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Dengue Hemorrhagic Fever (DHF): Vulnerability Model Based on Population and Climate Factors in Bengkulu City

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Abstract

Objective: The causes for the increasing number of dengue cases are complex and multifactorial. The approach taken must combine influencing factors, and comprehensive prevention strategy is needed that includes all the components of factors that influence dengue disease to predict the incidence of the disease. This research aimed to analyze the relationship between population and climate components including population density, population density <15 years old, sanitation, temperature, humidity and rainfall, on the incidence rate of Dengue Hemorrhagic Fever (DHF).

Material and Methods: This study used a cross-sectional design, with the research sample being all sub-districts in Bengkulu City, Indonesia (67 sub-districts). Data analysis was conducted using structural equation modeling to create a dengue modeling based on population and climate factors, through the SmartPLS application.

Results: Population and climate factors had a significant relationship with the incidence rate of dengue, with p-values of 0.018 and 0.000, respectively. Population and climate factors had a percentage effect on the incidence rate of dengue (36.9%).

Conclusion: Population and climate factors had an influence of 36.9% on the incidence of dengue. There were many factors affecting the incidence of dengue, so a more comprehensive modeling of the various influencing factors is needed.

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Dengue modeling is crucial as an early warning system for the early prevention of dengue outbreaks, so that the control strategies implemented can be more effective.

Keywords: climate, dengue modeling, early warning system, population, the incidence rate of dengue

Introduction

Dengue Hemorrhagic Fever (DHF) is a disease caused by the dengue virus, which is transmitted by the Aedes aegypti and Aedes albopictus. The dengue virus consists of 4 serotypes, namely: DENV-1, DENV-2, DENV-3, and DENV-4[1-2]. According to the World Health Organization (WHO) in 2020, there has been an increase in DHF cases of higher than 8 times in the past 2 decades, with approximately 1,372,248 cases being recorded in June 2022[3]. Indonesia ranks 4th as the largest contributor to DHF cases globally, with 22,331 cases, and the 2nd highest number of deaths, with 229 fatalities being reported[4,5].

In 2016, a total of 12 regencies and 3 cities from 11 provinces in Indonesia experienced a dengue outbreak, including Bengkulu City, with 8,487 cases and 108 deaths[6]. Dengue control strategies have been implemented including vector control and environmental improvements, resulting in Bengkulu Province ranking 26th out of 34 provinces in Indonesia for DHF cases in 2017[7].

Bengkulu Province also ranked 3rd highest in Indonesia in 2018, and had 1,439 DHF cases with 12 deaths (Incidence Rate (IR) 72.28 per 100,000 population and Case Fatality Rate (CFR) 0.84%), this may have happened because of sub-optimal community participation[8]. Bengkulu City contributed to the highest increase in DHF cases in the province, with 427 cases and 4 deaths (CFR 0.9%)[9].

Indonesia's natural conditions, as a tropical area, are suitable for the breeding of mosquitoes; including Ae. aegypti and Ae. Albopictus, as the main and secondary vector of dengue disease. Environmental factors, such as temperature and global warming, affect the breeding of mosquitoes and the proliferation of dengue virus in the mosquito's body. Season or climate also has a significant influence on the incidence of dengue infection[10,11].

Human factors, such as population density, mobility, immunity and the proportion of viremia have an influence on dengue transmission in the community[10,12]. Population density is supported by better transportation facilities, so that community mobilization is higher along with the expansion of peri-urban areas so that dengue infection reaches rural areas[13-14].

The causes of the increasing number of cases and the expanding affected areas are complex and multifactorial, which include viruses, vectors, the environment and human factors. Population density can also affect the number of cases of dengue in a certain area[10-13]. Prevention strategies are useful in predicting dengue incidence control efforts, so as they can be more focused and effective[14].

The WHO has committed to reducing dengue infection with its Global Strategy for Dengue Prevention and Control 2012-2020, and the Road Map for Neglected Tropical Diseases (NTDs) 2021-2023. The targets for dengue control include the reduction of the fatality rate from 0.8% in 2020 to 0% in 2030, and also develop five strategies; namely: control vector sustainability, vaccination, research and systems information[5,15,16].

The global strategy for dengue prevention and control consists of five main components, namely: control vector integrated selective with community and collaboration cross-sectoral, surveillance of disease by activities based on system information in vital health, preparedness for emergency, development capacity and training as well as research on control vectors[16,17].

This research aims to analyze the relationship between population and climate factors, which include: population density, population density <15 years, sanitation, temperature, humidity and rainfall, on the incidence rate of DHF.

Material and Methods

This research was approved by the Health Research Ethics Commission of the Faculty of Medicine, Diponegoro University: number 410/EC/KEPK/FK-UNDIP/XI/2022. The analysis was carried out using research and development in 67 subdistricts in Bengkulu City. Secondary data from related agencies will be tested for validity and reliability with structural equation modeling (SEM) from the SmartPLS application as a model builder. Then the components that meet the requirements will be statistically tested to see the relationship with the dengue incidence rate. The secondary data were collected from related agencies, namely the Bengkulu City Population and Civil Registry Service, the Bengkulu City Housing and Land Areas Office and the Bengkulu City Meteorology, Climatology, and Geophysics Agency.

Results

The distribution of DHF cases in Bengkulu City in 2021, occurred in 34 (50.75%) out of 67 sub-districts, with a total of 117 cases. The research variables were obtained from secondary data as shown in Table 1, which included the Population and Civil Registration Agency, Housing and Settlement Agency and Meteorology and Geophysics Agency of Bengkulu City.

Model analysis

The analysis technique was conducted using the SmartPLS application with structural model testing. This process aimed to determine the validity and reliability of the indicators of latent variables, and to establish the significant relationship between exogenous and endogenous factors to develop an appropriate model. The tests conducted for model analysis included the evaluation of the outer model, which assessed convergent and discriminant validity as well as composite reliability. After conducting the outer model evaluation, the inner model evaluation was performed, which included R-square and hypothesis testing.

Convergent validity

An indicator score was considered valid when it had a cross-loading with the latent variable construct being measured at ≥0.7 or a T-statistic value >1.96 at a significance level of 0.05 with a two-tailed test[18,19]. The results of the convergent validity are presented in Table 2. The indicator for a population <15 years did not meet the loading factor requirement of ≥0.70 and should be eliminated from the model, as shown in Figure 1. The final model showed that each indicator had met the requirement for convergent validity, and none were eliminated.

Composite reliability

Based on the results, variables with good reliability can be indicated by a composite reliability value >0.60[19,20]; as shown in Table 3. Table 3 showed that all variables met the reliability criteria and were reliable because their construct values with composite reliability values were >0.60.

R-square

Based on the results in Table 4, the R-square value was 0.369, indicating that the population and climate variables in this research explained the DHF incidence rate by 36.9%.

Hypothesis test

Based on the results in Table 4, the hypothesis testing results were as follows: the relationship between the population and climate factors was significant, with T-statistic of 2.367 and 5.786, respectively.

Tabel 1 Population and Climate Data in the Bengkulu City for 2021

No	Village	Subdistrict	Population aged <15 years (%)	Population density (/km^2)	Sanitation (%)	Temperature (°C)	Rainfall (/mm^2)	Humidity (%)	IR of DHF (per 100,000 population)
1	Pagar Dewa	Selebar	26.5	41.9	75.6	26.8	307.7	83.3	46.2
2	Sukarami		29.4	18.4	100.0	26.8	307.7	83.3	15.1
3	Sumur Dewa		29.3	12.6	100.0	26.8	307.7	83.3	20.5
4	Bumi Ayu		26.9	28.5	78.9	26.8	307.7	83.3	18.7
5	Betungan		31.7	7.5	79.0	26.8	307.7	83.3	93.6
6	Pekan Sabtu		29.6	10.3	100.0	26.8	307.7	83.3	54.1
7	Lingkar Barat	Gading Cempaka	23.8	37.3	100.0	26.8	307.7	83.3	42.9
8	Cempaka Permai		20.8	94.8	100.0	26.8	307.7	83.3	16.7
9	Sidomulyo		24.3	30.3	100.0	26.8	307.7	83.3	87.8
10	Jalan Gedang		24.6	42.6	100.0	26.8	307.7	83.3	16.1
11	Padang Harapan		24.6	30.4	100.0	26.8	307.7	83.3	97.8
12	Kampung Bali	Teluk Segara	23.9	70.5	100.0	27.0	296.4	83.6	0
13	Bajak		26.1	67.7	100.0	27.0	296.4	83.6	0
14	Tengah Padang		24.5	115.5	100.0	27.0	296.4	83.6	0
15	Pintu Batu		25.7	138.4	100.0	27.0	296.4	83.6	0
16	Malabero		24.7	99.7	100.0	27.0	296.4	83.6	0
17	Pasar Melintang		36.2	39.4	100.0	27.0	296.4	83.6	0
18	Kebun Ros		22.0	103.3	100.0	27.0	296.4	83.6	0
19	Jitra		23.3	54.2	100.0	27.0	296.4	83.6	0
20	Pasar Baru		22.9	68.4	100.0	27.0	296.4	83.6	0
21	Sumur Melele		24.2	105.4	100.0	27.0	296.4	83.6	0
22	Berkas		24.8	90.8	100.0	27.0	296.4	83.6	0
23	Pondok Besi		23.5	157.2	100.0	27.0	296.4	83.6	0
24	Kebun Keling		23.6	59.7	100.0	27.0	296.4	83.6	76.2
25	Bentiring	Muara Bangkahulu	31.2	8.8	100.0	27.0	296.4	83.6	20.4
26	Pematang Gubernur		26.9	19.3	100.0	27.0	296.4	83.6	19.1
27	Bentiring Permai		28.0	9.5	74.0	27.0	296.4	83.6	23.1
28	Beringin Raya		26.7	3.3	100.0	27.0	296.4	83.6	0
29	Rawa Makmur		26.1	38.7	73.3	27.0	296.4	83.6	0
30	Rawa Makmur		25.3	39.2	80.3	27.0	296.4	83.6	0
31	Permai		27.8	9.4	82.7	27.0	296.4	83.6	15.4
	Kandang Limun								
32	Padang Serai	Kampung Melayu	32.6	9.8	71.5	26.8	307.7	83.3	0
33	Teluk Sepang		27.1	1.8	53.5	26.8	307.7	83.3	0
34	Sumber Jaya		28.8	13.1	55.7	26.8	307.7	83.3	0
35	Kandang		27.5	33.0	100.0	26.8	307.7	83.3	51.4
36	Kandang Mas		28.3	37.4	79.9	26.8	307.7	83.3	0
37	Muara Dua		25.6	7.6	100.0	26.8	307.7	83.3	0

Tabel 1 (continued)

No	Village	Subdistrict	Population aged <15 years (%)	Population density (/km²)	Sanitation (%)	Temperature (°C)	Rainfall (/mm²)	Humidity (%)	IR of DHF (per 100,000 population)
38	Kuala Lempuing	Ratu Agung	25.9	35.7	70.0	27.0	296.4	83.6	54.9
39	Sawah Lebar		27.7	87.4	71.4	27.0	296.4	83.6	10.8
40	Sawah Lebar Baru		28.0	73.3	78.4	27.0	296.4	83.6	59.7
41	Kebun Tebeng		25.6	73.3	76.8	27.0	296.4	83.6	66.6
42	Nusa Indah		24.6	47.3	100.0	27.0	296.4	83.6	106.5
43	Tanah Patah		24.8	53.5	82.2	27.0	296.4	83.6	60.3
44	Kebun Beler		24.2	104.2	100.0	27.0	296.4	83.6	0
45	Kebun Kenanga		24.3	104.1	100.0	27.0	296.4	83.6	0
46	Anggut Atas	Ratu Samban	23.7	64.1	100.0	27.0	296.4	83.6	41.1
47	Anggut Dalam		23.9	37.6	100.0	27.0	296.4	83.6	0
48	Anggut Bawah		23.7	67.9	100.0	27.0	296.4	83.6	122.7
49	Kebun Geran		24.9	126	100.0	27.0	296.4	83.6	56.7
50	Pengantungan		26.6	185.2	100.0	27.0	296.4	83.6	0
51	Kebun Dahri		24.9	220.2	100.0	27.0	296.4	83.6	0
52	Penurunan		24.1	50.2	71.8	27.0	296.4	83.6	0
53	Padang Jati		28.3	61.3	100.0	27.0	296.4	83.6	28.6
54	Belakang Pondok		27.2	106.7	100.0	27.0	296.4	83.6	0
55	Sukamerindu	Sungai Serut	23.7	84.6	100.0	27.0	296.4	83.6	16.7
56	Tanjung Jaya		26.9	22.8	100.0	27.0	296.4	83.6	68.5
57	Tanjung Agung		26.2	23.3	100.0	27.0	296.4	83.6	93.4
58	Semarang		28.0	9.9	100.0	27.0	296.4	83.6	90.7
59	Surabaya		28.4	7.6	100.0	27.0	296.4	83.6	89.0
60	Kampung Kelawi		26.1	55.8	76.4	27.0	296.4	83.6	42.7
61	Pasar Bengkulu		26.4	39.3	64.0	27.0	296.4	83.6	103.7
62	Lingkar Timur	Singaran Pati	23.8	98.7	89.2	26.8	307.7	83.3	40.5
63	Timur Indah		27.2	47.1	100.0	26.8	307.7	83.3	0
64	Padang Nangka		24.7	126.0	61.5	26.8	307.7	83.3	0
65	Jembatan Kecil		26.2	42.3	100.0	26.8	307.7	83.3	31.1
66	Panorama		26.4	51.4	62.9	26.8	307.7	83.3	0
67	Dusun Besar		26.1	39.5	84.7	26.8	307.7	83.3	13.0

Table 2 Composite reliability value

Indicators and constructs	Loading (y)		Description
	Population variable		
Population Aged <15 years	0.080	<0,7	Convergent validity is not met
Sanitation	0.767	≥0,7	Convergent validity is met
Population density	2.220	≥0,7	Convergent validity is met
	Climate variable		
Humidity	8.279	≥0,7	Convergent validity is met
Rainfall	10.694	≥0,7	Convergent validity is met
Temperature	5.338	≥0,7	Convergent validity is met

Table 3 Composite reliability value

Variable	Composite reliability	Description
Population	0.653	Composite reliability is met
Climate	0.629	Composite reliability is met
Incidence rate dengue	1.000	Composite reliability is met

Table 4 T-statistic value

Influence between variables	T-statistic	p-value	R-square
Population	2.367	0.018	0.369
Climate	5.786	0.000	

Discussion

The results of the research that has been carried out are based on population and climate data for 2021. Data on population density, sanitation, temperature, humidity and rainfall fulfill the requirements for dengue vulnerability modeling. Population data less than 15 years do not meet the requirements for dengue vulnerability modeling. Data can be seen in Figures 1 and 2.

According to the concept of the Epidemiological Triangle, factors that influence the occurrence of dengue cases include the imbalance between the host, agent and environment. Host factors include the body's immune response and age. Environmental factors include geographical conditions, demographics, population mobility, customs, socio-economic conditions and the density of mosquitoes as disease vectors. The agent factor is the dengue virus. Due to the many factors that cause dengue disease, the data collected in this study is complete secondary data and can be analyzed from related institutions. The data obtained was subjected to statistical testing and dengue vulnerability modeling.

According to Denis (2023), there were 7 dimensions and 23 determinative indicators to measure the dengue vulnerability index, namely: the health service dimension, health workforce dimension, environmental health dimension[21], population dimension, community behavior dimension[22], disease control dimension and government dimension. Each dimension had its determinative indicators for the DHF vulnerability index[23].

The dimension of environmental health in DHF included the availability of waste disposal sites and schedules[24] as well as mosquito eradication schedules[25]. These 3 indicators affected the vulnerability index of a region to dengue, eradication of mosquito nests schedule had a significant impact on the density of the dengue vector population[26].

The population dimension had several indicators; namely: the percentage of education and income levels of the population, which influenced the behavior of the community[27]. Furthermore, population density affected the breeding sites of mosquitoes and the pattern of dengue virus transmission[28,29]. The map of total population density and population <15 years is illustrated in Figure 3.

The accurate assessment of the global, regional and national health situation as well as trends is crucial for evidence-based decision-making for public health. Understanding vulnerability to diseases can make a significant contribution to effective monitoring, prevention and control strategies[30]. Mapping the vulnerability of DHF based on various factors is essential for predicting increases in cases or outbreaks[31,32].

The dengue vulnerability model, developed in Bengkulu City for population and climate data for 2021, consists of components of population density, sanitation, temperature, humidity and rainfall. The challenge of vulnerability assessment was based on synthesizing the social and environmental differences to communicate, measure and imply the implications of certain hazards. Moreover, exposure and vulnerability measures were often multi-dimensional, and indicators were usually used as tools to simplify and integrate various measures into composite indices. This was because indicators were used to summarize large amounts of data into formats that are useful for decision-makers[14,33].

Limitations

The dengue vulnerability model that has been developed only consists of population and climate components, which are secondary data from related agencies. Therefore, it is recommended that future research can be developed by adding a component of factors that influence the incidence of dengue for both primary data and secondary data.

Conclusion

The factors of population density, sanitation, temperature, humidity and rainfall affected the incidence rate of dengue by 36.9%. Disease modeling, especially for infectious diseases like dengue, is crucial as an early warning system for the early prevention of dengue outbreaks, and so that any control strategies implemented can be more effective.

Conflict of interest

The authors declare that there are no conflicts of interest.

Acknowledgement

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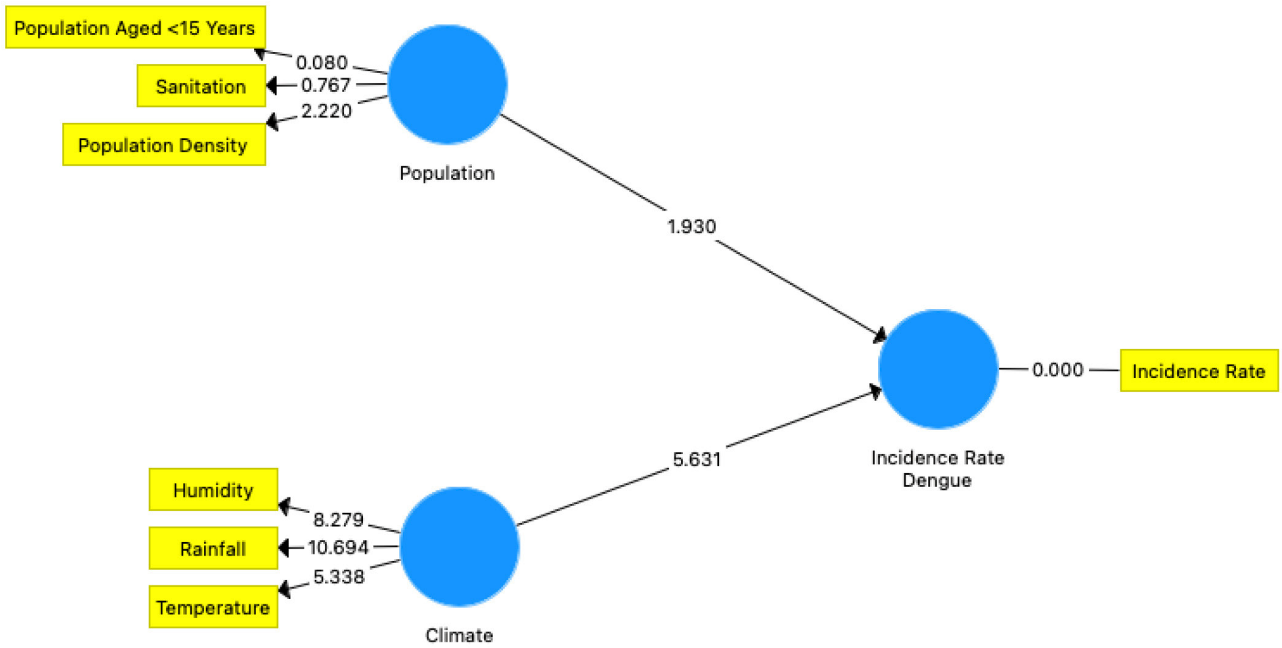
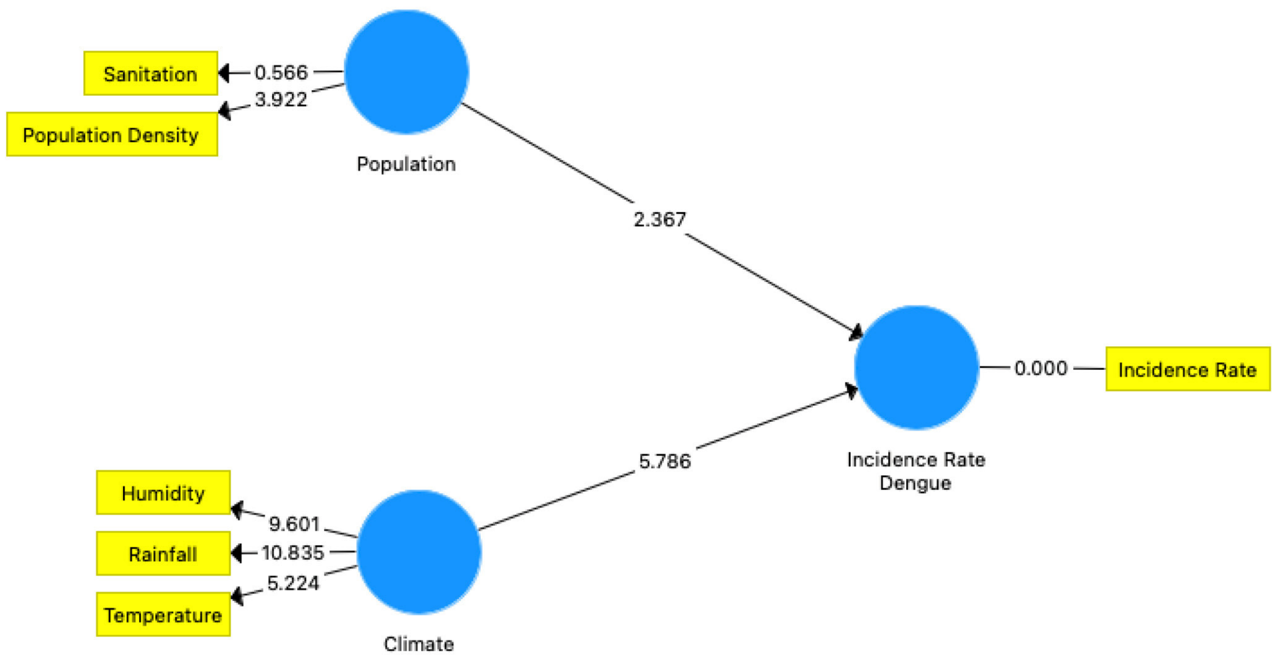


DHF=Dengue Hemorrhagic Fever

Figure 1 Initial DHF vulnerability model



DHF=Dengue Hemorrhagic Fever

Figure 2 Final DHF vulnerability model

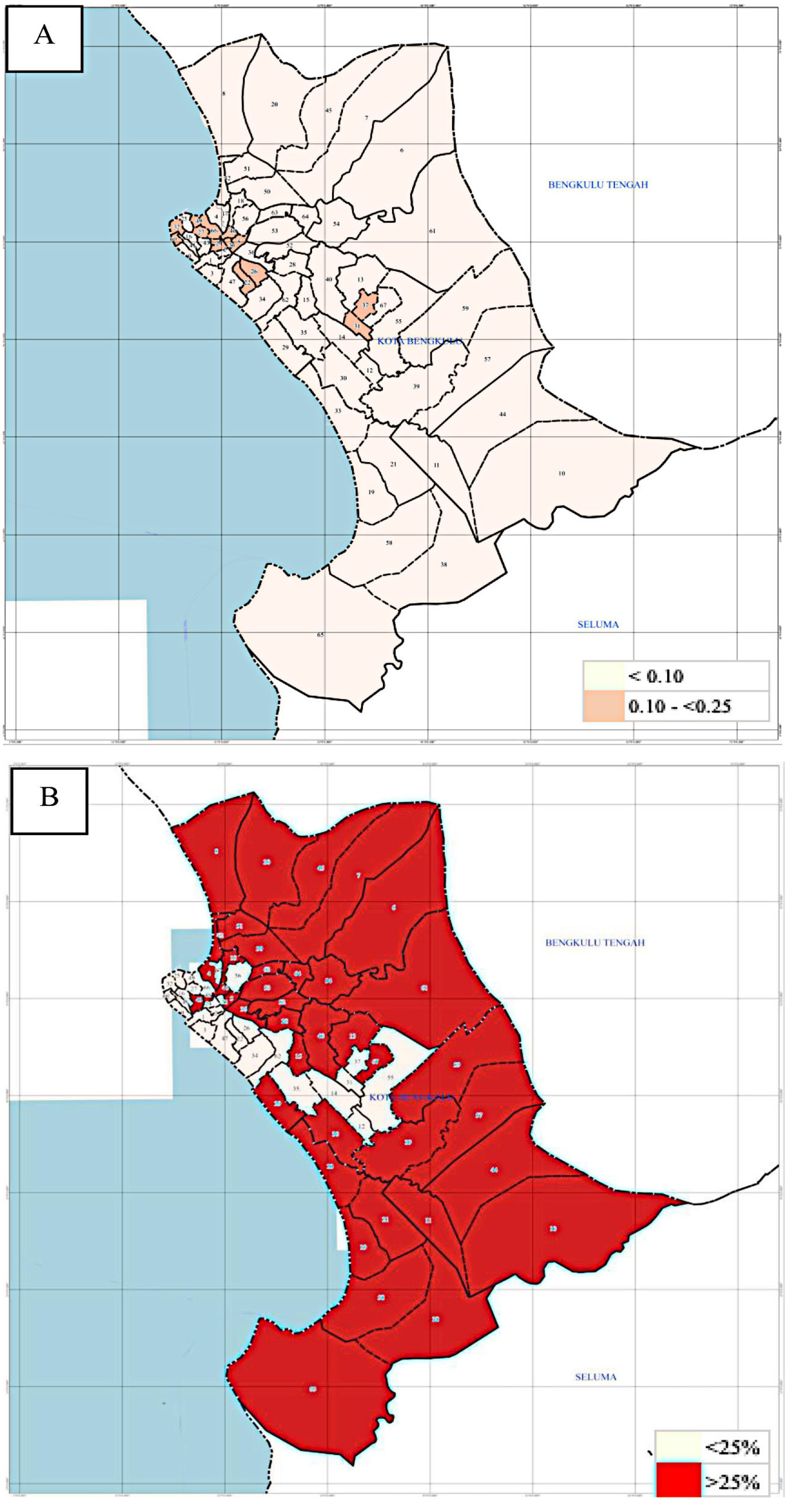


Figure 3 Map of (A) population density, (B) population <15 years, in Bengkulu City (2021)[37]

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