Application of Remote Sensing and GIS for Malaria Disease Susceptibility Area Mapping in Padang Cermin Sub-District, District of Pesawaran, Lampung Province

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Abstract. Malaria is epidemiologically a specific local infectious disease and can be studied spatially by taking into account the characteristics of malaria vector habitat. Padang Cermin Sub-District, District of Pesawaran, Lampung Province is one of the endemic areas of malaria which is geographically a coastal area dominated by water-flooded land use. That area supports the breeding and living place of *Anopheles sp* mosquitoes. The objectives of this study were mapping the malaria disease susceptibility area in Padang Cermin sub-district by using Landsat 8 imagery, identified the influence of physical environmental factors on the spread of malaria disease, and analyzed the spread of malaria disease based on environmental factors. The research method used scoring and overlay spatial analysis of spatial parameters supporting the breeding of malaria vector. Some parameters that can be extracted through Landsat 8 imagery for identification of malaria susceptibility, i.e. land use, soil texture, vegetation density with overall mapping accuracy of vegetation density, land use, and soil texture are 83.2%, 88.7%, and 83.7%, while other parameters resulted from spatial analysis of non-remote sensing data, i.e. temperature, rainfall, slope, altitude, and distance to river. These parameters are environmental factors that influence the spread of malaria disease. The results of the identification of malaria susceptibility showed that the areas with high levels of susceptibility are Sidodadi, Sukajaya Lempasing, Gebang, Padang Cermin, Hanau Berak, Way Urang, Tambangan, Hanura, Banjaran and Sanggi Village. This study showed that areas which are located on the coast are prone to malaria disease.

1. Introduction

Malaria is a disease caused by the Plasmodium parasite which is transmitted by the female *Anopheles sp.* mosquito [7]. Malaria is a life-threatening health problem that almost happened in every Indonesia's regions. Malaria disease problem is not only experienced by Indonesian, but this endemic disease can cause death and also threaten communities in various parts of the world, particularly in tropical and subtropical countries. According to World Health Organization data (2016), nearly half of the world's population is at risk of malaria. In 2015, there were roughly 212 million malaria cases and an estimated 429000 malaria deaths.

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Lampung Province is one of the malaria-endemic regions in Indonesia. In 2015, there were nearly 26722 malaria cases and 2 sufferers died. The percentage of malaria incidence confirmed by Health Department of the Lampung Province during 2010 to 2015 tended to increase. Lampung Province had Annual Parasite Incidence (API) index or indicator to measure malaria incidence as much as 0.41; 0.49; and 0.51; per 1000 population during 2013 to 2015. Lampung Province overall was categorized as a low level of malaria endemicity because of API Lampung Province index was still below the national average rate in 2010, i.e 1,96. However, some regions in Lampung Province showed a high level of malaria endemicity, such as Padang Cermin and Punduh Pidada sub-district, District of Pesawaran.

Malaria is epidemiologically a specific local infectious disease and can be studied spatially by taking into account the characteristics of malaria vector habitat. Remote sensing and Geographic Information System (GIS) can be utilized in planning and mapping the spread of malaria disease quickly and efficiently. The mapping results can be used to cope with and reduce the spread of malaria disease. This study is also related to supporting Indonesia’s Health Minister Program to eliminate malaria in the decentralization era. Global Malaria Programme (GMP) stated that malaria is a disease requires continuous observations, monitoring and evaluation, and appropriate formulation of policies and strategies.

Padang Cermin sub-district is one of the endemic areas of malaria which is geographically a coastal area dominated by water-flooded land use supports the breeding and living place of Anopheles sp. mosquito. Physical environmental factors, such as land use, vegetation density, soil texture temperature, rainfall, slope, altitude, and distance to the river may affect Anopheles sp. breeding. This study was aimed to map the malaria disease susceptibility area in Padang Cermin sub-district by using Landsat 8 imagery, identified the influence of physical environment factors on the spread of malaria disease, and analyzed the spread of malaria disease based on environmental factors.

2. Data and Methodology

2.1. Study Area and Data

This research was conducted in Padang Cermin Sub-District, District of Pesawaran, Lampung Province (Figure 1). This study used some secondary data are as follows: Indonesia Topographic Map scale 50,000; Landsat 8 OLI (June, 21st 2016); Geological Map of Tanjung Karang Sheet; boundary administration data of Pesawaran District; average daily temperature data (2014-2016) of Pesawaran District; average annual rainfall (2014-2016) data of Pesawaran District; and the amount cases of malaria disease data of Padang Cermin Sub-District 2016 from Health Department of the Lampung Province.

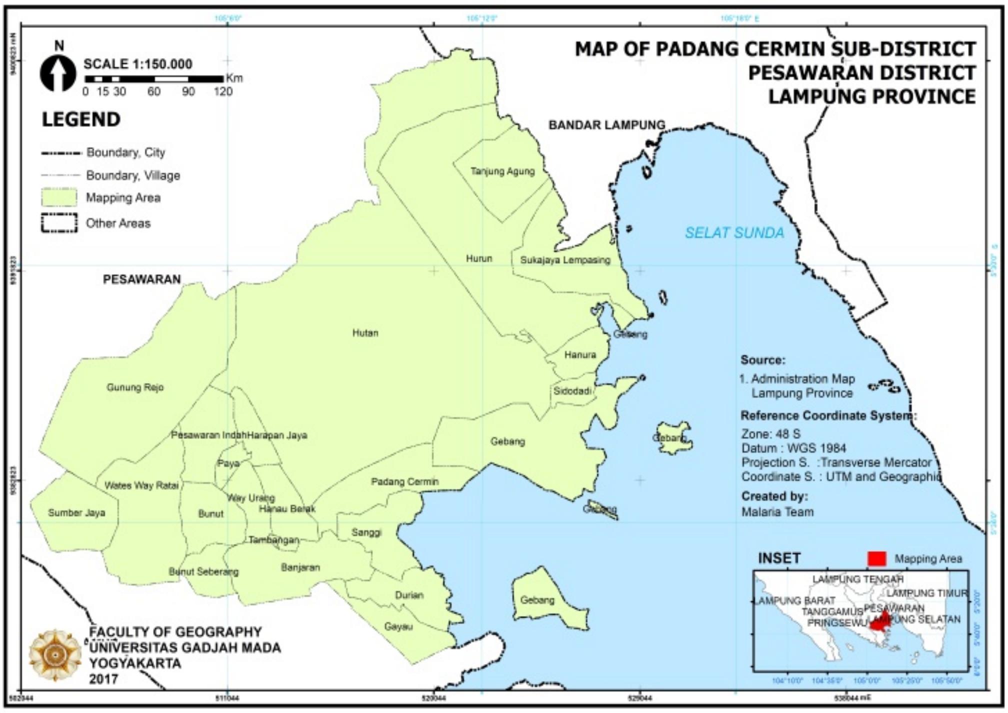

Figure 1. Research Location, Map of Padang Cermin Sub-District

2.2. Methodology
This study used quantitative spatial approach, and was divided into several stages (Figure 2), namely:

2.2.1. Data Pre-Processing
1) Radiometric Correction
Radiometric correction is performed to improve the visual quality of the image as well as correct the errors of pixel values that do not match the actual object reflectance. These errors can be caused by atmospheric disturbances during image recording or sensor error. The radiometric correction process in Landsat 8 OLI imagery can be performed according to the process issued by USGS (2013).
2) Geometric Correction
The process of image quality improvement in order to produce ready-to-use imagery for specific applications not only include radiometric correction but also need geometric correction. Geometric is related to the geographical position or distribution (geo-referenced data), either the position in the coordinate system or the information contained therein. Remote sensing imagery's geometric must have errors, such errors can arise because of the movement of satellites, earth rotation, the movement of sensor scanning mirror, and also earth curvature [4].

2.2.2. Data Processing
1) Vegetation Density Map
The vegetation density map was derived from the value of vegetation density pixel using Normalized Difference Vegetation Index (NDVI) transformation which is utilized near-infrared and red wavelengths on Landsat 8 OLI. The results of the index value were classed into three classes, i.e low, moderate, and high then further field checking was performed on each class (Table 1). The use of vegetation density in this research was related to the best breeding and living place of Anopheles sp. mosquito. The more dense vegetation will increase the convenience of a mosquito to grow and breed, whereas the low of vegetation density will reduce the convenience of a

mosquito to grow, it is because the direct contact habitat with sunlight can reduce the humidity of mosquito's habitat. Classification and the score of vegetation density classes are as follow:

Table 1. Classification and the Score of Vegetation Density Classes

Vegetation Density	Score
Low (<30%)	1
High (>60%)	2
Average (30-60%)	3

Source : Eiten (1968) in Ridwan, 2012

2) Land Use Map
Land use map was created from Landsat 8 OLI by visual interpretation using ArcGIS software to limit a homogeneous object that distinguishes with other appearance. Land use classification used I Made Sandy (1977) land use classification scheme on 1 : 100.000 scale with some modifications (Table 2). Land use related to the main habitat of the community as well as the habitat for breeding and survival of the mosquito *Anopheles sp.* Classification and the score of land use classes are as follow:

Table 2. Classification and the Score of Land Use Classes

Land Use	Score
River, mangrove, paddy fields, shrimp ponds	3
Bushes, crops, vacant land, forest	2
Settlement, garden	1

Source: Dulbahri (1992) with modifications in Sulistiarini (2011)

3) Soil Texture Map
Soil texture information was derived from the integration of geology map with landform map. The soil-formation is assumed from parent rock underneath or not the result of transformation nor translocation. The making of soil texture tentative map was performed by visual interpretation of rock types. Soil texture tentative map is used as the basis for sampling field to measure the accuracy of soil texture. The soil has physical properties in terms of the size of the soil particles. The more smooth soil texture causes the difficulty of soil to be passed by the water so the land will easily flood. Classification and the score of soil texture classes are as follow:

Table 3. Classification and the Score of Soil Texture Classes

Criteria	Soil Texture	Score
Fine – fairly smooth	Clay, dusty clay, sandy loam, loam, loamy clay, dusty clay loam	3
Average	Dusty, dusty loam, loam	2
A bit rough - rough	Sandy loam, loamy sand, sand	1

Source: Achmad, 2003 with modifications

4) Rainfall Map
Rainfall map was created from secondary data processing of annual mean rainfall data (mm/year) of rainfall stations around the research area. The annual mean rainfall data was processed using interpolation Inverse Distance Weighting (IDW) to produce an isohyet map, i.e. the lines connect the points that have the same rainfall intensity. The higher intensity of rainfall will increase the relative humidity that supports the survival of *Anopheles sp.* mosquito, which resulted in an increase the mosquitoes density. Classification and the score of rainfall classes are as follow:

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Table 4. Classification and the Score of Rainfall Classes

Criteria	Rainfall (mm/year)	Score
Low	<1000	1
Average	1000-2000	2
High	>2000	3

Source: Achmad, 2003 with modifications

5) Altitude Map
Altitude is related to the air temperature of an area that affects the breeding of malaria vector. The higher altitude of an area then the air temperature will tend to be lower. It will cause malaria vector inactive to bite and effect to the lower transmission level of malaria disease. Malaria disease vector lives in an ideal area that is not too high, i.e. between 100-500 above the sea level. The altitude map was created by interpolation contour data using topo to raster method. Classification and the score of altitude classes are as follow:

Table 5. Classification and the Score of Altitude Classes

Altitude (m)	Score
< 150	3
2.1. – 700	2
>700	1

Source: Idung, R. Fiolenta, M. et al. (2006) with modifications

6) Distance to River Map
A river is one of the ideal locations for malaria vector breeding place. The making of distance to river map is based on multiple buffer spatial analysis. The closest area to the river causes the risk of malaria disease will increase. Especially, if the river has a steady flow or tends to stagnate, it will make the risk of malaria disease higher because the larvae of Anopheles sp. prefers a steady flow to breathe through the spiracles. Classification and score of distance to river classes are as follow:

Table 6. Classification and the Score of Distance to River Classes

Distance (meter from river)	Score
<50	3
50- 300	2
>300	1

Source: Sunaryo, 2009 in Ridwan, 2012

7) Slope Map
The slope map is derived from Digital Elevation Model (DEM) which is produced from contour interpolation to slope information on percent units. Slope factor is related to the availability of puddles as the breeding place of malaria vector. On steep slopes, water tends to flow as surface runoff gravitationally to the lower area, whereas on the gentle slope has a high potential for the formation of puddles and may increase the breeding of malaria vector. Classification and score of slope classes are as follow:

Table 7. Classification and Score of Slope Classes

Slope	Score
0-8%	3
8-15%	2
15-25%, 25-45 %	1

Source: Bruce-Chwatt (1985) with modifications

8) Temperature map
The temperature map is created by converting the elevation data (DEM) into the value of temperature using Braak law. It used an assumption that temperature will reduce 0,61ºC every 1000 meter increase on the areas with elevation under 2000 meter above sea level. Then, the temperature also reduces 0,52ºC every 100 meter increase in the area with elevation above 2000 meter [9]. Classification and score of temperature classes are as follow:

Table 8. Classification and score air temperature factor

Temperature (°C/Year)	Score
<25	1
>27	2
25-27	3

Source: Bruce-Chwatt (1985) with modifications

2.2.3. Field Checking. Field checking was conducted to match the result of parameters interpretation and the extent of malaria susceptibility, as well as records of changes in the field based on samples that have been established in the previous stage. The checked field parameters were vegetation density, land use, and soil texture, while other parameters were extracted from secondary data so field checking was not needed. The sampling technique was used purposive random sampling with the total samples to be field tested were at least 30 samples. Purposive random sampling is a sampling of random population members by considering land units, reliefs, and accessibility levels. Each sample represents a specific land unit, consist of land use, vegetation density and soil texture parameter. This sampling method is based on the presence of unequal (heterogeneous) population members.

2.2.4. Interpretation Accuracy Measurement. The accuracy measurement was performed using a confusion matrix that matches the interpreted pixels by the pixel test sample, in which one test sample can consist of many pixels. Accuracy measurement is expressed in the form of producer's accuracy, user's accuracy, and overall accuracy. Accuracy measurement can be performed by multivariate or Kappa index [3] using formula as follows:

$$K = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} \times x_{+i})} \quad (1)$$

2.2.5. Reinterpretation. Reinterpretation was performed after the field checking and accuracy measurement of the tentative map. Reinterpretation is intended to justify misinterpretation based on field checking results in order to analyze using data that has been in accordance with actual conditions in the field. The reinterpreted map in this research is field checked parameter map, i.e vegetation density, land use, and soil texture map. The results of reinterpretation parameters map then can be used to perform further analysis of malaria susceptibility.

2.2.6. Spatial Analysis of The Influence of Each Parameter on Malaria Susceptibility. The influence of physical environment factors to the spread of malaria disease is analyzed by using quantitative analysis method, that is correlation analysis to know the relationship between two variables, the direction of variable and variable relation. Based on the use of physical environmental parameters that have been performed by field checking and reinterpretation, then malaria-prone areas map was generated by using overlays method. The class of malaria susceptibility is divided into three classes, i.e high, moderate and low susceptibility. The malaria susceptibility map is then validated to malaria incidence data and also conducted a descriptive qualitative analysis of the spread of malaria susceptibility.

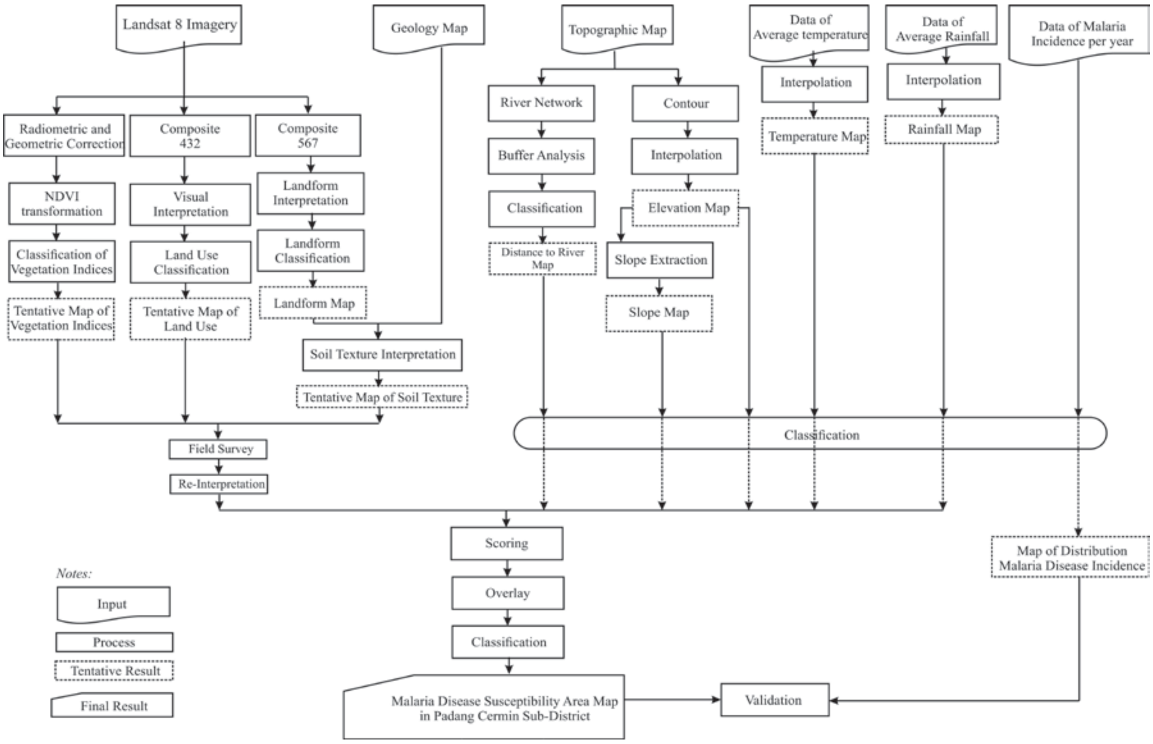

Figure 2. Malaria Disease Susceptibility Area Mapping Flowchart

3. Result

3.1. The Linkages between Anopheles Sp. and Field Conditions

The presence of mosquito species is influenced by environmental conditions, there are physical, chemical, and biological environments. Research shows Anopheles sundaicus sp. is the dominant Anopheles species in Pesawaran District. In addition, there are also other species influenced by diverse ecological circumstances. An. Sundaicus primarily liked the place of breeding with the brackish water such as lagoons, swamps, ponds, and embankment. Embankment land use is commonly found in Pesawaran District, especially in Padang Cermin Sub-District. Some of the existing embankment in the area are still active, but in some places, abandoned embankment are found no longer maintained. The interaction between soil on the abandoned embankment has increased the potential of Anopheles sundaicus mosquito breeding in the area. In addition, another inundated land use became one of the breeding places of Anopheles mosquito is mangrove.

Padang Cermin sub-district is located along the coast. Coastal areas have relatively higher humidity caused by large water evaporation. Mosquitoes generally liked the area with high humidity that has the optimal conditions for mosquito breeding. The faster mosquito breeding will increase the possibility to contact with humans, so the risk of transmission of malaria disease will be greater. Padang Cermin sub-district is also a region with high level of vegetation existence. The existence of vegetation can affect the life of mosquitoes, such as a breeding, shelter and foraging place, as well as a resting place for adult mosquito. In optimal conditions areas for mosquito breeding, the higher vegetation density level will increase the convenience level of mosquito growth. This condition is found in high-density mangrove vegetation.

3.2 Analysis of the Distribution of Malaria Hazard in Padang Cermin sub-district

Based on the ecological unit malaria disease susceptibility area map in Padang Cermin sub-district (Figure 3) shows most of the region is malaria-prone areas, especially in areas close to the coast. The areas close the coast are dominated by a high level of susceptibility due to the environmental factors of land use, namely, embankment is the preferred land use by Anopheles sp. mosquito. Not all parts of coastal areas have the high level of susceptibility, there are also some coastal areas that do not have the high level of susceptibility. This is due to the influence of other ecological factors that actually reduce the probability of malaria susceptibility.

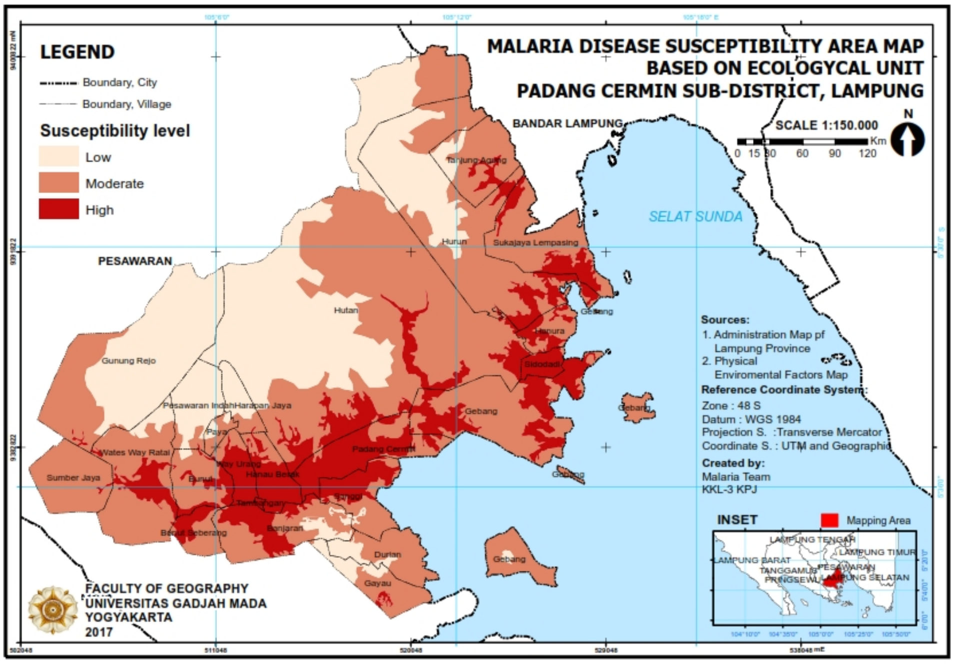

Figure 3. Map of the distribution of malaria vulnerability based on ecological unit

The high level of malaria susceptibility in coastal areas shows a link between malaria susceptibility and the spread of Anopheles sp. mosquito habitat, especially An. sundaicus which is the most dominant mosquito species in Padang Cermin sub-district. The areas in Northwest of Padang Cermin sub-district have the low level of susceptibility due to malaria susceptibility parameters in the region less support the existence of Anopheles sp. mosquito breeding habitat. The low level of susceptibility areas is found around the Forest area, Ratai mount, Pesawaran mount, and Betung mount. It caused by the ecological conditions do not suit with the characteristic of Anopheles sp. mosquito habitat: have a fairly steep slope and the altitude more than 700 meters. These characteristics may inhibit the development of Anopheles sp. Steep slopes can cause the high level of land erosion, so water tends to flow as surface runoff gravitationally to the lower area and puddles as Anopheles sp. breeding place are not formed. Meanwhile, the altitude more than 700 m closely related to the temperature that can affect the biological condition of Anopheles sp. Malaria susceptibility mapping result shows that areas close to coastal areas have higher levels of susceptibility, but these results should be compared with malaria incidence data to be more valid and appropriate.

3.3 Interview Results and their Relation to Malaria Incidence and Occurrence

Based on interviews with 10 scattered randomly interviewees in all samples of Padang Cermin sub-district, showed that the level of effectiveness of counseling or the introduction of a danger of malaria disease is 70%. The government has not been doing maximal training or counseling about malaria disease. This was marked by 30% of people said that they have never followed malaria education and lack of fogging routine. The government also has not provided the maximum malaria vaccination yet. Some interviewees said, there were a net allotment and medical assistance to deal with malaria but the aid has not evenly distributed yet and there was no clear information.

The dominant livelihoods of the Padang Cermin community are farmers and traders. The dominant community is domiciled on the edge of the rice field, has a cattle pen near to the house and does not have mosquito larva-eating fish. It may potentially increase the spread of malaria vector. In terms of daily habits, the community has been aware to use mosquito nets and anti-mosquito as preventive efforts of malaria disease. The most prevalent malaria incidents are found in Sukajaya Lempasing Village. There are several villages prone to malaria disease but has no occurrence of malaria disease. It can be influenced by mosquitoes fly patterns or non-sedentary human activity. Way Urang, Hanau Berak, Bunut Seberang and Tambangan are villages that do not have incident data.

Based on interviews results in Hanura Village, there are some areas that have abandoned embankment. The embankment and slum settlements are one of the land use that triggers the breeding of Anopheles sp. mosquito, causes many malaria cases occur. Rice cropping system that does not alternate with Palawija provide opportunities to Anopheles sp. mosquito to breed around the rice field.

3.4 Malaria Susceptibility and Incidence Map

In this research, malaria susceptibility map was conducted validation with malaria incidence map by the year 2016 (Figure 4). Malaria incidence map in 2016 was selected by adjusting the remote sensing imagery time of acquisition to know the relationship between physical conditions in the field with malaria incidence level. Based on the data, it was known that the malaria incidence in a period of 1 (one) year (Annual Parasite Incidence) in 2016 was the highest in Sukajaya Lempasing village with the number of occurrences as many as 913 cases. The high amount of malaria incidence most likely occurs due to physical environmental factors, and an individual factor of sufferers. Physical environmental factors were examined, namely, land use, soil texture, and vegetation density. The individual factors influence malaria incidence, namely gender, ages, type of work, and community behavior to consciously against malaria disease.

Based on malaria susceptibility map, administrationally can be aware that areas have the high level of susceptibility namely, Sidodadi, Sukajaya Lempasing, Gebang, Padang Cermin, Hanau Berak, Way Urang, Tambangan, Hanura, Banjaran, and Sanggi Village (Figure 5). The spread of malaria susceptibility on administrative units based on the extent dominant susceptibility area percentage. Areas with the high level of susceptibility do not always have a high incidence of malaria, as well as in areas with low to moderate level of susceptibility. It was caused by the individual and environmental factors. The existence of the settlements and the activities of the community in the area with high level of susceptibility will greatly affect the presence or absence of malaria incidence. While other factors that affect malaria incidence is the type of work, community behavior to consciously against malaria, population mobility, and the Anopheles sp. mosquito transmission.

Based on malaria incidence data, malaria sufferers are dominated by men aged over 17 years, because those age and gender group have a high mobility, especially related to the demands of the type of work. The dominant type of work that exists is embankment farmers who demand to work in embankment area as Anopheles sp. breeding place.

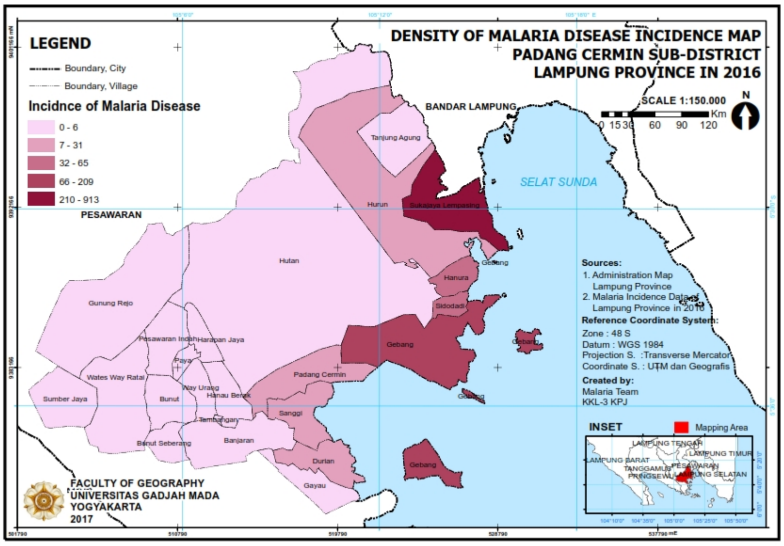

Figure 4. Map of Malaria Disease Incidence

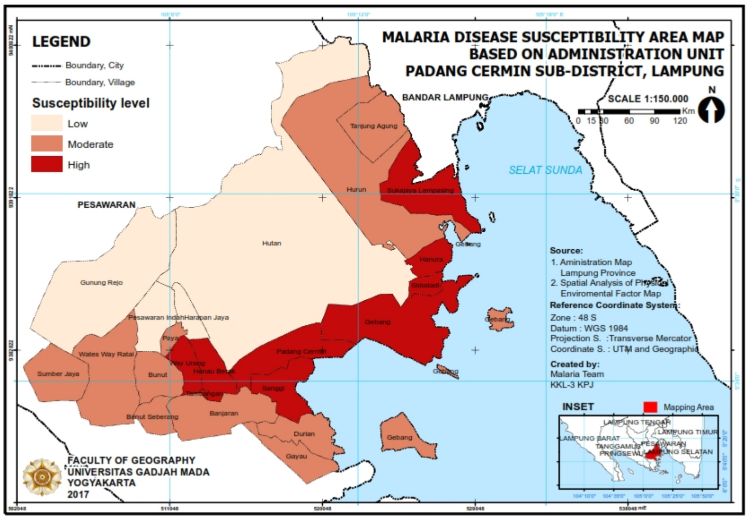

Figure 5. Map of the distribution of malaria vulnerability based on administrative unit

4. Conclusions

1) Physical environmental factors that affect the high level of malaria susceptibility in Padang Cermin sub-district are embankment and mangrove land use, moderate to high level of vegetation density, low altitude with the optimum temperature between 25-27℃, fine soil type, and the gentle slope that affect the presence of puddles as the malaria vector habitat.
2) The malaria susceptibility mapping result in Padang Cermin sub-district shows high-level susceptibility areas are found in Hanau Berak, Way Urang, Bunut Sebarang, Sanggih, Tambangan, Padang Cermin, Hanura, Sidodadi, Gebang and Sukajaya Lempasing village, while low-level susceptibility areas are found in Pesawaran Indah, Harapan Jaya, Hutan, and Gunung Rejo village.
3) The area of malaria susceptibility distribution in Padang Cermin sub-district belongs to high categorized spatially distributed in the coastal area with the influence of mangrove and embankment land use, low altitude and optimal temperature, while areas with the low level of malaria susceptibility are influenced by high altitude, low temperature, and steep slope.

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