The application of geographic information system for dengue epidemic in Southeast Asia: A review on trends and opportunity

Cipta Estri Sekarrini1, Sumarmi2, Syamsul Bachri2, Didik Taryana2 and Eggy Arya Giofandi3

Abstract
The infectious disease dengue hemorrhagic fever remains an unresolved global problem, with climatic conditions and the location of areas located at the equator more often infected with dengue fever. Various modeling approaches have been employed for the development of a dengue risk map. The geographic information system approach was used as an instrument in applying mathematical algorithms to process field vector data into a preventive objective which is studied, then the application of remote sensing provides spatial-temporal data related to land use/land cover data sources as other variable categories. Map of hotspots for dengue fever cases is used to identify the risk of dengue fever areas by applying various complex methodologies, analysis, and visualization of advanced data are needed for its application in public health. In the last 10 years, the increase in the publication of dengue hemorrhagic fever in Southeast Asia in reputable international journals has increased significantly.

Keywords
Dengue, disease dengue, epidemic, Southeast Asia

Introduction
The viral disease of dengue fever is transmitted by mosquitoes with a rapid spread in the spread of infection transmission of disease, improper control, and severe disease.1,2 Most of the Aedes aegypti and Aedes albopictus mosquitoes are in tropical and subtropical climates, transmission conditions are influenced by various factors including virus circulation, vector density, and population susceptibility.3,4 The pattern of infection increases in semi-urban areas, Southeast Asia is the dominant area affected by endemic dengue hemorrhagic fever, the presence of global cases (14.11%) in 2015 with an estimated 1.8 billion people at risk of dengue.5,6 Meanwhile, the incidence of dengue fever is reported with an estimated 50–100 million cases each year, and the number of epidemics that occur increases every 3–5 years.7 The spread is taking place rapidly in the Asia-Pacific region which is associated with globalization, developing rapidly unplanned and unregulated in urban development causing poor water storage and unsatisfactory sanitation conditions.8

Dengue virus infection causes various manifestations of low-grade fever, fatal shock syndrome, immunity develops after infection with one of the four viral types, and disease progression with secondary infection.9–11 The existence of dengue is classified as one of the water-related diseases, water-related diseases account for about 10% of global diseases.12 Cycles in the increase in the amount of shallow surface water such as water storage basins, wet areas, and

1Program Doctoral of Geography Education, Faculty of Social Science, State University of Malang, Malang, East Java, Indonesia
2Department of Geography Education, Faculty of Social Science, State University of Malang, Malang, East Java, Indonesia
3Department of Geography, Faculty of Social Science, State University of Padang, Padang, West Sumatera, Indonesia

Corresponding author:
Cipta Estri Sekarrin, Department of Geography Education, State University of Malang, A21 Building 1st Floor Kampus PPG UM Malang, Malang City, East Java 65145, Indonesia.
Email: ciptaputri123123@gmail.com

Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (https://creativecommons.org/licenses/by-nc/4.0/) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (https://us.sagepub.com/en-us/nam/open-access-at-sage).
swamps are a public concern about the future disturbance of
dengue mosquitoes. Environmental conditions with sparse
vegetation, transportation routes, low altitude, and urban
development after urbanization support *Aedes aegypti* to
become uncontrollable even though several criteria are
found outside the environment. This is also supported by
information on anthropogenic growth that affects the natural
environment, such as changes in land use accelerating the
problem of ecosystem damage. Most of the vector-
borne Diseases have a seasonal pattern in the case of vector
abundance which indicates that dengue is sensitive to cli-
tological factors. The need for knowledge and attitudes
of local residents in responding to the presence of dengue
mosquitoes in controlling vectors in infected areas.

The spatial approach provides information in a spatial
angle with the disease identification method covering two
classes of parametric and non-parametric categories. Non-
parametric method of spreading no statistical distribution
of spatial disease levels by applying local information in
the form of weighted disease levels from neighboring
areas looking at the boundaries between spatial regions as
well as the opposite category. Some studies on disease
geography are categorized into three classes related to the
ecological environment, disease clusters, and disease
distribution. Geographic information system-based disease
mapping information depends on the interests of research-
ers in sharpening directions regarding patterns, risk fac-
tors, and causes of disease in spatial relationships in the
research area. One of them is calculating population
 genetics in estimating distribution through spatial autocor-
relation analysis with several cases in eastern Thailand,
there is a relationship from spatial autocorrelation up to
1 km of the active spread of *Aedes aegypti*. Several
important factors affect DENV (dengue virus) transmis-
sion, where climate variables are kept to a minimum to
maintain DENV transmission with seasonal fluctuations in
parameters acting as determinants of strength and period
of transmission. An understanding of the climatological
interactions and the temporal-spatial distribution of infec-
tious diseases has stimulated research interest in infectious
disease epidemic modeling. An understanding is
needed to understand the relationship in estimating future
health impacts.

The ability to map the accessibility of health services
relying on the application of Euclidean buffers yields
results that would be useful, but the lack of investigation
of alternative approaches such as the option of applying kerne
density estimation to assess health care availability in
Nicaragua and combined with algebraic procedures in geo-
graphic information systems. The fuzzy logic approach
helps to identify the biogeographical interaction of vector
diseases in the risk of dengue fever to establish a bioge-
ographical framework for the location of the disease.
Currently, dengue risk mapping has focused on future sce-
narios, understanding of the distribution of dengue virus
transmission is far from perfect and needs to be evaluated
with additional variables and comparative methods in predict-
ing patterns and trends of dengue fever.

**Design and methods**

The search terms used are medical, biogeography, geo-
graphic information systems for medical, dengue model-
ing using geographic information systems, spatial-temporal
dengue outbreaks, the environment of the *Aedes aegypti*
mosquito, the influence of climate on dengue outbreaks,
and books related to the application of geographic methods
for health. The researchers examined excerpts from the
included papers focused on peer-reviewed papers related
to the development of geographic technology in the appli-
cation of health problems.

**E.g. Geographical epidemiology**

Spatial epidemiology identifies and distributes spatial vari-
ations in transmission risk through map visualization and
exploratory analysis through interpretation of geographic
points of view in epidemiological research. When indi-
viduals make a diagnosis of transmission, the need for data
to address events can be assumed to be an aggregate of
events, either country, department, or whatever, then the
relative risk measurement using the standard of mortality
and mobility ratios gives an analogous result. As long as
epidemiological spatial analysis means data in the form of
the same spatial unit, separate, and can run without geo-
graphic information systems with all the methods discussed
consider health data to be superior to area-based data.
Application of geographic information system with spatial
analysis and spatial statistics as a tool to increase explora-
tion of global factors and points. Spatial analysis tools are
becoming available for exploration of transmission relevant
to the surrounding environment, with the application of
factor X as an investigation case and factor Y as a mathe-
matical nomenclature variable through the spatial point
related to the incidence of y as a determinant risk factor for
diagnosing the transmission environment.

**E.g. Spatial transmission diffusion**

A phenomenon related to the geomedical use of geographic
information systems or remote sensing began to trend
around the 1990s, the existence of standardized geography
diffusion models began to provide a means to track con-
cepts in geomedical development and began to adopt inno-
vations over a period of time through scientific publica-
tions. The introduction of diffusion transmission is the
movement of locations without using a network or
system for interaction from the beginning of existence.
The descriptions of expansion, contact and diffusion of
shared configuration or use of change are adapted from
contact innovations in which individual relationships exist. The exploratory analysis investigates the understanding of disease patterns to select a more appropriate analysis and further resolving doubts that arose in early stage investigations. Several approaches have been used in the design of spatial diffusion statistical modeling ranging from simple models through single parameters based on normal, binomial, or Poisson distributions to multivariable regression models with distributions covering the number of exposure variables that relate the probability of an outcome to the intensity of exposure of the value of one or more variables.

Table 1. Characteristics of the study area.

| Urban/Rural | Findings | Country |
|-------------|----------|---------|
| Urban       | Data were collected from 2014 to 2016 related to address, gender, age, and anonymous code. Geocoding kernel density method was applied in determining the cluster of events with the southern and southeastern areas is riskier. The data was about 60% of the total data in the city of Bandung obtained from type B hospital information. | Indonesia |
| Urban       | An observational approach with cross-sectional spatial analysis found that women aged <25 years had a 54% higher percentage than men 46%. The cluster information occurred in March-April 2018 with a transmission radius of three km. | Indonesia |
| Rural       | One of the stages carried out in-depth is an interview approach with questions related to the environment and demography linked through secondary data analysis. The risk category was found in children and students. The highest cases reached (78.7%) of the 61 cases found (4.9%) resulted in death. | Indonesia |
| Urban       | The application of the random forest algorithm and ordinary least squares (OLS) regression is carried out statistically, if non-stationary through the geographically weighted regression stage. The obtained values of R² for the regression ranged from 0.364 to 0.671 and the k-means clustered dataset ranged from 0.395 to 0.945. The results of the GWR model between 0.675 and 0.876 resulted in a logical classification of the GIS grouping analysis. | Philippines |
| Rural       | The information approach was processed using a spatial mean center approach, standard distance, directional distribution analysis, and average nearest neighbor. The distance between events in 2008 was about 22,085 m and for the 2009 case with a distance of 20,318 m. Small-scale transmission with the presence in 2008 the ratio of nearest neighbors 0.225698 and z-score −55.444729 and in 2009 the spatial point of dengue cases found the ratio of nearest neighbors 0.264112 and z-score −45.748278. Information was related to the factors affecting the distribution pattern and direction of transmission. | Malaysia |
| Urban       | Climate and vegetation variables from 2008 to 2015 were used to predict the incidence of dengue fever through the autoregressive integrated moving average (ARIMA) model. The finding of quadratic correlation reached 0.869. | Philippines |
| Urban       | Dengue fever outbreaks were analyzed through 3 spatial statistics, namely, Moran’s I, Average Nearest Neighborhood (ANN), and Kernel Density to see the spatial distribution of cases. There is an average distance of 264.91 m with regional housing locations as identified places. | Malaysia |
| Urban       | The application of fuzzy techniques with epidemiological, environmental, and socio-economic approaches provides a level of model accuracy into four categories, namely positive predictive value (PPV) = 0.780, Negative Predictive Value (NPV) = 0.938, Sensitivity = 0.547, and Specificity = 0.978 with the application of the F0 measure. S. Mitigation effectiveness can increase as predictive modeling advances for more precise mitigation and planning consequences management. | Philippines |
| Urban       | The information found during the spatial-temporal period of at-risk groups is concentrated in the southeast and central regions. The clusters formed seven groups (p < 0.001) with the most at-risk cluster of 3.94 (p < 0.001, about 14% of the total population). Findings from all clusters are 71.4% in the same month for 3 years. | Malaysia |
| Urban       | Ecological and sociodemographic approaches were tested with multivariate and univariate logistic regression. The spatial statistical description of commercial areas mixed with residential and densely populated areas resulted (aOR = 2.23 and p = 0.009), while the findings in the sociodemographic model with the highest risk were >45 years old (aOR = 3.24, p = 0.003). Communities that apply clean environmental management have the smallest value (aOR = 1.91, p = 0.035). | Thailand |
control of infectious disease prevention in the Southeast Asian region.

Discussion

The application of geographic information systems in the world of health provides a broad overview of contributions, ranging from case visualization which is used as a tool in spatial epidemiology to help identify disease events and interventions. Case visualization is loaded into a simple display that can be accessed by civilians and health workers to find out information about risks around and the position of the address through the use of global position system input to the web to form health geo-information.

Collection of citation analysis to obtain article quality is sometimes unreliable because published articles still have lower citations. The author’s behavior of citing articles is motivated by various reasons, such as methodology, the correct variables produce useful study results. Researchers sometimes cite other papers for the opposite reason, regarding flawed or problematic methods and results. Therefore, it cannot be refuted as an indicator of a good article. Although there are no limitations regarding the results of the literature in the use of keywords and terms in producing relevant case studies. The use of ambiguous language related to technical terms such as climatology, environment, modeling, risk, and dengue mapping, in the literature studied was limited or resulted in bias in the search results.

The review is deliberately focused on studies of utilizing geographic information systems for dengue risk in the Southeast Asian region by linking health problems with existing problems in society, while a number of studies dealing with entomological risks are still minimally considered in the review.

Conclusion

This review has demonstrated the diversity of variables and modeling approaches for the creation of dengue fever risk maps. The growth related to the use of geographic information systems in dengue hemorrhagic fever modeling in reputable international journal publications, increasing both the quality and quantity of publications require various strategies for using variables. The pattern of analysis that is less standardized shows that the field of dengue risk mapping modeling will continue to develop, marked by high variability. Improving the ability of structured training interventions, providing learning references, training for writing that is supported by an academic atmosphere, and policies that encourage the renewal of variability encourage publication of publications. Despite the various limitations, dengue risk maps become a powerful tool to improve surveillance to prediction which depends on the acquisition of availability of good quality data requirements in terms of spatial and temporal resolution.

Acknowledgements

We thank the study team involved in the learning of Geography Information System for infectious disease analysis, especially to State University of Malang and State University of Padang that supported well either directly or indirectly and also thank you very much to the reviewers that gave valuable insight in this paper.

Author contributions

CES, designed and interpretation of data, conceptual, literature survey, analysis, and drafting the article; S, involved and contribute to conceptual, critical reviewing and final approval of the version to be submitted; SB, involved and contribute to conceptual, critical reviewing and final approval of the version to be submitted; DT, involved and contribute to conceptual, critical reviewing and final approval of the version to be submitted; EAG, interpretation of data, conceptual, literature survey, analysis, and drafting the article.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Significance for Public Health

This research has a novelty in helping reduce the transmission of dengue hemorrhagic fever with a spatial perspective, the endemic outbreak of dengue hemorrhagic fever which is transmitted from the aedes aegypti mosquito can be estimated using spatial technology of geographic information systems. This is important to explain regarding the development and opportunities of health information in controlling the Aedes aegypti mosquito outbreak in Southeast Asia. This will assist practitioners and health policy makers in making decisions in estimating the emergence of mosquito habitats.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

References

1. WHO. Global Strategy for Dengue Prevention and Control. Geneva: WHO Press, 2012. pp.1–43.
2. Chen WJ. Dengue outbreaks and the geographic distribution of dengue vectors in Taiwan: a 20-year epidemiological analysis. Biomed J 2018; 41: 283–289.
3. Khanikor B, Parida P, Yadav RNS, et al. Comparative mode of action of some terpene compounds against octopamine receptor and acetyl cholinesterase of mosquito and human system by the help of homology modeling and docking studies. J Appl Pharm Sci 2013; 3: 6–12.
4. Louis VR, Phalkey R, Horstick O, et al. Modeling tools for dengue risk mapping - a systematic review. Int J Health Geogr 2014; 13(1): 50.
5. WHO. Integrating neglected tropical diseases into global health and development: fourth WHO report on neglected tropical diseases. Geneva: World Health Organization, 2017. pp.1–267.
6. Maula AW, Fuad A and Utarini A. Ten-years trend of dengue research in Indonesia and south-east Asian countries: a bibliometric analysis. Glob Health Action 2018; 11(1): 1504398.
7. Mutunenri SR, Mopuri R, Naish S, et al. Spatial distribution and cluster analysis of dengue using self organizing maps in Andhra Pradesh, India, 2011–2013. Parasite Epidemiol Control 2018; 3(1): 52–61.
8. WHO. Comprehensive guidelines for prevention and control of dengue and dengue haemorrhagic fever. New Delhi: WHO SEARO, 2011. pp.159–168.
9. WHO. Dengue: guidelines for diagnosis, treatment, prevention and Control. Geneva: World Health Organization; WHO Press, 2009. pp.1–160.
10. Simmons CP, Farrar JJ, Nguyen VV, et al. Dengue. N Engl J Med 2012; 366: 1423–1432.
11. Bhatt S, Gething PW, Brady OJ, et al. The global distribution and burden of dengue. Nature 2013; 496: 504–507.
12. Dom NC, Madzlan MF, Nur S, et al. Water quality characteristics of dengue vectors breeding containers. Int J Mosq Res 2016; 3: 25–29.
13. Verdonschot PFM and Besse-Lototskaya AA. Flight distance of mosquitoes (Culicidae): a metadata analysis to support the management of barrier zones around rewetted and newly constructed wetlands. Limnologica 2014; 45: 69–79.
14. Van Benthem BH, Vanwambeke SO, Khantikul N, et al. Spatial patterns of and risk factors for seropositivity for dengue infection. Am J Trop Med Hyg 2005; 72: 201–208.
15. Myers SS and Patz JA. Emerging threats to human health from global environmental change. Annu Rev Environ Resour 2009; 34: 223–252.
16. Sarfraz MS, Tripathi NK, Faruque FS, et al. Mapping urban and peri-urban breeding habitats of Aedes mosquitoes using a fuzzy analytical hierarchical process based on climatic and physical parameters. Geospat Health 2014; 8: S685–S697.
17. Kim S, Kim S-Y, Oh J, et al. Effects of the 2018 heat wave on health in the elderly: implications for adaptation strategies to climate change. Environ Anal Heal Toxicol 2020; 35: e2020024.
18. Park J-W. Changing transmission pattern of Plasmodium vivax malaria in the Republic of Korea: relationship with climate change. Environ Health Toxicol 2011; 26: e2011001.
19. Negev M, Paz S, Clermont A, et al. Impacts of climate change on vector borne diseases in the Mediterranean basin – implications for preparedness and adaptation policy. Int J Environ Res Public Health 2015; 12(6): 6745–6770.
20. Park J-W, Cheong H-K, Honda Y, et al. Time trend of malaria in relation to climate variability in Papua New Guinea. Environ Health Toxicol 2016; 31: e2016003.
21. Santos CAG, Guerra-Gomes IC, Gois BM, et al. Correlation of dengue incidence and rainfall occurrence using wavelet transform for João Pessoa city. Sci Total Environ 2019; 647: 794–805.
22. Syed M, Saleem T, Syeda UR, et al. Knowledge, attitudes and practices regarding dengue fever among adults of high and low socioeconomic groups. J Pak Med Assoc 2010; 60: 243–247.
Gunungkidul Regency, Indonesia. *Indones J Geogr* 2020; 52(1): 80–89.

43. Valles JJ, Perez C and Blanco AC. Geospatial and Clustering Analysis of dengue cases using self-organizing maps: case of Quezon City, 2010–2015. *Int Arch Photogramm Rem Sens Spat Inf Sci* 2019; XLII: 455–462.

44. Abd Majid N, Muhamad Nazi N and Mohamed AF. Distribution and spatial pattern analysis on dengue cases in Seremban District, Negeri Sembilan, Malaysia. *Sustainability* 2019; 11: 3572.

45. Pineda Cortel MB, Clemente B and Nga PT. Modeling and predicting dengue fever cases in key regions of the Philippines using remote sensing data. *Asian Pac J Trop Med* 2019; 12: 60–66.

46. Hazrin M, Hiong HG, Jai N, et al. Spatial distribution of dengue incidence: a case study in Putrajaya. *J Geogr Inf Syst* 2016; 08: 89–97.

47. Buczak AL, Baugher B, Babin SM, et al. Prediction of high incidence of dengue in the Philippines. *PLoS Negl Trop Dis* 2014; 8: e2771.

48. Ling CY, Gruebner O, Krämer A, et al. Spatio-temporal patterns of dengue in Malaysia: combining address and sub-district level. *Geospat Health* 2014; 9: 131–140.

49. Koyadun S, Butraporn P and Kittayapong P. Ecologic and sociodemographic risk determinants for dengue transmission in urban areas in Thailand. *Interdiscip Perspect Infect Dis* 2012; 2012: 07949.