Spatial autocorrelation of dengue in relation to population density in Balangan District, Indonesia: an ecological study

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ABSTRACT

Dengue in Balangan Regency has the 2nd highest incidence rate (IR) in South Kalimantan at 126.64 per 100,000 population. This study aimed to determine the distribution pattern and conduct spatial analysis of dengue with population density in Balangan Regency. This quantitative research requires secondary data of dengue cases and Population Density in time series 2017-2021 with spatial analysis methods. The results showed that high dengue cases were in areas that had high density. Based on spatial analysis, dengue cases have a positive spatial relationship in 2017-2019 and a negative spatial relationship in 2020-2021 where dengue cases have a non-clustered distribution pattern (spread). Paringin City, East Paringin, Bungin, Maradap, Panggung, and Awayan villages are categorized as high-highly vulnerable to dengue. The findings of this study indicate that there is an influence of population density on the incidence of dengue. Monitoring of areas with high population density using spatial analysis is necessary for early detection of areas with high potential for dengue incidence.

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1. INTRODUCTION

Dengue is a viral disease transmitted from mosquitoes of the genus Aedes spp. which is the fastest growing mosquito in the world and has infected 390 million people every year [1]. According to data from the World Health Organization dengue cases have doubled, from 2.4 million cases in 2010 to 5.2 million in 2019 [2]. Dengue cases in Indonesia in 2022 were recorded at 131,265 cases, this number increased compared to 2018 of 65,602 cases. Deaths due to dengue in 2019 also increased compared to 2018 from 467 to 1,135 deaths. South Kalimantan Province, Indonesia is a dengue endemic area with an incidence rate (IR) of 56.10 per 100,000 population one of the highest districts is Balangan Regency with an IR of 126.64 per 100,000 population in 2019 [3].

Balangan Regency has high accessibility because it is crossed by the Trans Kalimantan road network system that connects the provincial capitals of East Kalimantan and Central Kalimantan, so that population growth in Balangan Regency has the potential to increase [4]. This needs to be watched out considering that environmental factors, namely population density, are considered to have an important influence on the increase and transmission of dengue disease, the denser the population, the easier it is for *Aedes sp*. mosquitoes to transmit the virus from one person to another. High population density and close proximity of houses can also make the spread of dengue more intensive in urban areas than in rural areas due to the flight distance of mosquitoes which is estimated to reach around 50-100 meters [5].

Based on the scientific perspective, spatial planning can be done by spatial mapping. Spatial mapping, especially in the field of diseases including dengue, serves as a form of area-based disease mitigation handling efforts [6]. The existence of geographic information system (GIS) in the form of disease distribution mapping can be a tool that can support the investigation and monitoring of areas at risk of dengue. Utilizing GIS will facilitate the next steps that must be taken in dealing with dengue in an area based on the characteristics of the area [7]–[9].

Based on this description, it is necessary to analyze the problem of distribution patterns and spatial analysis of dengue cases with population density in Balangan Regency. This study aimed to determine the distribution pattern and conduct spatial analysis of dengue with population density in Balangan Regency so that the pattern of dengue distribution based on population density is known as the basis for dengue control planning in Balangan Regency.

2. METHOD

2.1. Research location

This research was conducted in Balangan Regency with an area of 1,828 km2 consisting of 8 sub-districts, three villages and 154 villages, astronomically Balangan Regency is located between 2º 1' 37" to 2º 35' 58" South latitude and 144º 50' 24" to 115º 50' 24" East longitude. The administrative boundaries of Balangan Regency are west of Hulu Sungai Utara Regency, South of Hulu Sungai Tengah, East of Kotabaru Regency, and North of Tabalong Regency as shown in Figure 1. Balangan is one of the youngest regencies in South Kalimantan, established in 2003. The area of Balangan regency consists of 179,269 ha of land. The water area consists of 3,026 ha of swamp and 5,537 ha of river. Based on its geographical location, Balangan is strategic location because it is traversed by the Trans Kalimantan crossing and has a great opportunity to develop into a stopover city for traveling from Banjarmasin to East Kalimantan and Central Kalimantan.

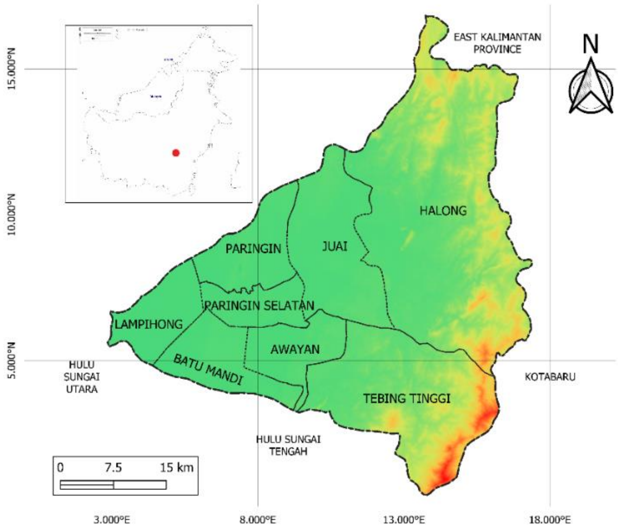

Figure 1. Administrative map of Balangan Regency

2.2. Data collection

The research methodology employed in this study was primarily based on secondary data analysis. The dataset encompasses dengue case records for each village within the Balangan Regency for the period spanning from 2017 to 2021, which was obtained from the Balangan Health Office. In parallel, population data was collected to calculate population density per village. This population data information was sourced from the Central Bureau of Statistics/*Badan Pusat Statistik* (BPS) of Balangan Regency. The utilization of these secondary datasets allowed for an extensive and comprehensive examination of the relationship between population density and dengue incidence in the region over the specified time frame. Through the spatial analysis of these data sources, the study aims to provide valuable insights into the spatial and temporal dynamics of dengue transmision in Balangan Regency. Data collection for analysis has been carried out by requesting permission from the Balangan Health Office with number B/11000/UN31.UPBJJ22/PK.02.04/2022.

2.3. Data analysis

The data that has been collected is then tabulated and analyzed spatially using GIS using QGIS 3.22.10 and GeoDA version 1.16 software to spatialize administrative map data, spatial autocorrelation and population density. In spatial analysis to determine the clustering of dengue disease, Morans'I statistical analysis and local indicators of spatial association (LISA) are used, which is a method that aims to determine the autocorrelation relationship between the distribution of dengue cases and population density. Statistically to see the effect of population density, simple linear regression test was conducted using SPSS IBM version 20.

3. RESULTS AND DISCUSSION

3.1. Characteristics of dengue patients

Dengue cases are clasification into dengue (DD) representing a general infection with flu-like symptoms, dengue fever (DF) indicating a milder form with high fever and discomfort, dengue hemorraghic fever (DHF) signifying a severe variant with bleeding complication and blood clotting abnormalities, and dengue shock syndrome (DSS) denoting the most critical, life-threatening stage with a significant drop in blood pressure leading to shock. The data from this study consists of several stages of dengue, ranging from mild to severe symptoms, as documented in the health department's data compilation, resulting in the presented data representing the overall categories of the disease. The number of dengue cases in Balangan Regency from 2017-2021 was 353 cases based on female gender with a percentage of 53%. The incidence of cases was 99.2% with 3% mortality. Based on age, the most incidence was at the age of >15 years as shown in Table 1.

Table 1. Distribution of dengue cases in Balangan Regency

Variable	Total	%	Years					p-value*
			2017	2018	2019	2020	2021	
Dengue clasification								
DF	12	3.40	2	0	6	4	0	<0.05
DHF	337	95.5	42	101	158	29	7	
DSS	4	1.1	0	3	0	0	1	
Gender								
Male	166	47	27	55	58	21	5	<0.05
Female	187	53	17	49	106	12	3	
Case								
Incidence	350	99.2	44	101	164	33	8	<0.05
Mortality	3	0.85	0	3	0	0	0	
Ages								
<5	31	8.78	10	8	10	0	3	
5-14	134	38	16	34	71	13	0	<0.05
>15	188	53.3	18	62	83	20	5	

*Linear regression. DF=Dengue fever; DHF=Dengue haemorrhagic fever, DSS=Dengue shock syndrome

3.2. Dengue case distribution map

The distribution of dengue cases in 157 Balangan villages in five consecutive years (2017-2021) tends to fluctuate. There were 44 cases in 2017 and the peak of the increase in dengue cases was in 2019 as many as 60 cases from 104 cases in 2018 to 164 cases with a total of 68 villages affected in 2019. Then in 2020-2021 there was a significant decrease, with 63 confirmed dengue cases in 2020 and eight cases in 2021 as presented in Figure 2.

3.3. Population density distribution map

Density in Balangan Regency varies; there are very high density, high, medium, and low. Very high density means having a population of >400 people/ha, high means population 200-400, medium 151-200, and low <150 people/ha. In 2021, the very high-density village is Paringin village, while the villages with a high-density category are Batu Mandi, Lampihong, Juai, and Paraingin Selatan villages. The rest are generally at medium and low density. Map of population density per village in Balangan Regency in Figure 3.

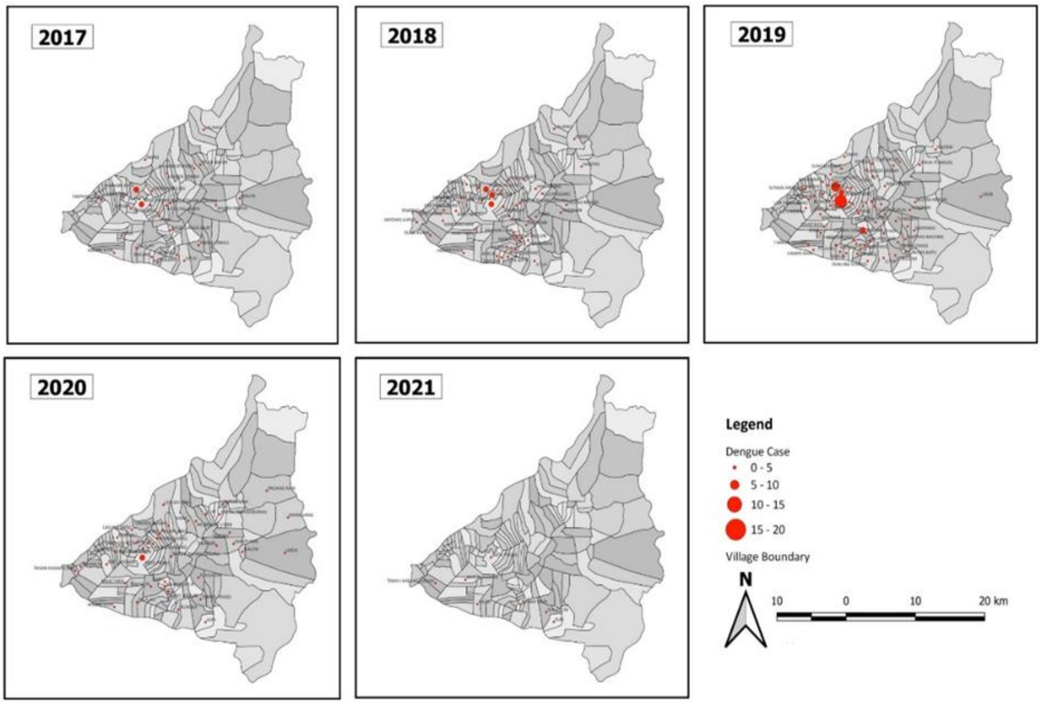

Figure 2. Dengue case distribution map in Balangan Regency 2017-2021

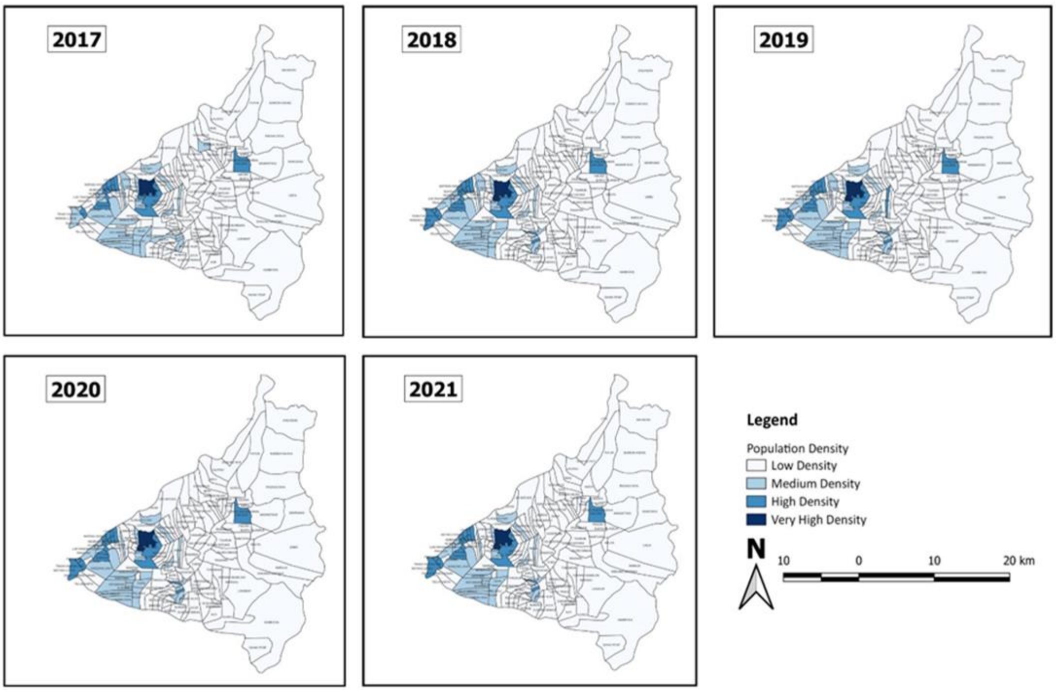

Figure 3. Map of population density in Balangan Regency 2017-2021

3.4. Overlay map of dengue cases with population density

The results of overlaying the map of dengue cases with population density show that areas that have a very dense population density category also have the potential to be affected by high dengue cases. Paringin Village has a very dense population density category and high dengue cases. The overlay map of dengue cases with population density in Balangan Regency 2017-2021 is shown in Figure 4.

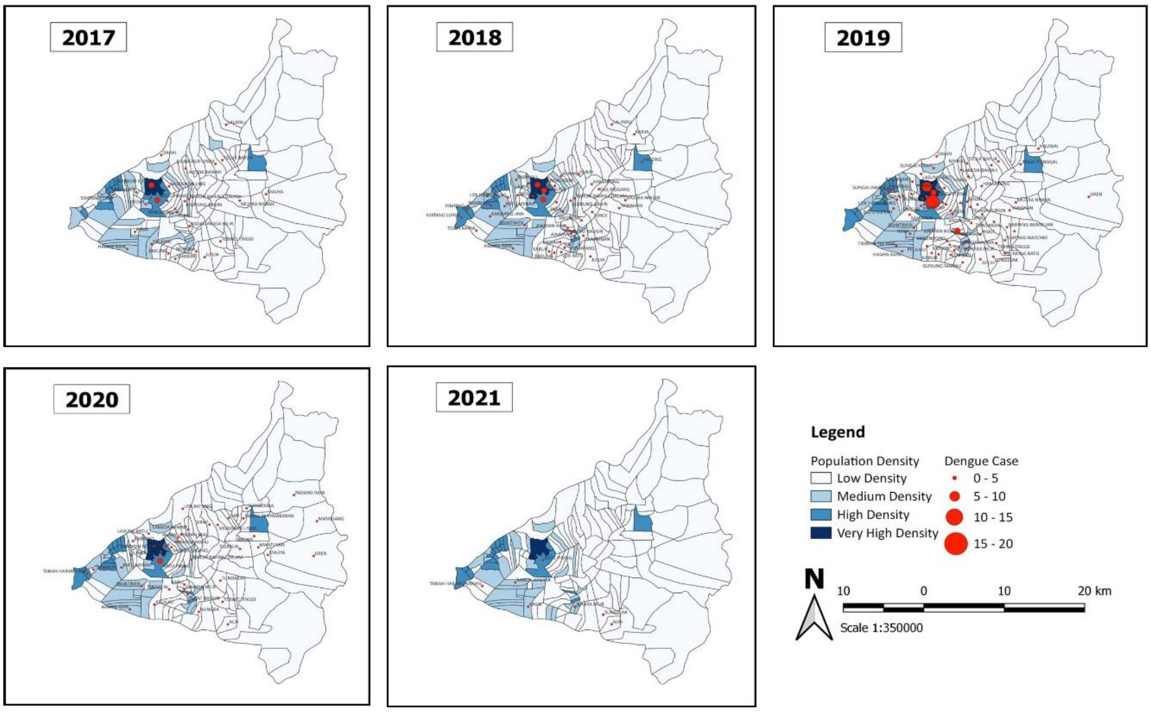

Figure 4. Overlay map of dengue cases with population density in Balangan Regency 2017-2021

3.5. Spatial autocorrelation of dengue cases with population density

The results of spatial autocorrelation analysis with the Moran index in 2017, 2018, and 2019 showed that there was a positive spatial relationship between population density and dengue incidence in Balangan District. The spatial relationship that occurs is not clustered (spread). Moran's I spatial autocorrelation analysis is presented in Table 2.

Table 2. Moran's I spatial autocorrelation analysis

Years	Moran's I index*
2017	0.005
2018	0.271
2019	0.195
2020	-0.016
2021	-1

*Moran's I spatial autocorrelation analysis

Spatial autocorrelation with the LISA approach can be seen in the spatial cluster map of dengue cases 2017-2021 in Figure 5. The results with the LISA analysis show that the villages that are categorized as high-high groups from 2017-2021 are Paringin, East Paringin, Bungin, Maradap, Panggung, and Awayan villages which are positive autocorrelation. So that the village is an area that is prioritized for handling dengue cases because it is vulnerable to dengue infection. In spatial autocorrelation analysis, High-high meant to areas where the value of dengue cases, is high and surrounded by neighbouring areas with similarly high values. Likewise, the other categories are defined according to the dengue cases that occur and the situation of the surrounding neighbour areas.

The effect of population density with dengue is moderate category where the R value is 0.274. The R-square value obtained is 0.075 or 7.5%, this indicates that population density affects the incidence of dengue in Balangan Regency only 7.5% while 92.5% is influenced by other factors. There is a real influence between population density on dengue (0.000) as shown in Table 3.

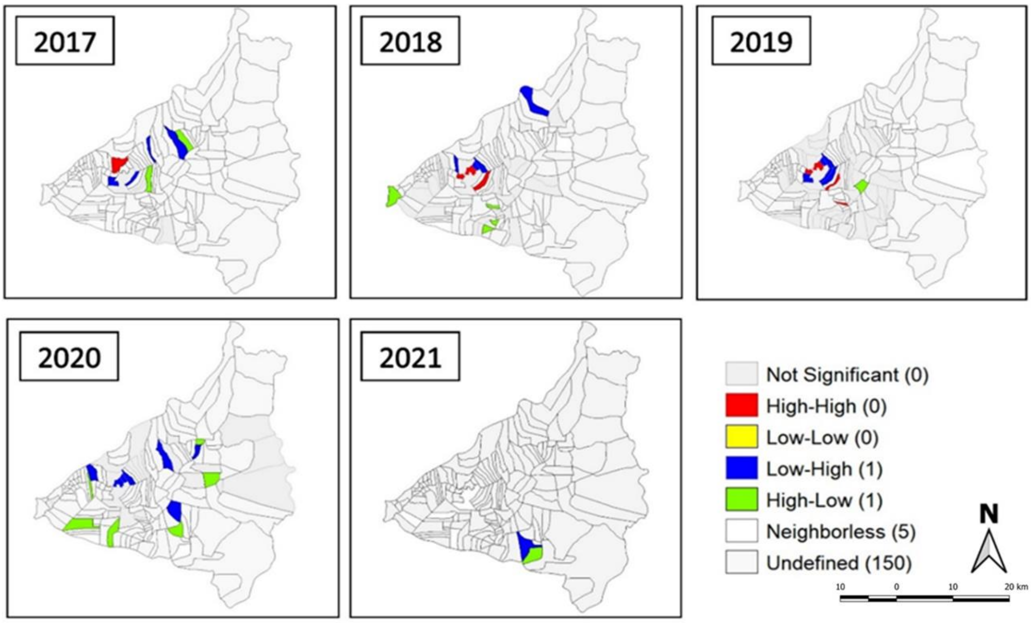

Figure 5. Spatial cluster map of dengue cases 2017-2021 with LISA

Table 3. Effect of population density on the incidence of dengue fever

Population desnity	Model summary		Anova		Coefficients	
	R	R-square	F	Sig.	t	Sig.*
	0.274	0.075	63.397	0.000	7.962	0.000

*linear regression

Dengue, transmitted primarily by *Aedes aegypti* and *Aedes albopictus*, is the fastest spreading mosquito-borne viral disease in the world [10]. The disease appears suddenly and has a high incidence rate, causing large-scale outbreaks that lead to severe public health emergencies [11]. Risk factors that can influence the occurrence of dengue fever include: home environment (house distance, house layout, container type, altitude and climate) [12], [13], biological environment [14], and social environment [15]. The research findings may reinforce previous epidemiological research, that the incidence of dengue in an area is sometimes influenced by surrounding areas that also have dengue cases. This is due to population mobility and the absence of boundaries for mosquitoes to fly. Human population density in densely populated areas may be more suitable for dengue transmission than in less populated areas (in addition to potential differences in mosquito breeding opportunities) [16], [17]. The distance between houses affects the spread of mosquitoes from one house to another, the closer the distance between houses, the easier it is for mosquitoes to spread to the next house [18]. Various infectious disease studies have shown that overcrowded and slum housing conditions are more likely to cause disease. The type of container, including the type of container here is the type/material of the container, the location of the container, shape, color, depth of water, cover and origin of water affect mosquitoes in choosing a place to lay eggs [19], [20].

The highest incidence of dengue cases in Balangan are Paringin, East Paringin, Bungin, Maradap, Panggung, and Awayan which are areas with similar characteristics. The distance between houses is not too dense, but with a large number of residents. Many economic activities are focused in the Paringin area as the city center and government center. This causes a lot of population mobility [21]. In addition, there are also many new housing developments that cause many used building containers. In addition, uninhabited houses with bathrooms containing water can also have an impact on high dengue cases [22].

Social Environment, people's habits that are detrimental to health and lack of attention to environmental hygiene such as the habit of hanging clothes, the habit of taking a nap, the habit of cleaning water reservoirs, the habit of cleaning the yard, and also community participation, especially in the context of cleaning mosquito nests, will lead to the risk of dengue transmission in the community [23]. This habit will be worse when people are difficult to get clean water, so they tend to store water in water reservoirs, because the landfill is often not washed and cleaned regularly and eventually becomes a potential breeding ground for *Aedes aegypti* mosquitoes [24].

Based on other research conducted in Laos and Thailand, their results indicate that intense dengue virus transmission can occur in a very narrow range of human population densities with high mosquito/human host ratios without tap water supply [25]. The areas with the highest cases already have commercial clean water facilities from local companies. Dengue cases in Indonesia are known to continue to increase [26] but since the discovery of the disease with a new virus variant, namely COVID-19, which spreads in almost all countries of the world, causing dengue case data to decrease in various countries. One of them is due to policies from various countries that prohibit their population from leaving the house so that activities in schools and environments at risk of dengue transmission are reduced; the policy is also implemented in Balangan Regency. In addition, for tropical countries such as Indonesia, the emergence of COVID-19 causes a double disease burden, so the health resilience system for dengue surveillance is weakened and focused on COVID-19 [27].

Programs include adult mosquito eradication by mass insecticide spraying, larvicide eradication through the 3M plus movement, community counseling, and community empowerment movement [26]. Although these programs have been implemented, dengue cases continue to increase, and dengue deaths have not decreased significantly; there is a need for strategies based on regional characteristics in Indonesia for dengue control. Results from other studies in Indonesia [28]–[31] and based on the results of this study prove that by knowing the areas with higher potential for dengue transmission, the government and cross-sectors can implement an early vigilance system and urge the community to participate in the larval eradication movement and be more vigilant against adult mosquitoes.

The study has certain limitations that must be addressed in future research endeavors. Primarily, the analysis in this study was confined to a limited set of variables. It is imperative to incorporate additional factors to gain a more comprehensive understanding of the phenomena under investigation. In particular, future analyses should contain climate variables and mosquito surveillance control as they can significantly impact virus transmission dynamics. Additionally, considering the various types of viruses and their modes of transmission could further enrich the analysis, providing a more nuanced and accurate representation of the complex interactions within the epidemiological landscape. Therefore, future studies should strive for a more holistic approach by encompassing a broader range of variables to advance our comprehension of these intricate phenomena.

4. CONCLUSION

In conclusion, the high population density in urban areas of Balangan Regency correlates with a notable incidence of dengue cases. However, despite the concentrated population, the distribution pattern, as indicated by the Moran index, is not clustered but rather dispersed. It is crucial to monitor regions with high population density, as they appear to be more vulnerable to potential surges in dengue cases. Spatial analysis can play a pivotal role in the early detection of areas at risk for a heightened dengue incidence. By utilizing such tools, public health authorities can proactively implement targeted interventions and preventive measures to effectively manage and mitigate the dengue outbreak in Balangan Regency. We suggest for combining various spatial analysis tools according to the purpose, we can improve our ability to detect and respond to health threats in high density areas.

In densely populated areas, close proximity between people might expedite the transmission of dengue. Consequently, to lessen the effect of dengue outbreaks and stop the disease's spread, a combination of vector control, community engagement, healthcare services, and collaborative efforts is crucial. To address the dynamic character of dengue transmission in densely populated areas, public health officials need to continually evaluate the effectiveness of intervention and modify methods to local circumstances.

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