly described as intelligent mapping systems, GIS offers a virtual representation of real-world environments. It facilitates the generation of interactive spatial and descriptive queries, supports spatial data analysis, and enables implementation in both analog and digital formats. [4]

The integration of public health and mapping was first introduced by Dr. John Snow in 1854 when he encountered significant challenges in addressing public health issues. This marked a pivotal moment in demonstrating the value of Geographic Information Systems (GIS) and spatial representation, which have since become essential tools for professionals in predicting and assessing public health risks. [4]

GIS has great potential in monitoring disease dynamics and vector distribution. This technology can be used to predict epidemics and conduct public health interventions, especially in Southeast Asia, where high temperatures greatly contribute to the spread of mosquito-borne viruses [5]. In addition, GIS enables a risk-based approach to improve disease surveillance and provide early warning of high-risk areas [6]. Various studies have utilized GIS as a tool to analyze geographic patterns of vector-borne diseases. One study stated that the combination of the National Communicable Disease Surveillance System database with GIS data can determine the speed and direction of dengue disease spread [7]. Another study showed the use of thematic maps to illustrate the geographical distribution and high incidence areas related to dengue, as well as a significant positive relationship between dengue transmission risk and age [8].

Studies related to the utilization of GIS in the spread of dengue have been conducted, but the literature that summarizes the benefits of GIS in the development of dengue epidemiological maps is still limited. Given the high prevalence of dengue to date, the utilization of GIS in supporting decision making and disease control is very important. This study aims to analyze techniques and summarize scientific evidence on the benefits of GIS in delivering information related to the spread of dengue as well as the possible improvement for future research in utilizing GIS for public health risks, especially dengue.

2. RESEARCH METHOD

The research method conducted bibliometric analysis using VOS [9] with PRISMA protocol to review, accumulate, and analyze findings from previous studies related to the utilization of Geographic Information System (GIS) on dengue fever. The article search strategy and research question preparation were conducted using the PICO framework, which includes Population (dengue patients), Intervention (utilization of GIS), Comparison (without utilization of GIS), and Outcome (information on dengue fever distribution). The article search was conducted through Google Scholar, Scopus, and PubMed databases using keywords: (“Geographic Information System”) AND (“Dengue Fever” OR “Dengue”).

Inclusion criteria included journal articles published between 2013 and 2023, open access, in English, and using predictive learning and classification approaches. Of the 440 articles identified, 11 articles met the inclusion criteria. Articles in the form of reviews, in languages other than English, not peer-reviewed, or not in final version were excluded from the final analysis. A PRISMA diagram illustrating the article selection procedure can be seen in Fig. 1.

The data extraction process was conducted with a focus on the main outcomes and methods used in each article. Four researchers analyzed the articles based on the title, abstract, journal content, research methods, study design, sample size, and results. The discussion continued by identifying similarities in the approaches used in the articles and identifying potential research gaps that could be the topic of future research. Data analysis was conducted systematically through reviews and analyzed qualitatively.

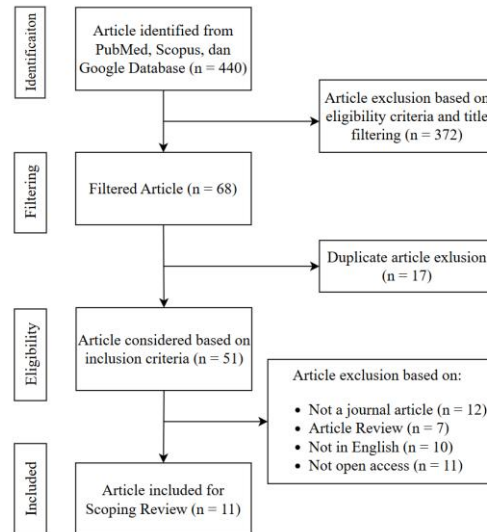


Figure 1. PRISMA Search Flow Diagram

3. RESULTS AND DISCUSSION

The utilization of GIS in the context of dengue disease spread mostly integrates mapping for spatial and temporal data distribution analysis with predictive learning approach (Table I). This approach allows researchers to not only understand the pattern of dengue spread geographically, but also predict its potential spread in the future based on identified risk factors.

Table 1. Benefits of GIS in the Spread of Dengue Disease

Authors and Year	Location	Database	Results	Method
Bryan Creencia et al., 2022 [10]	Cavite, Philippines	Google Scholar	Time series analysis was applied to project the number of dengue cases in 2022, 2024, and 2026. These predictions, together with the spatial provides a holistic picture of how dengue may spread in the province	Predictive Learning
Vargas et al., 2015 [11]	Itaboraí, Brazil	Scopus	The spatial unit of analysis used in this study is Local Surveillance Units (UVL), which acts as a methodological approach to integrate various sources of information related to disease, vector indices, and sociodemographic aspects of the city. These data are organized in various cartographic bases. As a multi-scale geographical phenomenon, dengue can be analyzed more deeply using UVL, allowing the identification of the distribution of dengue cases throughout the city.	Predictive Learning
Yanez & Canencia, 2017 [12]	Cayagan de Ora, Philippines	Google Scholar	The projection map created by geo-tagging the actual location of dengue virus infected respondents as well as the flight distance of mosquitoes proved to be very useful in supporting the continuous monitoring and surveillance of the affected communities in Barangay Cagayan de Oro.	Predictive Learning
Chaiphongpachara et al., 2017 [13]	Samut Songkhram, Thailand	Scopus	GIS is a very useful and efficient tool to support dengue surveillance in an area.	Predictive Learning
Mala & Jat, 2019 [14]	Dehli, India	Scopus	The application of spatio-temporal GIS for dengue provides benefits in identifying areas with potential outbreaks by determining spatial clusters of dengue cases at the local level. This spatio-temporal pattern analysis allows for improved prediction accuracy and can be used to reveal the inverse relationship between average wind speed and dengue incidence.	Predictive Learning, Cluster Analysis
Hernández-Avila et al., 2013 [15]	Mexico	PubMed	The development of a GIS-based web application for dengue disease (Dengue-SIG) was designed as a tool to support integrated analysis in epidemiological and entomological surveillance.	Predictive Learning, Cluster Analysis

Authors and Year	Location	Database	Results	Method
			Dengue-SIG allows identification of areas with increased risk of transmission as well as monitoring the effectiveness of vector control activities.	
Withanage et al., 2021 [16]	Gampaha, Sri Lanka	PubMed	This research proposes an early warning system (EWS) for dengue disease by utilizing GIS. The developed GIS-based model serves as an early warning tool that allows exploration and identification of the current condition of dengue in an area. The goal is to understand the pattern of disease spread and allocate limited public health resources effectively to prevent future dengue outbreaks and epidemics.	Predictive Learning, Cluster Analysis
Zambrano et al., 2019 [17]	Honduras	Scopus	Integration of GIS with clinical characteristics of diseases is necessary to obtain accurate epidemiological data to support public health systems. This information also has important benefits, including for risk assessment for travelers visiting certain regions in destination countries.	Predictive Learning
Brasil et al., 2015 [18]	Brazil	PubMed	This research develops a web application that utilizes digital image processing (DIP) algorithm and GIS to analyze dengue disease. This application is designed to help count the number of <i>Aedes aegypti</i> mosquito eggs and integrate it with GIS for direct visualization, decision support and analysis of collected data.	Classification
Zambrano et al., 2017 [19]	Honduras	Scopus	This study mapped Dengue and Chikungunya disease cases in Honduras in 2015 using GIS. GIS-based epidemiological maps proved useful in supporting decision-making for disease prevention and control, which remains a significant issue in the region, including in the face of new conditions.	Predictive Learning
Bessa Júnior et al., 2013 [20]	Mossoró, Brazil	PubMed	GIS-based spatial distribution was applied to identify dengue distribution patterns in Mossoró. The use of Geographic Information System (GIS) proved to be very useful in providing a clearer visualization of the level of endemicity, explaining the actual distribution of dengue cases in the area, as well as providing an effective tool for planning disease monitoring at the local level.	Predictive Learning

GIS-based techniques are able to identify risk areas and build an early warning system to predict disease prevalence, making it effective in dengue fever control efforts [21]. From the 11 articles reviewed, it is clear that the utilization of Geographic Information Systems can be combined with various methods other than predictive learning to understand and identify risk factors that affect the spread of dengue disease. This is in line with a previous study by Jayadas T.T.P., 2023, which stated that GIS-based risk maps are helpful in identifying dengue risk patterns and are expected to assist health agencies in prioritizing resources to risk areas [22].

In addition to risk factor analysis, other studies have also applied GIS with cluster analysis, as well as developed web-based applications using classification to present dengue spread information more comprehensively. This shows the variety of approaches that can be used in utilizing GIS to understand the impact of dengue disease and help control efforts.

Based on the findings from 11 articles on the utilization of GIS to track the spread of dengue, there are various benefits. Among them are increased accuracy in forecasting dengue cases, better monitoring and surveillance of affected communities, and more efficient dengue surveillance. GIS also allows the identification of the current situation of dengue in a region and the determination of areas potentially affected by the outbreak through the identification of spatial clusters at the local scale. In addition, the use of GIS supports decision-making in dengue prevention and control, and significantly improves visualization of disease prevalence. A study conducted by Fernández-Martínez B, et al., 2023 in Spain reported that early detection of dengue cases and vector management in high-risk areas should be prioritized to reduce the risk of autochthonous dengue. This approach also helps decision-making in disease prevention as well as improving visualization of endemicity levels [23].

Of the 8 articles that conducted risk analysis, 4 of them used Pearson correlation. Research by Bryan Creencia et al., 2022 and Mala & Jat, 2019 only tested the relationship between age and gender factors against dengue disease. The results showed that gender had a highly significant correlation, with the majority of dengue patients being male. Other significant risk factors include high population, settlement density, locations close to highways or toll roads, as well as areas that become breeding grounds for *Aedes aegypti* mosquitoes, such as stagnant water and leafy areas. Based on the study of Rejeki et al., 2021, urban areas with high population density accelerate the spread of infectious diseases. In addition, the mobility of individuals between geographic areas significantly contributes to the spread of infectious diseases [24].

Based on the identified environmental factors, prediction of potential dengue areas can be done by recognizing mosquito breeding sites and estimating the dispersal pattern (flight pattern) of *Aedes aegypti* mosquitoes. Brasil et al., 2015 tried to do this identification by developing a geographic information system-based digital image processing application, which is able to process mosquito egg count data using image recognition technology, then map the results directly through a web application.

ArcGIS has become one of the most popular tools in helping researchers visualize clusters and perform mapping. ArcGIS also provides analytic tools for cluster analysis and spatial-temporal distribution. Previous study by Lubrica, NVA, et al., 2023 on geographic information system-based dengue case analysis reported that clusters of dengue cases with high incidence rates were found in the western to southern parts of Baguio City, while some isolated cases were found in the southeast of the city. Low incidence dengue cases were found in the center of Baguio City, except for a few isolated cases in the northeast. Most clusters occurred in large barangay with high population, while densely populated barangay showed low case clusters [25].

The advantage of the GIS-based approach is the practicality of implementation supported by readily available GIS tools. However, the disadvantage is that the algorithms used are still limited and have not been developed specifically for each case. This approach is also affected by varying location factors, such as climate - winter, for example, can significantly reduce the number of dengue cases.

Data visualization in geographic information systems allows researchers to analyze and present geospatial data more easily and quickly. The resulting maps, graphs and diagrams help identify patterns, trends and relationships in the data, while facilitating better comprehension. In addition, geospatial visualization enables the presentation of findings in an engaging and understandable manner, thereby increasing the impact of research and supporting better decision-making in various fields. As an important tool in geographic information research and communication, geospatial data visualization plays a significant role in supporting a wide range of scientific and practical endeavors.

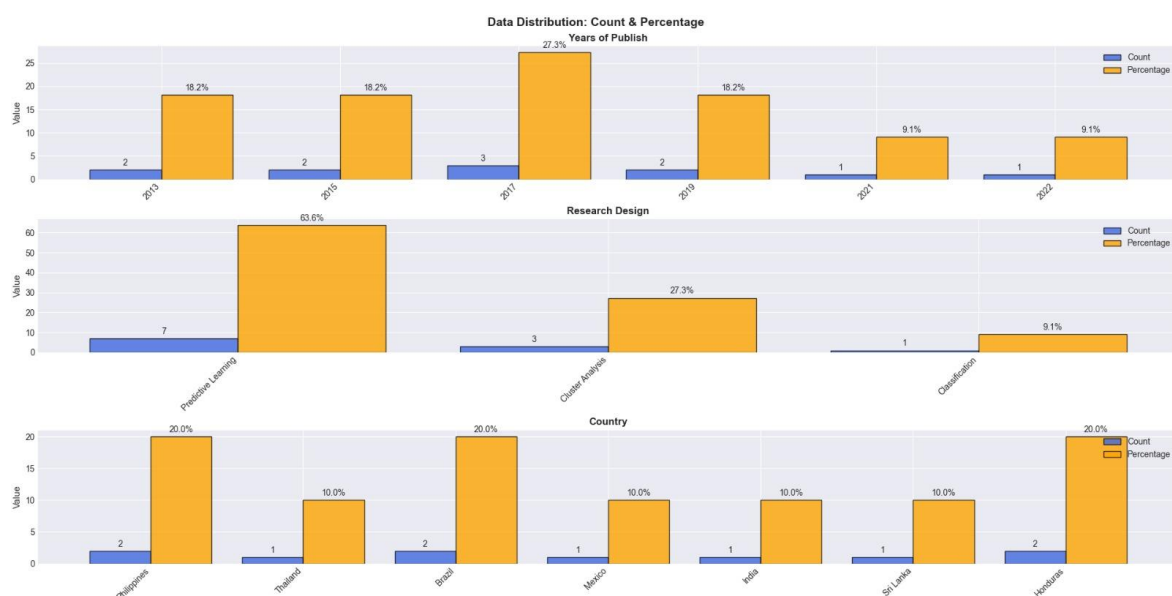


Figure 2. Data distribution of studies utilizing GIS in dengue disease

Fig 2. presents an overview of the data distribution in the bibliometric analysis of GIS applications in dengue disease management. The first section illustrates the distribution of studies over the years (2013–2022), showing peak research activity in 2017 (27.3%), with notable contributions in 2013, 2015, and 2019 (each 18.2%). The second section categorizes the **research designs** used in the selected studies, revealing

that most studies (63.6%) utilized **predictive learning models**, while others employed **cluster analysis (27.3%)** and **classification (9.1%)**. This reflects the emphasis on predictive analytics in GIS-based dengue research.

The third section highlights the **geographical distribution of the studies**, with notable contributions from **the Philippines, Brazil, and Honduras (each contributing 20%)**, followed by Thailand, Mexico, India, and Sri Lanka (10% each). The diverse geographic distribution of studies indicates a global interest in GIS-based dengue monitoring, particularly in tropical and subtropical regions where dengue is most prevalent. This visualization reinforces the significance of GIS in **dengue surveillance, prediction, and spatial analysis**, demonstrating its role in shaping data-driven public health strategies.

Of the 11 articles used in the discussion of the usefulness of GIS for dengue disease tracking, keywords correlation visualization was conducted using VOSviewer using a .ris file that had been previously generated using Mendeley Desktop. Fig. 3. shows the keyword relation using network visualization and overlay visualization.

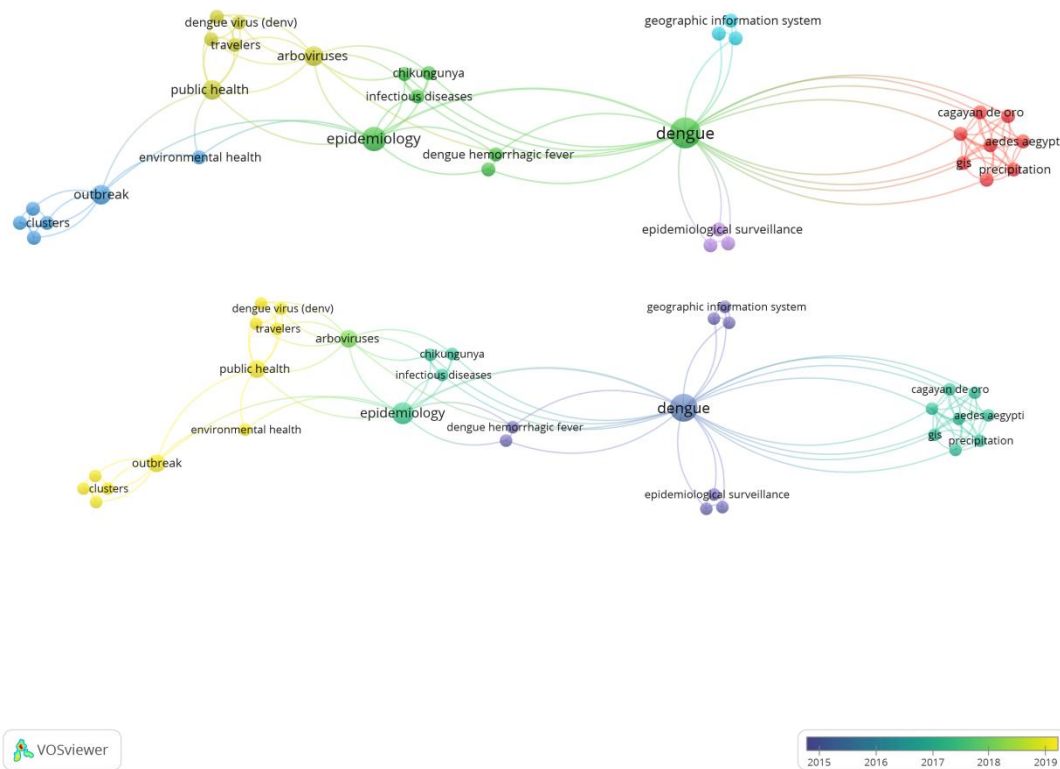


Figure 3. Co-occurrence Network Visualization (top) and Overlay Visualization (bottom) of keywords used in 11 selected articles

Network Visualization in Fig. 3 is divided into 6 clusters marked with different colors. Keywords that are in the same cluster mean that there is a strong relationship between words and are often used together in writing articles. Not only that, the relationship between clusters is also marked with lines that connect one word to another. The most frequently used keywords are shown in the node size of each word and “dengue” is the most frequently occurring word, followed by “epidemiology”, “arboviruses”, and “public health”.

Overlay Visualization is a type of visualization that group clusters using other attributes such as publication year. Visualization Fig. 2. shows the trend in the use of keywords from 2015 to 2019. Words such as “epidemiology” started to be used around 2017 while “public health” and “outbreak” were only used in 2020. Both visualizations suggest that dengue-related research tends to be related to epidemiology and monitoring methods.

4. CONCLUSION

Based on the research results, the use of Geographic Information System (GIS) proved to be useful in identifying the current situation of dengue spread in a region, determining areas potentially affected by the outbreak through spatial cluster analysis at the local scale, and predicting dengue cases more accurately. In

addition, GIS supports better monitoring and surveillance of affected communities, as well as providing more effective decision-making in dengue prevention and control. Future research is recommended to apply machine learning methods or develop more effective prediction algorithms to identify risk factors or the spread of dengue disease in various other locations. The resulting predictive model can be visualized using GIS to support decision making, both in efforts to treat and prevent dengue disease, or even other infectious diseases.

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