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Fuzzy Set Model of Dengue Using Imageries and the Geographic Information System in Palambang

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This report into the vulnerability and accuracy of Dengue Hemorrhagic Fever (DHF) uses the Fuzzy Set model. The analysis uses ten variables: 1) land use; 2) temperature; 3) altitude; 4) rainfall; 5) humidity; 6) population density; 7) slums, 8) mosquitos' flight radius, 9) number of cattle; and 10) distance between the river and the settlements. The aim of this study is to determine the vulnerability and accuracy of DHF in Palembang. The research is a quantitative study and was conducted in Palembang. The data used in the research is secondary and was gathered from corresponding agencies. The analysis implements the use of the Geographic Information Systems (GIS) and Fuzzy Set. After scoring the determining parameters on DHF, the level of its vulnerability in Palembang is categorized into three classes: low class with an area of 16,713 ha; medium class with an area of 13,872 ha; and high class with an area of 6,063 ha. The highest Fuzzy Set result on DHF in Palembang is 0.82, and the lowest is 0.46.

Key words: *geographic information system, vulnerability, accuracy, Fuzzy Set, dengue.*

Introduction

As a tropical country, Indonesia has a high potential for being a source of diseases caused by *Aedes aegypti,* which is endemic in the tropics (Candra, 2010). Dengue Hemorrhagic Fever (DHF) is regarded as a significant threat to public health because it spreads throughout tropical and sub-tropical regions, such as Indonesia (Vikram et al., 2015). Indonesia is located on the equator with warm and humid conditions, and an average temperature of 20° C to 30° C. For these reasons, many regions in the country are at risk of dengue fever. Dengue Hemorrhagic Fever (DHF) is influenced by several factors, including environmental conditions, population mobility, population density and the presence of artificial and natural containers in trash cans to landfills (Altassan et al., 2019; Syamsul, 2018).

The Incidence Rate (IR) of DHF in Indonesia tends to increase from year to year. In 2005, the IR was 43.31 per 100,000 of the population and reached 65.07 per 100,000 of the population in 2010 (Indonesian Ministry of Health, 2011). The spread of DHF also saw a rapid increase in areas it infected, increasing from 43.31% of all cities that were hit in 2005, to 75.25% in 2011 (Indonesian Ministry of Health, 2012). In South Sumatra, in particular, the number of DHF cases increased by 125.83% in 2015 from the previous year (Indonesian Ministry of Health, 2015). In 2014, there were 1,506 cases (IR of 19/100,000 population) with a total of four deaths (CFR 0.27%). Meanwhile, in 2015, the number of dengue cases reached 3,401 cases (IR of 42.6/100,000 population) with a total of 16 deaths (CFR 0.47%).

The Indonesia Health Profile (Indonesian Ministry of Health, 2015) shows that the highest number of dengue cases in 2015 was in Palembang, with 979 cases, followed by 431 cases in Banyuasin, and 330 cases in Prabumulih. In Palembang itself, DHF is a recurring health problem as it is an endemic disease in the city. The data shows that from 2010 to 2018, the level of Dengue Hemorrhagic Fever has fluctuated.

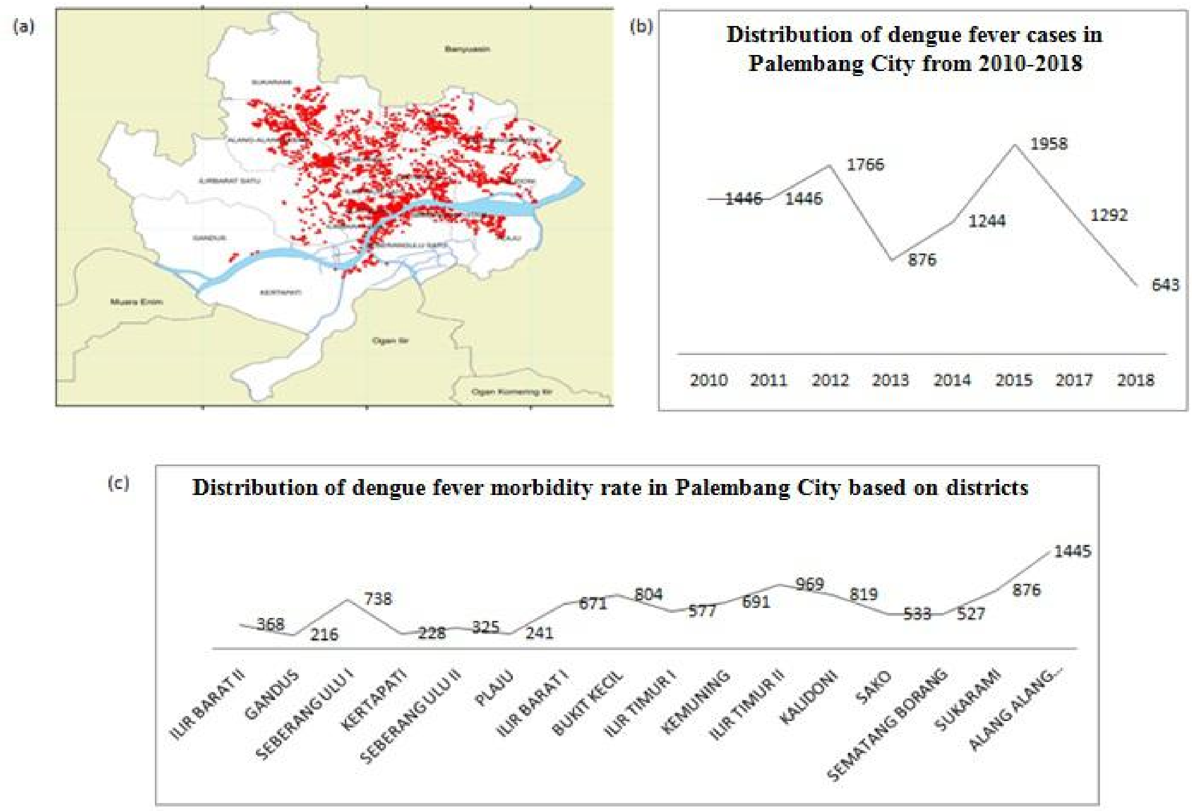


Figure 1. Distribution of DHF in Palembang

The highest number of DHF cases in Palembang occurred in 2015 where as many as 1,958 people were infected with the disease. Among the 16 districts in Palembang—before they were divided into 18 districts —the highest number of dengue cases occurred in the Alang-Alang Lebar district, with a total of 1,445 cases. To assess how the disease was spread, we have used a spatial modeling so that the vulnerability and accuracy of DHF can be clearly seen. With the implementation of the Fuzzy Set model, the total number of cases of DHF can be used as an estimate to determine its vulnerability and accuracy, taking into account the corresponding variables, such as the agent, the host, and the environment. This physical environment includes various aspects, ranging from temperature, rainfall, and humidity.

For the reason that it is a tropical country, Indonesia falls under the auspices of this research. The aforementioned climactic conditions cause a tropical country like Indonesia to have relatively high humidity, with an average temperature between 23.4–31.7° C, and an average annual rainfall of 227.23 mm (Meteorology, Climatology, and Geophysical Agency, 2008). This climatic condition has been noted by Prasetyo (2011), who argues that DHF cases will increase at temperatures between 25.50-28.50° C, and rainfall between 3–374 mm. Preliminary studies put Palembang in the second-highest rank in South Sumatra for its IR after Prabumulih Regency as of 2009. However, Palembang's 0.21% CFR of DHF is higher than Prabumulih's which is 0%. *Aedes aegypti* is a mosquito that can breed quickly and thrive in urban environments (Altassan et al., 2019).

The extreme weather in 2018 to early 2019 caused hundreds of Palembang residents catching DHF. Data from the city Health Office reported that there were at least 641 DHF cases infecting Palembang residents in 2018. In fact, almost half of the total cases were children of productive age, while 371 cases were children under the age of 15. The Head of the Division of Prevention and Control of Infectious Diseases of the Palembang Health Office, Fauziah, said that the number increased by 63 cases from the same period last year. The number of DHF cases, therefore, increased (Wulandari, 2019). As a city with the highest DHF cases in South Sumatra, Palembang had 226 cases in three months.

Dengue Hemorrhagic Fever (DHF) is a vector-borne disease caused by Dengue virus. The virus infects infants, children and adults alike. In general, the virus is transmitted through the bite of the female *Aedes aegypti* mosquito which stores the dengue virus in its eggs. Dengue Hemorrhagic Fever is found in tropical to subtropical regions, especially in Southeast Asia, Central America, and the Caribbean (Candra, 2010).

The high number of DHF cases in Palembang caught the researcher's interest in finding out its level vulnerability using a Geographic Information System (GIS) application. The application used in this research is 'Argis 10.4.1', using a Fuzzy logic method. The implementation of Fuzzy logic in Geographic Information Systems (GIS) is based on the fact that various phenomena on the surface of the earth are less representative when presented with a strict classification (Adzan and Danoedoro, 2012), because the generalizations presented are too excessive or inappropriate so that simpler and more flexible generalizations are needed, such as those found in a Fuzzy Set. The advantage of using Fuzzy logic is that the concept of Fuzzy logic is easy to understand and very flexible. It is based on the use of everyday language as well as the basic use of set theory so as to make the mathematical concepts that underlie Fuzzy reasoning easier to understand (Kusumadewi and Purnomo, 2010). Fuzzy models can be interpreted as a complete linguistic description (Fuzzy IF-THEN rule) of processes that can be combined into a model called the ‘Fuzzy system model’. Fuzzy model applications can be found in artificial intelligence, computer science, control techniques, decision making theory, expert systems, management science, research, robotics, among others. (Setiadji and Fwa, 2009).

Method

This research takes place in Palembang. Administratively, the city has 16 districts and 107 villages. Astronomically, Palembang is located between 2°52'–3°5' S, and 104°37'–104° E. Based on its geographical position, the northern, eastern, and western parts of Palembang border Banyuasin Regency, while the southern part borders Muara Enim Regency and Ogan Ilir Regency. Air temperature in Palembang is determined among other things by its altitude (from sea level) and its distance from the coast. In 2018, the maximum air temperature occurred in October, averaging at 34° C, while the minimum air temperature occurred in February and averaged at 23,732° C.

The wind speed is distributed evenly in each month across the city, ranging from 3.00 knots to 4.34 knots. Another factor affecting the rain and wind direction/speed is the difference in air pressure. Rainfall in one place is influenced by its climate conditions, topography and air flow/confluence. This results in different amounts of rainfall, depending on the month as well as the location where an observation is undertaken. The city’s average rainfall in 2018 ranged from 77.9 mm (September) to 452.80 mm (March). Palembang has relatively high humidity: in 2018 the average humidity in the city ranged from 84.80% (August) to 90.96% (November).

To answer the question of this research on the process of determining the disease-prone areas and the vulnerability of DHF using Fuzzy model thorough a Geographic Information Systems (GIS) application, this research will need to carry out the following stages:

1) Inputting the parameters of each determining indicator of Dengue Hemorrhagic Fever (DHF);
2) Scoring system;
3) Fuzzy.

For the parameters in determining DHF-prone areas in Palembang, the researcher uses three variables related to the disease: host factors, the environment, and the virus itself (Iswari, 2008; Ruliansyah and Gunawan, 2011). Determination of these parameters is done by using primary data tabulation analysis in accordance with the parameters of each variable, as follows:

Table 1. Classification of Land Use Variable as a Determinant of Dengue-Prone Areas

Variable	Classification	Score
Land use	Densely populated	6
	Office, School, Factory, Hotel, Market	5
	Less-densely populated	4
	Pool, Farm, Crops, Forest	3
	Empty land, Park	2
	Road, River	1

Source: Ruliansyah and Gunawan (2011)

Table 2. Classification of Altitude Variable as a Determinant of Dengue-Prone Areas

Variable	Classification	Score
Altitude	< 100 masl	6
	100–500 masl	3
	> 500 masl	1

Source: Ruliansyah and Gunawan (2011)

Table 3. Classification of Mosquitoes' Flight Ability Variable as a Determinant of Dengue-Prone Areas

Variable	Classification	Score
Mosquitoes' flight ability	< 240 meters	6
	240–750 meters	3
	> 750 meters	1

Source: Ruliansyah and Gunawan (2011)

Table 4. Classification of Rainfall Variable as a Determinant of Dengue-Prone Areas

Variable	Classification	Score
Rainfall	> 25 mm/day	6
	20–25 mm/day	5
	15–20 mm/day	4
	10–15 mm/day	3
	5–10 mm/day	2
	< 5 mm/day	1

Source: Ruliansyah and Gunawan (2011)

Table 5. Classification of Air Temperature Variable as a Determinant of Dengue-Prone Areas

Variable	Classification	Score
Air temperature	< 20, > 30	1
	20–24	2
	24–32	3

Source: Boekoesoe (2015)

Table 6. Classification of Distance to the Landfill Variable as a Determinant of Dengue-Prone Areas

Landfill	Description	Score
	> 1000 m	3
	100–1000 m	2
	< 100 m	1

Source: Aisyah (2000)

Table 7. Classification of Distance from the River to the Settlements Variable as a Determinant of Dengue-Prone Areas

Distance to the river	Description	Score
	> 1000 m	1
	100–1000 m	2
	< 100 m	3

Source: Aisyah (2000)

Table 8. Classification of Population Density Variable as a Determinant of Dengue-Prone Areas

Population density	Description	Score
	150 people/ha	1
	151–200 people/ha	2
	201–400 people/ha	3

Source: Indonesian Ministry of Public Works and Public Housing (2016)

Table 9. Classification of Livestock Population Variable as a Determinant of Dengue-Prone Areas

Livestock population	Description	Score
	> 1000	1
	100–1000	2
	< 100	3

Source: Aisyah (2000)

Table 10. Classification of Slums Variable as a Determinant of Dengue-Prone Areas

Slums	Description	Score
	19–44	1
	45–70	2
	71–95	3

Source: Indonesian Ministry of Public Works and Public Housing (2016)

The principles of data processing in Geographic Information Systems (GIS) can be simply illustrated as overlaying multiple maps. Determination of the boundaries of the area on each map is based on weighting or scoring certain values. This stage aims to obtain a map of the vulnerability of DHF in Palembang, namely by overlaying the ten variables that have been classified previously. The process of making an overlay is done by using the Analysis toolbox provided in the Argis 10.4.1 application. After obtaining the results of the vulnerability of (DHF) in Palembang, we can determine which areas are more prone to the disease with the Fuzzy model. Fuzzy Set is a set where the membership of each element has no clear boundaries. Fuzzy sets are most often used for object classifications or continuous value phenomena, where classes do not have clear boundaries.

In Fuzzy logic, Fuzzy Set is the grouping of things based on language variables expressed in the *Membership function*, where the *universe of course* is between 0 and 1. On a firm set (*crisp*), there are only two membership values, namely 0 or 1. Meanwhile, in the Fuzzy Set, the membership value is either μA (x) = 0 (which means x does not belong to the set A) or μA (x) = 1 (which means that x is a full member of the set A). The *Membership function* of a Fuzzy Set is expressed by the degree of membership of a value against its strict value ranging from 0 to 1. The *Membership function* defines how each point in the input space is mapped into weights or degrees of membership between 0 and 1.

The main purpose of using Fuzzy Set classification techniques is to provide solutions to the problems about accuracy resulting from the implementation of Boolean binary classification logic where the output is only true or false, which is one (1) or zero (0). One important consideration is that because environmental attributes are spatially diverse in nature, the presentation of a continuous function with a Fuzzy set, both in the assessment procedure and output presentation, is much more representative than the method of grouping attribute values into a category system (Bhatt et al., 2013). Data sources in this study are presented in diagram 2.

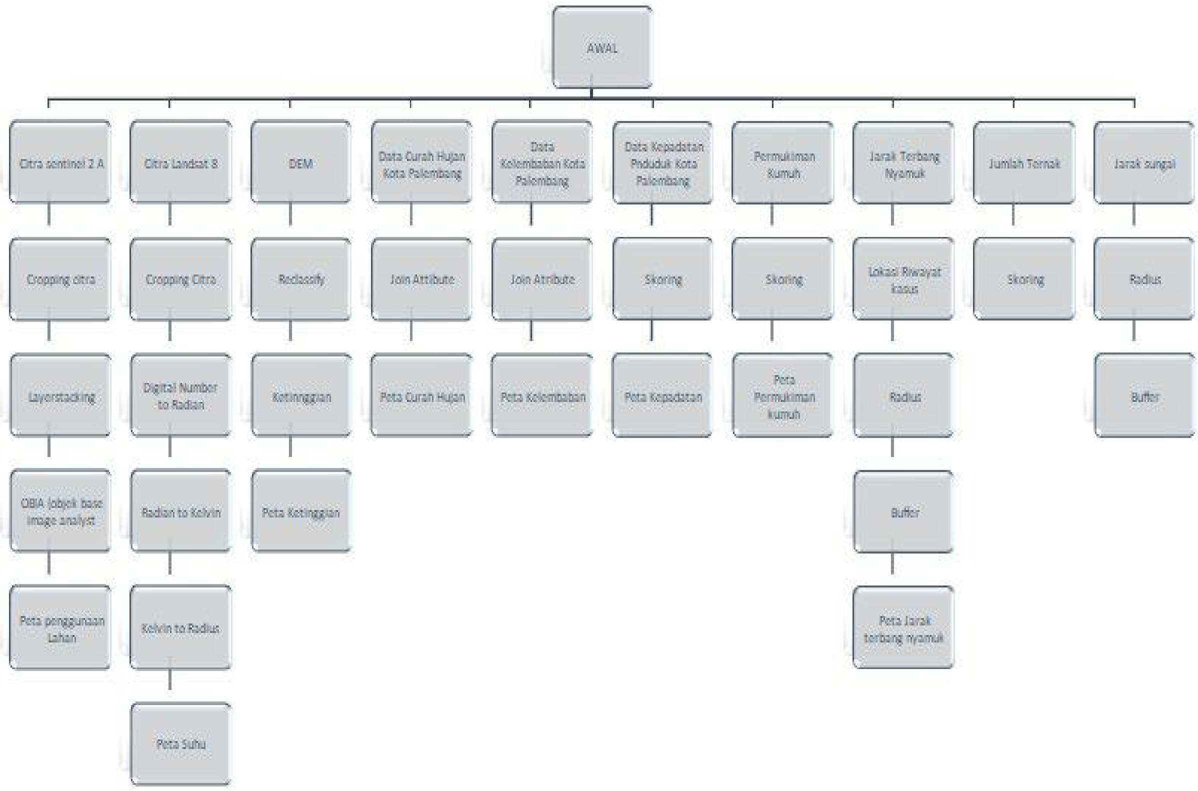


Figure 2. Research Data Variables

FINDINGS AND DISCUSSION

1.1 Data Input

1.1.1 Environmental Factors

Environmental factors are classified into four components: physical environment, chemical environment, biological environment and social environment. The physical environment includes climatic conditions, such as rainfall, humidity, air temperature, wind speed, sunlight and altitude. The physical environment directly influences the mosquito as a vector species in that it affects the population, lifespan and transmission (figure 3).

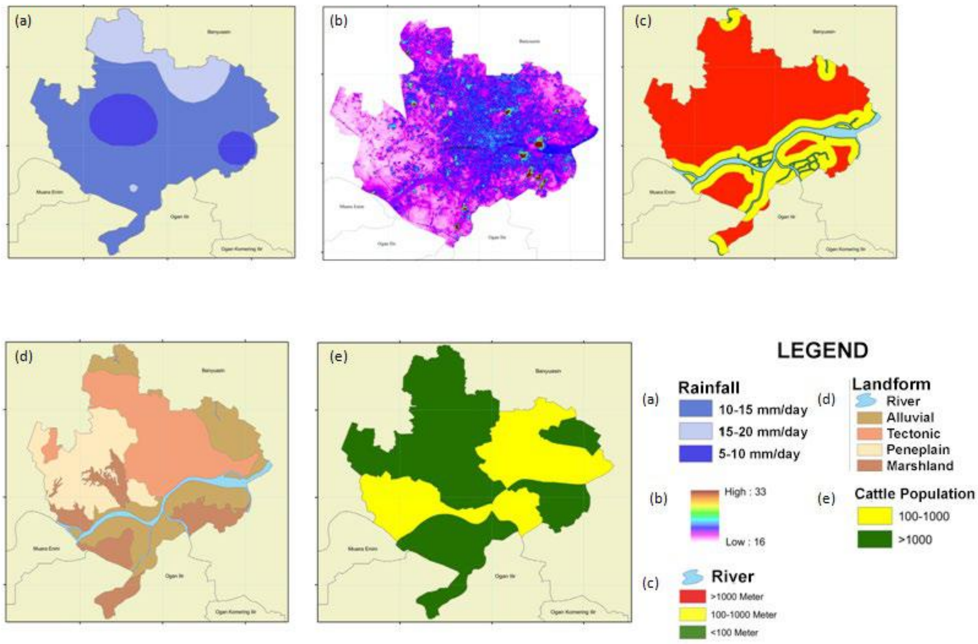


Figure 3. Environmental Factors that Affect Dengue Hemorrhagic Fever

The seasons in Palembang are generally the same as other places across Indonesia, in that it has a rainy season and a dry season. Data from the Meteorology, Climatology, and Geophysical Agency in April 2020 reports that air temperature in most areas of Palembang measures 32°C at its highest and 24°C at its lowest. Urban forests have an important role in decreasing air temperature in the microclimate of trees and other vegetation through evapotranspiration and that this can improve the city's overall air. This resulted in Palembang reaching its highest temperature ever recorded at 35.6°C in October 2012, and the minimum recorded temperature of 21.8°C in April 2012. The average maximum temperature is around 29–33°C, while the average minimum temperature is around 21.8–23.8°C (Andriani, 2001).

This particular temperature can affect mosquito's breeding, especially dengue-carrying mosquitoes, in that they are notably sensitive to temperature, humidity, and other environmental conditions which is in line with Sungono (2004), who conducted research in North Jakarta in 1999–2003, finding that there was a significant relationship between humidity and the incidence of DHF. Temperatures are now beginning to rise which causes a shift in the ecosystems, usually accompanied by environmental degradation, thereby increasing the chance for *Aedes aegypti* to breed (Andriani, 2001). Climate is one of the main components of the physical environment which consists of air temperature, humidity, rainfall and wind speed (Sukohar, 2014). Transmission of mosquito-borne diseases—including dengue—is very sensitive to temperature, rainfall, and humidity (Alhaeli et al., 2016; Altassan et al., 2019; Aziz et al., 2012; Morin, Comrie, and Ernst, 2013). Transmission will reach its peak at 29°C for *Aedes aegypti,* and 26°C for *Aedes albopictus* (Morin et al., 2013). The microclimate created by the interaction of rainfall, temperature, and humidity with land cover produces heterogeneity in all urban areas—suitable locations for mosquitoes (Morin et al., 2013).

Climate and other weather factors are proven to have an influence on dengue vectors (Li et al., 2017). For example, increased rainfall can provide a breeding ground for mosquitoes; higher temperatures help extend the mosquitoes' life cycle; and increased humidity is considered an important factor in creating suitable environments for the mosquitoes as a dengue vector (Bachri et al., 2017; Li et al., 2017). Climate model data can predict the number of dengue cases in the future, namely long-term weather data derived from prediction (Li et al., 2017). Humidity is the amount of water content or water vapor in the air. Humidity in Palembang measures around > 80%. Humidity is a significant factor in DHF cases (Sitorus, 2003; Sungono, 2004).

DEM provides information about the morphology of earth's surface in a digital raster format of the elevation value of each pixel (Bachri et al., 2017). It shows that Palembang is situated roughly < 1000 masl. Palembang's topography is generally lowland with an average altitude of + 4±12 masl, with the following composition: 48% drylands, 15% seasonal wetland and 35% permanent wetland. The highest location in Palembang is in Bukit Seguntang, Ilir Barat I District, with an altitude of about 10 masl. Meanwhile, the lowest location in Palembang is in the Lais River area in the Ilir Timur District II.

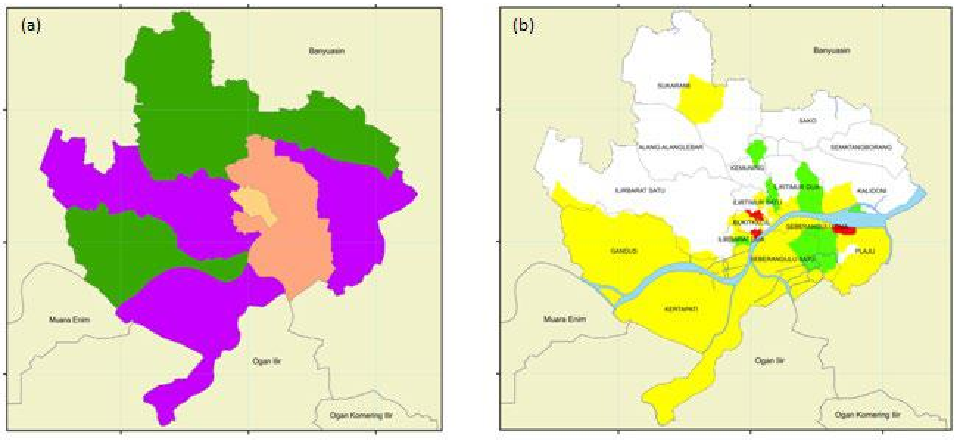
Palembang is divided into areas with flat to gentle slope topography, with slopes ranging from ± 0–3º, and areas with undulating topography with slopes ranging from ± 2±10º. There are slightly different topographic characteristics between Seberang Ulu and Seberang Ilir. Seberang Ulu has a relatively flat topography with most of its land below the maximum tidal level of the Musi River (+3.75 masl), except for lands that have been developed (and will be developed) where the surface has been artificially elevated (due to accumulation and reclamation). In Seberang Ilir, meanwhile, variations in topography (altitude) are found ranging from 4–20 masl. In addition, in Seberang Ilir, there are also micro-uses and "continuous" valleys and no steep topography. Up to a distance of five kilometres to the north of the Musi River, topographic conditions relatively incline toward the ridges and decline as it goes further north.

Thus, in principle, from the topographic aspect, there are no limiting factors for spatial development, regardless of the slope of the land. Altitude is an important factor in limiting the spread of mosquitoes. Some sources say that the *Aedes aegypti* mosquito lives at a level of 0–1,000 masl; and an altitude of 1,000–1,500 masl is the limit for the spread of *Aedes aegypti* (Lukmanjaya, 2012). But the present data shows that temperatures at altitudes of more than 1,000 masl are more suitable for mosquito's development. Mountainous areas that used to have relatively low temperatures are now beginning to rise, which causes a shift in the ecosystems accompanied by environmental degradation, thereby increasing the chance for *Aedes aegypti* to breed (Andriani, 2001).

Elevation significantly affects the ecological conditions required by the mosquito as a disease vector. In Indonesia, *Aedes aegypti* and *Aedes albopictus* mosquitoes can live in areas with an altitude of 1,000 masl (Sukohar, 2014). Rainfall also affects dengue. There are three classes of rainfall in the city based on the last five years of data from the Meteorology, Climatology, and Geophysical Agency of Palembang: 1) 5-10 mm/day; 2) 10-15 mm/day; and 3) 15-20 mm/day. Rainfall affects the transmission of DHF as it influences the lifespan and biting behavior of adult mosquitoes (Patz et al., 1998). Increased rainfall can increase the availability of breeding grounds for mosquitoes (Li et al., 2017), where higher rainfall results in more DHF cases (Candra, 2010).

1.1.1.1 Host Factor

The host factor in question is a patient with Dengue Hemorrhagic Fever (DHF). Host factor includes the patient's age, race, socioeconomic status, their way of life, marital status, heredity, nutrition, and immunity. The variables for host factor used in this study include the population density[(a)] and slums[(b)]



(a) population density (b) slums

'Density' is the ratio of the number of inhabitants per square kilometer. Areas with higher chances of transmitting DHF in general are those with denser population. The environment on these densely populated areas also makes it easier for mosquitoes to transmit DHF, given the mosquito's habit of delivering multiple bites (Susanto, 2007). The population density in Palembang reaches 4,052 people. The distance between houses affects the spread of mosquitoes, from one house to another as well – the closer the distance between houses, the easier the mosquitoes spread and/or move to the next house. Various studies of infectious diseases prove that crowded housing conditions and slums have a greater likelihood of developing mosquito-borne disease(s) (Mukono, 2006). The parameter that most influences the high vulnerability in the work area of the Kasihan Puskesmas is the density of the houses, which is then followed by population density (Lestanto, 2018).

Alghazali et al.and Ravianto (cited in Gholib, 2020) define *slums* as houses along with their surrounding environment that function as settlements and as a means of raising families, but are not suitable for habitation when viewed from the perspective of population density, infrastructure, educational, health, social and the cultural facilities of the community. Poor health and sanitation are usually characterized by dirty physical environments and the quick spread of infectious diseases.

In general, slums are defined as either a planned or unplanned residential area that is used for settlements where the buildings are below standards or inadequate, which is inhabited by dense, poor population. These slums are inhabited by people with low or even non-permanent income, or sub-system ventures who live below the poverty line. Financial shortages have an impact on people's behavior in designing homes, especially ventilation which is used to fight and prevent mosquitoes from entering the house, carrying other vector diseases (Alghazali et al., 2020). DHF transmission occurs through the bites of *Aedes aegypti,* especially the female *Albopictus* that has previously carried the virus in its body that it caught from other DHF patients. The *Aedes aegypti* mosquito originated in Brazil and Ethiopia and often bites humans in the morning and afternoon. People at risk of DHF are children under 15 years of age, and those who live in damp environments and slums (Candra, 2010).

RESEARCH PROCESS

1.1.2 Vulnerability of Dengue Hemorrhagic Fever (DHF)

The use of Geographic Information System (GIS) for researches on Dengue Hemorrhagic Fever has been widely implemented for surveillance, mapping, and epidemiological research. The information generated is used as an epidemiological tool for early warning systems for dengue outbreaks that allow its prevention, control of mosquitoes and increased readiness of health workers, health care facilities and the community (Lestanto, 2018). GIS is proven to be an important tool for the analysis and visualization of epidemiological data (Mala and Jat, 2019). To date, very limited work has been done in analyzing spatiotemporal variations in previous incidents (Bohra and Andrianasolo, 2001; Palaniyandi, 2014; Telle et al., 2016; Tiwari and Jain, 2013; Vikram et al., 2015). This analysis is carried out with GIS which includes buffer analysis, scoring/scaling analysis, and overlay analysis.

DHF is a disease caused by a potentially life-threatening virus where transmission occurs through the mosquito genus, *Aedes* (Nedjadi et al., 2015). The mosquito and virus vectors have grown geographically in recent decades, producing endemic diseases in 128 countries. The World Health Organization (WHO) estimates there are 96 million symptomatic cases each year (Bowman, Donegan and McCall, 2016). *Aedes aegypti* is the most prominent vector for DHF, while *Aedes albopictus* is considered a secondary vector. *Aedes aegypti* is widespread in the tropical and subtropical regions of Southeast Asia, especially in most urban areas (WHO, 2001). WHO estimates that more than 50 million dengue incidents and 20,000 dengue-related deaths occur every year worldwide. According to WHO, there were only nine countries affected by the disease in the 1970s. However, with the gradual expansion of the area of its prevalence over the past 25 years in the 20th century, this disease has now reached Indonesia and more than 100 other countries, and affected 50-100 million people each year (Aziz et al., 2012; Gubler, 2002).

Geographic Information Systems and remote sensing data can be utilized to conduct spatial analysis and measure the level of vulnerability based on eight parameters. These include population density, settlement density, distance to rivers, distance to temporary garbage dumps, rainfall intensity, the presence of bamboo plants, the presence of cattle pens, and mosquitoes' flight distance (Lestanto, 2018). This research on DHF in Palembang uses ten indicators: 1) land use; 2) temperature; 3) altitude; 4) rainfall; 5) humidity; 6) population density; 7) slums; 8) mosquitoes' flight radius; 9) livestock population; and 10) the distance between the river and the settlements. These indicators can be seen in Figure 10.

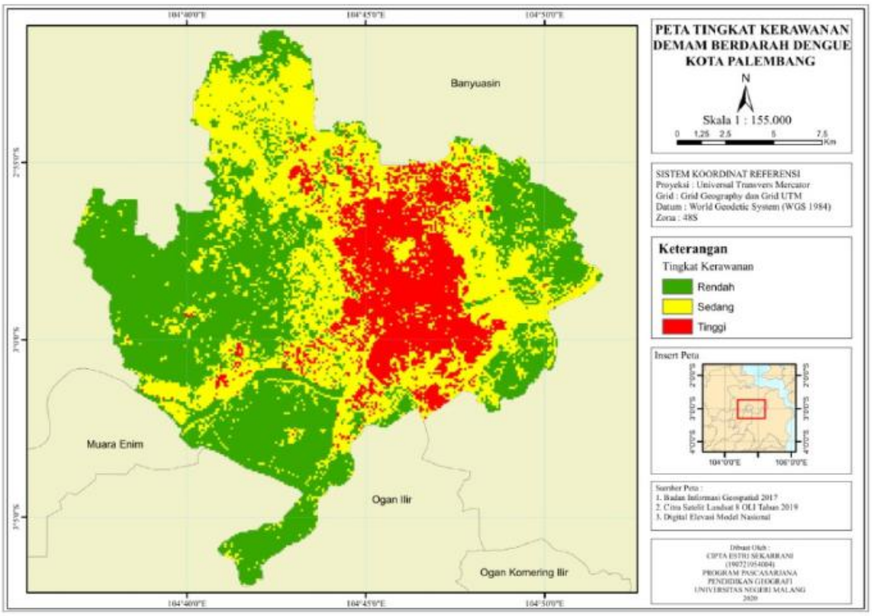


Figure 4. Map of DHF vulnerability level in Palembang

From the scoring results on all of the parameters that influence DHF, three classes are obtained: 1) low class, with a distribution area of 16,713 ha; 2) medium class, with a distribution area of 13,872 ha; and 3) high class, with a distribution area of 6,063 ha.

1.1.3 Accuracy in Determining the DHF-Prone Areas With a Fuzzy Set Model

4.1.2.1 Fuzzy Set

Fuzzy Set is where the membership of each element has no clear boundaries. Fuzzy sets are more often used for object classifications or continuous value phenomena, where classes do not have clear boundaries. In Fuzzy logic, a Fuzzy set is the grouping of things based on language variables expressed in the *Membership function*, where the *universe of course* is between 0 and 1. On a firm set (*crisp*), there are only two membership values, namely 0 or 1. Meanwhile, in the Fuzzy Set, the membership value is either μA (x) = 0, which means x does not belong to the set A, or μA (x) = 1, which means that x is a full member of the set A. The *Membership function* of a Fuzzy set is expressed by the degree of membership of a value against its strict value, ranging from 0 to 1. The *Membership function* defines how each point in the input space is mapped into weights or degrees of membership between 0 and 1.

The main purpose of using Fuzzy Set classification techniques is to provide solutions to the problems about accuracy resulting from the implementation of Boolean binary classification logic where the output is only true or false, which is one (1) or zero (0). One important consideration is that because environmental attributes are spatially very diverse in nature, the presentation of a continuous function with a Fuzzy set, both in the assessment procedure and output presentation, is much more representative than the method of grouping attribute values into a category system (Baja, Ramlan, and Ramli, 2011).

4.2.2.2 Fuzzy Set Input

The Fuzzy Set input in this study is all the parameters that have an impact on DHF. There are four indicators in this study: 1) land use; 2) mosquitoes' flight radius; 3) vulnerability to DHF; and 4) DHF distribution (figure 5).

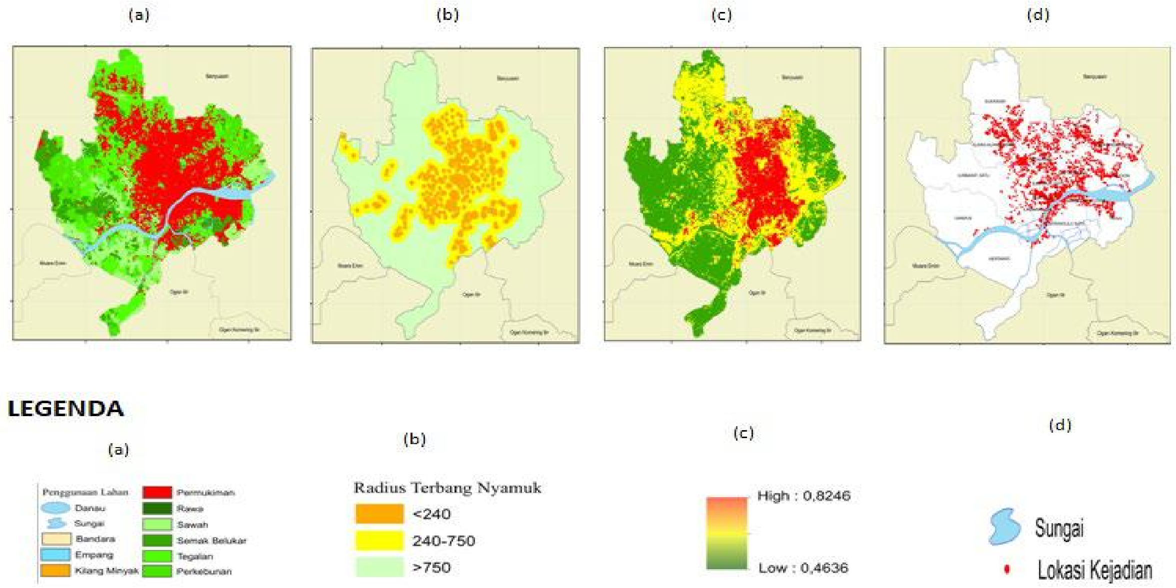


Figure 5. Fuzzy Set Variable

In many locations, DHF is associated with the inducement of vegetation, tree cover and land cover, given that these have a direct impact on the population size of adult *Aedes aegypti* as the main vector for the disease (Morin et al., 2013). Palembang has a total area of 40,022 ha. Analysis of land use patterns is intended to look at the current state of land use and its tendency to change. The results of this analysis will then be used as a basis for the policy of land use and designation in the coming years. This analysis is associated with land availability and suitability based on observations of the basic physical conditions of Palembang, especially for the use of cultivated land. In addition, this analysis also considers the appropriate land use structure, so that it is able to provide an appropriate and optimal land use direction. Land use in Palembang as of 2007 revealed a large amount of land had not been utilized. This is influenced by the spread of swampy areas throughout the city. As a whole, the developed spaces which can be classified as a new urban area occupies 1,134 ha of the land, or 9.16% of the total developed area in Palembang.

These developed spaces which are classified as an urban area are those used for trades, services, offices and industrial activities. This shows that from the total developed spaces in Palembang, the residential area occupies the largest space spanning up to 10,909.40 ha, or around 88.08% of the total developed spaces. However, land use had changed by 2019. This land use also plays a role in the spread of DHF in addition to many other factors that also influence it, such as the vectors themselves as well as the geographical conditions. These factors include land use and land change, and demographic and socioeconomic factors (Mala and Jat, 2019). Changes in land use are caused by population growth, wherein an increase of population increases the lands used. In addition, the high price of land also affects the houses people live in. There are still residents of Palembang who are classified as living in slums due to this (figure 2). Slums in Palembang are distributed in 59 urban villages (*kelurahan*) out of 107 in total. The regression effect of each independent variable has different results, namely educational variable (X_1) of 0.33; income (X_2) of 0.35; and employment (X_3) of 0.29. Palembang has a very strong city attraction, both in economic and non-economic way.

The mosquitoes' flight radius is obtained using the Buffer technique. Based on the mosquitoes' flight buffer radius in Palembang, the lowest yield is < 240 meters, while the highest is > 750 meters. Generally, female *Aedes aegypti* and *Aedes albopictus* have the power to fly as far as 50–100 meters, but Liew & Curtis report that both are able to fly easily and quickly when looking for breeding places (Chobanian et al., 2003).

4.2.23. *Membership Function* (MF)

The *Membership function* of a Fuzzy Set is expressed by the degree of membership of a value against its strict value ranging from 0 to 1. The *Membership function* defines how each point in the input space is mapped into weights or degrees of membership between 0 and 1.

Table 11. The *Membership function*

No	Variable	Class	*Membership function*
1	Cattle Pens	100–1000	0.6
		> 1000	0.3
2	Population Density	High	1
		Medium	0.6
		Low	0.3
3	Distance between the River and the Settlements	< 100	1
		100–1000	0.6
		> 1000	0.3
4	Rainfall	15–20 mm/day	0.8
		10–15 mm/day	0.6
		5–10 mm/day	0.4
5	Mosquitoes' Flight Radius	< 240	1
		240–750	0.6
		> 750	0.3
6	Temperature	33–28	1
		24–20	0.6
		20–16	0.3
7	Humidity	> 80%	0.6
	Altitude	< 100 masl	1
8	Slums	High	1
		Medium	0.6
		Low	0.4
		None	0.3
9	Land Use	Runway	1
		Lake	0.3

Pond	0.3
Oil refinery	1
Plantation	0.6
Settlements	1
Swamp	0.6
Crop	0.6
Bush	0.6
River	0.3
Moor	0.6

Source: Data processing (2020)

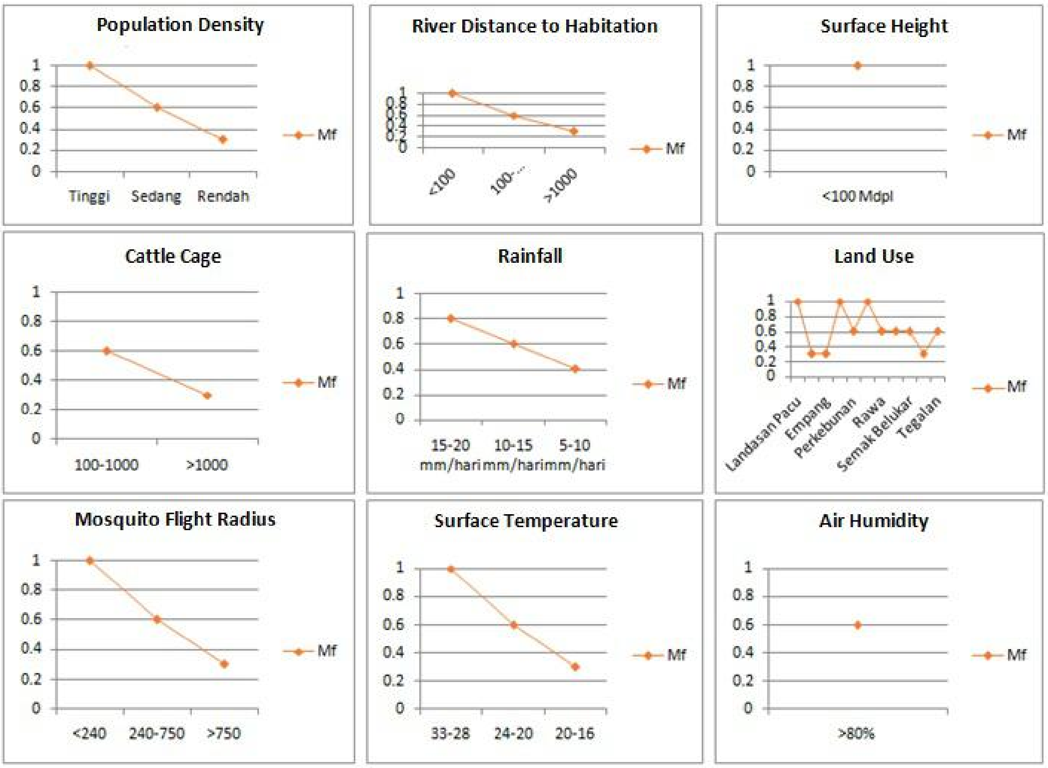
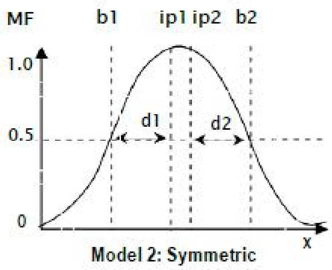
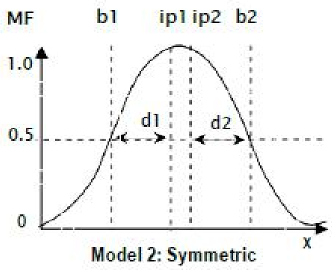
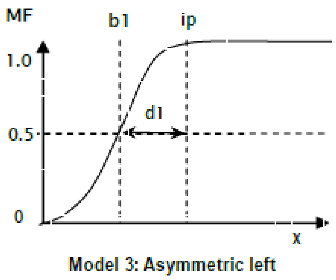


Figure 6. *Membership Function* Graph

The main purpose of using Fuzzy Set classification techniques is to provide solutions to the problems about accuracy resulting from the implementation of Boolean binary classification logic, where the output is only true or false, which is one (1) or zero (0). One important consideration is that because environmental attributes are spatially very diverse in nature, the presentation of a continuous function with a Fuzzy Set, both in the assessment procedure and output presentation, is much more representative than the method of grouping attribute values into a category system (Baja et al., 2011). From each of these parameters, the data collected will cover the entire Palembang, which is then classified in accordance with the case study of this research so that a parameter map can be obtained with each corresponding class.

Table 12. Curves, Parameters and the Peak Point of the *Membership Function*

No	Curve	Curve Type	Parameter	Peak Point
1		Symmetric	Surface Temperature Slums Humidity	28–24º C 71–95 60–80%
2		Asymmetric right	Land Use Rainfall	Dense Population > 25 mm/day
3		Asymmetric left	River Distance to Settlements Altitude Population Density Cattle Pens Mosquito Flight Radius	< 100 Meters < 100 masl < 150 People/ha < 100 < 240 Meter

Source: Data processing (2020)

Vulnerability of DHF was chosen to suppress the causes of the high number of DHF cases. The parameters used in this case are surface temperature, slums, humidity, land use, rainfall, distance between the river and the settlements, altitude, population density, cattle pens and mosquitoes' flight radius. Symmetric curves apply to parameters that have ideal values: 1) surface temperatures with a peak point of 28–24º C; 2) slums with a peak point of 71–95; and

3) humidity with a peak point of 60-80%. Asymmetric left curves apply to parameters with a characteristic of being better as the number increases. These include: the distance from river(s) to the settlement, altitude, population density, cattle pens and mosquitoes' flight radius. Meanwhile, asymmetric right curves apply to parameters with a characteristic of being better as the number decreases. These include land use and rainfall.

4.2.23 Group Weights Calculation

(A) Strong Group: Temperature, Humidity, Rainfall, Altitude
(B) Medium Group: Mosquitoes' Flight Ability, PL, Slums, Population Density
(C) Weak Group: River Distance to Settlement, Livestock Population

Determination of group weights:

$$
\begin{aligned}
4A + 4B + 2C &= 1 \\
4(4C) + 4(2C) + 2C &= 1 \\
16 + 8 + 2\,C &= 1 \\
26\,C &= 1 \\
C &= 1/26 \\
C &= 0.038
\end{aligned}
$$

(A) Strong Group : 0.038 x 16
: 0.608

(B) Medium Group : 0.038 x 8
: 0.304

(C) Weak Group : 0.038 x 2
: 0.076

4.2.24 Individual Weights Calculation

Individual Weight (group weight: number of members in each group)

A = 0.608/4
0.152

B = 0.304/4
0.076

C = 0.076/2
0.038

4.2.25 JMF/ *Fuzzification* (Individual Weights x MF)

Table 13. *Fuzzification*

No	Class	Individual Weight	*Membership function*	*Fuzzification*
1	Cattle			
	100–1000	0.6	0.6	0.36
	> 1000	0.3	0.3	0.09
2	Population Density			
	Class			
	High	1	1	1
	Medium	0.6	0.6	0.36
	Low	0.3	0.3	0.09
				0
3	River Distance to Habitation			0
	Class			
	< 100	0.038	1	0.038
	100-1000	0.0228	0.6	0.01368
	> 1000	0.0114	0.3	0.00342
				0
4	Rainfall			0
	Class			
	15–20 mm/day	0.1216	0.8	0.09728
	10–15 mm/day	0.0912	0.6	0.05472
	5–10 mm/day	0.0608	0.4	0.02432
				0
5	Mosquito Flight Radius			0
	Class			

	< 240	0.076	1	0.076
	240–750	0.0456	0.6	0.02736
	> 750	0.0228	0.3	0.00684
				0
6	Temperature			0
	Class			
	33–28	0.152	1	0.152
	24–20	0.0912	0.6	0.05472
	20–16	0.0456	0.3	0.01368
				0
7	Air Humidity			0
	Class			
	> 80%	0.0912	0.6	0.05472
				0
8	Altitude			0
	Class			
	< 100 masl	0.152	1	0.152
				0
9	Slums			0
	Class			
	High	0.076	1	0.076
	Medium	0.0456	0.6	0.02736
	Low	0.0304	0.4	0.01216
	None	0.0228	0.3	0.00684
				0
10	Land Use			0
	Class			

Runway	0.076	1	0.076
Lake	0.0228	0.3	0.00684
Dam	0.0228	0.3	0.00684
Oil Refinery	0.076	1	0.076
Plantation	0.0456	0.6	0.02736
Habitation	0.076	1	0.076
Swamp	0.0456	0.6	0.02736
Field	0.0456	0.6	0.02736
Shrubs	0.0456	0.6	0.02736
River	0.0228	0.3	0.00684
Moor	0.0456	0.6	0.02736

Source: Data processing (2020)

All indicators are rasterized using the tools in 'Arc-Toolbox' in the Conversion Tools - To Raster - Polygon to Raster. Next, in the value field, select the value table, and then Cellsize is changed to 10 to get a smoother raster. After all indicators have been rasterized, the next step is to calculate the fuzzy logic. After that, click on Spatial Analyst Tools - Overlay - Weighted Sum, then enter all indicators, then set storage and press OK. Here, weighted sum is used because of the overlaying of several rasters, multiplying each by the given weight and calculating the sum.

1. Working principle of Fuzzy Membership: Changing the input raster to the scale of 0 to 1, which shows the strength of membership in a set based on the specified *fuzzification* algorithm.
2. Fuzzy Overlay working principle: Combining Fuzzy membership raster data together based on the selected overlay type.
3. Work principle Weighted Overlay: Overlaying several rasters using a general measurement scale and the weight of each raster according to their interests.
4. Working principle of Weighted Sum: Overlaying several rasters, multiplying each by the given weight given and adding them together.

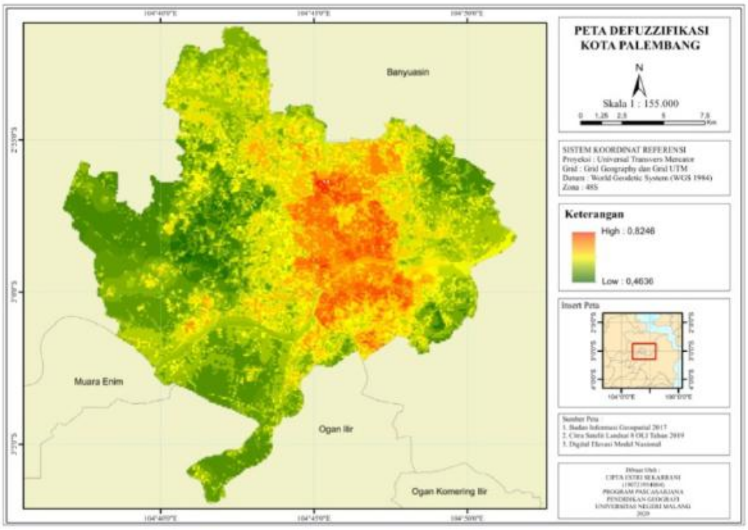


Figure 7. *Fuzzification* Results

Figure 7 explains the result of weighted sum with values ranging from 1 to 0. The highest Fuzzy Set result of Palembang is at 0.82, while the lowest is at 0.46.

CONCLUSION

By using both spatial and non-spatial data in Geographic Information Systems we determined that the level of vulnerability and accuracy of DHF is a contributing variable. There are three variables in this study: the host factor; environmental factor; and virus/vector factors. The level of DHF's vulnerability in Palembang is categorized into three classes: low, medium and high classes. The classification defines the low class with an area spanning 16,713 ha; the medium class with an area spanning 13,872 ha; and the high class with an area spanning 6,063 ha. The Fuzzy Set model shows each parameter that has a peak point affects the development of *Aedes aegypti* mosquitoes.

Surface temperature affects the spread of *Aedes* mosquitoes at temperatures of 28–24º C. Slums, in this case, are at a high level with a score of 71–95. Meanwhile, humidity has a range of 60–80%. The type of land use that most influences the development of mosquitoes is residential. This is because the denser a settlement becomes, the easier it is for mosquitoes to breed. Settlement affects the population density in an area as well, making it a variable in itself that affects the development of mosquitoes—i.e. with density of < 150 people/ha. In addition, the population density and the distance between houses also have an impact on the flight radius of mosquitoes, where denser houses will make the mosquitoes easier to breed in the neighborhood. In this case, a distance of > 240 meters is used as a reference point for the development of *Aedes aegypti* mosquitoes. Rainfall measures at > 25 mm/day. Rivers also affect the development of *Aedes* mosquitoes, more precisely their distance to the settlements, which in this case is < 100 meters. Altitude measures at < 1000 masl. Livestock owned by the community can also cause faster and more prolific breeding of *Aedes* mosquitoes, in that more cattle means more mosquitoes; here, it measures at < 100 animals.

From this study on DHF in Palembang using the Fuzzy Set model, three types of curves are obtained as the results: symmetric curves, asymmetric left curves and asymmetric right curves. Asymmetric left curves apply to parameters with a characteristic of being better as the number increases. These include: the distance from river(s) to the settlement, altitude, population density, cattle pens and mosquitoes' flight radius. Meanwhile, asymmetric right curves apply to parameters with a characteristic that they are better as the number decreases. These include land use and rainfall.

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