Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2022 Mar 26; 10(G):422-429.
https://doi.org/10.3889/oamjms.2022.9125
eISSN: 1857-9655
Category: *G - Nursing*
Section: *Nursing in Gynecology and Obstetrics*

Euclidean Distance Modeling of Musi River in Controlling the Dengue Epidemic Transmission in Palembang City

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Edited by: Sasho Stoleski
Citation: Sekarrini CE, Sumarmi S, Bachri S, Taryana D, Giofandi EA. Euclidean Distance Modeling of Musi River in Controlling the Dengue Epidemic Transmission in Palembang City. Open Access Maced J Med Sci. 2022 Mar 26; 10(G):422-429. https://doi.org/10.3889/oamjms.2022.9125
Keywords: Ecology; Dengue outbreak; Euclidean distance; Mosquito
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Received: 31-Jan-2022
Revised: 21-Feb-2022
Accepted: 16-Mar-2022

Funding: This research did not receive any financial support.
Competing Interest: The authors have declared that no competing interest exists.

Abstract

BACKGROUND: Various attempts have been made to control the population of *Aedes aegypti* with the help of chemicals or by engineering Wolbachia pipientis, an obligate intracellular bacterium that is passed down through Dengue Virus and arbovirus infections to manipulate the monthly average reproductive yield. This study reviews the phenomenon of the river border area which is one of the habitats for the *A. aegypti* mosquito in the Musi River, Palembang City.

AIM: The application of the Euclidean distance method in this study was carried out to determine the environmental exposure of settlements along the river basin area.

METHODS: The research methodology was carried out objectively related to data on dengue incidence in 2019. It was carried out by taking location coordinates through the application of geographic information systems and the use of satellite imagery for data acquisition of existing buildings. This stage is followed by bivariate statistical calculations using the application of Weights of Evidence where the probability value of the measurement is described using the Area Under Curve (AUC). Processing and accumulation carried out with existing buildings will result in a calculation of the estimated size of the exposure area.

RESULTS: The results obtained provide information, where the natural breaks jeanks value of 0.007–0.016 range results in 1465ha of heavily exposed building area. The value of the temporary bivariate statistical calculation will produce an AUC probability number of 0.44 which describes the relationship between the Musi river and the findings of dengue symptoms in the sub-districts around the Musi river border area, Palembang City. Swamp soil conditions are vulnerable to being a habitat where *A. aegypti* larvae are found.

CONCLUSIONS: Based on the analysis that we obtained from the population of dengue incidence and the condition of the river basin area showed a significant structure with the distribution of dengue incidence, it is known that the presence of buildings on the river Musi banks has a greater risk of infectious diseases transmissions and natural disasters ranging from sanitation, hygiene, and flooding to river erosion.

Introduction

Some vector communicable diseases are transmitted by the *Aedes aegypti* mosquito, although there is still the possibility of being transmitted by the *Aedes albopictus* mosquito [1], [2], [3]. Dengue fever remains a major public health problem in the global tropics and subtropics where an estimated 390 million people have been infected by vector-borne viruses with 96 million developing the symptomatic disease [1], [4]. In general, each region has different characteristics, especially related to climatological conditions. Local cultural characteristics are also known to produce several cases with different values [4]. The condition of the mosquito cycle in metamorphosis from egg to adult stage takes ranging from one and a half to 3 weeks. The life span of an adult mosquito ranges from 2 weeks to 1 month, depending on the environmental conditions of the dengue habitat [5], [6]. Climate change is considered to be a major driving force in accelerating DENV transmission and epidemics with ecological, demographic, behavioral, and socioeconomic conditions as the main determinants of local dengue risk [4], [7].

The current surveillance system is still unable to capture information about the source of infection, whether it was obtained locally or imported from an unknown sub-district and whether the case was obtained from the sub-district where it was reported [6]. Some visual media and posters need to be encouraged to build awareness of fever prevention dengue coupled with the socialization of disposing of garbage considering that garbage can be a place for mosquitoes to lay eggs [8]. It is necessary to update the identification of potential vectors of dengue virus or other mosquito-borne diseases in certain areas as an implication of how important it is to understand how disease occurs [9], [10]. The purpose of using GIS for studies is often to model predictions, for example, multiple layers of vector disease indication data may be combined spatially to predict vector disease prevention as output maps. Predictive information results are sometimes used as a research exercise in exploring the findings that form a certain set of assumptions aimed at evaluating the performance of a model [11]. Some researchers expect an increasing trend in the future with increasing urban areas, land clearing, and climate change conditions [12], [13].

The improved research in the application of geographic information systems and remote sensing technology has studied the spatial relationship between vector infectious diseases and factors affecting the spread of dengue [14], [15]. Information from the GIS method produces disease maps with varying levels that are continuously displayed in the map output, which is an advantage over disease levels for sub-districts. The conceptual view can model the facts in the field. It does not expect disease rates to change abruptly throughout a statistical area observation for which information is collected and stored as disease data [14].

Many studies have applied probabilistic models. It is important to apply this model before entering other statistical models to gain a better understanding of the spatial extent of dengue outbreaks, especially in certain areas, so that they can be well planned in-depth [15]. The cluster-level analysis involves categorization where a large group of observations is divided into smaller groups to display observations in each group that is relatively similar with the same characteristics and vice versa [16], [17]. Modeling complex interactive relationships between disease and climate has been recognized in many studies as a difficult problem [18], [19]. The possibility of disproving a prediction without any refutation cannot be considered science, even if the methods used to make it follow good scientific practice and result in risks associated with something you propose can never be denied [19].

Based on the phenomena that occur, it is more interested in exploring health symptoms by applying a spatial geography approach. The evidence regarding the general way of thinking spatially is to identify the location of the incident; it shows the increased special research related to transmission by estimating the range of transmission to settlements around the location of the incident. The differences found to involve the existence of built-up land as a place for daily activities along the river border. Therefore, the purpose of this study was to determine the estimated area of exposure by forming clusters of the potential level of dengue outbreak transmissions in the Musi River border, Palembang City.

Methods

The research methodology was carried out objectively related to data on the incidence of dengue fever in 2019, secondary data on the event were obtained from the Palembang City Health Office in 2020. The surveillance data on the incidence of dengue hemorrhagic fever were carried out by taking location coordinates through the application of geographic information systems and the use of satellite imagery to the acquisition of existing building data.

Research areas

The observation study area is located in ten sub-districts, namely, Gandus, Kertapati, Ilir Barat Dua, Seberang Ulu Satu, Bukit Kecil, Seberang Ulu Dua, Plaju, Kalidoni, Ilir Timur Dua, and Ilir Timur Satu sub-districts which are located along the Musi river. The connected river network is surrounded by settlements located in waterlogged land. After the economic center was growing in the early 1820s, trade routes using ship transportation made the Musi river border a central part of the South Sumatran economy. The dynamics of faster growth is an ideal reason to study the invasion of *A. aegypti* in areas prone to waterlogging whose population depends on fluvial land conditions.

Mosquito data collection

Mosquito data were collected from several sub-districts along the Musi River border. Figure 1 and Table 1 summarize the characteristics associated with the data for each sub-district in the Musi River. The map is made in a geographic information system software program using a vector format obtained from field survey data collection activities. Surveys were carried out from various locations along the port to map the historical locations of events in 2019 that were more closely related to those around them. The location of the occurrence estimated *A. aegypti* has the main function as a potential fluvial transit in the presence of domestic *A. aegypti*.

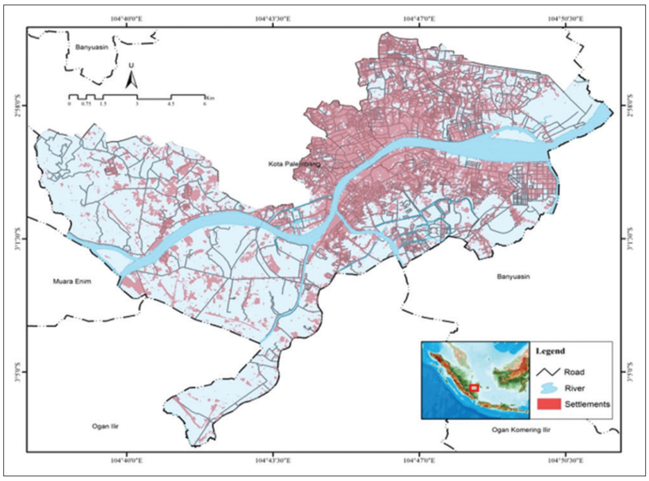

Figure 1: Research site

Table 1: Characteristics of the study area

Sub district	Total occurrence	Percentage	Resident population
Bukit Kecil	28	4.40	50.301
Gandus	180	28.30	65.782
Ilir Barat Dua	52	8.18	73.269
Ilir Timur Satu	200	31.45	79.268
Ilir Timur Dua	20	3.14	95.963
Kalidoni	20	3.14	112.932
Kertapati	34	5.35	92.084
Plaju	20	3.14	90.734
Seberang Ulu Satu	30	4.72	94.122
Seberang Ulu Dua	52	8.18	107.101
Total	636	100.00	861.556

Data analysis technique

The analytical methods applied in the study area are described in this section. The spatial concept approach is carried out by understanding the location, distance, area, pattern, distribution, and spatial associations where will help to understand the analysis during the research process [20], [21]. The location of the dengue incidence in 2019 was processed into spatial data with latitude and longitude numbers which are known to produce data in vector format. Sentinel 2B satellite-based remote sensing data was recorded July 31, 2021, through the https://scihub.copernicus.eudi page. The process of generating data for existing buildings along the Musi River border using the Normalized Difference Built-up Index transformation developed by Zha *et al*. [21]. Information on the Musi River in this case is obtained in the form of vector data. We used the estimation of genetic isolation (636 events) by different distance models for the findings of the *A. aegypti* sample data by combining the Euclidean distance on the Musi River route. Development that combines the possibility of *A. aegypti* in various building conditions with the frequency of transmission around the Musi River. We calculated the probability of infection by applying bivariate statistics. Dengue data were obtained from the field in 2020 in ten different sub-districts plus a waterlogged land approach as one of the determinants in sharpening the analysis.

Euclidean distance

Distance is defined as the measured position of the concept of near and far by providing a central concept in geography that will lead to the development of further concepts to be built. The metric description allows the measurement of space to be passed through several approaches [22]. The probability of an individual to the furthest neighboring distance depends on the calculation of the Euclidean distance by displaying the level of infection probability of an individual susceptible to infected transmission. The proposed new strategy related to local area immunization is carried out by immunizing neighbors around infected individuals. Determination of the critical immunization radius is carried out as an effective condition to reduce epidemic prevalence in local area networks [23]. Elements that contribute to the implementation of Euclidean distance on epidemic transmission include acceptability, accessibility, and availability factors that make up the relative structure [24]. The mathematical algorithm [25] of Euclidean distance is defined as follows.

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

Bivariate statistics

Bivariate detection depends on the shape of the data distribution which is characterized in the form of a covariance matrix. A well-known use is through the distance between the pixel values and the distribution of the observation locations [26]. The statistical model applied to determine the transmission of dengue outbreaks is using the Weights of Evidence (WoE) statistical model and Area Under Curve (AUC) testing. The WoE statistical model belongs to the category of bivariate approach which is based on the probability of some binary patterns to predict other binary patterns [27], [28]. The WoE equation developed by [11] is as follows:

$$W^{+} = ln\left[\frac{P\{B|A\}}{P\{B|A\}}\right] \quad (2)$$

$$W- = ln\left[\frac{P\{n \mid A\}}{P\{n \mid A\}}\right] \quad (3)$$

There are two basic parameters used for the model process, namely positive weight (W^{+}) and negative weight (W^{-}). The P-value, in this case, is the probability, In is the natural algorithm, B and $\underline{B}$ are the presence or absence of the condition side in each factor, while A and $\bar{A}$ are found or not found in each variable [11], [28].

Results

Field data collection was carried out during January until April in all sub-districts around the river border. The findings generated in this study are discussed in this section. The distribution of the incidence of dengue outbreaks was described based on the Euclidean distance of the Musi river to the residences along the river (Figure 2). The results of the application of the bivariate regression model framework are used to determine the probability of finding potential exposure events. Meanwhile, to find out whether the process is running according to the hypothesis, it is done using the river range. This is discussed in this section.

River conditions are one of the favorite habitats for mosquitoes. The existence of a landscape that is rich in water sources makes it easier for mosquitoes to

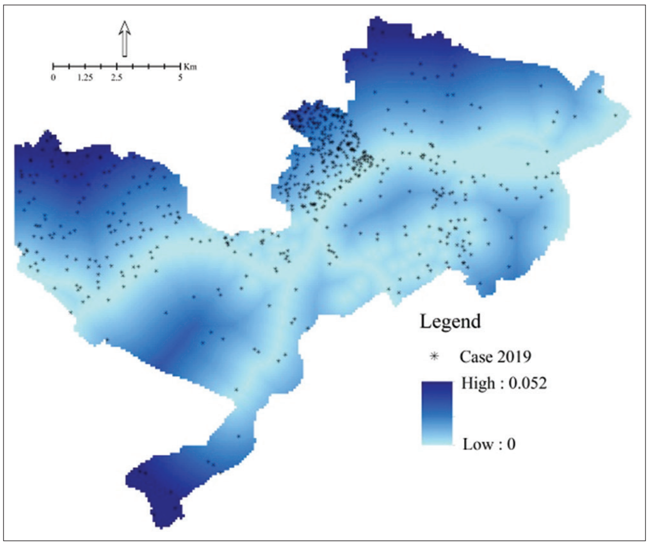

Figure 2: Euclidean distance map

use the ecosystem to breed. Rivers which are always synonymous with slum areas or slum areas make it very easy to find small animals such as mosquitoes, flies, rats, insects plus a river landscape whose borders are swampy soils that are very easy to find puddles up to flood plains [29], [30]. The soil in the river when entering the rainy season with conditions of increased water discharge plus the condition of the buildings around it will turn out to be watertight so that the settlements are flooded by water [31], [32]. This inundation condition will gradually form a new ecosystem [33]. Several disasters due to hydrometeorology will emerge, ranging from economic disasters, health, social, and transportation disasters.

Problems of health outbreaks, especially dengue outbreaks described from river data were obtained using the Euclidean distance algorithm which forms a relative structure. After applying the Euclidean distance search in the river area, the next step is to correct the WoE statistical model to see the binary pattern of each population by calculating the Euclidean distance. Euclidean values are divided into 20 classes through the division of natural breaks Jenks to simplify the calculation of WoE and AUC values. Significant deficits were detected in WoE calculations among ten class ids (IDs 2, 3, 4, 5, 12, 14, 15, 16, 19, and 20) in (Table 2). In this case, the lowest minus deficit value reaches −5.85705. Distribution across 20 classes including the previously mentioned class ids, found the highest surplus in class 6 ids up to 0.443506. The majority of the incidence of epidemic dengue is found in id classes 1 to 6 with the respective incidence rates are 72, 42, 29, 35, 26, and 32, respectively. The resulting total density class ranges from 0.330288122 and the total FR value reaches 19.38042. Meanwhile, the IVM value obtained was −6.45112, and W+, W−, to C overall (−6.46143, 0.002692, −6.46412) resulted in a total WoE value ranging from −6.41027.

Overall, the Euclidean distance used to estimate settlement exposure is divided into four categories. The value of each category is calculated based on the natural breaks Jenks class starting from the very high class (<0.007) from the riverbank boundary. However, the peak findings were found at values (0.007–0.016) and belonged to the high grade of the following locations. Furthermore, for dengue outbreaks, it was found in the value (0.016–0.030) with a medium-class category, while in the low category (0.030–0.052) there was a little incidence of dengue outbreaks. The natural breaks Jenks value are used as a value to calculate the exposure area which is divided based on the calculation of the Euclidean distance. The visual appearance of the exposure area map is displayed (Figure 3) with map information (a) a map of the calculation of natural breaks Jenks of the Musi river border, while mapping information (b) a map of the zoning category of exposure to dengue outbreak transmission in settlements in 2021 in ten sub-districts along the Musi river border.

The transmission of dengue outbreaks along the Musi River basin, Palembang City resulted in 636 cases (Table 1). This enormous movement forms the increasing transmission of the *A. aegypti* mosquito. Potential exposure that will occur can be determined

Table 2: Calculation of the value of weight of evidence

ID	Class	Factor	Epid	Tot_ls	Class_dens	Map_dens	FR	IVM	W+	W−	C	WoE
1	4240	0.210057	72	72.21006	0.017030674	0.01704236	0.999314	−0.00069	−0.0007	0.000185	−0.00088	0.001809
2	2799	0.138667	42	42.13867	0.015054901	0.01704236	0.883381	−0.124	−0.12602	0.018926	−0.14494	−0.14225
3	2319	0.114887	29	29.11489	0.012554932	0.01704236	0.73669	−0.30559	−0.31014	0.034199	−0.34434	−0.34165
4	2142	0.106118	35	35.10612	0.016389411	0.01704236	0.961687	−0.03907	−0.03973	0.004617	−0.04435	−0.04166
5	1593	0.07892	26	26.07892	0.016370948	0.01704236	0.960603	−0.04019	−0.04088	0.003428	−0.0443	−0.04161
6	1263	0.062571	32	32.06257	0.025386042	0.01704236	1.489585	0.398498	0.407022	−0.03379	0.440813	0.443505
7	985	0.048799	17	17.0488	0.017308425	0.01704236	1.015612	0.015491	0.015762	−0.00082	0.016577	0.01927
8	848	0.042011	16	16.04201	0.018917466	0.01704236	1.110026	0.104384	0.106293	−0.00492	0.111214	0.113906
9	753	0.037305	14	14.0373	0.018641839	0.01704236	1.093853	0.089707	0.091335	−0.00371	0.095042	0.097734
10	663	0.032846	16	16.03285	0.024182272	0.01704236	1.418951	0.349918	0.357208	−0.01458	0.371785	0.374478
11	519	0.025712	14	14.02571	0.027024494	0.01704236	1.585725	0.461042	0.471249	−0.01585	0.487095	0.489788
12	438	0.021699	7	7.021699	0.016031277	0.01704236	0.940672	−0.06116	−0.06219	0.001338	−0.06353	−0.06083
13	346	0.017141	6	6.017141	0.017390582	0.01704236	1.020433	0.020227	0.020581	−0.00036	0.020944	0.023636
14	287	0.014218	2	2.014218	0.007018183	0.01704236	0.411808	−0.8872	−0.89734	0.008595	−0.90594	−0.90325
15	274	0.013574	3	3.013574	0.010998447	0.01704236	0.645359	−0.43795	−0.44408	0.004953	−0.44903	−0.44634
16	225	0.011147	3	3.011147	0.013382875	0.01704236	0.785271	−0.24173	−0.24544	0.00246	−0.2479	−0.24521
17	204	0.010107	4	4.010107	0.019657385	0.01704236	1.153443	0.142751	0.145415	−0.00159	0.14701	0.149702
18	151	0.007481	4	4.007481	0.026539608	0.01704236	1.557273	0.442936	0.452645	−0.00428	0.456927	0.459619
19	97	0.004806	1	1.004806	0.01035882	0.01704236	0.607828	−0.49786	−0.50464	0.001925	−0.50656	−0.50387
20	39	0.001932	0	0.001932	4.95417E-05	0.01704236	0.002907	−5.84064	−5.85778	0.001962	−5.85974	−5.85705
Total	20,185	1	343	344	0.330288122	0.34084716	19.38042	−6.45112	−6.46143	0.002692	−6.46412	−6.41027

Source: Analysis, 2021. WoE: Weights of evidence, FR: Frequency Ratio, IVM: Informatin Value Ratio Method.

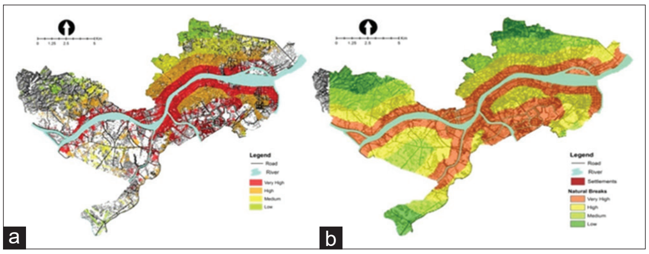

Figure 3: Map of the exposure area

based on the number of settlements along the border. The environment of the river border area which has the characteristics of a dense population forms the urban structure of slums. Problems that are prone to be found are related to how to create drainage and sanitation of residences that can prevent mosquitoes from breeding comfortably and laying eggs in the area.

Information related to the amount of exposure in residential areas along the river border is shown in (Table 4). From Table 4, it is known that the more land is built; the increase in potential exposure also tends to increase. The existence of the position of the building in a vulnerable area and located next to a river will result in a faster vector transmission value. The total exposure area for the built-up sector is divided into four categories, where the total exposure value that occurs in 2021 will reach 4506 hectares. The category of natural breaks jeans value <0.007 is categorized as very high, while 0.007–0.016 is categorized as high. The natural breaks jeans value of 0.016–0.030 is in the medium category, and 0.030–0.052 is in a low category.

One of the orientations of geography is the use of a spatial approach as an orientation in solving a problem [34]. We have used data collected from a time series related to the incidence of dengue outbreaks, starting from January until December with address codes to explore the spatial incidence of dengue cases in Indonesia river border area. The use of Euclidean distance to explore the probability of river range with dengue incidence was also applied in this study with substantial clustering of transmissions within the community. The existence of a consistent chain of transmission in the study area decreased in the clustering of cases from the class grouped into the community (Tables 2 and 3).

Discussion

The finding indicated that there is a significant risk of an infected individual then infecting others in his or her surroundings, this is a necessary increase to reduce the potential risk of dengue transmission. If people's attitudes can change towards a clean lifestyle, then the structure of the sanitation environment will move optimally [35]. Health services, health workers, health systems, facilities, and infrastructure can be used as alternative policies to realize endemic prevention [36].

Although the probability value is categorized as low from perfect, short-term information from the Euclidean river distance can be used as a significant estimate of the spatial dependence that needs to be observed between surrounding settlements. Theoretically, the *A. aegypti* mosquito can fly as far as 400 m with favorable migratory environmental conditions, mainly consisting of meteorological factors and regional landscapes [9]. This theory has similarities in the Euclidean distance that used in the study, with the characteristic landscape of the research area, namely moist and cool, that has the potential as a place for breeding. The presence of human habitation near stagnant water areas is a concern regarding the emergence of *A. aegypti* mosquitoes through the spread of daily flights to find hosts, mates, oviposition, food, and resting places being the most important treatment in disturbing situations.

Consistent observations related to dengue movement and prevention of 3M (drain, cover, bury) water reservoirs in reducing the breeding habitat of *A. aegypti*. The level of sensitivity regarding concern

Table 3: Calculation of the value of weight of evidence

ID	WoE_Value	Area	Tot_Area	Tot_Area_%	Ls	Total Ls	Tot_ls_%	AUC
1	−5857	39	39	0.001932	0	0	0	0
2	−903	287	326	0.016151	2	2	0.005830904	4.15E-05
3	−503	97	423	0.020956	1	3	0.008746356	3.5E-05
4	−446	274	697	0.034531	3	6	0.017492711	0.000178
5	−341	2319	3016	0.149418	29	35	0.102040816	0.006866
6	−245	225	3241	0.160565	3	38	0.110787172	0.001186
7	−142	2799	6040	0.299232	42	80	0.233236152	0.023852
8	−60	438	6478	0.320931	7	87	0.253644315	0.005282
9	−41	3735	10,213	0.50597	61	148	0.43148688	0.063388
10	1	4240	14,453	0.716027	72	220	0.641399417	0.112684
11	19	985	15,438	0.764825	17	237	0.690962099	0.032509
12	23	346	15,784	0.781967	6	243	0.70845481	0.011994
13	97	753	16,537	0.819272	14	257	0.749271137	0.02719
14	113	848	17,385	0.861283	16	273	0.795918367	0.032458
15	149	204	17,589	0.87139	4	277	0.807580175	0.008103
16	374	663	18,252	0.904236	16	293	0.854227405	0.027292
17	443	1263	19,515	0.966807	32	325	0.947521866	0.056369
18	459	151	19,666	0.974288	4	329	0.959183673	0.007132
19	489	519	20,185	1	14	343	1	0.025187
Total		20,185			343			0.441747

Source: Analysis, 2021. AUC: Area under the curve.

Table 4: Calculation of the built-up sector exposure area

Serial number	Natural breaks jeanks	Description	Exposure area (Ha)
1	<0.007	Strongly high	1892
2	0.007 s/d 0.016	High	1465
3	0.016 s/d 0.030	Medium	768
4	0.030 s/d 0.052	Low	381

Source: Analysis, 2021.

for the environment needs to be increased as an alternative to preventing environmental disasters and surrounding diseases [37]. The potential role of human movement in reducing the acceleration of virus transmission is also supported by epidemic correlation with other environmental factors to increase the spatial separation between mosquitoes. Preparing spiritual and physical endurance through various literature efforts can increase the body's immunity against infectious disease infections [38]. Various treatments such as Artemisinin Combination Therapy, Rapid Diagnostic Tests, and patient compliance in taking drugs are the leading response for patients suffering from dengue outbreaks [39].

The spatial correlation in ecological conditions represented by the incidence of dengue outbreaks between river ranges also explains the observations. Higher levels of movement across sub-districts would suppress spatial dependence with local population mixing which our observations are consistent with influencing movement across sub-districts along the Musi River in recent years. The existence of houses that have long been built along the banks of the river with the position of the front yard facing the river, entering the current era of regional development has changed the pattern of buildings with the position of the house changing 180o affecting the behavior of residents toward the river so that it turns into a final disposal site for organic and non-organic waste [40]. When entering the dry season, non-organic waste such as glass, cans, used plastic, tires, and others tend to be disposed of in any place. Therefore, disposal such as open ground in urban or rural suburbs is necessary [41]. Several mosquito control efforts, such as insecticide fogging, can partially reduce the number of mosquitoes. Insecticide fogging has been widely used in all countries in Southeast Asia [42].

Thus, the projected increase in the incidence of dengue fever through zoning the Euclidean distance of the river differs from the adaptation strategy, ranging from the approach of local communities to the application of advanced technology as an effort to adapt to the adverse impacts that may be caused by climate change. We have reported some conclusions regarding the relationship between the incidence of dengue outbreaks in the Musi river border and the Euclidean distance of the river using the WoE statistical model. The results found are more diverse with a lower probability value. We argue that our results will provide a better description of the empirical model. In addition, we expect an increase in the future impact of dengue fever events given the likelihood of the worst occurring more widely.

Conclusions

Based on the population of dengue incidence and the condition of the river basin area that we studied, the results show that a significant structure with the distribution of dengue incidence due to the *A. aegypti* mosquito occurs on a regional scale. The drawbacks that we found related to the probability value from the application of bivariate geostatistics resulted in an AUC value ranging from 0.44 obtained from 20 natural breaks Jenks classes with distance categories using the calculation of the Euclidean distance value. During the research, it found that the advantages the presence of buildings on the Musi river banks has a greater risk of transmitting infectious diseases to natural disasters ranging from flooding to river erosion. This information becomes one of the bases in understanding the dense population structure, population environment, and population of dengue incidence resulting in information related to the influence of landscapes on connectivity on the Musi River border, Palembang City, it increases the knowledge about *A. aegypti* which has concomitant consequences related to controlling transmission and vector capacity.

Acknowledgement

We thank the study team involved in this research especially to Universitas Negeri Malang and Universitas Negeri Padang that have supported either directly or indirectly, then to European Space Agency and Geospatial Information Agency for providing the data used in this research, and to reviewers who had given valuable input to this paper.

Authors' Contributions

Cipta Estri Sekarrini: Conception, design, acquisition, analysis, and interpretation of data and drafting the article. Sumarmi: Conception, critical reviewing and final approval of the version to be submitted. Syamsul Bachri: Design, critical reviewing and final approval of the version to be submitted. Didik Taryana: Critical reviewing and final approval of the version to be submitted. Eggy Arya Giofandi: Acquisition, analysis, and interpretation of data.

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