Climate Change Risk and Adaptation Assessment

Greater Malang

Sectoral Report
Health

June 2012

Ministry of Environment

Climate Change Risk and Adaptation Assessment for the Health Sector – Greater Malang

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Climate Risk and Adaptation Assessment for the Health Sector – Greater Malang

Draft Final Report

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX FIGURE

LIST OF APPENDIX TABLE

CHAPTER 1 INTRODUCTION

1.1 Background

Accumulation of greenhouse gasses for decades had been widely accepted as the cause of changing pattern of climate all over the globe. Climate projections indicate that mean wet-season rainfall and length of dry season will increase. Moreover, rise in intensity and frequency of extreme events like El Nino, which have caused major floods, droughts and fires, are already noticeable in the Asian region.

There are many evidences showing that the changes in climate are affecting human health such as temperature related morbidity, deaths injuries from extreme events, vector and rodents borne diseases, water borne diseases, etc (see Figure 1.1).

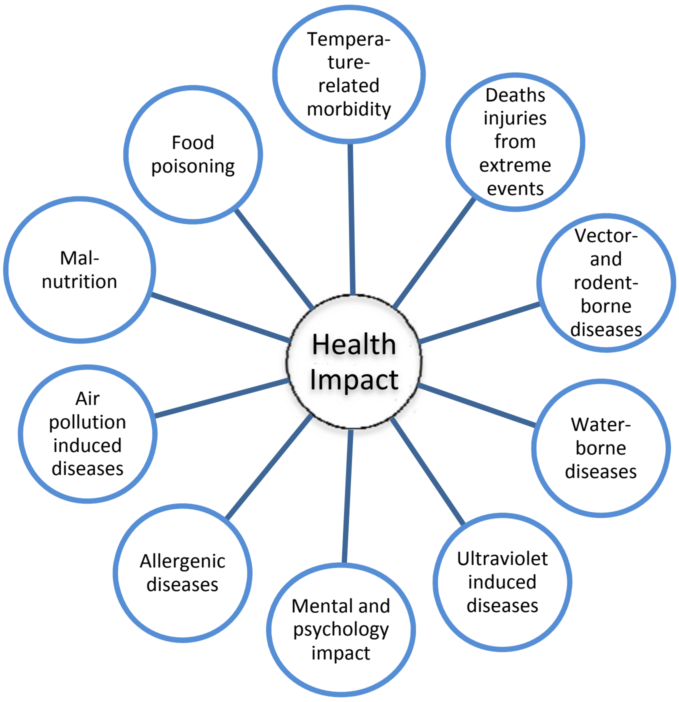


Figure 1.1 Climate Change Impact on Human Health

Stimuli of climate change consist of temperature rise, change of precipitation, sea level rise, and increase of extreme weather. Those stimuli of climate change pose health impact, such as morbidity and mortality due to temperature rise, disasters due to extreme weather, air pollution increase, water and food borne disease, and vector and rat borne disease.

The stimuli of climate change could influence human health in two ways, i.e. directly and indirectly (see Figure 1.2):

- Directly, such as increase of deaths and injuries due to exposure to seasonal change (temperature, rainfall, sea level rise, and the increase of weather extreme frequency).
- Indirectly, through changing environmental factors such as the changes in the quality of the environment (water, air, and food quality), the thinning of ozone layer, scarcity of water resources, loss of ecological functions, and degradation of lands which eventually influence human health. Indirect impacts cover: (a) mortality and morbidity due to climate change-induces diseases e.g. water and food borne disease, and vector-borne disease;

(b) Malnutrition, due to crops failure as a result of increase in extreme wheather frequencies.

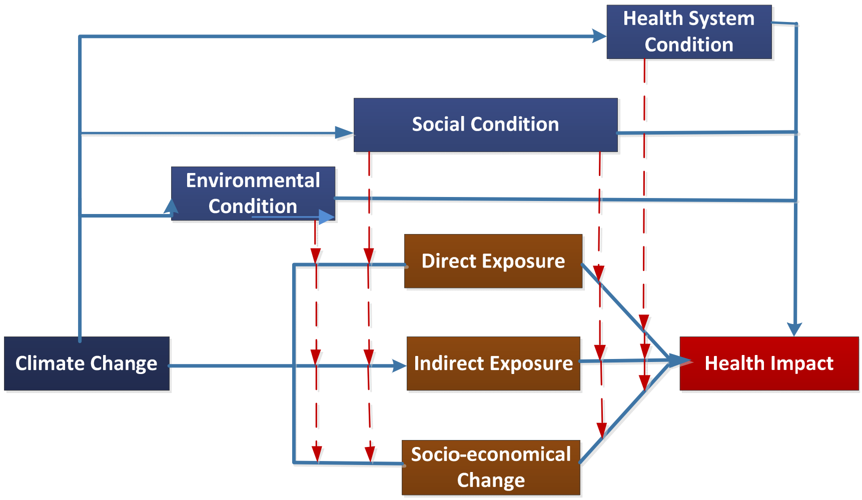


Figure 1.2 Schematic Diagram of Relationship Pattern of Climate Influence on Health, Impacting Directly as well as Influenced by the Modification of the Environmental Conditions, Social, and Health System (IPCC, Working Group II, 2008)

The climate affects human health via direct and indirect pathway as decribed in Figure 1.2 and Table 1.1. Direct pathway is caused by extreme event. More frequent extreme climate events potentially increase the number of people suffering from deaths, injuries, and post-traumatics disorders. Indirect pathway occurs via less direct mechanisms, but in greater magnitude than more direct impacts. For example, changes in average temperature and precipitation pattern could result in increasing number of people at risk of infectious diseases and increasing cases of malnutrition problem especially in developing countries. The mechanism are include changes in the pattern of transmission of many infectious diseases – especially waterborne, food-borne and vector-borne diseases – and regional food productivity (McMichael et al., 2002). Climate change currently contributes to the global burden of disease and premature deaths. Moreover, rising sea-level has threatened the coastal population health by reducing water supply quality and there are many cases of deteriorating air quality in urban areas that could lead to the increase of respiratory diseases. At this early stage, the effects are small but are projected to progressively increase in all countries and regions (IPCC, 2007).

Table 1.1: Hazards of Climate Change as related to the Health Sector (ICCSR, 2010)

Climate change	Direct Hazard	Non-direct Hazard
Temperature (T) increase	- Heat waves - Increase of evapo-transpiration together with change in rainfall will decrease surface stream, causing: o Scarcity of water supply o Droughts o Disturbance of water balance	- Increase in temperature influences breeding, development, age, and distribution of malaria vector, DHF, chikungunya, and filariasis. - Increase in temperature, will expand distribution of vectors and enhance development of parasites to become infective. - Decrease of water availability affecting agriculture, thus causing harvest failure, indirectly causing malnutrition
Change of rainfall pattern (CH)	Increase of surface stream and land humidity, causing:	- Flood and water balance disturbance could affect sanitation

Climate change	Direct Hazard	Non-direct Hazard
	- Floods - Disturbance of water balance - Landslides Together with increase in temperature, will decrease surface stream, causing: - Decrease of water availability - Droughts	condition and bring water borne disease such as diarrhea. - Flood and water balance disturbance could affect harvest failure, causing malnutrition. - Rainfall influence type and number of habitat for vector breeding. - Change in rainfall together with increase of temperature and relative humidity, could increase as well as decrease disease vector population density and contact between vector and humans.
Sea Level Rise (SLR)	With the increased level of extraction of certain ground water, sea water intrusion will occur, such that it will influence availability of fresh water and sanitation functions.	- Sanitation function disturbance affects the increase of water borne disease spread such as diarrhea. - Change of coastal ecosystems affects the increase of mosquito's breeding site
Increased frequency and intensities of extreme weather	- Rainfall above normal causing increased surface stream and land humidity, resulting in flooding and landslides. - Hurricanes	- Flood, storm, and landslide disaster may cause mortality - Flood, storm, and landslide disaster may cause settlement damage, further causing refuge and many health disturbance - Impact on human immunity

Climate change affects health through many processes such as microbe contamination and dynamics transmission, agro-ecosystem and hydrology, and socio-economy and demography (see Figure 1.2). These processes are also affected by modulation of social, economy, and development condition.

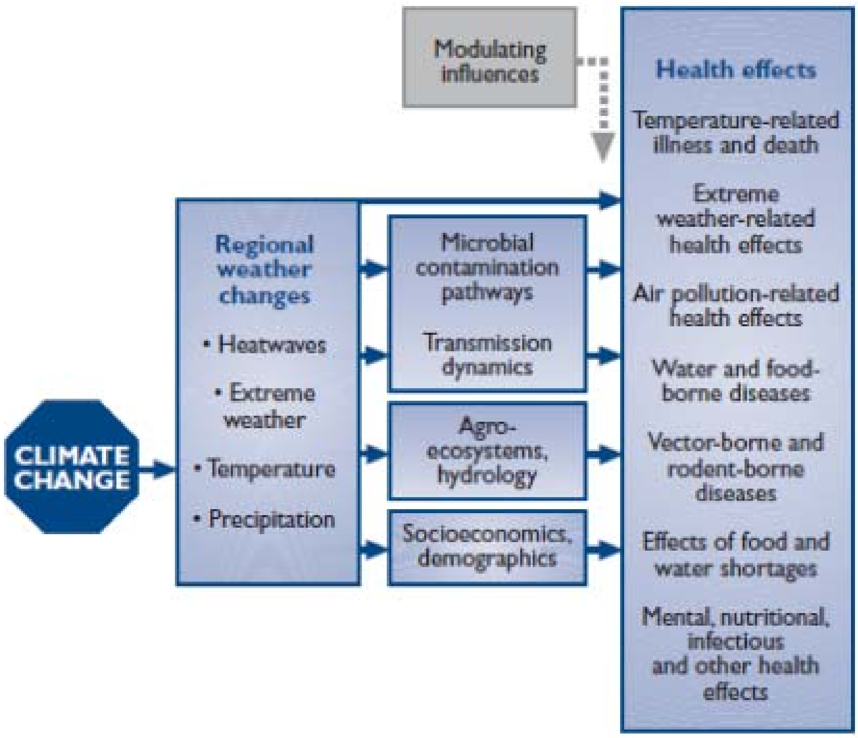


Figure 1.3 Pathways by which Climate Change Affect Human Health (Patz et al, 2000)

Indonesia is one of the archipelagic, developing nations that are believed to be more vulnerable to various impacts of climate change. Vulnerability is defined as the extent to which a natural or social system is susceptible to sustaining damage from climate change, and is a function of the magnitude of climate change, the sensitivity of the system to changes in climate and the ability to adapt the system to changes in climate. Hence, a highly vulnerable system is one that is highly sensitive to modest changes in climate and one for which the ability to adapt is severely constrained (IPCC 2000a, in Olmos, 2001). Adaptive capacity in coping with climate change impacts depends on socio-economic factors and varied in every nation. Adaptation measures are essential in reducing vulnerability and aggravating impacts of climate change, hence, it received less attention than climate change mitigation (Olmos, 2001), despite the fact that adapting to climate change is an urgent issue in developing countries, especially in small islands area.

The necessity for adaptation measures at national and local levels is rapidly emerging as central issue in the debates around policy responses to climate change. Therefore, adopting coherent set of approach, framework and methodologies in assessing vulnerability and adaptive capacity are indispensable in order to set priorities, designs and implementation of climate adaptation strategy.

1.2 Objectives

The objectives of this assessment are as follows:

- To determine the methods of vulnerability and risk assessment to climate change in the health sector in accordance to the micro-level assessment approach.
- To produce the vulnerability map and analysis of risk to climate change in Greater Malang, as well as in the design of adaptation strategy in health sector,
- To build the capacity of stakeholders related to the vulnerability and adaptation issues in health sector, especially on the local level.
- To contribute relevant information regarding Climate Change Vulnerability & Adaptation of the Health Sector to the Climate Change Adaptation and Vulnerability Database to be used by local governments and stakeholders in Greater Malang.
- To contribute Risk Analysis & Adaptation Options for the Health Sector to the Final Document for the local governments of Malang which provides step by step guidance for the integration of adaptation options and their corresponding financing on the basis of the VA into annual sectoral plans (of the present RPJM) and for the next RPJM (2015-2019)
- To develop the "Health Sector" part of the national VA Guidelines based on the lessons drawn from the VA exercise in Greater Malang.

This assessment also serve as a pilot project of vulnerability assessment in the health sector conducted in an urban and rural area which methods, tools and concepts can potentially be used in other city in Indonesia with similar characteristic to Malang and use a micro-level approach.

1.3 Scope of Assessment

The scope of this assessment includes the identification of hazards and assessment of vulnerabilities and risks to climate change in the health sector based on the "micro level-multi sectoral approach" in the area of Greater Malang, which cover Malang City, Malang District and Batu City.

This assessment will be focused on vector-borne diseases (malaria and DHF) and water-borne diseases (diarrhea), but other health impacts, namely temperature-related morbidity and mortality, air pollution induced diseases, malnutrition, and injuries and deaths due extreme events will also be discussed in smaller portions.

CHAPTER 2 GENERAL DESCRIPTION, HEALTH SECTOR, CLIMATE CHANGE ISSUES OF MALANG

2.1 Regional Description

Greater Malang is the second largest city in East Java province, Indonesia. The name of Malang is taken from a temple namely Malang Kucecwara. The name of the temple is now applied to the motto of Malang. Malang Kucecwara literally means God has destroyed the false and enforced the right. Greater Malang is divided into three administrative region, namely Malang City, Malang District and Batu City. The three regions are shown geographically in figure 2.1.

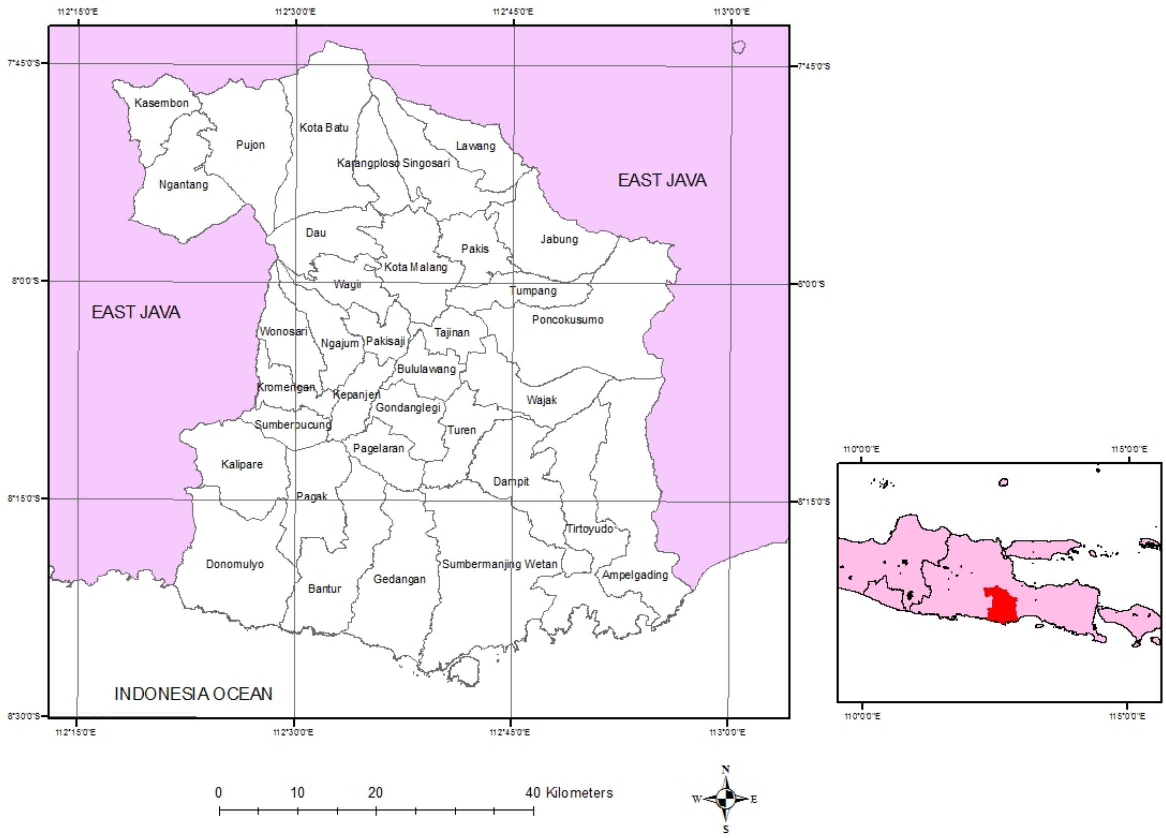


Figure 2.1 Geographic Map of Greater Malang

Batu City and Malang City located in the northern area of Greater Malang, while Malang District encircle those two cities and verge with Indonesia Ocean.

2.1.1 Geographic and Topographic Profile of Malang City

Malang City is located between 112,06°-112,07° N and 7,06°-8,02° S with an area of about 110,06 km^2. Geographical borders of Malang City are as follow:

North : Singosari sub district and Karang Ploso sub district
East : Pakis sub district and Tumpang sub district
South : Tajinan sub district and Pakisaji sub district
West : Wagir sub district and Dau sub district.

Malang City consists of mostly highland with elevation between 440-667 m above sea level. One of the highest spot in Malang City is the Buring Mountain which located in east part of Malang City.

The average air temperature in Malang city which recorded in 2010 is 25,1°C with the maximum temperature of 25.8°C and minimum temperature of 23.9°C. In 2007, the average humidity is 79%-85% with the maximum humidity of 99% and minimum humidity of 37%. From the observation of Kalangploso Climate Station, it is documented that highest rainfall occurs in February, March and April while low rainfall occurs in June and September. The maximum wind velocity occurs in August, September and June.

Malang City consists of 5 sub districts and 57 villages as can be seen in Table 2.1. The largest sub district is Kedung Kandang sub district (39.89 km^2) which consists of 12 villages and the smallest is Klojen sub district (8,83 km^2) which consist of 11 villages.

Table 2.1: Subdistricts and villages located in Malang City

No	Sub Districts	Total Area (km^2)	Villages
1	Kedung Kandang	39.89	12
2	Sukun	20.97	11
3	Klojen	8.83	11
4	Blimbing	17.77	11
5	Lowokwaru	22.6	12
Total		110.06	57

2.1.2 Demography of Malang City

Health status of a community depends upon the dynamic relationship between number of people, their composition and distribution. While it is common for a developing country to have high population growth rate, it will create a burden to population health and social infrastructure, especially in urban areas, which has very limited carrying capacity. Slum areas with poor infrastructure and sanitation will emerge due to population explosion, which in turn will bring hazard should extreme climate occur.

Population of Malang City in 2008 amounted to 816,637 peoples with population distribution that tends to evenly in every sub district as can be seen in Table 2.2. Gender ratio in Malang City showed domination of female population in almost every sub district. Only Lowokwaru sub district that has more male population than the female population. As can be seen in Table 2.2, the male population in Lowokwaru sub district reaches the number of 92,236 while the female population reaches the number of 89,618 this makes the gender ratio reaches the number of 102.9%.

Table 2.2: Population Number in Malang City

No.	Sub District	Population Number	Male	Female	Gender Ratio (male/female)%
1	Kedung Kandang	162,104	80,421	81,683	98.5
2	Sukun	174,868	87,054	87,814	99.1
3	Klojen	126,760	60,252	66,508	90.6
4	Blimbing	171,051	84,701	86,350	98.1
5	Lowokwaru	181,854	92,236	89,618	102.9
Total		816,637	404,664	411,973	98.2

Source: Malang City Health Profile, 2008

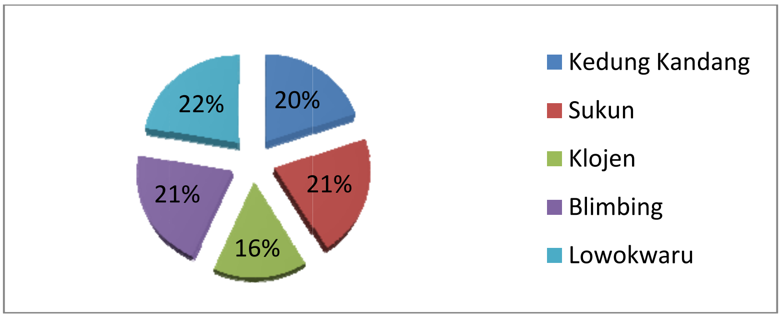


Figure 2.2 Distribution Population in Malang City's Sub District

Population growth and the level of population density in Malang City from 2004-2008 can be seen in Figure 2.3. Population number in Malang City from 2004 until 2008 has increased. The increasing of population number in Malang City will also increase the socio-economy problem in the society. This condition also can affect the health degree of people in Malang City. The population density can affect some disease case and will affect the environmental health in Malang City (Profil Kesehatan Kota Malang 2008).

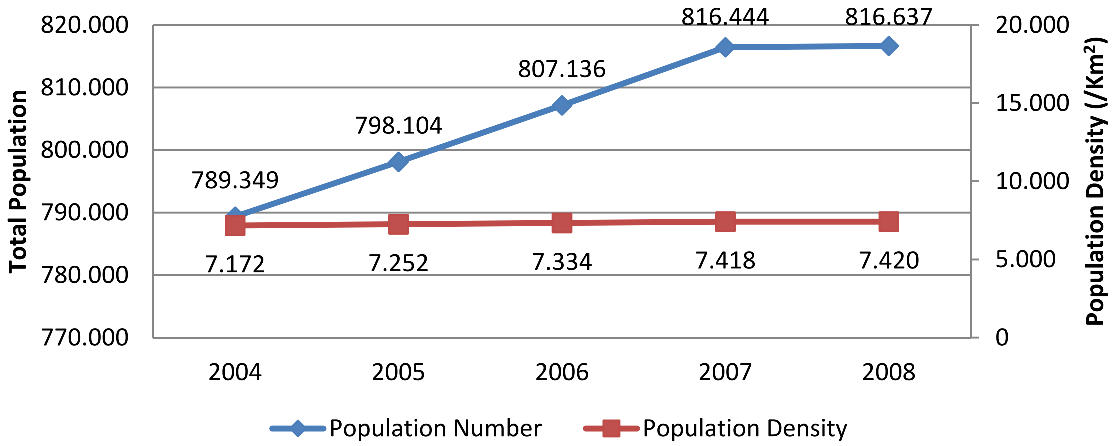


Figure 2.3 Population Growth and Population Density in Malang City

(*Source: Malang City Health Profile, 2008*)

Population density also plays an important role in determining public health. In densely populated area, disease usually spread more intense, especially in crowded slum area where sanitation is poor and clean water supply is scarce. In 2008, population density in Malang City is about 7,420 people/km^2. The highest population density was found in Klojen Sub District with 14,356 people per km^2. While the lowest population density found in Kedung Kandang Sub District with 4,064 people/km^2. The details can be seen in Table 2.3 below.

Table 2.3 Population Density of Malang City in 2008

No.	Sub District	Total Area (km²)	Population Number	Population Density (people/km²)
1	Kedung Kandang	39.89	162,104	4,064
2	Sukun	20.97	174,868	8,339
3	Klojen	8.83	126,760	14,356
4	Blimbing	17.77	171,051	9,626
5	Lowokwaru	22.6	181,854	8,047
Total		110.06	816,637	7,420

Source: Malang City Health Profile, 2008

In 2008, 22.48% population of Malang City are young age (0-14 years), 70.06% of productive age (aged 15-59 years), and only 7.46% over 60 years old. Therefore, dependency ratio of Malang City population is 37.5 and it means that every 1,000 people in productive aged bear around 37-38 people in non-productive aged. Male population in Malang City that is fewer than female population, especially in the 60+ age group, shows that women in Malang City have higher life expectancy than men. Life expectancy represents the average life span and is an indicator of the overall health of a country. Life expectancy can fall due to famine, war, disease and poor health. Thus, high life expectancy suggests improvements in health and welfare increase life expectancy. The higher the life expectancy, the better shape a country is. The reasons why female life expectancy is higher than men are not fully understood. More details are shown in Figure 2.5.

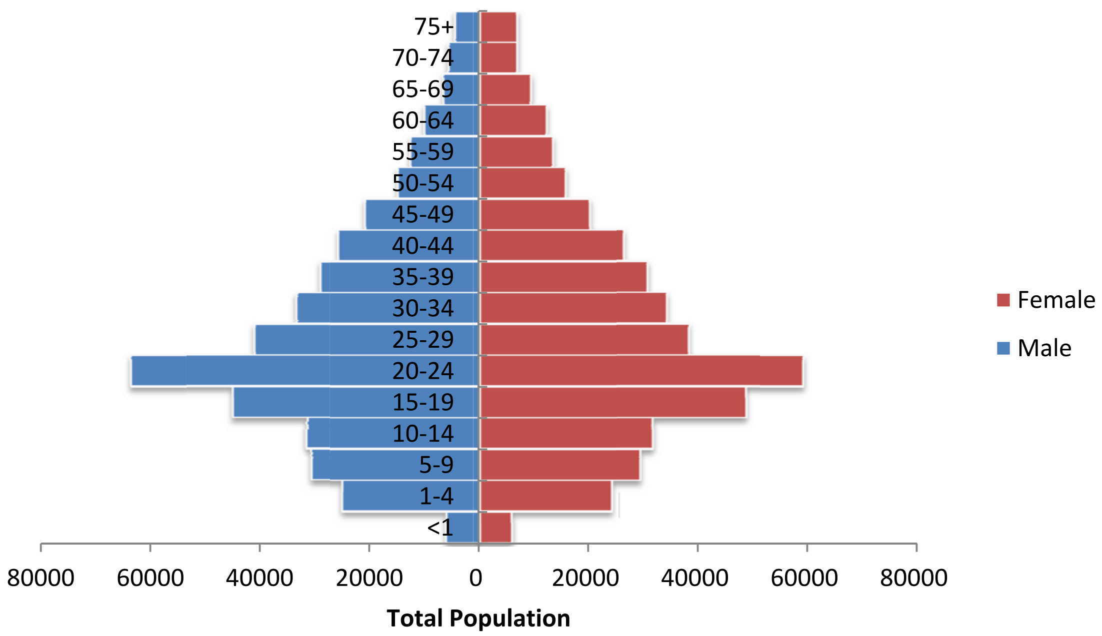


Figure 2.4 Population Pyramid in Malang City 2008

Source: Profil Kesehatan Kota Malang 2008

2.1.3 Demography of Malang District

Malang District consist of 33 sub districts with number of population tend to increase in three subsequent years, 2008 to 2009. Poncokusumo is the most dense sub district on 2008 with 2,471 peoples per Km^2. Population density will affect the speed of disease transmission by providing large number of host and ease of direct/indirect contact between peoples.

Table 2.4: Population in Malang District for 2008-2010

No.	Sub Districts	Population			Density (/Km^2)
		2008	2009	2010	2008
1	Tumpang	72,924	73,651	74,352	549
2	Poncokusumo	88,817	89,701	90,554	2,471
3	Jabung	73,837	74,572	75,281	1,629
4	Pakis	131,196	132,502	133,762	1,355
5	Lawang	110,028	111,125	112,182	1,204
6	Singosari	159,036	160,620	162,148	1,240

No.	Sub Districts	Population			Density (/Km^2)
		2008	2009	2010	2008
7	Karangploso	70,005	70,702	71,374	487
8	Dau	51,532	52,045	52,540	362
9	Pujon	63,096	63,724	64,330	567
10	Ngantang	52,974	53,501	54,010	2,291
11	Kasembon	31,232	31,543	31,843	1,388
12	Kepanjen	104,923	105,969	106,977	958
13	Sumber Pucung	49,334	49,825	50,299	2,132
14	Kromengan	36,654	37,019	37,371	802
15	Pakisaji	81,084	81,891	82,670	901
16	Ngajum	47,734	48,209	48,668	1,008
17	Wonosari	43,315	43,746	44,162	513
18	Wagir	75,291	76,041	76,764	346
19	Pagak	45,783	46,239	46,680	550
20	Donomulyo	66,026	66,683	67,317	449
21	Kalipare	57,426	57,998	58,550	385
22	Bantur	70,693	71,397	72,076	1,020
23	Gedangan	49,705	50,200	50,677	1,322
24	Gondanglegi	142,083	81,316	82,090	814
25	Bululawang	64,606	65,249	65,870	1,186
26	Wajak	76,226	76,985	77,717	1,724
27	Tajinan	47,091	47,560	48,012	929
28	Turen	109,071	110,157	111,205	412
29	Dampit	124,522	125,762	126,958	696
30	Sumbermanjing Wetan	97,619	98,591	99,529	472
31	Ampelgading	54,834	55,380	55,907	1,357
32	Tirtoyudo	66,275	66,935	67,572	549
33	Pagelaran	N/A	62,181	62,772	2,471
Malang District		75,467	73,909	74,612	1,013

2.1.4 Demography of Batu City

Batu City only consist of three subdistricts with Batu as the most dense area. Bumiaji has larger population in 2008 to 2010 than Junrejo, however it is the most scarce area due to large settlement areas.

Table 2.5: Population in Batu City for 2008-2010

No.	Sub Districts	Population			Density (/Km)
		2008	2009	2010	2008
1	Batu	81,065	84,829	97,881	1,976
2	Junrejo	40,910	44,739	50,447	1,768
3	Bumiaji	51,320	54,542	58,652	444
Batu City		57,765	61,370	68,993	1,396

2.2 Health Profile of Greater Malang

2.2.1 National and Regional Strategic Issues of Health Sector

The role of health development has a large role in global development, particularly in the Disease Control and Environmental Health, which has a larger portion of the Millennium Development Goals. Health development is aimed to increase awareness, willingness and ability to live a healthy life for everyone in regards to manifestation of optimum community health. The government had been trying to establish new paradigm on health to encourage people to be self-reliant, particularly in maintaining their own health through higher awareness. Therefore, a healthy nation will be achieved. In certain areas in Indonesia, locally specific infectious diseases problems still occur, and the incidence of morbidity and mortality is closely related to environmental health. Hence, some programs become a top priority to be implemented, including maternal and child health, poor health services, utilization of health personnel, control of communicable and non-infectious diseases, prevention of malnutrition and health crisis caused by disaster. Strengthening of the operational capabilities as well as directional controls and continuous, are required, especially in districts in which the problem arise.

In the framework of decentralization or regional autonomy on health, quality of health information systems is determined by the quality of the health system at districts level. National Health System cannot be applied instantly in the every area. Specific attention to regional issues, aspirations of local communities, and other elements must be taken into account.One of the government's efforts to give an equal distribution of health services to the community is to provide health facilities, especially Public Health Centers (Puskesmas) and Public Health Sub-Centers (Puskesmas Pembantu) because the facilities were able to reach all social strata.

2.2.2 Health Status of Malang City

Capability of local government to provide a good environment, infrastructure, and education will determine health status of an area, which is roughly represented by mortality, morbidity, maternal death rate, birth rate, and other parameters.

A. Immunization

Immunization is basically the process by which an individual's immune system becomes fortified against an agent, by exposure of the agent in a controlled way so the body can learn to protect itself. This can be done through various techniques, most commonly vaccination, as the administration of antigenic material (vaccine) to produce immunity to a disease. Vaccination is generally considered to be the most effective and cost-effective method against microorganisms or viral agents, thus preventing infectious diseases. Percentage of infant immunization coverage in Malang City shown in Table 2.6. According to Indonesia MDGs report, immunization is crucial in reducing infant mortality, especially measles vaccine. Target of Indonesia MDGs is that in 2014, coverage of measles immunization is expected to reach 93 percent (RKP 2011). Almost every PHC in Malang City already meet this target except Janti, Pandanwangi, Dinoyo, Kendalsari PHC. Table 2.7 shows total case and morbidity rate of infectious disease that can be prevented by immunization.

Table 2.6: Percentage of Infant Immunization Coverage in Malang City 2008

NO	Sub District	PHC	Total Infant	BCG		DPT1+HB1		DPT3+HB3		POLIO3		MEASLES3		HEPATITIS B3	
				TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%
1	Kedung Kandang	Kedungkandang	1,034	1,020	98.65	1,172	100	1,153	100	1,167	100	937	90.62	-	-
		Gribig	1,212	1,460	100	1,305	100	1,326	100	1,279	100	1268	100	-	-
		Arjowinangun	805	865	100	826	100	756	93.91	781	97.02	791	98.26	-	-
2	Sukun	Janti	1,306	1,235	94.56	1,186	90.81	1,189	91.04	1,216	93.11	1,083	82.92	-	-
		Ciptomulyo	704	898	100	1,005	100	778	100	789	100	833	100	-	-
		Mulyorejo	1,174	1,315	100	1,247	100	1,141	97.19	1,184	100	1,105	94.12	-	-
3	Klojen	Arjuno	669	1,109	100	1,166	100	1,015	100	988	100	918	100	-	-
		Bareng	807	1,006	100	1,039	100	936	100	932	100	873	100	-	-
		Rampal Celaket	429	652	100	648	100	679	100	595	100	589	100	-	-
4	Blimbing	Cisadea	675	1,125	100	744	100	775	100	786	100	775	100	-	-
		Kendalkerep	1,186	1,223	100	1,212	100	1,272	100	1,390	100	1,348	100	-	-
		Pandanwangi	1,191	877	73.64	967	81.19	1,424	100	1,006	84.47	846	71.03	-	-
5	Lowokwaru	Dinoyo	1,017	1,285	100	1,133	100	1,031	100	1,058	100	919	90.36	-	-
		Mojolangu	685	799	100	726	100	730	100	765	100	733	100	-	-
		Kendalsari	887	860	96.96	773	87.15	787	88.73	767	86.47	796	89.74	-	-
TOTAL			13781	15729	1100	15,729	100	14992	100	14,992	100	13,814	100	-	-

Table 2.7: Total Case and Morbidity Rate of Infectious Diseases that can be prevented by Immunization (PD3I) in Malang City 2008

No	Sub District	Public Health Center	Total Case PD3I						
			Diphtheria	Pertussis	Tetanus	Neonatorum Tetanus	Measles	Polio	Hepatitis B
1	Kedung Kandang	Kedungkandang	1	-	-	-	4	-	1
		Gribig	1	-	-	-	-	-	-
		Arjowinangun	1	-	-	-	-	-	-
2	Sukun	Janti	-	-	-	-	2	-	3
		Ciptomulyo	1	-	-	-	8	-	-
		Mulyorejo	-	-	-	-	1	-	-
3	Klojen	Arjuno	-	-	-	-	15	-	1
		Bareng	-	-	-	-	-	-	-
		Rampal Celaket	1	-	-	-	18	-	1
4	Blimbing	Cisadea	-	-	-	-	3	-	-
		Kendalkerep	1	-	-	-	-	-	-
		Pandanwangi	-	-	-	-	5	-	-
5	Lowokwaru	Dinoyo	1	-	-	-	1	-	-
		Mojolangu	2	-	-	-	-	-	1
		Kendalsari	1	-	-	-	1	-	-
TOTAL			10	-	-	-	58	-	7

Table 2.8 shows the immunization coverage in 2008. Can be seen that almost every sub district have done the immunization. Indeed, there are 5 PHC that reach 100% coverage. The lowest point is gained by Janti and Kendalsari PHC with only 33,33% of immunization coverage. Districts with low UCI coverage need serious attention since those districts possess higher risk of infectious diseases transmission and increase the possibility for epidemic event occurrence Moreover, Universal Child Immunizations (UCI) is one of important indicator used in determine the accomplishment of Healthy Indonesia 2010 Program.

Table 2.8: Universal Child Immunizations (UCI) Coverage in Malang City 2008

No	Sub District	PHC	Total Villages	Villages with UCI	%Villages UCI
1	Kedung Kandang	Kedungkandang	4	3	75
		Gribig	4	3	75
		Arjowinangun	4	2	50
2	Sukun	Janti	3	1	33.33
		Ciptomulyo	3	3	100
		Mulyorejo	5	3	60
3	Klojen	Arjuno	4	4	100
		Bareng	4	4	100
		Rampal Celaket	3	3	100
4	Blimbing	Cisadea	2	2	100
		Kendalkerep	4	4	100
		Pandanwangi	5	-	-
5	Lowokwaru	Dinoyo	6	4	66.67
		Mojolangu	3	3	100
		Kendalsari	3	1	33.33
TOTAL			57	40	70.18

B. Epidemic Events

Heath management consists of two different efforts, which are preventive and curative effort. Comprehensive data concerning disease prevalence is needed to arrange the standard in preventive and curative therapy. In general, diseases are classified into communicable and non communicable disease. The high prevalence of communicable disease in Malang City influenced by community behavior, economic condition, environment and climate factors. In 2008, 4 epidemic events had occurred in Malang City, with dengue fever as the highest outbreak as shown in Table 2.9. This can be happen because most area in Malang City is the highland area with the mild temperature which is very suitable for Aedes Aegepty as the vector of dengue fever to breed. High frequency of epidemic events also influenced by the increase of health professional's sensitivity to finding, managing and reporting the epidemic events to higher authorities.

Table 2.9: Epidemic Events in Malang City 2008

No.	Disease	Number of Case	Number of Death	Attack Rate (%)	CFR (%)
1	Acute Flaccid Paralyse (AFP)	2	-	0.004	0
2	Dengue Fever	50	3	0.1	6
3	Food Poisoning	-	-	-	-
4	Hepatitis	-	-	-	-

C. Health Facility

In order to improve public health in Malang City, health facilities and adequate infrastructure in terms of both quality and quantity, are required. Health facilities include hospital, PHC, IHC, and other facility.

- Hospital

  Hospital is a facility of health service with complete health equipment so that it plays important roles to population health in regards to curative treatment. As can be seen in Table 2.9, the hospital in Malang City already well-specialized. There are nine general hospitals in Malang City with various ownerships, the details that can be seen in Table 2.10.

Table 2.10: Number of Hospital in Malang City based on its Ownership 2008

No	Type of Hospital	Ownership						Total
		Central Government	Province Government	City Government	TNI/POLRI	BUMN	Private	
1	General Hospital	0	1	0	2	1	5	9
2	Mental Ward	0	0	0	0	0	0	0
3	Maternity Hospital	0	0	0	0	0	4	4
4	Other Special Hospital	0	0	0	0	0	9	9

Table 2.11: General Hospital in Malang City 2008

No	Hospital Name	Type of service	Number of Beds
1	RSUD Saiful Anwar	General	822
2	RS Panti Waluyo	General	210
3	RS Lavalette	General	141
4	RS Panti Nirmala	General	161
5	RSI Aisyah	General	90
6	RSI Dinoyo	General	67
7	RST Soepraoen	General	300
8	RUMKITBANG Malang	General	50
9	RS Permata Bunda	General	50
Total			1,891

- Public Health Center (PHC/Puskesmas)

  Public Health Center (PHC) have important role in maintaining and improving public health. Every sub district in Malang City has PHC facilities, with relatively cheap medical cost so it is affordable by lower-middle income families.

Table 2.12: Public Health Center (PHC) in Malang City based on its Ownership 2008

No	Type of PHC	Ownership						Total
		Central Government	Province Government	City Government	TNI/POLRI	BUMN	Private	
1	Treatment	0	0	2	0	0	0	2
2	Non Treatment	0	0	13	0	0	0	13
3	Mobile	0	0	15	0	0	0	15
4	Auxiliary	0	0	33	0	0	0	33

Table 2.13: PHC in Sub District of Malang City for 2008

No.	Sub District	PHC
1	Kedung Kandang	Kedungkandang
		Gribig
		Arjowinangun
2	Sukun	Janti
		Ciptomulyo
		Mulyorejo
3	Klojen	Arjuno
		Bareng
		Rampal Celaket
4	Blimbing	Cisadea
		Kendalkerep
		Pandanwangi
5	Lowokwaru	Dinoyo
		Mojolangu
		Kendalsari

- Integrated Health Center (IHC/Posyandu)

  Integrated Health Center (IHC) is a health facility, which focused in immunization and other health program for under-five children. Total numbers of IHC in Malang City is 641 that distributed in every Sub District. As can be seen in Table 2.14, Sukun sub district has the highest number of IHC while Klojen and Lowokwaru sub district has the lowest number of IHC.

Table 2.14: Integrated Health Center (IHC) in Malang City 2008

No	Sub District	IHC
1	Kedung Kandang	131
2	Sukun	152
3	Klojen	108
4	Blimbing	142
5	Lowokwaru	108
Total		641

Table 2.15: Integrated Health Center (IHC) in Malang City 2008 based on its Strata

NO	Sub District	PHC	Number of IHC				
			PRATAMA	MADYA	PURNAMA	MANDIRI	Total
1	Kedung Kandang	Kedungkandang	3	6	27	-	36
		Gribig	-	1	51	-	52
		Arjowinangun	-	13	26	4	43
2	Sukun	Janti	13	14	41	3	71
		Ciptomulyo	8	21	16	-	45
		Mulyorejo	-	6	29	1	36
3	Klojen	Arjuno	-	11	25	-	36
		Bareng	-	1	47	2	50
		Rampal Celaket	1	9	9	3	22
4	Blimbing	Cisadea	-	1	34	2	37

NO	Sub District	PHC	Number of IHC				
			PRATAMA	MADYA	PURNAMA	MANDIRI	Total
		Kendalkerep	5	22	30	1	58
		Pandanwangi	3	12	29	3	47
5	Lowokwaru	Dinoyo	-	1	37	1	39
		Mojolangu	-	5	26	-	31
		Kendalsari	-	3	32	3	38
Total			33	126	459	23	641

- Health Professionals

  Capacity and support of health professionals, such as doctors, dentists, nurses, midwives, and others, are other main factor contributes to public health status. In 2008, there are 2,925 health professionals which scattered in various work units (see Table 2.16).

Table 2.16: Number of Health Professionals in Malang City Based on their Work Units

No	Work Units	Medical Personnel	Nurse & Midwife	Pharmacist	Dietician	Medical Technician	Sanitation	Public Health	Total
1	PHC (including PUSTU and POLINDES/ POLKESDES)	61	153	29	18	16	15	4	296
2	Hospital	319	1,440	89	48	100	7	10	2,013
3	Training Institution	5	88	2	6	-	2	48	151
4	Other Health Facility	122	176	6	2	93	-	-	399
5	Health Department	18	17	9	4	4	4	10	66
Total		525	1,874	135	78	213	28	72	2,925

2.2.3 Condition of Sanitation

Other facilities which could give an effect to human health are clean water facility, WWTF (Waste Water Treatment Facility), latrine, and healthy houses, which affect the occurrence of diseases in Malang.

A. Clean Water Facility

A safe, reliable, affordable, and easily accessible water supply is essential for good health. A poor water supply impacts health by causing acute infectious diarrhea, repeat or chronic diarrhea episodes (Hunter et al., 2010), especially after floods or other weather-related extreme events. Water supply may be polluted by agents of infectious diseases, for example: floods can introduce diseases agents into water bodies that are utilized for daily uses and leaks in water supply distribution system can cause contamination to drinking water. Lack of clean water supply can also affect health by limiting productivity and the maintenance of personal hygiene (Hunter et al., 2010). Personal hygiene is known to have close relation with diseases, especially those who are transmitted by microbial agents. Water availability, quality and stream flow are sensitive to changes in temperature and precipitation, therefore, climate change will affect water supply for community, and posing health hazard due to water availability and quality.

Table 2.17: Clean Water Coverage in Malang City

No	Sub District	PHC	Number of Family	Number of Family Using Clean Water	%
1	Kedung Kandang	Kedungkandang	12,466	8,150	65.38
		Gribig	17,539	14,039	80.04
		Arjowinangun	9,481	4,248	44.81
2	Sukun	Janti	18,449	10,883	58.99
		Ciptomulyo	15,269	9,297	60.89
		Mulyorejo	16,953	15,418	90.95
3	Klojen	Arjuno	10,329	7,880	76.29
		Bareng	15,792	14,553	92.15
		Rampal Celaket	6,625	4,898	73.93
4	Blimbing	Cisadea	10,559	8,985	85.09
		Kendalkerep	16,748	14,836	88.58
		Pandanwangi	16,715	11,070	66.23
5	Lowokwaru	Dinoyo	18,578	13,118	70.61
		Mojolangu	13,743	12,863	93.60
		Kendalsari	10,554	8,980	85.09
Total			209,800	159,218	75.51

B. Wastewater Facility

Wastewater treatment facility help reduce the amount of domestic wastes added to the bodies of surface water. There are two facility type which are used widely, the septic tank and communal facilities. Presentation of both facilities in current area also avoid the pathogenic microbe from contaminating the water supply, especially when using shallow well as the main water source.

Table 2.18: Waste water coverage in Malang City

NO	Sub District	PHC	Number of House	WWTF		
				Number of House Examined	% House with WWTF	% House with Healthy WWTF
1	Kedung Kandang	Kedungkandang	12,466	8,969	96.05	77.68
		Gribig	17,539	12,342	97.87	76.18
		Arjowinangun	9,481	587	97.96	74.61
2	Sukun	Janti	18,449	13,170	97.24	68.63
		Ciptomulyo	15,269	4,223	97.63	68.30
		Mulyorejo	16,953	5,074	97.62	77.99
3	Klojen	Arjuno	10,329	1,208	97.60	79.05
		Bareng	15,792	4,452	97.96	77.48

NO	Sub District	PHC	Number of House	WWTF		
				Number of House Examined	% House with WWTF	% House with Healthy WWTF
		Rampal Celaket	6,625	4,676	97.78	77.34
4	Blimbing	Cisadea	10,559	8,406	97.88	78.12
		Kendalkerep	16,748	7,621	97.85	78.03
		Pandanwangi	16,715	10,645	97.88	77.91
5	Lowokwaru	Dinoyo	18,578	14,810	97.92	77.43
		Mojolangu	13,743	10,581	97.89	78.09
		Kendalsari	10,554	7,860	97.98	88.00
Total			209,800	114,624	97.65	76.92

C.Latrine Facility

Latrine facility is necessary in preventing the spreading of diseases, especially diseases related to human feces such as diarrhea. Lack of sanitation facility can contribute to health in an area. In some rural areas, people used to defecate in rivers, ponds, plantations, etc. Such practice has potential contamination to water supply and soil, and in the end affect spread of diseases and community health. In addition, poor construction and management of latrine facility can also emerge health problem. For example, sanitation project, that does not involve local community, is usually unsuccessful. The constructed, but poorly maintained, latrine facility is abandoned, and can become breeding places of disease vector.

Table 2.19: Proportion of Houses with Latrine in Malang City

NO	Sub District	PHC	Number of House	Latrine		
				Number of House Examined	% House with Latrine	% Latrine in Good Condition
1	Kedung Kandang	Kedungkandang	12,466	8,969	96.05	77.68
		Gribig	17,539	12,342	97.87	76.18
		Arjowinangun	9,481	587	97.96	74.61
2	Sukun	Janti	18,449	13,170	97.24	68.63
		Ciptomulyo	15,269	4,223	97.63	68.30
		Mulyorejo	16,953	5,074	97.62	77.99
3	Klojen	Arjuno	10,329	1,208	97.60	79.05
		Bareng	15,792	4,452	97.96	77.48
		Rampal Celaket	6,625	4,676	97.78	77.34
4	Blimbing	Cisadea	10,559	8,406	97.88	78.12
		Kendalkerep	16,748	7,621	97.85	78.03
		Pandanwangi	16,715	10,645	97.88	77.91
5	Lowokwaru	Dinoyo	18,578	14,810	97.92	77.43
		Mojolangu	13,743	10,581	97.89	78.09
		Kendalsari	10,554	7,860	97.98	88.00
Total			209,800	114,624	97.67	76.99

C. Healthy Houses

Healthy house is defined as residential building that meets several health requirements. Healthy houses should be equipped with latrine, clean water facilities and waste water disposal facilities. It also has good ventilation, appropriate density residential homes and it floors are not made of soil .

Table 2.20: Proportion of Healthy Housing in Malang City

No	Sub District	PHC	Healthy House				
			Number of Houses	Number of Houses Examined	%House Examined	Number of Healthy Houses	%Healthy House
1	Kedung Kandang	Kedungkandang	10,989	7,440	67.7	6,459	86.81
		Gribig	17,708	2,980	16.83	2,483	83.32
		Arjowinangun	9,363	1,642	17.54	1,290	78.56
2	Sukun	Janti	51,143	578	1.13	529	91.52
		Ciptomulyo	7,078	550	7.77	490	89.09
		Mulyorejo	15,269	4,223	27.66	4,223	100
3	Klojen	Arjuno	8,482	1,168	13.77	811	69.43
		Bareng	16,606	803	4.84	611	76.09
		Rampal Celaket	4,996	1,273	25.48	1,241	97.49
4	Blimbing	Cisadea	8,034	539	6.71	469	87.01
		Kendalkerep	13,142	7,200	54.79	6,796	94.39
		Pandanwangi	12,095	4,804	39.72	4,804	100
5	Lowokwaru	Dinoyo	54,345	8,420	15.49	7,937	94.26
		Mojolangu	8,738	197	2.25	158	80.2
		Kendalsari	11,361	1,010	8.89	948	93.86
Total			249,349	42,827	20.70467	39,249	91.65

2.3 Sensitive/Vulnerable Population

Human is receptor who receives the impact of climate change. Therefore, human classification by different level of vulnerability is needed. The results of research from experts in the field of health and medicine indicate that the most vulnerable populations to diseases due to climate change are children aged under 5 years old (under-fives). The high level of vulnerability of children is mainly due to the imperfect immune system even though since birth, babies have immune system derived from the mother, especially for exclusive-breastfed babies. Therefore, data on the number of infants and mothers who died every year are required to complete the vulnerability assessment.

Crude death rate (CDR) or mortality rate is a measure of the number of deaths (in general, or due to a specific cause) in some population, scaled to the size of that population, per unit time. Mortality rate is typically expressed in units of deaths per 1000 individuals per year; thus, a mortality rate of 9.5 in a population of 100,000 would mean 950 deaths per year in that entire population, or 0.95% out of the total. The crude mortality rate is a very general indicator/index of the health status of a geographic area or population. This type of crude rate is not appropriate for comparison of different populations or areas due to the significant impact of age in mortality data and different age-distributions in different populations. Age-adjusted mortality rates should be used for comparative analysis.

Maternal mortality rate (MMR) is defined as the number of maternal deaths related to childbearing divided by the number of live births (or by the number of live births + fetal deaths) in that year. According to WHO, a maternal death is defined as the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes. Maternal mortality is a key indicator of health worldwide and reflects the ability of women to secure not only maternal health care services but also other health care services.

Table 2.21: Health Condition of Under Five Children in Malang City

NO	Sub District	PHC	Total Infants			% Alive Birth	Total Infants Mortality	Total Under Five	Under Five Mortality
			Alive Birth	Death Birth	Total Birth				
1	Kedung Kandang	Kedungkandang	490	8	498	1.61	7	5,333	0
		Gribig	672	11	683	1.61	4	6,253	0
		Arjowinangun	785	3	788	0.38	9	4,154	0
2	Sukun	Janti	1,144	15	1,159	1.29	21	6,735	0
		Ciptomulyo	624	3	627	0.48	3	3,632	0
		Mulyorejo	691	10	701	1.43	10	6,054	0
3	Klojen	Arjuno	1,917	8	1,925	0.42	6	3,452	0
		Bareng	1,864	7	1,871	0.37	7	4,161	0
		Rampal Celaket	1,247	6	1,253	0.48	1	2,214	1
4	Blimbing	Cisadea	947	4	951	0.42	4	3,484	0
		Kendalkerep	230	5	235	2.13	13	6,118	0
		Pandanwangi	1,702	8	1,710	0.47	23	6,145	0
5	Lowokwaru	Dinoyo	476	5	481	1.04	15	5,245	1
		Mojolangu	647	6	653	0.92	7	3,533	0
		Kendalsari	673	4	677	0.59	6	4,575	0
TOTAL			14,109	103	14,212	0.725	136	71,088	2
Mortality Rate (reported)							9.6		0.1

Table 2.22: Maternal Mortality Rate in Malang City

No	Sub District	PHC	Alive Birth	Maternal Mortality
1	Kedung Kandang	Kedungkandang	490	0
		Gribig	672	1
		Arjowinangun	785	0
2	Sukun	Janti	1,144	0
		Ciptomulyo	624	0
		Mulyorejo	691	1
3	Klojen	Arjuno	1,917	0
		Bareng	1,864	0
		Rampal Celaket	1,247	0
4	Blimbing	Cisadea	947	0
		Kendalkerep	230	0
		Pandanwangi	1,702	0
5	Lowokwaru	Dinoyo	476	1
		Mojolangu	647	0
		Kendalsari	673	1

No	Sub District	PHC	Alive Birth	Maternal Mortality
TOTAL			14109	4
Mortality Rate (Reported)				28.35

2.4 Vector-Borne Diseases

Climate change gives many impacts to agriculture, water, coastal, and health sector. In general, climate change could affect human health in form of temperature-related morbidity, deaths and injuries from extreme events, vector-and rodent-borne diseases, water-borne diseases, ultraviolet induced diseases, mental and psychology impacts, allergenic diseases, air pollution induced diseases, malnutrition, and food poisoning. The major health impacts discussed in this report will be divided into 3 main diseases. The most commonly studied by researchers are vector-borne diseases (DHF and malaria) and water-borne diseases (diarrhea). The last one is malnutrition problems, although in this assessment, malnutrition will not be included in the analysis because it only occurred in small percentages.

2.4.1 DHF (Dengue Hemorrhagic Fever)

Dengue hemorrhagic fever (DHF) are acute febrile diseases transmitted by mosquitoes, which occur in the tropics, can be life-threatening, and are caused by four closely related virus serotypes of the genus Flavivirus (e.g *Aedes aegypti*), family Flaviviridae that are maintained in a human-mosquitoes-human cycle in most urban centers of the tropics (Gubler, 1997 cited from IPCC Human Health Report). Unlike malaria, dengue is more prevalence in urban areas rather than rural areas. It occurs widely in the tropics, including continental USA (www.cdc.gov), northern Argentina, northern Australia, Europe, and Southeast Asia include Indonesia, Laos, Malaysia, Philippines, and Vietnam. The geographic distribution of the dengue viruses and mosquito vectors (*Aedes aegypti* and *Aedes albopictus*) has expanded to the point that dengue has become a major tropical urban health problem (Gubler, 1997, 1998b cited from IPCC Human Health Report). Dengue is primarily an urban disease; more than half of the world's population lives in areas of risk (Gubler, 1997, 1998b cited from IPCC Human Health Report). In tropical areas of the world, dengue transmission occurs year-round but has a seasonal peak in most countries during months with high rainfall and humidity.

DHF is characterized initially by a fever lasting up to a week, followed by bleeding gums and nose and internal bleeding. If not treated quickly, a life-threatening loss of blood can occur, leading to dengue shock syndrome (DSS), internal bleeding, organ failure, and death. For people unable to get extensive treatment, DHF fatality rates can range up to 20 percent (Kim Knowlton et al., 2009).

As mentioned above, Indonesia is one of Southeast Asia country, which has experienced DHF disease. Since it was first discovered in 1968 in Surabaya and Jakarta, the number of cases continued to increase both in number of case and distribution of area affected. An increasing number of DHF that sporadically caused outbreaks every year when the largest outbreak occurred in 1998 at 16 provinces with IR = 35.19 per 100,000 population and CFR 2%. In 1999, IR value was declined sharply to 10.17. However, in subsequent years IR values tend to increase where in 2000, 2001, 2002, and 2003 respectively were 15.99, 21.66, 19.24, 23.87 (Thomas Suroso et al.,2003). Although Government of Indonesia has launched the Healthy Indonesia 2010 program which focused on the disease prevention, high disease outbreaks indicate that applied preventive programs has not been implemented properly by the community. Up until now, each corner of both urban and rural always has death cases caused by DHF.

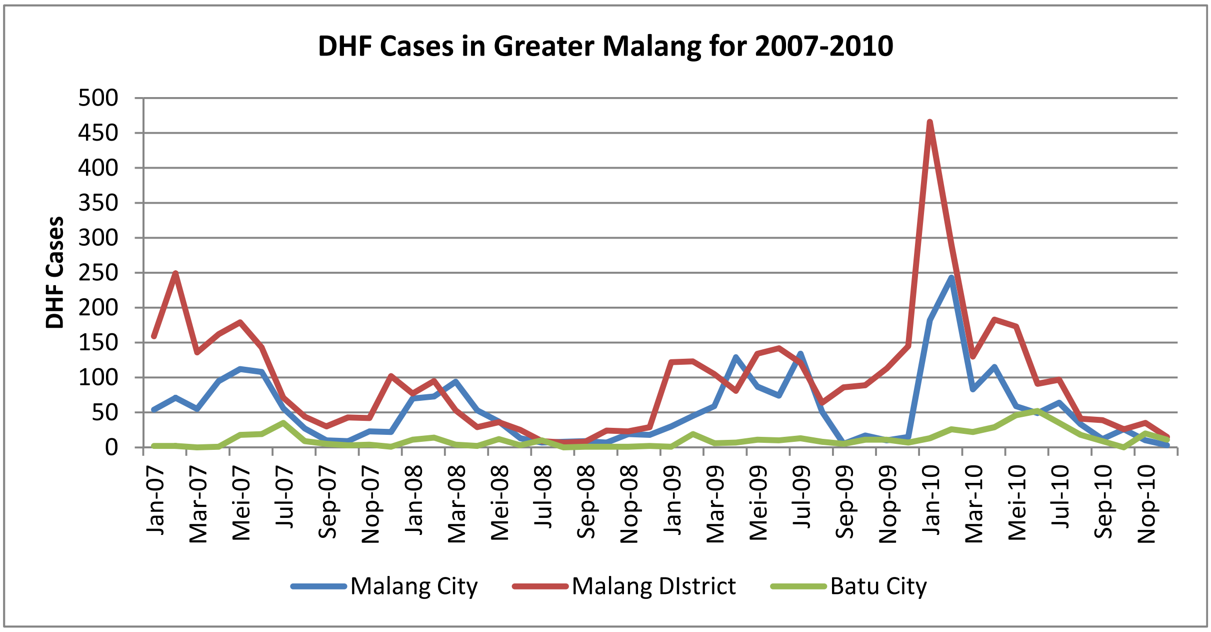


Figure 2.5 DHF Cases Malang City for Year 2007-2009

Source: Malang City Health Profile, 2009

2.4.2 Malaria

Malaria is a life-threatening parasitic disease transmitted by mosquitoes. It was once thought that the disease came from fetid marshes, hence the name ‘malaria’ (bad air). In 1880, scientists discovered the real cause of malaria—a one-cell parasite called plasmodium. Later they discovered that the parasite is transmitted from person to person through the bite of a female Anopheles mosquito, which requires blood to nurture her eggs. Today approximately 40% of the world's population—mostly those living in the world's poorest countries—is at risk of malaria. The disease was once more widespread but it was successfully eliminated from many countries with temperate climates during the mid-20th century. Today malaria is found throughout the tropical and sub-tropical regions of the world and causes more than 300 million acute illnesses and at least one million deaths annually. Ninety per cent of deaths due to malaria occur in Africa, south of the Sahara—mostly among young children. Malaria kills an African child every 30 seconds. Many children who survive an episode of severe malaria may suffer from learning impairments or brain damage. Pregnant mothers and their unborn children are also particularly vulnerable to malaria, which is a major cause of perinatal mortality, low birth weight and maternal anemia (RBM, 2010).

Distribution of malaria disease has been occurred in several nations especially in subtropics and tropic region, including Indonesia. In contrast with DHF, malaria disease experienced a declining trend in which the largest number of malaria occurred in 2003 while the lowest number occurred in 2005. Malaria has similar characteristic with DHF. Climate change would be expected to have the following spatial-temporal effects on malaria (Kovats et al., 2001 cited from Lieshout, M. Van et al., 2004):

- Increase its distribution where it is currently limited by low temperature—epidemic malaria may become present in new areas;
- Decrease its distribution where it becomes too dry for mosquitoes to be sufficiently abundant for transmission;
- Increase or decrease the months of transmission in areas with ‘‘stable’’ malaria, some areas may change from unstable to stable malaria, and some may change from stable to unstable malaria;

- Increase the risk of localized outbreaks in areas where disease is eradicated but vectors are still present, such as in Europe or the United States.

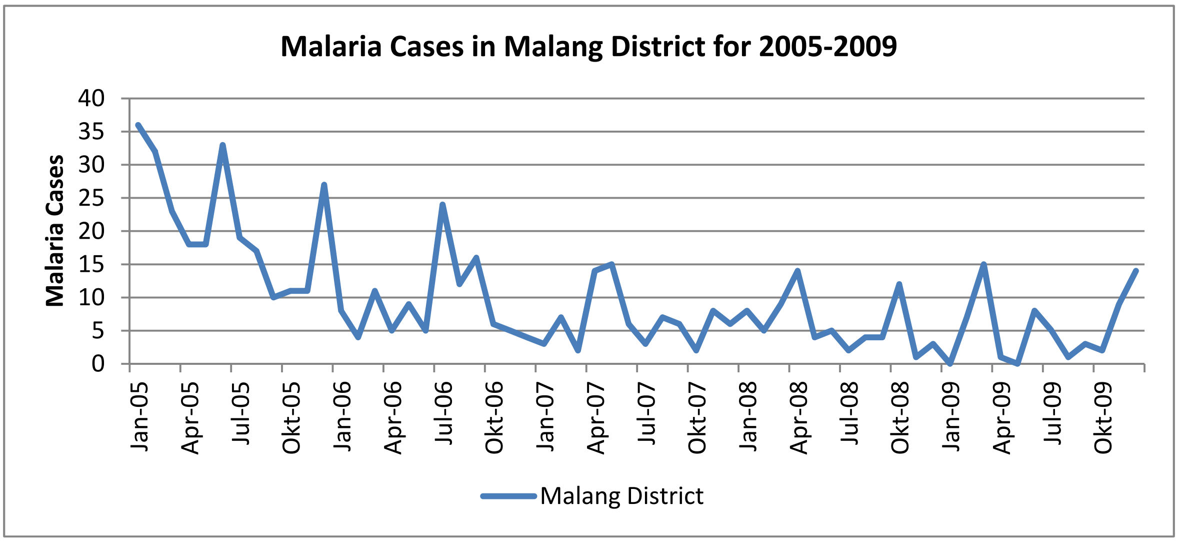


Figure 2.6 Malaria Cases Malang District for Year 2005-2009

Source: Malang District Health Profile, 2009

2.4.3 Diarrhea

Diarrhea is a disease caused by virus and bacterial infections, which entered into alimentary tract through food and beverages. Due to its spreading mostly through water, diarrhea is classified in water-borne diseases. There are two major classes of diarrhea, watery diarrhea and bloody diarrhea, which differ in capabilities of etiologic agents to evade the mucosal layer of gastrointestinal tract. Figure 2.7 and Figure 2.8 shows number of diarrhea cases in Greater Malang and its geographical distribution. Most of diarrhea occurred in urban areas or highly populated areas, since the infectious agent are easily transferred through inadequate protection of water source by fecal-oral route. Community in high density areas often share their water source or sanitation facilities, increasing risk factor in developing this disease. Therefore, if the water source which contaminated by diarrhea-causing agent was ingested by particular person then the whole community will infected by the same disease, since they use the same water source.

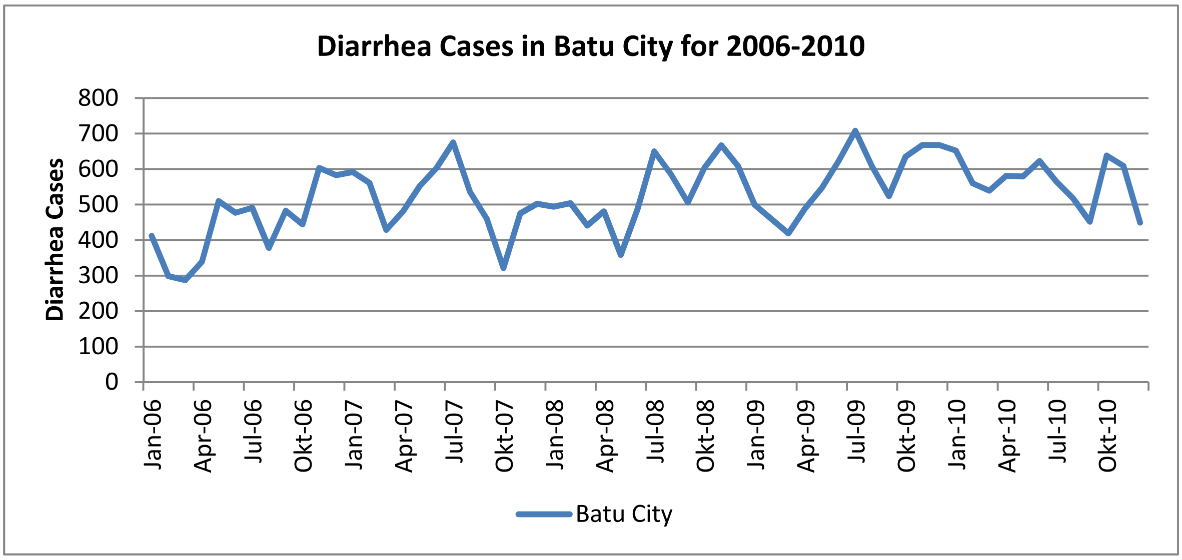


Figure 2.7 Diarrhea Cases in Batu City for Year 2006-2010

Source: Batu City Health Profile, 2010

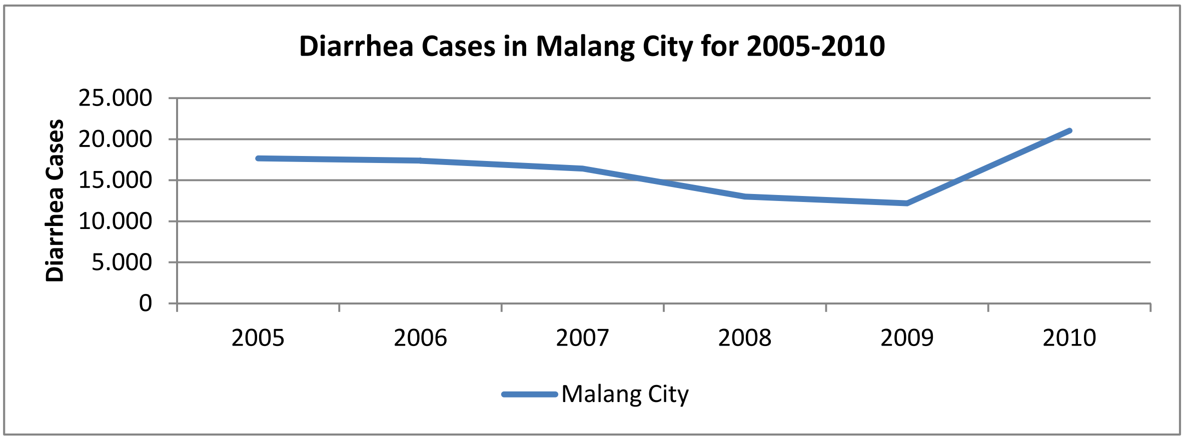


Figure 2.8 Diarrhea Cases in Malang City for Year 2005-2010

Source: Malang City Health Profile, 2010

CHAPTER 3 METHODOLOGY OF ASSESSMENT

This chapter describes methods used in risk and adaptation assessment on health sector in Greater Malang. In general, research framework on this study can be explained in Figure 3.1.

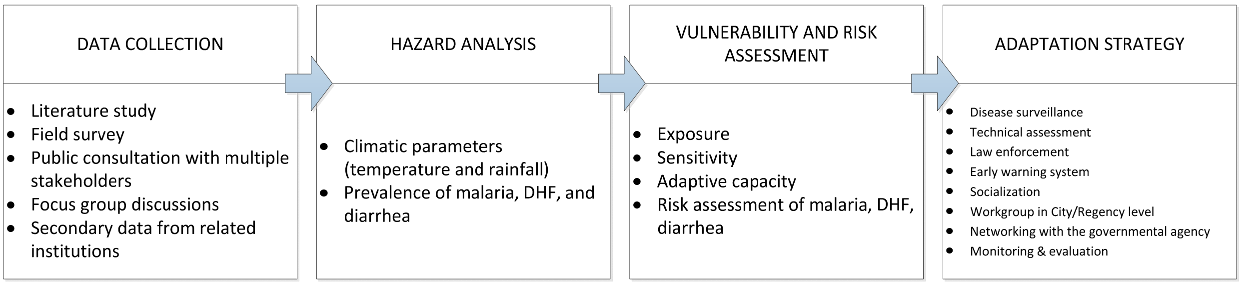


Figure 3.1 Assessment Framework

Detail of methodology is explained as follow:

- Sub-chapter 3.1 describes data collection method and method to calculate relation between climate change stimuli and health hazard. Sub-chapter 3.1 also describes method of analysis of health hazard affected by climatic factors. This sub-chapter elaborates data required in analysis, data collection method, and application of statistical method in hazard analysis.
- Sub-chapter 3.2 describes assumptions about future trends for climate and projection of health hazard including DHF, malaria and diarrhea.
- Sub-chapter 3.3 describes method of vulnerability analysis, including terms used in vulnerability analysis and factors affecting vulnerability.
- Sub-chapter 3.4 describes method of projection of vulnerability, including assumptions about future conditions affecting vulnerability.
- Sub-chapter 3.5 describes method of risk analysis, emphasizes on definition of risk that is constructed from interaction of hazard and vulnerability
- Sub-chapter 3.6 describes method of projection of risk including assumptions about future conditions affecting risk.
- Sub-chapter 3.7 describes method of adaptation strategy formulation both existing condition and future projection.

3.1 Data Collection

This paper draws upon primary and secondary data sources focusing on vector and water borne disease, vulnerability factor, and local health policy. Primary sources include information provided directly by local health department representatives, hospital representatives, local government officials, NGO and private sector, at interview and many roundtable meetings. Organized by local government, KLH, Ausaid, and GIZ, these roundtable meetings were held many times during 2010-2011 in Malang city, Malang district, Batu city, Jakarta city and Bandung city. Field surveys were also conducted in Malang area to investigate health, disease, mosquitos, and sanitation condition.

Secondary sources draw from a range of reports, articles, papers, and presentations that have been developed over the last 15 years by the WHO, UNFCC, IPCC, and others. The publications highlight both the linkages between climate change and health, vulnerability and risk assessment, and the roles of mitigation and adaptation practices.

3.2 Relation between Climate Change Stimuli and Health Hazard

Climate change stimuli such as temperature, rainfall, extreme events, and sea level rise, can affect public health (see Figure 3.2). Based on data availability, we select vector-borne disease (DHF and malaria) and water-borne disease (diarrhea) as main health hazard that are affected by climatic stimuli.

3.2.1 Vector-borne disease

The temporal and spatial changes in temperature, precipitation and humidity that are expected to occur under different climate change scenarios will affect the biology and ecology of vectors and intermediate hosts and consequently the risk of disease transmission. The risk increases because, although arthropods can regulate their internal temperature by changing their behaviour, they cannot do so physiologically and are thus critically dependent on climate for their survival and development (Lindsay and Birley, 1996; in Githeko et al., 2000). As shown in Figure 3.3, mosquito species are responsible for transmission of most vector-borne diseases, and are sensitive to temperature changes as immature stages in the aquatic environment and as adults. If water temperature rises, the larvae take a shorter time to mature (Rueda et al., 1990, in Githeko et al., 2000) and consequently there is a greater capacity to produce more offspring during the transmission period. In warmer climates, adult female mosquitoes digest blood faster and feed more frequently (Gilies, 1953, in Githeko et al., 2000), thus increasing transmission intensity.

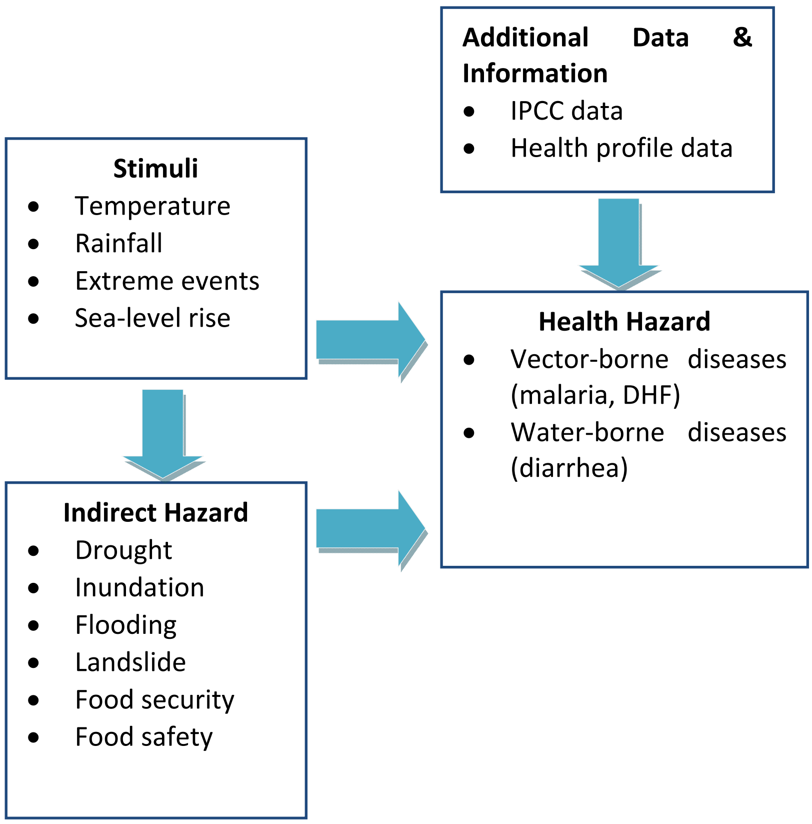


Figure 3.2 Relation between Climate Change Stimuli and Health Hazard

Similarly, malaria parasites and viruses complete extrinsic incubation within the female mosquito in a shorter time as temperature rises (Turell, 1989, in Githeko et al., 2000), thereby increasing the proportion of infective vectors. Changing precipitation patterns can also have short and long term effects on vector habitats. Increased precipitation has the potential to increase the number and quality of breeding sites for vectors such as mosquitoes, ticks and snails, and the density of vegetation, affecting the availability of resting sites. Disease reservoirs in rodents can increase when favourable shelter and food availability lead to population increases, in turn leading to disease outbreaks (Githeko et al., 2000). Thus, as conclusion, Figure 3.3 describes those mechanism and relation between climate variables (temperature, precipitation, and humidity), the vector population (gonotropic cycle, breeding places, vector survival, biting rate, recrutment rate) and parasite development rate (infection probability and transmission rate).

Figure 3.3 Mechanism of Climate Change Impact to Vector Borne Diseases

3.2.2 Water-borne disease

Many diarrheal diseases (infectious intestinal disease) peak in cases during the hottest months of the year. Climate change could greatly influence water resources and sanitation in situations where water supply is effectively reduced. Temperature and relative humidity directly influence the rate of replication of bacterial and protozoan pathogens and the survival of enteroviruses in the environment. Rainfall, and especially heavy rainfall events, may affect the frequency and level of contamination of drinking-water (WHO, 2003), through following mechanism:

- Heavy precipitation causes sewers to overflow and people come into contact with pathogens and faecal matter.
- Heavy rainfall causes contamination of surface or coastal water if the sewers are used as storm drains.
- Heavy rainfall leads to agricultural run off contaminated with livestock faeces into surface water, which reaches the public water supply or direct contact with humans.

- Heavy rainfall leads to failure in a wastewater treatment plant.
- Drought reduces the amount of surface water and groundwater, leading to increasing concentrations of pathogens and the use of alternative sources of water that are less potable.

3.2.3 Hazard Data Availability in Greater Malang

Diarrhea is a water-borne diseases that is strongly affected by change in climatic factors, such as drought, sea level rise, and rainfall pattern, that distress water resources and sanitation (WHO, 2003). Moreover, many scientific evidences suggest that DHF and malaria are top vector-borne diseases that are strongly affected by change in climate stimuli, such as temperature, precipitation, and humidity.

Hazard analysis is more focused on aspects with high-potential changes due to climate change. After conducting FGDs with health-related experts, analyses of hazards to health sector include vector-borne diseases hazard analysis (DHF and malaria) and water-borne diseases (diarrhea).

To analyze climate change impact to vector-borne disease, such as malaria, at least we need data of:
(1) Population scenario;
(2) Variability and climate change scenario;
(3) Human's immunity to vector infection and vector borne level to humans;
(4) Vector's immunity probability to environmental factors: temperature and rainfall;
(5) Vector transmission potential: vector capacity, vector reproduction level, vector quantity density, vector incubation period, and temperature range during incubation.

Even so, currently, disease vector distribution data in Indonesia is only limited in a few specific areas in Indonesia, thus there is no complete national data in all of Indonesia. So, in this study, we use relevant disease event data as proxy. Proxy is data which is considered to represent a parameter with certain level of accuracy. In this case, disease event is used as disease vector distribution proxy. In this study, we used incidence rate (IR) data of 3 infectious diseases which are malaria, dengue fever, and diarrhea, because the three are the main diseases which have high incidence rate in Indonesia Thus, in order to see correlation between climatic factor and DHF and malaria cases, daily, weekly or monthly data is required. Based on field survey, secondary data collecting, and interview in Greater Malang, there are monthly DHF, malaria and diarrhea data for 2007-2010 is available.

Other data that strongly required is the climatic data, rainfall and temperature, for the same period with the existing and projection of hazard analysis. On this study, scientific basis team (Dr. Tri Wahyu Hadi and team) has developed baseline climate analysis to obtain required information regarding temperature and rainfall pattern in Greater Malang. In health sector, climate variability is very important. Climate variability, which is defined as short-term fluctuations around the mean climate state on a fine time scale, especially in temperature and rainfall parameters, may be epidemiologically more relevant than the mean temperature increase in an area (Patz et al., 2000 in Zhou et al., 2004). Temperature affects the development rates and survivorship of parasites and mosquito vectors, while rainfall influences the availability of mosquito larval habitats and thus mosquito demography. The use of either temperature or rainfall alone is not sensitive enough for the detection of anomalies that are associated with disease epidemics (Githeko & Ndegwa, 2001, Shanks et al., 2002, Hay et al., 2002, in Zhou et al, 2004), temperature and rainfall may have synergistic effects on disease transmission.

3.3 Hazard Projection 2030 based on Future Climate Trends

In this study, we used two method to calculate health hazard projection, i.e Poisson regression analysis and compartment model. Poisson regression analysis is stochastic approach and compartment model is deterministic approach. Both Poisson regression analysis and Compartment model are described as follow.

3.3.1 Poisson Regression Analysis

As mentioned earlier, assessment of causal relationship between prevalence of DHF with temperature and rainfall as climatic factors will be conducted as part of hazard analysis in this study. Several studies had succeeded in utilizing multiple regression analysis in finding statistical association between climate variability and diseases incidence.

The general purpose of multiple regressions is to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable.The general computational problem that needs to be solved in multiple regression analysis is to fit a straight line to a number of points. In the multivariate case, when there is more than one independent variable, the regression line cannot be visualised in the two-dimensional space, but can be computed just as easily. It is possible to construct a linear equation containing all variables. In general multiple regression procedures will estimate a linear equation of the form:

$$Y = b_0+b_1X_1+b_2X_2+...+b_kX_k \quad \text{(Eq. 3.1)}$$

Where k is the number of predictors. Note that in this equation, the regression coefficients (or b_0, b_1, b_2...b_k coefficients) represent the independent contributions of each independent variable to the prediction of the dependent variable.

3.3.1.1 Previous Study of Poisson Regression Analysis for DHF, Malaria, and Diarrhea

Vulnerability assessment of climate change, particularly in health sector, is newly introduced in Indonesia. Therefore, previous studies regarding assessment of climatic factors and diseases must be evaluated to develop the methods that are used in this study. Studies regarding correlation between DHF, malaria, and diarrhea and climatic factors are as follow.

a. DHF

Studies regarding correlation between DHF and climatic factors are as follow.

- *Lu et al., (2009), Guangzhou, China*
  Lu et al., (2009) assessed time series analysis of dengue fever and weather in Guangzhou,China. Data (2001-2006) collected in this study consist of monthly notified dengue fever cases and monthly weather data, including minimum temperature (Tmin), maximum temperature (Tmax), total rainfall, minimum relative humidity (Hmin) and wind velocity. Spearman rank correlation tests were performed to examine the relationship between monthly dengue incidence and weather variables with a lag of zero to three months. The monthly dengue incidence was modeled using a generalize destimating equations (GEE) approach, with a Poisson distribution. This model enables both specification of anover-dispersion term and a first-order auto regressive structure that accounts for the auto correlation of monthly numbers of dengue cases. A basic multivariate Poisson regression model can be written as:

$$\ln(Y) = \beta_0 + \beta_1 T_{min} + \beta_2 T_{max} + \beta_3 \text{Rain} + \beta_4 \text{Wind} + \beta_5 H_{min} \quad \text{(Eq. 3.2)}$$

The model that adjusts for first-order autocorrelation can be written as:

$$\ln(Y_t) = \beta_0 + \beta_1 \ln(Y_{t-1}) + \beta_2 T_{min} + \beta_3 T_{max} + \beta_4 \text{Rain} + \beta_5 \text{Wind} + \beta_6 H_{min} \qquad \text{(Eq. 3.3)}$$

where Tmin, Tmax, Rain, Wind and Hmin stand for monthly minimum and maximum temperatures, total rainfall, minimum relative humidity and wind velocity, respectively.

As GEE are not a full likelihood-modeling method, the Akaike information criterion (AIC) cannot be used for model selection. Quasi-likelihood based information criterion (QICu) then were computed to select the most parsimonious model. Highly correlated explanatory variables were included in separate models to avoid multi collinearity. When using QICu to compare two models, the model with the smaller statistic was preferred. Models with ΔQICu $\leq$ 2 were considered to be equivalent and preferred the model with fewest parameters.All analyses were performed using SAS version 9 for Windows (SAS Institute, Inc., Cary, North Carolina).

- *Hii et al., (2009), Singapore*
  Hii et al., (2009) correlated climate variability and increase in intensity and magnitude of dengue incidence in Singapore. Data collected (2002-2007) in this study were weekly dengue data, midyear population, daily mean temperature, and rainfall. Weekly mean temperature and cumulative rainfall were aggregated from daily weather data. A time series Poisson regression model that simultaneously included time factors such as time trend, lagged terms of weather predictors, lags of dengue cases as auto regressive terms was established, accounted for changes in size of the population by offsetting midyear population. Predictors were modelled as smooth cubic spline functions given 3 degrees of freedom (df) each, with exception for the smooth function of trend that was allowed 6 df. The sensitivity of the df of the trend were tested by doubling it. Over-dispersion in the Poisson regression models were allowed:

$$Y(t) \sim \text{Poisson}\,(\mu(t))$$
$$\text{Log}(\mu(t)) = \beta_0 + \log(pop_t) + \beta_1 AR(den_t) + \sum_{i=1}^{5}(S[temp_i, df] + S[prep_i, df] + S(trend, df) \qquad \text{(Eq. 3.4)}$$

Where:
β_i = parameter estimates;
t_i = time series in weeks;
log (pop_t) = offset midyear population;
AR(den_t) = auto regressive term of dengue cases;
S_i = cubic spline smoothing function with corresponding degree of freedom (df);
$temp_i$ = weekly mean temperature at specific lag strata, i;
$prep_i$ = weekly cumulative rainfall at specific lag strata, i;
where i corresponds to 1-5 lag strata, week 1-4, 5-8, 9-12, 13-16, 17-20;
trend corresponds to week number starting from the first week in year 2000.

Mid year population was included as an offset to adjust for annual population growth or decay in the modelled relative risk. Whereas auto regressive terms ranging from 1 to 8 weeks were estimated by summing average duration of incubation period in infected person, infectious period of host and survival period of female Aedes mosquitoes. Concurrently, lag terms ranging from 1 to 20 weeks for temperature and rainfall were created to analyse relative risks between weather predictors and dengue with effect of different time lag. Cross-correlation coefficients of each weather variable and dengue cases as well as literature reports were examined to estimate maximum lag terms. Trend and seasonality pattern in collected data were identified by using time series plot of dengue cases and to be controlled as an unmeasured confounders by the smooth function of time trend.

Model fit was evaluated by Akaike's Information Criterion (AIC) and further validated by plotting predicted residuals against observed data, observing residual sequence plot and analysing normality tests. Furthermore, Auto correlation (ACF) and partial auto correlation (PACF) were evaluated to avoid confounding of the risk estimates by unknown sources and shrinking of the variance associated with parameter estimates. To account for this, they modelled auto regressive terms. PACF was also examined to avoid over fitting (which could occur if allowing the trend too much flexibility) signalled by extremely high proportion of negative PACF. Data were analysed using R2.8.1.

- *Hales et al., (1999), South Pacific Islands*
  Study conducted by Hales et al., (1999) attempted to connect El Nino and the dynamics of vector-borne disease transmission. This study accounted for monthly reports of dengue fever cases, and rainfall and temperature data, which monthly estimates were determined using INGRID World Wide Web interface to access the gridded National Center for Atmospheric Research/National Centers for Environmental Prediction (NCAR/NCEP) reanalysis data set. Data were examined for evidence of seasonal patterns by averaging within months over all years. The data were aggregated to produce January-December annual averages for each year of the study.

  Pearson correlations were calculated between SOI and temperature, SOI and rainfall, and SOI and dengue fever. Cross-correlations between monthly reports of dengue fever cases in each of the countries were calculated using SPSS software. A series of bar charts showing correlations for all possible combinations of the islands at specified lag periods were created.

- *Nakhapakorn and Tripathi (2004), Thailand*
  An information value based analysis of physical and climatic factors affecting dengue fever and dengue haemorrhagic fever incidence were conducted by Nakhapakorn and Tripathi (2004) in Thailand. Major factors considered for analysis of the occurrence of DF/DHF cases were rainfall, temperature, humidity, and land use/land cover types. DF/DHF outbreaks in Sukhothai, Thailand occurred in 1997, 1998 and 2001 was noticed that the dengue outbreak coincided with El Nino years, which are normally associated with high temperature and low rainfall. Land cover type map was obtained using digital remote sensing data from Landsat (Thematic Mapper), utilizing the Maximum Likelihood Classifier (MLC). Various output classes generated were subsequently verified based on the field observations.

  Regression analysis was used to explore the relationship between the monthly climatic parameters and the number of incidences of DF/DHF in Sukhothai province. Multiple regression analysis is employed to develop an empirical model to predict the dengue incidences. The independent variables were used to predict changes in the dependent variable in the rainy and non-rainy seasons.This model was verified using the R2 statistics. Number of peoples affected by DF/DHF was used as the dependent variable and the rainfall (R), temperature (T) and relative humidity (H) were considered as the independent variables. Multiple regression analysis was carried out for each of the observations of the occurrence of DF/DHF cases and monthly climatic data of 5 years (1997–2001). The Empirical Relationship-1 (ER-1) between number of DF/DHF cases and the climatic data attime t (Tt, Rt and Ht) during 5 years is listed in ER-1.

- *Zhang et al., (2010), China*
  Zhang et al., (2010) tried to assess effect of climate variability and haemorrhagic fever with renal syndrome transmission in Northeastern China. Data on the notified monthly

HFRS cases, and local climate data on monthly rainfall, relative humidity (RH), and land surface temperature (LST) for the study period were obtained. ENSO is the most important coupled ocean–atmosphere phenomenon that affects global climate variability and the climate in China (Huang and Wu 1989). The multivariate ENSO index (MEI) was used as an indicator of the global climate pattern.

A description of climate variables and disease incidence were summarized and cross-correlation analysis were performed to assess the associations between climate variables and the number of HFRS cases for a range of lags. In this study, lags of up to 6 months were included and climatic variables with the maximum correlation coefficients were presented. Time-series Poisson regression analysis that allowed for auto correlation, seasonality, and lag effects after correcting for over dispersion were performed. Temporal associations between climate variability and the disease are often confounded by patterns in seasonal and long-term trends (i.e., interannual change trend) (Hashizume et al. 2009). To control the impact of seasonality and long-term trends, indicator variables for "month" and "year" of on set in the model were created. Climatic variables for the months preceding the HFRS outbreaks have been shown to be important. Thus, to account for the lagged effect of the climatic variables on the number of HFRS cases, climatic variables over a range of lags into the model were incorporated.

The basic Poisson regression model were used for this study:

$$
\begin{aligned}
\ln(Y_t) = {} & \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots \\
& + \beta_p Y_{t-p} + \beta_{p+1} \text{rainfall}_t \\
& + \beta_{p+2} \text{rainfall}_{t-1} + \ldots \\
& + \beta_{p+q} \text{rainfall}_{t-q} + \beta_{p+q+1} RH_t \\
& + \beta_{p+q+2} RH_{t+1} + \ldots + \beta_{p+q+r} RH_{t-r} \\
& + \beta_{p+q+r+1} LST_t + \beta_{p+q+r+2} LST_{t-1} \\
& + \ldots + \beta_{p+q+r+s} LST_{t-s} \\
& + \beta_{p+q+r+s+1} MEI_t \\
& + \beta_{p+q+r+s+2} MEI_{t-1} + \ldots \\
& + \beta_{p+q+r+s+u} MEI_{t-u} + \\
& + \beta_{p+q+r+s+u+v} \text{month} \\
& + \beta_{p+q+r+s+u+v+1} \text{year}, \qquad \text{(Eq. 3.5)}
\end{aligned}
$$

where month as the dummy variable and the others as continuous variables were included in the model, and p, q, r, s, t, u, and v were lags determined by correlation analyses (Bi et al. 2008); β denotes the regression coefficients, and Y represents the number of cases. A step wise approach was used in the analysis to retain variables that contributed to a significant improvement in model fit as determined by the maximum likelihood ($\alpha = 0.05$). Associations between determinants and notifications of HFRS cases are presented as incidence rate ratios (IRRs) that were derived from estimated regression parameters from the final model. All estimates of IRR were complemented by a 95% confidence interval (CI) and p-value. We determined the goodness-of-fit of the models using both time series (e.g., autocorrelation function and partial auto correlation function of residuals) and the pseudo-R2. Finally, the results from the empirical data during the period of January 1997 to December 2005 were used to develop the models, and data from January 2006 to December 2007 were used to validate the forecasting ability of the models. SPSS software (version 16.0; SPSS Inc., Chicago, IL, USA) was used to perform all the analyses.

The studies above is summarized in Table 3.1 below.

Table 3.1: Summary of DHF Studies Using Regression Analysis

Study	Parameter	Methods
Lu et al., (2009), Guangzhou, China	Monthly notified dengue fever cases and monthly weather data, including minimum temperature (Tmin), maximum temperature (Tmax), total rainfall, minimum relative humidity (Hmin) and wind velocity	Time series Poisson regression analysis was performed using data on monthly weather variables and monthly notified cases of dengue fever. Estimates of the Poisson model parameters was implemented using the Generalized Estimating Equation (GEE) approach; the quasi-likelihood based information criterion (QICu) was used to select the most parsimonious model.
Hii et al., (2009), Singapore	Weekly dengue data, midyear population, daily mean temperature, and rainfall	A time series Poisson regression model including time factors such as time trends, lagged terms of weather predictors was employed, considered autocorrelation and accounted for changes in population size by offsetting
Hales et al., (1999), South Pacific Islands	Monthly reports of dengue fever cases, and rainfall and temperature data, which monthly estimates were determined using INGRID World Wide Web interface to access the gridded National Center for Atmospheric Research/National Centers for Environmental Prediction (NCAR/NCEP) reanalysis data set	Pearson correlations was used to calculate temporal correlations between annual averages of the southern oscillation index (SOI), local temperature and rainfall, dengue fever; and temporal correlations between monthly reports of dengue fever cases on different islands.
Nakhapakorn and Tripathi (2004), Thailand	Rainfall, temperature, humidity, and land use/land cover types	Multiple regression analysis is employed to develop an empirical model to predict the dengue incidences. The independent variables were used to predict changes in the dependent variable in the rainy and non-rainy seasons.This model was verified using the R2 statistics.
Zhang et al., (2010), China	Monthly rainfall, relative humidity (RH), and land surface temperature (LST), data on hemorrhagic fever with renal syndrome (HFRS) transmission, multivariate El Niño Southern Oscillation (ENSO) index (MEI) was used as an indicator of the global climate pattern	Time-series Poisson regression models to examine the independent contribution of climatic variables to HFRS transmission, over a range of lags..

b. Malaria

Studies regarding correlation between Malaria and climatic factors are as follow.

b.1) Zou et al., (2003), East African Islands

Zhou et al., (2003) conducted a study regarding association between climate variability and malaria epidemics in seven sites of East African highlands. Malaria epidemics is represented by number of malaria outpatients, which were available varies from 10 to 20 years among the seven sites. The meteorological data from 1978 to 1998 were actual weather station records, including daily maximum and minimum temperature and daily rainfall at each of the sevensites. The maximum and minimum monthly temperature and monthly rainfall were calculated from the daily records and used for all analyses. Malaria vector population dynamics were not examined because the corresponding long-term data on trends in Anopheles vector populations are not available for the study sites. The study was emphasized in whether climate warming has occurred and climate variability was higher in 1989–1998 than in 1978–1988 because frequent malaria outbreaks have occurred in the East African highlands since 1989.

For each of the seven study sites, average maximum monthly temperature, minimum monthly temperature, and rainfall over the periods of 1978–1988 and 1989–1998 were compared by using the t test. Climate variability is measured by the annual variance of the three meteorological variables (maximum temperature, minimum temperature, and rainfall). Changes in monthly minimum and maximum temperature and rainfall at each site were expressed as standardized anomalies relative to the 1961–1990 mean for each site. The 1961–1990 mean was obtained from the almanac characterization tool (ACT) for each site. The standardized anomaly is calculated as the difference between time series data and the mean values divided by the standard deviation. Annual variance in the maximum and minimum monthly temperature and rainfall in any given year was calculated from the 12-month mean. The difference in the mean annual variance of the three meteorological variables between 1978–1988 and 1989–1998 was tested by using the t test, assuming different variances for each period.

Epidemic detection was based on the method proposed by Cullen et al. The epidemic alert threshold for each month was determined as the average monthly malaria cases in the past 5 years plus two times the standard deviation. Malaria case data were not transformed. The proportion of the total number of epidemic months between 1978–1988 and 1989–1998 was calculated. Statistical association between climate variability and malaria incidence was analysed as follow. The number of malaria outpatients, Nt, at a given time is likely to be affected by the previous number of malaria outpatients (auto regression), seasonality, and climate variability. Thus, the dynamics of the number of monthly malaria outpatients can be modeled as:

$$N_t = f(N_{i<t}, t) + g(T_{min}(t), T_{max}(t), R_{ain}(t)) + e_t, \qquad \text{(Eq. 3.6)}$$

Where

$$f(N_{i<t}, t) = \alpha + \sum_{i=1}^{d} \beta_i N_{t-i} + b_1 cos\left(\frac{2\pi}{12}t\right) + b_2 \sin\left(\frac{2\pi}{12}t\right)$$

$$g = r_1 \sum_{i=\tau_1}^{\tau_{min}} T_{min}(i) + r_2 \sum_{i=\tau_2}^{\tau_{max}} T_{max} + r_3 \sum_{i=\tau_3}^{\tau_R} R_{ain}(i) + r_4 \sum_{i=\tau_1}^{\tau_{min}} T_{min}(i) \times \sum_{i=\tau_3}^{\tau_R} R_{ain}(i) + r_5 \sum_{i=\tau_2}^{\tau_{max}} T_{max}(i) \times \sum_{i=\tau_3}^{\tau_R} R_{ain}(i). \quad \text{(Eq. 3.7)}$$

The term $f(N_{i<t}, t)$ is a higher-order auto regressive model that tests the effect of auto regression, $g(T_{min}(t), T_{max}(t), R_{ain}(t))$ represents the effects of climate variability on malaria incidence, and e_t represents random noise. N_t was not adjusted for annual human population growth rates because the number of hospitals generally increases in proportion to human population size increase, and thus the human population size that each hospital has served remains similar during the study period. Parameter α is the deterministic drift, and β_i measures the lagged effect (autoregression). Parameter d, the maximum number of lagged months, is determined by the lagged autoregression analysis between monthly malaria incidences.

Seasonality in the number of malaria outpatients was implemented by the sin and cos functions; r_i is the regression coefficient, T_{min} and T_{max} represent minimum and maximum monthly temperature, and R_{ain} represents monthly rainfall. The terms (τ_1, τ_{min}), (τ_2, τ_{max}), and (τ_3, τ_R) represent the time lag periods when minimum and maximum monthly temperature and rainfall exhibited significant lagged correlation with the number of malaria outpatients as determined by the significance tests of cross-correlation function.

Equation 3.6 and 3.7 above allows for testing two alternative hypotheses. The first hypothesis is that malaria dynamics were primarily determined by the autoregressive effect (i.e., number of malaria outpatients at time *t* is determined by the malaria incidences in previous months) and seasonality. In this case, f should account for most variance in malaria outpatient time series data. The alternative hypothesis is that climate variability should be the most important factor if the majority of the variance in the number of malaria outpatients is contributed by *g*. The effects of autoregression, seasonality, and climatic variability on malaria incidences were analyzed by using the following two-step method. In the first step, we assumed g ' 0 in Eq. 3.8 and 3.9 (i.e., climate variability plays no role), and functional form off were determined by using the forward stepwise regression method. The proportion of variance in malaria temporal variation accounted for by autoregression and seasonality was calculated. In the second step, the predicted effects of autoregression and seasonality were subtracted from monthly malaria outpatient time series and then performed forward step wise multiple regression analyses on the residuals to determine the functional form of *g* and the variance of malaria outpatient time series contributed by meteorological variables, using meteorological data as independent variables. In both steps, only variables that met the 0.05 significance level were entered into the model in the step wise regression analysis.

Impacts of climate fluctuation on malaria incidences were conducted through sensitivity analysis, assuming political and socioeconomic factors remain the same. The scenarios included :

(1) monthly temperature increase by 1–3.5°C in February–April (the range of mean global land surface temperature increase by year 2100 predicted by the Inter governmental Panel on Climate Change) ;
(2) rainfall increase by 22% (the average fluctuation of rainfall in April and May during 1961–1990 for the seven study sites); and
(3) changes in both temperature and rainfall simultaneously. The predicted change in the number of monthly malaria outpatients as a result of climatic condition changes was computed as the percentage of changes in malaria outpatient numbers relative to those under the average climatic condition between 1961 and 1990.

b.2) Pascua et al. (2007)

Pascual et al. (2007) conducted a study to assess shifting pattern in malaria incidence and rainfall pattern in African highland. The malaria data consist of a monthly time series that correspond to the confirmed cases from positive blood slides for symptomatic inpatients. The rainfall data consist of three monthly time series for local meteorological stations Time-series susceptible–infected–recovered (TSIR) models for infectious diseases consist of two main components. The first is a procedure to reconstruct the time series of susceptibles and the second is a transmission equation. The model here is a simplification of the TSIRS (Time Series Susceptible–Infectious–Recovered–Susceptible) model in, originally formulated for diseases with temporary immunity. Here, it was considered that there is no loss of immunity and that the total population is constant in time with a constant turn over time T of individuals in the study area. Under the latter assumption, the reconstruction of susceptibles S_t is straightforward

$$S_t = S_{t-1} - C_t + B - D\frac{S_{t-1}}{N} \qquad \text{(Eq. 3.8)}$$

where C_t is the number of cases at time t; the constant D is the number of total deaths per time interval obtained as N/T; and B is the number of births per time interval, equal to D, since the total population size N is constant. It was assumed that the initial fraction of susceptible individuals is 1 consistent with the observations of negligible levels of immunity to malaria in the highlands in 1970. The transmission equation for the dynamics of cases is given by

$$C_t = \beta_{t-1}\beta_{seas}\left(\sum_{k=1:9} C_{t-k}\frac{S_{t-1}}{N}\right)\varepsilon_{t-1}, \qquad \text{(Eq. 3.9)}$$

where ε_t is an error term; and the transmission rate β has two components, a seasonal one, β_{seas}, and a long-term β_t encompassing variability at longer time scales than seasonal. It is assumed that infected individuals are able to transmit the disease for a period of nine months. Because β_t is not specified but determined from the model fit itself, the model is semi-parametric, so model was fitted with the semi-parametric approach, using log-transformed malaria cases.

Besides seasonality itself, there are two places where evidence for extrinsic forcing is reflected: β_t and the error terms ε_t, as the residuals of the model in the text. The variability in these two terms, β_t and ε_t, reflects sources of inter annual variability in the dynamics of cases that are not captured by either the fluctuations of susceptibles or changes in seasonal transmissibility. The studies above is summarized in Table 3.2 below.

Table 3.2: Summary of Malaria Studies Using Regression Analysis

Study	Parameter	Methods
Zou et al., (2003), East African Islands	Number of malaria outpatients, daily maximum and minimum temperature, daily rainfall	Nonlinear mixed-regression model to investigate the association between autoregression (number of malaria outpatients during the previous time period), seasonality and climate variability, and the number of monthly malaria outpatients of the past 10–20 years
Pascua et al., (2007)	Monthly malaria case and monthly rainfall data	The time-series susceptible–infected–recovered model, a simplification of the TSIRS (Time Series Susceptible–Infectious–Recovered–Susceptible)

Study	Parameter	Methods
		model, originally formulated for diseases with temporary immunity. The assumption was, there is no loss of immunity and that the total population is constant in time with a constant turn over time T of individuals in study area.

c. Diarrhea

Many diarrheal diseases (infectious intestinal disease) peak in cases during the hottest months of the year. Climate change could greatly influence water resources and sanitation in situations where water supply is effectively reduced. Temperature and relative humidity directly influence the rate of replication of bacterial and protozoan pathogens and the survival of enteroviruses in the environment. Rainfall, and especially heavy rainfall events, may affect the frequency and level of contamination of drinking-water (WHO, 2003), through following mechanism:

- Heavy rainfall causes sewers to overflow and people come into contact with pathogens and faecal matter.
- Heavy rainfall causes contamination of surface or coastal water if the sewers are used as storm drains.
- Heavy rainfall leads to agricultural run off contaminated with livestock faeces into surface water, which reaches the public water supply or direct contact with humans.
- Heavy rainfall leads to failure in a wastewater treatment plant.
- Drought reduces the amount of surface water and groundwater, leading to increasing concentrations of pathogens and the use of alternative sources of water that are less potable.

Time–series methods can be used to quantify an association between variation (daily, weekly or monthly) in diarrhea outcomes and environmental temperature (WHO, 2003). Several previous studies had succecced in utilizing time series and poisson regression in estimating relationship of temperature and diarhoeall cases (Singh, 2001, Checkley etal., 2000, Kovats et al., 2003, D'Souza et al., 2003; in WHO, 2003).

In Malang case, there are no sufficient data available. In ideal case, if the data are available, it could utilize time series analysis to assess effect on climatic factor to diarrhea. First, scatter plots could be made of the diarrhea prevalence, temperature, and rainfall. Result of scatter plot study could suggest the trend on diarrhea disease to climatic variables. Then Pearson correlation coefficients could be calculated. Finally, multivariate linear regression analyses could be attempted.

3.3.1.2 Poisson Regression Analysis for Malang

After reviews of several previous studies regarding correlation between climatic factors and disease were conducted, time series Poisson regression analysis, as developed by Lu et al., (2009) was selected due to data availability in Malang area.

First, some exercises to discover the correlation between DHF cases and rainfall and between DHF cases and temperature in Malang area were conducted using Pearson correlation and Spearman correlation. Next, Poisson regression were developed to further assess correlation between DHF case and rainfall and temperature.The assumptions in Poisson Regression include:

1) Logarithm of the disease rate changes linearly with equal increment increases in the exposure variable.
2) Changes in the rate from combined effects of different exposures or risk factors are multiplicative.
3) At each level of the covariates the number of cases has variance equal to the mean.
4) Observations are independent.

Methods to identify violations of assumption to determine whether variances are too large or too small include plots of residuals versus the mean at different levels of the predictor variable. In the case of normal linear regression, diagnostics of the model used plots of residuals against fits (fitted values). This means that the same diagnostics can be used in Poisson Regression.

In Poisson, the number of times an event occurs in a common form of data. The Poisson distribution is often used the model count data. If Y is the number of occurrences, its probability distribution can be written as

$$f(y) = \frac{\mu^y e^{-\mu}}{y!}, y = 0, 1, 2, \ldots \qquad \text{(Eq. 3.10)}$$

Where μ is the average number of occurrences (Dobson, 2002).

In the situation data that we have, the events related to varying amounts of 'exposure' which need to be taken into account when modeling the rate events. Poisson regression is used in this case. The other explanatory variables (in addition to 'exposure') were categorical.

Hypotheses about the parameters (in this case, rainfall and temperature) can be tested using Wald, score or likelihood ratio statistics, as in Lu et al. (2009). Meanwhile, the data can be analyzed using R or SAS to obtain the Poisson regression model.

The interaction between climatic factors and occurrence of diseases is described mathematically in equation as follow:

$$\text{Ln (Yt)} = \beta 0 + \beta 1 \text{ Ln(Yt-1)} + \beta 2\text{T2} + \beta 3\text{Rt} + \beta 4\text{Pt} + \hat{P}$$

Where:
Yt = the number of disease cases in month t;
Tt = the average temperature in month t;
Rt = the rainfall in month t;
Pt = the population size in month t;
$\hat{P}$ = The relative of population growth in month t;

It is assumed that

Yt ~ Poisson (μt)

Where μt is the logarithm of its expected value in month t that is modeled by a linear combination of the auto regressive term of diseases case numbers, the rainfall, the average temperature, and the (estimated) population size. According to prior statistical analysis, we propose seven models, shown in table 3.3, for predicting the number of diseases cases, which are given as follows:

- The predictors of Model 1 and Model 2 are the monthly cumulative rainfall, the monthly average temperature, and the (estimated) monthly population size.
- The predictors of Model 3 and Model 4 are the monthly cumulative rainfall, the monthly average temperature, and the (estimated) rate of population growth.

- The predictors of Model 5 and Model 6 are the monthly cumulative rainfall and the monthly average temperature. In these models we set the population size as a set off.
- The predictors of model 7 are the monthly cumulative rainfall and the monthly average temperature. In this model, we do not use population data.

Table 3.3: Equation Used in Mathematical Modeling for Determination of Future Hazards Trend

MODEL	EQUATION	REMARK
1	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 T_t + \beta_3 H_t + \beta_4 Pop_t + e_t$	Use time lag 1 month
2	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 \ln(\mu_{t-2}) + \beta_3 T_t + \beta_4 H_t + \beta_5 Pop_t + e_t$	Use time lag 2 month
3	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 T_t + \beta_3 H_t + \beta_4 RatePop_t + e_t$	Use time lag 1 month; Use rate of populations
4	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 \ln(\mu_{t-2}) + \beta_3 T_t + \beta_4 H_t + \beta_5 RatePop_t + e_t$	Use time lag 2 month; use rate of population
5	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 T_t + \beta_3 H_t + \beta_4 \ln(Pop_t) + e_t$	Use time lag 1 month; use population as offset
6	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 \ln(\mu_{t-2}) + \beta_3 T_t + \beta_4 H_t + \beta_5 \ln(Pop_t) + e_t$	Use time lag 2 month; use population as offset
7	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 \ln(\mu_{t-2}) + \beta_3 T_t + \beta_4 H_t + e_t$	Predictors are the monthly cumulative rainfall and the monthly average temperature; not use population data and the

Comparison between subsequent models is carried out by calculating Root Mean Square Error (RMSE), Standard Deviation (SD), and Akaike Information Criteria (AIC) as shown in the following equation. The preferred model is the one with the minimum RMSE, SD and AIC value.

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(xi-\bar{x})^2}{n}}$$

$$\text{SD} = \sqrt{\frac{\sum_{i=1}^{n}((xi-\bar{x}i)-d_{xi})^2}{n}}$$

Where:
x_i = actual disease case numbers
$\bar{x}_i$ = predicted disease case numbers
d_{xi} = mean residue$(x_i - \bar{x}_i)$
N = number of data

$$\text{AIC} = 2k + n[Ln(RSS)]$$

Where:
RSS = residual sum of squares

3.3.2 Compartment Model Analysis

A compartment model provides a framework for the study of transport between different compartments of a system. In epidemiology, models of the behavior of an infectious disease in a large population of people consider each individual as being in a particular state. These states are often called compartments, and the corresponding models are called compartment models. DHF, malaria, and diarrhea are such infectious disease that can be analyzed by this compartment model. This study assume that a person can be in one of three states, e.g. susceptible (S), infectious (I) or recovered (R). Individuals move from the Susceptible state (S) to the Infectious state (I) by mixing or interacting with infectious individual/vectors. After exposure to microparasitic infection, individuals who recover (R) from a disease will enter a third state where they may immune to subsequent infection. Since these three compartments S (for susceptible), I (for infectious) and R (for recovered) are standard convention labels. Therefore, this model is also called the SIR model.

Compartment model has been used widely in epidemiology study. For example, a compartment model was used to analyse dengue outbreaks in Salvador for 1995–1996 and 2002 (Yang *et al.* 2009). Compartment model also was used to analyze the dynamics of dengue for testing the vector control strategies (Esteva & Yang 2005; Ferreira *et al.* 2008; Yang & Ferreira 2008). Compartment model by using the next generation operator approach was used to compute the basic reproductive number, *R*0, associated with the disease-free equilibrium (Diekmann & Heesterbeek 2000; Van den Driessche & Watmough 2002). Compartment model to compute the basic reproductive number was also conducted for Brazil case (Favier *et al.* 2006; Pinho et al, 2010), Singapore case (Burattini *et al.* 2008) and city of Salvador case (Wallinga & Lipsitch, 2007).

DHF, malaria, and diarrhea are such infectious disease that can be analyzed by the compartment model. We include the temperature and rainfall effect to this compartment model by assuming that in DHF and malaria case:

- The seasonal nature of transmission may reflect the influence of climate on the transmission cycle.
- Increases in temperature and precipitation can lead to increased mosquitos abundance by increasing their development rate, decreasing the length of reproductive cycles, stimulating egg-hatching, and providing sites for egg deposition.
- Higher temperature further abets transmission by shortening the incubation period of the virus in the mosquito
- Mosquito species are responsible for transmission and they are sensitive to temperature changes as immature stages in the aquatic environment and as adults.
- If water temperature rises, the larvae take a shorter time to mature and consequently there is a greater capacity to produce more offspring during the transmission period.
- In warmer climates, adult female mosquitoes digest blood faster and feed more frequently, thus increasing transmission intensity.
- Malaria parasites and viruses complete extrinsic incubation within the female mosquito in a shorter time as temperature rises, thereby increasing the proportion of infective vectors.
- Changing rainfall patterns can also have short and long term effects on vector habitats.
- Increased rainfall has the potential to increase the number and quality of breeding sites for mosquitoes and the density of vegetation, affecting the availability of resting sites.

In diarrhea case, we assume effect of rainfall and temperature are as follow:

- Climate change could greatly influence water resources and sanitation in situations where water supply is effectively reduced.
- Temperature and relative humidity directly influence the rate of replication of bacterial and protozoan pathogens and the survival of enteroviruses in the environment.

In compartment model approach, controlling dengue and malaria transmission is based on the control of the growth of the mosquito, temperature and rainfall. In diarrhea transmission, control factors are bacterium Escherichia coli growth, temperature and rainfall. The basic reproductive number, *R*0, as the most common measure of the strength of an epidemic is also used in calculation. The model developed here is based upon the one given in Jafaruddin and Sofyan (2011), where the mosquito population related to the winged female form of the mosquito.

In this study, we developed compartment model for DHF, malaria, and diarrhea. For example, Figure 3.14 show schematic of the compartment model for DHF. Compartment model shows the circle process between healthy and ill persons. The mosquitoes are the outer factor which carried the virus in the first place. Then the non-virus carrier mosquitoes could becomes the carrier when bites the ill person. There are two important variables, so called the b and μ. The b refers to the power of mosquitoes to bite, while the μ is the possibilities of person to get infected by dengue virus. Two coefficient are varies depend on the spatial, climatic or social condition.

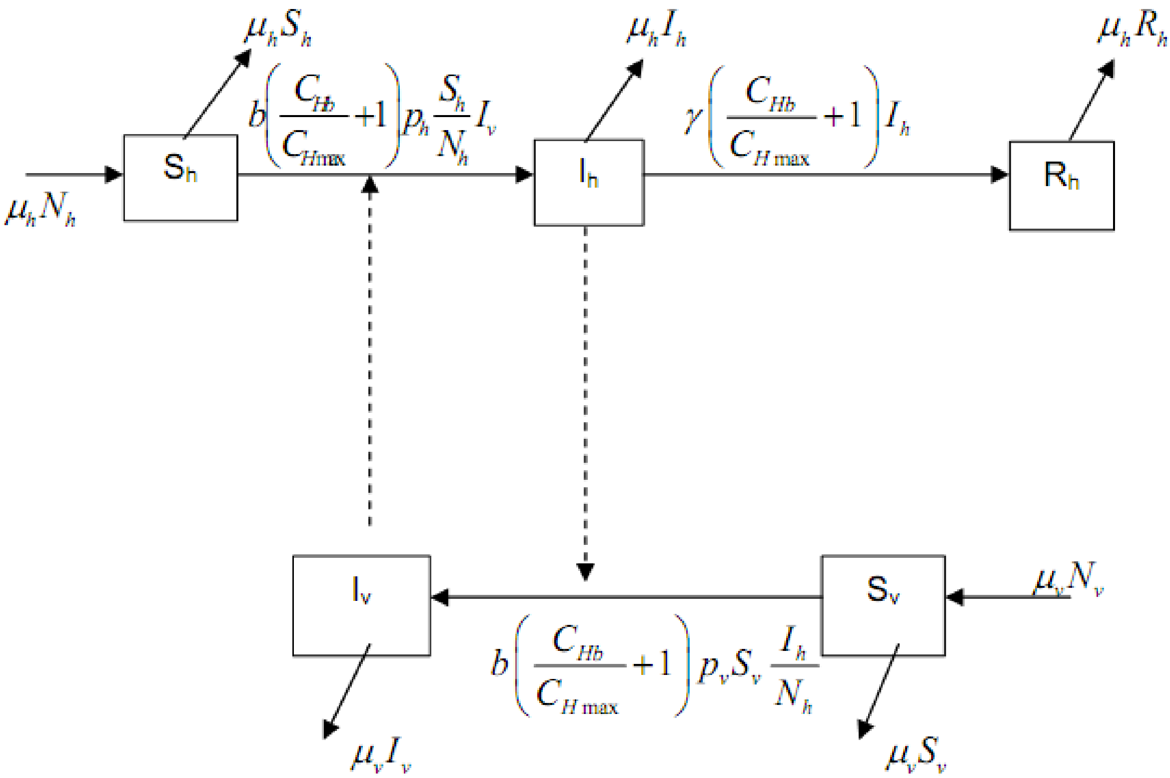


Figure 3.4 Schematic of the compartment modeling of DHF

$$\begin{cases} \dfrac{dS_h}{dt} = \mu_h N_h - b\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right)p_h\dfrac{S_h}{N_h}I_v - \mu_h S_h \\ \dfrac{dI_h}{dt} = b\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right)p_h\dfrac{S_h}{N_h}I_v - \left(\gamma\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right)+\mu_h\right)I_h \\ \dfrac{dR_h}{dt} = \gamma\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right)I_h - \mu_h R_h \end{cases}$$

$$\begin{cases} \dfrac{dS_v}{dt} = \mu_v N_v - b\left(\dfrac{C_b}{C_{\max}}+1\right)p_v S_v\dfrac{I_h}{N_h} - \mu_v S_v \\ \dfrac{dI_v}{dt} = b\left(\dfrac{C_b}{C_{\max}}+1\right)p_v S_v\dfrac{I_h}{N_h} - \mu_v I_v \end{cases}$$

With:
Sh = Susceptible human (Healthy person)
Ih = Infected human (Ill Person)
Iv = Invected mosquitos
Sv = Susceptible mosquitos
Rh = Recovered human

Detail explanation of compartment model method is described in Attachment C about Compartment Model Analysis.

3.3.3 Residual Analysis Method

A time series is a collection of observations made sequentially in time. The time series can be described in terms of three components:

Time Series= Trend + Cycle + Residual (irregular variation)

Most time series exhibit a variation at a fixed period such as the seasonal variation in temperature. Beneath this cycle can be a long-term change in the mean (trend) that may be a true linear trend or a cycle in the data beyond the length of the time series. The shorter the time series the greater chance that the observed trends are due to low frequency (long) cycle. The residuals are components that are not associated with either the dominant cycles or trend.

Johansson et al. (2009) used residual analysis before conducted Poisson regression model analysis. Johansson et al. (2009) analyzed the association of temperature and precipitation with dengue transmission in each of 77 municipalities of Puerto Rico over a 20 year period using adaptive natural cubic splines to adjust for seasonal confounding. They used a hierarchical statistical model to examine local associations over time and spatial heterogeneity in the estimated local associations. At the first stage, within each municipality, they estimated the local short-term association between monthly variation in weather variables and monthly variation in dengue incidence while controlling for the smooth seasonal pattern of each covariate and reducing autocorrelation in the residuals. More specifically, they fitted municipality-specific Poisson regression models with monthly dengue incidence regressed on monthly average temperature or precipitation with a population offset and a natural cubic spline function of time. Based on those methods Johansson et al. (2009) could characterized the spatial heterogeneity of the relationship between weather and dengue transmission in Puerto Rico but they did not predict for dengue future trend. Since our goal is looking for the best method for dengue case prediction related with climate factor then Johansson method is not appropriate for this study. Unfortunately, there are lack research that elucidating relation between weather and dengue transmission by using residual method and used their finding to predict the future dengue trends. Similar with dengue, there are also lack research in malaria and diarrhea cases.

In Malang case, the relationship between weather and dengue transmission have been conducted by Poisson regression model. Poisson regression model has been used wider by public health researcher in the world compare than residual method. Therefore, in Malang case it is only use one method, namely Poisson regression model, for elucidating the relationship between weather and dengue, malaria, and diarrhea transmission.

3.3.4 Selection the Methodology for DHF, Malaria, and Diarrhea Prediction

As described in sub chapter 3.3.1 - 3.3.3 there are 3 method for elucidating the relationship between weather and DHF, malaria, and diarrhea transmission, namely Residual Method, Poisson Regression Model, and Compartment Model. In order to predict future DHF, malaria and diarrhea case related with climate, it is necessary to select the best method among those approach and finally we select compartment model with the reason as follow:

- Residual method and Poisson regression model are statistical - time series analysis method that its result depend on the amount of data. Thus, we found several difficulties to conduct those methods in Malang case since data availability is very limited. In addition, both residual method and Poisson regression model are lack used as DHF, malaria, and diarrhea prediction method.
- Based on our experience, compartment model is still can be used to predict both DHF, malaria, and diarrhea cases eventhough the amount of data are limited.

Based on those reason, we choose compartment model as prediction method for future DHF, malaria, and diarrhea in Malang area. However there are several limitation of compartment method as follow:

- Theoretical models of dengue transmission dynamics based on mosquito biology support the importance of temperature and precipitation in determining transmission patterns, but empirical evidence has been lacking especially in Indonesia. On global scales, several studies have highlighted common climate characteristics of areas where transmission occurs. Meanwhile, longitudinal studies of empirical data have consistently shown that temperature and precipitation correlate with dengue transmission but have not demonstrated consistency with respect to their roles.
- Moreover, all of the equations used to define compartment models discussed above represent Finite Difference equations. In a Finite Difference equation, the time step in this case is fixed one month and the value at the current time step is used to predict the value at the next time step. Computationally efficient, this approach is fast and lends itself to simple solutions. Unfortunately, it is also inaccurate. In reality, time is a continuous variable. Trying to predict the number of people that will be infectious one day from now based on the number infectious now will give a different answer than trying to predict the number of people infectious one hour from now, given the number infectious now, and repeating that calculation every hour. If the variables in the compartment model are changing slowly relative to the length of the fixed time step, then a finite difference algorithm will behave well. However, if the variables are changing rapidly, for instance, at the onset of an epidemic, finite difference algorithms can produce nonsensical results.

As conclusion, there is still many weakness in prediction methods for future DHF, malaria, and diarrhea cases in Malang. The prediction results in this study may be categorized as a preliminary study that those need further researches due to get better result.

3.4 Vulnerability Assessment

Vulnerability is often defined as the capacity to be harmed. It is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007). Therefore, vulnerability is defined as the conditions that increase the susceptibility of a community to the impact of hazards, in this case, impacts on health sector (UN ISDR Report, 2004). The same report also suggest that level of vulnerability is determined by:

- Physical factors, refers to ‘exposures’ that covers population density, remoteness of a settlement, and location site.
- Social factors, such as public health, sanitation infrastructure in community, education, security, good governance, social equity, cultural aspects, etc.
- Economic factors, including individuals, communities, and nations economical status and access to socio-economic infrastructures, such as health care facilities.
- Environmental factors, such as reduced access to clean air and water, and appropriate sanitation and waste management and diminished biodiversity.

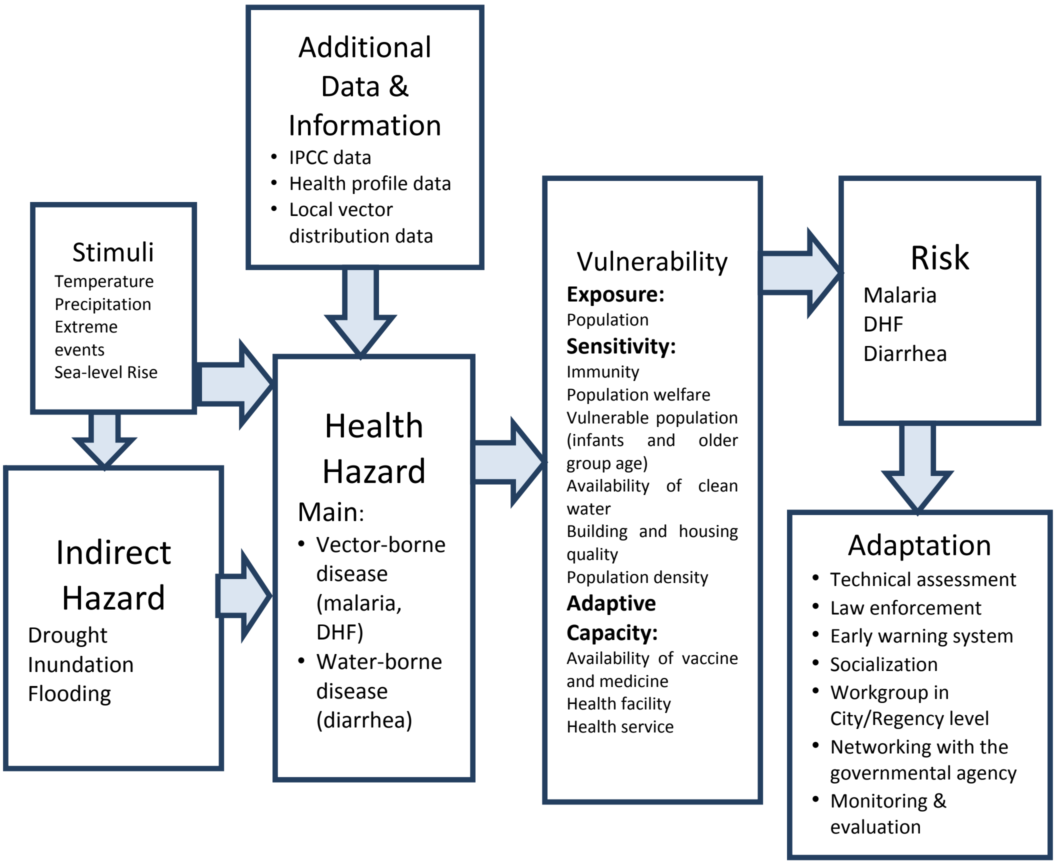


Figure 3.5 General Schematic of Vulnerability and Risk Assessment in Health Sector

Vulnerability assessment in health sector-related to climate change requires a study to examine the relationship/interaction between human healths to changes of climate factors. But first, some definitions regarding several terms on this assessment must be addressed. Fourth assessment report of IPCC suggest that vulnerability (V) consists of at least three variables, i.e., Exposure (E), Sensitivity (S) and Adaptive Capacity (AC) (IPCC, 2007)

- Exposure (E) is described as a physical aspect of vulnerability. In this case, exposure will be stressed on physical aspects of impacts due to climate change, such as level of population density, level of isolation of a settlement area and location, design, and the availability of material for important infrastructure construction (Affeltranger, et al. 2006).
- Sensitivity (S) is defined as a potential level of ability to response to a kind of climate change condition, such as the spread of malfunction, structure and composition within an ecosystem (UNEP and WMO, 1996).
- Adaptation capacity (AC) is referred to as the potential capability of a system to adapt, to cope, and to reduce impacts of climate change, in terms of both availability and quality of its human resource and infrastructure on impacted sector. AC very much influences the

vulnerability of the population/area impacted by hazards of climate change (Bohle et al., 1994; Downing et al., 1999; Kelly and Adger, 1999; Mileti, 1999; Kates, 2000).

Interaction between human health and changing climatic factors is shown in Figure 3.5. In Figure 3.5 we could see the stimuli originating from climatic factors (temperature, rainfall, extreme events and sea level rise). Changes to these stimuli will have an impact on human health and the environment. The main impact to human health caused by changes in stimuli are the changes in the occurrence of vector-borne disease (malaria and DHF) incidences, the increase in malnutrition cases, and injuries or even deaths caused by extreme events. Another effect is the increase of water-borne disease (diarrhea) cases. In Figure 3.5 the population numbers belongs to exposure. While sensitivity covers immunity, welfare level of the population/age, supply and distribution of food, and sanitation. The availability of vaccines and drugs, as well as quality and quantity of health facilities and experts, are indicators in determining the adaptive capacity.

It can be concluded that vulnerability will increase along with rise of exposure and sensitivity. It means that a population with higher exposure is more vulnerable to hazard effect of climate change. Amount of population is commonly used as the indicator of exposure, as more crowded area receive more challenges to the environmental carrying capacity. High population number will increase the number of people at risk to climate change. For example, dense population in urban area, where human contacts are common, will have higher risk of infectious diseases since the distribution of diseases is much easier than in non-crowded population.

Correspondingly, a more sensitive population will be more vulnerable to health effect of climate change. Their ability to response may affect the chance to survive. Population with low water supply, bad sanitation, and disability or as we can say, are more sensitive, are more likely to receive severe damage from climate change hazards. For example, infants are known to be more susceptible than adults since their body functions are not developing yet. Population with high proportion of infants tends to have higher incidence rate of diarrhea as common childhood diseases, this incidence will be worsen by water-borne disease burden from climate change. In contrary, vulnerability can be reduced by enhancement of adaptive capacity. Better health facilities, capable health professionals, and easier access to vaccines and medicines, provide buffer againts the climate hazards. For example, DHF can be tackled by providing adequate health facility and service. This elaboration can be inscribed in following expression (as adopted from ICCSR 2010).

$$V = \frac{f(E \times S)}{AC}$$

In order to assess the vulnerability of population in health sector, forementioned indicators that includes in exposure, sensitivity, and adaptive capacity must be assessed. This is also plays important role in future prediction of climate health impacts. Consequently, as mentioned before, level of vulnerability of an area can be determined by exposure, sensitivity, and adaptive capacity, while level of risk is determined by the presence and intensity of hazard, along with level of vulnerability. Therefore this phase will assess relationship of vulnerability affected by:

- exposure (population density)
- sensitivity (clean water supply, vaccination, age group, immunity)
- adaptive capacity (health facilities and professionals, drugs availability)

In the analysis and presentation of hazards data, vulnerability and risk, GIS (Geographic Information System) is used as a tool for easy data management; plotting the geographical location of the data to drawn the map of hazard, vulnerability and risk; and calculating the values and the level of hazard, vulnerability and risk from an area.

3.4.1 Vulnerability Indicators for Dengue Hemorrhagic Fever

The vulnerability indicator for DHF is indicated by several parameters outlined in the Table 3.4 below.

Table 3.4: Vulnerability Indicators of Dengue Hemorrhagic Fever

Component	Indicators	Remarks
Exposure	Population	Exposure means population, not area
Sensitivity	Source of water supply	Existence of piped-water (PDAM) in the house. Mosquitoes uses uncover water containers for breeding site.
	Urban population density	DHF mosquitoes is multiple biter therefore DHF sensitive to population density
	Mobility of people: travellers & seasonal migrant workers	Amount of moving people per area in a defined time
Adaptive Capacity	Provision of health facility: RS, puskesmas, pustu, posyandu	Emergency room availability is important. It is need to define the coverage area of each health facility
	Accessibility to health facility: distance and poverty	GIS analysis may produce this data in future

3.4.2 Vulnerability Indicators for Malaria

The vulnerability indicator for malaria indicated by several parameters outlined in the Table 3.5 below.

Table 3.5: Vulnerability Indicators of Malaria

Component	Parameter/Variable	Remarks
Exposure	Population in corresponding area.	Exposure means population, not area. High population bear higher risk of Malaria occurrence.
Sensitivity	Distance from mosquitos breeding site (swamp, rice field, plantation, forest, and inundated area)	Anthropophilic mosquitoes could easily reach the settlement to bites people living near the breeding site.
	Type of housing (healthy and non-healthy house)	Percentage of the healthy and non-healthy house. Healthy house build by solid materials, therefore reducing the risk of mosquitoes penetrate into the house.
	Type of profession (Persons works in potentially breeding site and non breeding site)	Percentage of fisherman, gardener, farmer and office worker.
Adaptive Capacity	Availability of mangrove area	Mangroves prevent mosquitoes breeding by providing suitable canopy against sunlight and provide suitable condition for larvae's predators.
	Provision of health facility (hospital, puskesmas, etc)	Define by coverage of health facility, not the quantity of facility.
	Accesibility to health facility affected by distance and poverty	Needs further GIS analysis

3.4.3 Vulnerability Indicators for Diarrhea

The vulnerability indicator for diarrhea is indicated by several parameters outlined in the Table 3.6 below.

Table 3.6: Vulnerability Indicators of Diarrhea

Component	Parameter/Variable	Remarks
Exposure	Population	Exposure means population, not area. Dense populations are more likely to consume food & water that contaminated by similar agents of diarrhea.
Sensitivity	Household sanitation facility: Houses with toilet and without toilet.	Peoples who live in a house with no toilet facilities, often defecate in plantation, rice fields, sewage, or rivers without further fecal processing.
	Source of water supply (PDAM or others)	Source of household water (cooking, drinking, washes dishes, etc): piped water, dig well, rain, river, etc. Drinking contaminated water is the main pathway of diarrheal disease transmission.
	Prolonged flood area	Flood pollute the drinking water source
	Proporsion of sensitive age: infant and old people	Infant and old people have low immunity
Adaptive Capacity	Immunization	Coverage of typhoid, cholera, and dysentery immunization
	Provision of health facility: RS, puskesmas, pustu, posyandu	It is needed to define the coverage area of each health facility
	Accessibility to health facility: distance and poverty	GIS analysis may produce this data in future

3.4.4 Selection Process of Vulnerability Indicators

Several vulnerability indicators for DHF, malaria and diarrhea had discussed above. Ideally, all indicators are utilized in order to assess vulnerability level of an area. However, not all indicators are applicable in this study due to availability of data. Therefore, Analytic Hierarchy Process (AHP), a decision-making technique, is used to determine the most suitable indicators and its rank weight.

AHP is a structured technique for dealing with complex decisions. Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem—it is a process of organizing decisions that people are already dealing with, but trying to do in their heads. Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood—anything at all that applies to the decision at hand. Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations.

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision-making techniques. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action. The results of indicator selection and weight of each indicator are presented in Table 3.7. AHP scores is recalculated based on available variable.

Table 3.7: Selected Vulnerability Indicators for DHF, Malaria, and Diarrhea

Diseases	Original Parameters	Original AHP Scores	Available Variable	Adjusted AHP Score
DHF				
	Urban Population	0.27	Urban Population	0.372
	Source of water supply	0.097	Source of water supply	0.118
	Urban Population Density	0.226	Urban Population Density	0.312
	Mobility of people	0.083	-	
	Provision of health facility	0.18	Provision of health facility	0.198
	Accessibility to health facility	0.144	-	
Malaria				
	Population living near mosquito breeding site	0.302	Population living near mosquito breeding site	0.471
	Distance from Mosquito breeding site	0.217	Distance from Mosquito breeding site	0.275
	Type of housing	0.135	Type of housing	0.141
	Type of profession	0.037	-	
	Availability of mangrove area	0.095	-	
	Provision of health facility	0.111	Provision of health facility	0.113
	Accessibility to health facility	0.103		
Diarrhea				
	Urban population	0.146	Urban population	0.28
	Household sanitation facility	0.183	Household sanitation facility	0.244
	Source of water supply	0.152	Source of water supply	0.217
	Prolonged flood area	0.087	-	
	Proportion of sensitive age group	0.078	-	
	Immunization	0.077	-	
	Provision of health facility	0.15	Provision of health facility	0.259
	Accessibility to health facility	0.127	-	

The database used in this vulnerability study is available from demographic survey of Great Malang in year 2008 by local and national government, such as BPS and Health Department. GIS maps also supported the spatial data availability.

3.4.5 Calculation of Vulnerability Scores

The exposure (E) and sensitivity (S) parameters have positive influence to vulnerability values, whereas adaptive capacity (AC) has negative influence. The total vulnerability value could be determined by simple equation as follow:

$$V \text{ total} = f(E, S, AC) = \sum (AHP \ x \ V)$$

Where AHP is AHP proportional score and V is vulnerability score of each indicator.

Therefore, to achieve the final vulnerability score for each district, two steps of calculation are adopted. The first step is decomposing the quantity value of each parameter into one finite scale, 0-1 range. The next step is by multiplication the proportional score with AHP proportional score that produce the final vulnerability score.

3.4.5.1 Calculation of Vulnerability Scores to Dengue Hemorrhagic Fever

Equations used to calculate the proportional scale of vulnerability scores of each parameter in corresponding district are as follow:

A. Urban population

Aedes aegypti, the DHF vector, has unique preference to live and breed in freshwater. Populations facing the risk to get infected since freshwater container, ornamental plants, and garden are commonly present in society, particularly in urban area.

$$Vp = AHP \times (Pv/Pt)$$

Where:
Vp = Vulnerability score of population indicator
Pv = Number of population in corresponding villages
Ht = Total number of population in city

B. Urban Population Density

Density parameter refers to total population per hectare area, or Building Basic Coefficient or Koefisien Dasar Bangunan (KDB) per hectare area (Sudiarso, 2003). Building density is also identified based on ratio of paved land in each environmental unit and land coverage, where an area is called to be densely populated if total building reach 80-150 buildings per hectare, or KDB reach >75% for dense settlements. While if population density is reviewed from number of occupants per land area, density of an area can be classified as follow (Mahmudah, 2007):

- Low density : <150 occupants/Ha
- Moderate density : 151-200 occupants /Ha
- High density : 201-400 occupants/Ha
- Very high density >400 occupants/Ha.

The density classification scores (Ds) are as follow:

- Score for low density population : 0.2
- Score for moderate density population : 0.4
- Score for high density population : 0.8
- Score for very high density population: 0.9

The vulnerability value is determined by AHP-based scoring system as follow:

$$Vpd = AHP \times Ds$$

Where:
Vpd = Vulnerability score of population density indicator
Ds = Density classifications score

C. Source of Water Supply
Water supply in houses are divided into two categories: houses covered by public utility company service of piped-water (PDAM or Perusahaan Daerah Air Minum), and those that are not covered by PDAM. It is common for houses without piped-water to store water for daily use in large containers. Unfortunately, mosquitoes are uses uncovered, commonly freshwater for breeding site. Therefore, houses with piped-water are considered to have less sensitivity than those, which are not.
The vulnerability scores due to non-piped water supply are as follow:

$$Vws = AHP \times (Hnw/Hv)$$

Where:
Vws = vulnerability score of water supply indicator
Hnw = Number of Houses with non piped water supply
Hv = Total number of house in corresponding villages

D. Provision of health facility (hospitals, puskesmas, pustu, posyandu)
Based on health profile data, each health facility has their ideal service capacities. Health facilities that exceed those capacities, might not work properly. Therefore vulnerability score is calculated by using proportion number of health facility divided by ideal number of health facility.

$$Vhf = AHP \times (Hf/Hi)$$

Where:
Vhf = Vulnerability score of health facility indicator
Hf = Number of available health facilities
Hi = Number of ideal health facilities

3.4.5.2 Calculation of Vulnerability Scores to Malaria

Equations used to calculate the proportional scale of vulnerability scores of each parameter in corresponding district are as follow:

A. Populations living near mosquito's breeding site possess higher probability of infection by malarial protozoa, thereby have higher vulnerability score. GIS data provide the population living near or far from the mosquito's breeding site. The vulnerability score is determined by equation:

$$Vpm = AHP \times (Pn/Pv)$$

Where:
Vpm = Vulnerability score of Populations living near mosquito's breeding site indicator
Pn = Number of populations living near breeding site in corresponding villages
Pv = Total population in corresponding villages

B. House Distance from Breeding Site
Places which set as potential breeding site are forest, plantation, rice fields, rivers, and swamps. Visual interpretation of GIS map is used to determine the amount of houses near those areas (radius 500 m from breeding site). Vulnerability of malaria can be reduced by increasing distance of populations from breeding site. The vulnerability score can be calculated using the following equation:

$$Vhm = AHP \times (Hn/Hv)$$

Where:
Vhm = Vulnerability score of houses living near mosquito's breeding site indicator
Hn = Number of houses near breeding site in corresponding villages (radius 500 m)
Hv = Total number of houses in corresponding villages

C. Type of housing (non-permanent house)
Non-permanent house has not good conctruction therefore mosquito can enter the house easily. The vulnerability score can be determined using the following equation:

$$Vnp = AHP \times (Hnp/Hv)$$

Where:
Vnp = Vulnerability score of non-permanent houses indicator
Hnp = Number of non-permanent housing in corresponding villages
Hv = Total number of houses in corresponding villages

D. Provision of health facility (hospital, PHC, IHC)
The calculation of vulnerability score is similar with adaptive capacity of DHF that presented in earlier section.

3.4.5.3 Calculation of Vulnerability Scores to Diarrhea

Equations used to calculate the proportional scale of vulnerability scores of each parameter in corresponding district are as follow:

A. Population
Diarrhea easily transmitted through fecal-oral route, particularly in crowded area and put the entire population at risk of diarrheal transmission. The vulnerability score could be calculated by following equation:

$$Vp = AHP \times (Pv/Pt)$$

Where:
Vp = Vulnerability score of population indicator
Pv = Number of population in corresponding villages
Ht = Total number of population in city

B. Household sanitation facility
Availability of proper sanitation facilities could prevent leakage of fecal matter which results in contamination of food and water. The vulnerability score could be calculated using equation as follow:

$$Vsf = AHP \times (Hnt/Hv)$$

Where:
Vsf = Vulnerability score of sanitation facility indicator
Hnt = Number of houses not equipped with toilet in corresponding villages
Hv = Total number of houses in corresponding villages

C. Source of Water Supply
Water supply in houses are divided into two categories: houses covered by public utility company service of piped-water (PDAM or Perusahaan Daerah Air Minum), and those that are not covered by PDAM. It is common for houses without piped-water to store water for daily use in large containers. Unfortunately, mosquitoes are uses uncovered, commonly freshwater for breeding site. Therefore, houses with piped-water are considered to have less sensitivity than those, which are not.
The vulnerability scores due to non-piped water supply are as follow:

$$Vws = AHP \times (Hnw/Hv)$$

Where:
Vws = vulnerability score of water supply indicator
Hnw = Number of Houses with non piped water supply
Hv = Total number of house in corresponding villages

D. Provision of health facility (hospitals, puskesmas, pustu, posyandu)
The calculation of vulnerability score is similar with adaptive capacity of DHF and Malaria that presented in earlier section.

3.5 Vulnerability Projection Analysis for 2030

Assessments of vulnerability projection in the future are carried out by the same method as the baseline vulnerability assessment (see Chapter 3.4). The difference is only the data input. The data source for future vulnerability calculation is provided by local and national government documents as follows:

a. Regional Layout Masterplan (Rencana Tata Ruang Wilayah) 2030
b. Health programs targeted for 2030
c. Projection landuse outlined in the GIS map for 2030

Additional calculation and assumption is also carried out to completing the unavailable data.

3.6 Risk Analysis

Potential loss caused by climate hazards within a region and certain period can be determined through risk assessment. According to United Nation, risk is defined as probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induce hazards and vulnerable conditions. Conventionally, risk is expressed by following notation (UN ISDR, 2004):

$$R = H \times V$$

Where,

R = risk
H = hazard, a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.
V = vulnerability

In other words, even if hazards are present, severe health risks are unlikely to occur if the community is not vulnerable. Therefore, assessing and reducing vulnerability is the crucial part of risk assessment in order to minimize health risk induced by climatic factors, by setting up adaptation strategy on health sector.

Disease case numbers are influenced by social, geographic and climatic condition, therefore variation of health condition within national scope is very high. However, it's very unlikely to appraising the health condition in certain area without comparing it with fixed standard of health. In order to create five classification of hazard for risk matrix calculation, the percentile concept is adopted. Using distributive statistical method, all disease case numbers for year 2008 in all sub district are collected, arranged and calculated to determined the zero, first, second, third and fourth percentile. The vulnerability categories are also determined by the same method.

Table 3.8: Hazard and Vulnerability Categorization based on Percentile Concept

Borderline Condition	Categories/Level
< Percentile 1	Very Low
Percentile 1 < Incidence < Percentile 2	Low
Percentile 2 < Incidence < Percentile 3	Moderate
Percentile 3 < Incidence < Percentile 4	High
>Percentile 4	Very High

The Risk Assessment Matrix standardizes qualitative risk assessment and facilitates the categorization of health risk. In this study, hazard and vulnerability are categorized into five levels, which is very low, low, moderate, high and very high. Level of risk is determined by matching the position of hazard and vulnerability data in corresponding district with the color of the matrix. Figure 3.6 shows the Risk Assessment Matrix used in this study, with the green area resemble very low risk, the yellow area resemble low risk, the dark yellow resemble moderate risk, the orange area for high risk and the red area resemble very high risk.

		Hazard				
Vulnerability		Very Low	Low	Moderate	High	Very High
	Very Low	(Very Low Risk)	(Very Low Risk)	(Low Risk)	(Low Risk)	(Moderate Risk)
	Low	(Very Low Risk)	(Low Risk)	(Low Risk)	(Moderate Risk)	(High Risk)
	Moderate	(Low Risk)	(Low Risk)	(Moderate Risk)	(High Risk)	(High Risk)
	High	(Low Risk)	(Moderate Risk)	(High Risk)	(High Risk)	(Very High Risk)
	Very High	(Moderate Risk)	(High Risk)	(High Risk)	(Very High Risk)	(Very High Risk)

Figure 3.6 Risk Assessment Matrix

3.7 Risk Projection Analysis for 2030

The future risk assessment is conducted in the same way as the existing risk assessment (see Chapter 3.6). The difference is only data input. Future risk is calculated from future hazard and future vulnerability. Future risk is expressed by following notation:

$$R_f = H_f \times V_f$$

Where,

R_f = future risk

H_f = future hazard, a prediction of potentially damaging physical event, phenomenon or human activity in the future that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

V_f = future vulnerability, a prediction of vulnerability

3.8 Adaptation Strategy Formulation

Adaptation is intended to reduce climate change vulnerabilities and impacts. That means any consideration of adaptation planning must begin with consideration of risks associated with climate change vulnerabilities and impacts, to the extent that these can be anticipated. More specifically, adaptation includes (1) the strategies, policies, and measures implemented to avoid, prepare for, and effectively respond to the adverse impacts of climate change on natural and human systems (to the extent that they can be anticipated), and (2) the social, cultural, economic, geographic, ecological, and other factors that determine the vulnerability of places, systems, and populations (NRC, 2010).

Adaptation to global warming and climate change is a response to climate change that seeks to reduce the vulnerability of natural and human systems to climate change effects. Even origin cause of climate change is effectively reduced or eliminated through mitigation attempts, climate change and its effects will last for many years, thus, adaptation will be necessary, especially in developing countries. Previous study has identify adaptive capacity, which includes health status disparity (gap between rich and poor), disease's double burden (society suffer both infectious disease and non-infectious disease), limited facility and health service, limited clean water and sanitation facilities and clean and healthy lifestyle, which is still not fully implemented (ICCSR, 2010).

Setting of Priority in Adaptation Strategy integrated into the Development Planning.

Climate change stimuli in the form of temperature increase and sea level rise affects all areas of kecamatan and kabupaten in equal intensity. But changes in rainfall pattern depend on local climate and weather characteristics. Spatially therefore, stimuli caused by changes in rainfall pattern needs serious attention in the hazard analysis. Assessment of vulnerability in the study area indicated areas with various level of vulnerability. Using risk analysis method, areas can be identified as having very low to very high vulnerability. Priority for adaptation can therefore be concentrated in high vulnerability areas.

Areas with high and very high risks need to be analyzed for its causes to determine whether it is caused by high vulnerability or by high hazard factors, or by both factors. Based on the results, adaptive strategy in Great Malang Area are divided to 4 (four) category, namely A, B, C, and D, where A is the most priority area, following by B as second priority, C as third priority, and D as last priority. Those categories are described as follow:

(A) **First priority: Areas with high risk due to high hazard and high vulnerability.**
This high risk area is first priority to be improved because it has high both hazard and vulnerability. For areas of such criteria, the first attention should be given to the management of hazard against dengue, malaria and diarrhea since patient's wellness is of utmost priority. The next attention is given to the betterment of the environmental quality, provision of save water supply, sanitation and health facility.

(B) **Second priority: Adaptation strategy for areas with high risk due to high hazard only.**
This area is second priority to be improved because it has high hazard but has low vulnerability. For areas such as this, management of hazard, either for dengue, malaria and diarrhea should be given high attention, both through prevention and treatment. The second attention is the management of the environment such as improvement of save water supply, sanitation and clean and healthy environment.

(C) **Third priority: Areas with high risk due to high vulnerability only.**
This area is third priority to be improved because it has low hazard but has high vulnerability. For areas such as this, the management of vulnerability is main attention, such as develop better and healthier environment, save water supply, and environmental sanitation. Management of slum areas and de-urbanization should be integrated within. The improvement of and better access to health facilities should have high attention and should be adjusted to the real need of the community. For rural areas, improving the access to health facilities become high attention by either lowering the health cost or by providing public transport facility for easy access.

(D) **Last priority: Areas with low risk due to low hazard and low vulnerability.**
This area is low risk area and last priority to be improved because it has low both hazard and vulnerability. The main task to this area is keep the environment in health condition. Campaign and community education to prevent both dengue, malaria and diarrhea is also important.

Setting of priority based on time

Temporal based setting of priority strategy requires the analysis of human and financial resources. Time wise, short term adaptation strategy incorporate what the local government can do first for the community based on the availability of the human resources and the availability of the financial support. The combination of priority setting based on high risk area and priority based on the ability and availability of the government is considered as the best strategy.

Midterm and long term adaptation strategy should incorporate the solving of fundamental issues such as over population, urbanization, unequal provision and distribution of health facilities, low provision of save water supply and poor sanitation. To formulate a midterm and long term strategy of adaptation, Bappeda should set the priority of fundamental conditions which cause the health problems. Detail explanation about this is described in Appendix D.

Setting of priority based on geographic condition and demography

Based on geographic condition and demography, two specific study areas can be determined, the urban and rural study area. Urban area is characterized by:
- Densely populated area
- High mobility
- Relatively easy access to health facility
- Relative complex of infrastructure and health sanitation
- Diminished natural sustainability.

Rural area is characterized by:
- Sparsely populated community housing
- Low mobility of its population
- Limited access to health facilities due to distance and means of transportation
- Relatively high level of social and community concern and care
- Basic and relatively simple infrastructure and health facilities
- Good environmental sustainability

Based on the differentiation on urban and rural area of study, different approach should be considered. Priority approach of urban area should be directed to:
- Re-development of slums and high density populated housings
- Better disease surveillance and monitoring of highly mobile population
- Better provision of health facilities and infrastructure for low income population
- Improving the ability of the community to early detection of vector borne diseases such as dengue and malaria
- Increase personal and public concern of the community on their own environment
- Integrated infrastructure management on environmental sanitation involving various stakeholders
- Proclamation of community Healthy City and Healthy Markets
- Strict control and supervision of its natural environmental sustainability

Adaptation priorities for rural areas include:
- Better community access to health facilities especially by narrowing the distance and making health transportation more available.
- To increase the participatory role of the community by reactivation of the now extinct POKJANAL (National Working Group on Health Activities) formerly promoted by kemendagri (the Ministry of Interior).
- Provision of free laboratory examination for dengue and malaria detection
- Infrastructure and environmental sanitation management based on natural condition and local sustainability.

In relation to climate change adaptation, priority should be given to the management of dengue, malaria and diarrhea in both rural and urban area. The adaptation strategy should include:
- A gradual shift of health policy from predominantly curative-mitigative to preventive-adaptive and promotive approach type of policy in the long run.
- Gradual shift in policy also occurred from following reactive strategy responding to health programs centrally directed, to more loosely proactive strategy responding to local

impact of climate change to improve the adaptive capacity and resilience of the local community.
- Shift is also expected gradually from policy of independency of the Ministry of Health to a multi institution teamwork managed together by various local authorities under the coordination of a higher level coordinator (provincial level). The adaptation strategy involves various authorities who include the ministry of health, public works, sanitation and BMKG (bureau of weather forecast and climatology). Involvement comes also from research centers and universities, NGOs, and community leaders.
- Health adaptation planning program is designed to be sustainable and integrated to the long term development planning of the city.

The detailed strategic implementation of adaptation against dengue, malaria and diarrhea are as follow:
- The policy shift from curative to preventive approach is manifested through the increase in the intensity of disease surveillance. Surveillance will be more accurately planned, integrated and sustainable. The 3M Plus Program becomes a priority, followed by fogging and distribution of Abate larvicide granules in mosquito breeding sites. Environmental health and sanitation program will have high priority as well.
- Shift from reactive to proactive policy is implemented by actively collecting and accumulating local data and information such as data on the prevalence and species of local vector mosquitoes, its habitat and n breeding preferences, to be used for control and eradication of the dengue malaria. Accumulation of local data on infectious diarrhea, characteristics of the local conditions is to be used to decrease the morbidity and mortality caused by diarrhea.
- Uncontrolled urbanization and population growth, if not managed properly my cause serious impact on health sector. Good and even population distribution policy may solve some of the overcrowding problem in the city. It may also solve the problem on per capita scarcity of health facilities in some areas and competition for the existing natural resources which may be the start of solving the health problem.
- Provision of clean water is the key to solve some of the health problems, especially infectious diseases and diseases of the environment. Low supplies of clean water in the study area indicate a better priority in the future. Improvement may dramatically solve many of the health problems and may significantly lower the morbidity and mortality of many diseases.
- Individual and integrated communal sanitation facilities in many areas of study are low or lacking. Improvement is needed for better integrated sanitation facility, waste water facility and clean water installation. Control of climate influenced diseases such as diarrhea may benefit from these improvements.
- Provision of clean water and sanitation facilities is a multi-sectored program activity. Its implementation requires integration into the mid- and longterm development planning.
- To get a better result, existing PSN Program (eradication of mosquito breeding habitat), should also put in mind the aspect of delivering the information, the number and qualification of its staff, the willingness of the head of the Puskesmas to implement the program in his work area, and the attitude shown to the community member. Working team should be formed for the extra work, together with the work distribution, and inter-relation with other organization.

CHAPTER 4 HAZARD ANALYSIS

This chapter provides results of hazard analysis related to climatic factors and diseases, including vector and water-borne disease. Climatic factors utilized in analysis covers temperature and rainfall, in which this study tries to assess their relationships with DHF, malaria and diarrhea incidence in Greater Malang. Since the study was conducted in micro-scale approach, calculation and analysis of hazard was done in sub-district/city levels. Greater Malang has high level of difference between district and the two cities, particularly in term of geographic and social pattern; therefore, micro-scale approach is the most appropriate study method to conduct. However, data availability is still a major concern and become the limiting factor contribute to incomprehensive outlook. Occurrence of diseases in the past and current time is used as hazard baseline and mathematical modeling is used to assess the future trend of hazard. Determination of the most appropriate mathematical modeling is explained in the following section.

4.1 Existing DHF Hazard Analysis in Correlation with Climate Condition

4.1.1 Description of Available Data

Generally, the incidence of DHF tend to increase prior to increment of rainfall. Figure 4.1 to Figure 4.3 Shows the trend of the DHF cases and monthly rainfall for five subsequent years. The graphic also provide basic information of the correlation between rainfall and DHF cases.

4.1.1.1 DHF Cases in Malang City

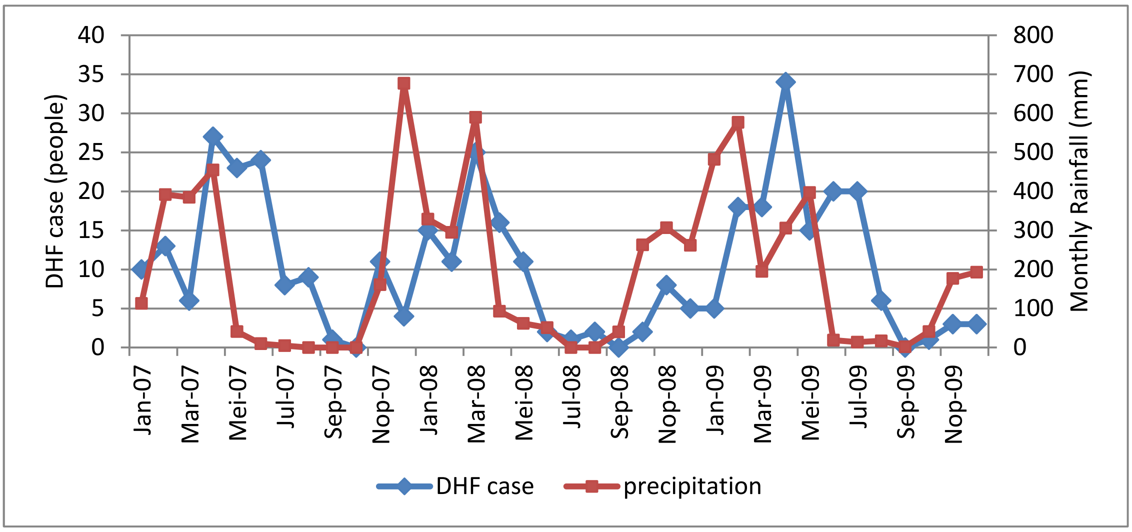


Figure 4.1 Trend of DHF Cases and Monthly Rainfall in Sukun for Year 2007-2009

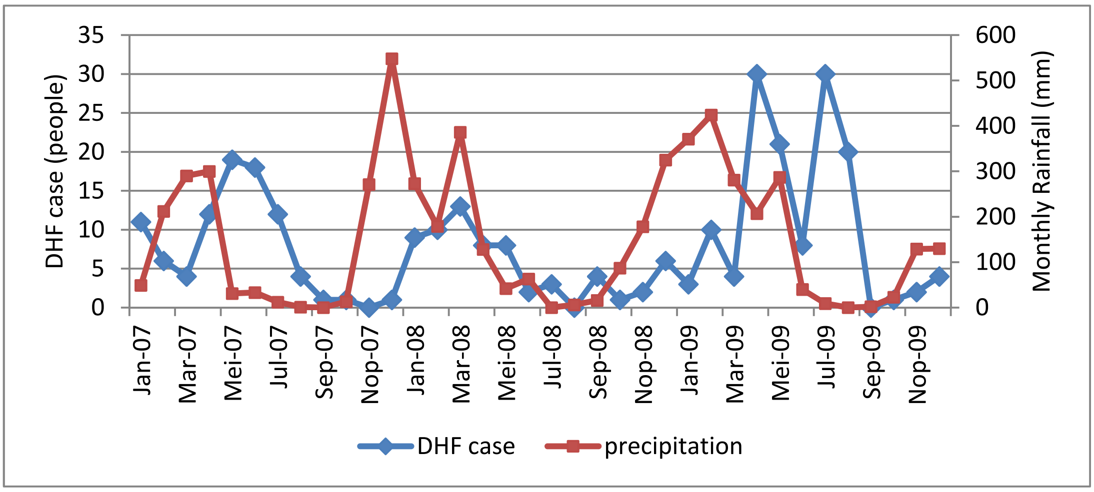


Figure 4.2 Trend of DHF Cases and Monthly Rainfall in Kedungkandang for Year 2007-2009

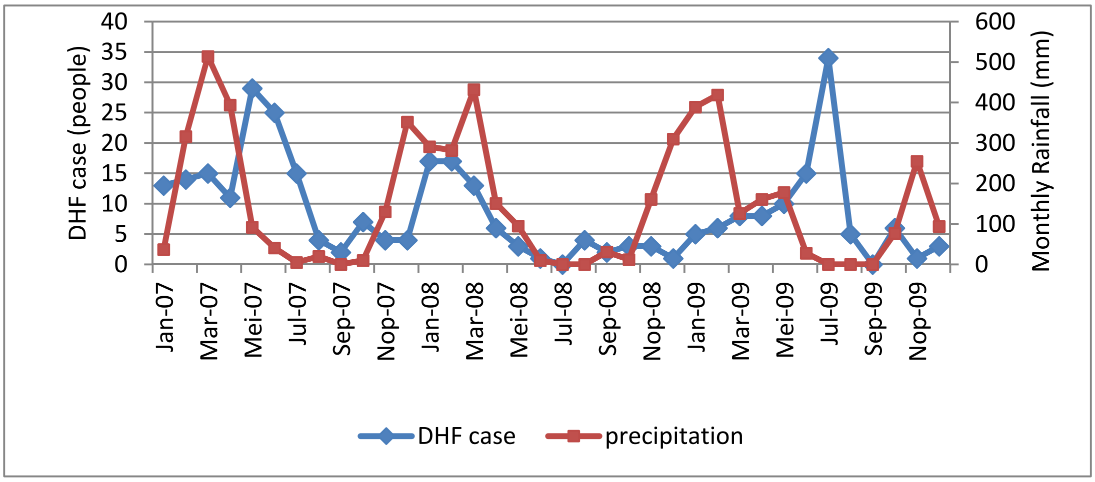


Figure 4.3 Trend of DHF Cases and Monthly Rainfall in Blimbing for Year 2007-2009

4.1.1.2 DHF Cases in Batu City

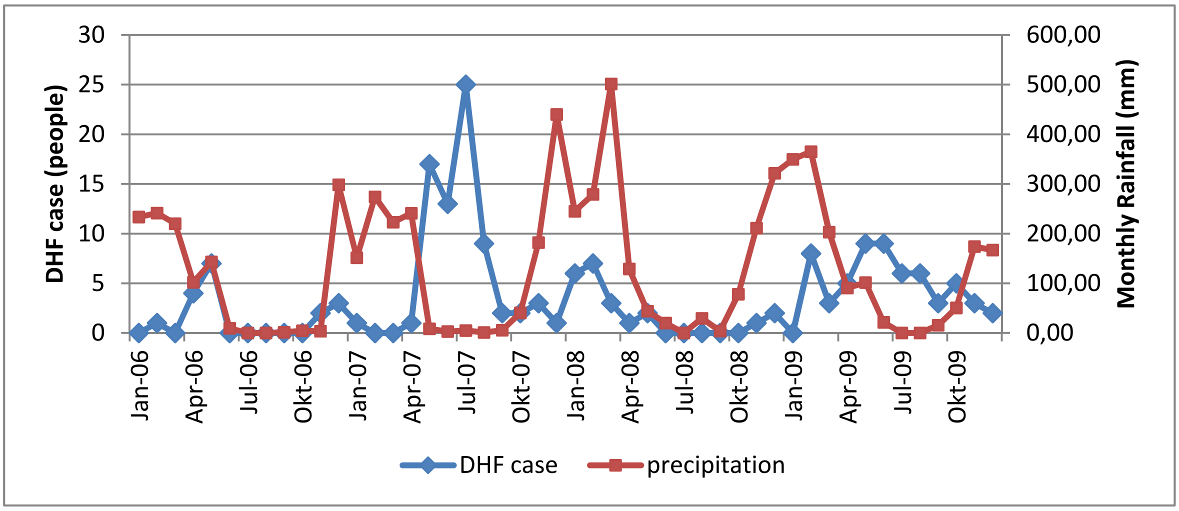


Figure 4.4 Trend of DHF Cases and Monthly Rainfall in Kota Batu for Year 2007-2009

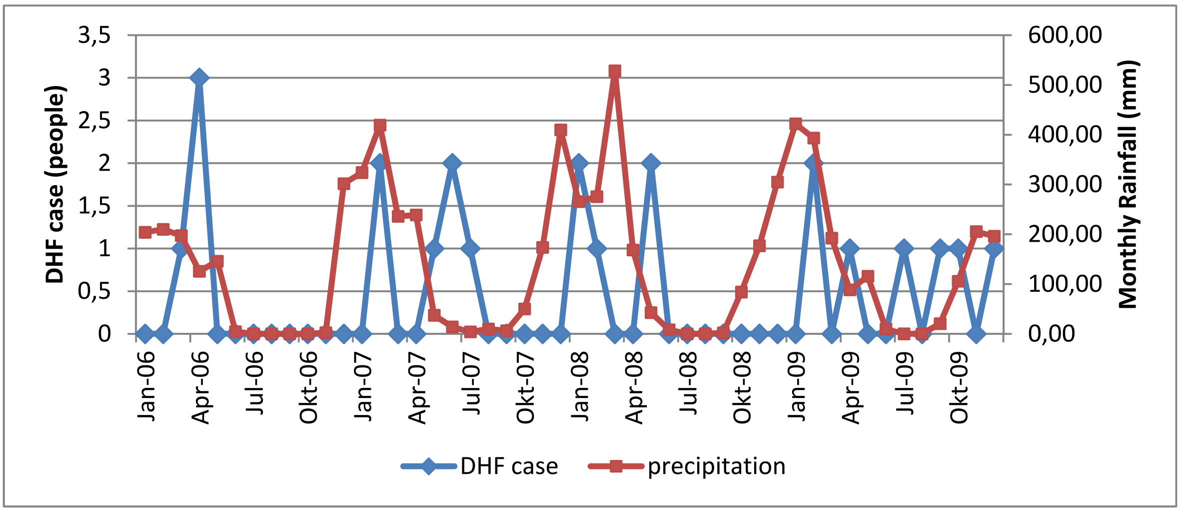


Figure 4.5 Trend of DHF Cases and Monthly Rainfall in Bumiaji for Year 2007-2009

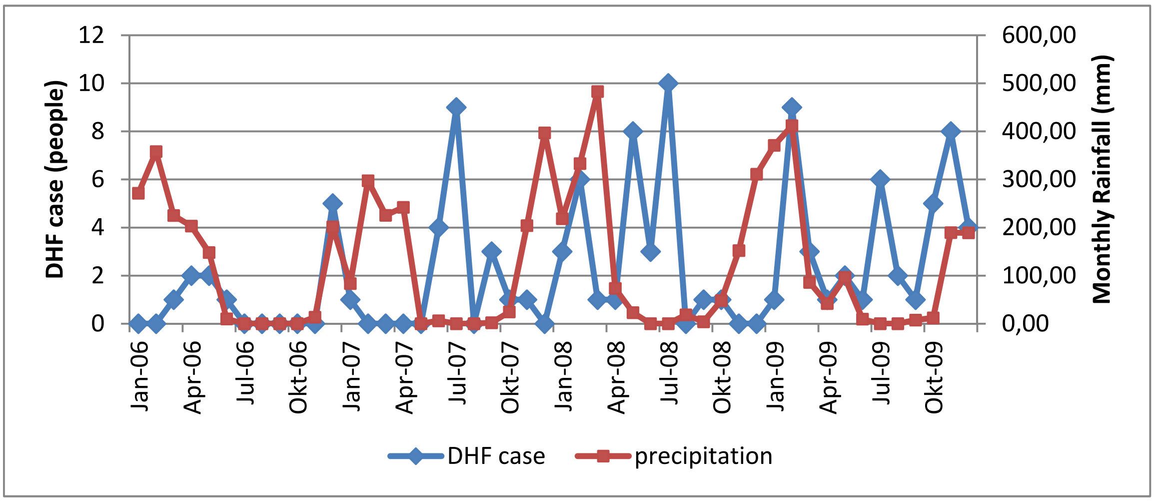


Figure 4.6 Trend of DHF Cases and Monthly Rainfall in Junrejo for Year 2007-2009

4.1.1.3 DHF Cases in Malang District

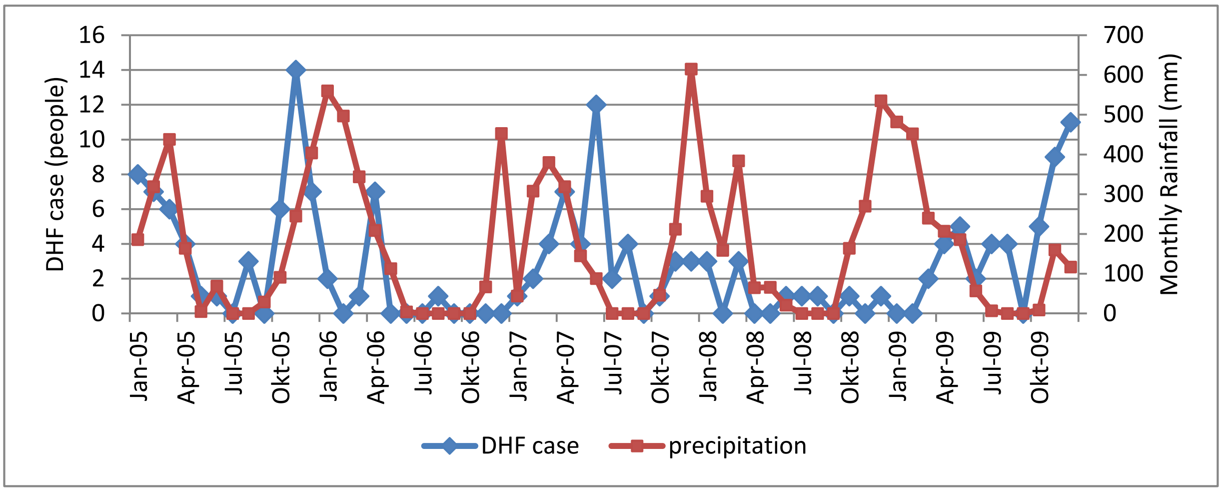


Figure 4.7 Trend of DHF Cases and Monthly Rainfall in Tumpang for Year 2007-2009

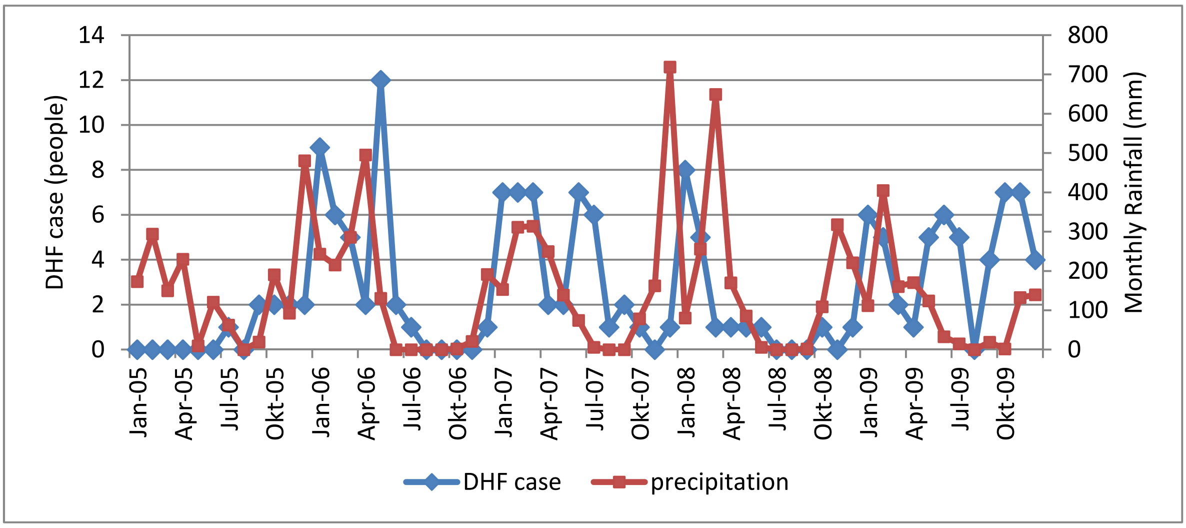


Figure 4.8 Trend of DHF Cases and Monthly Rainfall in Kepanjen for Year 2007-2009

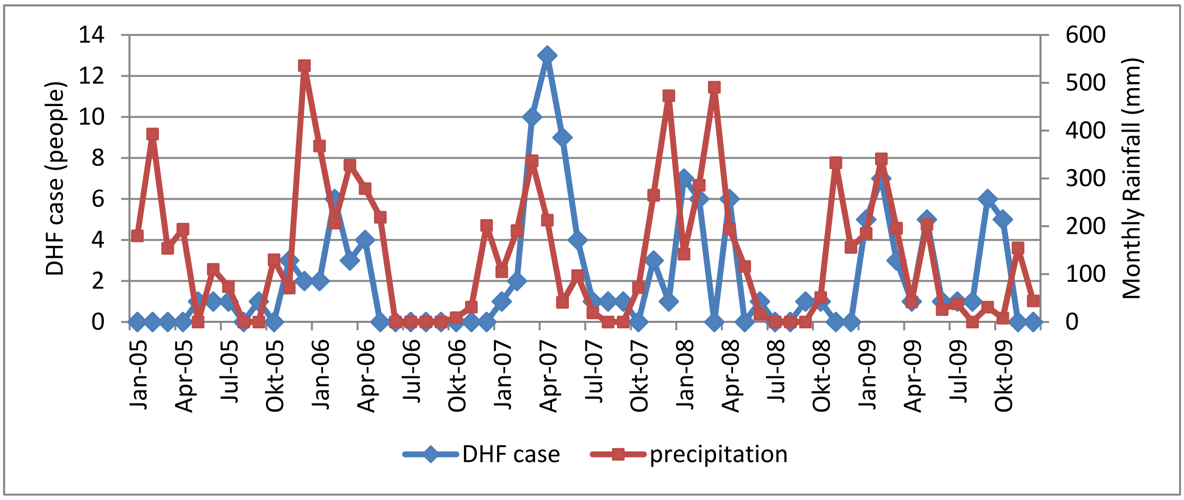


Figure 4.9 Trend of DHF Cases and Monthly Rainfall in Sumberpucung for Year 2007-2009

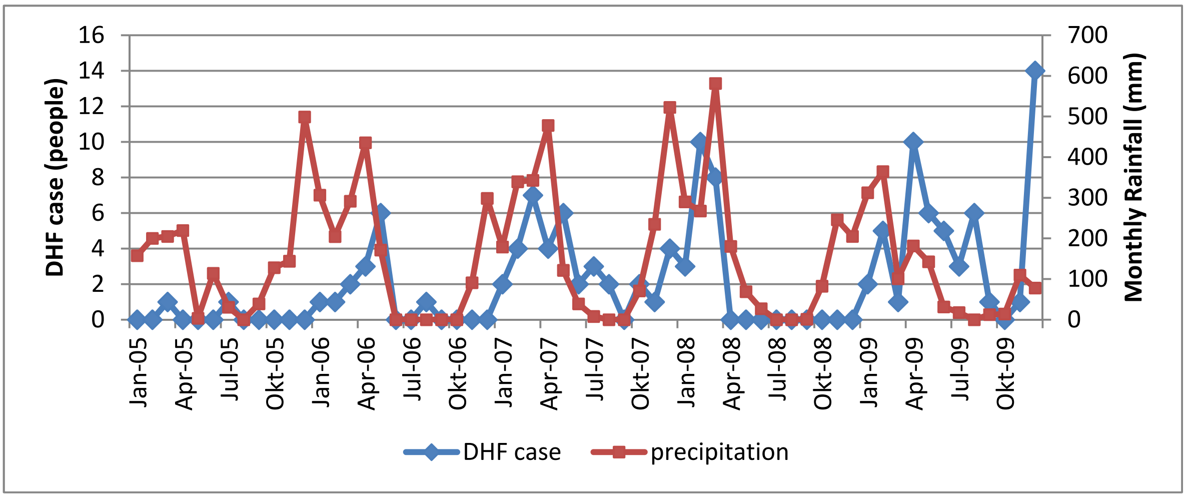


Figure 4.10 Trend of DHF Cases and Monthly Rainfall in Bululawang for Year 2007-2009

Figures below shows the number of DHF cases and prevalence rate of DHF in Malang District for three subsequent years, 2008-2009, by GIS presentation. DHF is more likely to occur in more densely populated. However, marked improvement was seen in 2007 with lower DHF cases.

(a)

(b)

(c)

Figure 4.11 DHF Case in Malang District for Year (a) 2007, (b) 2008, and (c) 2009.

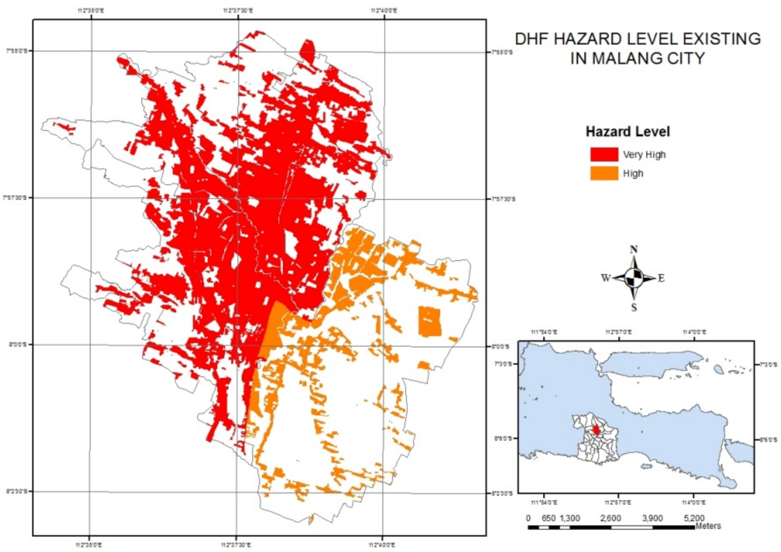
4.1.2 Results of Existing Hazard Analysis of DHF in Greater Malang

Hazard analysis is calculated based on percentile rank positioning. The percentile 0-5 become the border of each categories of hazard. The percentile was obtained from the summarize of prevalence rate of DHF in all region of Greater Malang for year 2007-2010 as a baseline.

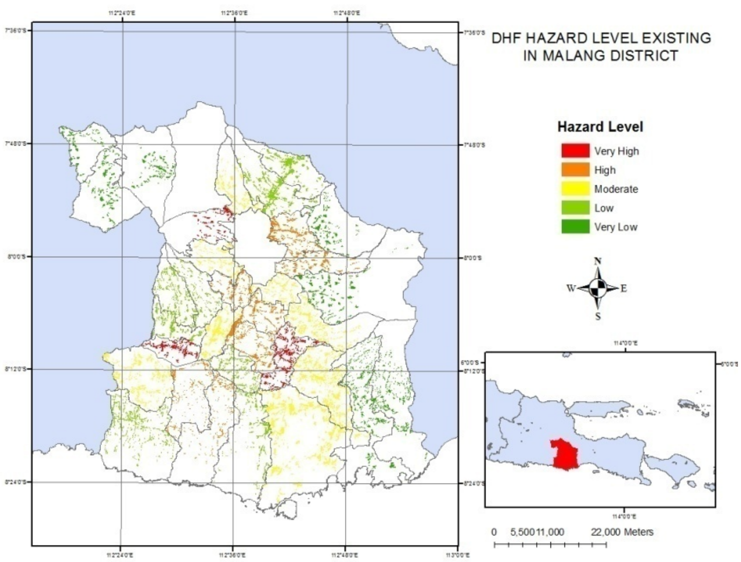
Table 4.1: Results of DHF Hazard Analysis in Greater Malang

No.	Sub Districts	Hazard		
		Population (2008)	Average Prevalence (2007-2010) /1,000 Occupants	Level
Malang City				
1	Kedung Kandang	162,104	0.532	High
2	Sukun	174,868	0.707	Very High
3	Klojen	126,760	1.125	Very High
4	Blimbing	171,051	0.601	Very High
5	Lowok Waru	181,854	0.696	Very High
Malang District				
6	Tumpang	73,651	0.453	High
7	Poncokusumo	89,701	0.089	Very Low
8	Jabung	74,572	0.107	Very Low
9	Pakis	132,502	0.561	High
10	Lawang	111,125	0.185	Low
11	Singosari	160,620	0.185	Low
12	Karangploso	70,702	0.325	Moderate
13	Dau	52,045	0.803	Very High
14	Pujon	63,724	0.026	Very Low
15	Ngantang	53,501	0.075	Very Low
16	Kasembon	31,543	0.032	Very Low
17	Kepanjen	105,969	0.358	Moderate
18	Sumber Pucung	49,825	0.690	Very High
19	Kromengan	37,019	0.270	Low
20	Pakisaji	81,891	0.572	High
21	Ngajum	48,209	0.180	Low
22	Wonosari	43,746	0.167	Low
23	Wagir	76,041	0.276	Moderate
24	Pagak	46,239	0.550	High
25	Donomulyo	66,683	0.245	Low
26	Kalipare	57,998	0.317	Moderate
27	Bantur	71,397	0.569	High
28	Gedangan	50,200	0.266	Low
29	Gondanglegi	81,316	0.477	High
30	Bululawang	65,249	0.571	High
31	Wajak	76,985	0.384	Moderate
32	Tajinan	47,560	0.308	Moderate
33	Turen	110,157	0.705	Very High
34	Dampit	125,762	0.277	Moderate
35	Sumbermanjing Wetan	98,591	0.289	Moderate

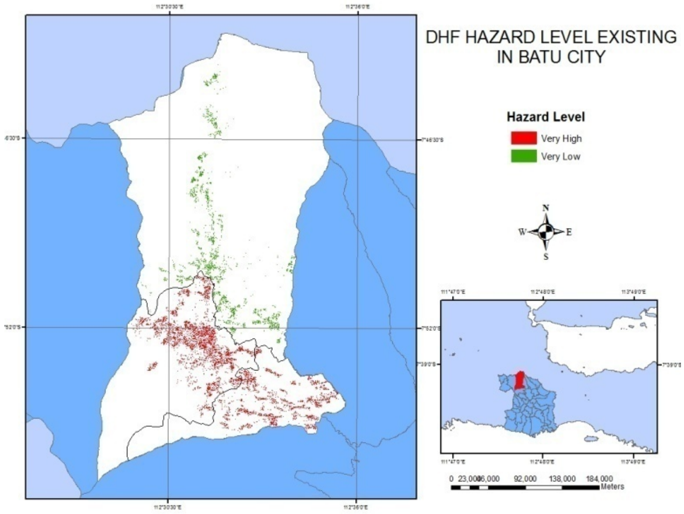
No.	Sub Districts	Hazard		
		Population (2008)	Average Prevalence (2007-2010) /1,000 Occupants	Level
36	Ampelgading	55,380	0.096	Very Low
37	Tirtoyudo	66,935	0.080	Very Low
38	Pagelaran	62,181	0.175	Low
Batu City				
39	Batu	89,843	0.592	Very High
40	Junrejo	45,340	0.692	Very High
41	Bumiaji	56,876	0.109	Very Low



(a)



(b)



(c)

Figure 4.12 Existing DHF Hazard Level in: Malang City (a), Malang District (b), Batu City (c)

4.2 Future Projection of DHF Hazard Using Compartment and Poisson Regression Model in Correlation with Climate Change

4.2.1 Estimation of Existing DHF Hazard by Using Compartment Model

Hazard analysis by means of mathematical modeling is conducted for every sub districts in Greater Malang that mentioned in the earlier chapter. Required data in this assessment are monthly DHF incidence rate, monthly rainfall and temperature, and population. Population data and monthly DHF cases were collected from Health Department of Malang for years 2005-2010, while Scientific Basis Team provide the temperature and rainfall data. Figure 4.1 illustrate the trend of DHF incidence rate in each sub-districts of Malang City, Malang District and Batu City.

The compartment model approach the trend of disease occurrence by following the rainfall or temperature trends. However, the population number is influencing as well. It is seen that the estimated DHF more accurately follow the trend of actual disease in rainfall as main factor. The error of estimation is higher in areas with higher number of DHF.

The final results from the compartment model are the constant number (μ) and the coefficient number (b). These two numbers is used in the equation for calculate the estimation of disease in corresponding year. Therefore, the most fitted μ and b constant is chosen from the period which has the least difference of annual average cases between the actual and estimated case. These constant is utilized in future hazard projection in the next section. The estimation of actual case by compartment model is established in sub districts level. Therefore, the number of case in Greater Malang is based on the summation of each sub districts. Figure 4.18 shows the actual and estimated DHF case in Malang District, Malang City, Batu City and Dau Sub district using the compartment model equation. Calculation in sub districts levels are calculated In the similar manner.

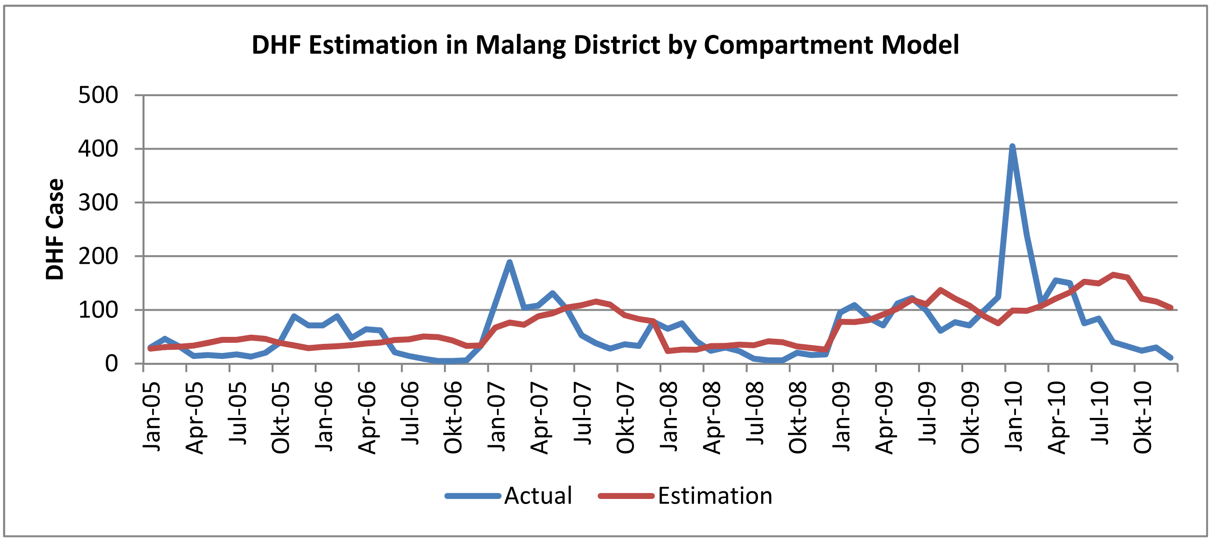


Figure 4.13 Compartment Model Calculation for Estimation Existing DHF in Malang District

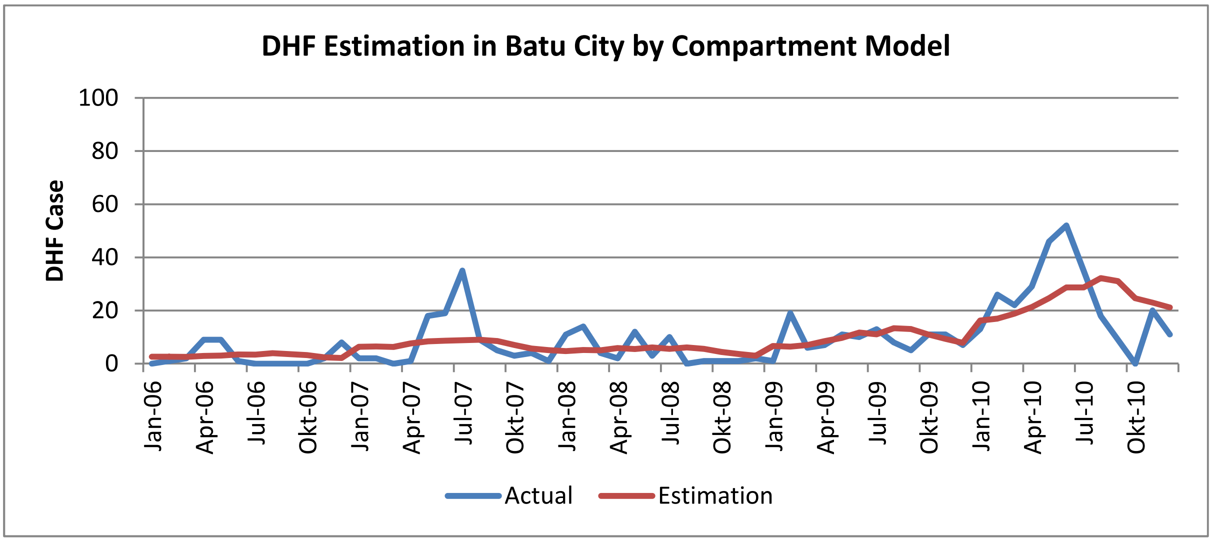


Figure 4.14 Compartment Model Calculation for Estimation Existing DHF in Batu City

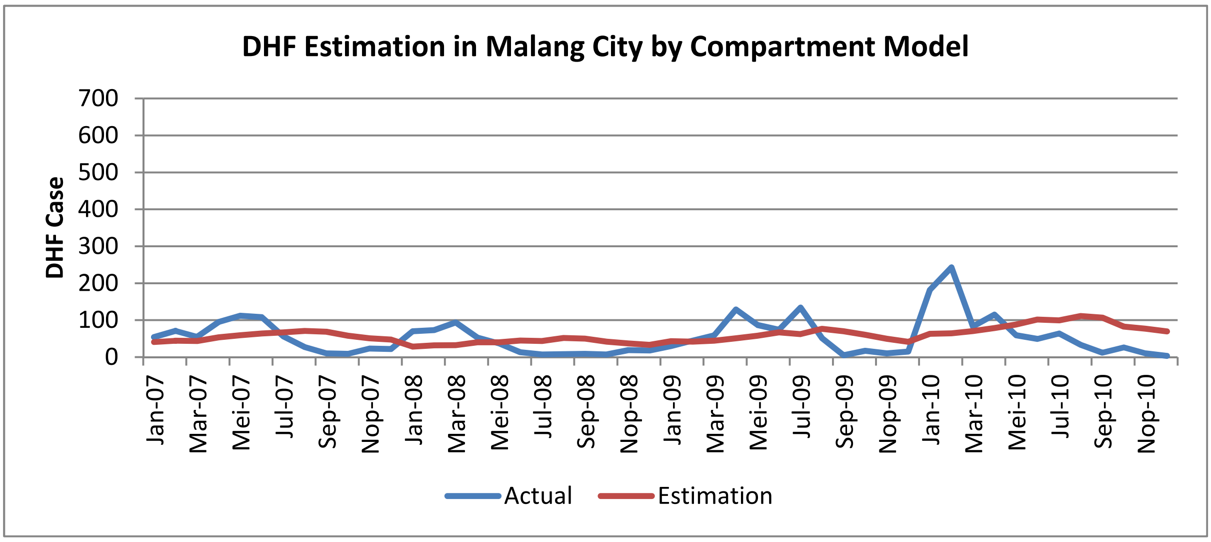


Figure 4.15 Compartment Model Calculation for Estimation Existing DHF in Malang City

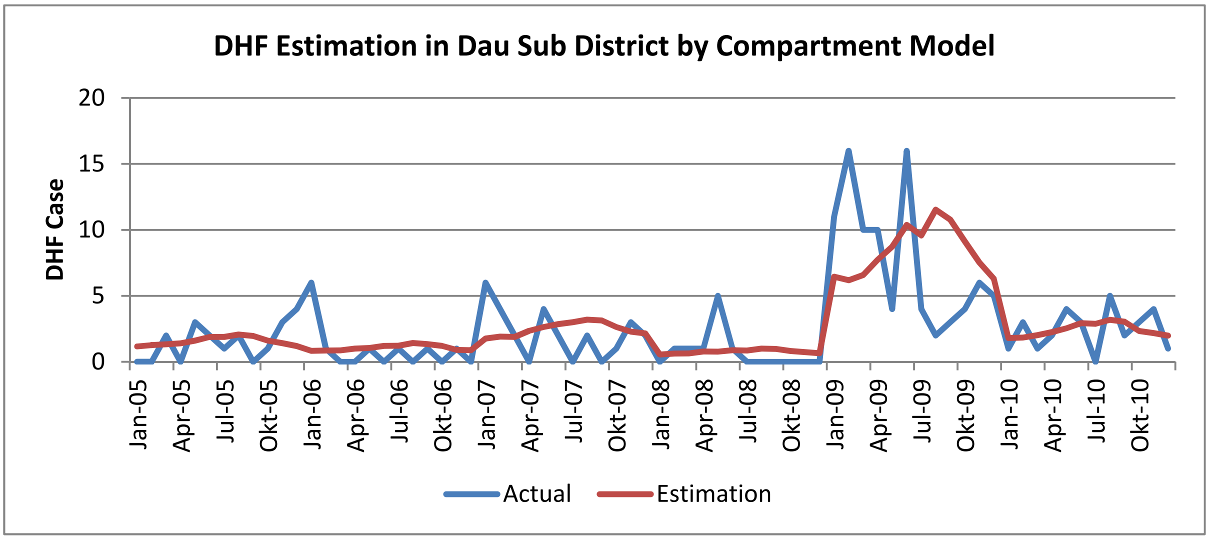


Figure 4.16 Compartment Model Calculation for Estimation Existing DHF in Dau Sub District

4.2.2 Results of DHF Hazard Projection 2030 by Compartment Model

The constant b and μ in the fittest actual and estimated DHF is then choosen to build future projection of DHF in Greater Malang. Other data required are the projection of population number and climatic variable, such as rainfall and temperature. Figure below shows the projection of DHF in Malang City, Malang District and Batu City. Other districts are calculated in the same manner and the results are outlined in Table 4.15

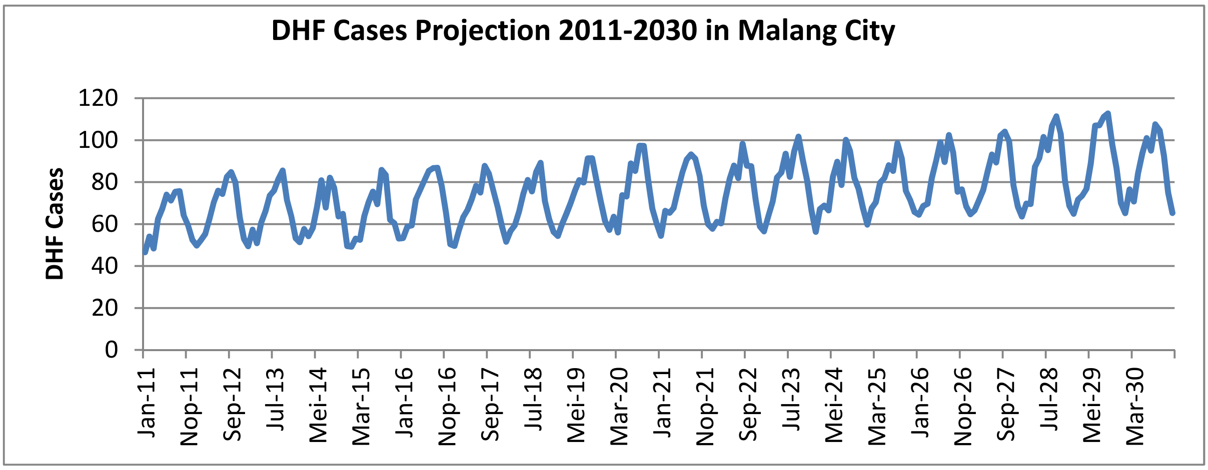


Figure 4.17 DHF Hazard Projection 2011-2030 for Malang City

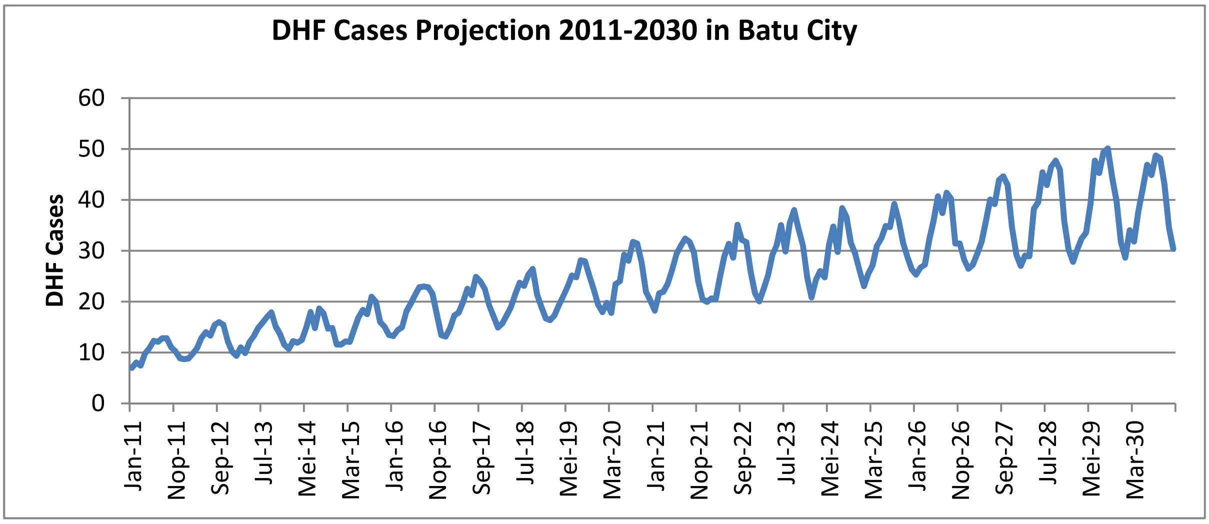


Figure 4.18 DHF Hazard Projection 2011-2030 for Batu City

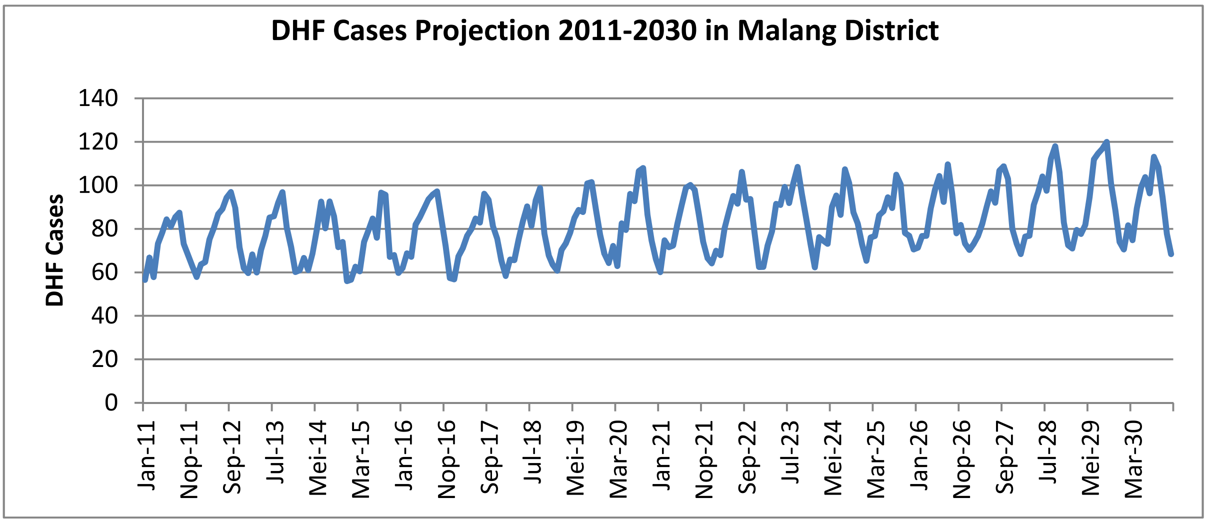


Figure 4.19 DHF Hazard Projection 2011-2030 for Malang District

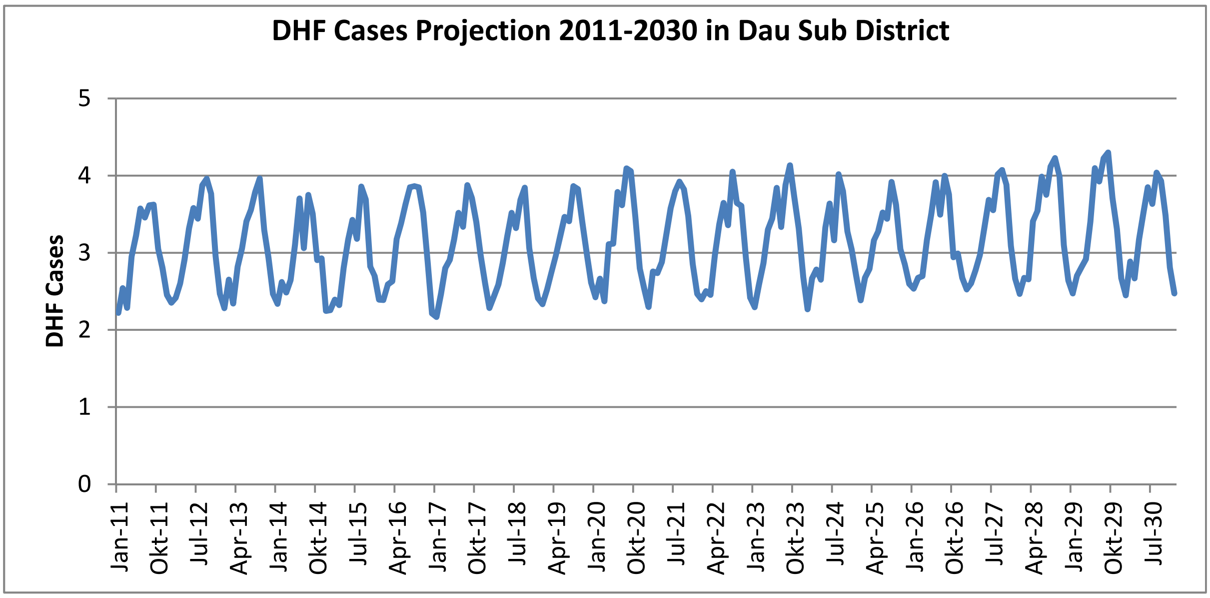


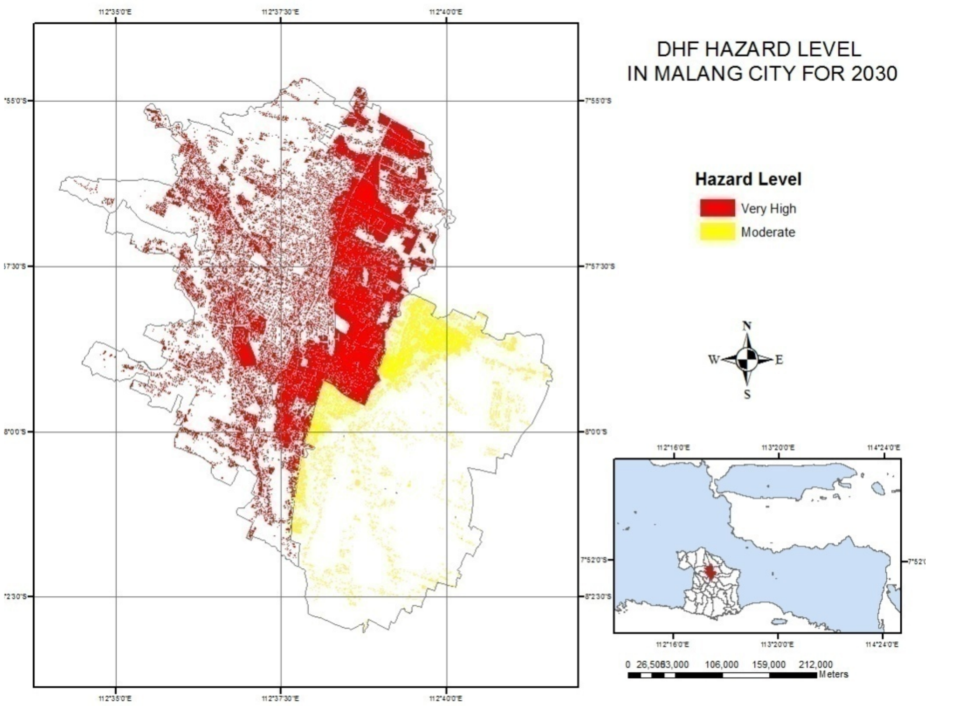
Figure 4.20 DHF Hazard Projection 2011-2030 for Dau Sub District

Results of hazard projection using the compartment model are outlined in the table below. While the GIS map or future hazard are shown in Figure 4.21.

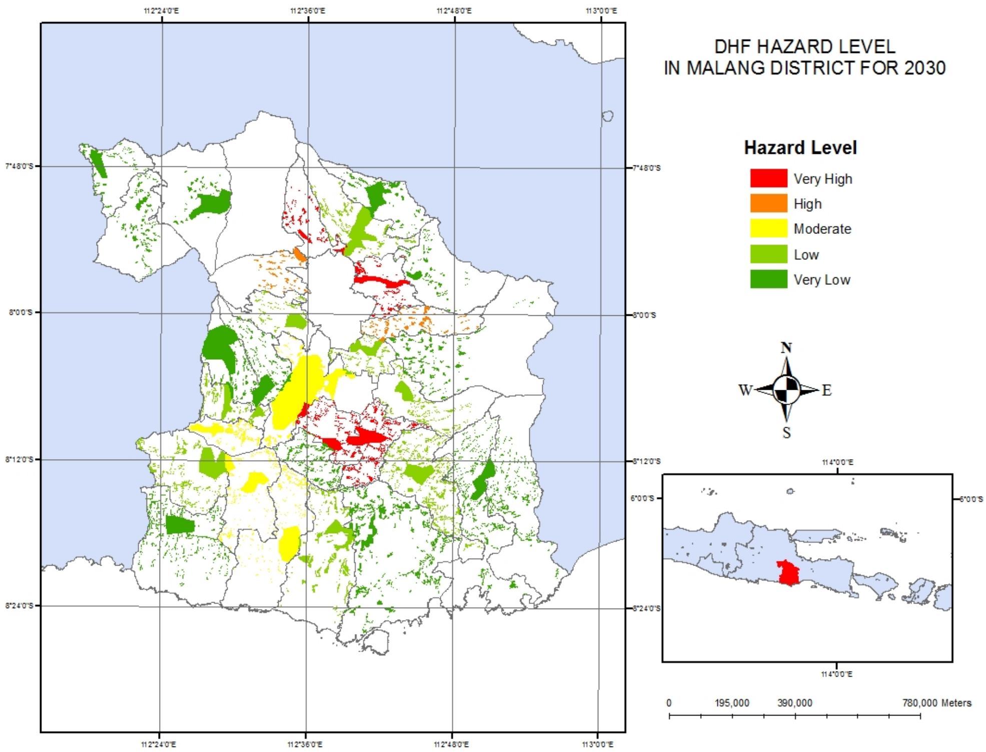
Table 4.2: Categories of DHF Hazard in 2030

No.	Sub Districts	Hazard		
		Population (2030)	Average Prevalence (2030) /1,000 Occupants	Level (2030)
Malang City				
1	Kedung Kandang	291,410	0.4	Moderate
2	Sukun	206,420	1.0	Very High
3	Klojen	108,790	2.4	Very High
4	Blimbing	197,010	0.9	Very High
5	Lowok Waru	287,130	0.9	Very High
Malang District				
6	Tumpang	110,484	0.5	High
7	Poncokusumo	127,702	0.1	Very Low
8	Jabung	103,319	0.2	Very Low
9	Pakis	169,905	1.0	Very High
10	Lawang	138,176	0.2	Very Low
11	Singosari	217,268	0.2	Low
12	Karangploso	83,014	0.6	Very High
13	Dau	84,696	0.5	High
14	Pujon	93,352	0.0	Very Low
15	Ngantang	83,567	0.1	Very Low
16	Kasembon	44,879	0.1	Very Low
17	Kepanjen	138,788	0.4	Moderate

No.	Sub Districts	Hazard		
		Population (2030)	Average Prevalence (2030) /1,000 Occupants	Level (2030)
18	Sumber Pucung	82,257	0.4	Moderate
19	Kromengan	58,195	0.2	Low
20	Pakisaji	110,763	0.4	Moderate
21	Ngajum	73,402	0.1	Very Low
22	Wonosari	68,230	0.1	Very Low
23	Wagir	108,633	0.2	Low
24	Pagak	75,122	0.4	Moderate
25	Donomulyo	118,855	0.2	Very Low
26	Kalipare	99,617	0.2	Low
27	Bantur	105,872	0.3	Moderate
28	Gedangan	75,560	0.2	Low
29	Gondanglegi	80,121	0.9	Very High
30	Bululawang	90,470	0.4	Moderate
31	Wajak	125,670	0.2	Low
32	Tajinan	72,188	0.2	Low
33	Turen	162,295	0.7	Very High
34	Dampit	175,207	0.2	Low
35	Sumbermanjing Wetan	140,892	0.2	Very Low
36	Ampelgading	85,014	0.1	Very Low
37	Tirtoyudo	94,308	0.1	Very Low
38	Pagelaran	98,889	0.1	Very Low
Batu City				
39	Batu	142,103	2.4	Very High
40	Junrejo	77,748	1.3	Very High
41	Bumiaji	89,794	0.4	Moderate


DHF HAZARD LEVEL
IN MALANG CITY FOR 2030
Hazard Level
Very High
Moderate
N
W
E
S
0 26,500 53,000 106,000 159,000 212,000
Meters

(a)


DHF HAZARD LEVEL
IN MALANG DISTRICT FOR 2030
Hazard Level
Very High
High
Moderate
Low
Very Low
N
W
E
S
0 195,000 390,000 780,000 Meters

(b)

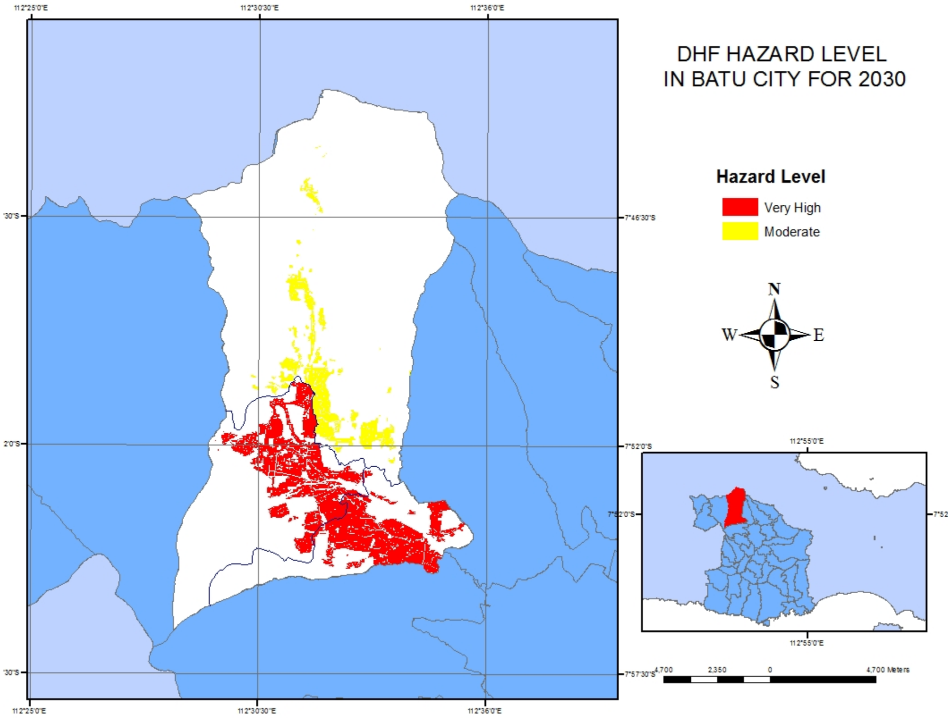


Figure 4.21 Hazard Map of DHF Projection 2030 in: Malang City (a), Malang District (b), Batu City (c)

4.3 Comparison of DHF Hazard Levels in 2008 and 2030

Comparison of DHF hazard levels in Malang for 2008 and 2030 is described in Table 4.3 below.

Table 4.3: Comparison of Existing and Future Hazard Categorization for DHF in Malang

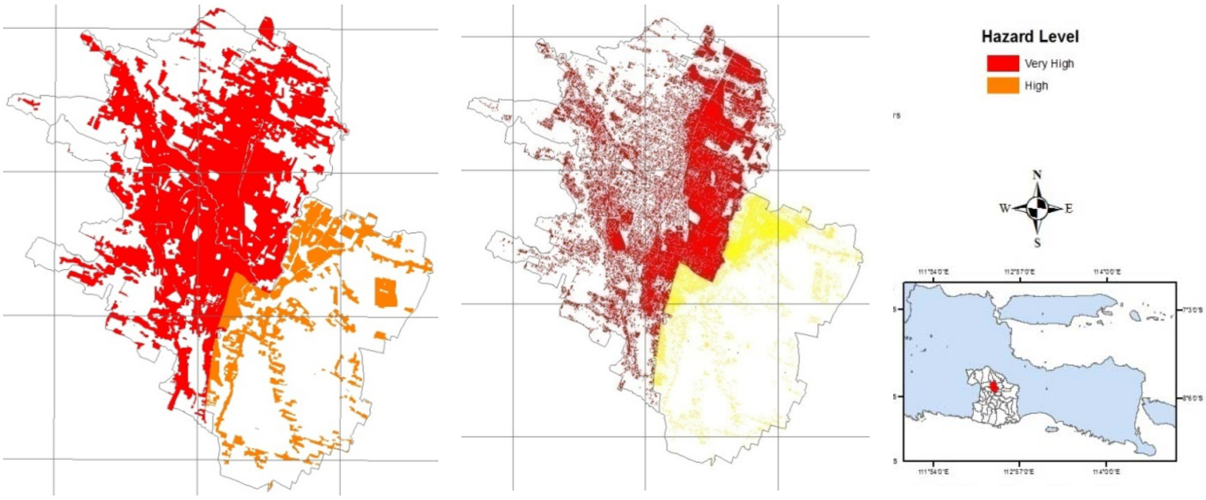
No	Sub Districts	Hazard (DHF)				Comparison
		Average Prevalence (2007-2010) /1,000 Occupants	Level (2007-2010)	Prevalence (2030) /1,000 Occupants	Level (2030)	
Malang City						
1	Kedung Kandang	0.532	High	0.4	Moderate	-1
2	Sukun	0.707	Very High	1.0	Very High	0
3	Klojen	1.125	Very High	2.4	Very High	0
4	Blimbing	0.601	Very High	0.9	Very High	0
5	Lowok Waru	0.696	Very High	0.9	Very High	0
Malang District						
6	Tumpang	0.453	High	0.5	High	0
7	Poncokusumo	0.089	Very Low	0.1	Very Low	0
8	Jabung	0.107	Very Low	0.2	Very Low	0
9	Pakis	0.561	High	1.0	Very High	+1
10	Lawang	0.185	Low	0.2	Very Low	-1

No	Sub Districts	Hazard (DHF)				Comparison
		Average Prevalence (2007-2010) /1,000 Occupants	Level (2007-2010)	Prevalence (2030) /1,000 Occupants	Level (2030)	
11	Singosari	0.185	Low	0.2	Low	0
12	Karangploso	0.325	Moderate	0.6	Very High	+2
13	Dau	0.803	Very High	0.5	High	-1
14	Pujon	0.026	Very Low	0.0	Very Low	0
15	Ngantang	0.075	Very Low	0.1	Very Low	0
16	Kasembon	0.032	Very Low	0.1	Very Low	0
17	Kepanjen	0.358	Moderate	0.4	Moderate	0
18	Sumber Pucung	0.690	Very High	0.4	Moderate	-2
19	Kromengan	0.270	Low	0.2	Low	0
20	Pakisaji	0.572	High	0.4	Moderate	-1
21	Ngajum	0.180	Low	0.1	Very Low	-1
22	Wonosari	0.167	Low	0.1	Very Low	-1
23	Wagir	0.276	Moderate	0.2	Low	-1
24	Pagak	0.550	High	0.4	Moderate	-1
25	Donomulyo	0.245	Low	0.2	Very Low	-1
26	Kalipare	0.317	Moderate	0.2	Low	-1
27	Bantur	0.569	High	0.3	Moderate	-1
28	Gedangan	0.266	Low	0.2	Low	0
29	Gondanglegi	0.477	High	0.9	Very High	+1
30	Bululawang	0.571	High	0.4	Moderate	-1
31	Wajak	0.384	Moderate	0.2	Low	-1
32	Tajinan	0.308	Moderate	0.2	Low	-1
33	Turen	0.705	Very High	0.7	Very High	0
34	Dampit	0.277	Moderate	0.2	Low	-1
35	Sumbermanjing Wetan	0.289	Moderate	0.2	Very Low	-2
36	Ampelgading	0.096	Very Low	0.1	Very Low	0
37	Tirtoyudo	0.080	Very Low	0.1	Very Low	0
38	Pagelaran	0.175	Low	0.1	Very Low	-1
Batu City						
39	Batu	0.592	Very High	2.4	Very High	0
40	Junrejo	0.692	Very High	1.3	Very High	0
41	Bumiaji	0.109	Very Low	0.4	Moderate	+2

Note:

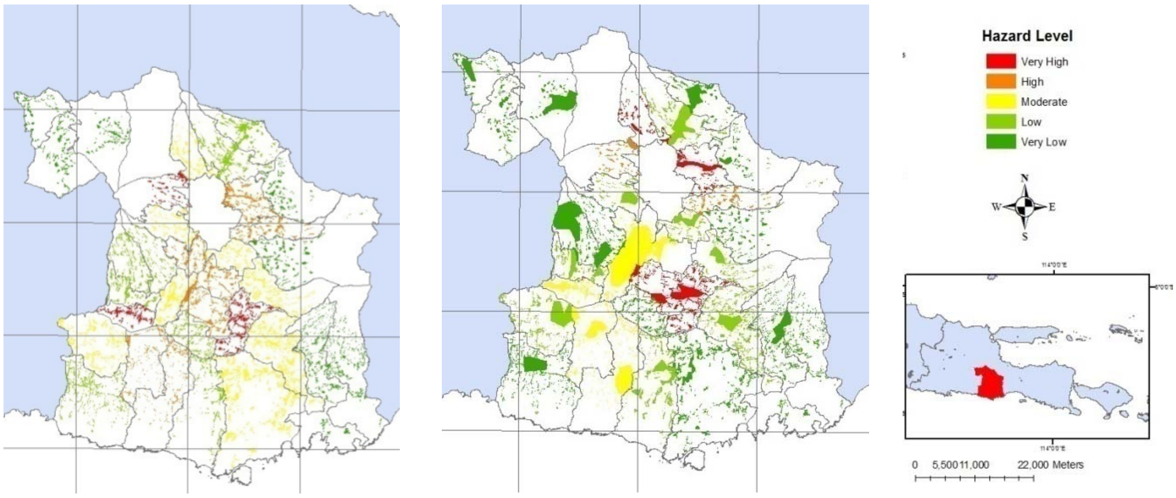
+1 : increase one level -1 : decrease one level
+2 : increase two level -2 : decrease two level
+3 : increase three level -3 : decrease three level
+4 : increase four level -4 : decrease four level
0 : same level

Comparison of DHF hazard map in Malang for 2008 and 2030 is described in Figure 4.22 below.



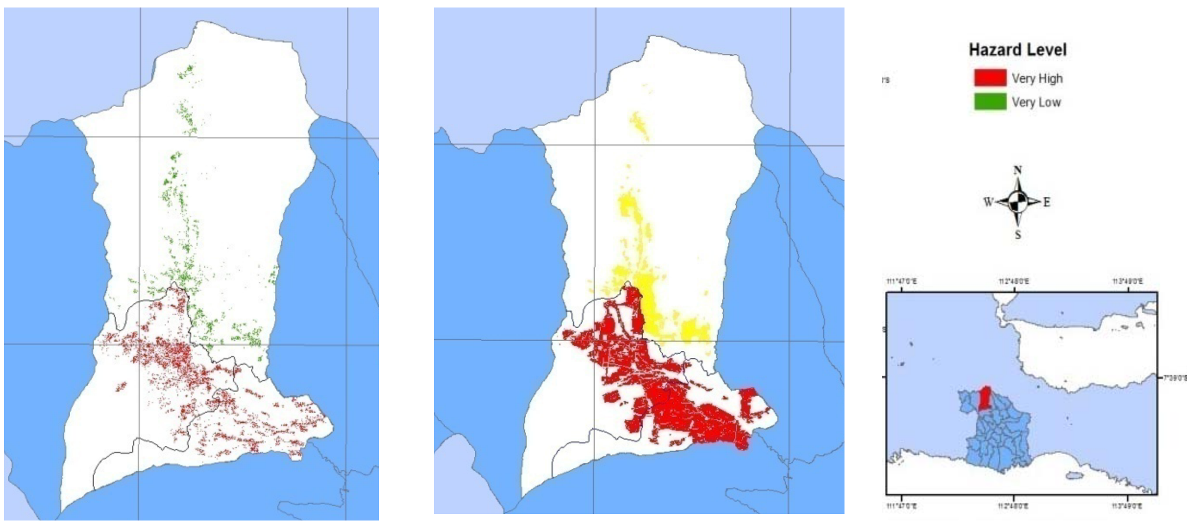
DHF Hazard Map 2008 DHF Hazard Map 2030

(a) DHF Hazard Level in Malang City



DHF Hazard Map 2008 DHF Hazard Map 2030

(b) DHF Hazard Level in Malang District



DHF Hazard Map 2008 DHF Hazard Map 2030

(c) DHF Hazard Level in Batu City

Figure 4.22 Comparison between DHF Hazard Map 2008 and 2030

4.4 Existing Malaria Hazard Analysis in Correlation with Climate Condition

4.4.1 Description of Available Data

Malaria is more likely to occur in more rural areas. Some of *Anopheles sp. a*re able to breed in the freshwater and brackish water. However they life is also depends on the availability of manrove in the shore areas. Since mangrove has protective effect toward malaria and DHF, high malaria case in southern area of Malang is also influenced by the diminished mangrove area. Data of malaria incidence only available for Malang District, therefore this hazard analysis only able to assess the risk of malaria in Malang District.

(a)

(b)

Figure 4.23 Malaria Occurrence in Malang District for: 2007 (a), 2008 (b), 2009 (c)

4.4.2 Results of Existing Malaria Hazard Analysis

Hazard analysis is calculated based on percentile rank positioning. The percentile 0-5 become the border of each categories of hazard. The percentile was obtained from the summarize of prevalence rate of Malaria in all region of Malang for year 2007-2010 as a baseline.

Table 4.4 Results of Existing Malaria Hazard Analysis in Malang District

No.	Sub District	Population (2008)	Average Prevalence (2007-2010) /1,000 populations	Level
1	Tumpang	73,651	0.0	Very Low
2	Poncokusumo	89,701	0.0	Very Low
3	Jabung	74,572	0.0	Very Low
4	Pakis	132,502	0.0	Very Low
5	Lawang	111,125	0.0	Very Low
6	Singosari	160,620	0.0	Very Low
7	Karangploso	70,702	0.0	Very Low
8	Dau	52,045	0.0	Very Low
9	Pujon	63,724	0.0	Low
10	Ngantang	53,501	0.0	Moderate
11	Kasembon	31,543	0.1	Moderate
12	Kepanjen	105,969	0.0	Low
13	Sumber Pucung	49,825	0.2	Moderate
14	Kromengan	37,019	0.0	Very Low
15	Pakisaji	81,891	0.0	Very Low
16	Ngajum	48,209	0.0	Very Low
17	Wonosari	43,746	0.0	Very Low
18	Wagir	76,041	0.0	Very Low
19	Pagak	46,239	0.0	Low
20	Donomulyo	66,683	0.1	Moderate
21	Kalipare	57,998	0.0	Very Low
22	Bantur	71,397	0.1	Moderate
23	Gedangan	50,200	0.0	Very Low
24	Gondanglegi	81,316	0.0	Very Low
25	Bululawang	65,249	0.0	Moderate
26	Wajak	76,985	0.0	Very Low
27	Tajinan	47,560	0.0	Low
28	Turen	110,157	0.0	Low
29	Dampit	125,762	0.0	Very Low
30	Sumbermanjing Wetan	98,591	0.1	Moderate
31	Ampelgading	55,380	0.0	Low
32	Tirtoyudo	66,935	0.0	Very Low
33	Pagelaran	62,181	0.0	Very Low

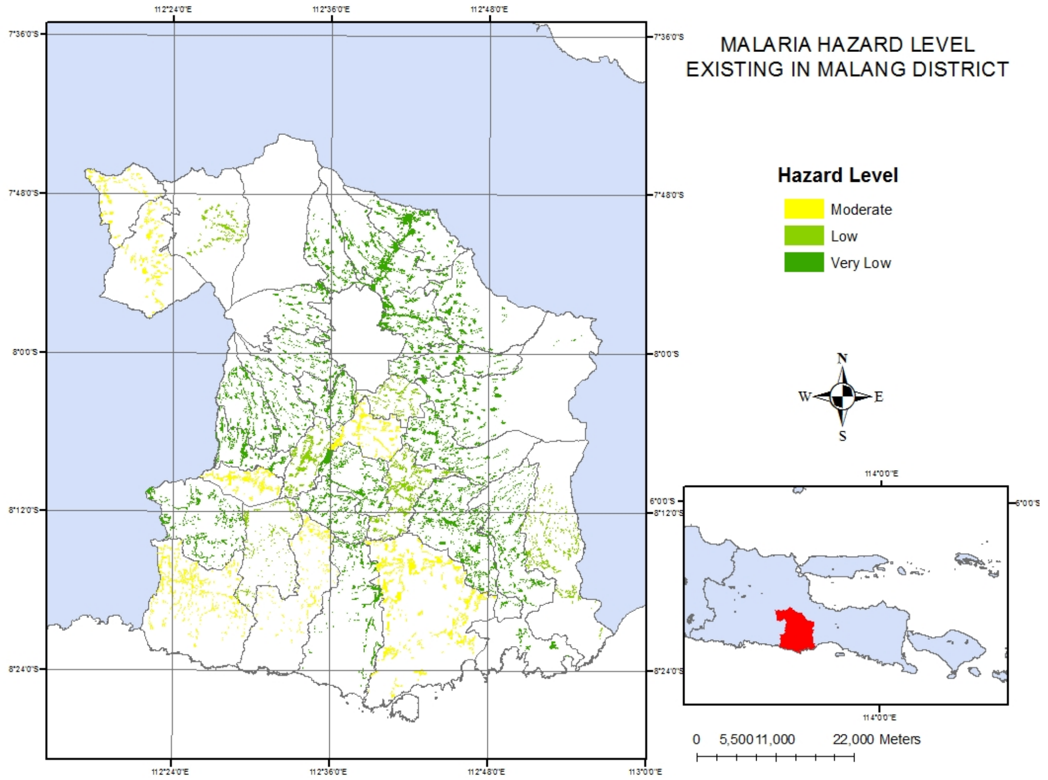


Figure 4.24 Hazard Map of Existing Malaria in Malang District

4.5 Future Projection of Malaria Hazard Using Compartment Model in Correlation with Climate Change

Since malaria only available in Malang District, the hazard of malaria in Malang City and Batu City are unable to be calculated.

4.5.1 Estimation of Existing Malaria Hazard by Using Compartment Model

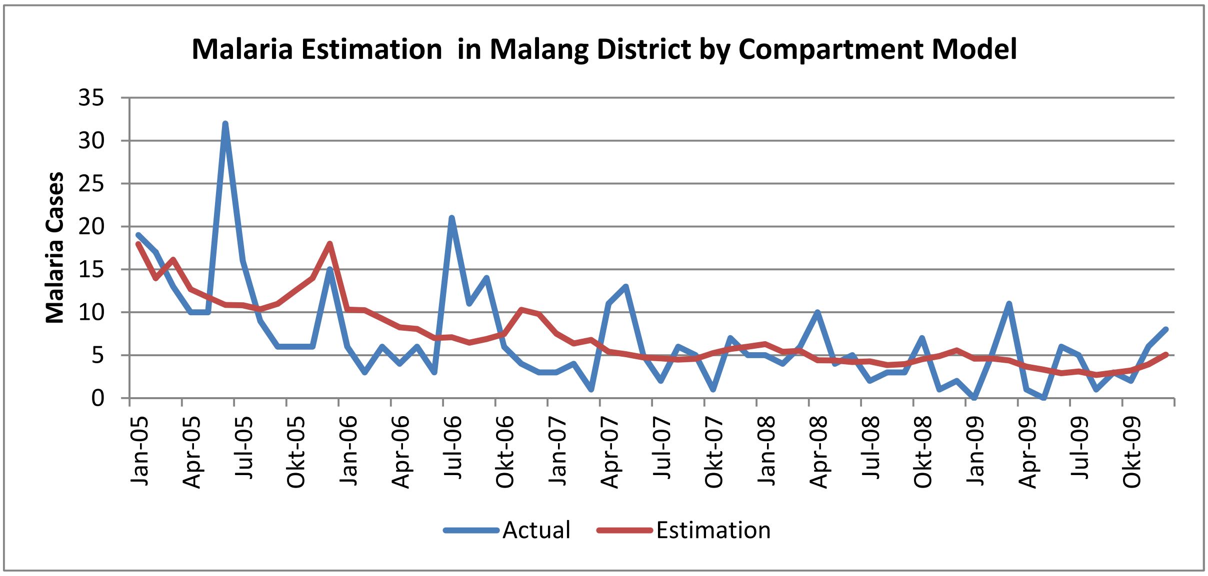


Figure 4.25 Malaria Estimation 2005-2009 in Malang District by Compartment Model

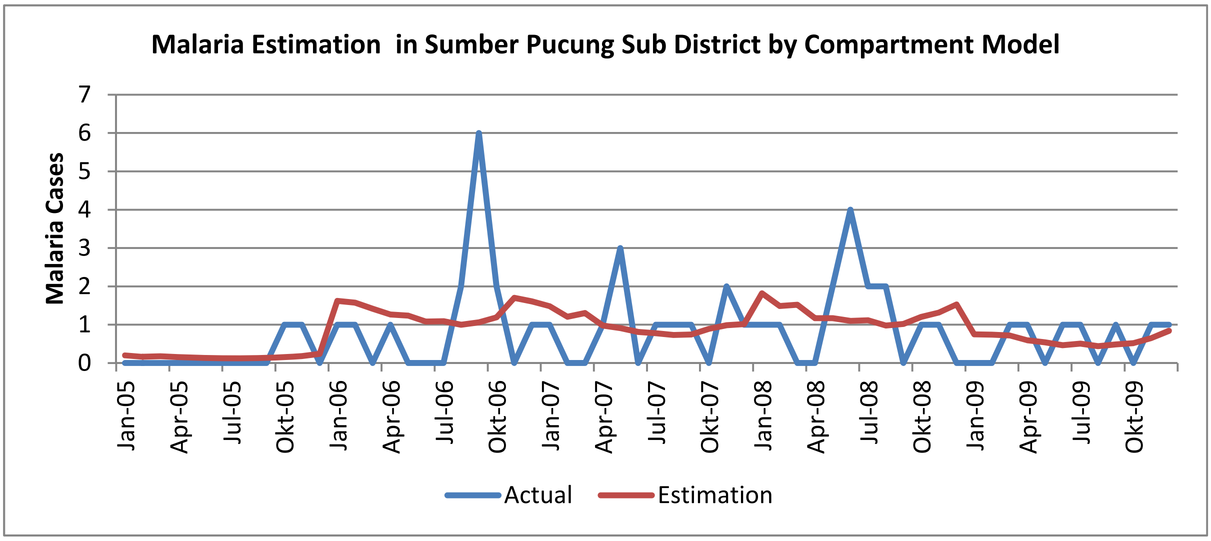


Figure 4.26 Malaria Estimation 2005-2009 in Sumber Pucung Sub District by Compartment Model

4.5.2 Results of DHF Hazard Projection 2030 by Compartment Model

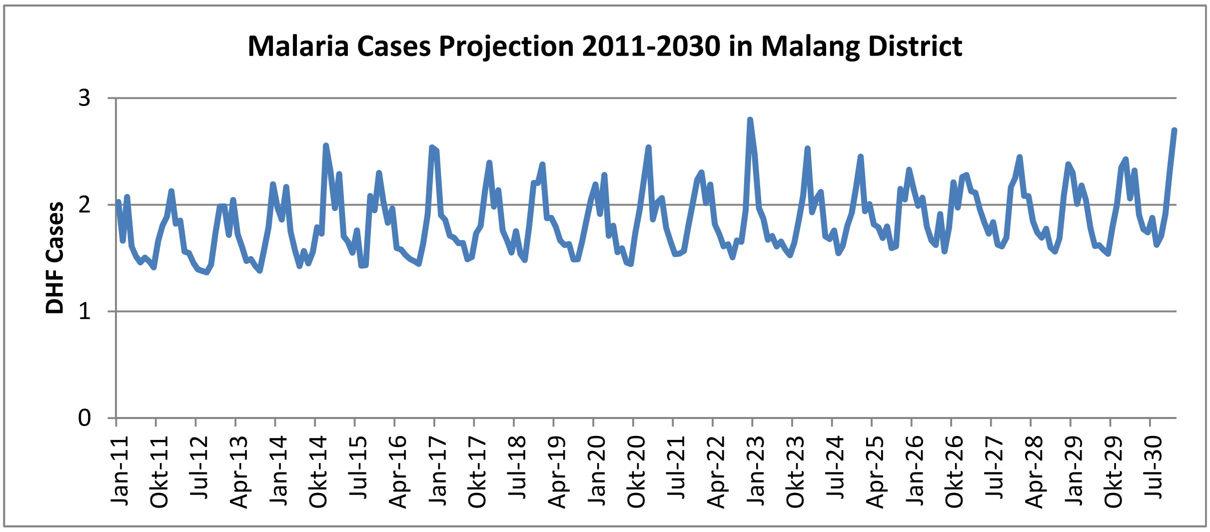


Figure 4.27 Malaria Hazard Projection 2011-2030 for Malang District

Table 4.5: Projection Hazard Categories of Malaria in Malang District

No.	Sub Districts	Hazard		
		Population (2030)	Average Prevalence (2030) /1,000 Occupants	Level (2030)
1	Tumpang	110,484	0	Very Low
2	Poncokusumo	127,702	0	Very Low
3	Jabung	103,319	0	Very Low
4	Pakis	169,905	0	Very Low
5	Lawang	138,176	0	Very Low

No.	Sub Districts	Hazard		
		Population (2030)	Average Prevalence (2030) /1,000 Occupants	Level (2030)
6	Singosari	217,268	0	Very Low
7	Karangploso	83,014	0	Very Low
8	Dau	84,696	0	Very Low
9	Pujon	93,352	0	Very Low
10	Ngantang	83,567	0	Very Low
11	Kasembon	44,879	0	Very Low
12	Kepanjen	138,788	0	Very Low
13	Sumber Pucung	82,257	0.03647	Moderate
14	Kromengan	58,195	0	Very Low
15	Pakisaji	110,763	0	Very Low
16	Ngajum	73,402	0	Very Low
17	Wonosari	68,230	0	Very Low
18	Wagir	108,633	0	Very Low
19	Pagak	75,122	0	Very Low
20	Donomulyo	118,855	0.06731	Moderate
21	Kalipare	99,617	0	Very Low
22	Bantur	105,872	0.08501	Moderate
23	Gedangan	75,560	0	Very Low
24	Gondanglegi	80,121	0	Very Low
25	Bululawang	90,470	0.01105	Very Low
26	Wajak	125,670	0	Very Low
27	Tajinan	72,188	0	Very Low
28	Turen	162,295	0.00616	Very Low
29	Dampit	175,207	0	Very Low
30	Sumbermanjing Wetan	140,892	0.02129	Low
31	Ampelgading	85,014	0	Very Low
32	Tirtoyudo	94,308	0	Very Low
33	Pagelaran	98,889	0	Very Low

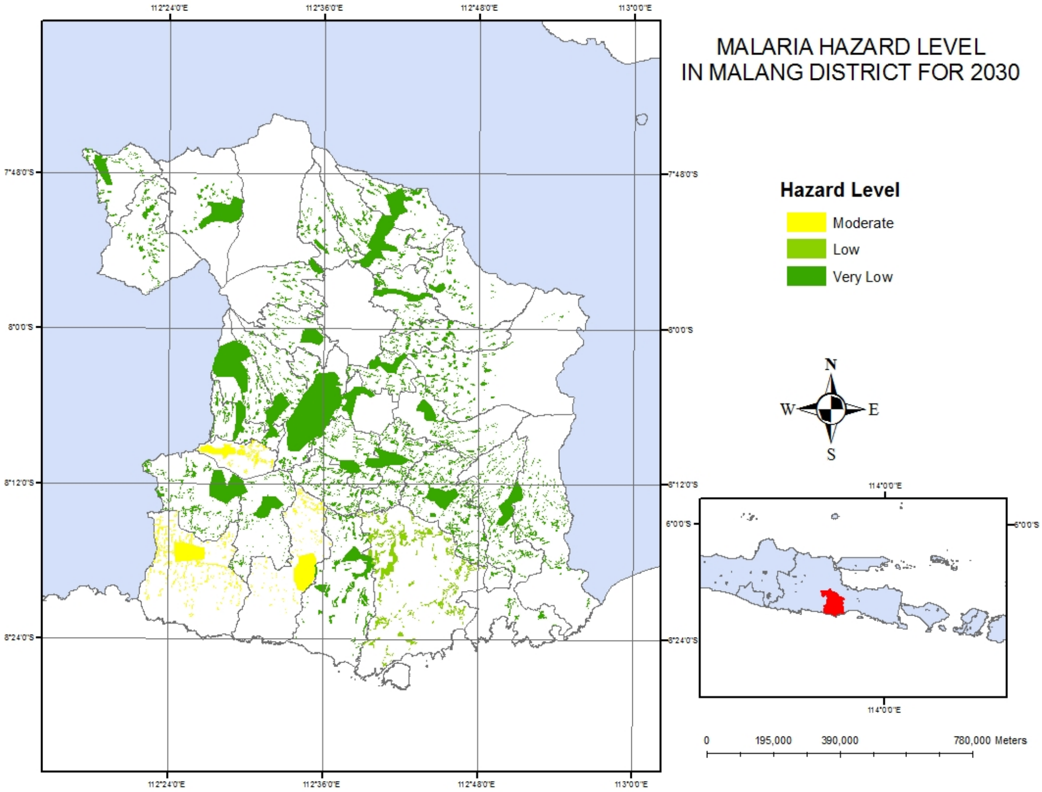


Figure 4.28 Hazard Map of Malaria Projection 2030 in Malang District

4.6 Comparison of Malaria Hazard Levels in 2008 and 2030

Comparison of Malaria hazard levels in Malang District in 2008 and 2030 is described in Table 4.6 below.

Table 4.6: Comparison of Existing and Future Hazard Categorization for Malaria in Malang District

No	Sub Districts	Hazard (Malaria)				Comparison
		Average Prevalence (2007-2010) /1,000 Occupants	Level (2008)	Prevalence (2030) /1,000 Occupants	Level (2030)	
1	Tumpang	0.0	Very Low	0	Very Low	0
2	Poncokusumo	0.0	Very Low	0	Very Low	0
3	Jabung	0.0	Very Low	0	Very Low	0
4	Pakis	0.0	Very Low	0	Very Low	0
5	Lawang	0.0	Very Low	0	Very Low	0
6	Singosari	0.0	Very Low	0	Very Low	0
7	Karangploso	0.0	Very Low	0	Very Low	0
8	Dau	0.0	Very Low	0	Very Low	0
9	Pujon	0.0	Low	0	Very Low	-1

No	Sub Districts	Hazard (Malaria)				Comparison
		Average Prevalence (2007-2010) /1,000 Occupants	Level (2008)	Prevalence (2030) /1,000 Occupants	Level (2030)	
10	Ngantang	0.0	Moderate	0	Very Low	-2
11	Kasembon	0.1	Moderate	0	Very Low	-2
12	Kepanjen	0.0	Low	0	Very Low	-1
13	Sumber Pucung	0.2	Moderate	0.03647	Moderate	0
14	Kromengan	0.0	Very Low	0	Very Low	0
15	Pakisaji	0.0	Very Low	0	Very Low	0
16	Ngajum	0.0	Very Low	0	Very Low	0
17	Wonosari	0.0	Very Low	0	Very Low	0
18	Wagir	0.0	Very Low	0	Very Low	0
19	Pagak	0.0	Low	0	Very Low	-1
20	Donomulyo	0.1	Moderate	0.06731	Moderate	0
21	Kalipare	0.0	Very Low	0	Very Low	0
22	Bantur	0.1	Moderate	0.08501	Moderate	0
23	Gedangan	0.0	Very Low	0	Very Low	0
24	Gondanglegi	0.0	Very Low	0	Very Low	0
25	Bululawang	0.0	Moderate	0.01105	Very Low	-2
26	Wajak	0.0	Very Low	0	Very Low	0
27	Tajinan	0.0	Low	0	Very Low	-1
28	Turen	0.0	Low	0.00616	Very Low	-1
29	Dampit	0.0	Very Low	0	Very Low	0
30	Sumbermanjing Wetan	0.1	Moderate	0.02129	Low	-1
31	Ampelgading	0.0	Low	0	Very Low	-1
32	Tirtoyudo	0.0	Very Low	0	Very Low	0
33	Pagelaran	0.0	Very Low	0	Very Low	0

Note:
+1 : increase one level -1 : decrease one level
+2 : increase two level -2 : decrease two level
+3 : increase three level -3 : decrease three level
+4 : increase four level -4 : decrease four level
0 : same level

Comparison of Malaria hazard map in Malang District for 2008 and 2030 is described in Figure 4.29 below.

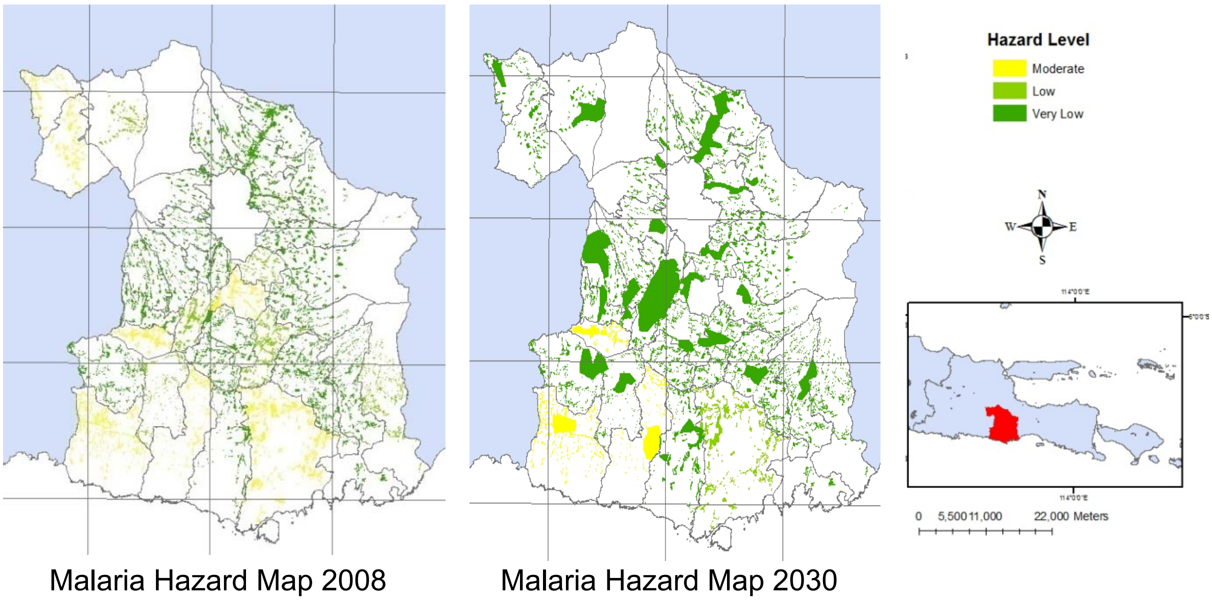


Figure 4.29 Comparison between Malaria Hazard Map 2008 and 2030

4.7 Existing Diarrhea Hazard Analysis in Correlation with Climate Condition

4.7.1 Description of Available Data

Figure 4.30 shows diarrhea occurrence in sub-district in Malang City for 2007-2009 and its prevalence is described in Figure 4.31.

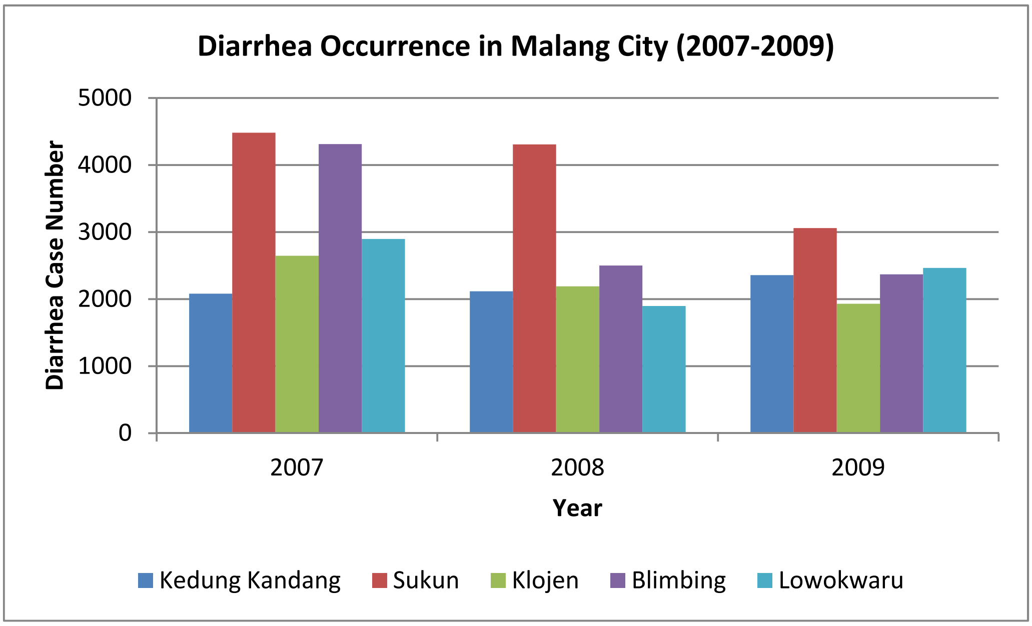


Figure 4.30 Diarrhea Occurrence in Sub districts of Malang City (2007-2009)

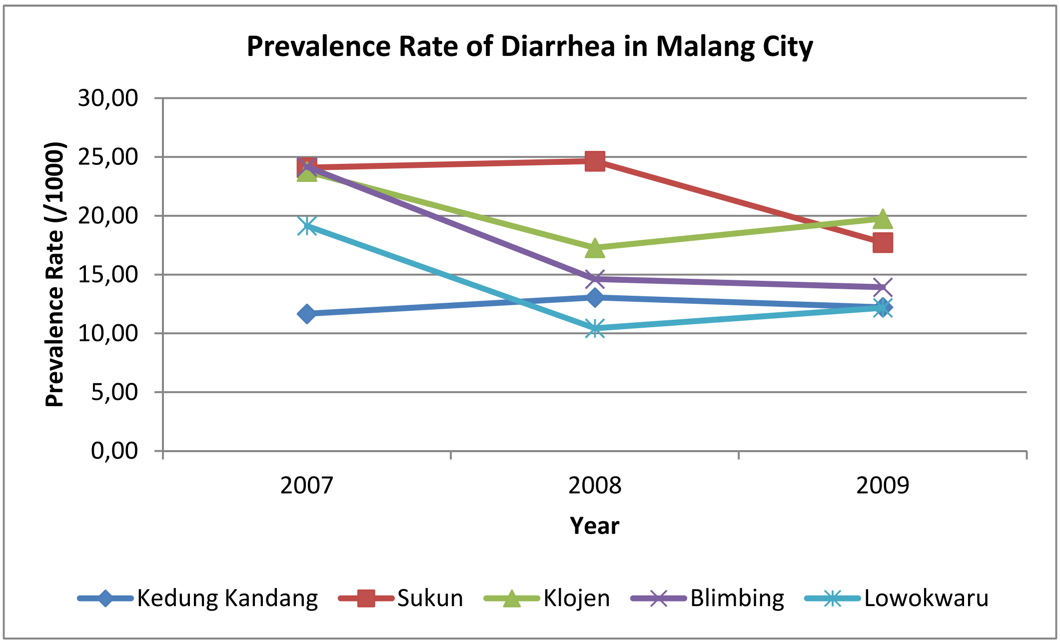


Figure 4.31 Prevalence Rate of Diarrhea in Five Sub districts of Malang City (2007-2009)

Figure 4.30 and 4.31 shows that diarrhea is more common in Sukun Sub district and occur in lower prevalence in Lowokwaru Sub district. However, diarrhea occur more than 1,000 cases per year in all subdistricts. Since diarrhea is a preventable disease, its need serious attention to limit the disease spreading especially in children and elderly peoples which more vulnerable.

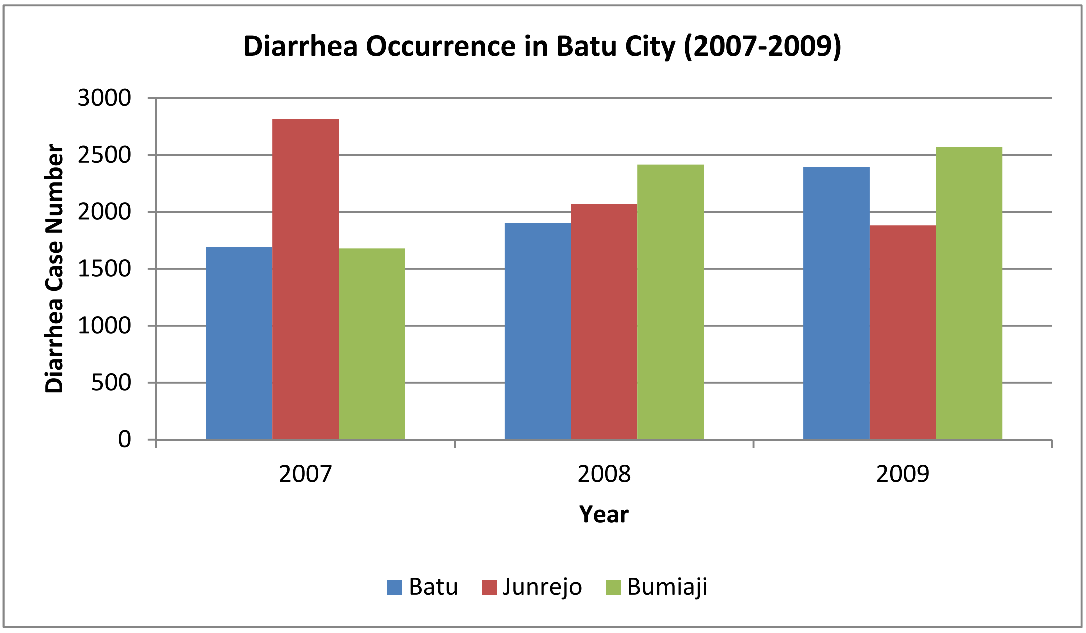


Figure 4.32 Diarrhea Occurrence in Three Sub districts of Batu City (2007-2009)

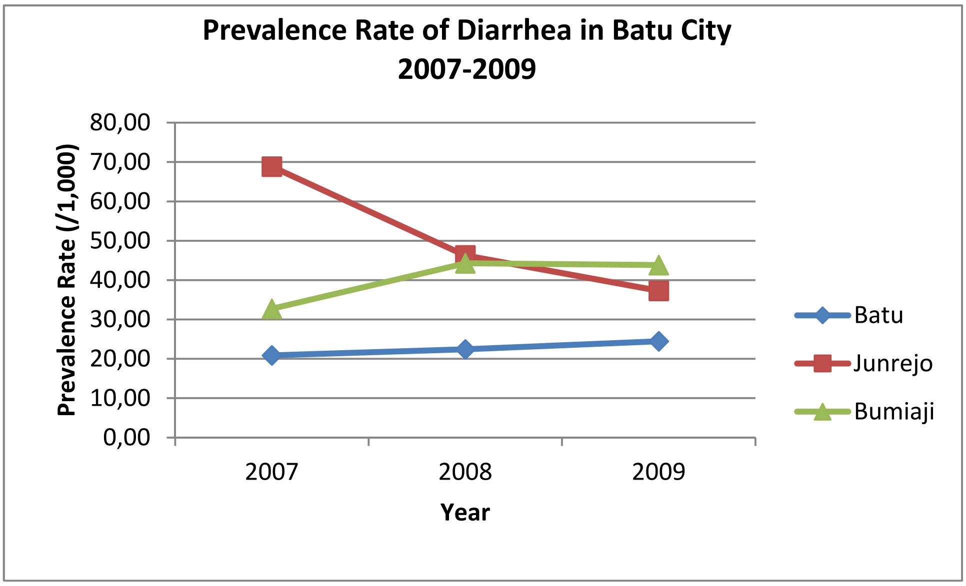


Figure 4.33 Prevalence Rate of Diarrhea in Three Sub districts of Batu City (2007-2009)

Prevalence rate of diarrhea in Junrejo for 2007 is 70 person per 1,000 population. This number is exceedingly high than prevalence rate of diarrhea in any sub districts of Malang City. While Batu sub district has the lowest prevalence of diarrhea in three subsequent years.

4.7.2 Results of Existing Diarrhea Hazard Analysis

The three years average of prevalence (2007-2009) is used to categorize the hazard in sub districts level as shown in table below. Figures 4.32 show areas with different levels of diarrhea disease hazard.

Table 4.7: Existing Hazard Categories of Diarrhea in Malang City and Batu City

Sub Districts	Hazard		
	Population (2008)	Average Prevalence (2007-2009) /1,000 Occupants	Level (2008)
Malang CIty			
Kedung Kandang	162,104	12.3	Very Low
Sukun	174,868	22.2	Moderate
Klojen	126,760	20.3	Moderate
Blimbing	171,051	17.6	Low
Lowok Waru	181,854	13.9	Very Low
Batu City			
Batu	89,843	22.6	High
Junrejo	45,340	50.8	Very High
Bumiaji	56,876	40.3	Very High

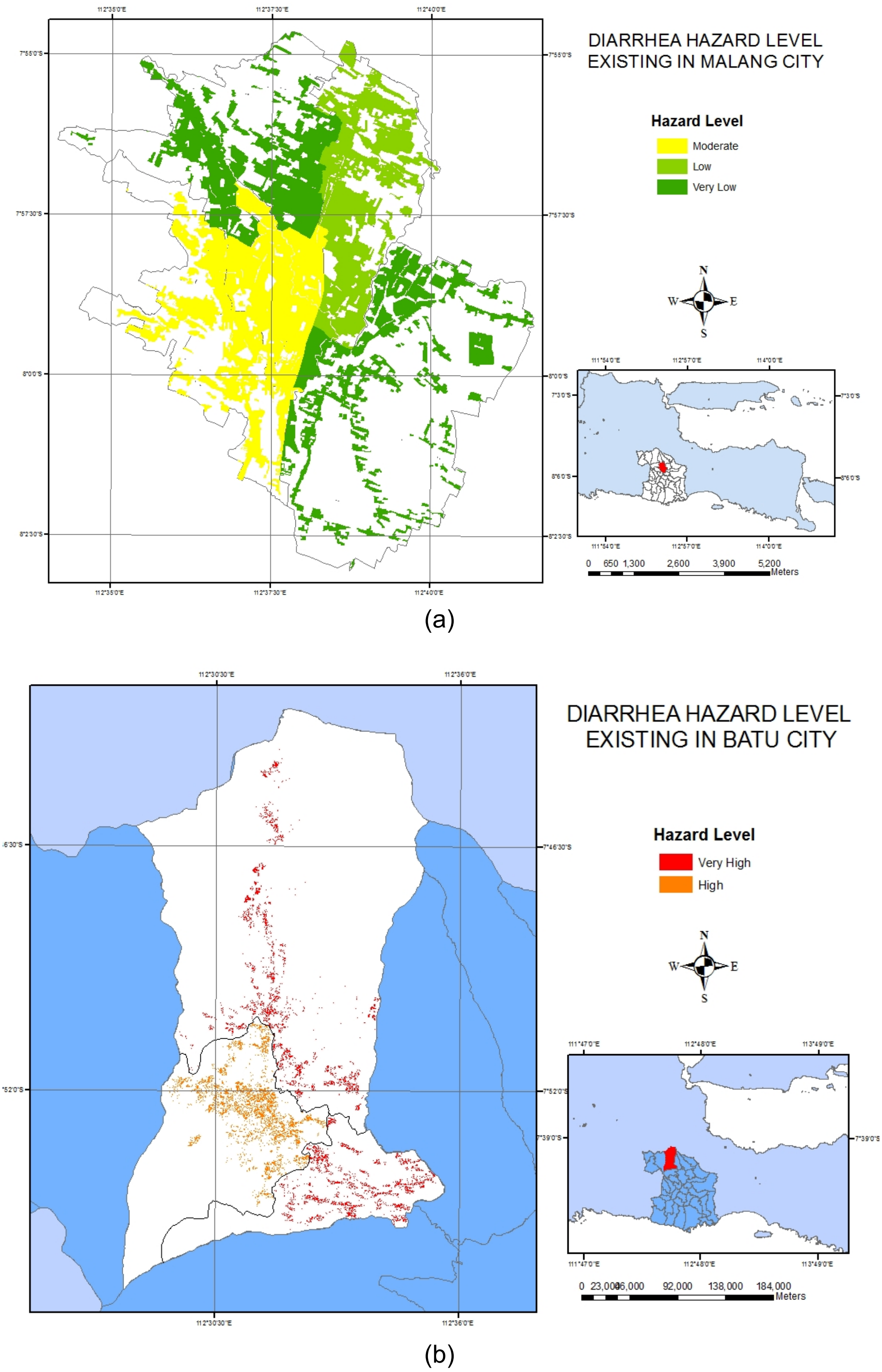


Figure 4.34 Existing Hazard Map of Diarrhea in: Malang City (a) and Batu City (b)

4.8 Future Projection of Diarrhea Hazard in Correlation with Climate Change

4.8.1 Estimation of Existing Diarrhea Hazard by Using Compartment Model

Hazard analysis by means of mathematical modeling is conducted for every sub districts in Malang City and Batu City that mentioned in the earlier chapter. Required data in this assessment are monthly Diarrhea incidence rate, monthly rainfall and temperature, and population. Population data and monthly Diarrhea cases were collected from Health Department of Malang for years 2005-2010, while Scientific Basis Team provide the temperature and rainfall data

Existing diarrhea hazard in Batu City, Malang City and two sub district in those city is estimated by the compartment equation and the results is outlined in the figures below. Existing estimation in other districts are calculated in the same manner

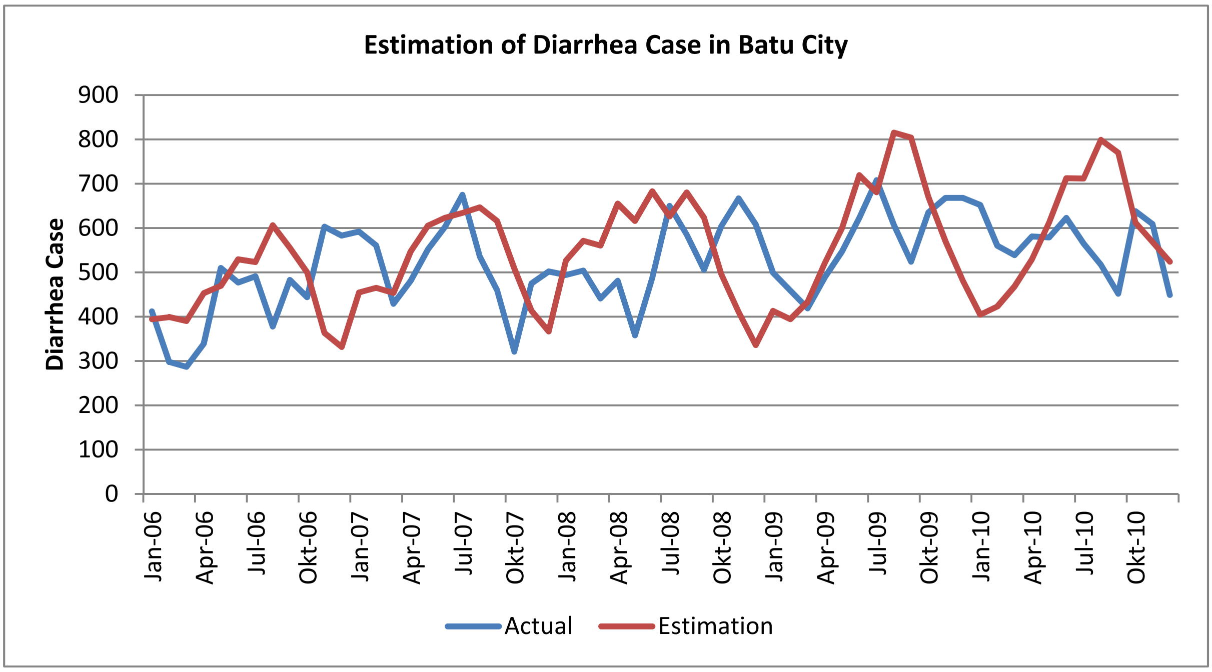


Figure 4.35 Actual and Estimation of Existing Diarrhea Case in Batu City

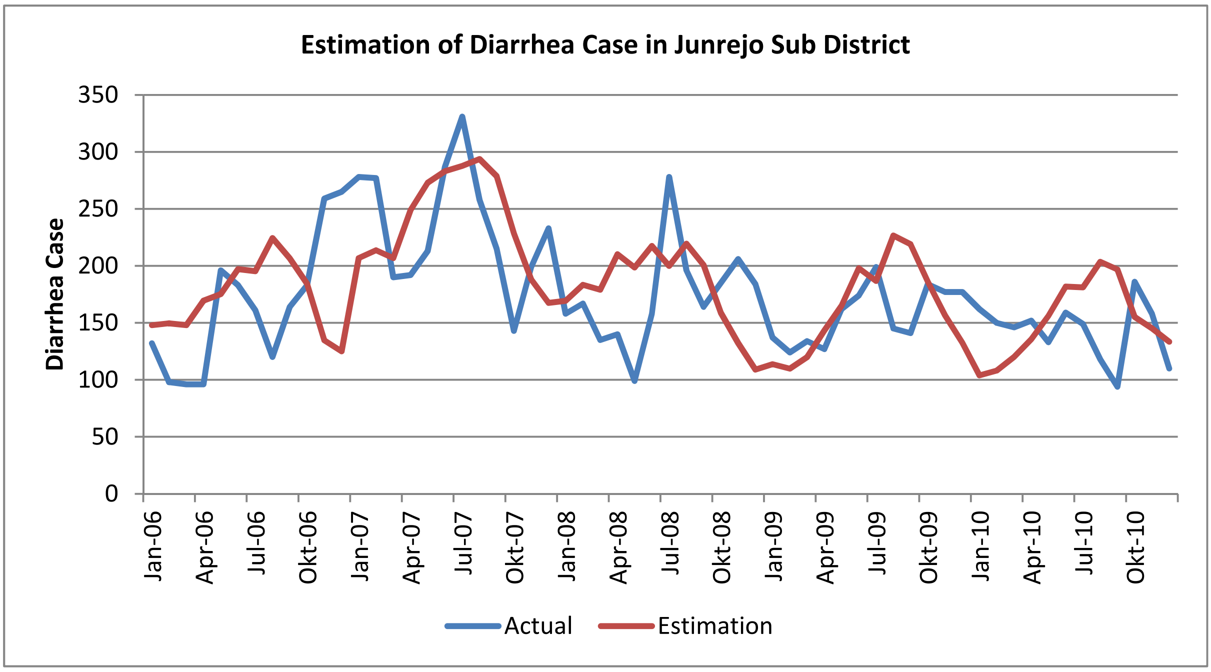


Figure 4.36 Actual and Estimation of Existing Diarrhea Case in Junrejo Sub District

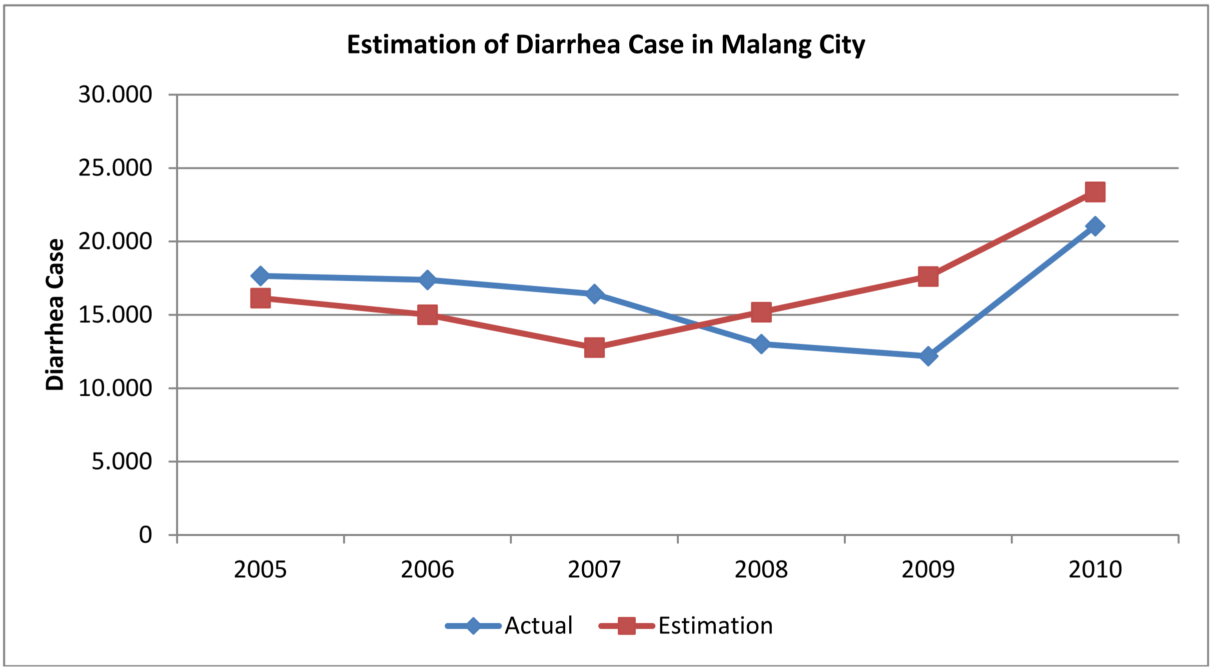


Figure 4.37 Actual and Estimation of Existing Diarrhea Case in Malang City

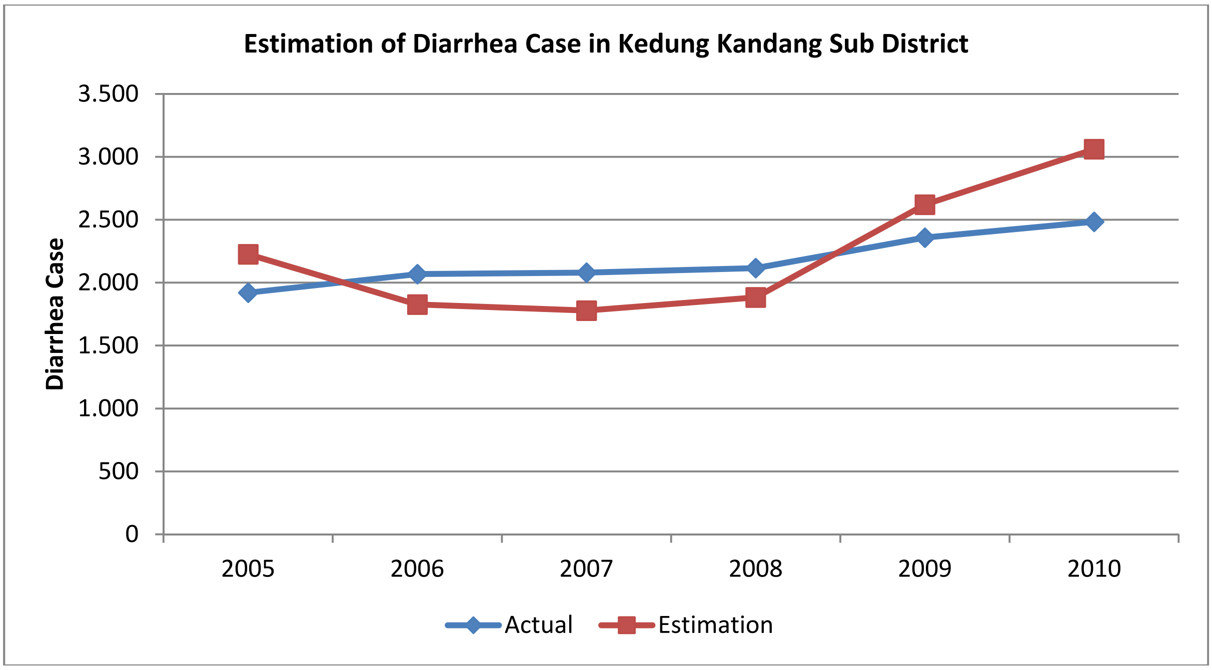


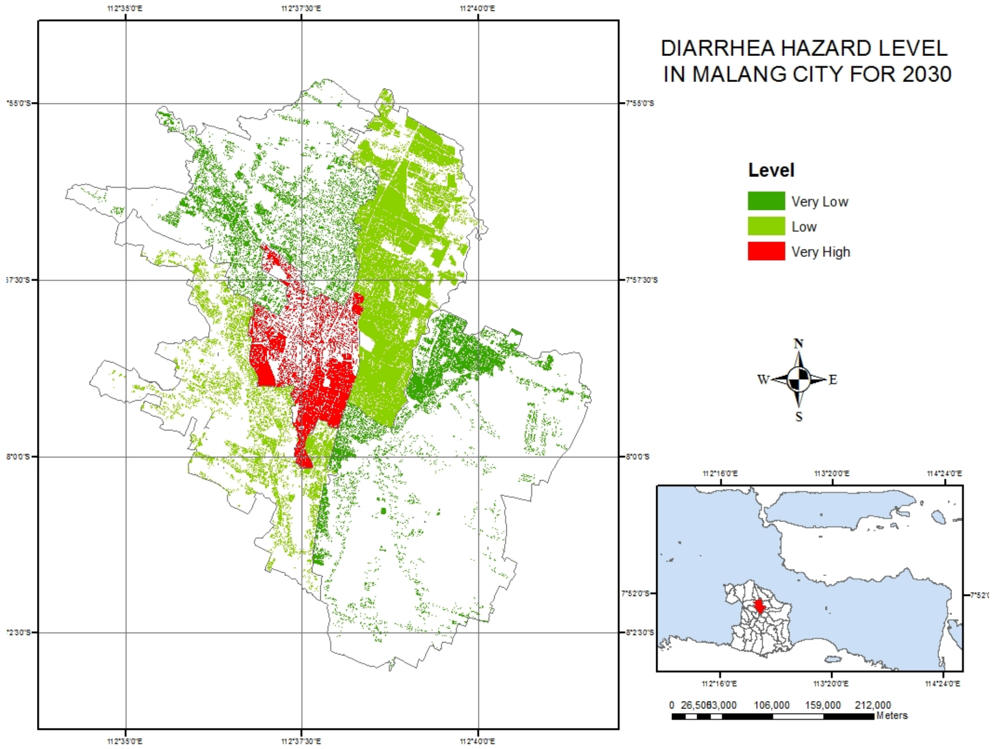
Figure 4.38 Actual and Estimation of Existing Diarrhea Case in Kedung Kandang Sub District

4.8.2 Results of Diarrhea Hazard Projection 2030 by Compartment Model

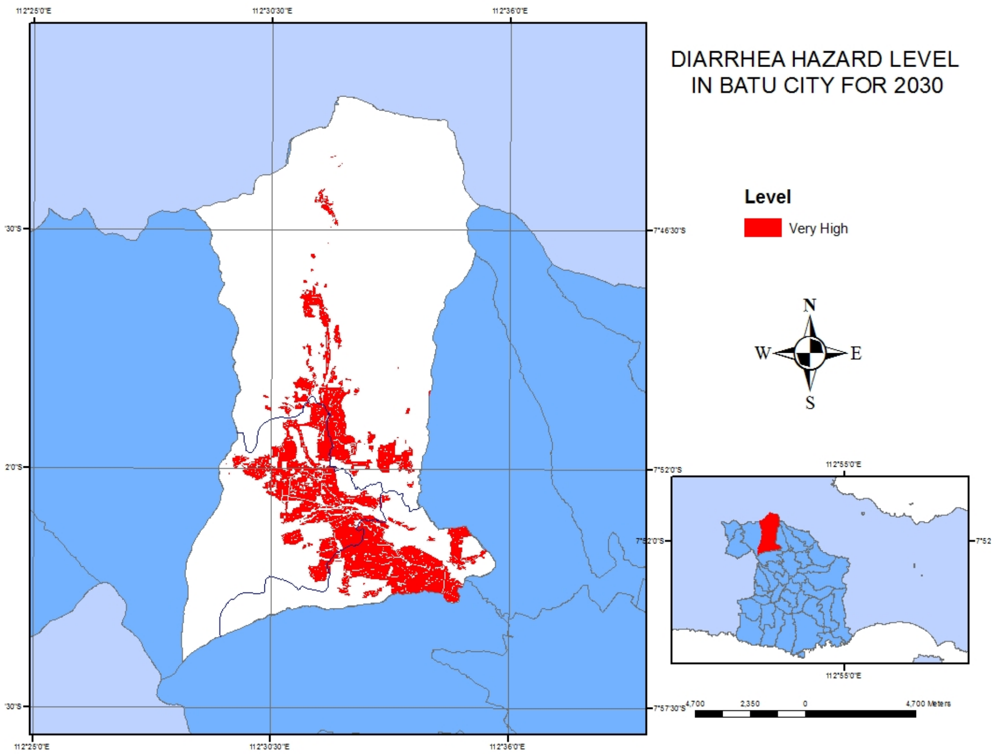
Diarrhea hazard projection of Malang City and Batu City for 2030 by compartment model was calculated and its result was classified in categories as shown in Table 4.8 below.

Table 4.8: Categories of Diarrhea Hazard of Malang City and Batu City in 2030

Districts	Hazard		
	Population (2030)	Average Prevalence (2030) /1,000 Occupants	Level (2030)
Malang City			
Kedung Kandang	291,410	7.18	Very Low
Sukun	206,420	19.73	Low
Klojen	108,790	35.10	Very High
Blimbing	197,010	18.16	Low
Lowok Waru	287,130	9.18	Very Low
Batu City			
Batu	142,103	66.35	Very High
Junrejo	77,748	101.83	Very High
Bumiaji	89,794	69.19	Very High



(a)



(b)

Figure 4.39 Hazard Map of Diarrhea Cases for 2030 in (a) Malang City and (b) Batu City

4.9 Comparison of Diarrhea Hazard Levels in 2008 and 2030

Comparison of diarrhea hazard levels in Malang City and Batu City in 2008 and 2030 is described in Table 4.9 below.

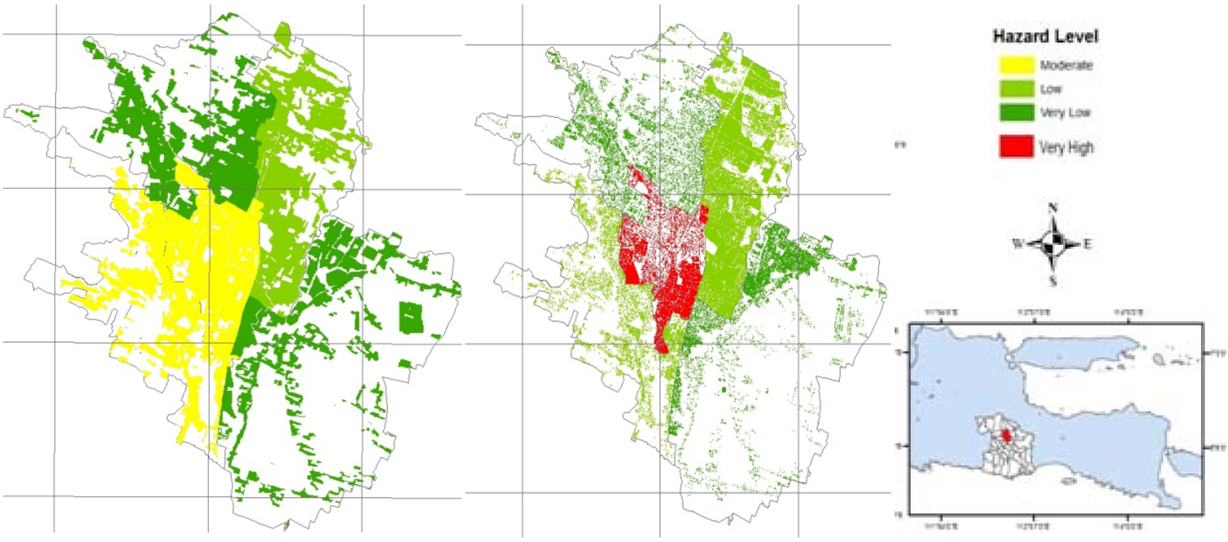
Table 4.9: Comparison of Existing and Future Hazard Categorization for Diarrhea in Malang City and Batu City

No	Sub Districts	Hazard (Diarrhea)				Comparison
		Average Prevalence (2007-2009) /1,000 Occupants	Level (2008)	Prevalence (2030) /1,000 Occupants	Level (2030)	
Malang City						
1	Kedung Kandang	12.3	Very Low	7.18	Very Low	0
2	Sukun	22.2	Moderate	19.73	Low	-1
3	Klojen	20.3	Moderate	35.10	Very High	+2
4	Blimbing	17.6	Low	18.16	Low	0
5	Lowok Waru	13.9	Very Low	9.18	Very Low	0
Batu City						
6	Batu	22.6	High	66.35	Very High	+1
7	Junrejo	50.8	Very High	101.83	Very High	0
8	Bumiaji	40.3	Very High	69.19	Very High	0

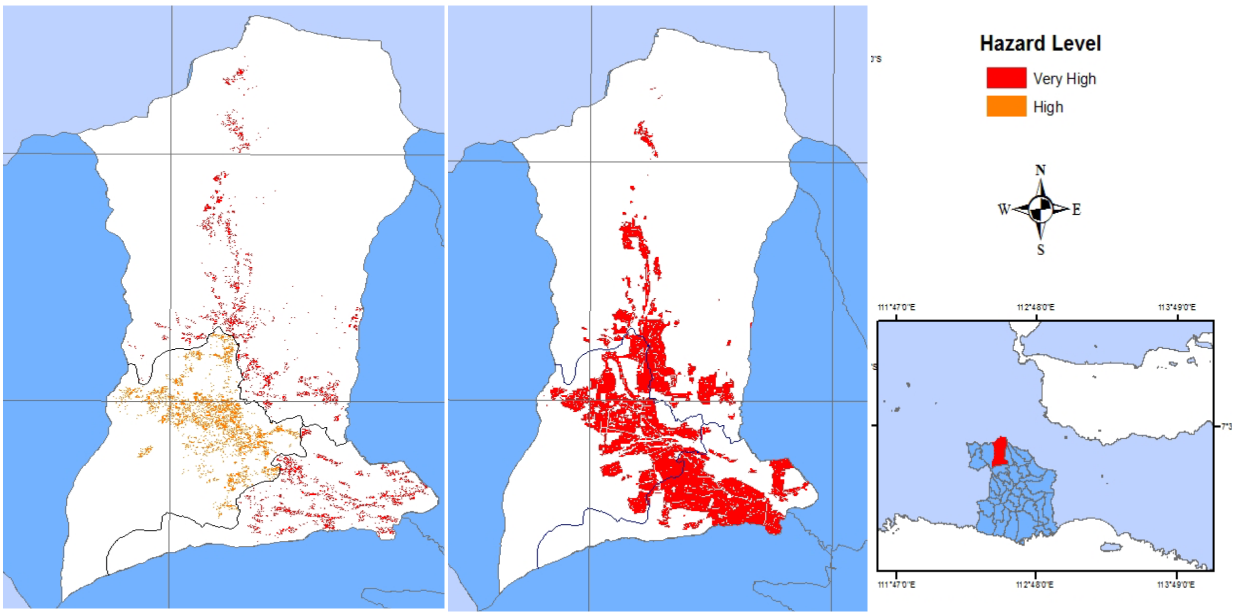
Note:

+1 : increase one level -1 : decrease one level
+2 : increase two level -2 : decrease two level
+3 : increase three level -3 : decrease three level
+4 : increase four level -4 : decrease four level
0 : same level

Comparison of diarrhea hazard map in Malang City and Batu City for 2008 and 2030 is described in Figure 4.40 below.



Diarrhea Hazard Map 2008 Diarrhea Hazard Map 2030
(a) Diarrhea Hazard Level in Malang City



Diarrhea Hazard Map 2008 Diarrhea Hazard Map 2030
(a) Diarrhea Hazard Level in Batu City

Figure 4.40 Comparison between Diarrhea Hazard Map 2008 and 2030

CHAPTER 5 VULNERABILITY ASSESSMENT

This chapter discusses vulnerability assessment to climate change on health sector in Malang City, Batu City and Malang District. Vulnerability is defined as the extent to which a natural or social system is susceptible to sustaining damage from climate change, and is a function of the magnitude of climate change, the sensitivity of the system to changes in climate and the ability to adapt the system to changes in climate. Different socio-geographic characteristic allows variation of vulnerability condition between districts.

5.1 DHF Vulnerability Analysis

Vulnerability of DHF is calculated from 4 variables, namely amount of population, population density, source of water supply, and provision of health facility. Vulnerability score of each variable is shown in Table 5.1. Vulnerability total of each sub district is also calculated and categorized; its result is shown in Table 5.1.

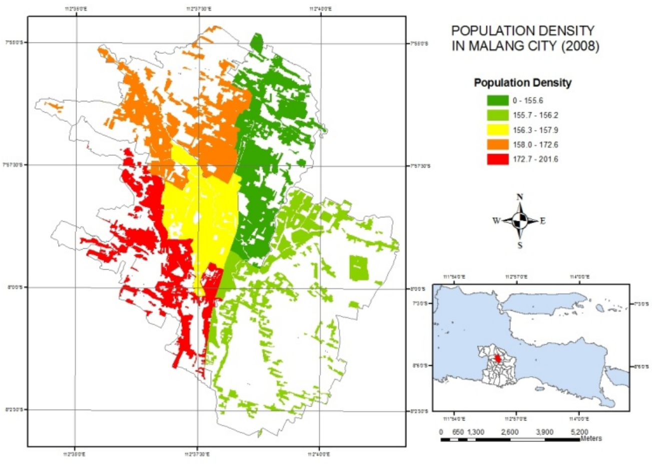
Table 5.1: Results of Existing Vulnerability Score to DHF in Greater Malang

No	Sub Districts	Vp	Vpd	Vnp	Vhf	Vtotal	Levels
Malang City							
1	Kedung Kandang	0.07	0.125	0.038	0.03	0.21	Very High
2	Sukun	0.08	0.250	0.070	0.03	0.37	Very High
3	Klojen	0.06	0.125	0.054	0.08	0.16	High
4	Blimbing	0.08	0.125	0.064	0.04	0.22	Very High
5	Lowok Waru	0.08	0.125	0.064	0.03	0.24	Very High
Malang District							
6	Tumpang	0.01	0.062	0.088	0.04	0.12	Low
7	Poncokusumo	0.01	0.062	0.106	0.04	0.15	Moderate
8	Jabung	0.01	0.062	0.109	0.03	0.15	High
9	Pakis	0.02	0.062	0.055	0.03	0.11	Very Low
10	Lawang	0.02	0.062	0.041	0.05	0.07	Very Low
11	Singosari	0.02	0.062	0.096	0.03	0.15	High
12	Karangploso	0.01	0.062	0.042	0.04	0.08	Very Low
13	Dau	0.01	0.062	0.102	0.04	0.13	Moderate
14	Pujon	0.01	0.062	0.102	0.05	0.13	Low
15	Ngantang	0.01	0.062	0.110	0.04	0.14	Moderate
16	Kasembon	0.00	0.062	0.116	0.06	0.12	Low
17	Kepanjen	0.02	0.062	0.072	0.05	0.10	Very Low
18	Sumber Pucung	0.01	0.062	0.118	0.04	0.15	High
19	Kromengan	0.01	0.062	0.118	0.04	0.15	Moderate
20	Pakisaji	0.01	0.062	0.076	0.03	0.12	Low
21	Ngajum	0.01	0.062	0.101	0.04	0.13	Low
22	Wonosari	0.01	0.062	0.006	0.05	0.03	Very Low
23	Wagir	0.01	0.062	0.118	0.03	0.16	Very High
24	Pagak	0.01	0.062	0.037	0.05	0.06	Very Low

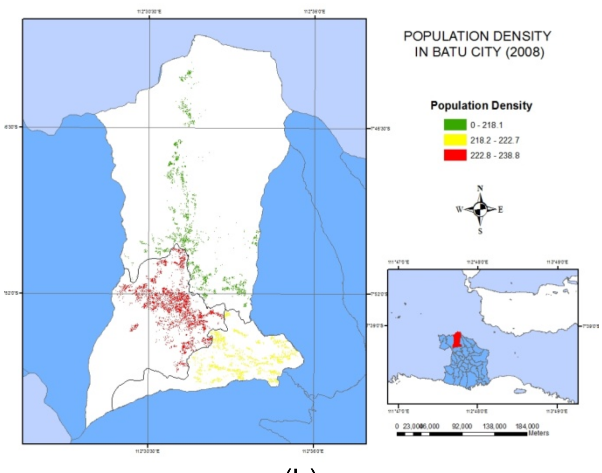
No	Sub Districts	Vp	Vpd	Vnp	Vhf	Vtotal	Levels
25	Donomulyo	0.01	0.062	0.106	0.04	0.14	Moderate
26	Kalipare	0.01	0.062	0.107	0.05	0.13	Moderate
27	Bantur	0.01	0.062	0.118	0.04	0.15	High
28	Gedangan	0.01	0.062	0.118	0.04	0.15	High
29	Gondanglegi	0.01	0.062	0.051	0.05	0.08	Very Low
30	Bululawang	0.01	0.062	0.085	0.04	0.12	Low
31	Wajak	0.01	0.062	0.063	0.04	0.10	Very Low
32	Tajinan	0.01	0.062	0.084	0.04	0.11	Low
33	Turen	0.02	0.062	0.107	0.05	0.14	Moderate
34	Dampit	0.02	0.062	0.118	0.03	0.17	Very High
35	Sumbermanjing Wetan	0.02	0.062	0.074	0.04	0.12	Low
36	Ampelgading	0.01	0.062	0.106	0.04	0.14	Moderate
37	Tirtoyudo	0.01	0.062	0.118	0.04	0.15	High
38	Pagelaran	0.01	0.062	0.118	0.04	0.15	High
Batu City							
39	Batu	0.17	0.250	0.025	0.05	0.39	Very High
40	Junrejo	0.09	0.250	0.020	0.05	0.31	Very High
41	Bumiaji	0.11	0.250	0.000	0.03	0.33	Very High

Vp = Vulnerability based on Population Number
Vpd = Vulnerability based on Population Density
Vnp = Vulnerability based on Non-Piped Water Facility
Vhf = Vulnerability based on Health Facility
Vtotal = Summation of vulnerability to DHF in corresponding area

Figure 5.1-5.4 show DHF vulnerability score for each variable for 2008. Figure 5.1 shows population density, Figure 5.2 shows percentage of piped water coverage, Figure 5.3 shows coverage of health facility, and Figure 5.4 shows total vulnerability level of DHF.



(a)



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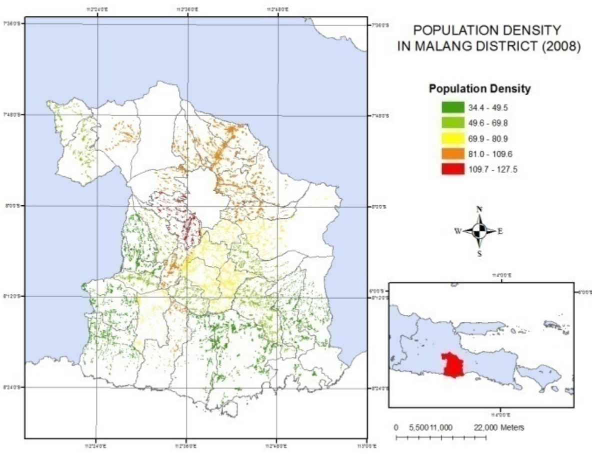
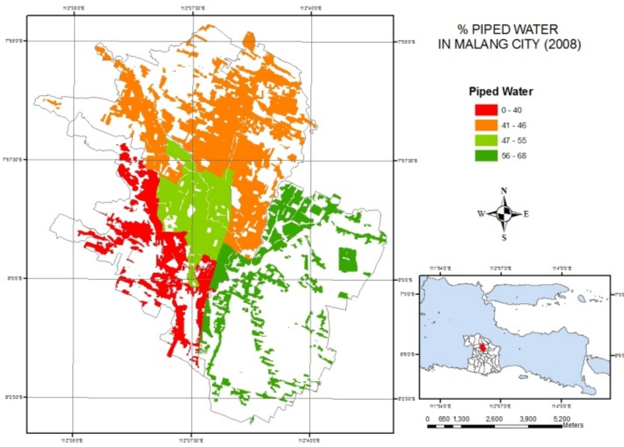
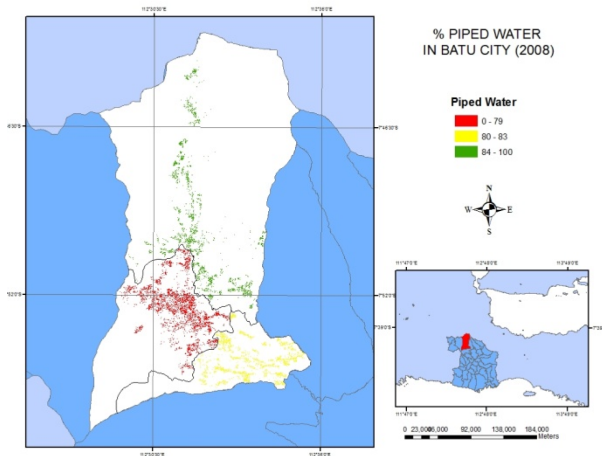


(c)

Figure 5.1 Existing Population Density 2008 in (a) Malang City, (b) Batu City, and (c) Malang District



(a)



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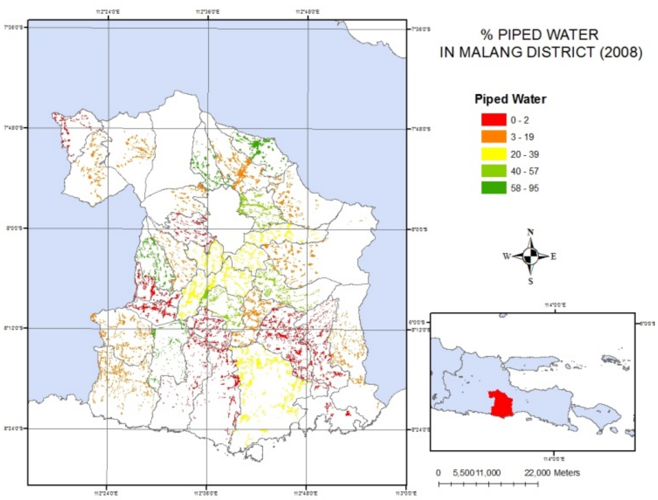
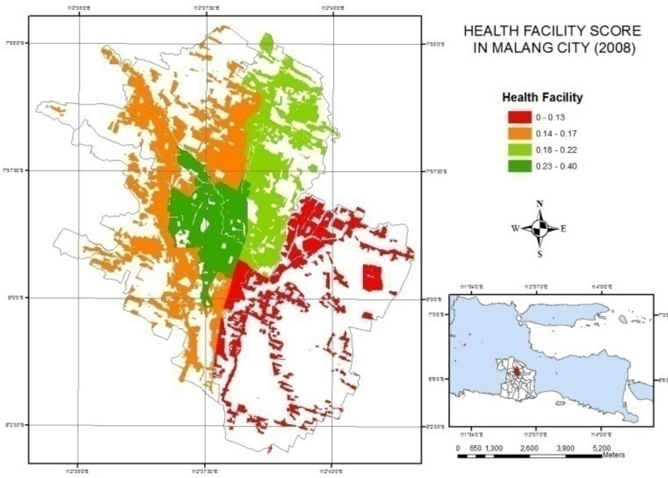
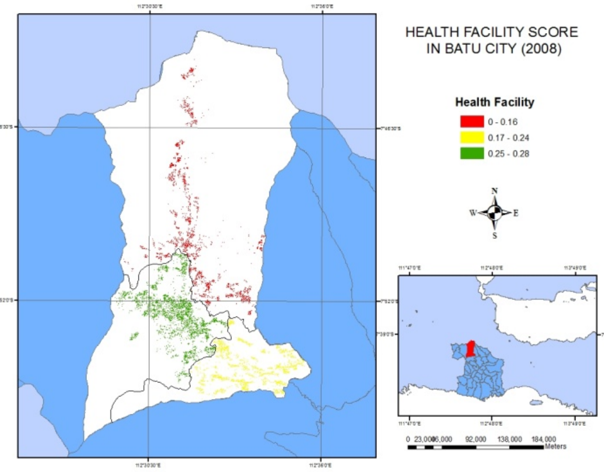


(c)

Figure 5.2 Existing Piped Water Coverage for 2008 in (a) Malang City, (b) Batu City, and (c) Malang District



(a)



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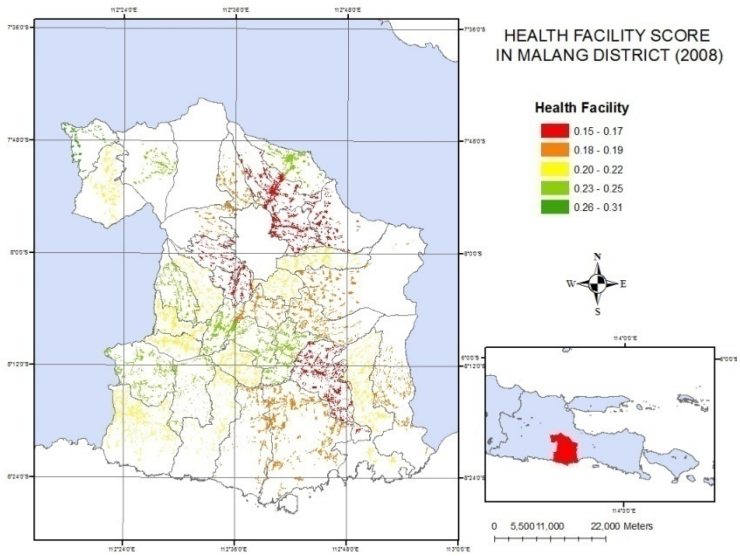
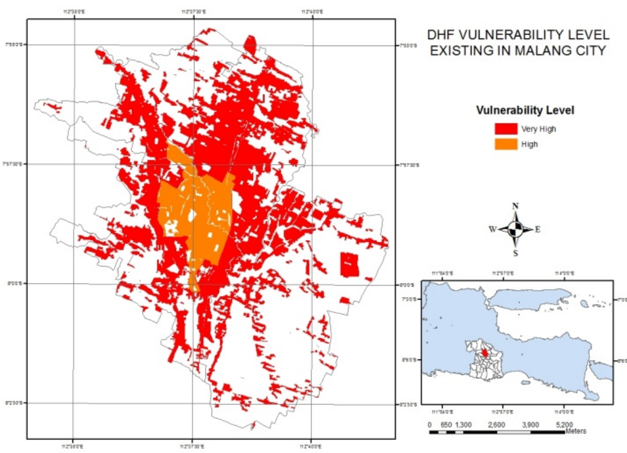
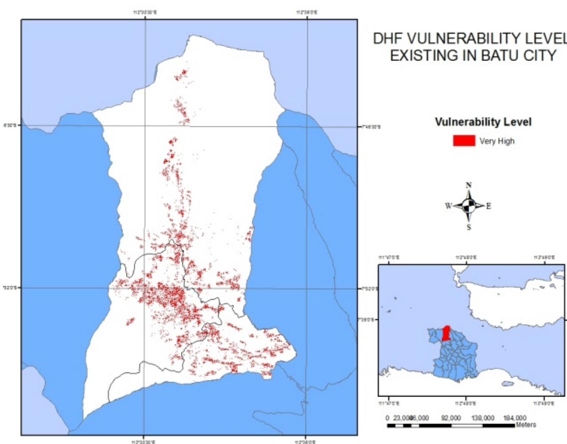


(c)

Figure 5.3 Existing Health Facility Score for 2008 in (a) Malang City, (b) Batu City, and (c) Malang District



(a)



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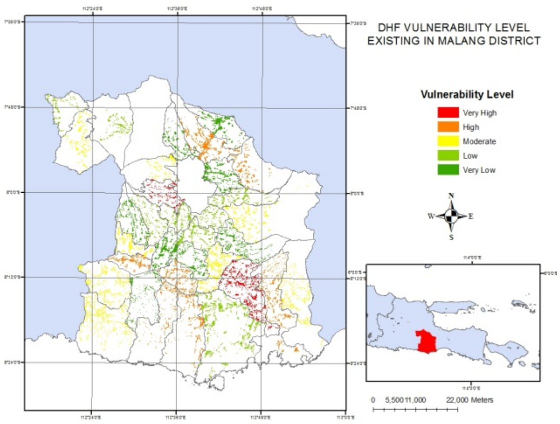


(c)

Figure 5.4 Existing Vulnerability Level to DHF for 2008 in (a) Malang City, (b) Batu City, and (c) Malang District

5.2 Projection 2030 of DHF Vulnerability Analysis

Vulnerability score of DHF in Greater Malang for 2030 is described in Table 5.2.

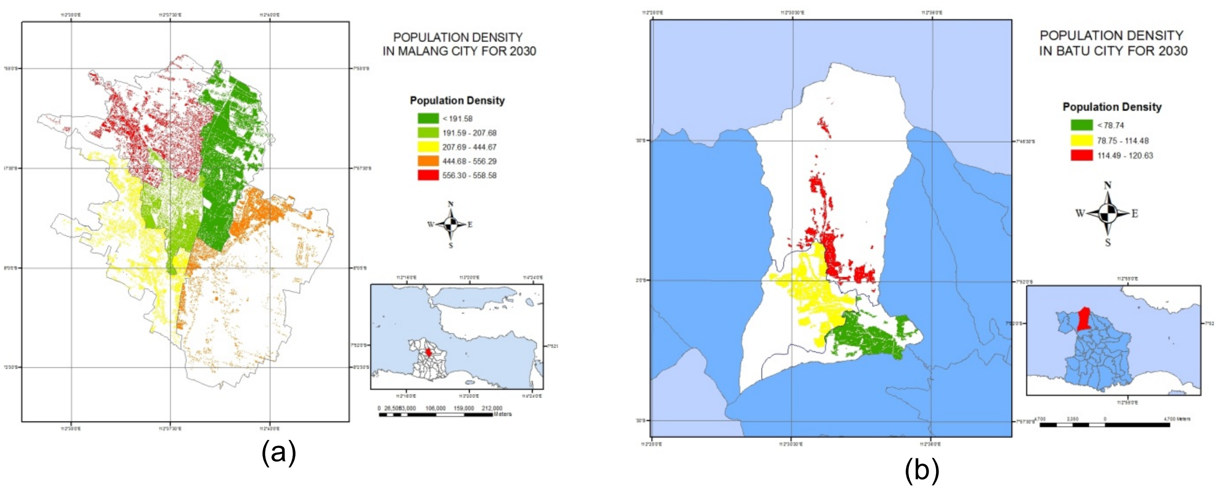
Table 5.2: Results of Vulnerability Score to DHF in Greater Malang 2030

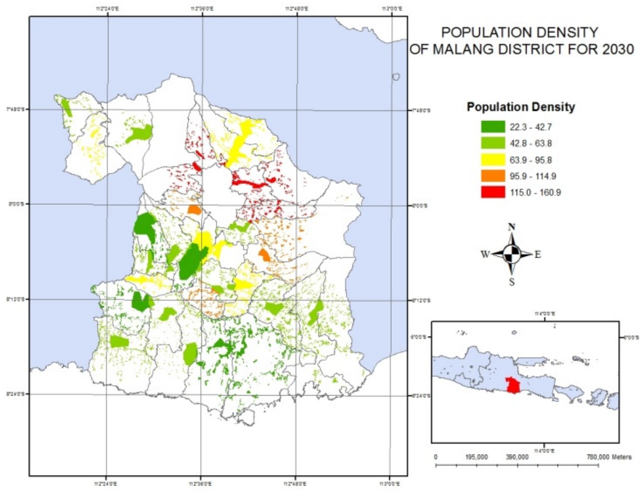
No	Sub Districts	Vp	Vpd	Vnp	Vhf	Vtotal	Levels
Malang City							
1	Kedung Kandang	0.10	0.281	0.076	0.01	0.44	Very High
2	Sukun	0.07	0.281	0.050	0.03	0.37	Very High
3	Klojen	0.04	0.250	0.047	0.09	0.24	Very High
4	Blimbing	0.07	0.125	0.081	0.04	0.24	Very High
5	Lowok Waru	0.10	0.281	0.062	0.02	0.42	Very High
Malang District							
6	Tumpang	0.032	0.062	0.082	0.03	0.13	Low
7	Poncokusumo	0.037	0.062	0.105	0.03	0.16	High
8	Jabung	0.030	0.125	0.109	0.02	0.22	Very High
9	Pakis	0.049	0.062	0.055	0.02	0.11	Very Low
10	Lawang	0.040	0.062	0.000	0.04	0.04	Very Low
11	Singosari	0.062	0.062	0.041	0.02	0.10	Very Low
12	Karangploso	0.024	0.062	0.042	0.03	0.08	Very Low
13	Dau	0.024	0.062	0.080	0.02	0.13	Low
14	Pujon	0.027	0.062	0.000	0.03	0.04	Very Low
15	Ngantang	0.024	0.062	0.099	0.03	0.14	Moderate
16	Kasembon	0.013	0.062	0.012	0.04	0.04	Very Low
17	Kepanjen	0.040	0.062	0.000	0.03	0.04	Very Low
18	Sumber Pucung	0.024	0.062	0.067	0.02	0.11	Low
19	Kromengan	0.017	0.062	0.051	0.03	0.09	Very Low
20	Pakisaji	0.032	0.062	0.000	0.03	0.05	Very Low

No	Sub Districts	Vp	Vpd	Vnp	Vhf	Vtotal	Levels
21	Ngajum	0.021	0.062	0.000	0.03	0.04	Very Low
22	Wonosari	0.020	0.062	0.000	0.03	0.04	Very Low
23	Wagir	0.031	0.062	0.049	0.02	0.10	Very Low
24	Pagak	0.021	0.062	0.000	0.03	0.04	Very Low
25	Donomulyo	0.034	0.062	0.050	0.02	0.10	Very Low
26	Kalipare	0.028	0.062	0.012	0.03	0.06	Very Low
27	Bantur	0.030	0.062	0.000	0.03	0.04	Very Low
28	Gedangan	0.022	0.062	0.000	0.02	0.05	Very Low
29	Gondanglegi	0.023	0.062	0.008	0.05	0.03	Very Low
30	Bululawang	0.026	0.062	0.056	0.03	0.10	Very Low
31	Wajak	0.036	0.062	0.063	0.02	0.12	Low
32	Tajinan	0.021	0.062	0.000	0.03	0.04	Very Low
33	Turen	0.046	0.062	0.068	0.03	0.12	Low
34	Dampit	0.050	0.062	0.084	0.02	0.14	Moderate
35	Sumbermanjing Wetan	0.040	0.062	0.056	0.03	0.11	Very Low
36	Ampelgading	0.024	0.062	0.070	0.02	0.12	Low
37	Tirtoyudo	0.027	0.062	0.077	0.03	0.12	Low
38	Pagelaran	0.028	0.062	0.110	0.02	0.16	High
Batu City							
39	Batu	0.17	0.062	0.035	0.03	0.23	Very High
40	Junrejo	0.09	0.062	0.035	0.03	0.16	Very High
41	Bumiaji	0.11	0.062	0.035	0.02	0.19	Very High

Vp = Vulnerability based on Population Number
Vpd = Vulnerability based on Population Density
Vnp = Vulnerability based on Non-Piped Water Facility
Vhf = Vulnerability based on Health Facility
Vtotal = Summation of vulnerability to DHF in corresponding area

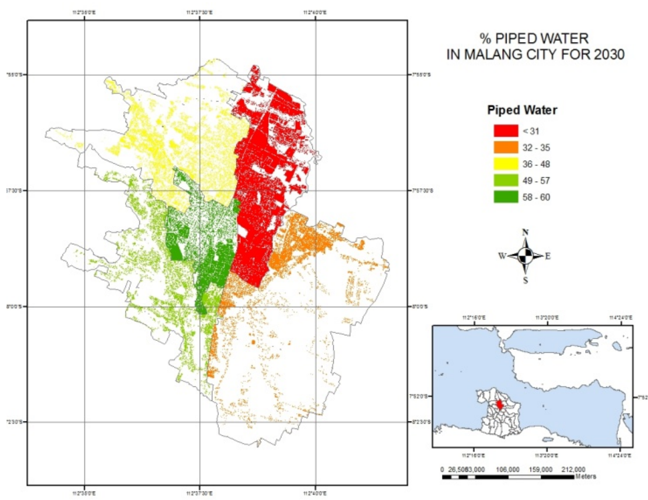
Figure 5.5-5.8 show DHF vulnerability score for each variable for 2030 in GIS format. Figure 5.5 shows population density, Figure 5.6 shows percentage of piped water coverage, Figure 5.7 shows coverage of health facility, and Figure 5.8 shows total vulnerability level of DHF.



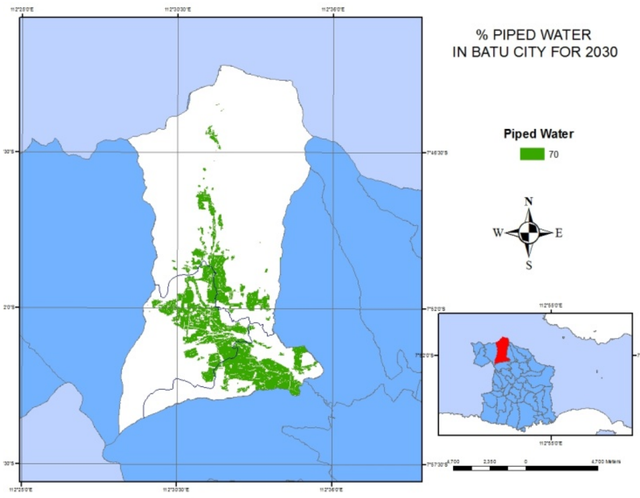


(c)

Figure 5.5 Projection of Population Density for 2030 in (a) Malang City, (b) Batu City, and (c) Malang District



(a)



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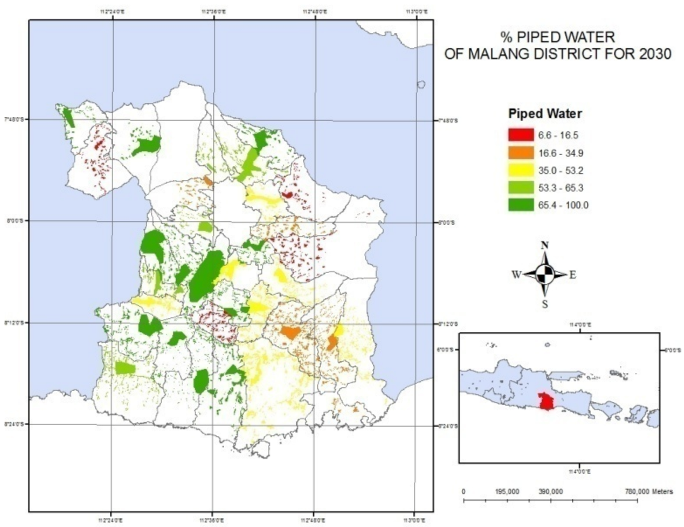
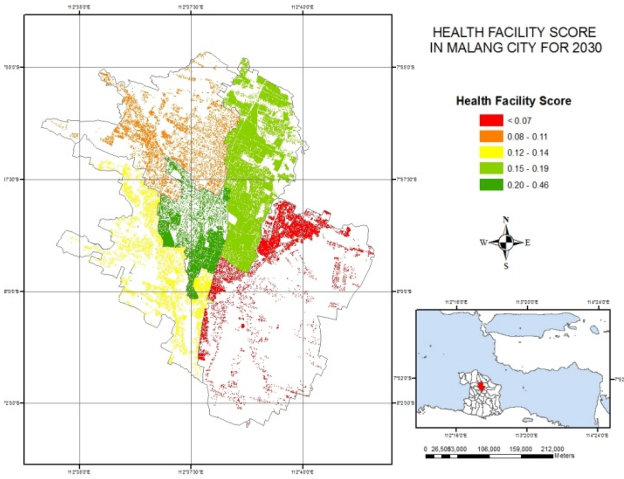
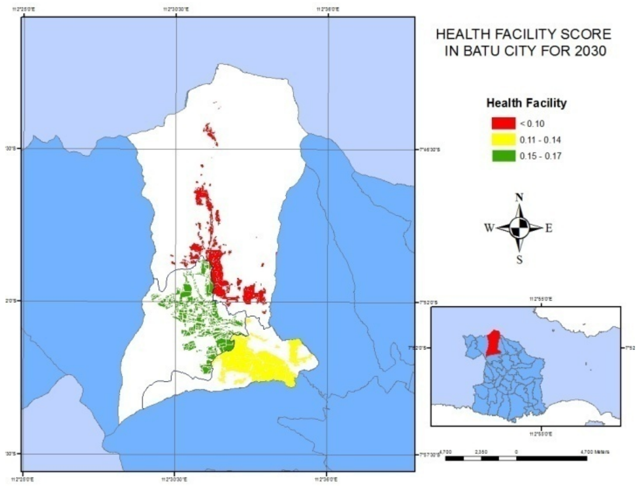


(c)

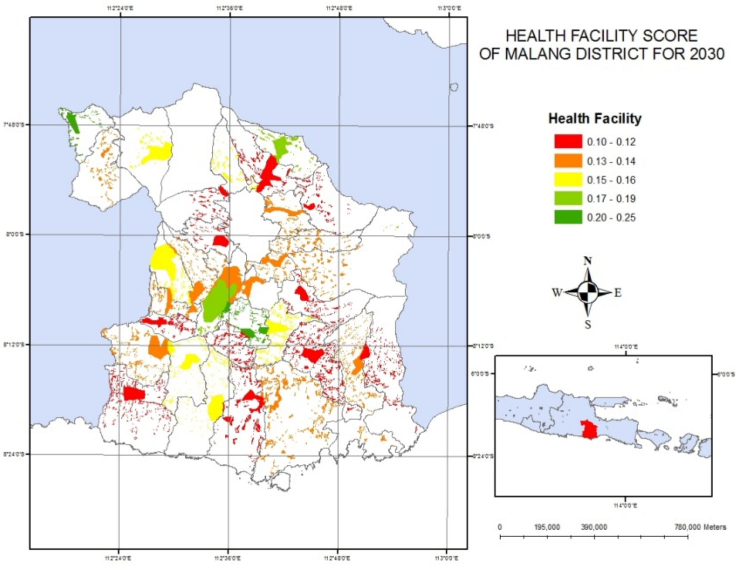
Figure 5.6 Projection of Piped Water Coverage for 2030 in (a) Malang City, (b) Batu City, and (c) Malang District



(a)

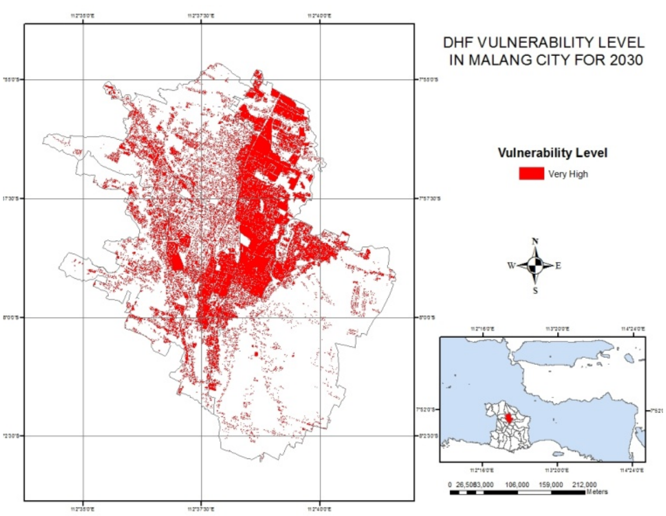


(b)

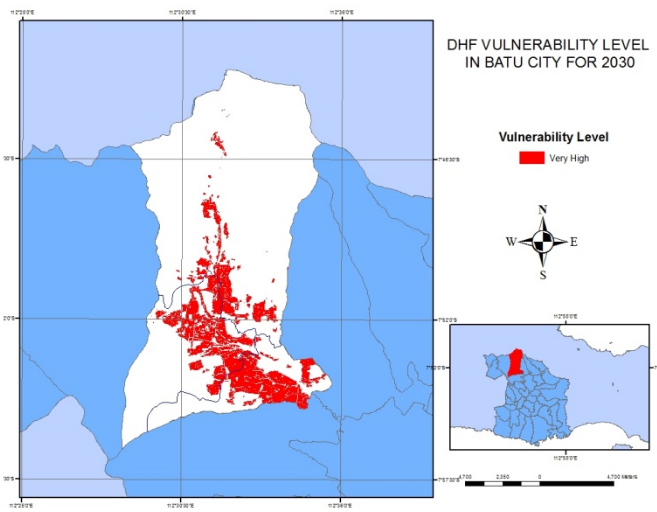


(c)

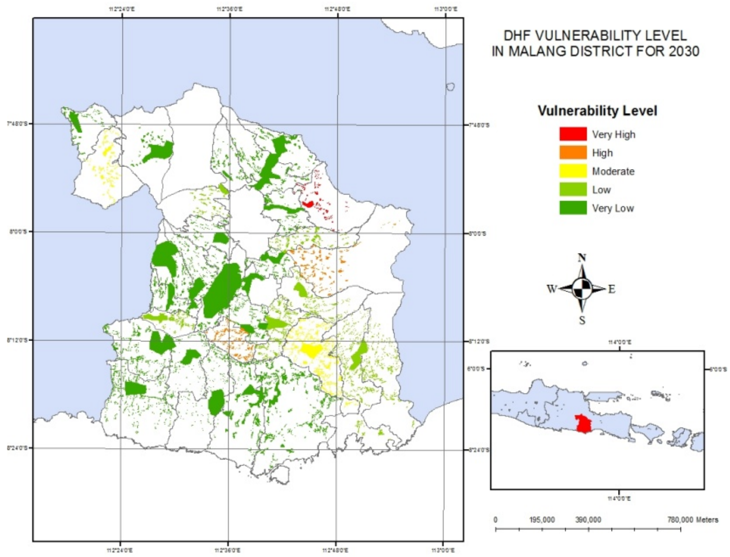
Figure 5.7 Projection of Health Facility Score for 2030 in (a) Malang City, (b) Batu City, and (c) Malang District



(a)



(b)



(c)

Figure 5.8 Vulnerability Level Projection to DHF for 2030 in (a) Malang City, (b) Batu City, and (c) Malang District

5.3 Comparison of DHF Vulnerability Levels in 2008 and 2030

Comparison of DHF Vulnerability levels in Greater Malang for 2008 and 2030 is described in Table 5.3 below.

Table 5.3: Results of Existing Vulnerability Score to DHF in Greater Malang

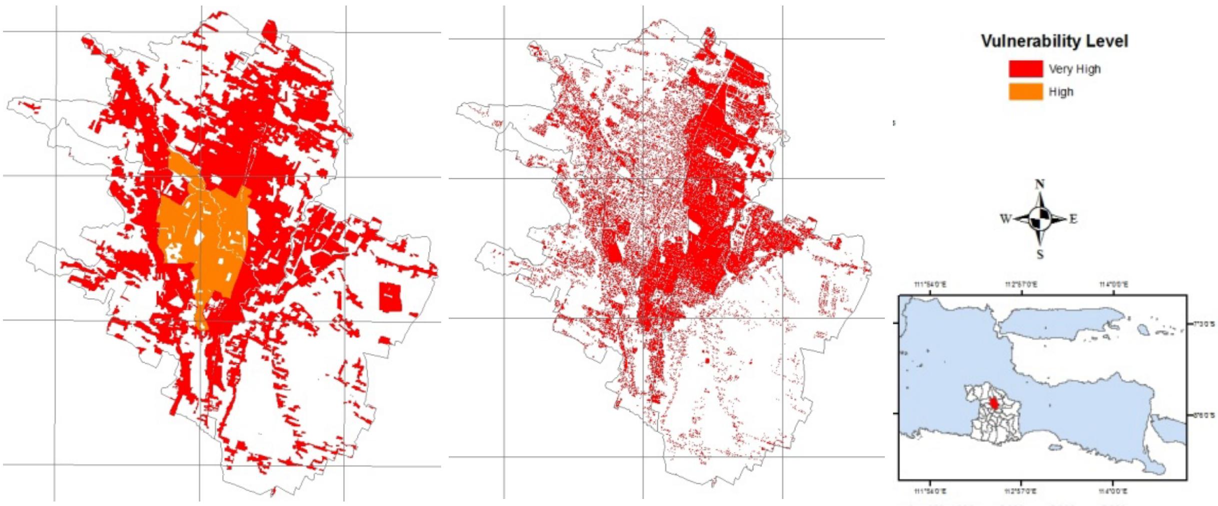
No	Sub Districts	Levels 2008	Levels 2030	Comparison
Malang City				
1	Kedung Kandang	Very High	Very High	0
2	Sukun	Very High	Very High	0
3	Klojen	High	Very High	+1
4	Blimbing	Very High	Very High	0
5	Lowok Waru	Very High	Very High	0
Malang District				
6	Tumpang	Low	Low	0
7	Poncokusumo	Moderate	High	+1
8	Jabung	High	Very High	+1
9	Pakis	Very Low	Very Low	0
10	Lawang	Very Low	Very Low	0
11	Singosari	High	Very Low	-3
12	Karangploso	Very Low	Very Low	0
13	Dau	Moderate	Low	-1
14	Pujon	Low	Very Low	-1
15	Ngantang	Moderate	Moderate	0
16	Kasembon	Low	Very Low	-1
17	Kepanjen	Very Low	Very Low	0
18	Sumber Pucung	High	Low	-2
19	Kromengan	Moderate	Very Low	-2
20	Pakisaji	Low	Very Low	-1
21	Ngajum	Low	Very Low	-1

No	Sub Districts	Levels 2008	Levels 2030	Comparison
22	Wonosari	Very Low	Very Low	0
23	Wagir	Very High	Very Low	-4
24	Pagak	Very Low	Very Low	0
25	Donomulyo	Moderate	Very Low	-2
26	Kalipare	Moderate	Very Low	-2
27	Bantur	High	Very Low	-3
28	Gedangan	High	Very Low	-3
29	Gondanglegi	Very Low	Very Low	0
30	Bululawang	Low	Very Low	-1
31	Wajak	Very Low	Low	+1
32	Tajinan	Low	Very Low	-1
33	Turen	Moderate	Low	-1
34	Dampit	Very High	Moderate	-2
35	Sumbermanjing Wetan	Low	Very Low	-1
36	Ampelgading	Moderate	Low	-1
37	Tirtoyudo	High	Low	-2
38	Pagelaran	High	High	0
Batu City				
39	Batu	Very High	Very High	0
40	Junrejo	Very High	Very High	0
41	Bumiaji	Very High	Very High	0

Note:

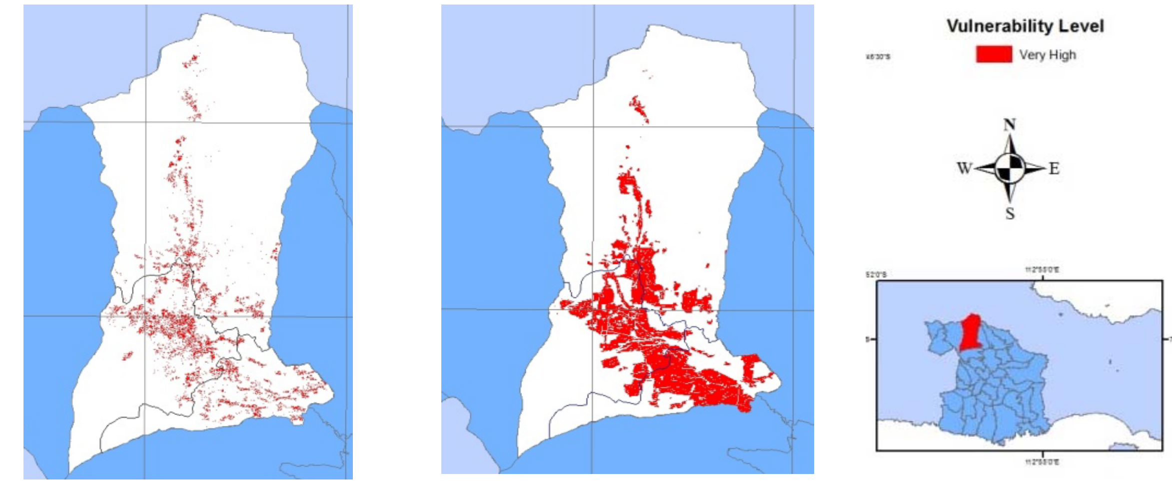
+1 : increase one level　　-1 : decrease one level
+2 : increase two level　　-2 : decrease two level
+3 : increase three level　　-3 : decrease three level
+4 : increase four level　　-4 : decrease four level
0 : same level

Comparison of DHF Vulnerability map in Malang for 2008 and 2030 is described in Figure 5.9 below.



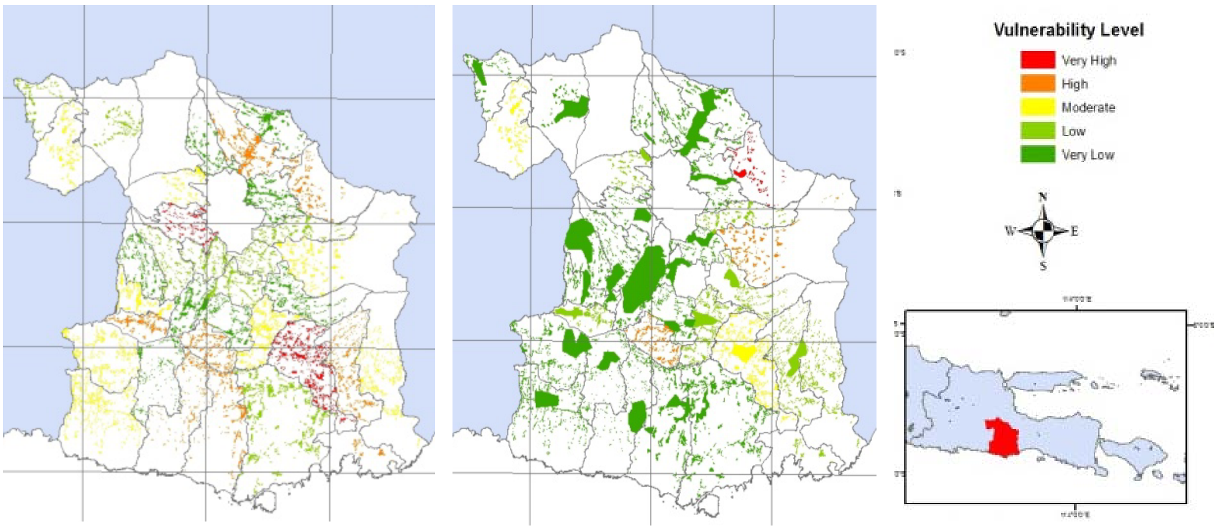
DHF Vulnerability Map 2008　　DHF Vulnerability Map 2030

(a) DHF Vulnerability Level in Malang City



DHF Vulnerability Map 2008 DHF Vulnerability Map 2030

(b) DHF Vulnerability Level in Batu City



DHF Vulnerability Map 2008 DHF Vulnerability Map 2030

(c) DHF Vulnerability Level in Malang District

Figure 5.9 Comparison between DHF Vulnerability Map 2008 and 2030

5.4 Malaria Vulnerability Analysis

Vulnerability of malaria in each variable and each subdistrict in 2008 are described in Table 5.4.

Table 5.4: Results of Existing Vulnerability Score to Malaria in Malang District

No	Sub Districts	Vpb	Vhb	Vnp	Vhf	Vtotal	Levels
1	Tumpang	0.39	0.192	0.012	0.02	0.57	Moderate
2	Poncokusumo	0.42	0.215	0.028	0.02	0.64	Moderate
3	Jabung	0.29	0.128	0.050	0.02	0.45	Very Low
4	Pakis	0.25	0.147	0.141	0.02	0.52	Low
5	Lawang	0.28	0.146	0.141	0.03	0.54	Moderate
6	Singosari	0.19	0.128	0.071	0.02	0.38	Very Low
7	Karangploso	0.42	0.218	0.141	0.02	0.76	Very High
8	Dau	0.36	0.153	0.039	0.02	0.53	Low

No	Sub Districts	Vpb	Vhb	Vnp	Vhf	Vtotal	Levels
9	Pujon	0.34	0.150	0.000	0.03	0.46	Very Low
10	Ngantang	0.47	0.222	0.000	0.02	0.67	High
11	Kasembon	0.42	0.198	0.141	0.03	0.73	High
12	Kepanjen	0.11	0.059	0.141	0.03	0.29	Very Low
13	Sumber Pucung	0.45	0.191	0.043	0.02	0.66	High
14	Kromengan	0.44	0.183	0.141	0.02	0.74	Very High
15	Pakisaji	0.18	0.088	0.093	0.02	0.34	Very Low
16	Ngajum	0.43	0.194	0.107	0.02	0.71	High
17	Wonosari	0.31	0.132	0.071	0.03	0.48	Low
18	Wagir	0.25	0.151	0.141	0.02	0.53	Low
19	Pagak	0.31	0.132	0.077	0.03	0.49	Low
20	Donomulyo	0.43	0.168	0.141	0.02	0.71	High
21	Kalipare	0.39	0.176	0.054	0.03	0.60	Moderate
22	Bantur	0.38	0.159	0.141	0.02	0.65	High
23	Gedangan	0.44	0.214	0.141	0.02	0.77	Very High
24	Gondanglegi	0.37	0.181	0.064	0.03	0.58	Moderate
25	Bululawang	0.14	0.067	0.067	0.02	0.26	Very Low
26	Wajak	0.29	0.132	0.046	0.02	0.45	Very Low
27	Tajinan	0.37	0.149	0.027	0.02	0.52	Low
28	Turen	0.42	0.198	0.007	0.03	0.59	Moderate
29	Dampit	0.41	0.205	0.141	0.02	0.74	Very High
30	Sumbermanjing Wetan	0.40	0.194	0.025	0.02	0.60	Moderate
31	Ampelgading	0.45	0.189	0.141	0.02	0.76	Very High
32	Tirtoyudo	0.45	0.217	0.141	0.02	0.79	Very High
33	Pagelaran	0.47	0.240	0.141	0.02	0.83	Very High

Vpb = Vulnerability based on Population Near Breeding Site
Vhb = Vulnerability based on House Near Breeding Site
Vnp = Vulnerability based on Non Permanent Housing
Vhf = Vulnerability based on Health Facility
Vtotal = Summation of vulnerability to Malaria in corresponding area

Figure 5.9-5.13 show malaria vulnerability score for each variable for 2008 in GIS format. Figure 5.9 shows population near breeding site, Figure 5.10 shows amount of house near breeding site, Figure 5.11 shows percentage non permanent housing, Figure 5.12 shows coverage of health facility, and Figure 5.13 shows total vulnerability level of malaria.

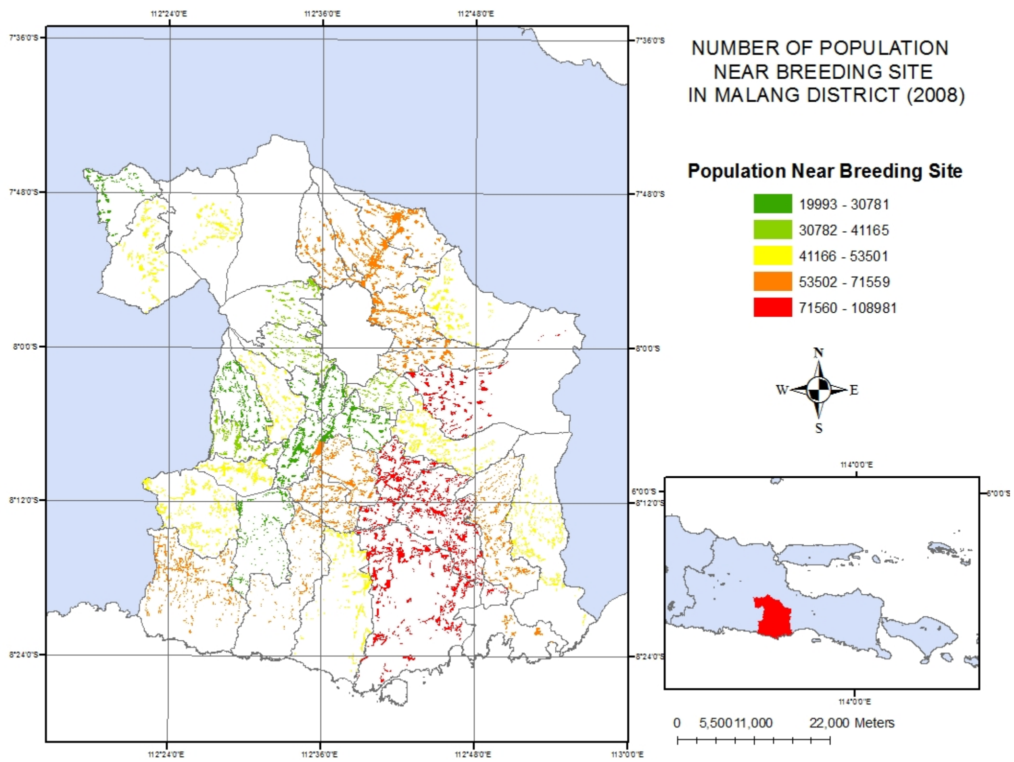


Figure 5.10 Existing Population Near Breeding Site for 2008 in Malang District

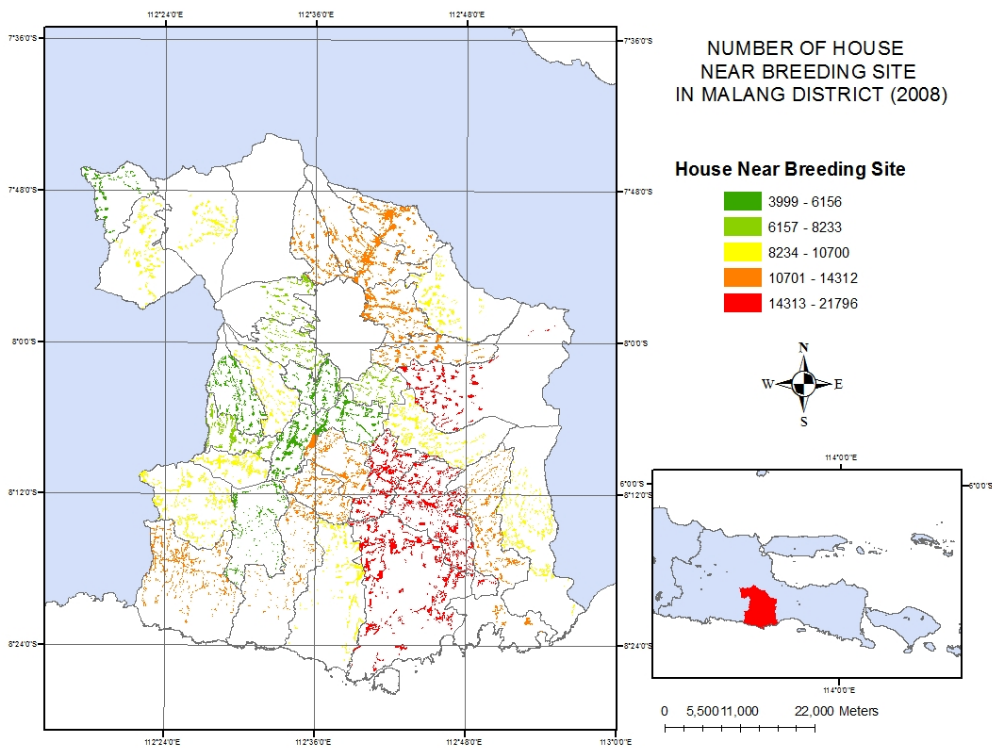


Figure 5.11 Existing House Near Breeding Site for 2008 in Malang District

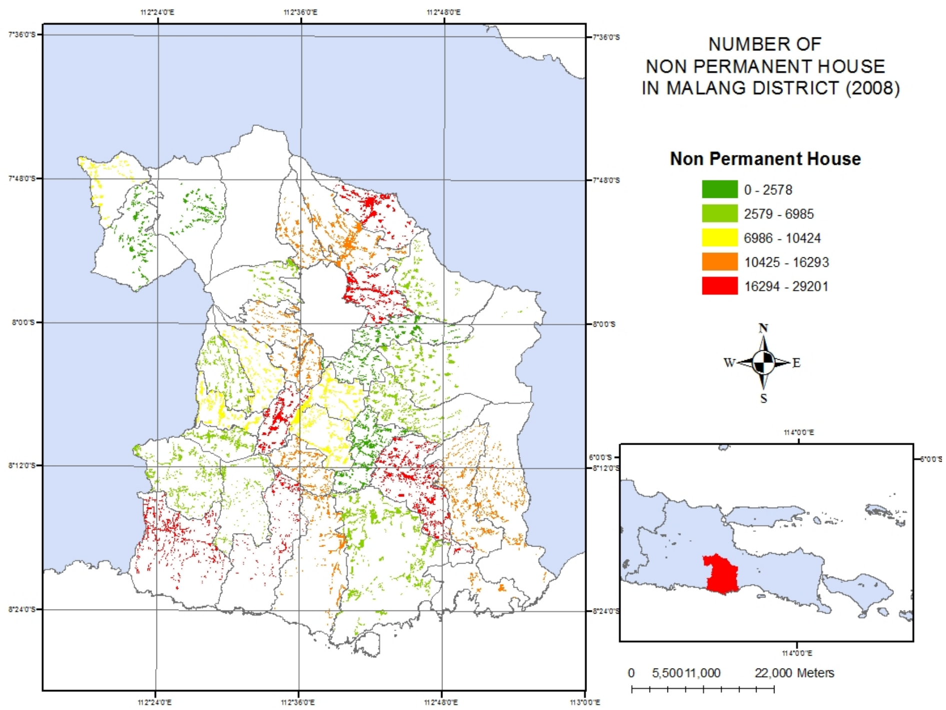


Figure 5.12 Existing Non Permanent Housing for 2008 in Malang District

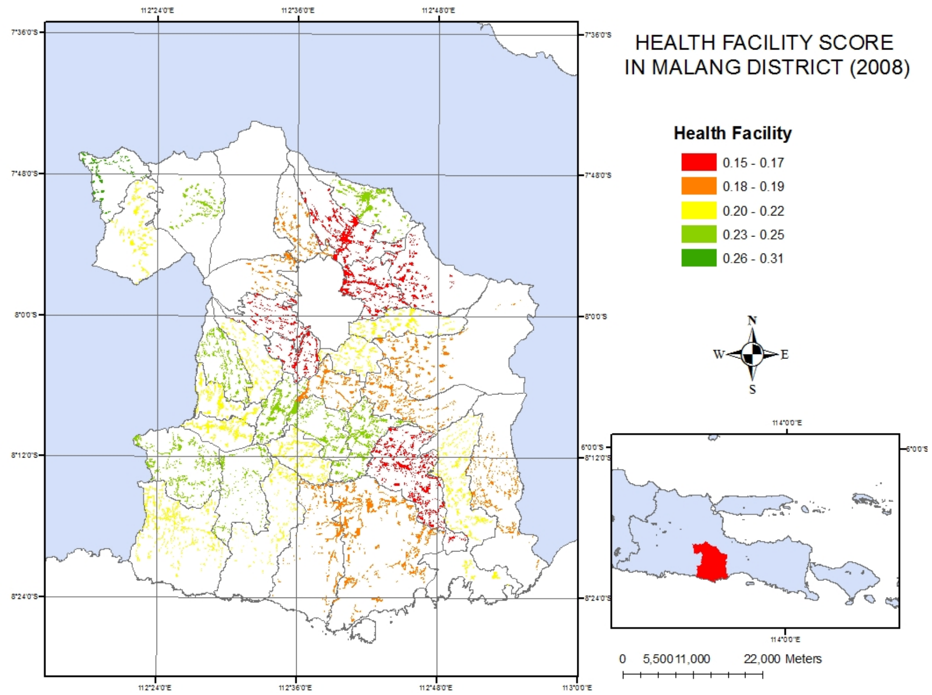


Figure 5.13 Existing Health Facility Score for 2008 in Malang District

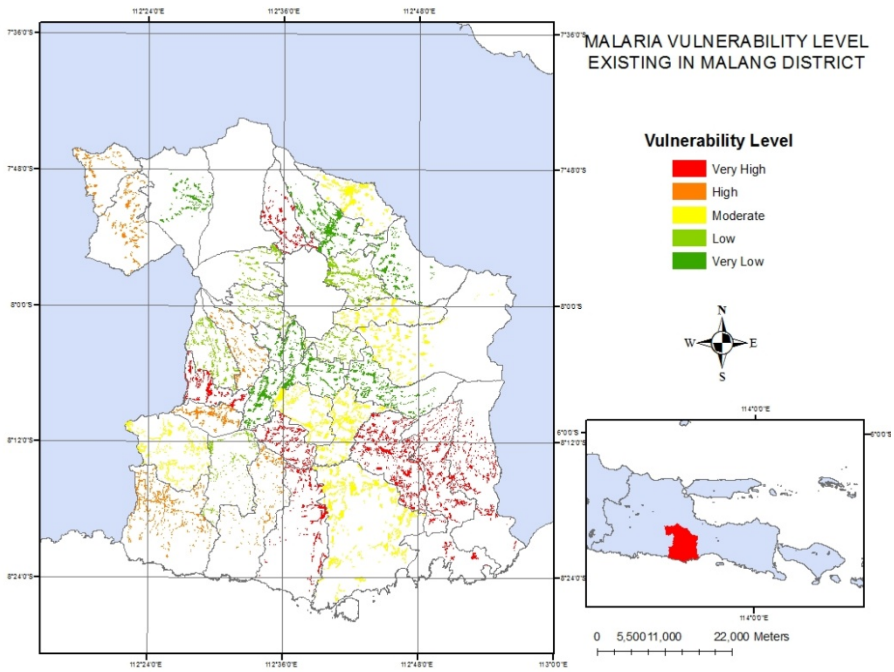


Figure 5.14 Existing Vulnerability Level to Malaria for 2008 in Malang District

5.5 Projection 2030 of Malaria Vulnerability Analysis

Malaria vulnerability score for 2030 is calculated and its result is shown in Table 5.4.

Table 5.5: Results of Vulnerability Score to Malaria in Malang District 2030

No	Sub Districts	Vpb	Vhb	Vnp	Vhf	Vtotal	Levels
1	Tumpang	0.38	0.286	0.005	0.02	0.66	High
2	Poncokusumo	0.42	0.306	0.027	0.02	0.74	Very High
3	Jabung	0.30	0.185	0.050	0.02	0.52	Low
4	Pakis	0.26	0.193	0.141	0.02	0.58	Moderate
5	Lawang	0.24	0.155	0.080	0.02	0.45	Very Low
6	Singosari	0.16	0.144	0.006	0.02	0.30	Very Low
7	Karangploso	0.42	0.255	0.141	0.02	0.80	Very High
8	Dau	0.38	0.260	0.013	0.02	0.63	Moderate
9	Pujon	0.11	0.071	0.000	0.02	0.16	Very Low
10	Ngantang	0.47	0.346	0.000	0.02	0.80	Very High
11	Kasembon	0.34	0.225	0.016	0.03	0.55	Moderate
12	Kepanjen	0.07	0.050	0.000	0.02	0.10	Very Low
13	Sumber Pucung	0.45	0.314	0.000	0.02	0.75	Very High
14	Kromengan	0.41	0.266	0.061	0.02	0.72	High
15	Pakisaji	0.09	0.064	0.000	0.02	0.14	Very Low
16	Ngajum	0.38	0.260	0.000	0.02	0.62	Moderate

No	Sub Districts	Vpb	Vhb	Vnp	Vhf	Vtotal	Levels
17	Wonosari	0.23	0.156	0.000	0.02	0.37	Very Low
18	Wagir	0.17	0.144	0.059	0.01	0.36	Very Low
19	Pagak	0.22	0.149	0.000	0.02	0.35	Very Low
20	Donomulyo	0.38	0.263	0.074	0.02	0.70	High
21	Kalipare	0.28	0.215	0.000	0.02	0.48	Low
22	Bantur	0.25	0.158	0.000	0.02	0.39	Very Low
23	Gedangan	0.41	0.301	0.000	0.02	0.69	High
24	Gondanglegi	0.35	0.170	0.013	0.03	0.50	Low
25	Bululawang	0.20	0.130	0.033	0.02	0.35	Very Low
26	Wajak	0.29	0.213	0.045	0.02	0.53	Low
27	Tajinan	0.33	0.202	0.000	0.02	0.51	Low
28	Turen	0.39	0.275	0.000	0.02	0.65	High
29	Dampit	0.38	0.268	0.101	0.02	0.74	Very High
30	Sumbermanjing Wetan	0.39	0.271	0.004	0.02	0.65	High
31	Ampelgading	0.42	0.270	0.098	0.02	0.77	Very High
32	Tirtoyudo	0.41	0.279	0.092	0.02	0.77	Very High
33	Pagelaran	0.47	0.380	0.132	0.02	0.96	Very High

Vpb = Vulnerability based on Population Near Breeding Site
Vhb = Vulnerability based on House Near Breeding Site
Vnp = Vulnerability based on Non Permanent Housing
Vhf = Vulnerability based on Health Facility
Vtotal = Summation of vulnerability to Malaria in corresponding area

Figure 5.14-5.18 show malaria vulnerability score for each variable for 2030 in GIS format. Figure 5.14 shows population near breeding site, Figure 5.15 shows amount of house near breeding site, Figure 5.16 shows percentage non permanent housing, Figure 5.17 shows coverage of health facility, and Figure 5.18 shows total vulnerability level of malaria.

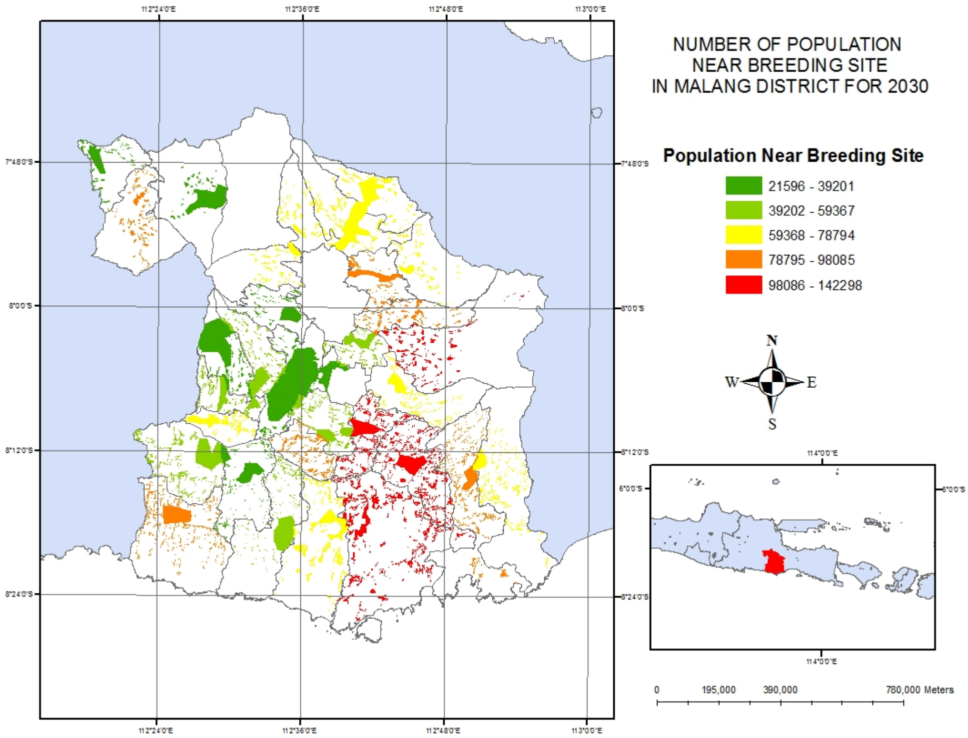


Figure 5.15 Projection of Population Near Breeding Site for 2030 in Malang District

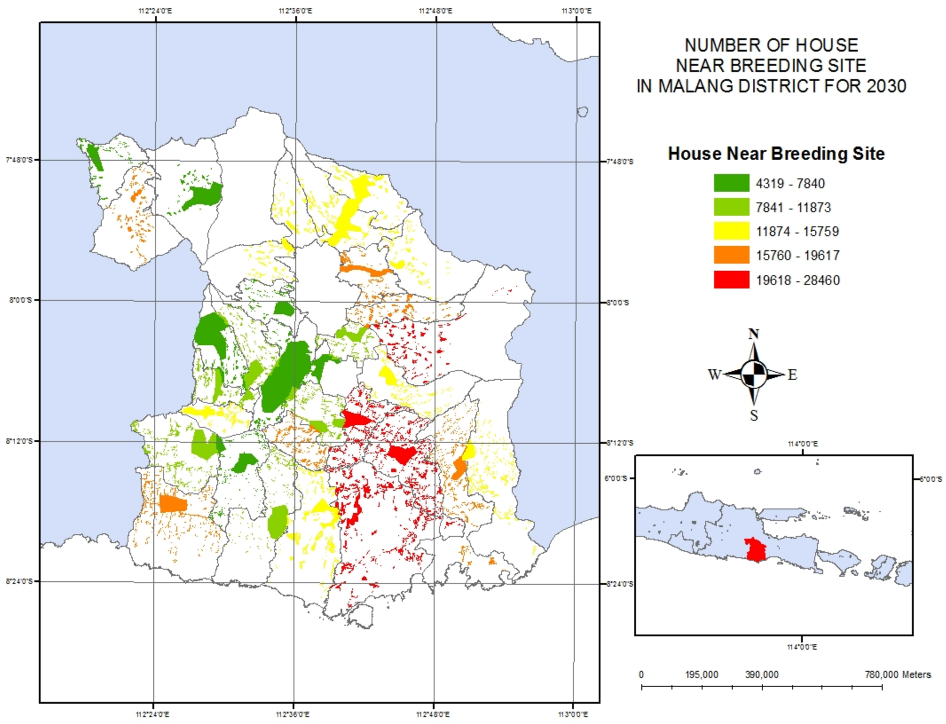


Figure 5.16 Projection of House Near Breeding Site for 2030 in Malang District

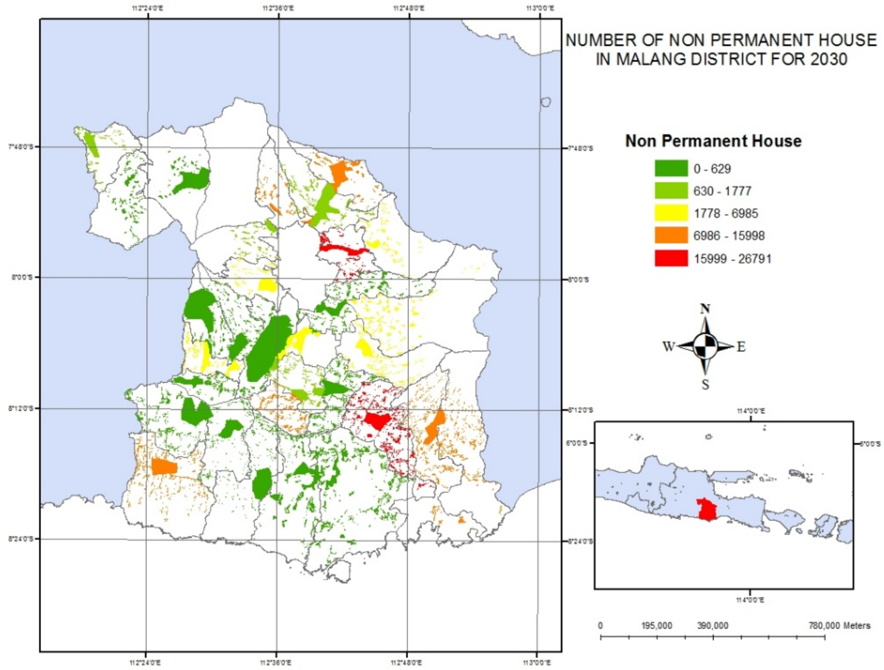


Figure 5.17 Projection of Non Permanent Housing for 2030 in Malang District

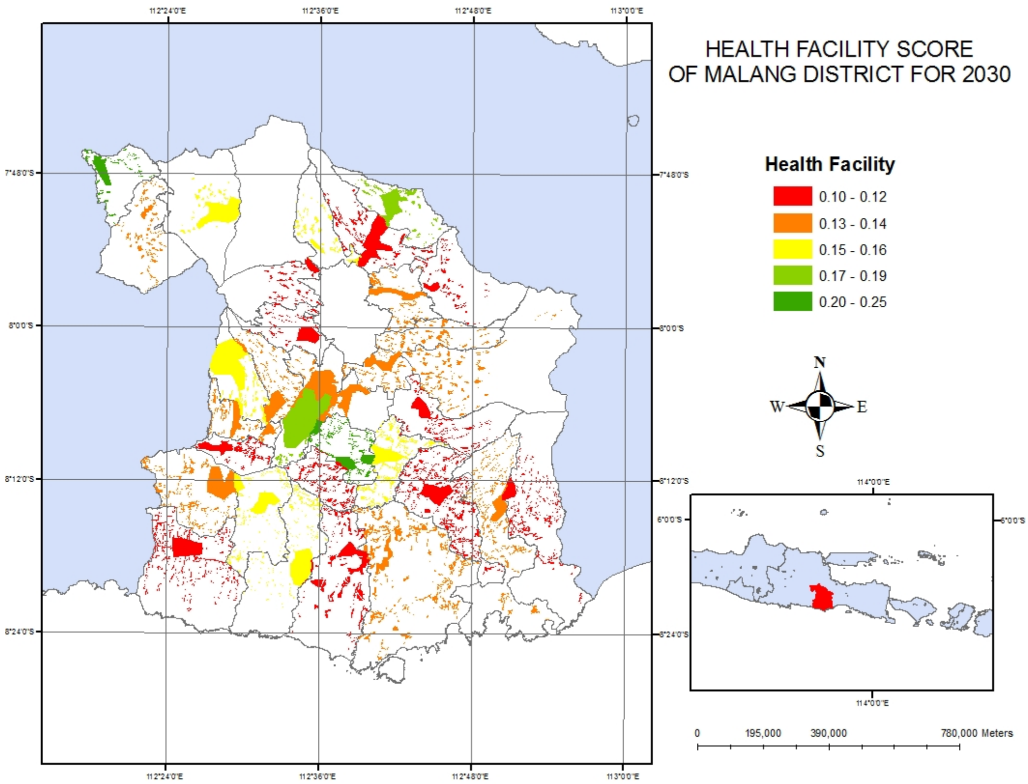


Figure 5.18 Projection of Health Facility Score for 2030 in Malang District

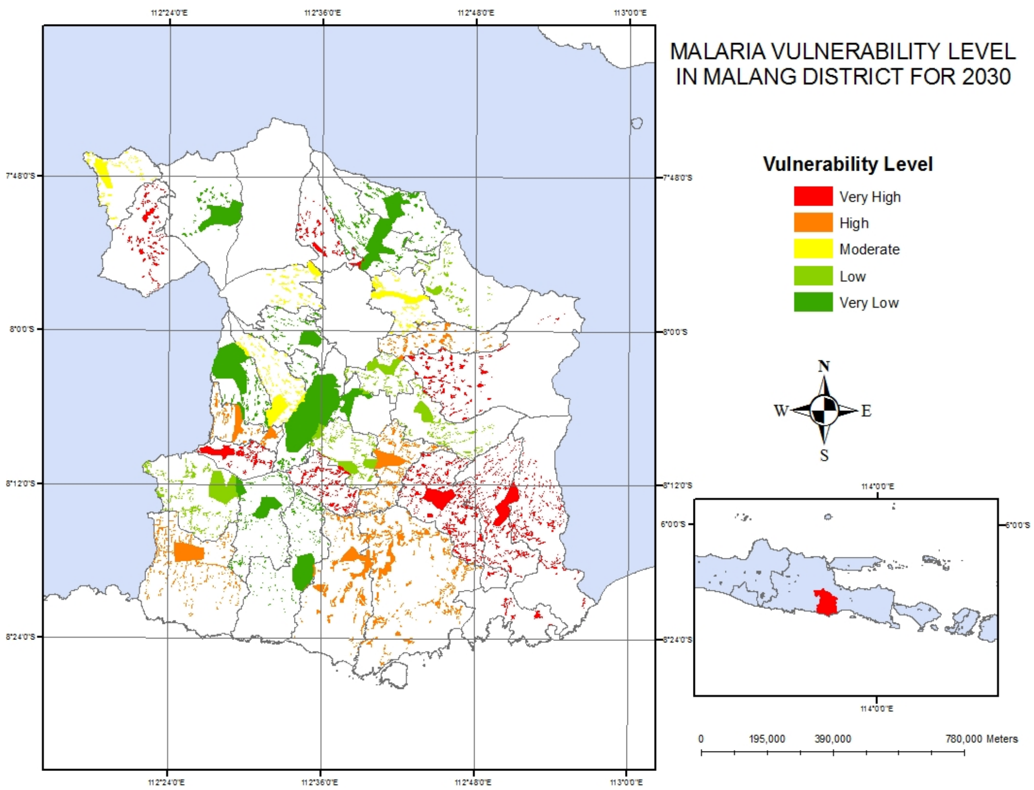


Figure 5.19 Projection of Malaria Vulnerability Level for 2030 in Malang District

5.6 Comparison of Malaria Vulnerability Levels in 2008 and 2030

Comparison of malaria vulnerability levels in Malang District for 2008 and 2030 is described in Table 5.6 below.

Table 5.6: Results of Existing Vulnerability Score to Malaria in Malang District

No	Sub Districts	Levels 2008	Levels 2030	Comparison
1	Tumpang	Moderate	High	+1
2	Poncokusumo	Moderate	Very High	+2
3	Jabung	Very Low	Low	+1
4	Pakis	Low	Moderate	+1
5	Lawang	Moderate	Very Low	-2
6	Singosari	Very Low	Very Low	0
7	Karangploso	Very High	Very High	0
8	Dau	Low	Moderate	+1
9	Pujon	Very Low	Very Low	0
10	Ngantang	High	Very High	+1
11	Kasembon	High	Moderate	-1
12	Kepanjen	Very Low	Very Low	0
13	Sumber Pucung	High	Very High	+1
14	Kromengan	Very High	High	-1
15	Pakisaji	Very Low	Very Low	0
16	Ngajum	High	Moderate	-1
17	Wonosari	Low	Very Low	-1
18	Wagir	Low	Very Low	-1
19	Pagak	Low	Very Low	-1
20	Donomulyo	High	High	0
21	Kalipare	Moderate	Low	-1
22	Bantur	High	Very Low	-3

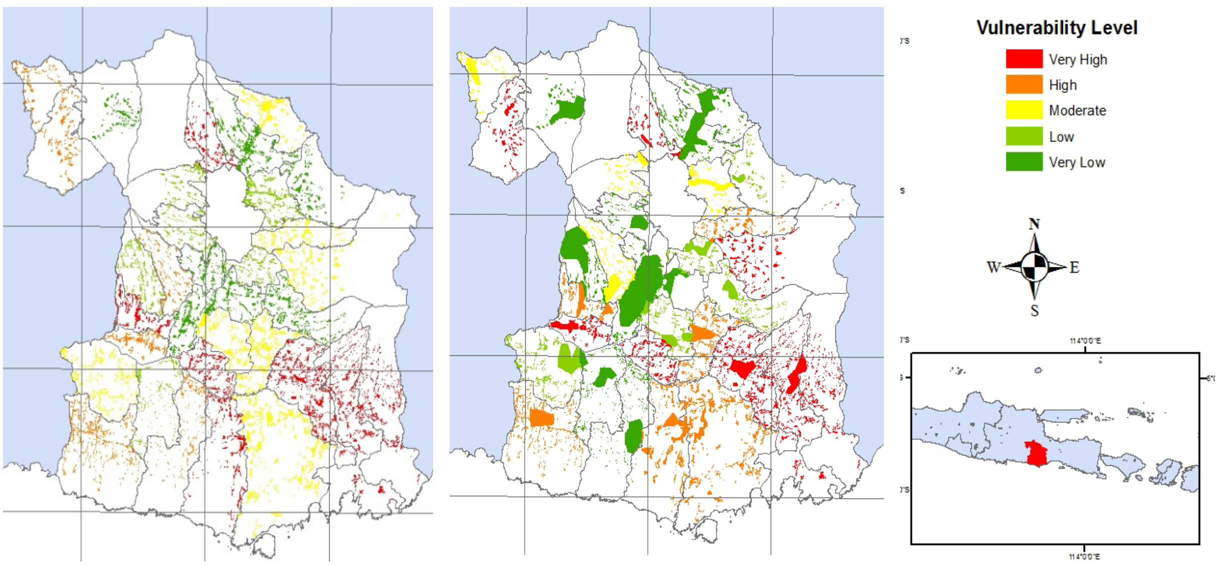
No	Sub Districts	Levels 2008	Levels 2030	Comparison
23	Gedangan	Very High	High	-1
24	Gondanglegi	Moderate	Low	-1
25	Bululawang	Very Low	Very Low	0
26	Wajak	Very Low	Low	+1
27	Tajinan	Low	Low	0
28	Turen	Moderate	High	+1
29	Dampit	Very High	Very High	0
30	Sumbermanjing Wetan	Moderate	High	+1
31	Ampelgading	Very High	Very High	0
32	Tirtoyudo	Very High	Very High	0
33	Pagelaran	Very High	Very High	0

Note:

+1 : increase one level
+2 : increase two level
+3 : increase three level
+4 : increase four level
0 : same level

-1 : decrease one level
-2 : decrease two level
-3 : decrease three level
-4 : decrease four level

Comparison of Malaria Vulnerability map in Malang District for 2008 and 2030 is described in Figure 5.20 below.



Malaria Vulnerability Map 2008 Malaria Vulnerability Map 2030

Figure 5.20 Comparison between Malaria Vulnerability Map 2008 and 2030

5.7 Diarrhea Vulnerability Analysis

Vulnerability score of diarrhea in 2008 is calculated and its result is shown in Table 5.5.

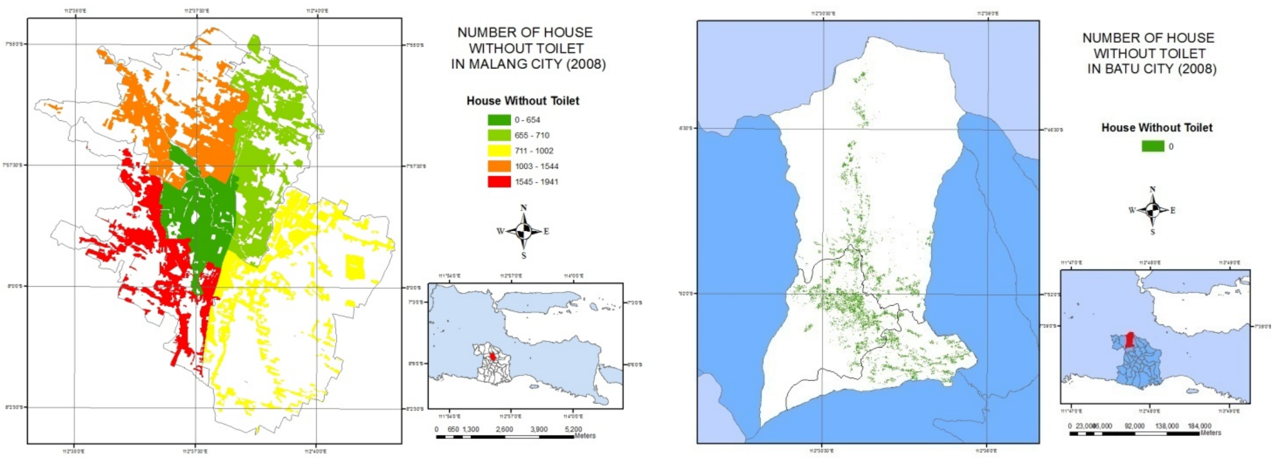
Table 5.7: Results of Existing Vulnerability Score to Diarrhea in Malang City and Batu City

No	Sub Districts	Vp	Vht	Vpw	Vhf	Vtotal	Levels
Malang City							

No	Sub Districts	Vp	Vht	Vpw	Vhf	Vtotal	Levels
1	Kedung Kandang	0.056	0.006	0.070	0.03	0.10	Moderate
2	Sukun	0.060	0.006	0.130	0.04	0.15	Very High
3	Klojen	0.043	0.005	0.098	0.10	0.04	Low
4	Blimbing	0.059	0.005	0.117	0.06	0.12	High
5	Lowok Waru	0.062	0.005	0.117	0.04	0.14	Very High
Batu City							
6	Batu	0.131	0.000	0.046	0.07	0.11	Moderate
7	Junrejo	0.066	0.000	0.036	0.06	0.04	Very Low
9	Bumiaji	0.083	0.000	0.001	0.04	0.04	Very Low

Vp = Vulnerability based on Population Number
Vht = Vulnerability based on House without Toilet
Vpw = Vulnerability based on Piped Water Coverage
Vhf = Vulnerability based on Health Facility
Vtotal = Summation of vulnerability to Diarrhea in corresponding area

Figure 5.19-5.22 show diarrhea vulnerability score for each variable for 2008 in GIS format. Figure 5.19 shows proportion of houses without toilet, Figure 5.20 shows coverage of piped water, Figure 5.21 shows coverage of health facility, and Figure 5.22 shows total vulnerability level of diarrhea in 2008.



(a) (b)

Figure 5.21 Existing Houses without Toilet for 2008 in (a) Malang City and (b) Batu City

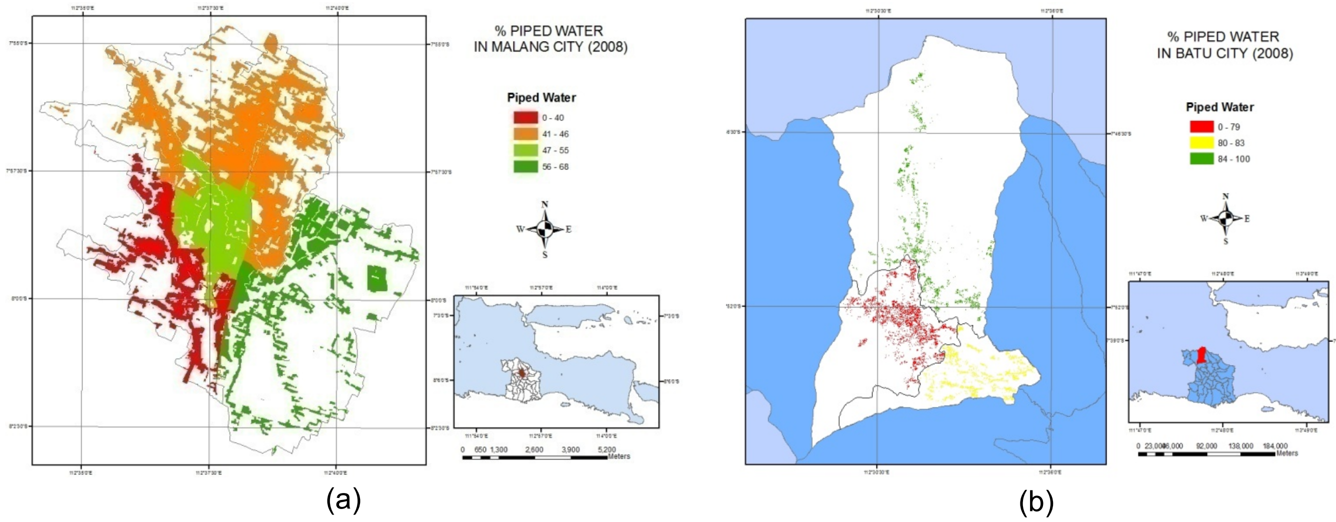


Figure 5.22 Existing Piped Water Coverage for 2008 in (a) Malang City and (b) Batu City

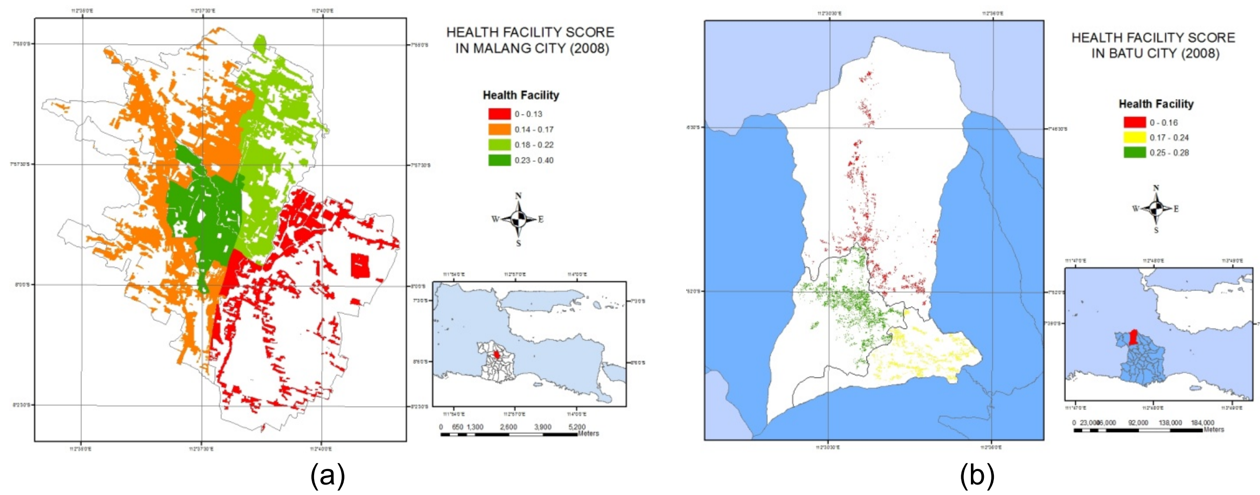


Figure 5.23 Existing Health Facility Score for 2008 in (a) Malang City and (b) Batu City

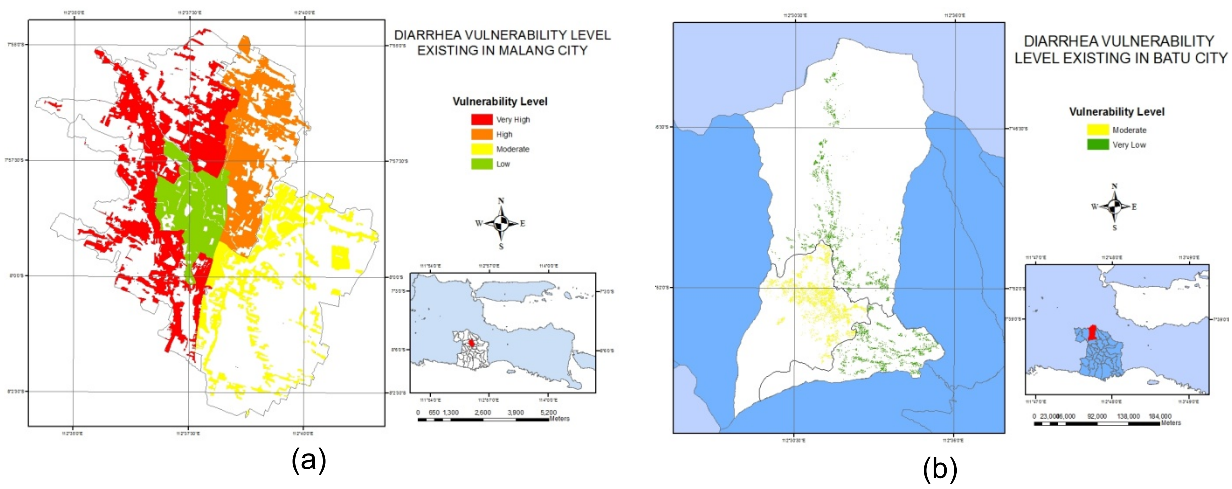


Figure 5.24 Existing Vulnerability Level to Diarrhea for 2008 in (a) Malang City and (b) Batu City

5.8 Projection 2030 of Diarrhea Vulnerability Analysis

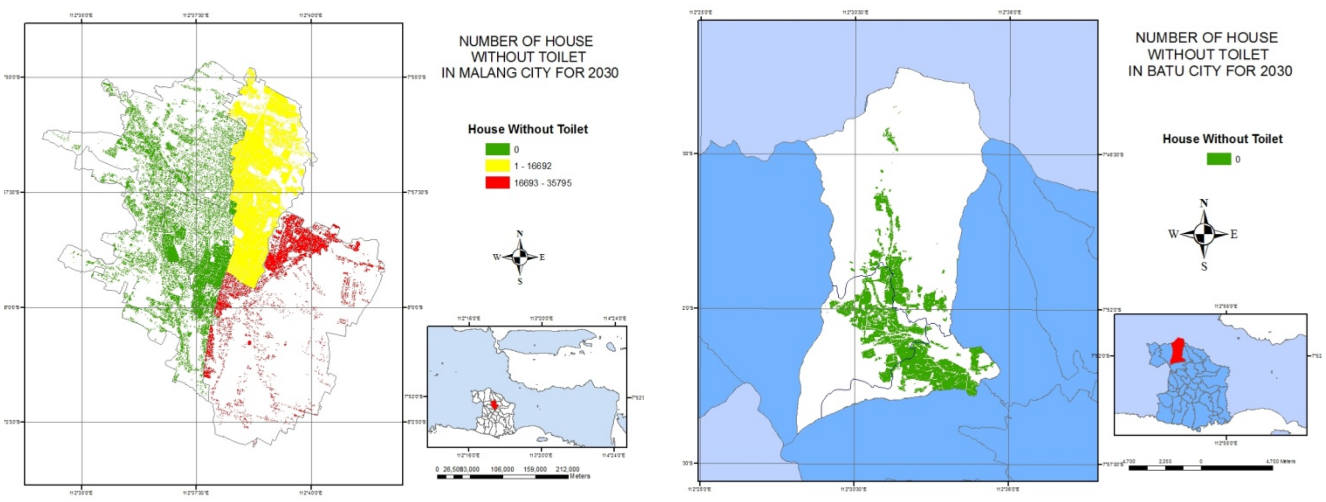
Vulnerability score of projected diarrhea 2030 is calculated and its result is shown in Table 5.6.

Table 5.8: Results of Vulnerability Score to Diarrhea in Malang City and Batu City 2030

No	Sub Districts	Vp	Vht	Vpw	Vhf	Vtotal	Levels
Malang City							
1	Kedung Kandang	0.075	0.120	0.140	0.03	0.31	Very High
2	Sukun	0.053	0	0.093	0.04	0.11	Moderate
3	Klojen	0.028	0	0.086	0.12	0.00	Very Low
4	Blimbing	0.051	0.083	0.150	0.05	0.23	Very High
5	Lowok Waru	0.074	0	0.114	0.03	0.15	Very High
Batu City							
6	Batu	0.128	0	0.065	0.05	0.14	Very High
7	Junrejo	0.070	0	0.065	0.04	0.09	Moderate
8	Bumiaji	0.081	0	0.065	0.03	0.11	High

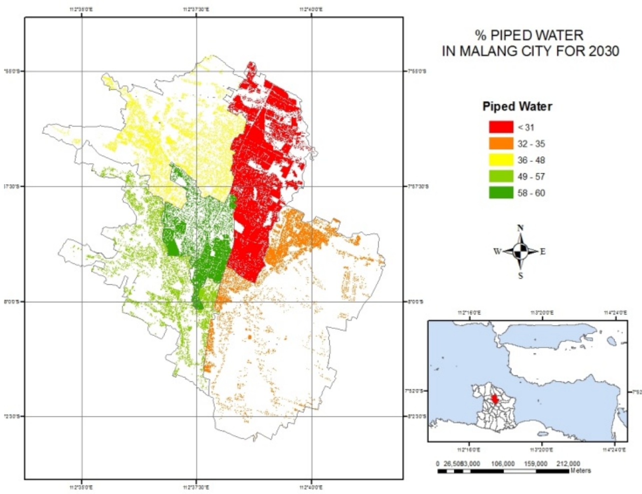
Vp = Vulnerability based on Population Number
Vht = Vulnerability based on House without Toilet
Vpw = Vulnerability based on Piped Water Coverage
Vhf = Vulnerability based on Health Facility
Vtotal = Summation of vulnerability to Diarrhea in corresponding area

Figure 5.23-5.26 show diarrhea vulnerability score for each variable for 2030 in GIS format. Figure 5.23 shows proportion of houses without toilet, Figure 5.24 shows coverage of piped water, Figure 5.25 shows coverage of health facility, and Figure 5.26 shows total vulnerability level of diarrhea in 2030.

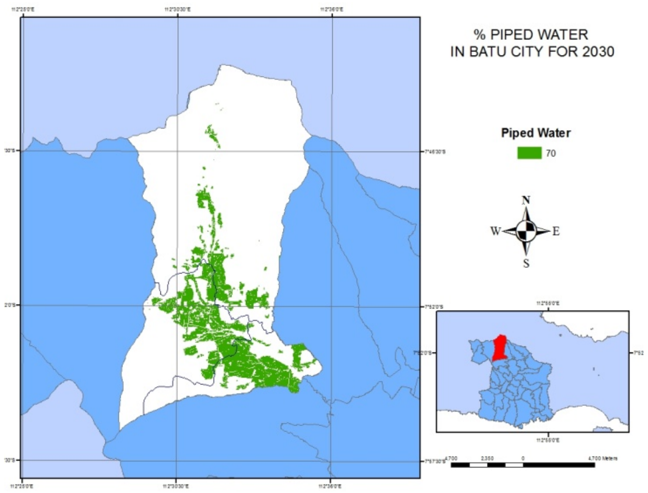


(a) (b)

Figure 5.25 Projection of House without Toilet for 2030 in (a) Malang City and (b) Batu City

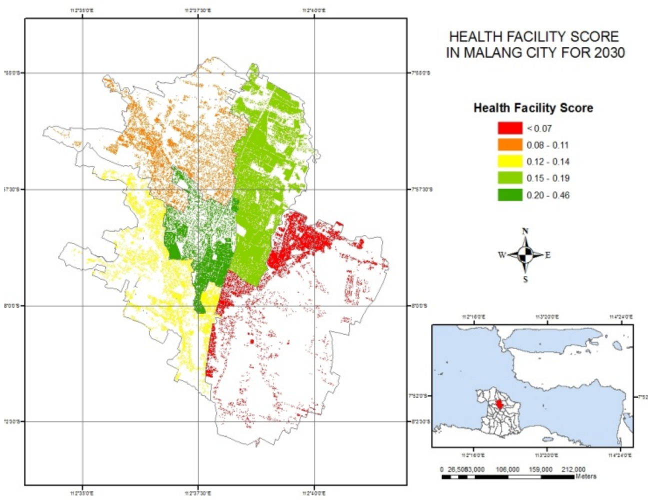


(a)

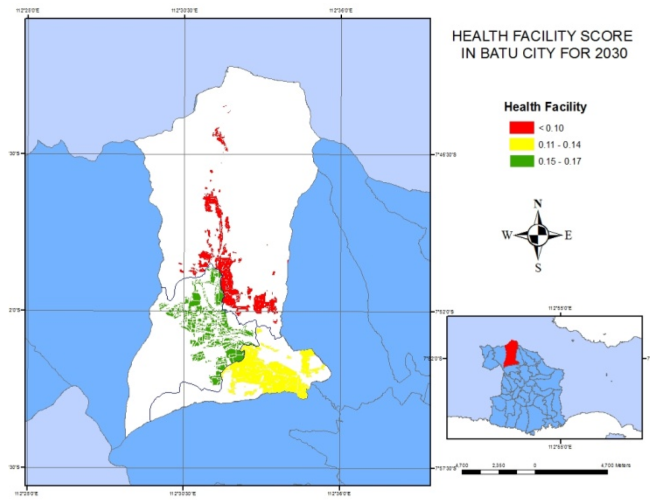


(b)

Figure 5.26 Projection of Piped Water Coverage for 2030 in (a) Malang City and (b) Batu City

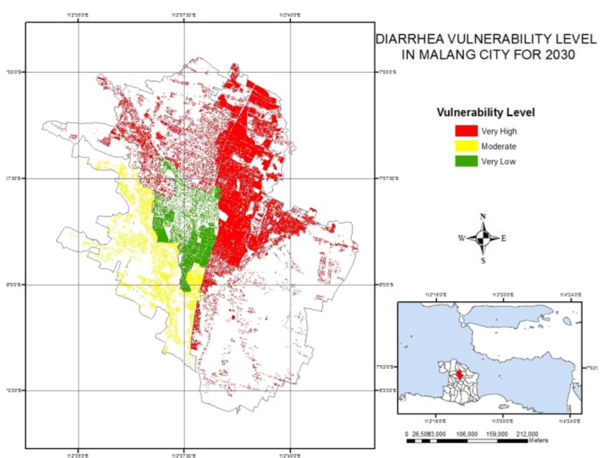


(a)

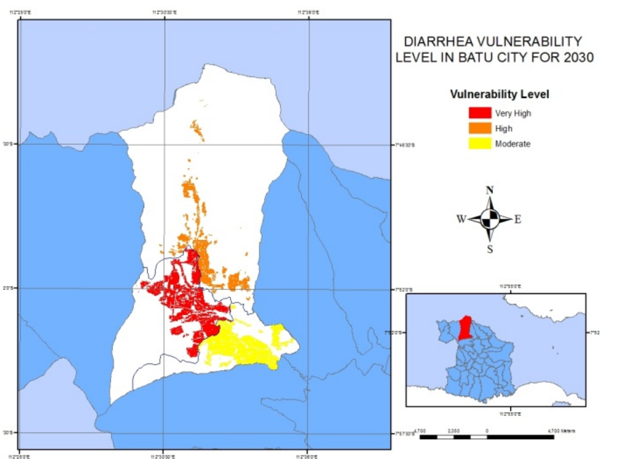


(b)

Figure 5.27 Projection of Health Facility Scores for 2030 in (a) Malang City and (b) Batu City



(a)



(b)

Figure 5.28 Projection of Diarrhea Vulnerability Level for 2030 in (a) Malang City and (b) Batu City

5.9 Comparison of Diarrhea Vulnerability Levels in 2008 and 2030

Comparison of Malaria Vulnerability levels in Malang City and Batu City for 2008 and 2030 is described in Table 5.9 Below.

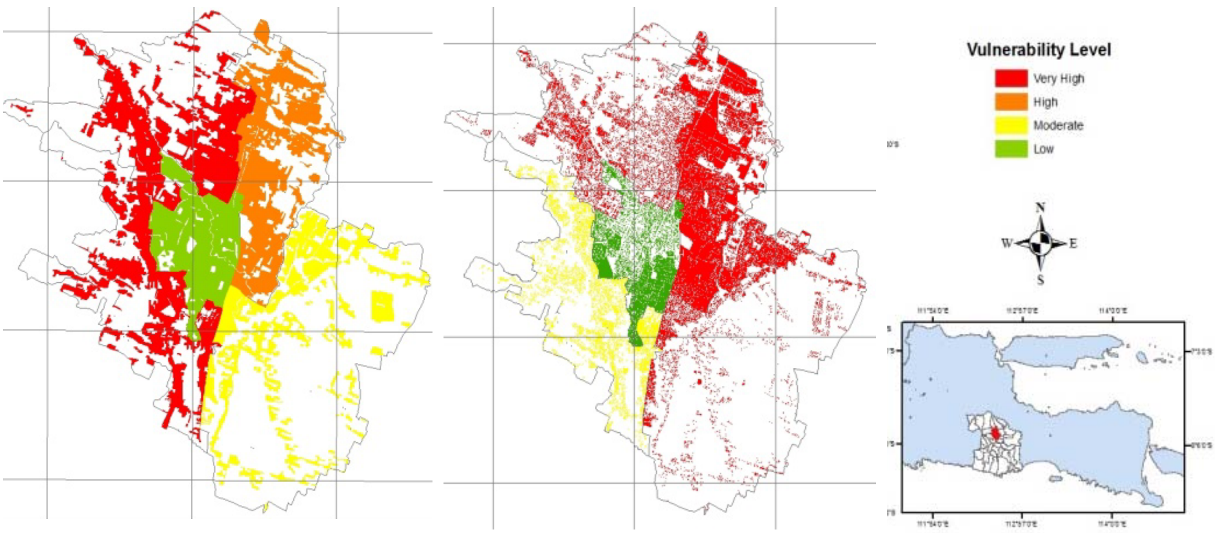
Table 5.9: Results of Existing Vulnerability Score to Diarrhea in Malang City and Batu City

No	Sub Districts	Levels 2008	Levels 2030	Comparison
Malang City				
1	Kedung Kandang	Moderate	Very High	+2
2	Sukun	Very High	Moderate	-2
3	Klojen	Low	Very Low	-1
4	Blimbing	High	Very High	+1
5	Lowok Waru	Very High	Very High	0
Batu City				
6	Batu	Moderate	Very High	+2
7	Junrejo	Very Low	Moderate	+2
8	Bumiaji	Very Low	High	+3

Note:

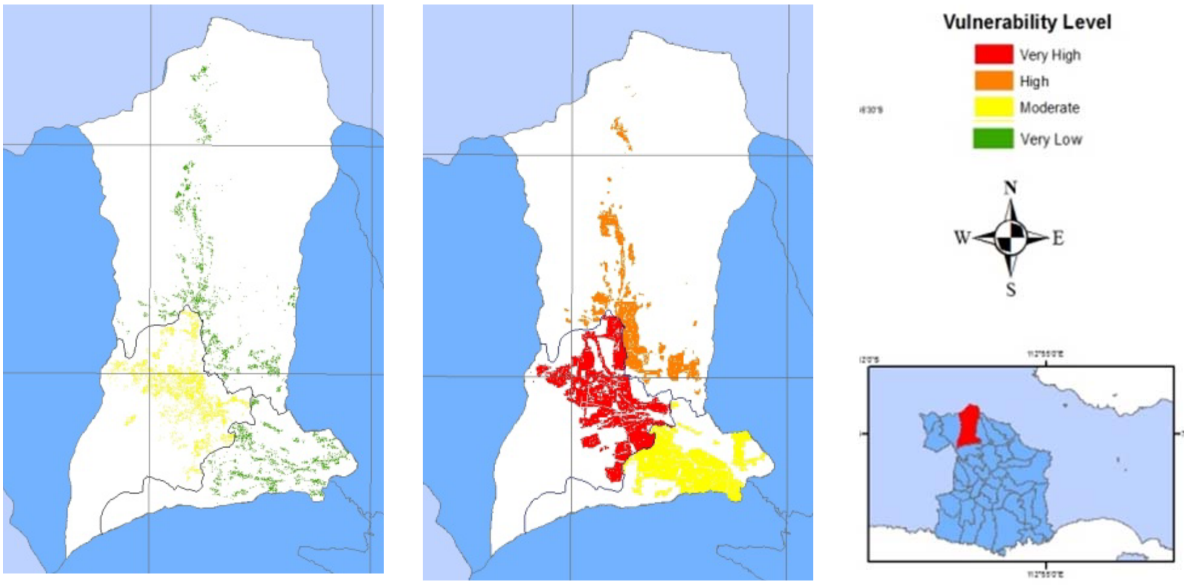
+1 : increase one level — -1 : decrease one level
+2 : increase two level — -2 : decrease two level
+3 : increase three level — -3 : decrease three level
+4 : increase four level — -4 : decrease four level
0 : same level

Comparison of diarrhea vulnerability map in Malang City and Batu City for 2008 and 2030 is described in Figure 5.29 below.



Diarrhea Vulnerability Map 2008 — Diarrhea Vulnerability Map 2030

(a) Diarrhea Vulnerability Level in Malang City



DHF Vulnerability Map 2008 DHF Vulnerability Map 2030

(b) DHF Vulnerability Level in Batu City

Figure 5.29 Comparison between Diarrhea Vulnerability Map 2008 and 2030

CHAPTER 6 RISK ASSESSMENT

Methodology to calculate risk assessment is described in detail in Chapter 3.6. Risk score are calculated using basic equation:

$$R = H \times V \quad (6.1)$$

Where:

R = risk
H = hazard
V = vulnerability

In this study, risk for 2008 is calculated based on hazard and vulnerability data in 2008, and projected risk 2030 is calculated based on hazard and vulnerability in 2030. The risk score is measured through matrix method (see Figure 3.16).

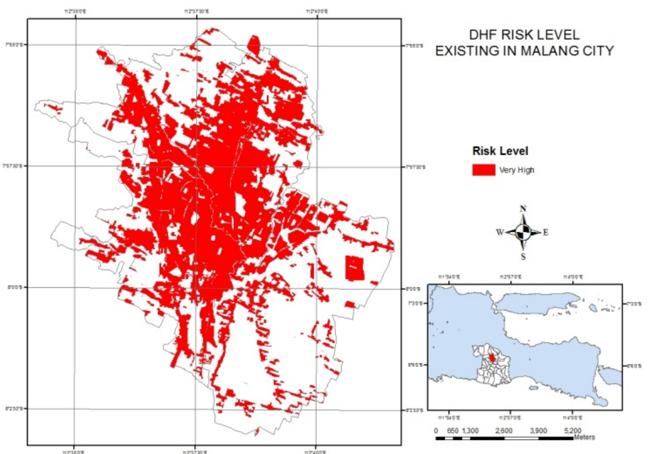
6.1 Risk Assessment of DHF

Risk of DHF in corresponding districts is determined according to the Risk Assessment Matrix. The results in tabular form are shown in table 6.1, while Risk Map is shown in Figure 6.1.

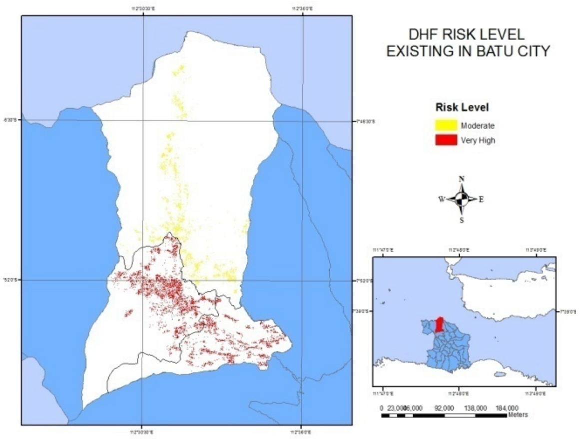
Table 6.1: Existing Risk Levels of DHF in Greater Malang

No	Sub Districts	Hazard		Vulnerability		Levels
		Average prevalence (2008-2010) /1,000 Occupants	Level	Score	Level	
Malang City						
1	Kedung Kandang	0.532	High	0.21	Very High	Very High
2	Sukun	0.707	Very High	0.37	Very High	Very High
3	Klojen	1.125	Very High	0.16	High	Very High
4	Blimbing	0.601	Very High	0.22	Very High	Very High
5	Lowok Waru	0.696	Very High	0.24	Very High	Very High
Malang District						
6	Tumpang	0.453	High	0.12	Low	High
7	Poncokusumo	0.089	Very Low	0.15	Moderate	Very Low
8	Jabung	0.107	Very Low	0.15	High	Very Low
9	Pakis	0.561	High	0.11	Very Low	High
10	Lawang	0.185	Low	0.07	Very Low	Low
11	Singosari	0.185	Low	0.15	High	Low
12	Karangploso	0.325	Moderate	0.08	Very Low	Moderate
13	Dau	0.803	Very High	0.13	Moderate	Very High
14	Pujon	0.026	Very Low	0.13	Low	Very Low
15	Ngantang	0.075	Very Low	0.14	Moderate	Very Low
16	Kasembon	0.032	Very Low	0.12	Low	Very Low
17	Kepanjen	0.358	Moderate	0.10	Very Low	Moderate
18	Sumber Pucung	0.690	Very High	0.15	High	Very High
19	Kromengan	0.270	Low	0.15	Moderate	Low

No	Sub Districts	Hazard		Vulnerability		Levels
		Average prevalence (2008-2010) /1,000 Occupants	Level	Score	Level	
20	Pakisaji	0.572	High	0.12	Low	High
21	Ngajum	0.180	Low	0.13	Low	Low
22	Wonosari	0.167	Low	0.03	Very Low	Low
23	Wagir	0.276	Moderate	0.16	Very High	Moderate
24	Pagak	0.550	High	0.06	Very Low	High
25	Donomulyo	0.245	Low	0.14	Moderate	Low
26	Kalipare	0.317	Moderate	0.13	Moderate	Moderate
27	Bantur	0.569	High	0.15	High	High
28	Gedangan	0.266	Low	0.15	High	Low
29	Gondanglegi	0.477	High	0.08	Very Low	High
30	Bululawang	0.571	High	0.12	Low	High
31	Wajak	0.384	Moderate	0.10	Very Low	Moderate
32	Tajinan	0.308	Moderate	0.11	Low	Moderate
33	Turen	0.705	Very High	0.14	Moderate	Very High
34	Dampit	0.277	Moderate	0.17	Very High	Moderate
35	Sumbermanjing Wetan	0.289	Moderate	0.12	Low	Moderate
36	Ampelgading	0.096	Very Low	0.14	Moderate	Very Low
37	Tirtoyudo	0.080	Very Low	0.15	High	Very Low
38	Pagelaran	0.175	Low	0.15	High	Low
Batu City						
39	Batu	0.592	Very High	0.39	Very High	Very High
40	Junrejo	0.692	Very High	0.31	Very High	Very High
41	Bumiaji	0.109	Very Low	0.33	Very High	Very Low



(a)



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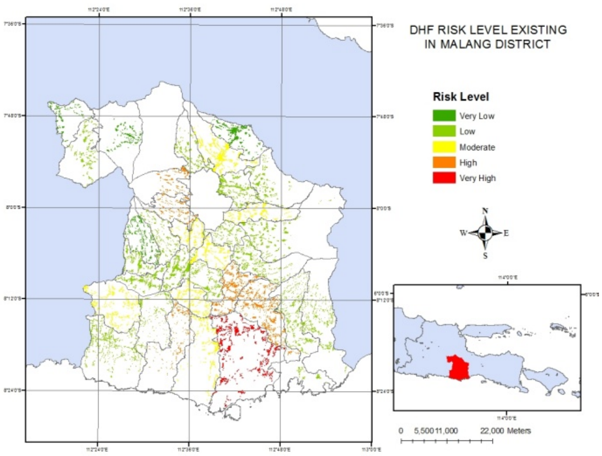


(c)

Figure 6.1 Existing Risk of DHF in: (a) Malang City, (b) Batu City, and (c) Malang District

Table 6.2 mentioned the major factor influence the very high risk score of DHF in each sub districts of Greater Malang.

Table 6.2: Factors Influence the Risk Score 2008 in Sub districts with Very High Risk Score of DHF

Districts and Sub Districts		Component	Main Causal Factors
Malang City	Sukun	Hazard	High prevalence of DHF
		Vulnerability	High population density
	Klojen	Hazard	High prevalence of DHF
		Vulnerability	High population density
	Blimbing	Hazard	High prevalence of DHF
		Vulnerability	High population density
	Lowok Waru	Hazard	High prevalence of DHF
		Vulnerability	High population density
Malang District	Dau	Hazard	High prevalence of DHF
		Vulnerability	Low piped water coverage
	Sumber Pucung	Hazard	High prevalence of DHF
		Vulnerability	Low piped water coverage
	Turen	Hazard	High prevalence of DHF
		Vulnerability	Low piped water coverage
Batu City	Batu	Hazard	High prevalence of DHF
		Vulnerability	High population density
	Junrejo	Hazard	High prevalence of DHF
		Vulnerability	High population density

6.2 Projection Risk Assessment of DHF

Risk of DHF in corresponding sub districts is determined according to the Risk Assessment Matrix. The results in tabular form are shown in table 6.3, while Risk Map is shown in Figure 6.2.

Table 6.3: Projection Risk Levels of DHF in Greater Malang 2030

No	Sub Districts	Hazard		Vulnerability		Levels
		Average prevalence (2030) /1,000 Occupants	Level	Score	Level	
Malang City						
1	Kedung Kandang	0.4	Moderate	0.44	Very High	High
2	Sukun	1.0	Very High	0.37	Very High	Very High
3	Klojen	2.4	Very High	0.24	Very High	Very High
4	Blimbing	0.9	Very High	0.24	Very High	Very High
5	Lowok Waru	0.9	Very High	0.42	Very High	Very High
Malang District						
6	Tumpang	0.5	High	0.13	Low	Moderate
7	Poncokusumo	0.1	Very Low	0.16	High	Low
8	Jabung	0.2	Very Low	0.22	Very High	Moderate
9	Pakis	1.0	Very High	0.11	Very Low	Moderate
10	Lawang	0.2	Very Low	0.04	Very Low	Very Low
11	Singosari	0.2	Low	0.10	Very Low	Very Low
12	Karangploso	0.6	Very High	0.08	Very Low	Moderate
13	Dau	0.5	High	0.13	Low	Moderate
14	Pujon	0.0	Very Low	0.04	Very Low	Very Low
15	Ngantang	0.1	Very Low	0.14	Moderate	Low
16	Kasembon	0.1	Very Low	0.04	Very Low	Very Low
17	Kepanjen	0.4	Moderate	0.04	Very Low	Low
18	Sumber Pucung	0.4	Moderate	0.11	Low	Low
19	Kromengan	0.2	Low	0.09	Very Low	Very Low
20	Pakisaji	0.4	Moderate	0.05	Very Low	Low
21	Ngajum	0.1	Very Low	0.04	Very Low	Very Low
22	Wonosari	0.1	Very Low	0.04	Very Low	Very Low
23	Wagir	0.2	Low	0.10	Very Low	Very Low
24	Pagak	0.4	Moderate	0.04	Very Low	Low
25	Donomulyo	0.2	Very Low	0.10	Very Low	Very Low
26	Kalipare	0.2	Low	0.06	Very Low	Very Low
27	Bantur	0.3	Moderate	0.04	Very Low	Low
28	Gedangan	0.2	Low	0.05	Very Low	Very Low
29	Gondanglegi	0.9	Very High	0.03	Very Low	Moderate
30	Bululawang	0.4	Moderate	0.10	Very Low	Low

No	Sub Districts	Hazard		Vulnerability		Levels
		Average prevalence (2030) /1,000 Occupants	Level	Score	Level	
31	Wajak	0.2	Low	0.12	Low	Low
32	Tajinan	0.2	Low	0.04	Very Low	Very Low
33	Turen	0.7	Very High	0.12	Low	High
34	Dampit	0.2	Low	0.14	Moderate	Low
35	Sumbermanjing Wetan	0.2	Very Low	0.11	Very Low	Very Low
36	Ampelgading	0.1	Very Low	0.12	Low	Very Low
37	Tirtoyudo	0.1	Very Low	0.12	Low	Very Low
38	Pagelaran	0.1	Very Low	0.16	High	Low
Batu City						
39	Batu	2.4	Very High	0.23	Very High	Very High
40	Junrejo	1.3	Very High	0.16	Very High	Very High
41	Bumiaji	0.4	Moderate	0.19	Very High	High

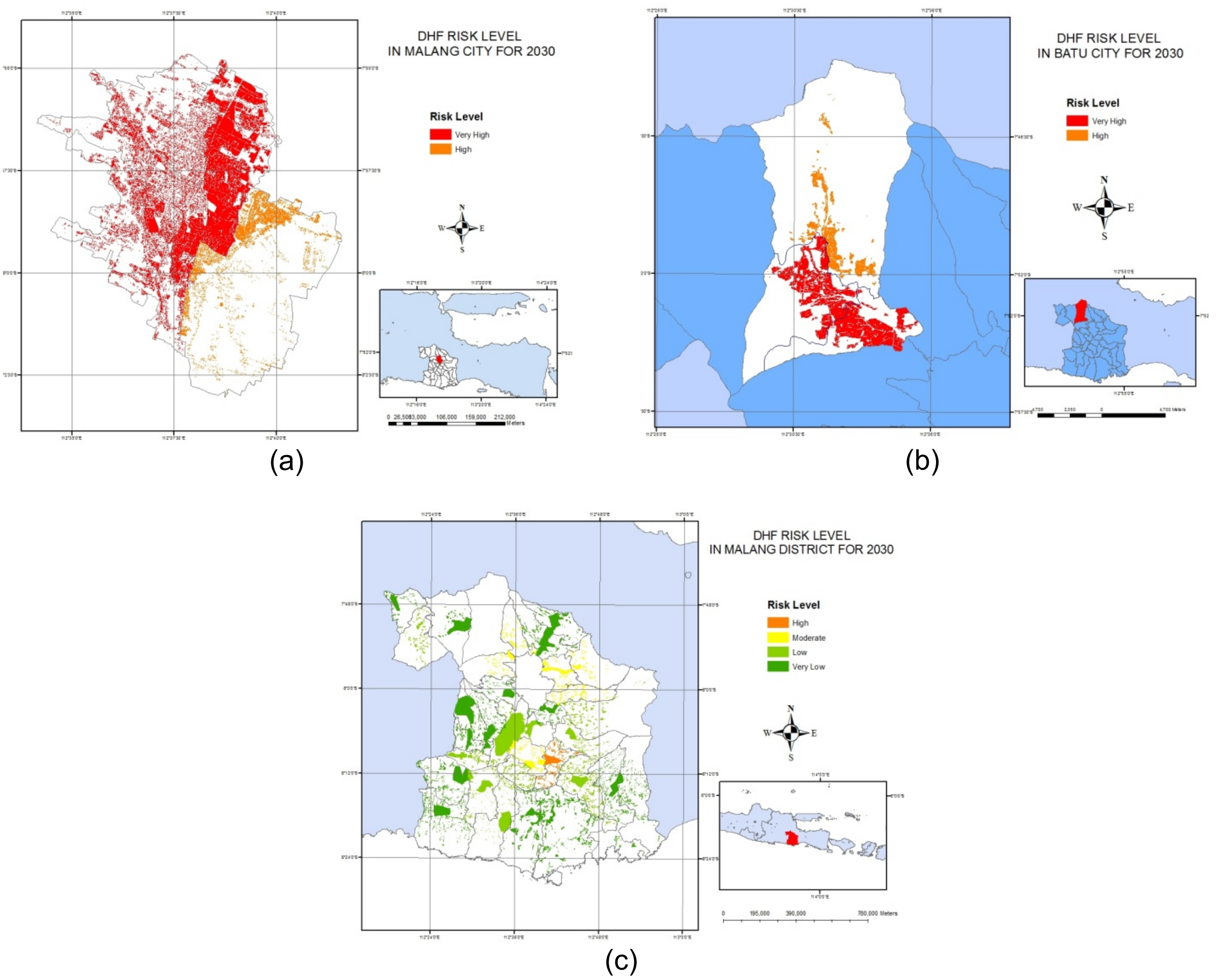


Figure 6.2 Projection Risk of DHF in (a) Malang City, (b) Batu City, and (c) Malang District

Table 6.4 shows factors influence the risk score 2030 in sub districts with very high risk score of DHF. In 2030, the sub districts that have very high risk in DHF are Sukun, Klojen, Blimbing, and Lowok Waru in Malang City and Batu and Junrejo in Batu City.

Table 6.4: Factors Influence the Risk Score 2030 in Sub districts with Very High Risk Score of DHF

Districts and Sub Districts		Component	Main Causal Factors
Malang City	Sukun	Hazard	High prevalence of DHF
		Vulnerability	High population density
	Klojen	Hazard	High prevalence of DHF
		Vulnerability	High population density
	Blimbing	Hazard	High prevalence of DHF
		Vulnerability	High population density
	Lowok Waru	Hazard	High prevalence of DHF
		Vulnerability	High population density
Batu City	Batu	Hazard	High prevalence of DHF
		Vulnerability	High population density
	Junrejo	Hazard	High prevalence of DHF
		Vulnerability	High population density

6.3 Comparison of DHF Risk Levels in 2008 and 2030

Comparison of DHF risk levels in Greater Malang for 2008 and 2030 is described in Table 6.5 below.

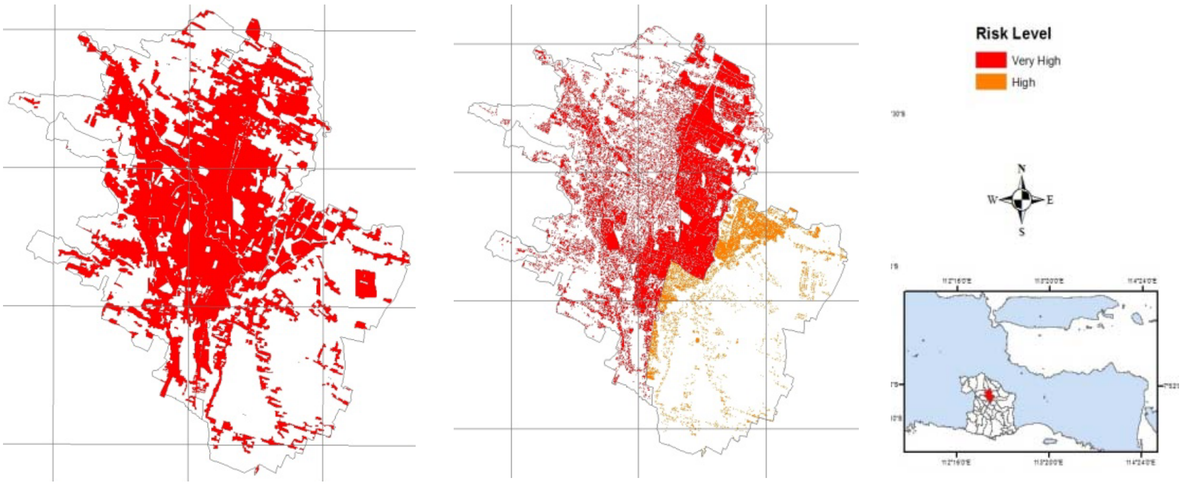
Table 6.5: Comparison of DHF Risk Level in Greater Malang for 2008 and 2030

No	Sub Distict	Risk 2008	Risk 2030	Comparison
Malang City				
1	Kedung Kandang	Very High	High	-1
2	Sukun	Very High	Very High	0
3	Klojen	Very High	Very High	0
4	Blimbing	Very High	Very High	0
5	Lowok Waru	Very High	Very High	0
Malang District				
6	Tumpang	High	Moderate	-1
7	Poncokusumo	Very Low	Low	+1
8	Jabung	Very Low	Moderate	+2
9	Pakis	High	Moderate	-1
10	Lawang	Low	Very Low	-1
11	Singosari	Low	Very Low	-1
12	Karangploso	Moderate	Moderate	0
13	Dau	Very High	Moderate	-2
14	Pujon	Very Low	Very Low	0
15	Ngantang	Very Low	Low	+1
16	Kasembon	Very Low	Very Low	0
17	Kepanjen	Moderate	Low	-1
18	Sumber Pucung	Very High	Low	-3

No	Sub Distict	Risk 2008	Risk 2030	Comparison
19	Kromengan	Low	Very Low	-1
20	Pakisaji	High	Low	-2
21	Ngajum	Low	Very Low	-1
22	Wonosari	Low	Very Low	-1
23	Wagir	Moderate	Very Low	-2
24	Pagak	High	Low	-2
25	Donomulyo	Low	Very Low	-1
26	Kalipare	Moderate	Very Low	-2
27	Bantur	High	Low	-2
28	Gedangan	Low	Very Low	-1
29	Gondanglegi	High	Moderate	-1
30	Bululawang	High	Low	-2
31	Wajak	Moderate	Low	-1
32	Tajinan	Moderate	Very Low	-2
33	Turen	Very High	High	-1
34	Dampit	Moderate	Low	-1
35	Sumbermanjing Wetan	Moderate	Very Low	-2
36	Ampelgading	Very Low	Very Low	0
37	Tirtoyudo	Very Low	Very Low	0
38	Pagelaran	Low	Low	0
Batu City				
39	Batu	Very High	Very High	0
40	Junrejo	Very High	Very High	0
41	Bumiaji	Very Low	High	+3

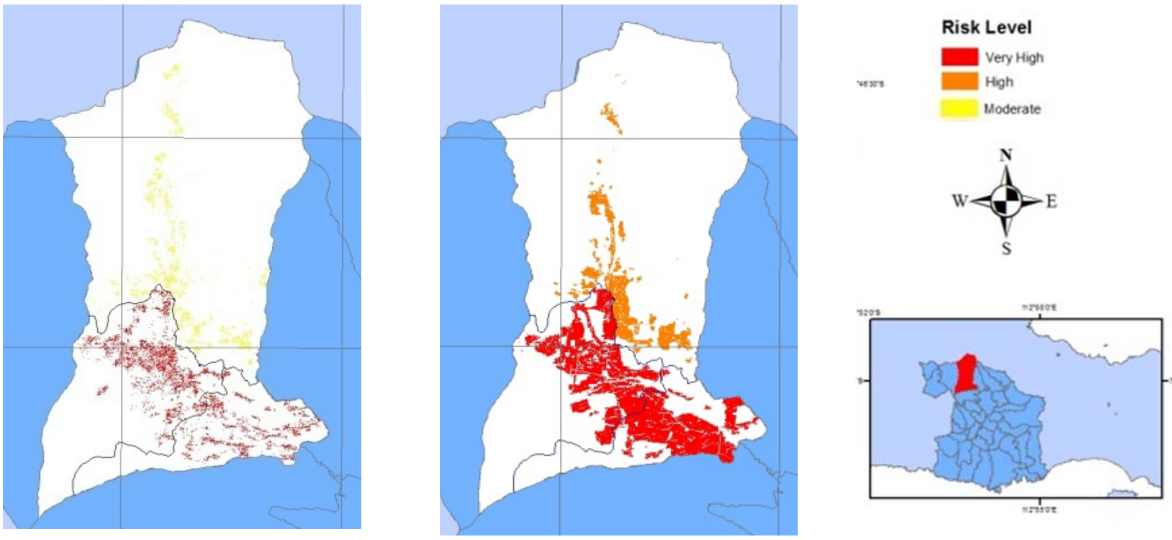
Note:
+1 : increase one level — -1 : decrease one level
+2 : increase two level — -2 : decrease two level
+3 : increase three level — -3 : decrease three level
+4 : increase four level — -4 : decrease four level
0 : same level

Comparison of DHF risk map in Greater Malang for 2008 and 2030 is described in Figure 6.3 below.



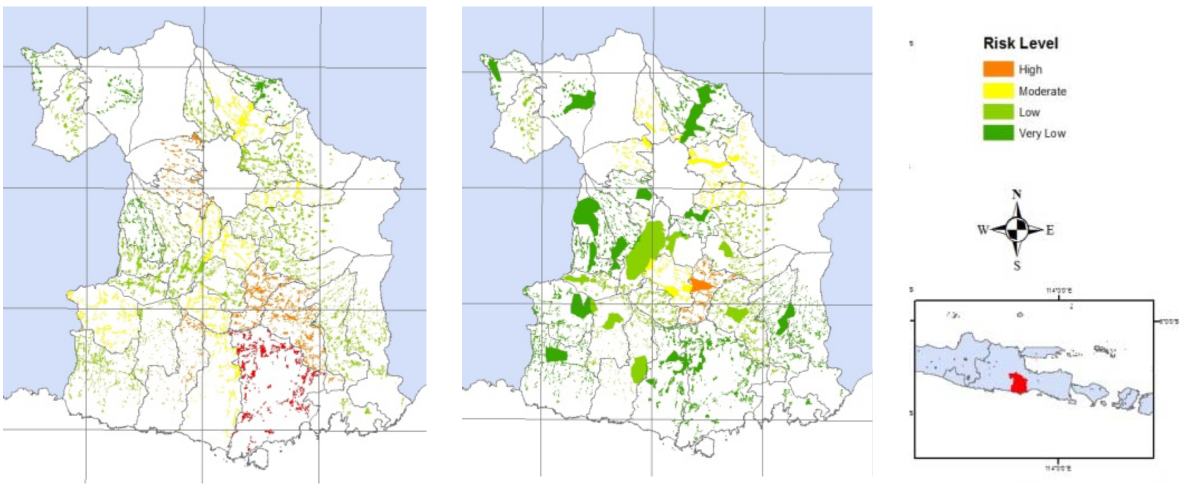
DHF Risk Map 2008 DHF Risk Map 2030

(a) DHF Risk Level in Malang City



DHF Risk Map 2008 DHF Risk Map 2030

(b) DHF Risk Level in Batu City



DHF Risk Map 2008 DHF Risk Map 2030

(c) DHF Risk Level in Malang Dstrict

Figure 6.3 Comparison of DHF Risk Map in 2008 and 2030

6.4 Risk Assessment of Malaria

Risk of malaria existing in 2008 in corresponding sub districts is determined according to the Risk Assessment Matrix. The results in tabular form are shown in Table 6.4, while Risk Map is shown in Figure 6.3.

Table 6.6: Existing Risk Levels of Malaria in Malang District

No	Sub Districts	Hazard		Vulnerability		Levels
		Average prevalence (2008-2010) /1,000 Occupants	Level	Score	Level	
1	Tumpang	0	Very Low	0.57	Moderate	Low
2	Poncokusumo	0.011	Very Low	0.64	Moderate	Low
3	Jabung	0	Very Low	0.45	Very Low	Very Low
4	Pakis	0.015	Very Low	0.52	Low	Very Low
5	Lawang	0	Very Low	0.54	Moderate	Low
6	Singosari	0	Very Low	0.38	Very Low	Very Low
7	Karangploso	0	Very Low	0.76	Very High	Moderate
8	Dau	0	Very Low	0.53	Low	Very Low
9	Pujon	0.021	Low	0.46	Very Low	Very Low
10	Ngantang	0.038	Moderate	0.67	High	High
11	Kasembon	0.095	Moderate	0.73	High	High
12	Kepanjen	0.022	Low	0.29	Very Low	Low
13	Sumber Pucung	0.214	Moderate	0.66	High	High
14	Kromengan	0	Very Low	0.74	Very High	Moderate
15	Pakisaji	0	Very Low	0.34	Very Low	Very Low
16	Ngajum	0	Very Low	0.71	High	Low
17	Wonosari	0	Very Low	0.48	Low	Very Low
18	Wagir	0	Very Low	0.53	Low	Very Low
19	Pagak	0.029	Low	0.49	Low	Low
20	Donomulyo	0.070	Moderate	0.71	High	High
21	Kalipare	0	Very Low	0.60	Moderate	Low
22	Bantur	0.074	Moderate	0.65	High	High
23	Gedangan	0	Very Low	0.77	Very High	Moderate
24	Gondanglegi	0.011	Very Low	0.58	Moderate	Low
25	Bululawang	0.046	Moderate	0.26	Very Low	Low
26	Wajak	0	Very Low	0.45	Very Low	Very Low
27	Tajinan	0.028	Low	0.52	Low	Low
28	Turen	0.030	Low	0.59	Moderate	Low
29	Dampit	0.011	Very Low	0.74	Very High	Moderate
30	Sumbermanjing Wetan	0.081	Moderate	0.60	Moderate	Moderate
31	Ampelgading	0.024	Low	0.76	Very High	High
32	Tirtoyudo	0.015	Very Low	0.79	Very High	Moderate
33	Pagelaran	0	Very Low	0.83	Very High	Moderate

Two main components responsible for the higher risk in certain area are the hazard and vulnerability of malaria. There are no very high risk on malaria, therefore Table 6.6 show the high risk causal factor. Table 6.6 shows the major factors that become the causal of high risk score in corresponding area. In the future, these components need special attention to being managed and controlled in order to decreasing the malaria incidence in society.

Table 6.7: Factors Influence the Risk Score 2008 in Sub districts of Greater Malang with High Risk Score of Malaria

District	Sub District	Component	Main Causal Factors
Malang District	Ngantang	Vulnerability	Large number of population near the mosquitoes breeding site
	Kasembon	Vulnerability	Large proportion of non permanent housing
	Sumber Pucung	Vulnerability	Low health facility coverage
	Donomulyo	Vulnerability	Large proportion of non permanent housing
	Bantur	Vulnerability	Large proportion of non permanent housing; Low health facility coverage
	Ampelgading	Vulnerability	Large number of population near the mosquitoes breeding site ; Large proportion of non permanent housing; Low health facility coverage

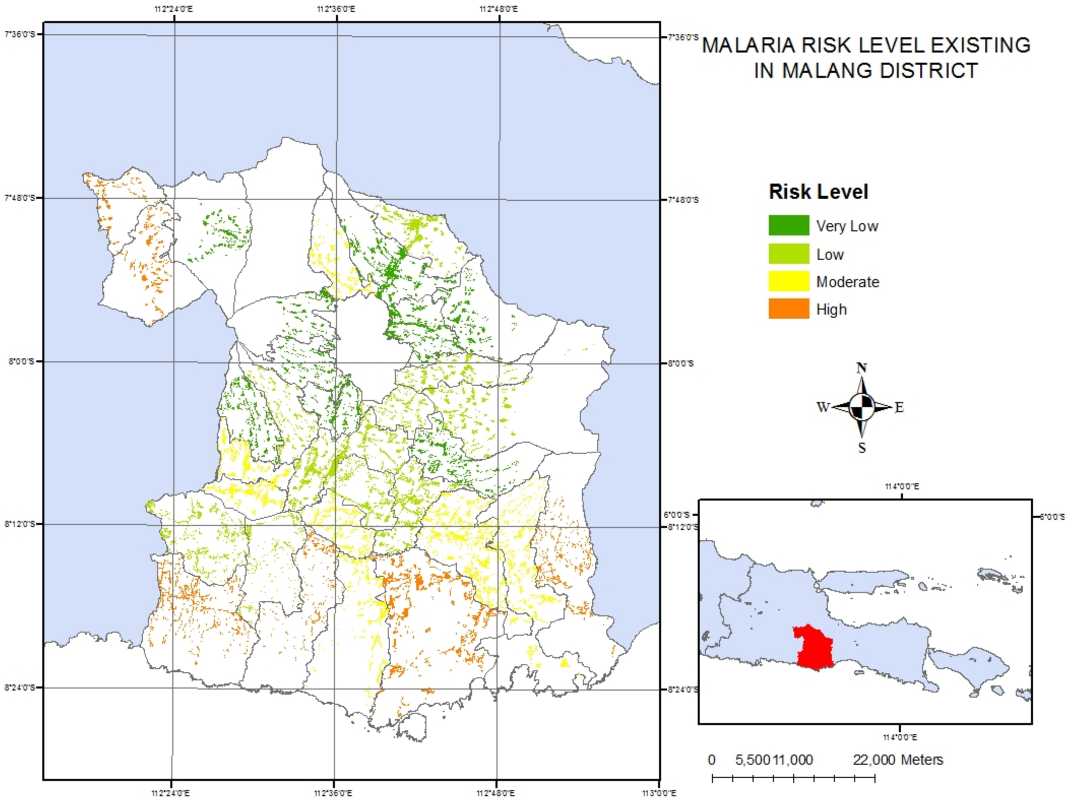


Figure 6.4 Existing Risk of Malaria in Malang District

6.5 Projection Risk Assessment of Malaria

There are no cases of malaria in Malang city and Batu city therefore there are Malang District only is analyzed (see table 6.7). Risk of Malaria in corresponding sub districts is determined according to the Risk Assessment Matrix. The results in tabular form are shown in Table 6.7, while Risk Map is shown in Figure 6.4.

Table 6.8: Projection Risk Levels of Malaria in Greater Malang 2030

No	Sub Districts in Malang District	Hazard		Vulnerability		Levels
		Average prevalence (2030) /1,000 Occupants	Level	Score	Level	
1	Tumpang	0	Very Low	0.66	High	Low
2	Poncokusumo	0	Very Low	0.74	Very High	Moderate
3	Jabung	0	Very Low	0.52	Low	Very Low
4	Pakis	0	Very Low	0.58	Moderate	Low
5	Lawang	0	Very Low	0.45	Very Low	Very Low
6	Singosari	0	Very Low	0.30	Very Low	Very Low
7	Karangploso	0	Very Low	0.80	Very High	Moderate
8	Dau	0	Very Low	0.63	Moderate	Low
9	Pujon	0	Very Low	0.16	Very Low	Very Low
10	Ngantang	0	Very Low	0.80	Very High	Moderate
11	Kasembon	0	Very Low	0.55	Moderate	Low
12	Kepanjen	0	Very Low	0.10	Very Low	Very Low
13	Sumber Pucung	0.04	Moderate	0.75	Very High	High
14	Kromengan	0	Very Low	0.72	High	Low
15	Pakisaji	0	Very Low	0.14	Very Low	Very Low
16	Ngajum	0	Very Low	0.62	Moderate	Low
17	Wonosari	0	Very Low	0.37	Very Low	Very Low
18	Wagir	0	Very Low	0.36	Very Low	Very Low
19	Pagak	0	Very Low	0.35	Very Low	Very Low
20	Donomulyo	0.07	Moderate	0.70	High	High
21	Kalipare	0	Very Low	0.48	Low	Very Low
22	Bantur	0.09	Moderate	0.39	Very Low	Low
23	Gedangan	0	Very Low	0.69	High	Low
24	Gondanglegi	0	Very Low	0.50	Low	Very Low
25	Bululawang	0.01	Very Low	0.35	Very Low	Very Low
26	Wajak	0	Very Low	0.53	Low	Very Low
27	Tajinan	0	Very Low	0.51	Low	Very Low
28	Turen	0.01	Very Low	0.65	High	Low
29	Dampit	0	Very Low	0.74	Very High	Moderate
30	Sumbermanjing Wetan	0.02	Low	0.65	High	Moderate
31	Ampelgading	0	Very Low	0.77	Very High	Moderate
32	Tirtoyudo	0	Very Low	0.77	Very High	Moderate
33	Pagelaran	0	Very Low	0.96	Very High	Moderate

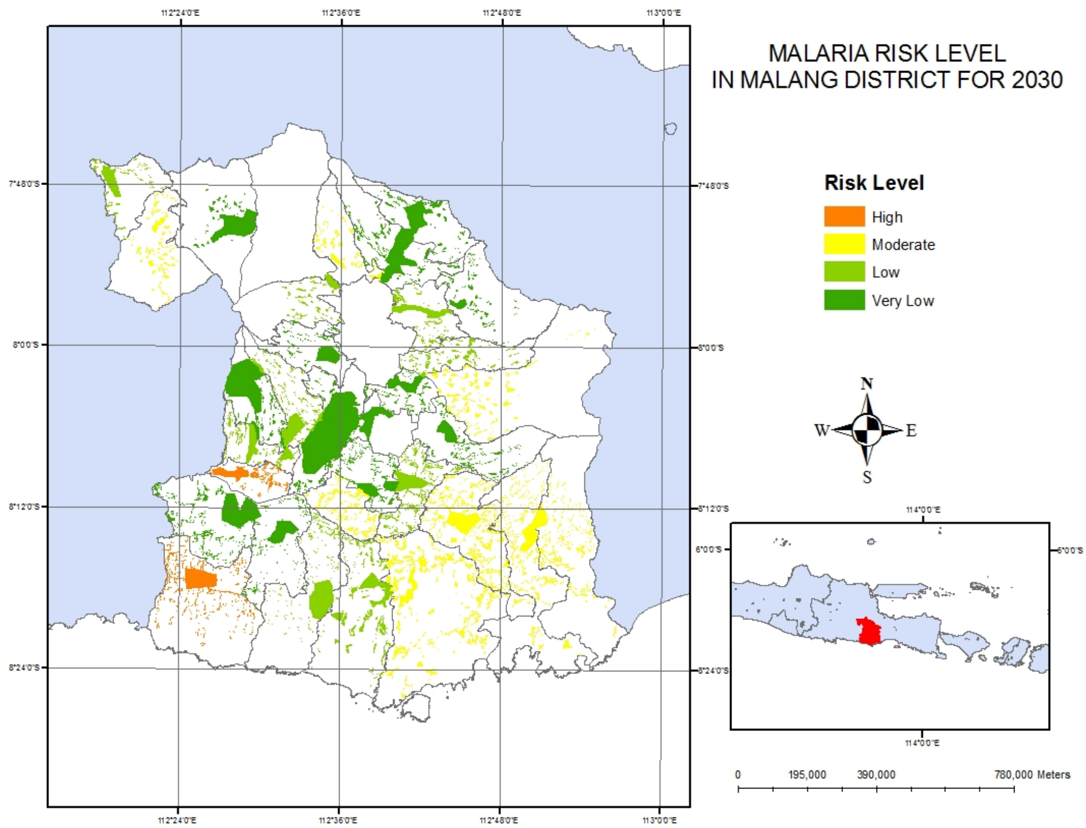


Figure 6.5 Projection Risk of Malaria in Malang District

Table 6.8 shows factors influence the risk score 2030 in sub districts of Malang District with High Risk Score of Malaria

Table 6.9: Factors Influence the Risk Score 2030 in Sub districts of Greater Malang with High Risk Score of Malaria

District	Sub District	Component	Main Causal Factors
Malang District	Sumber Pucung	Vulnerability	Low health facility coverage
	Donomulyo	Vulnerability	Large proportion of non permanent housing

6.6 Comparison of Malaria Risk Levels in 2008 and 2030

Comparison of Malaria risk levels in Malang District for 2008 and 2030 is described in Table 6.10 below.

Table 6.10: Comparison of Malaria Risk Level in Malang District for 2008 and 2030

No	Sub Districts	Levels 2008	Levels 2030	Comparison
1	Tumpang	Low	Low	0
2	Poncokusumo	Low	Moderate	+1
3	Jabung	Very Low	Very Low	0
4	Pakis	Very Low	Low	+1
5	Lawang	Low	Very Low	-1

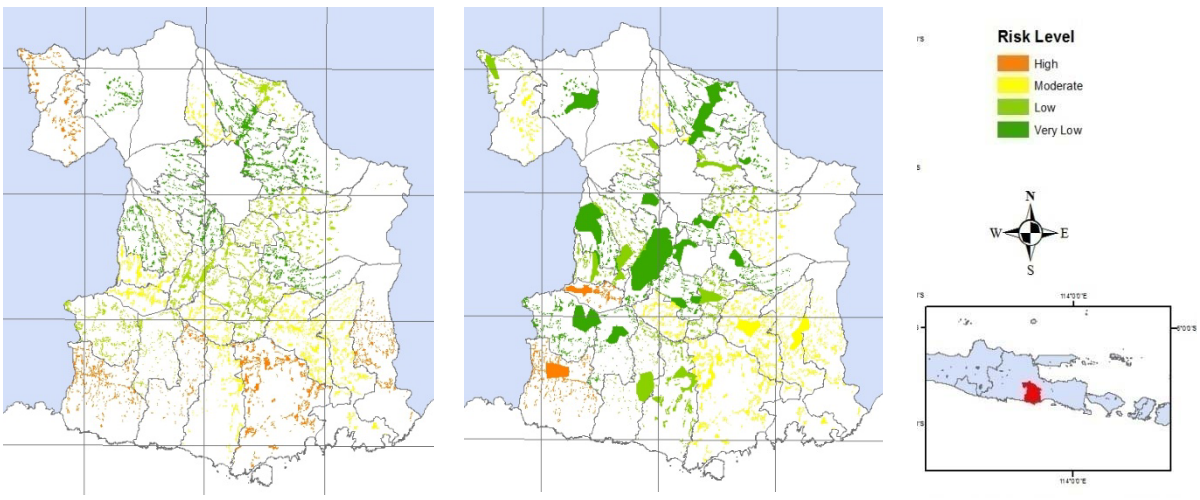
No	Sub Districts	Levels 2008	Levels 2030	Comparison
6	Singosari	Very Low	Very Low	0
7	Karangploso	Moderate	Moderate	0
8	Dau	Very Low	Low	+1
9	Pujon	Very Low	Very Low	0
10	Ngantang	High	Moderate	-1
11	Kasembon	High	Low	-2
12	Kepanjen	Low	Very Low	-1
13	Sumber Pucung	High	High	0
14	Kromengan	Moderate	Low	-1
15	Pakisaji	Very Low	Very Low	0
16	Ngajum	Low	Low	0
17	Wonosari	Very Low	Very Low	0
18	Wagir	Very Low	Very Low	0
19	Pagak	Low	Very Low	-1
20	Donomulyo	High	High	0
21	Kalipare	Low	Very Low	-1
22	Bantur	High	Low	-2
23	Gedangan	Moderate	Low	-1
24	Gondanglegi	Low	Very Low	-1
25	Bululawang	Low	Very Low	-1
26	Wajak	Very Low	Very Low	0
27	Tajinan	Low	Very Low	-1
28	Turen	Low	Low	0
29	Dampit	Moderate	Moderate	0
30	Sumbermanjing Wetan	Moderate	Moderate	0
31	Ampelgading	High	Moderate	-1
32	Tirtoyudo	Moderate	Moderate	0
33	Pagelaran	Moderate	Moderate	0

Note:

+1 : increase one level
+2 : increase two level
+3 : increase three level
+4 : increase four level
0 : same level

-1 : decrease one level
-2 : decrease two level
-3 : decrease three level
-4 : decrease four level

Comparison of Malaria Risk map in Malang District for 2008 and 2030 is described in Figure 6.6 below.



Malaria Risk Map 2008

Malaria Risk Map 2030

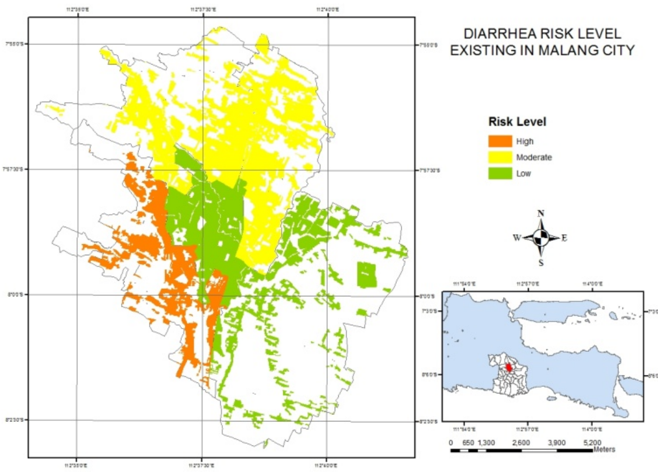
Figure 6.6 Comparison between Malaria Risk Map 2008 and 2030

6.7 Risk Assessment of Diarrhea

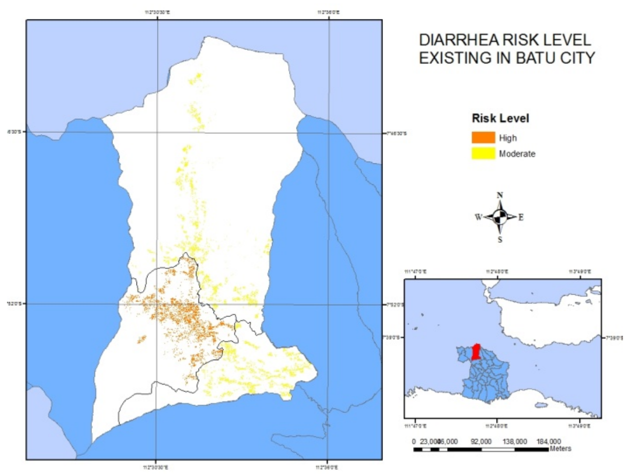
Risk of Diarrhea in corresponding sub districts is determined according to the Risk Assessment Matrix. The results in tabular form are shown in Table 6.9, while Risk Map is shown in Figure 6.5.

Table 6.11: Existing Risk Levels of Diarrhea in Malang City and Batu City

No	Sub Districts	Hazard		Vulnerability		Levels
		Average prevalence (2008-2010) /1,000 Occupants	Level	Score	Level	
Malang City						
1	Kedung Kandang	12.312	Very Low	0.10	Moderate	Low
2	Sukun	22.153	Moderate	0.15	Very High	High
3	Klojen	20.267	Moderate	0.04	Low	Low
4	Blimbing	17.572	Low	0.12	High	Moderate
5	Lowok Waru	13.921	Very Low	0.14	Very High	Moderate
Batu City						
6	Batu	22.580	High	0.11	Moderate	High
7	Junrejo	50.796	Very High	0.04	Very Low	Moderate
8	Bumiaji	40.276	Very High	0.04	Very Low	Moderate



(a)



(b)

Figure 6.7 Existing Risk of Diarrhea in (a) Malang City and (b) Batu City

Therefore, these areas need more attention and the community needs to enhance the development of local strength toward diarrhea in the future. For general, high population number becomes the major causal which results in very high risk of diarrhea (see Table 6.10).

Table 6.12: Factors Influence the Risk Score 2008 with High Risk Score of Diarrhea

Sub Districts with High Risk of	Component	Main Causal Factors

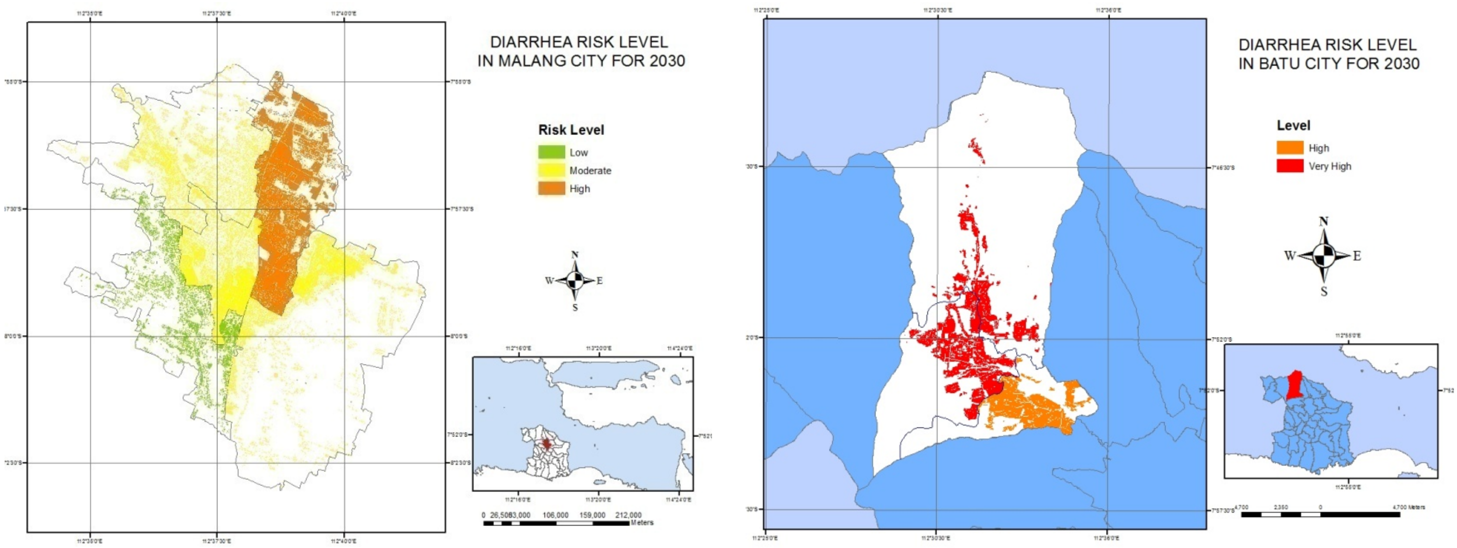
Diarrhea			
Malang City	Sukun	Vulnerability	Low piped water coverage
Batu City	Batu	Hazard	High prevalence of diarrhea

6.8 Projection Risk Assessment of Diarrhea

Risk of Diarrhea in corresponding sub districts is determined according to the Risk Assessment Matrix. The results in tabular form are shown in Table 6.11, while Risk Map is shown in Figure 6.6.

Table 6.13: Projection Risk Levels of Diarrhea in Malang City and Batu City 2030

No	Sub Districts	Hazard		Vulnerability		Levels
		Average prevalence (2030) /1,000 Occupants	Level	Score	Level	
Malang City						
1	Kedung Kandang	7.18	Very Low	0.31	Very High	Moderate
2	Sukun	19.73	Low	0.11	Moderate	Low
3	Klojen	35.10	Very High	0.00	Very Low	Moderate
4	Blimbing	18.16	Low	0.23	Very High	High
5	Lowok Waru	9.18	Very Low	0.15	Very High	Moderate
Batu City						
6	Batu	66.35	Very High	0.14	Very High	Very High
7	Junrejo	101.83	Very High	0.09	Moderate	High
8	Bumiaji	69.19	Very High	0.11	High	Very High



(a) (b)

Figure 6.8 Projection 2030 Risk of Diarrhea in (a) Malang City and (b) Batu City

Table 6.12 shows Factors Influence the Risk Score 2030 in Sub districts with High and Very High Risk Score of Diarrhea. In 2030, the area that have high and very high risk are Blimbing, Batu, Junrejo and Bumiaji.

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Table 6.14: Factors Influence the Risk Score 2030 in Sub districts with High and Very High Risk Score of Diarrhea

Sub Districts with High Risk of Diarrhea		Component	Main Causal Factors
Malang City	Blimbing	Vulnerability	Low piped water coverage
Batu City	Batu	Hazard	High prevalence of diarrhea
Batu City	Junrejo	Hazard	High prevalence of diarrhea
Batu City	Bumiaji	Hazard	High prevalence of diarrhea

6.9 Comparison of Diarrhea Risk Levels in 2008 and 2030

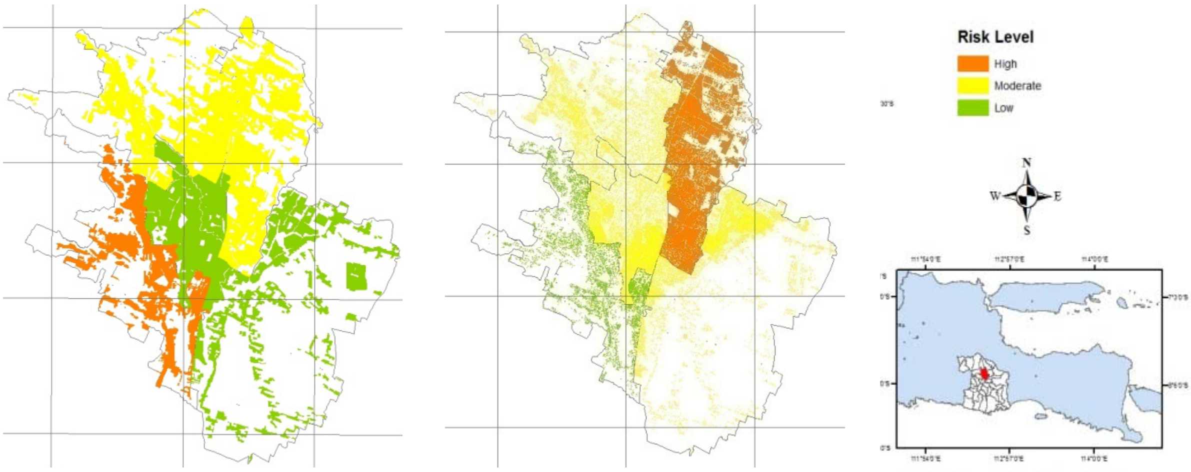
Comparison of Diarrhea risk levels in Malang City and Batu City for 2008 and 2030 is described in Table 6.15 below.

Table 6.15: Comparison of Diarrhea Risk Level in Malang City and Batu City for 2008 and 2030

No	Sub Districts	Levels 2008	Levels 2030	Comparison
Malang City				
1	Kedung Kandang	Low	Moderate	+1
2	Sukun	High	Low	-2
3	Klojen	Low	Moderate	+1
4	Blimbing	Moderate	High	+1
5	Lowok Waru	Moderate	Moderate	0
Batu City				
6	Batu	High	Very High	+1
7	Junrejo	Moderate	High	+1
8	Bumiaji	Moderate	Very High	+2

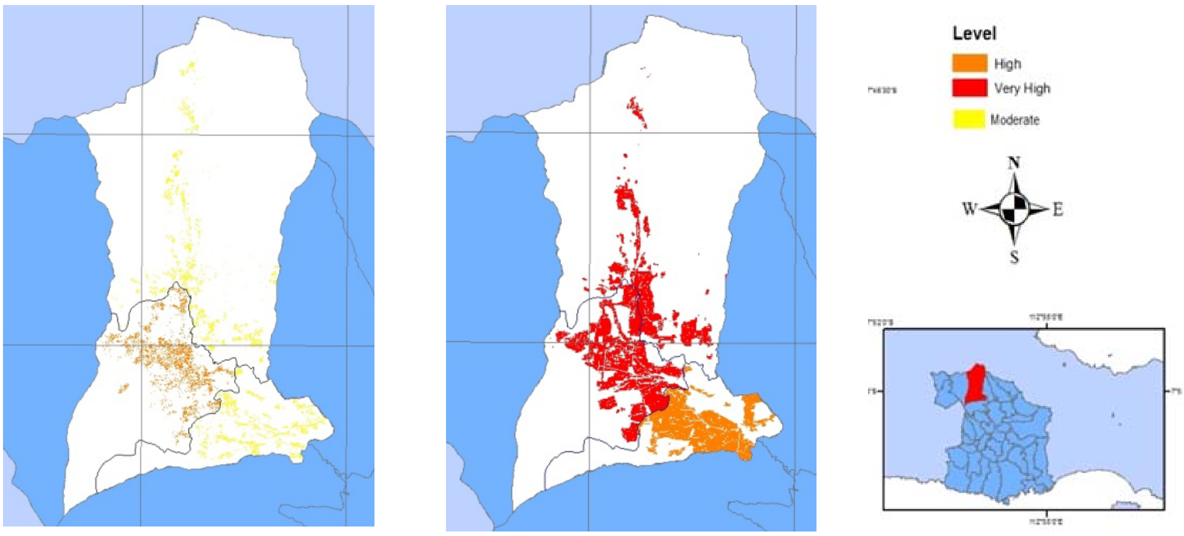
Note:
+1 : increase one level　　-1 : decrease one level
+2 : increase two level　　-2 : decrease two level
+3 : increase three level　　-3 : decrease three level
+4 : increase four level　　-4 : decrease four level
0 : same level

Comparison of Diarrhea risk map in Malang City and Batu City for 2008 and 2030 is described in Figure 6.9 below.



Diarrhea Risk Map 2008 | Diarrhea Risk Map 2030

(d) Diarrhea Risk Level in Malang City



DHF Risk Map 2008 | DHF Risk Map 2030

(e) DHF Risk Level in Batu City

Figure 6.9 Comparison between Diarrhea Risk Map 2008 and 2030

CHAPTER 7 ADAPTATION STRATEGY

7.1 Intoduction

Greater Metropolitan Malang show climate change impact which brought specific alteration in environmental condition. Specifically, we analyze the increment of rainfall and temperature, which will affect the nature of disease agents in Greater Malang (see Chapter 6).

In this Chapter, we analyze the adaptation strategy appropriate for the current climate change condition and projection to the future. The three guiding principles for the adaptation strategies in the health sector of Greater Malang include:

- Adaptation in health sector requires a policy switches from curative dominance to preventive and promotive activity in the long run. Findings from climate change studies should be incorporated into health education and promotion programs. Existing health regulations should also be reviewed to include mitigation and adaptation strategies in anticipation of future climate changes.
- Health sector should not be working alone in tackling the situation especially those related to or affected by climate changes. A concerted and integrated effort should include other relevant departments such as BMKG, research centers, etc. The policy shift in the future may see effort for less short-term (2010-2020) mitigation type of activity and more of a long term (2030-2050) adaptation approach.

Many diseases and health problems that may be exacerbated by climate change in Greater Malang can be effectively prevented with adequate financial and human public health resources, including training, surveillance and emergency response, and prevention and control programs. Adaptation enhances a population's coping ability and may protect against current climatic variability as well as against future climatic changes. It includes the strategies, policies, and measures undertaken now and in future to reduce the potential adverse health effects.

The rebuilding and maintaining of public health infrastructure is often viewed as the “most important, cost-effective, and urgently needed” adaptation strategy. Generally, the strategy consists of two major components, which is proactive strategy that deals with reduction of climate change effect and reactive strategy that deals with enhancement of community strength toward diseases occurrence. This chapter is focusing on adaptation strategy toward Dengue Hemorrhagic Fever (DHF), malaria and diarrhea. Moreover, the adaptation program is diverse, based on the risk level and the onset of action of each program.

As discussed in Sub-chapter 3.8, adaptation strategy in health sector is divided to 4 (four) category, namely A, B, C, and D, where A is the most priority area, following by B, C, and D. The categories are described as follow:

(A) First priority: Areas with high risk due to high hazard and high vulnerability.

This high risk area is first priority to be improved because it has high both hazard and vulnerability. For areas of such criteria, the first attention should be given to the management of hazard against dengue, malaria and diarrhea since patient’s wellness is of utmost priority. The next attention is given to the betterment of the environmental quality, provision of save water supply, sanitation and health facility.

(B) Second priority: Adaptation strategy for areas with high risk due to high hazard only.

This area is second priority to be improved because it has high hazard but has low vulnerability. For areas such as this, management of hazard, either for dengue, malaria and diarrhea should be given high attention, both through prevention and treatment. The second attention is the management of the environment such as improvement of save water supply, sanitation and clean and healthy environment.

(C) Third priority: Areas with high risk due to high vulnerability only.

This area is third priority to be improved because it has low hazard but has high vulnerability. For areas such as this, the management of vulnerability is main attention, such as develop better and healthier environment, save water supply, and environmental sanitation. Management of slum areas and de-urbanization should be integrated within. The improvement of and better access to health facilities should have high attention and should be adjusted to the real need of the community. For rural areas, improving the access to health facilities become high attention by either lowering the health cost or by providing public transport facility for easy access.

(D) Last priority: Areas with low risk due to low hazard and low vulnerability.

This area is low risk area and last priority to be improved because it has low both hazard and vulnerability. The main task to this area is keep the environment in health condition. Campaign and community education to prevent both dengue, malaria and diarrhea is also important.

7.2 Adaptation Strategy for DHF in Greater Malang

Based on analyzing the hazard, vulnerability and risk level both in 2008 and 2030, adaptation strategy categories of DHF for each sub district in Greater Malang are defined as shown in Table 7.1. Adaptation strategy is defined as A, B, C, and D category depend on its hazard and vulnerability level.

Table 7.1: Adaptation Strategy of DHF in Greater Malang

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Malang City											
1	Kedung Kandang	H	M	-1	VH	VH	0	VH	H	-1	A
2	Sukun	VH	VH	0	VH	VH	0	VH	VH	0	A
3	Klojen	VH	VH	0	H	VH	+1	VH	VH	0	A
4	Blimbing	VH	VH	0	VH	VH	0	VH	VH	0	A
5	Lowok Waru	VH	VH	0	VH	VH	0	VH	VH	0	A
Malang District											
6	Tumpang	H	H	0	L	L	0	H	M	-1	B
7	Poncokusumo	VL	VL	0	M	H	+1	VL	L	+1	C
8	Jabung	VL	VL	0	H	VH	+1	VL	M	+2	C
9	Pakis	H	VH	+1	VL	VL	0	H	M	-1	B
10	Lawang	L	VL	-1	VL	VL	0	L	VL	-1	D
11	Singosari	L	L	0	H	VL	-3	L	VL	-1	C
12	Karangploso	M	VH	+2	VL	VL	0	M	M	0	B
13	Dau	VH	H	-1	M	L	-1	VH	M	-2	B
14	Pujon	VL	VL	0	L	VL	-1	VL	VL	0	D
15	Ngantang	VL	VL	0	M	M	0	VL	L	+1	D
16	Kasembon	VL	VL	0	L	VL	-1	VL	VL	0	D
17	Kepanjen	M	M	0	VL	VL	0	M	L	-1	D
18	Sumber Pucung	VH	M	-2	H	L	-2	VH	L	-3	A
19	Kromengan	L	L	0	M	VL	-2	L	VL	-1	C
20	Pakisaji	H	M	-1	L	VL	-1	H	L	-2	B

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
21	Ngajum	L	VL	-1	L	VL	-1	L	VL	-1	D
22	Wonosari	L	VL	-1	VL	VL	0	L	VL	-1	D
23	Wagir	M	L	-1	VH	VL	-4	M	VL	-2	C
24	Pagak	H	M	-1	VL	VL	0	H	L	-2	B
25	Donomulyo	L	VL	-1	M	VL	-2	L	VL	-1	D
26	Kalipare	M	L	-1	M	VL	-2	M	VL	-2	D
27	Bantur	H	M	-1	H	VL	-3	H	L	-2	A
28	Gedangan	L	L	0	H	VL	-3	L	VL	-1	C
29	Gondanglegi	H	VH	+1	VL	VL	0	H	M	-1	B
30	Bululawang	H	M	-1	L	VL	-1	H	L	-2	B
31	Wajak	M	L	-1	VL	L	+1	M	L	-1	D
32	Tajinan	M	L	-1	L	VL	-1	M	VL	-2	D
33	Turen	VH	VH	0	M	L	-1	VH	H	-1	B
34	Dampit	M	L	-1	VH	M	-2	M	L	-1	C
35	Sumbermanjing Wetan	M	VL	-2	L	VL	-1	M	VL	-2	D
36	Ampelgading	VL	VL	0	M	L	-1	VL	VL	0	D
37	Tirtoyudo	VL	VL	0	H	L	-2	VL	VL	0	C
38	Pagelaran	L	VL	-1	H	H	0	L	L	0	C
Batu City											
39	Batu	VH	VH	0	VH	VH	0	VH	VH	0	A
40	Junrejo	VH	VH	0	VH	VH	0	VH	VH	0	A
41	Bumiaji	VL	M	+2	VH	VH	0	VL	H	+3	C

Note: Comp.= comparison Adap Str.= adaptation strategy category

Each category in Table 7.1 has different adaptation strategy as shown in Table 7.2.

Table 7.2: Adaptation Strategy for DHF for Each Category in Greater Malang

Category	Adaptation Strategy
(A) First priority area: high risk area because it has high both hazard and vulnerability.	• Mosquito source reduction • Community and village level of vector management (pesticide fogging program at high incidence and specific locations) • Vaccination on vulnerable population (still on trial) • Whole hospital and Puskesmas emergency alert • Increased Routine surveillance of DHF • Improvement of housing condition • Better piped-water supply and covered water storage • Control of population density • Development of early warning method based on meteorogical surveillance
(B) Second priority area: area that has high hazard but low vulnerability	• Mosquito source reduction • Community and village level of vector management (pesticide fogging program at high incidence and specific locations) • Vaccination on vulnerable population (still on trial) • Whole hospital and Puskesmas emergency alert • Increased Routine surveillance of DHF

Category	Adaptation Strategy
(C) Third priority area: area that has high vulnerability but low hazard	• Improvement of housing condition • Better water supply and covered water storage • Control of population density • Development of early warning method based on meteorogical surveillance
(D) Last priority area: area that has low both hazard and vulnerability	• Household level of vector management (Abate, spray cans, mosquito coils, repellents etc.) • Routine yearly seasonal spraying • Community awareness program • Routine implementation of 3M Plus program • Non-Routine, sentinel surveillance of DHF • Individual patient treatment

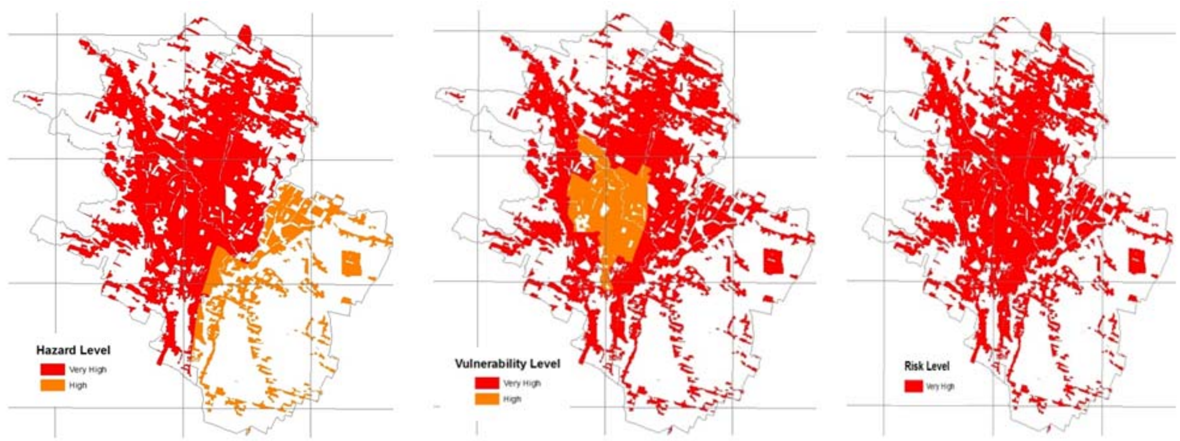
7.2.1 Adaptation Strategy of DHF in Malang City

Table 7.3 show hazard, vulnerability and risk in each sub districts in Malang City both in 2008 and 2030. Moreover, visualization of each hazard, vulnerability and risk in each sub districts in Malang City both in 2008 and 2030 are drew in Figure 7.1. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of each sub districts in Malang City can be defined as shown in Table 7.4.

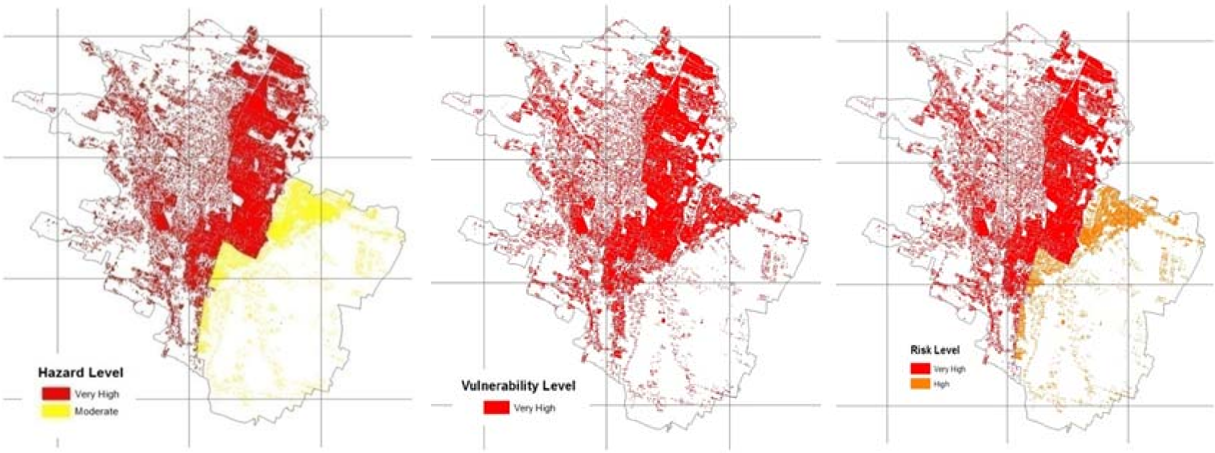
Table 7.3 Hazard, Vulnerability and Risk of DHF in Malang City

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
1	Kedung Kandang	H	M	-1	VH	VH	0	VH	H	-1	A
2	Sukun	VH	VH	0	VH	VH	0	VH	VH	0	A
3	Klojen	VH	VH	0	H	VH	+1	VH	VH	0	A
4	Blimbing	VH	VH	0	VH	VH	0	VH	VH	0	A
5	Lowok Waru	VH	VH	0	VH	VH	0	VH	VH	0	A

Note: Comp.= comparison Adap Str.= adaptation strategy category



Hazard 2008 Vulnerability 2008 Risk 2008



Hazard 2030 Vulnerability 2030 Risk 2030

Figure 7.1 Map of Hazard, Vulnerability and Risk of DHF in Malang City

As shown in Table 7.3, all sub district in Malang City have high until very high hazard and vulnerability level in 2008 and those be predicted increase in 2030 to become very high. Therefore Kedung Kandang, Sukun, Klojen, Blimbing and Lowok Waru are categorized as type A in adaptation strategy category. Vulnerability problem in those area is mainly caused by high population density. Based on this classification, in general Malang City should be treated as the most priority area because have very high hazard and vulnerability level in all area. In detail, adaptation strategy of DHF for sub district in Malang City is described in Table 7.4 below.

Table 7.4: Adaptation Strategy Category of DHF for Each Sub Districts in Malang City

Category	Sub Districts	Adaptation Strategy
A	• Kedung Kandang • Sukun • Klojen • Blimbing • Lowok Waru	• Mosquito source reduction • Community and village level of vector management (pesticide fogging program at high incidence and specific locations) • Vaccination on vulnerable population (still on trial) • Whole hospital and Puskesmas emergency alert • Increased Routine surveillance of DHF • Improvement of housing condition • Better piped-water supply and covered water storage • Control of population density • Development of early warning method based on meteorogical surveillance
B	• None	• None
C	• None	• None
D	• None	• None

7.2.2 Adaptation Strategy of DHF in Malang District

Table 7.5 show hazard, vulnerability and risk in each sub district in Malang District both in 2008 and 2030. Moreover, visualization of each hazard, vulnerability and risk in each sub district in Malang District both in 2008 and 2030 are drew in Figure 7.2. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of each sub district in Malang District can be defined as shown in Table 7.6.

Table 7.5 Hazard, Vulnerability and Risk of DHF in Malang District

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
1	Tumpang	H	H	0	L	L	0	H	M	-1	B
2	Poncokusumo	VL	VL	0	M	H	+1	VL	L	+1	C
3	Jabung	VL	VL	0	H	VH	+1	VL	M	+2	C
4	Pakis	H	VH	+1	VL	VL	0	H	M	-1	B
5	Lawang	L	VL	-1	VL	VL	0	L	VL	-1	D
6	Singosari	L	L	0	H	VL	-3	L	VL	-1	C
7	Karangploso	M	VH	+2	VL	VL	0	M	M	0	B
8	Dau	VH	H	-1	M	L	-1	VH	M	-2	B
9	Pujon	VL	VL	0	L	VL	-1	VL	VL	0	D
10	Ngantang	VL	VL	0	M	M	0	VL	L	+1	D
11	Kasembon	VL	VL	0	L	VL	-1	VL	VL	0	D
12	Kepanjen	M	M	0	VL	VL	0	M	L	-1	D
13	Sumber Pucung	VH	M	-2	H	L	-2	VH	L	-3	A
14	Kromengan	L	L	0	M	VL	-2	L	VL	-1	C
15	Pakisaji	H	M	-1	L	VL	-1	H	L	-2	B
16	Ngajum	L	VL	-1	L	VL	-1	L	VL	-1	D
17	Wonosari	L	VL	-1	VL	VL	0	L	VL	-1	D
18	Wagir	M	L	-1	VH	VL	-4	M	VL	-2	C
19	Pagak	H	M	-1	VL	VL	0	H	L	-2	B
20	Donomulyo	L	VL	-1	M	VL	-2	L	VL	-1	D
21	Kalipare	M	L	-1	M	VL	-2	M	VL	-2	D
22	Bantur	H	M	-1	H	VL	-3	H	L	-2	A
23	Gedangan	L	L	0	H	VL	-3	L	VL	-1	C
24	Gondanglegi	H	VH	+1	VL	VL	0	H	M	-1	B
25	Bululawang	H	M	-1	L	VL	-1	H	L	-2	B
26	Wajak	M	L	-1	VL	L	+1	M	L	-1	D
27	Tajinan	M	L	-1	L	VL	-1	M	VL	-2	D
28	Turen	VH	VH	0	M	L	-1	VH	H	-1	B
29	Dampit	M	L	-1	VH	M	-2	M	L	-1	C
30	Sumbermanjing Wetan	M	VL	-2	L	VL	-1	M	VL	-2	D
31	Ampelgading	VL	VL	0	M	L	-1	VL	VL	0	D
32	Tirtoyudo	VL	VL	0	H	L	-2	VL	VL	0	C
33	Pagelaran	L	VL	-1	H	H	0	L	L	0	C

Note: Comp.= comparison Adap Str.= adaptation strategy category

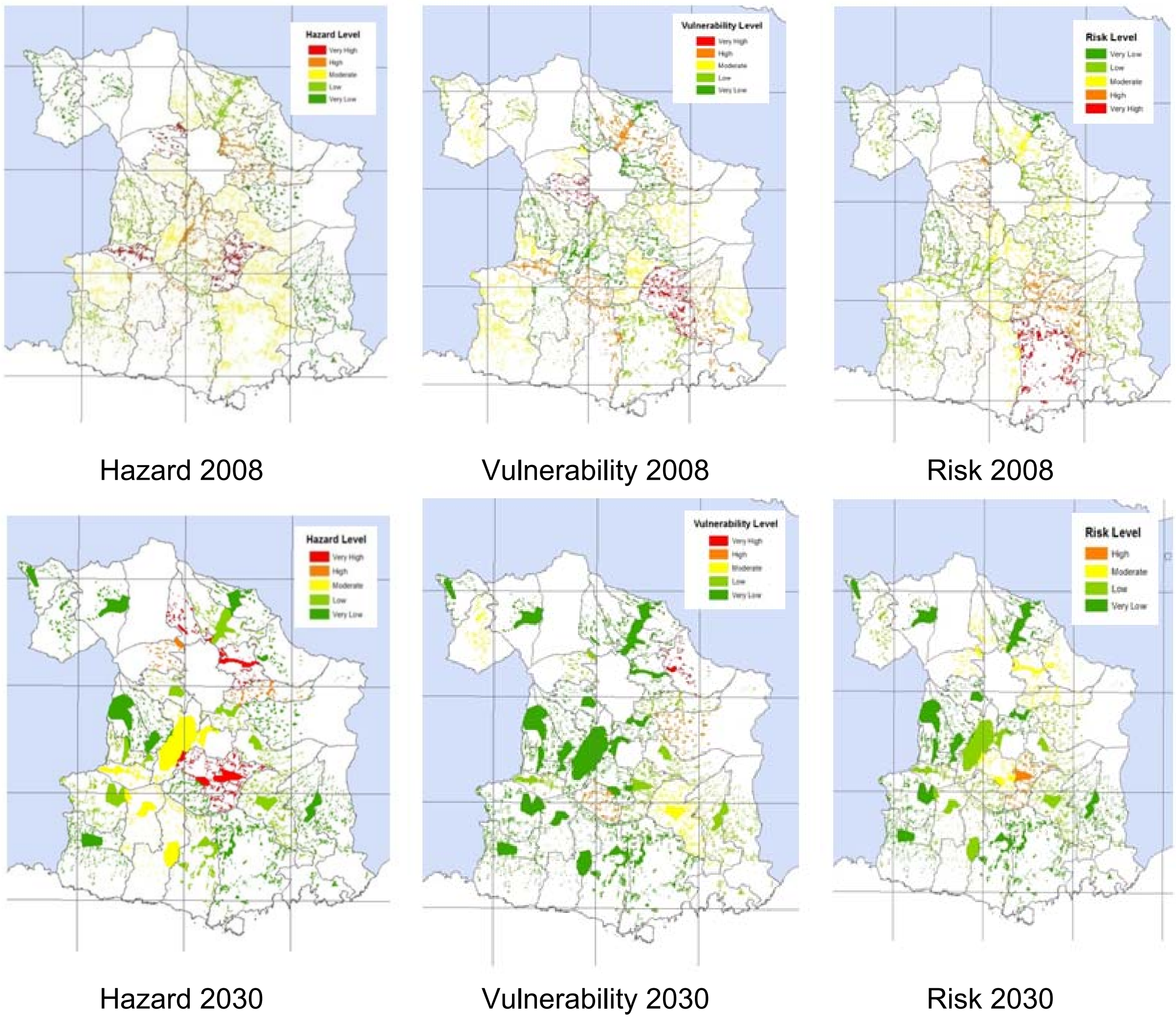


Figure 7.2 Map of Hazard, Vulnerability and Risk of DHF in Malang District

As shown in Table 7.5 and Figure 7.2, sub districts that have high hazard level in 2008 are Sumber Pucung, Bantur, Tumpang, Pakis, Karangploso, Dau, Pakisaji, Pagak, Gondanglegi, Bululawang and Turen. In 2030 most of them still have high hazard level. However, nine sub districts have low vulnerability level there are Tumpang, Pakis, Karangploso, Dau, Pakisaji, Pagak, Gondanglegi, Bululawang and Turen therefore those are defined as category B in adaptation strategy category. Sumber Pucung and Bantur are defined as category A because there not only high hazard but also high vulnerability level. Vulnerability problem in Sumber Pucung is mainly caused by low piped water coverage. In Malang District, Sumber Pucung and Bantur are most priority area that have to be improved both hazard and vulnerability control.

Other sub districts have low hazard and vulnerability level therefore there are defined as category D, namely Lawang, Pujon, Ngantang, Kasembon, Kepanjen, Ngajum, Wonosari, Donomulyo, Kalipare, Wajak, Tajinan, Sumbermanjing Wetan and Ampelgading. Moreover other sub districts have low hazard level and high vulnerability level therefore there are defined as category C, namely Poncokusumo, Jabung, Singosari, Kromengan, Wagir, Gedangan, Dampit, Tirtoyudo and Pagelaran. In detail, adaptation strategy for each sub district in Malang District is described in Table 7.6 below.

Table 7.6 Adaptation Strategy Category of DHF for Each Sub Districts in Malang District

Category	Sub Districts	Adaptation Strategy
A	• Sumber Pucung • Bantur	• Mosquito source reduction • Community and village level of vector management (pesticide fogging program at high incidence and specific locations) • Vaccination on vulnerable population (still on trial) • Whole hospital and Puskesmas emergency alert • Increased Routine surveillance of DHF • Improvement of housing condition • Better piped-water supply and covered water storage • Control of population density • Development of early warning method based on meteorogical surveillance
B	• Tumpang • Pakis • Karangploso • Dau • Pakisaji • Pagak • Gondanglegi • Bululawang • Turen.	• Mosquito source reduction • Community and village level of vector management (pesticide fogging program at high incidence and specific locations) • Vaccination on vulnerable population (still on trial) • Whole hospital and Puskesmas emergency alert • Increased Routine surveillance of DHF
C	• Poncokusumo • Jabung • Singosari • Kromengan • Wagir • Gedangan • Dampit • Tirtoyudo • Pagelaran.	• Improvement of housing condition • Better water supply and covered water storage • Control of population density Development of early warning method based on meteorogical surveillance
D	• Lawang • Pujon • Ngantang • Kasembon • Kepanjen • Ngajum • Wonosari • Donomulyo • Kalipare • Wajak • Tajinan • Sumbermanjing Wetan • Ampelgading.	• Household level of vector management (Abate, spray cans, mosquito coils, repellents etc.) • Routine yearly seasonal spraying • Community awareness program • Routine implementation of 3M Plus program • Non-Routine, sentinel surveillance of DHF • Individual patient treatment

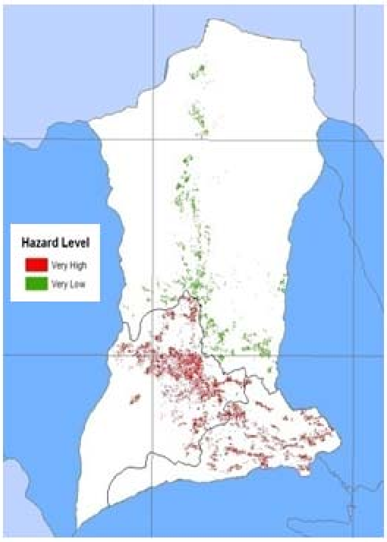
7.2.3 Adaptation Strategy of DHF in Batu City

Similar with Malang District, hazard, vulnerability and risk of DHF in each sub district in Batu City both in 2008 and 2030 is described in Table 7.7 and its map is drew in Figure 7.3. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of DHF for each sub district in Batu City can be defined as shown in Table 7.8.

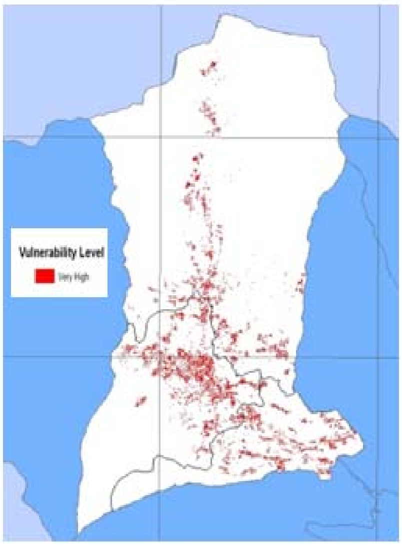
Table 7.7 Hazard, Vulnerability and Risk of DHF in Batu City

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
1	Batu	VH	VH	0	VH	VH	0	VH	VH	0	A
2	Junrejo	VH	VH	0	VH	VH	0	VH	VH	0	A
3	Bumiaji	VL	M	+2	VH	VH	0	VL	H	+3	C

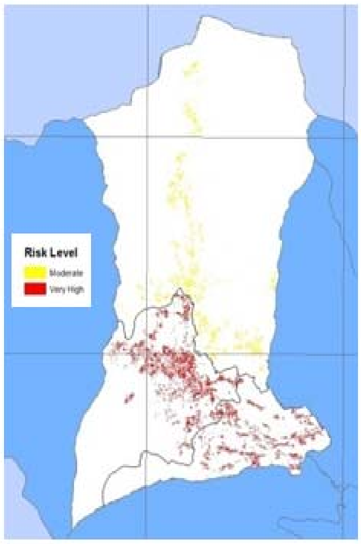
Note: Comp.= comparison Adap Str.= adaptation strategy category



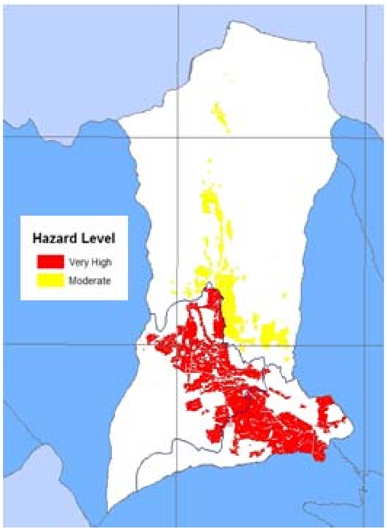
Hazard 2008



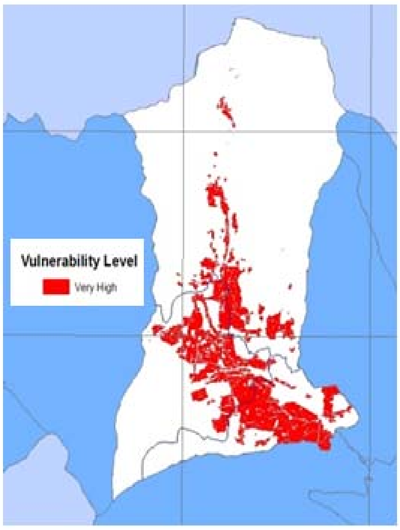
Vulnerability 2008



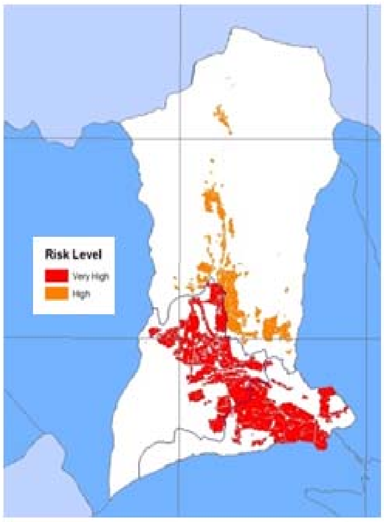
Risk 2008



Hazard 2030



Vulnerability 2030



Risk 2030

Figure 7.3 Map of Hazard, Vulnerability and Risk of DHF in Batu City

In Batu City, sub districts Batu and Junrejo have very high hazard and vulnerability level in 2008 and those be predicted still very high hazard and vulnerability level in 2030. Therefore Batu and Junrejo are categorized as type A of adaptation strategy. Hazard problem in Batu and Junrejo is mainly caused by high prevalence of DHF and vulnerability problem is mainly caused by high population density. In Batu City, in term of DHF control and eradication, Batu and Junrejo should be treated as the most priority area. Moreover, Bumiaji has low hazard but high vulnerability level therefore Bumiaji is categorized as type C of adaptation strategy. In detail, adaptation strategy for each sub district in Batu City is described in Table 7.8 below.

Table 7.8 Adaptation Strategy Category of DHF for Each Sub Districts in Batu City

Category	Sub Districts	Adaptation Strategy
A	• Batu • Junrejo	• Mosquito source reduction • Community and village level of vector management (pesticide fogging program at high incidence and specific locations) • Vaccination on vulnerable population (still on trial) • Whole hospital and Puskesmas emergency alert • Increased Routine surveillance of DHF • Improvement of housing condition • Better piped-water supply and covered water storage • Control of population density • Development of early warning method based on meteorogical surveillance
B	• None	• None
C	• Bumiaji	• Improvement of housing condition • Better water supply and covered water storage • Control of population density Development of early warning method based on meteorogical surveillance
D	• None	• None

7.3 Adaptation Strategy for Malaria in Malang District

Similar with DHF, hazard, vulnerability and risk level of malaria both in 2008 and 2030 have been analyzed and adaptation strategy categories of malaria for each sub district in Malang District are defined as shown in Table 7.9. Adaptation strategy of malaria is defined as A, B, C, and D category depend on its hazard and vulnerability level following methodology as described in sub-chapter 7.1.

Table 7.9: Adaptation Strategy of Malaria in Malang District

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
1	Tumpang	VL	VL	0	M	H	+1	L	L	0	C
2	Poncokusumo	VL	VL	0	M	VH	+2	L	M	+1	C
3	Jabung	VL	VL	0	VL	L	+1	VL	VL	0	D
4	Pakis	VL	VL	0	L	M	+1	VL	L	+1	D
5	Lawang	VL	VL	0	M	VL	-2	L	VL	-1	D
6	Singosari	VL	VL	0	VL	VL	0	VL	VL	0	C

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
7	Karangploso	VL	VL	0	VH	VH	0	M	M	0	C
8	Dau	VL	VL	0	L	M	+1	VL	L	+1	D
9	Pujon	L	VL	-1	VL	VL	0	VL	VL	0	D
10	Ngantang	M	VL	-2	H	VH	+1	H	M	-1	C
11	Kasembon	M	VL	-2	H	M	-1	H	L	-2	C
12	Kepanjen	L	VL	-1	VL	VL	0	L	VL	-1	D
13	Sumber Pucung	M	M	0	H	VH	+1	H	H	0	C
14	Kromengan	VL	VL	0	VH	H	-1	M	L	-1	C
15	Pakisaji	VL	VL	0	VL	VL	0	VL	VL	0	D
16	Ngajum	VL	VL	0	H	M	-1	L	L	0	C
17	Wonosari	VL	VL	0	L	VL	-1	VL	VL	0	D
18	Wagir	VL	VL	0	L	VL	-1	VL	VL	0	D
19	Pagak	L	VL	-1	L	VL	-1	L	VL	-1	D
20	Donomulyo	M	M	0	H	H	0	H	H	0	C
21	Kalipare	VL	VL	0	M	L	-1	L	VL	-1	D
22	Bantur	M	M	0	H	VL	-3	H	L	-2	C
23	Gedangan	VL	VL	0	VH	H	-1	M	L	-1	C
24	Gondanglegi	VL	VL	0	M	L	-1	L	VL	-1	D
25	Bululawang	M	VL	-2	VL	VL	0	L	VL	-1	D
26	Wajak	VL	VL	0	VL	L	+1	VL	VL	0	D
27	Tajinan	L	VL	-1	L	L	0	L	VL	-1	D
28	Turen	L	VL	-1	M	H	+1	L	L	0	C
29	Dampit	VL	VL	0	VH	VH	0	M	M	0	C
30	Sumbermanjing Wetan	M	L	-1	M	H	+1	M	M	0	C
31	Ampelgading	L	VL	-1	VH	VH	0	H	M	-1	C
32	Tirtoyudo	VL	VL	0	VH	VH	0	M	M	0	C
33	Pagelaran	VL	VL	0	VH	VH	0	M	M	0	C

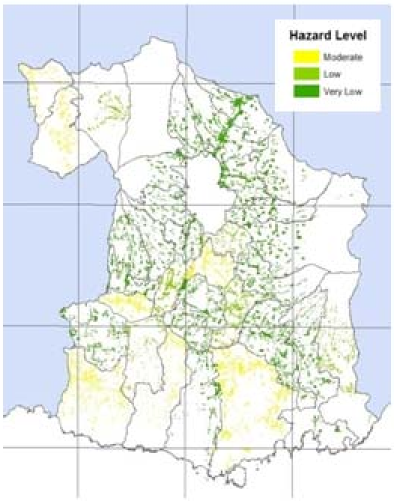
Note: Comp = comparison, Adap Str. = adaptation strategy category

Each category in Table 7.10 has different adaptation strategy as shown in Table 7.11.

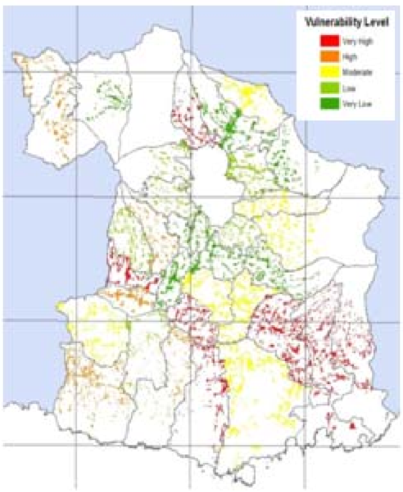
Table 7.10: Adaptation Strategy for Malaria for Each Category in Malang

Category	Adaptation Strategy
(A) First priority area: high risk area because it has high both hazard and vulnerability.	• Mosquito source reduction • Citywide level of malaria vector management (pesticide fogging program at high incidence and specific locations) • Vaccination on vulnerable population (currently still on development) • Whole hospital emergency alert • Increased routine surveillance of malaria • Improvement of housing condition • Meteorological surveillance (rainfall, temperature) • Coastal reclamation (drying of swamps and lagoons) • Mangrove re-forestation • Legislative measures (enforcement of existing

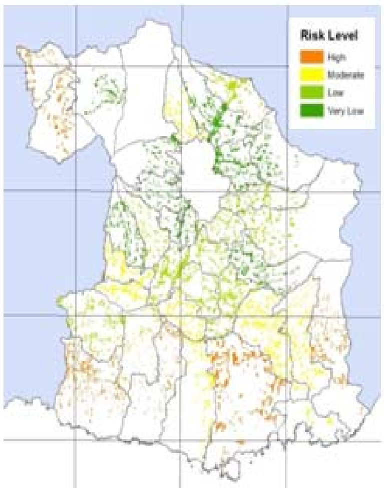
Category	Adaptation Strategy
	regulation on environment and health)
(B) Second priority area: area that has high hazard but low vulnerability	• Mosquito source reduction • Citywide level of malaria vector management (pesticide fogging program at high incidence and specific locations) • Vaccination on vulnerable population (currently still on development) • Whole hospital emergency alert • Increased routine surveillance of malaria
(C) Third priority area: area that has high vulnerability but low hazard	• Improvement of housing condition • Meteorological surveillance (rainfall, temperature) • Coastal reclamation (drying of swamps and lagoons) • Mangrove re-forestation • Legislative measures (enforcement of existing regulation on environment and health)
(D) Last priority area: area that has low both hazard and vulnerability	• Household level of mosquito bites prevention (Abate, spray cans, mosquito coils, repellents etc.) • Routine annual or twice per year seasonal spraying • Community malaria awareness program • Depend on cases, non-routine (sentinel surveillance of Malaria species) or routine mosquito quarterly surveillance (measurement of mosquito density index) • Availability and provision of prophylactic anti malaria tablets • Individual patient treatment



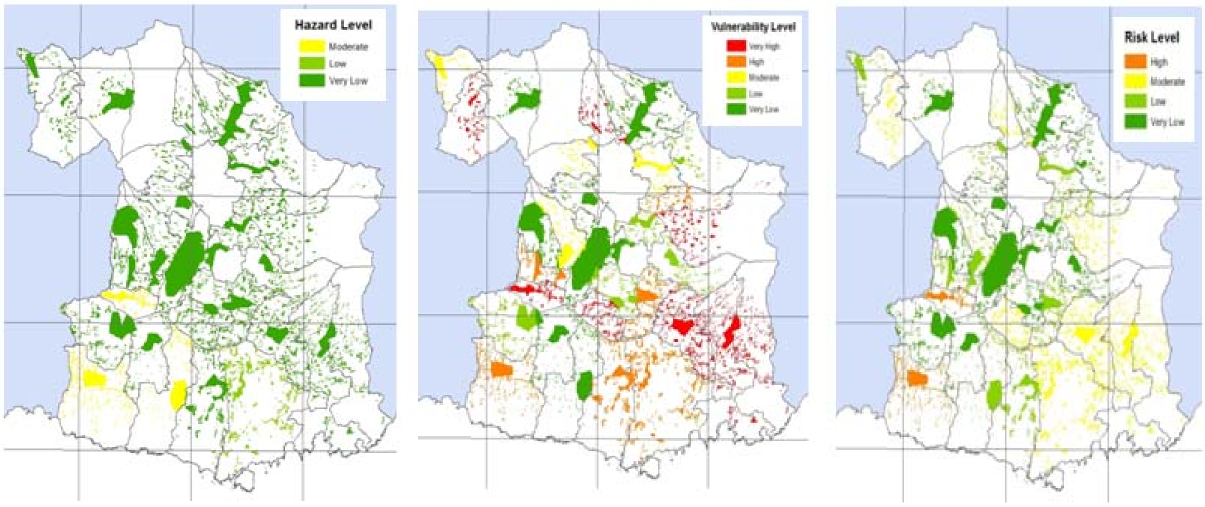
Hazard 2008



Vulnerability 2008



Risk 2008



Hazard 2030 Vulnerability 2030 Risk 2030

Figure 7.4 Map of Hazard, Vulnerability and Risk of Malaria in Malang District

As shown in Table 7.10 and Figure 7.4, all sub districts in Malang District have low hazard level in 2008 and be predicted still low hazard in 2030. However eighteen sub districts have high vulnerability therefore there are defined as category C in adaptation strategy, namely Tumpang, Poncokusumo, Singosari, Karangploso, Ngantang, Kasembon, Sumber Pucung, Kromengan, Ngajum, Donomulyo, Bantur, Gedangan, Turen, Dampit, Sumbermanjing Wetan, Ampelgading, Tirtoyudo, Pagelaran. Vulnerability problem in Kasembon and Donomulyo is mainly caused by large proportion of non permanent housing. Vulnerability problem in Ngantang is mainly caused by large number of population near the mosquitoes breeding site. Low health facility coverage is mainly vulnerability problem in Sumber Pucung, Bantur and Ampelgading. In Bantur other vulnerability problem is mainly caused by large proportion of non permanent housing. In Ampelgading other vulnerability problem is mainly caused by large number of population near the mosquitoes breeding site and large proportion of non permanent housing.

Other sub districts are defined as category D because there have low hazard level and low vulnerability level, there are Jabung, Pakis, Lawang, Dau, Pujon, Kepanjen, Pakisaji, Wonosari, Wagir, Pagak, Kalipare, Gondanglegi, Bululawang, Wajak, Tajinan. Based on this classification, in general Malang District has low hazard level for Malaria in all area but high vulnerability in partial area. In detail, adaptation strategy of Malaria for each sub district in Malang District described in Table 7.11 below.

Table 7.11 Adaptation Strategy for Malaria for Each Category in Malang District

Category	Sub Districts	Adaptation Strategy
A	• None	• None
B	• None	• None
C	• Tumpang • Poncokusumo • Singosari • Karangploso • Ngantang • Kasembon • Sumber Pucung • Kromengan • Ngajum	• Improvement of housing condition • Meteorological surveillance (rainfall, temperature) • Coastal reclamation (drying of swamps and lagoons) • Mangrove re-forestation Legislative measures (enforcement of existing regulation on environment and health)

Category	Sub Districts	Adaptation Strategy
	• Donomulyo • Bantur • Gedangan • Turen • Dampit • Sumbermanjing Wetan • Ampelgading • Tirtoyudo • Pagelaran	
D	• Jabung • Pakis • Lawang • Dau • Pujon • Kepanjen • Pakisaji • Wonosari • Wagir • Pagak • Kalipare • Gondanglegi • Bululawang • Wajak • Tajinan	• Household level of mosquito bites prevention (Abate, spray cans, mosquito coils, repellents etc.) • Routine annual or twice per year seasonal spraying • Community malaria awareness program • Depend on cases, non-routine (sentinel surveillance of Malaria species) or routine mosquito quarterly surveillance (measurement of mosquito density index) • Availability and provision of prophylactic anti malaria tablets • Individual patient treatment

7.4 Adaptation Strategy for Diarrhea in Greater Malang

By using similar methodology with DHF and malaria, hazard, vulnerability and risk level of diarrhea both in 2008 and 2030 have been analyzed and adaptation strategy categories of diarrhea for each sub district in Malang are defined as shown in Table 7.12. Adaptation strategy of diarrhea is defined as A, B, C, and D category depend on its hazard and vulnerability level.

Table 7.12: Adaptation Strategy of Diarrhea in Greater Malang

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Malang City											
1	Kedung Kandang	VL	VL	0	M	VH	+2	L	M	+1	C
2	Sukun	M	L	-1	VH	M	_2	H	L	-2	C
3	Klojen	M	VH	+2	L	VL	-1	L	M	+1	B
4	Blimbing	L	L	0	H	VH	+1	M	H	+1	C
5	Lowok Waru	VL	VL	0	VH	VH	0	M	M	0	C
Batu City											
6	Batu	H	VH	+1	M	VH	+2	H	VH	+1	A
7	Junrejo	VH	VH	0	VL	M	+2	M	H	+1	B
8	Bumiaji	VH	VH	0	VL	H	+3	M	VH	+2	A

Note: Comp = comparison, Adap Str. = adaptation strategy category

Each category in Table 7.12 has different adaptation strategy as shown in Table 7.13

Table 7.13: Adaptation Strategy Category of Diarrhea for Each Sub District in Malang

Category	Adaptation Strategy
(A) First priority area: high risk area because it has high both hazard and vulnerability.	• Whole hospital emergency alert and increased access to emergency treatment. If epidemic warning (KLB) occurs do citywide hospital alert and decrease in morbidity and mortality • Availability of drugs and antibiotic against diarrhea and develop rapid diarrheal diagnostic agents • Better training of hospital personnel during emergency diarrheal outbreak and increased routine surveillance of diarrhea agents • Meteorological surveillance (rainfall, temperature) and development of early warning method based on meteorogical surveillance • Increased community participation • If flood occur do better sanitation system in flood refugee camps • Development of drainage infrastructure in flood prone areas • Widening and deepening of existing drains and canals • Improvement of household sewer system and adaptation of greywater usage • Legislative measures (enforcement of existing regulation on environment and health) • Kampung(villages) improvement sanitation program • Extensive use of piped-water (PDAM) and increased of household piped-water
(B) Second priority area: area that has high hazard but low vulnerability	• Whole hospital emergency alert and increased access to emergency treatment. If epidemic warning (KLB) occurs do citywide hospital alert and decrease in morbidity and mortality • Availability of drugs and antibiotic against diarrhea and develop rapid diarrheal diagnostic agents • Better training of hospital personnel during emergency diarrheal outbreak and increased routine surveillance of diarrhea agents • Meteorological surveillance (rainfall, temperature) and development of early warning method based on meteorogical surveillance • Increased community participation • If flood occur do better sanitation system in flood refugee camps
(C) Third priority area: area that has high vulnerability but low hazard	• Development of drainage infrastructure in flood prone areas • Widening and deepening of existing drains and canals • Improvement of household sewer system and adaptation of greywater usage • Legislative measures (enforcement of existing regulation on environment and health) • Kampung(villages) improvement sanitation program • Extensive use of piped-water (PDAM) and increased of household piped-water • Improvement of health facility
(D) Last priority area: area that has low both hazard and vulnerability	• Household level of waterborne disease prevention • Boiling of household water • Non-Routine, sentinel surveillance of diarrhea agents • Soap and clean water hand washing training as prophylaxis against hand to mouth infection

7.4.1 Adaptation Strategy of Diarrhea in Malang City

Table 7.14 show hazard, vulnerability and risk of diarrhea in each sub district in Malang City both in 2008 and 2030. Moreover, its visualization are drew in Figure 7.5.. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy for diarrhea of each sub district in Malang City can be defined as shown in Table 7.15.

Table 7.14: Hazard, Vulnerability and Risk of Diarrhea in Malang City

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
1	Kedung Kandang	VL	VL	0	M	VH	+2	L	M	+1	C
2	Sukun	M	L	-1	VH	M	_2	H	L	-2	C
3	Klojen	M	VH	+2	L	VL	-1	L	M	+1	B
4	Blimbing	L	L	0	H	VH	+1	M	H	+1	C
5	Lowok Waru	VL	VL	0	VH	VH	0	M	M	0	C

Note: Comp = comparison, Adap Str. = adaptation strategy category

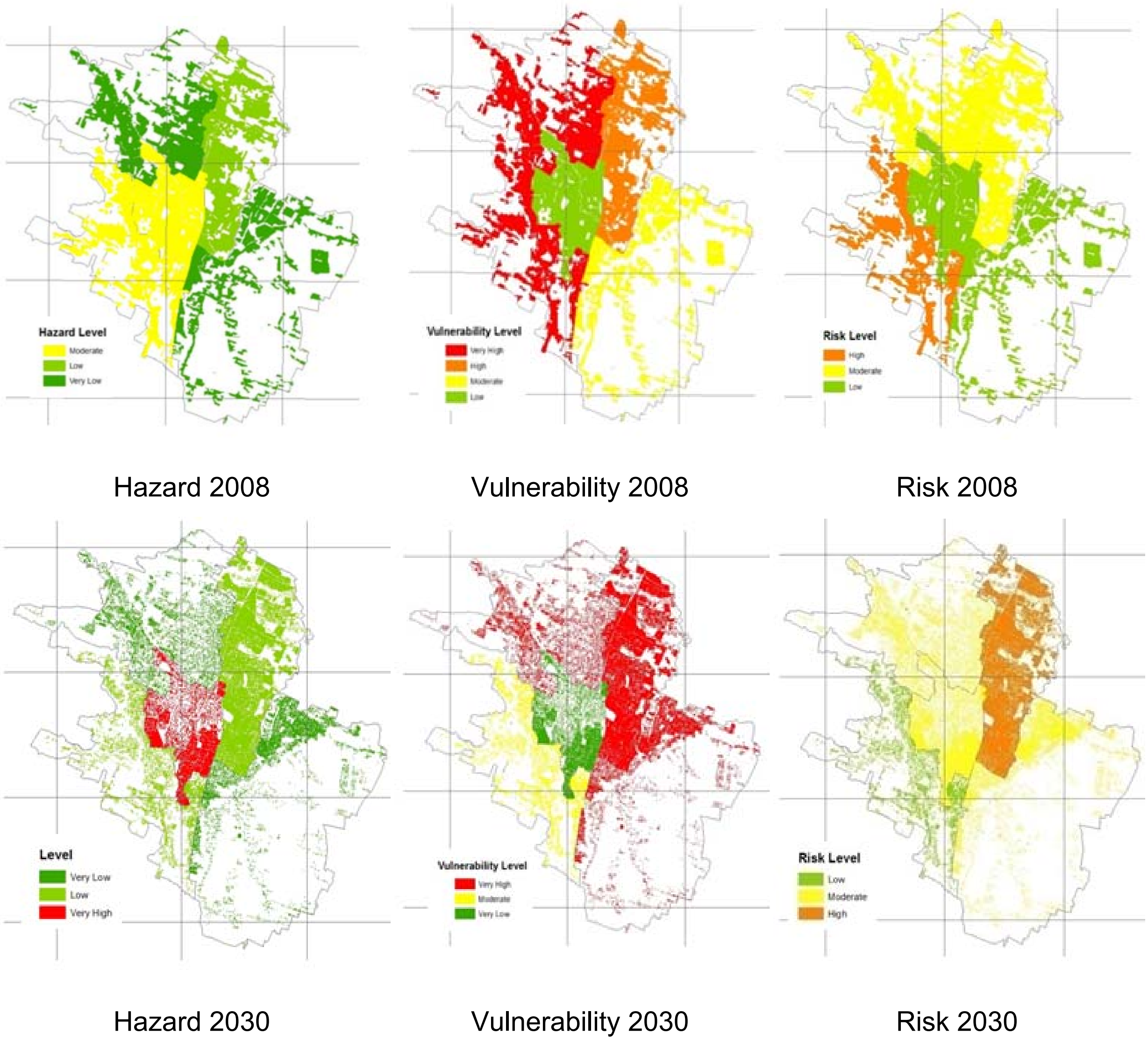


Figure 7.5 Map of Hazard, Vulnerability and Risk of Diarrhea in Malang City

As shown in Table 7.14, Klojen has moderate hazard level in 2008 and be predicted increase in 2030 to became very high. However Klojen has low vulnerability in 2008 and be predicted became very low in 2030, therefore Klojen is categorized as type B in adaptation strategy category. Moreover Kedung Kandang, Sukun and Blimbing have low hazard level in 2008 and those be predicted still low hazard in 2030, but those have high vulnerability level in 2008 and be predicted still high in 2030. Therefore Kedung Kandang, Sukun and Blimbing are categorized as type C in adaptation strategy category. Vulnerability problem in Sukun and Blimbing is mainly caused by low piped water coverage. In detail, adaptation strategy of Diarrhea for sub district in Malang City is described in Table 7.15 below.

Table 7.15: Adaptation Strategy of Diarrhea for Each Category in Malang City

Category	Sub Districts	Adaptation Strategy
A	• None	• None
B	• Klojen	• Whole hospital emergency alert and increased access to emergency treatment. If epidemic warning (KLB) occurs do citywide hospital alert and decrease in morbidity and mortality • Availability of drugs and antibiotic against diarrhea and develop rapid diarrheal diagnostic agents • Better training of hospital personnel during emergency diarrheal outbreak and increased routine surveillance of diarrhea agents • Meteorological surveillance (rainfall, temperature) and development of early warning method based on meteorogical surveillance • Increased community participation • If flood occur do better sanitation system in flood refugee camps
C	• Kedung Kandang • Sukun • Blimbing • Lowok Waru	• Development of drainage infrastructure in flood prone areas • Widening and deepening of existing drains and canals • Improvement of household sewer system and adaptation of greywater usage • Legislative measures (enforcement of existing regulation on environment and health) • Kampung(villages) improvement sanitation program • Extensive use of piped-water (PDAM) and increased of household piped-water Improvement of health facility
D	• None	• None

7.4.2 Adaptation Strategy of Diarrhea in Batu City

Table 7.16 show hazard, vulnerability and risk of diarrhea in each sub district in Batu City both in 2008 and 2030. Moreover, its visualizations are drew in Figure 7.6. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of diarrhea of each sub district in Batu City can be defined as shown in Table 7.17.

Table 7.16: Hazard, Vulnerability and Risk of Diarrhea in Batu City

No	Sub Districts	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
1	Batu	H	VH	+1	M	VH	+2	H	VH	+1	A
2	Junrejo	VH	VH	0	VL	M	+2	M	H	+1	B
3	Bumiaji	VH	VH	0	VL	H	+3	M	VH	+2	A

Note: Comp = comparison, Adap Str. = adaptation strategy category

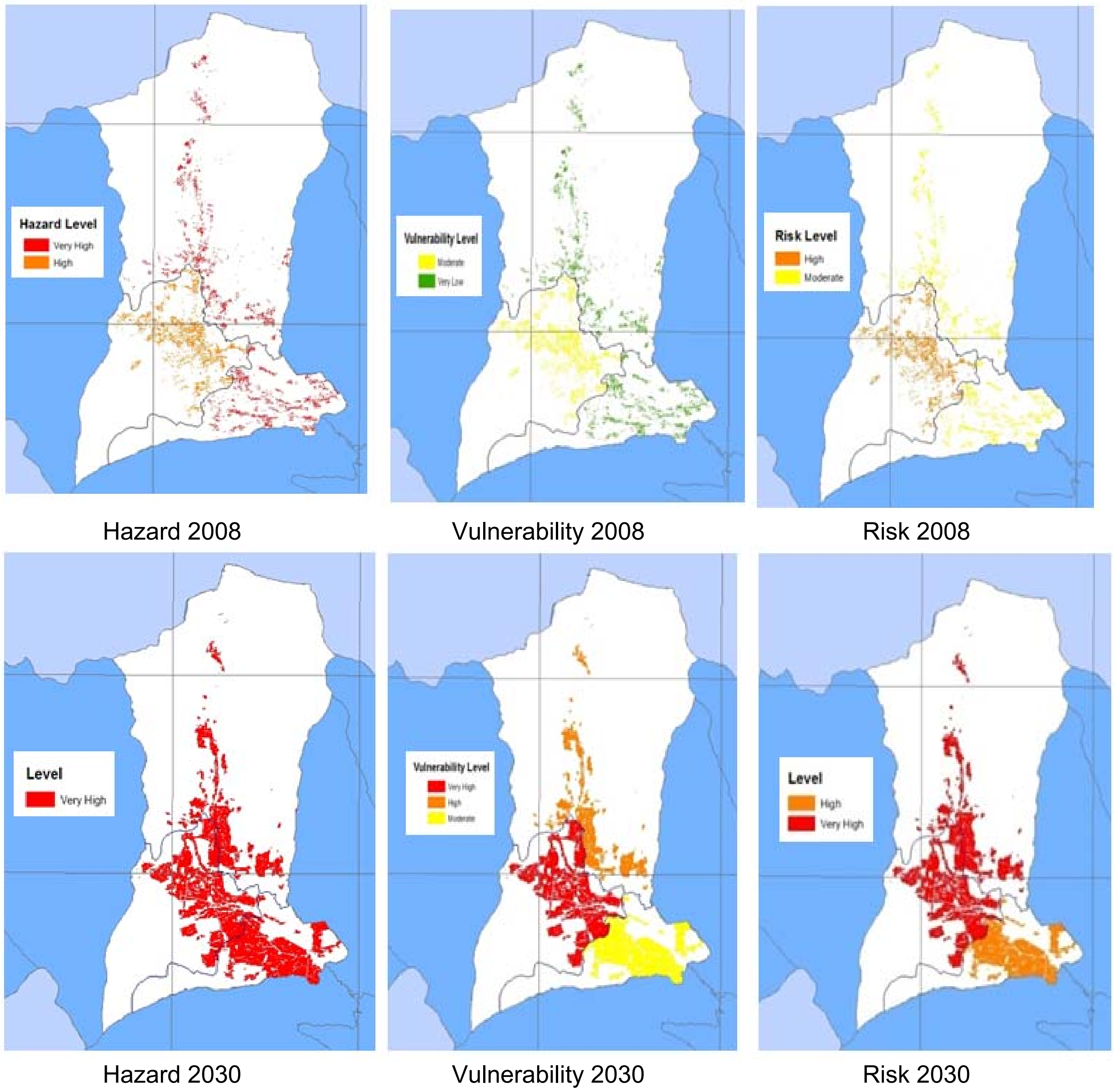


Figure 7.6 Map of Hazard, Vulnerability and Risk of Diarrhea in Batu City

As Shown in Table 7.16 In Batu City, sub districts Batu and Bumiaji have high hazard level and vulnerability in 2008 and those be predicted still high hazard and vulnerability level in 2030. Therefore Batu and Bumiaji are is categorized as type A of adaptation strategy. Moreover, Junrejo has very high hazard level in 2008 and be predicted still very high in 2030 but Junrejo has low vulnerability level therefore Junrejo is categorized as type B of adaptation strategy. Based on this classification, in general Batu City have high hazard level in all area and low vulnerability level in partial area. In detail, adaptation strategy for each sub district in Batu City is described in Table 7.17 below.

Table 7.17: Adaptation Strategy of Diarrhea for Each Category in Batu City

Category	Sub Districts	Adaptation Strategy
A	• Batu • Bumiaji	• Whole hospital emergency alert and increased access to emergency treatment. If epidemic warning (KLB) occurs do citywide hospital alert and decrease in morbidity and mortality • Availability of drugs and antibiotic against diarrhea and develop rapid diarrheal diagnostic agents • Better training of hospital personnel during emergency diarrheal outbreak and increased routine surveillance of diarrhea agents • Meteorological surveillance (rainfall, temperature) and development of early warning method based on meteorogical surveillance • Increased community participation • If flood occur do better sanitation system in flood refugee camps • Development of drainage infrastructure in flood prone areas • Widening and deepening of existing drains and canals • Improvement of household sewer system and adaptation of greywater usage • Legislative measures (enforcement of existing regulation on environment and health) • Kampung(villages) improvement sanitation program • Extensive use of piped-water (PDAM) and increased of household piped-water
B	• Junrejo	• Whole hospital emergency alert and increased access to emergency treatment. If epidemic warning (KLB) occurs do citywide hospital alert and decrease in morbidity and mortality • Availability of drugs and antibiotic against diarrhea and develop rapid diarrheal diagnostic agents • Better training of hospital personnel during emergency diarrheal outbreak and increased routine surveillance of diarrhea agents • Meteorological surveillance (rainfall, temperature) and development of early warning method based on meteorogical surveillance • Increased community participation • If flood occur do better sanitation system in flood refugee camps
C	• None	None
D	• None	• None

CHAPTER 8 CONCLUSION AND RECCOMENDATION

8.1 Conclusion

8.1.1 Hazard Analysis

Existing and future hazard for DHF, malaria, and diarrhea were analyzed as shown in Table 8.1. Moreover, to know impact of future climate to hazard, comparison of those future and existing hazard has been conducted by put +1 for increasing 1 level, +2 for increasing 2 level, etc. The sub districts that they have same level, they are marked by 0. As discussed in chapter 4, there are not all data are available. In Malang city and Batu city malaria cases data are not available and in Malang district diarrhea case data is not available, therefore in Table 8.1, the not available data is shown as blank table.

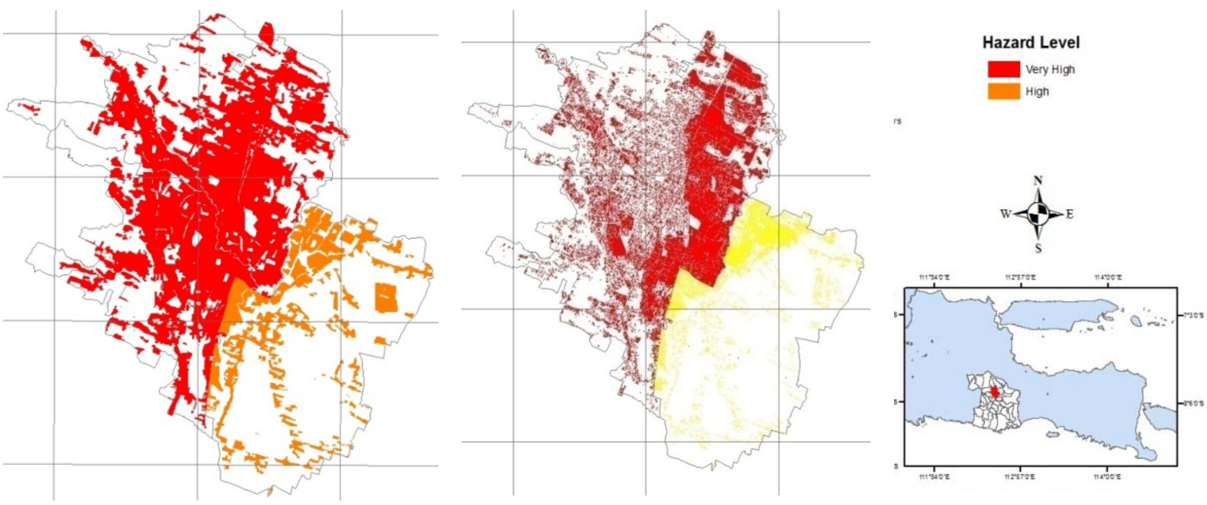
Table 8.1: Comparison of Existing and Future Hazard Categorization for DHF, Malaria and Diarrhea in Greater Malang

No	Sub Districts	Hazard DHF			Hazard Malaria			Hazard Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
Malang City										
1	Kedung Kandang	H	M	-1				VL	VL	0
2	Sukun	VH	VH	0				M	L	-1
3	Klojen	VH	VH	0				M	VH	+2
4	Blimbing	VH	VH	0				L	L	0
5	Lowok Waru	VH	VH	0				VL	VL	0
Malang District										
6	Tumpang	H	H	0	VL	VL	0			
7	Poncokusumo	VL	VL	0	VL	VL	0			
8	Jabung	VL	VL	0	VL	VL	0			
9	Pakis	H	VH	+1	VL	VL	0			
10	Lawang	L	VL	-1	VL	VL	0			
11	Singosari	L	L	0	VL	VL	0			
12	Karangploso	M	VH	+2	VL	VL	0			
13	Dau	VH	H	-1	VL	VL	0			
14	Pujon	VL	VL	0	L	VL	-1			
15	Ngantang	VL	VL	0	M	VL	-2			
16	Kasembon	VL	VL	0	M	VL	-2			
17	Kepanjen	M	M	0	L	VL	-1			
18	Sumber Pucung	VH	M	-2	M	M	0			
19	Kromengan	L	L	0	VL	VL	0			
20	Pakisaji	H	M	-1	VL	VL	0			
21	Ngajum	L	VL	-1	VL	VL	0			
22	Wonosari	L	VL	-1	VL	VL	0			
23	Wagir	M	L	-1	VL	VL	0			
24	Pagak	H	M	-1	L	VL	-1			
25	Donomulyo	L	VL	-1	M	M	0			

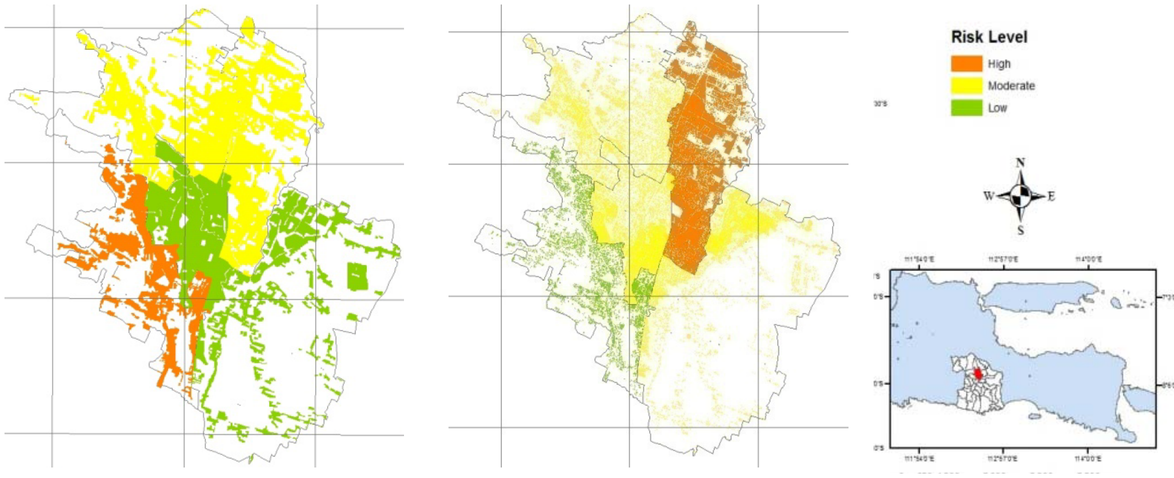
No	Sub Districts	Hazard DHF			Hazard Malaria			Hazard Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
26	Kalipare	M	L	-1	VL	VL	0			
27	Bantur	H	M	-1	M	M	0			
28	Gedangan	L	L	0	VL	VL	0			
29	Gondanglegi	H	VH	+1	VL	VL	0			
30	Bululawang	H	M	-1	M	VL	-2			
31	Wajak	M	L	-1	VL	VL	0			
32	Tajinan	M	L	-1	L	VL	-1			
33	Turen	VH	VH	0	L	VL	-1			
34	Dampit	M	L	-1	VL	VL	0			
35	Sumbermanjing Wetan	M	VL	-2	M	L	-1			
36	Ampelgading	VL	VL	0	L	VL	-1			
37	Tirtoyudo	VL	VL	0	VL	VL	0			
38	Pagelaran	L	VL	-1	VL	VL	0			
Batu City										
39	Batu	VH	VH	0				H	VH	+1
40	Junrejo	VH	VH	0				VH	VH	0
41	Bumiaji	VL	M	+2				VH	VH	0

Note:
Comp = comparison between 2008 and 2030
+1 : increase one level -1 : decrease one level
+2 : increase two level -2 : decrease two level
+3 : increase three level -3 : decrease three level
+4 : increase four level -4 : decrease four level
0 : same level

Comparison between existing and future hazard is also illustrated in spatial view. Figure 8.3 shows comparison between existing and future DHF and diarrhea hazard in spatial view for Malang City. Figure 8.4 shows comparison between existing and future DHF and malaria hazard in spatial view for Malang District. Figure 8.5 shows comparison between existing and future DHF and diarrhea hazard in spatial view for Batu City.

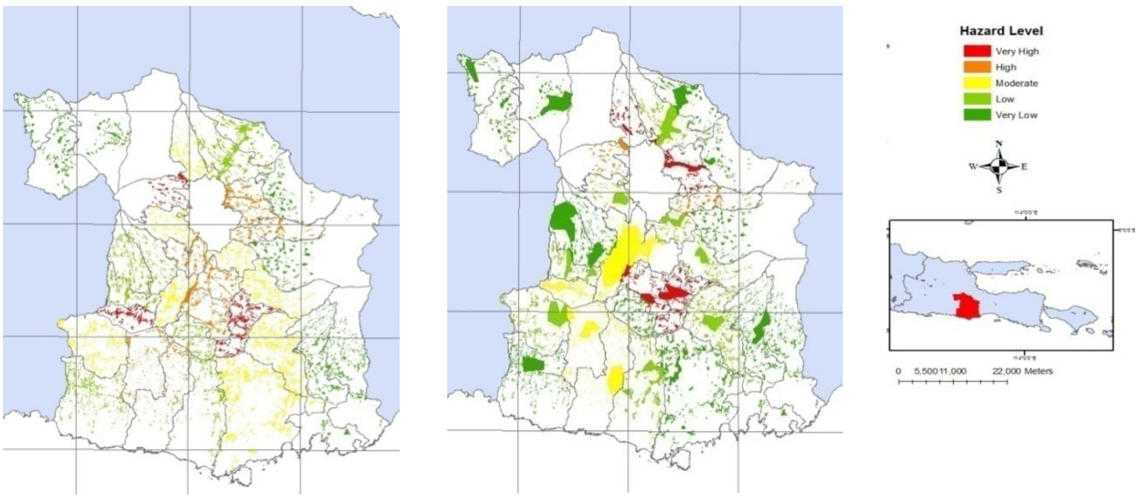


(a) DHF Hazard 2008 DHF Hazard 2030

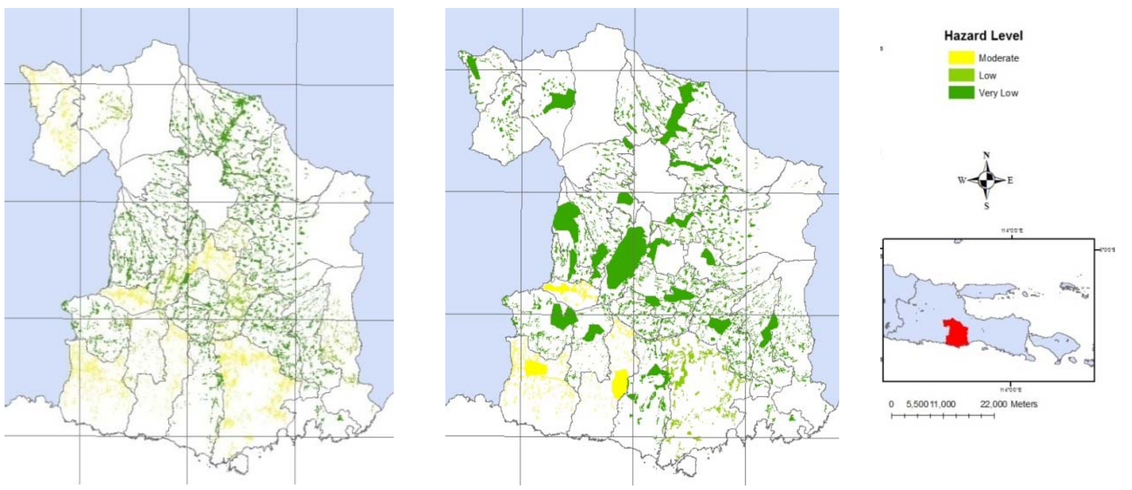


(b) Diarrhea Risk 2008 Diarrhea Risk 2030

Figure 8.1 Comparison between (a) DHF and (b) Diarrhea Hazard Map in Malang City for 2008 and 2030



(a) DHF Hazard 2008 DHF Hazard 2030



(b) Malaria Hazard 2008 Malaria Hazard 2030

Figure 8.2 Comparison between (a) DHF and (b) Malaria Hazard Map in Malang District for 2008 and 2030

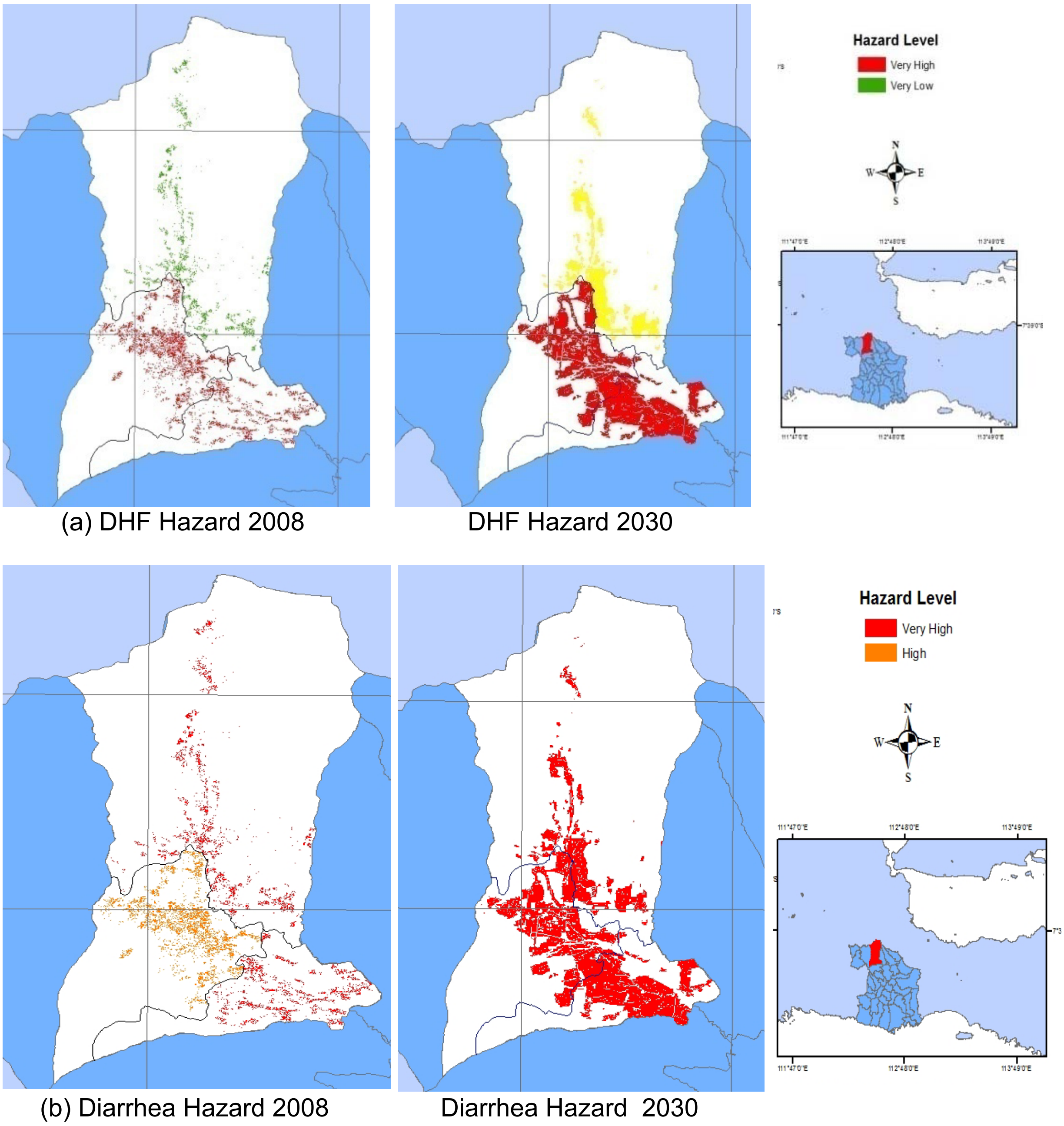


Figure 8.3 Comparison between (a) DHF and (b) Diarrhea Hazard Map in Batu City for 2008 and 2030

8.1.2 Vulnerability Analysis

Comparison of DHF, Malaria and Diarrhea vulnerability levels in Malang for 2008 and 2030 is described in Table 8.2 below. Blank table is caused by non-available data.

Table 8.2: Comparison of Existing and Future Vulnerability Categorization for DHF, Malaria and Diarrhea in Greater Malang

No	Sub Districts	Vulnerability DHF			Vulnerability Malaria			Vulnerability Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
Malang City										
1	Kedung Kandang	VH	VH	0				M	VH	+2
2	Sukun	VH	VH	0				VH	M	_2
3	Klojen	H	VH	+1				L	VL	-1
4	Blimbing	VH	VH	0				H	VH	+1
5	Lowok Waru	VH	VH	0				VH	VH	0
Malang District										
6	Tumpang	L	L	0	M	H	+1			
7	Poncokusumo	M	H	+1	M	VH	+2			
8	Jabung	H	VH	+1	VL	L	+1			
9	Pakis	VL	VL	0	L	M	+1			
10	Lawang	VL	VL	0	M	VL	-2			
11	Singosari	H	VL	-3	VL	VL	0			
12	Karangploso	VL	VL	0	VH	VH	0			
13	Dau	M	L	-1	L	M	+1			
14	Pujon	L	VL	-1	VL	VL	0			
15	Ngantang	M	M	0	H	VH	+1			
16	Kasembon	L	VL	-1	H	M	-1			
17	Kepanjen	VL	VL	0	VL	VL	0			
18	Sumber Pucung	H	L	-2	H	VH	+1			
19	Kromengan	M	VL	-2	VH	H	-1			
20	Pakisaji	L	VL	-1	VL	VL	0			
21	Ngajum	L	VL	-1	H	M	-1			
22	Wonosari	VL	VL	0	L	VL	-1			
23	Wagir	VH	VL	-4	L	VL	-1			
24	Pagak	VL	VL	0	L	VL	-1			
25	Donomulyo	M	VL	-2	H	H	0			
26	Kalipare	M	VL	-2	M	L	-1			
27	Bantur	H	VL	-3	H	VL	-3			
28	Gedangan	H	VL	-3	VH	H	-1			
29	Gondanglegi	VL	VL	0	M	L	-1			
30	Bululawang	L	VL	-1	VL	VL	0			
31	Wajak	VL	L	+1	VL	L	+1			
32	Tajinan	L	VL	-1	L	L	0			
33	Turen	M	L	-1	M	H	+1			
34	Dampit	VH	M	-2	VH	VH	0			
35	Sumbermanjing Wetan	L	VL	-1	M	H	+1			
36	Ampelgading	M	L	-1	VH	VH	0			

No	Sub Districts	Vulnerability DHF			Vulnerability Malaria			Vulnerability Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
37	Tirtoyudo	H	L	-2	VH	VH	0			
38	Pagelaran	H	H	0	VH	VH	0			
Batu City										
39	Batu	VH	VH	0				M	VH	+2
40	Junrejo	VH	VH	0				VL	M	+2
41	Bumiaji	VH	VH	0				VL	H	+3

Note:
Comp = comparison between 2008 and 2030
+1 : increase one level -1 : decrease one level
+2 : increase two level -2 : decrease two level
+3 : increase three level -3 : decrease three level
+4 : increase four level -4 : decrease four level
0 : same level

Comparison between existing and future vulnerability is also illustrated in spatial view. Figure 8.6 shows comparison between existing and future DHF and Diarrhea vulnerability in spatial view for Malang City. Figure 8.7 shows comparison between existing and future DHF and Malaria vulnerability in spatial view for Malang District. Figure 8.8 shows comparison between existing and future DHF and Diarrhea vulnerability in spatial view for Batu City.

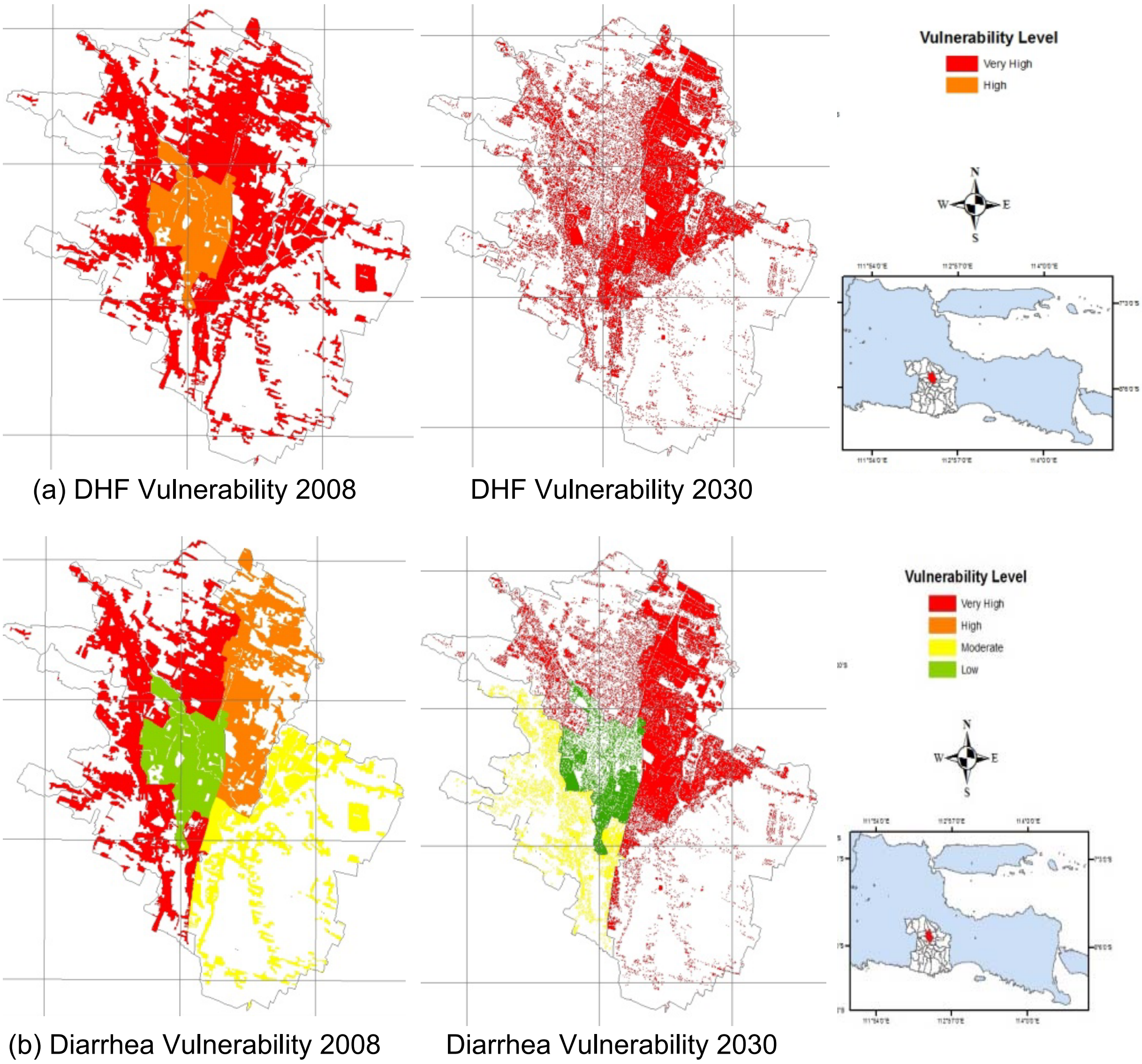


Figure 8.4 Comparison between (a) DHF and (b) Diarrhea Vulnerability Map in Malang City for 2008 and 2030

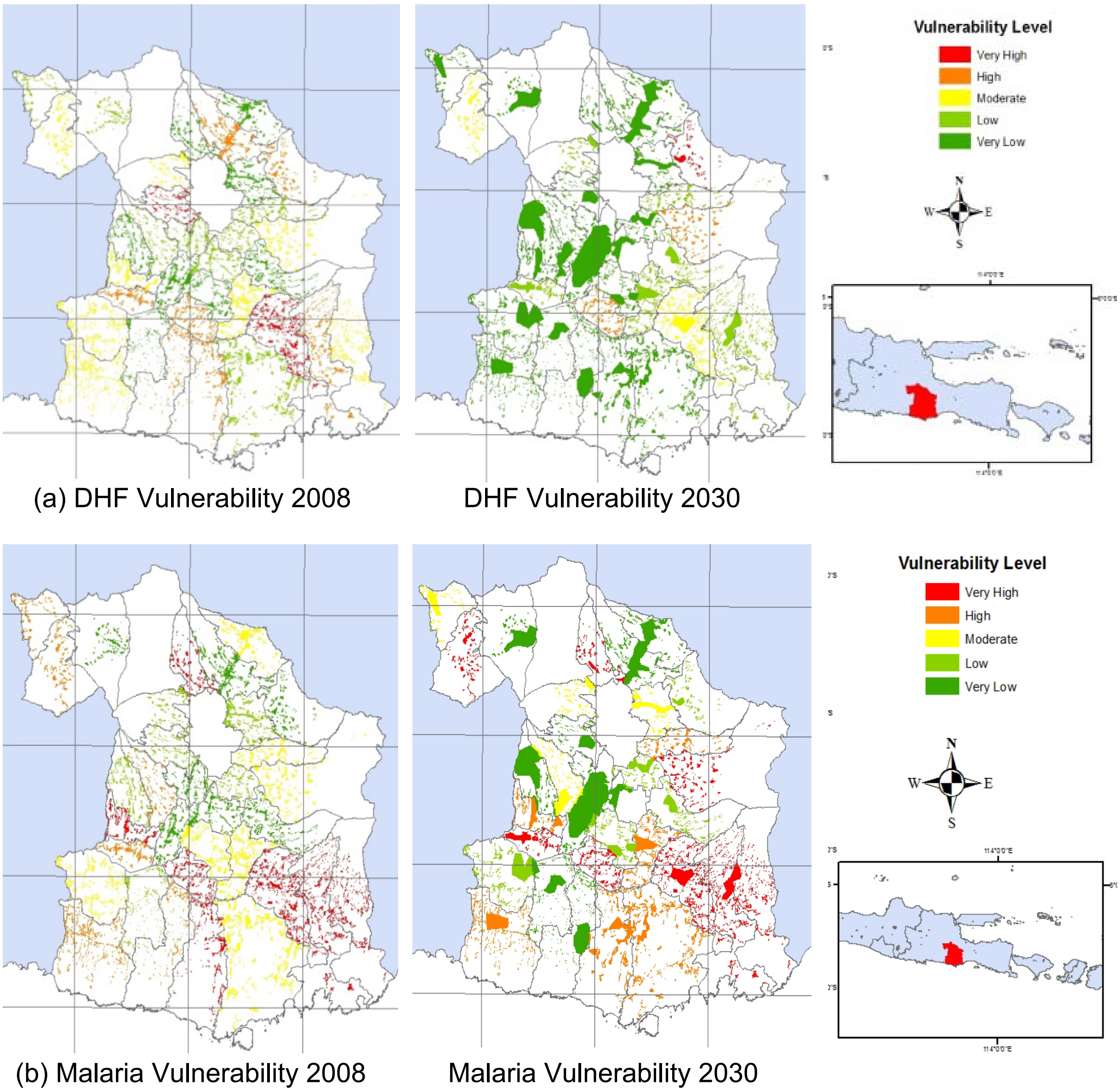


Figure 8.5 Comparison between (a) DHF and (b) Malaria Vulnerability Map in Malang Districts for 2008 and 2030

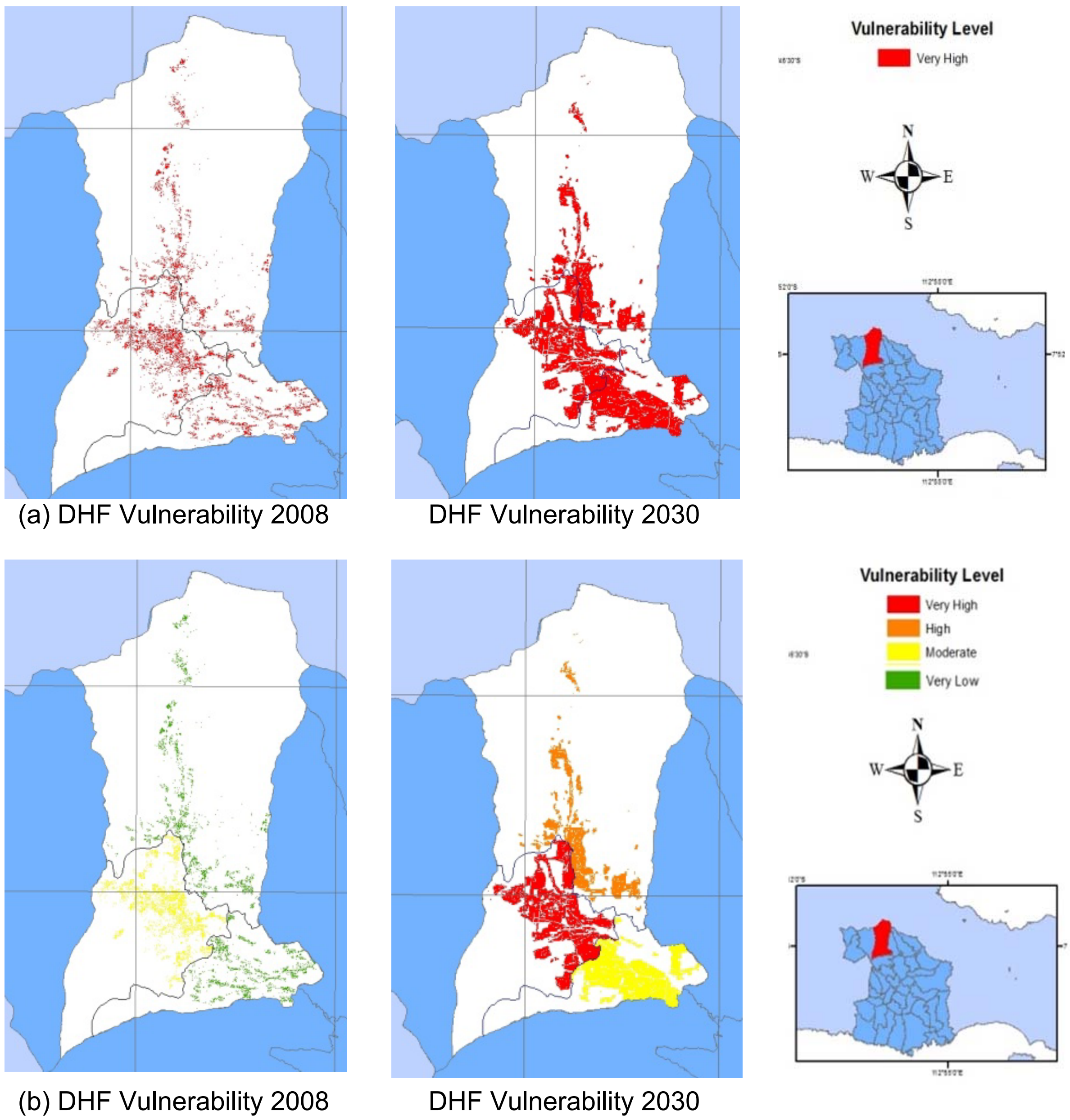


Figure 8.6 Comparison between (a) DHF and (b) Diarrhea Vulnerability Map in Batu City for 2008 and 2030

8.1.3 Risk Analysis

Comparison of DHF, Malaria and Diarrhea Risk levels in Malang for 2008 and 2030 is described in Table 8.3 below. Bank table is caused by non-available data.

Table 8.3: Comparison of Existing and Future Risk Categorization for DHF, Malaria and Diarrhea in Greater Malang

No	Sub Districts	Risk DHF			Risk Malaria			Risk Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
Malang City										
1	Kedung Kandang	VH	H	-1				L	M	+1
2	Sukun	VH	VH	0				H	L	-2
3	Klojen	VH	VH	0				L	M	+1
4	Blimbing	VH	VH	0				M	H	+1
5	Lowok Waru	VH	VH	0				M	M	0
Malang District										
6	Tumpang	H	M	-1	L	L	0			
7	Poncokusumo	VL	L	+1	L	M	+1			
8	Jabung	VL	M	+2	VL	VL	0			
9	Pakis	H	M	-1	VL	L	+1			
10	Lawang	L	VL	-1	L	VL	-1			
11	Singosari	L	VL	-1	VL	VL	0			
12	Karangploso	M	M	0	M	M	0			
13	Dau	VH	M	-2	VL	L	+1			
14	Pujon	VL	VL	0	VL	VL	0			
15	Ngantang	VL	L	+1	H	M	-1			
16	Kasembon	VL	VL	0	H	L	-2			
17	Kepanjen	M	L	-1	L	VL	-1			
18	Sumber Pucung	VH	L	-3	H	H	0			
19	Kromengan	L	VL	-1	M	L	-1			
20	Pakisaji	H	L	-2	VL	VL	0			
21	Ngajum	L	VL	-1	L	L	0			
22	Wonosari	L	VL	-1	VL	VL	0			
23	Wagir	M	VL	-2	VL	VL	0			
24	Pagak	H	L	-2	L	VL	-1			
25	Donomulyo	L	VL	-1	H	H	0			
26	Kalipare	M	VL	-2	L	VL	-1			
27	Bantur	H	L	-2	H	L	-2			
28	Gedangan	L	VL	-1	M	L	-1			
29	Gondanglegi	H	M	-1	L	VL	-1			
30	Bululawang	H	L	-2	L	VL	-1			
31	Wajak	M	L	-1	VL	VL	0			
32	Tajinan	M	VL	-2	L	VL	-1			
33	Turen	VH	H	-1	L	L	0			
34	Dampit	M	L	-1	M	M	0			
35	Sumbermanjing Wetan	M	VL	-2	M	M	0			
36	Ampelgading	VL	VL	0	H	M	-1			
37	Tirtoyudo	VL	VL	0	M	M	0			
38	Pagelaran	L	L	0	M	M	0			
Batu City										
39	Batu	VH	VH	0				H	VH	+1

No	Sub Districts	Risk DHF			Risk Malaria			Risk Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
40	Junrejo	VH	VH	0				M	H	+1
41	Bumiaji	VL	H	+3				M	VH	+2

Note:
Comp = comparison between 2008 and 2030

+1 : increase one level	-1 : decrease one level
+2 : increase two level	-2 : decrease two level
+3 : increase three level	-3 : decrease three level
+4 : increase four level	-4 : decrease four level
0 : same level	

Comparison between existing and future risk is also illustrated in spatial view. Figure 8.9 shows comparison between existing and future DHF and Diarrhea risk in spatial view for Malang City. Figure 8.10 shows comparison between existing and future DHF and Malaria risk in spatial view for Malang District. Figure 8.11 shows comparison between existing and future DHF and Diarrhea risk in spatial view for Batu City.

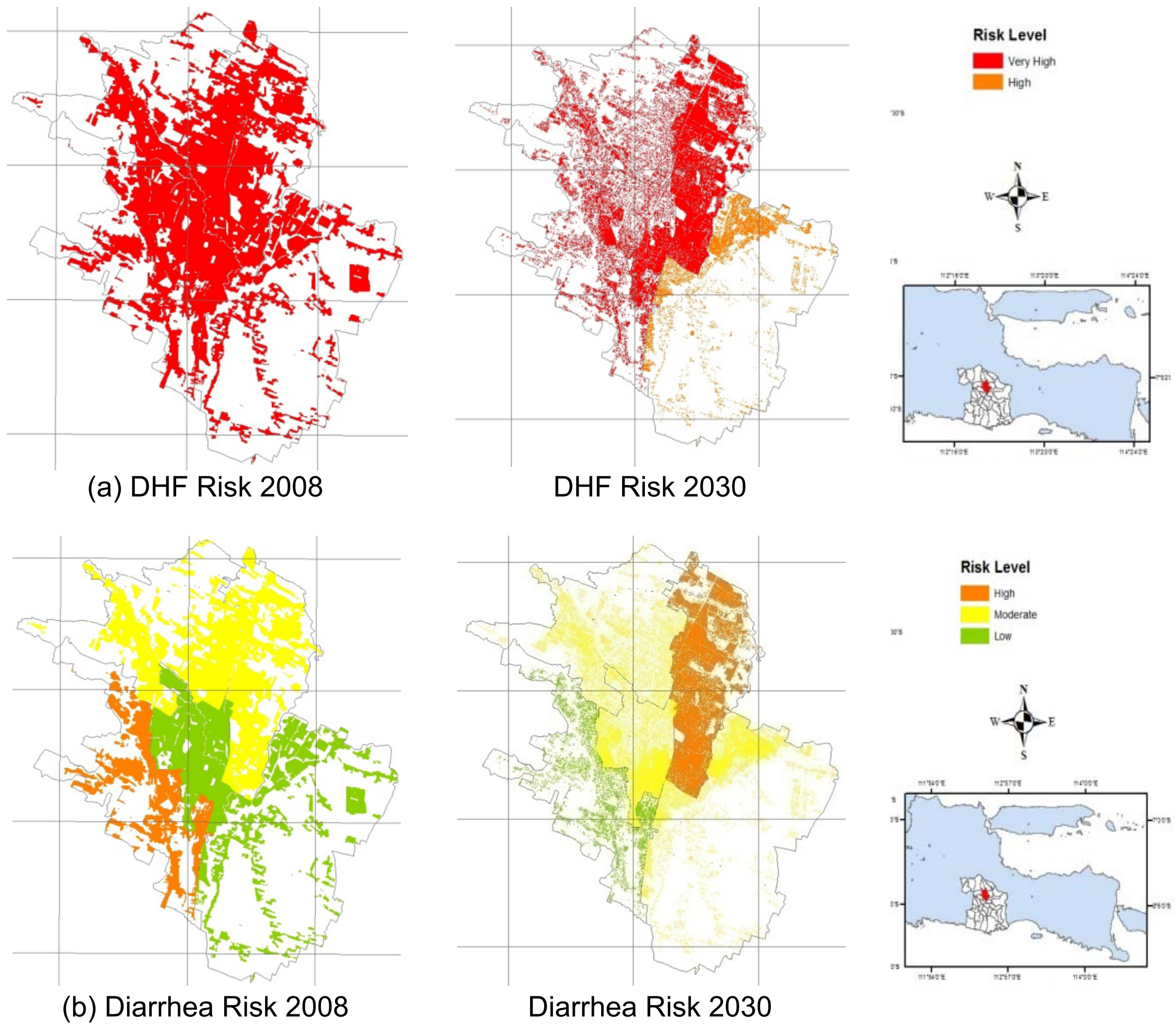


Figure 8.7 Comparison between (a) DHF and (b) Diarrhea Risk Map in Malang City for 2008 and 2030

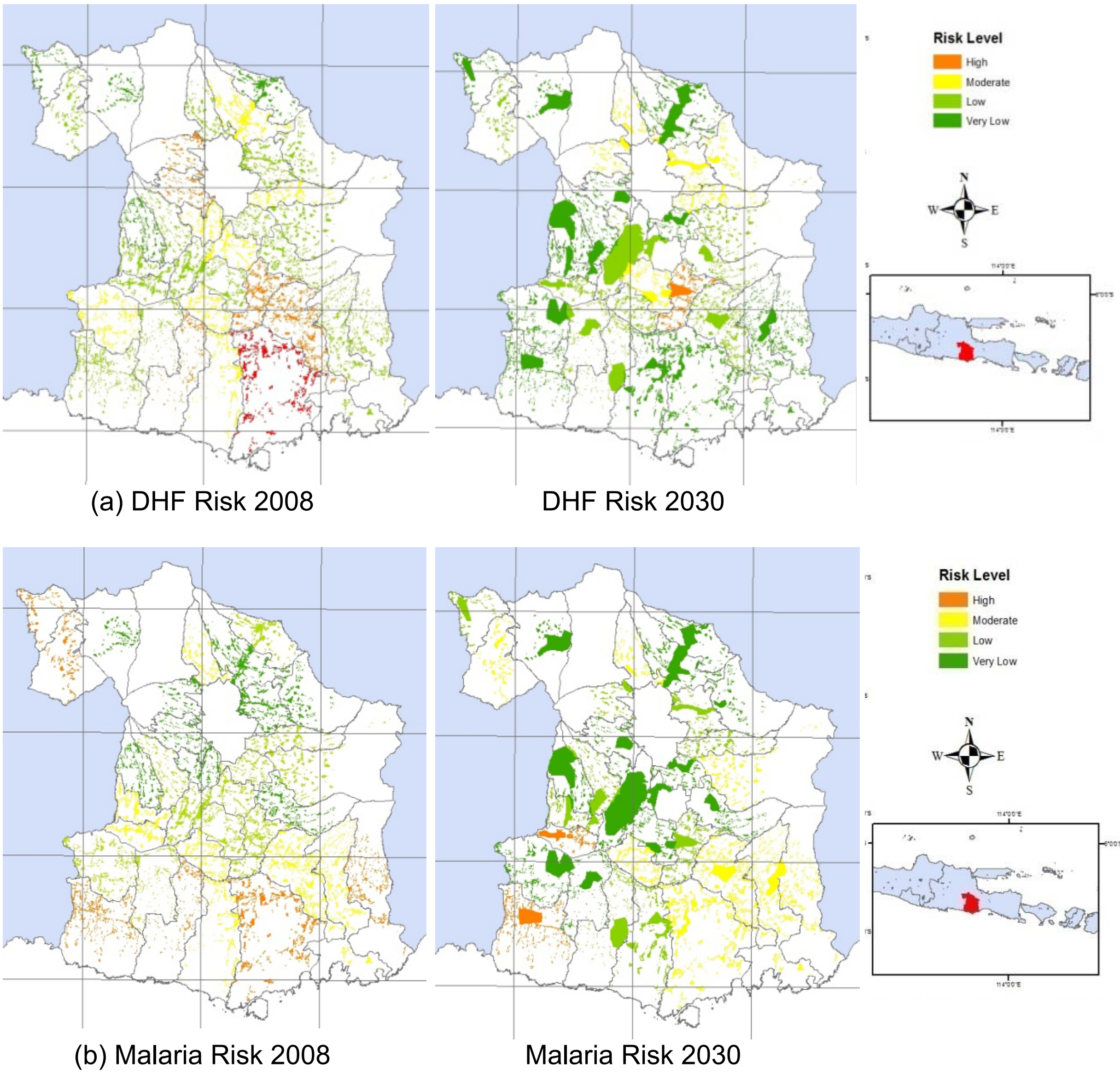


Figure 8.8 Comparison between (a) DHF and (b) Malaria Risk Map in Malang District for 2008 and 2030

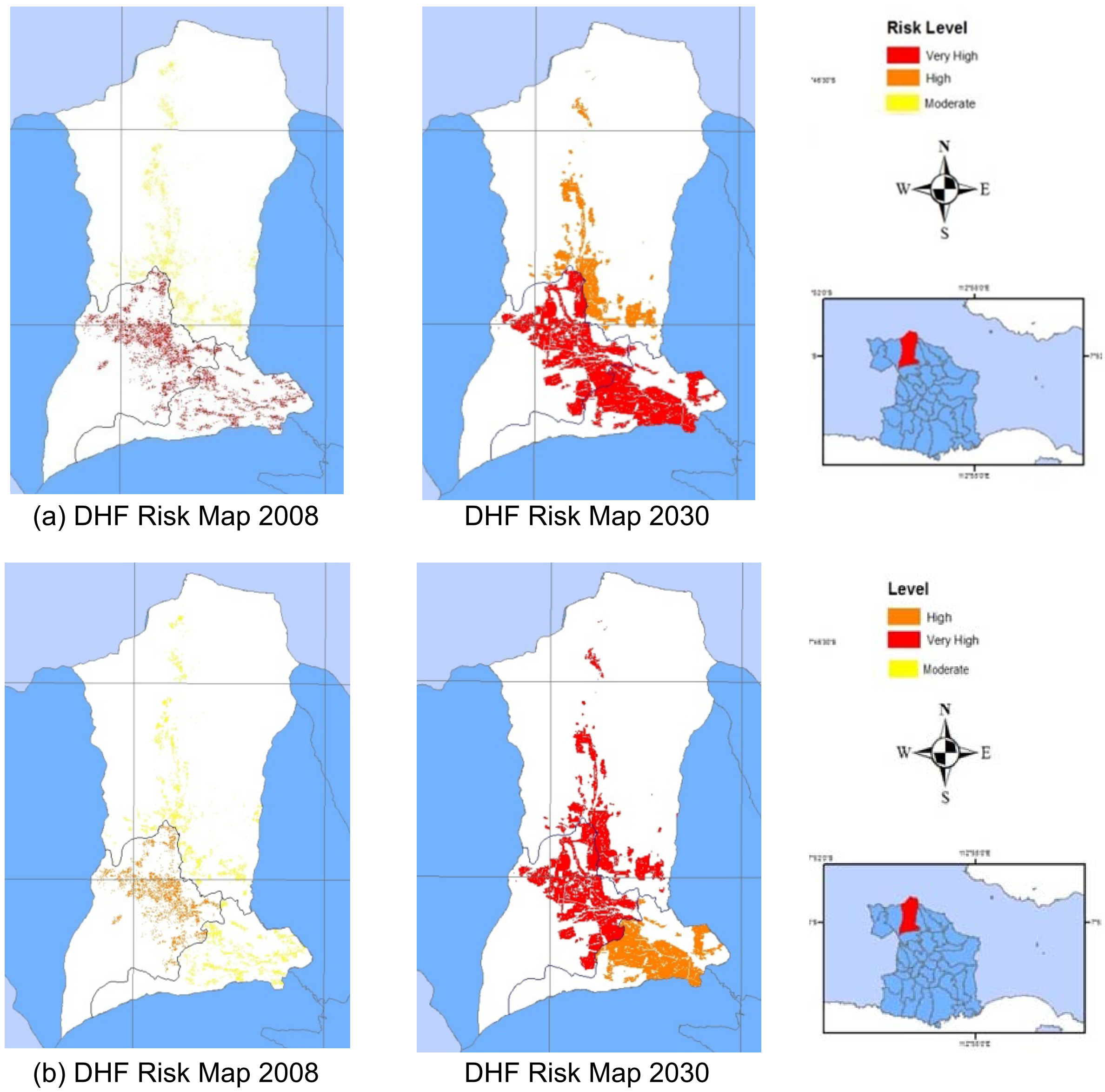


Figure 8.9 Comparison between (a) DHF and (b) Diarrhea Risk Map in Batu City for 2008 and 2030

8.1.4 Adaptation Strategy

Adaptation strategy in health sector is divided to 4 (four) category, namely A, B, C, and D, where A is the most priority area, following by B, C, and D, respectively. The categories are described as follow:

(A) First priority: Areas with high risk due to high hazard and high vulnerability.

This high risk area is first priority to be improved because it has high both hazard and vulnerability. For areas of such criteria, the first attention should be given to the management of hazard against dengue, malaria and diarrhea since patient's wellness is of utmost priority. The next attention is given to the betterment of the environmental quality, provision of save water supply, sanitation and health facility.

(B) Second priority: Adaptation strategy for areas with high risk due to high hazard only.

This area is second priority to be improved because it has high hazard but has low vulnerability. For areas such as this, management of hazard, either for dengue, malaria and diarrhea should be given high attention, both through prevention and treatment. The second attention is the management of the environment such as improvement of save water supply, sanitation and clean and healthy environment.

(C) Third priority: Areas with high risk due to high vulnerability only.

This area is third priority to be improved because it has low hazard but has high vulnerability. For areas such as this, the management of vulnerability is main attention, such as develop better and healthier environment, save water supply, and environmental sanitation. Management of slum areas and de-urbanization should be integrated within. The improvement of and better access to health facilities should have high attention and should be adjusted to the real need of the community. For rural areas, improving the access to health facilities become high attention by either lowering the health cost or by providing public transport facility for easy access.

(D) Last priority: Areas with low risk due to low hazard and low vulnerability.

This area is low risk area and last priority to be improved because it has low both hazard and vulnerability. The main task to this area is keep the environment in health condition. Campaign and community education to prevent both dengue, malaria and diarrhea is also important.

Based on those categories, adaptation strategy for DHF, malaria, and diarrhea for each sub-district in Malang was defined as shown in Table 8.4 as follow. Blank table is caused by non-available data.

Table 8.4: Adaptation Strategy Category of DHF Malaria and Diarrhea for Each Sub District in Malang

No	Sub Districts	Adaptation Strategy for DHF	Adaptation Strategy for Malaria	Adaptation Strategy for Diarrhea
Malang City				
1	Kedung Kandang	A		C
2	Sukun	A		C
3	Klojen	A		B
4	Blimbing	A		C
5	Lowok Waru	A		C
Malang District				
6	Tumpang	B	C	
7	Poncokusumo	C	C	
8	Jabung	C	D	
9	Pakis	B	D	
10	Lawang	D	D	
11	Singosari	C	C	
12	Karangploso	B	C	
13	Dau	B	D	
14	Pujon	D	D	
15	Ngantang	D	C	
16	Kasembon	D	C	
17	Kepanjen	D	D	
18	Sumber Pucung	A	C	
19	Kromengan	C	C	
20	Pakisaji	B	D	

No	Sub Districts	Adaptation Strategy for DHF	Adaptation Strategy for Malaria	Adaptation Strategy for Diarrhea
21	Ngajum	D	C	
22	Wonosari	D	D	
23	Wagir	C	D	
24	Pagak	B	D	
25	Donomulyo	D	C	
26	Kalipare	D	D	
27	Bantur	A	C	
28	Gedangan	C	C	
29	Gondanglegi	B	D	
30	Bululawang	B	D	
31	Wajak	D	D	
32	Tajinan	D	D	
33	Turen	B	C	
34	Dampit	C	C	
35	Sumbermanjing Wetan	D	C	
36	Ampelgading	D	C	
37	Tirtoyudo	C	C	
38	Pagelaran	C	C	
Batu City				
39	Batu	A		A
40	Junrejo	A		B
41	Bumiaji	C		A

8.2 Reccomendation

In this report, adaptation strategies in health sector in order to reduce climate change vulnerabilities and impacts were defined. Therefore, any consideration of adaptation planning in health sector must begin with consideration of risks associated with climate change vulnerabilities and impacts, to the extent that these can be anticipated. For example, adaptation planning consider the category of each area where category A is the most priority area, following by B as second priority, C as third priority, and D as last priority. Moreover, adaptation planning in health sector in Great Malang Area should consider specific social, cultural, and economi factors such as health status disparity (gap between rich and poor), behavior and lifestyle.

Great Malang Area consists of urban, sub-urban and rural area. Therefore adaptation planning in health sector should consider those geographic and demography condition. Adaptation plannings in Malang city and Batu city that mainly are characterized by urban and sub-urban area should be directed to (1) re-development of slums and high density populated housings, (2) better disease surveillance and monitoring of highly mobile population, (3) better provision of health facilities and infrastructure for low income population, (3) improving the ability of the community to early detection of vector borne diseases such as dengue and malaria, (4) increase personal and public concern of the community on their own environment, (5) integrated infrastructure management on environmental sanitation involving various stakeholders, (6) proclamation of community Healthy City and Healthy Markets, and (7) strict control and supervision of its natural environmental sustainability.

Moreover, adaptation planning in Malang district that mainly are characterized by sub-urban and rural area should be directed to (1) better community access to health facilities especially by narrowing the distance and making health transportation more available, (2) to increase the participatory role of the community by reactivation of the now extinct POKJANAL (National Working Group on Health Activities) formerly promoted by Kemendagri (the Ministry of Interior), (3) provision of free laboratory examination for dengue and malaria detection, and (4) infrastructure and environmental sanitation management based on natural condition and local sustainability.

In fact, laws and regulations enforcement are important factor in adaptation planning. The laws and regulations should be directed to enforce gradual shift of health policy from predominantly curative-mitigative to preventive-adaptive and promotive approach type of policy in the long run. Gradual shift in policy also occurred from following reactive strategy responding to health programs centrally directed, to more loosely proactive strategy responding to local impact of climate change to improve the adaptive capacity and resilience of the local community. Shift is also expected gradually from policy of independency of the health institution to a multi institution teamwork managed together by various local authorities under the coordination of a higher level coordinator (Bappeda and provincial level).

Malang city has many high reputation universities. Therefore, those universities should lead researches to provide hazard and vulnerability data used by government planning body (Bappeda) and by executive bodies for implementation in mitigation and adaptation. Moreover, improving climate information and applications for the whole Great Malang Area through work with the local BMKG meteorological office, and other users would be valuable for enhancing flood and drought preparedness and infectious disease awareness. This would require improved forecasting ability at the local level, which is currently quite lacking. The BMKG Meteorological Department should develop a forecasting system to facilitate early warning system for mosquito borne and waterborne diseases management. Its research center should also develop a drought risk map for the area and setting up drought information centers to provide timely information to relevant organizations.

Increasing access to, and the quality of, health care and other social services will also reduce the Great Malang Area's vulnerability to climate risks. This includes supporting local organizations to deliver social welfare services that are responsive to the local community's needs. People in the area currently felt that nongovernmental organization (LSM) working on health could be more active by helping to coordinate health development programs jointly between government health office, LSM, and the private health sector. Funds should also be made available to assist local disadvantaged groups, or provide a type of insurance for households affect by climate hazards. Moreover, promoting community awareness on climate change effect on health and empowerment in local administration and planning for development will better ensure Great Malang Area’s livelihoods and adaptation. Bappeda as development planners may also draw on local knowledge when managing natural resources such as wetlands, water, and soil. Bappeda should design and implement a valuable community health monitoring program that works with locals health authorities to identify imminent health hazards.

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APPENDIX A DATA OF HAZARD

Table A. 1 DHF Incidences (Cases) in Each Villages in Malang City in 2007

Sub District	Villages	DHF Cases 2007											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Klojen	Klojen	0	1	3	4	3	3	7	3	0	0	1	0
	Rampal Celaket	1	0	1	1	1	1	0	0	0	0	0	0
	Samaan	0	1	1	1	3	3	0	1	0	0	1	3
	Kidul Dalem	0	0	0	1	0	0	0	0	0	0	0	1
	Kauman	0	0	0	2	0	0	0	0	0	0	1	0
	Oro-oro Dowo	2	2	3	2	3	3	1	1	0	0	0	0
	Penanggungan	0	0	1	3	1	1	0	0	1	0	0	0
	Bareng	1	2	0	4	3	3	0	0	0	0	0	0
	Sukoharjo	0	0	1	1	2	2	1	0	0	0	0	1
	Gading Kasri	1	0	0	0	0	0	0	0	0	0	0	1
	Kasin	2	0	0	3	2	1	0	2	2	0	0	0
Sukun	Ciptomulyo	0	0	0	0	3	3	0	0	0	0	1	0
	Gadang	0	2	1	2	0	3	4	1	0	0	0	0
	Kebonsari	0	0	0	2	0	0	0	1	0	0	0	0
	Bandungrejosari	3	1	0	7	3	0	2	1	0	0	4	2
	Tanjungrejo	0	0	0	2	2	2	0	1	0	0	0	0
	Sukun	1	5	4	7	4	4	0	2	0	0	2	1
	Mulyorejo	1	0	0	1	1	1	0	0	1	0	1	0
	Bandulan	0	0	0	3	4	4	1	0	0	0	1	0
	Karang Besuki	0	3	0	1	1	1	1	1	0	0	2	1
	Pisang Candi	1	1	1	2	4	4	0	2	0	0	0	0
	Bakalan Krajan	4	1	0	0	1	2	0	0	0	0	0	0
Kedungkandang	Kedungkandang	0	1	0	1	3	3	3	1	1	0	0	0
	Kotalama	0	0	0	0	3	3	3	0	0	1	0	0
	Buring	0	1	1	1	0	0	0	0	0	0	0	0
	Wonokoyo	0	0	0	0	0	0	0	0	0	0	0	0
	Mergosono	0	0	1	2	0	0	0	0	0	0	0	0
	Bumiayu	0	0	0	0	1	1	0	0	0	0	0	0
	Arjowinangun	0	0	0	0	0	0	0	0	0	0	0	0
	Tlogowaru	0	0	0	0	0	0	0	0	0	0	0	0
	Lesanpuro	0	0	0	3	2	2	5	0	0	0	0	0
	Sawojajar	7	2	2	1	8	8	1	2	0	0	0	1
	Madyopuro	2	1	0	3	2	1	0	0	0	0	0	0
	Cemorokandang	2	1	0	1	0	0	0	1	0	0	0	0
Lowokwaru	Mojolangu	0	0	2	6	5	5	2	2	0	0	0	0
	Tunjungsekar	1	1	0	1	3	3	0	0	0	0	0	0
	Tasikmadu	0	2	0	0	0	0	0	0	0	0	0	0
	Tulusrejo	1	2	1	0	1	1	0	0	0	0	0	2
	Jatimulyo	0	0	1	5	3	3	6	1	1	0	1	1

Sub District	Villages	DHF Cases 2007											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Lowokwaru	2	1	1	1	1	1	0	0	2	1	4	0
	Dinoyo	1	1	3	1	3	3	1	0	0	0	0	1
	Merjosari	8	7	5	5	0	0	1	0	0	0	0	1
	Tlogomas	0	8	3	0	5	5	0	0	0	0	0	0
	Sumbersari	0	10	1	0	1	2	0	0	0	0	0	0
	Tunggulwulung	0	0	0	1	0	0	0	0	0	0	0	1
	Ketawanggede	0	0	3	3	1	1	2	0	0	0	0	1
	Pandanwangi	1	0	0	1	4	3	5	0	0	1	0	1
	Purwodadi	0	3	2	1	3	2	2	0	0	2	1	0
	Polowijen	3	3	0	2	0	0	1	0	0	1	0	0
	Arjosari	0	0	0	0	3	3	1	0	0	0	0	0
	Bale Arjosari	0	0	1	0	0	0	0	0	0	0	0	0
Blimbing	Purwantoro	6	2	3	0	6	5	0	2	0	0	3	0
	Blimbing	1	2	0	2	1	1	3	0	0	1	0	0
	Bunulrejo	2	3	4	2	7	4	0	2	1	1	0	0
	Polehan	0	1	5	1	4	4	0	0	1	0	0	0
	Kesatrian	0	0	0	2	1	1	3	0	0	1	0	1
	Jodipan	0	0	0	0		2	0	0	0	0	0	2

Table A. 2 DHF Incidences (Cases) in Each Villages in Malang City in 2008

Sub District	Villages	DHF Cases 2008											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Klojen	2	1	2	0	0	0	0	1	0	0	0	1
	Rampal Celaket	1	2	1	0	0	0	0	0	0	0	0	1
	Samaan	2	0	0	0	0	0	0	1	1	0	0	0
	Kidul Dalem	0	2	0	4	1	1	0	0	0	0	1	0
	Kauman	2	1	8	2	1	0	0	0	0	0	0	0
Klojen	Oro-oro Dowo	1	2	4	0	1	1	0	0	0	0	0	0
	Penanggungan	0	2	1	0	0	1	1	0	0	0	0	0
	Bareng	5	5	4	2	1	1	0	0	0	1	2	0
	Sukoharjo	4	2	2	2	1	0	0	0	0	0	0	0
	Gading Kasri	1	1	2	1	1	1	0	0	0	0	0	0
	Kasin	1	5	7	3	1	0	0	0		0	0	0
	Ciptomulyo	1	1	3	0	0	0	0	0	0	0	0	0
	Gadang	0	1	1	0	1	0	0	0	0	0	0	0
	Kebonsari	0	1	0	2	0	0	0	0	0	0	1	0
	Bandungrejosari	1	1	6	4	0	0	0	1	0	0	4	1
Sukun	Tanjungrejo	2	2	2	2	4	1	0	0	0	0	0	0
	Sukun	4	3	5	3	2	1	0	0	0	0	1	1
	Mulyorejo	1	0	0	0	1	0	0	0	0	0	1	1
	Bandulan	2	0	1	1	1	0	1	1	0	1	1	0
	Karang Besuki	3	2	3	3	0	0	0	0	0	1	0	1

Sub District	Villages	DHF Cases 2008											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Pisang Candi	1	0	4	1	0	0	0	0	0	0	0	0
	Bakalan Krajan	0	0	0	0	0	0	0	0	0	0	0	1
Kedungkandang	Kedungkandang	0	0	2	0	3	0	1	0	0	0	0	1
	Kotalama	1	0	1	0	0	1	0	0	0	0	0	0
	Buring	0	0	0	0	0	0	1	0	0	0	0	0
	Wonokoyo	0	0	0	0	0	0	0	0	0	0	0	0
	Mergosono	1	1	2	0	0	0	0	0	0	0	0	0
	Bumiayu	4	0	0	0	0	0	0	0	0	0	0	0
	Arjowinangun	0	1	1	0	0	0	0	0	0	0	0	0
	Tlogowaru	0	0	0	0	0	0	0	0	0	0	0	0
	Lesanpuro	0	2	0	3	0	0	0	0	0	0	2	1
	Sawojajar	2	4	5	3	5	1	1	0	4	1	0	4
	Madyopuro	1	1	2	2	0	0	0	0	0	0	0	0
	Cemorokandang	0	1	0	0	0	0	0	0	0	0	0	0
Lowokwaru	Mojolangu	0	1	0	1	2	0	1	0	0	0	1	0
	Tunjungsekar	1	1	1	1	0	0	0	0	2	0	0	0
	Tasikmadu	0	0	0	0	0	0	0	0	0	0	0	0
	Tulusrejo	0	0	1	1	1	1	0	0	0	0	0	0
	Jatimulyo	2	3	1	1	0	0	1	0	0	0	1	0
	Lowokwaru	1	1	3	1	1	1	0	0	0	0	1	0
	Dinoyo	2	2	0	3	2	1	0	0	0	0	0	3
	Merjosari	2	1	2	1	0	0	0	0	0	0	0	1
	Tlogomas	0	0	2	0	1	0	0	0	0	0	0	0
	Sumbersari	1	0	0	0	0	0	0	0	0	0	0	0
	Tunggulwulung	0	0	1	0	1	0	0	0	0	0	0	0
	Ketawanggede	1	3	1	0	0	0	0	0	0	0	0	0
Blimbing	Pandanwangi	1	4	2	0	0	0	0	1	0	1	0	0
	Purwodadi	3	3	1	1	0	0	0	0	1	2	1	0
	Polowijen	0	1	1	2	0	0	0	1	1	0	0	0
	Arjosari	2	1	2	0	0	0	0	1	0	0	0	0
	Bale Arjosari	0	0	1	0	0	0	0	0	0	0	0	0
	Purwantoro	3	2	0	0	1	1	0	0	0	0	0	1
	Blimbing	2	4	0	0	1	0	0	1	0	0	1	0
	Bunulrejo	4	2	4	3	1	0	0	0	0	0	1	0
	Polehan	1	0	0	0	0	0	0	0	0	0	0	0
	Kesatrian	1	0	2	0	0	0	0	0	0	0	0	0
	Jodipan	0	0	0	0	0	0	0	0	0	0	0	0

Table A. 3 DHF Incidences (Cases) in Each Villages in Malang City in 2009

Sub District	Villages	DHF Cases 2009											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Klojen	Klojen	4	1	1	3	3	0	1	1	1	0	0	0

Sub District	Villages	DHF Cases 2009											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Rampal Celaket	2	0	2	0	4	3	2	1	2	0	0	0
	Samaan	2	1	1	3	1	0	4	0	0	0	0	0
	Kidul Dalem	0	0	0	0	2	2	1	0	0	0	0	0
	Kauman	0	0	1	0	2	1	2	1	0	1	1	0
	Oro-oro Dowo	0	2	3	2	3	3	4	0	0	4	0	3
	Penanggungan	0	0	0	3	2	1	2	0	0	0	0	0
	Bareng	2	1	3	1	3	2	2	0	0	2	0	0
	Sukoharjo	1	0	1	2	2	2	3	2	0	2	1	0
	Gading Kasri	1	0	1	3	1	2	4	0	1	0	0	0
	Kasin	0	0	2	8	1	1	4	0	1	0	0	0
Sukun	Ciptomulyo	1	1	0	0	1	2	0	1	0	1	0	0
	Gadang	0	1	2	1	2	5	0	3	0	0	0	0
	Kebonsari	0	0	0	0	1	3	0	0	0	0	0	0
	Bandungrejosari	3	3	3	10	3	1	6	1	0	0	0	0
	Tanjungrejo	1	2	3	14	2	1	8	1	0	0	0	3
	Sukun	0	1	0	2	1	3	6	0	0	0	1	0
	Mulyorejo	0	1	0	1	2	2	0	0	0	0	0	0
	Bandulan	0	4	2	1	1	0	0	0	0	0	2	0
	Karang Besuki	0	2	4	1	0	0	0	0	0	0	0	0
	Pisang Candi	0	3	4	4	2	0	0	0	0	0	0	0
	Bakalan Krajan	0	0	0	0	0	3	0	0	0	0	0	0
Kedungkandang	Kedungkandang	0	0	1	1	2	1	2	1	0	0	0	0
	Kotalama	0	4	1	1	3	2	10	1	0	1	0	2
	Buring	0	0	0	0	1	1	0	1	0	0	0	0
	Wonokoyo	0	0	0	2	1	0	0	0	0	0	0	0
	Mergosono	0	0	0	0	2	0	5	2	0	0	0	0
	Bumiayu	0	0	0	1	2	0	2	3	0	0	0	0
	Arjowinangun	0	0	0	0	4	0	3	1	0	0	0	0
	Tlogowaru	0	0	0	0	0	0	0	0	0	0	0	0
	Lesanpuro	0	1	2	3	2	0	0	2	0	0	2	2
	Sawojajar	0	3	0	16	2	4	8	7	0	0	0	0
	Madyopuro	2	2	0	5	2	0	0	0	0	0	0	0
	Cemorokandang	1	0	0	1	0	0	0	2	0	0	0	0
Lowokwaru	Mojolangu	1	2	2	1	3	2	3	1	0	0	0	0
	Tunjungsekar	0	1	1	4	2	1	2	4	0	0	0	0
	Tasikmadu	0	0	0	0	2	2	1	2	0	0	0	0
	Tulusrejo	0	1	0	3	2	2	1	2	0	0	0	0
	Jatimulyo	2	0	2	8	1	0	2	3	0	0	0	0
	Lowokwaru	0	0	3	3	2	2	2	0	0	0	2	0
	Dinoyo	0	0	0	2	3	1	5	0	0	0	0	0
	Merjosari	0	2	0	0	0	3	0	3	0	0	0	0
	Tlogomas	1	0	2	1	0	1	3	0	0	0	0	1

Sub District	Villages	DHF Cases 2009											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Sumbersari	0	0	2	9	0	0	1	0	0	0	0	0
	Tunggulwulung	1	0	1	0	1	0	1	0	0	0	0	1
	Ketawanggede	0	0	1	1	1	0	0	0	0	0	0	0
Blimbing	Pandanwangi	1	1	0	0	1	1	4	2	0	1	0	0
	Purwodadi	1	3	3	0	0	1	2	0	0	2	0	1
	Polowijen	0	0	0	0	1	2	3	0	0	1	0	0
	Arjosari	0	1	1	0	1	2	0	1	0	0	0	1
	Bale Arjosari	0	0	0	0	0	0	2	0	0	0	0	0
	Purwantoro	1	0	0	1	2	2	3	0	0	2	0	0
	Blimbing	1	1	1	5	2	2	4	2	0	0	0	0
	Bunulrejo	1	0	1	1	1	0	6	0	0	0	1	0
	Polehan	0	0	1	1	1	2	7	0	0	0	0	1
	Kesatrian	0	0	1		1	3	2	0	0	0	0	0
	Jodipan	0	0	0		0	0	1	0	0	0	0	0

Table A. 4 DHF Incidences (Cases) in Each Villages in Malang City in 2010

Sub District	Villages	DHF Cases 2010											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Klojen	Klojen	4	4	1	5	5	1	0	0	0	0	1	0
	Rampal Celaket	5	8	2	4	2	3	0	0	1	0	1	0
	Samaan	6	7	2	2	0	2	0	1	0	2	0	0
	Kidul Dalem	3	3	0	2	0	1	0	0	0	0	0	0
	Kauman	2	6	4	3	1	2	2	0	0	1	0	0
	Oro-oro Dowo	7	6	5	2	3	1	1	2	0	0	0	0
	Penanggungan	4	5	2	2	0	1	1	1	0	0	0	0
	Bareng	5	10	1	1	2	1	3	2	0	0	0	0
	Sukoharjo	7	4	3	3	1	2	1	3	0	1	0	0
	Gading Kasri	5	5	0	2	1	1	2	0	0	0	0	0
	Kasin	4	5	2	2	0	1	0	0	0	2	1	0
Sukun	Ciptomulyo	3	3	0	1	1	1	0	0	1	0	0	0
	Gadang	3	4	6	0	1	0	1	0	1	0	0	0
	Kebonsari	2	3	1	1	1	1	1	1	0	0	0	0
	Bandungrejosari	2	8	0	1	1	0	1	0	0	0	0	1
	Tanjungrejo	4	6	0	1	2	0	2	1	0	2	0	0
	Sukun	9	10	3	8	5	1	6	4	0	0	0	0
	Mulyorejo	3	3	0	2	0	1	0	0	0	1	0	0
	Bandulan	2	4	1	3	3	1	6	1	0	0	0	0
	Karang Besuki	3	9	3	1	1	0	2	2	0	1	0	0
	Pisang Candi	3	6	1	3	2	0	1	1	0	0	0	0
	Bakalan Krajan	2	2	1	0	0	0	1	0	0	0	0	0
Kedungkandang	Kedungkandang	1	2	0	1	0	0	0	1	0	0	0	0
	Kotalama	5	5	6	1	2	2	1	1	0	1	1	0

Sub District	Villages	DHF Cases 2010											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Buring	2	4	1	0	0	1	0	0	1	1	0	0
	Wonokoyo	0	0	0	0	0	0	0	0	0	0	0	0
	Mergosono	2	0	0	1	0	1	1	0	0	0	0	0
	Bumiayu	7	5	0	0	1	0	0	0	0	1	2	1
	Arjowinangun	2	5	1	1	1	1	0	0	0	0	0	0
	Tlogowaru	0	0	0	0	1	0	0	0	0	1	0	0
	Lesanpuro	1	7	3	4	1	0	1	0	0	0	0	0
	Sawojajar	4	5	4	9	1	0	2	2	0	2	0	0
	Madyopuro	1	7	2	5	2	0	0	0	0	0	0	0
	Cemorokandang	0	3	0	2	0	0	0	0	0	0	0	0
Lowokwaru	Mojolangu	4	6	2	2	4	3	1	1	0	2	0	0
	Tunjungsekar	4	3	0	2	0	0	0	0	0	2	0	0
	Tasikmadu	2	3	1	0	2	2	2	0	0	0	0	0
	Tulusrejo	2	2	0	1	2	2	0	0	0	1	1	0
	Jatimulyo	1	4	0	1	0	0	0	0	0	0	0	0
	Lowokwaru	1	1	3	1	0	0	1	0	0	1	0	0
	Dinoyo	3	2	0	0	0	2	0	0	0	0	0	0
	Merjosari	4	3	1	1	0	0	0	0	0	0	1	0
	Tlogomas	4	3	1	2	0	2	5	0	1	1	0	0
	Sumbersari	7	5	1	5	0	0	4	4	1	1	0	0
	Tunggulwulung	2	4	1	2	0	2	0	1	0	0	0	0
	Ketawanggede	0	4	0	1	0	0	1	0	0	1	0	0
Blimbing	Pandanwangi	6	5	1	3	0	2	0	0	0	0	0	0
	Purwodadi	6	5	3	3	4	0	3	0	2	0	0	0
	Polowijen	3	4	2	2	0	0	0	1	0	0	1	0
	Arjosari	2	2	1	3	1	0	3	0	0	0	0	0
	Bale Arjosari	3	3	0	2	0	0	1	0	2	0	0	0
	Purwantoro	5	4	4	3	3	2	4	2	1	1	0	0
	Blimbing	4	1	0	0	2	0	0	0	1	0	0	0
	Bunulrejo	5	3	6	6	0	2	2	1	0	0	1	0
	Polehan	0	3	1	0	0	2	1	0	0	0	0	0
	Kesatrian	1	4	0	1	0	2	1	0	0	0	0	0
	Jodipan	0	5	0	1	0	0	1	0	0	0	0	0

Table A. 5 Yearly DHF Incidences (Cases) in Great Malang Area 2007-2009

District/City	Sub District	DHF Incidences (cases)		
		2007	2008	2009
Malang City	Kedung Kandang	89	66	133
	Sukun	136	98	143
	Klojen	108	109	151
	Blimbing	143	70	101

District/City	Sub District	DHF Incidences (cases)		
		2007	2008	2009
	Lowok Waru	166	65	128
Batu City	Batu	74	22	59
	Junrejo	19	34	43
	Bumiaji	6	5	7
Malang District	Tumpang	43	11	46
	Poncokusumo	4	10	10
	Jabung	11	4	9
	Pakis	87	29	107
	Lawang	17	3	42
	Singosari	34	15	40
	Karangploso	27	9	33
	Dau	26	9	91
	Pujon	2	1	2
	Ngantang	8	0	4
	Kasembon	1	2	0
	Kepanjen	43	19	52
	Sumber Pucung	46	22	35
	Kromengan	11	2	17
	Pakisaji	34	15	92
	Ngajum	16	1	9
	Wonosari	6	4	12
	Wagir	18	10	35
	Pagak	50	3	23
	Donomulyo	21	3	25
	Kalipare	34	4	17
	Bantur	48	9	65
	Gedangan	16	9	15
	Gondanglegi	94	28	35
	Bululawang	37	21	54
	Wajak	24	18	47
	Tajinan	11	8	25
	Turen	105	32	96
	Dampit	67	15	22
	Sumbermanjing Wetan	57	12	16
	Ampelgading	7	2	7
	Tirtoyudo	5	3	8
	Pagelaran	0	0	33

Table A. 6 Yearly Malaria Incidences (Cases) in Great Malang Area 2007-2009

District/City	Sub District	Malaria Incidences (Cases)		
		2007	2008	2009
Malang City	Kedung Kandang			
	Sukun			
	Klojen			
	Blimbing			
	Lowok Waru			
Batu City	Batu			
	Junrejo			
	Bumiaji			
Malang District	Tumpang	0	0	0
	Poncokusumo	2	0	1
	Jabung	0	0	0
	Pakis	1	4	1
	Lawang	0	0	0
	Singosari	0	0	0
	Karangploso	0	0	0
	Dau	0	0	0
	Pujon	1	3	0
	Ngantang	4	0	2
	Kasembon	2	1	6
	Kepanjen	6	0	1
	Sumber Pucung	11	14	7
	Kromengan	0	0	0
	Pakisaji	0	0	0
	Ngajum	0	0	0
	Wonosari	0	0	0
	Wagir	0	0	0
	Pagak	0	4	0
	Donomulyo	3	4	7
	Kalipare	0	0	0
	Bantur	1	2	13
	Gedangan	0	0	0
	Gondanglegi	3	1	0
	Bululawang	4	1	4
	Wajak	0	0	0
	Tajinan	4	0	0
	Turen	7	1	2
	Dampit	0	3	1
	Sumbermanjing Wetan	12	9	3

District/City	Sub District	Malaria Incidences (Cases)		
		2007	2008	2009
	Ampelgading	0	4	0
	Tirtoyudo	2	1	0
	Pagelaran	0	0	0

Table A. 7 Yearly Diarrhea Incidences (Cases) in Great Malang Area 2007-2009

District/City	Sub District	Diarrhea Incidences (Cases)		
		2007	2008	2009
Malang City	Kedung Kandang	2080	2116	2358
	Sukun	4483	4309	3059
	Klojen	2646	2191	1931
	Blimbing	4314	2500	2370
	Lowok Waru	2897	1898	2465
Batu City	Batu	1692	1901	2394
	Junrejo	2816	2070	1881
	Bumiaji	1679	2415	2571

APPENDIX B RESULT OF HAZARD CALCULATION BY USING POISSON REGRESSION

B. Poisson Regression Calculation for Great Malang Area

Poisson regression model was calculated for DHF incidence in Malang City, Batu City, and Malang District. Malaria and Diarrhea case were not calculated because the lack of its data availability. DHF incidence is calculated by using 7 Poisson Regression Model as shown in Table B.1.

Table B. 1: Equation Used in Poisson Regression Model

MODEL	EQUATION	REMARK
1	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 T_t + \beta_3 H_t + \beta_4 Pop_t + e_t$	Use time lag 1 month
2	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 \ln(\mu_{t-2}) + \beta_3 T_t + \beta_4 H_t + \beta_5 Pop_t + e_t$	Use time lag 2 month
3	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 T_t + \beta_3 H_t + \beta_4 RatePop_t + e_t$	Use time lag 1 month; Use rate of populations
4	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 \ln(\mu_{t-2}) + \beta_3 T_t + \beta_4 H_t + \beta_5 RatePop_t + e_t$	Use time lag 2 month; use rate of population
5	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 T_t + \beta_3 H_t + \beta_4 \ln(Pop_t) + e_t$	Use time lag 1 month; use population as offset
6	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 \ln(\mu_{t-2}) + \beta_3 T_t + \beta_4 H_t + \beta_5 \ln(Pop_t) + e_t$	Use time lag 2 month; use population as offset
7	$\ln(\mu_t) = \beta_0 + \beta_1 \ln(\mu_{t-1}) + \beta_2 \ln(\mu_{t-2}) + \beta_3 T_t + \beta_4 H_t + e_t$	Predictors are the monthly cumulative rainfall and the monthly average temperature; not use population data and the

B.1 Poisson Regression Calculation for Malang City

Poisson Regression Model was conducted for DHF case in 5 subdistrict in Malang city. Detail calculation is shown in Appendix B. For example, the result of calculation for Klojen subdistrict is given in the Table B.2.

Table B. 2: Poisson Regression Model Calculation of DHF Case Data for 2008-2010 in Klojen Subdistrik, Malang City

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
β0	-2.0828	-5.5303	-13.4535	-16.1774	35.1108	33.6495	-20.4987
β1	0.8218	0.2364	0.8436	0.1452	0.8431	0.2462	0.1303
β2	0.2214	0.6762	0.5395	0.7546	0.2601	0.6920	0.7465
β3	0.0009	0.3528	-0.0001	0.6413	0.0008	0.3934	0.8169
β4	0.0000	0.0012	-7.4104	0.0000	-3.5807	0.0011	-0.0007
β5		0.0000		-6.8471		-3.7677	
RMSE	12.2701	13.1311	12.9454	13.7132	12.4167	13.2665	13.4912
AIC	309.9386	306.9952	313.6892	309.9448	310.7699	307.6929	306.8349
SD	11.8089	12.7102	12.2444	13.0672	11.9301	12.8262	12.7615

According to RMSE, SD, and AIC calculation, Model 1 is deemed as the best model compare to other six models and these best model is illustrated in Figure A.1. Model 1 has equation as follow:

$$\ln(\mu_t) = -2.08 + 0.82 \ln(\mu_{t-1}) + 0.22\, T_t + 0.0009\, H_t + 0.00\, Pop_t + e_t$$

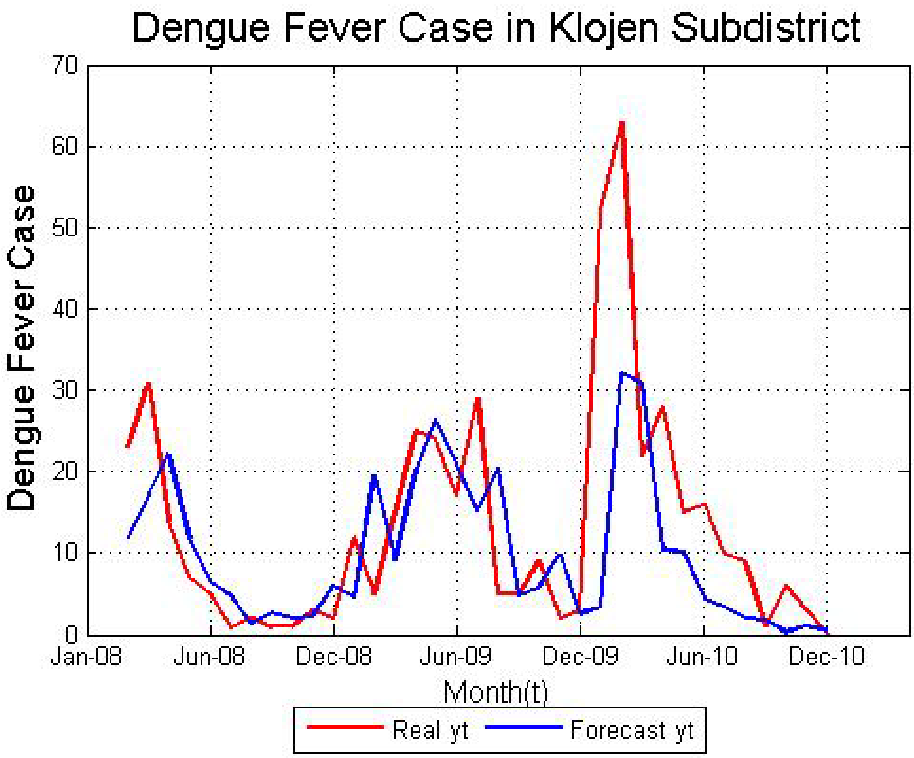


Figure B. 1 Poisson Regression Model Analysis for Klojen Subdistrict, Malang City

Poisson regression model was calculated for DHF incidence in 5 subdistricts in Malang City. The calculation result and plot of them are described as follow.

Kedung Kandang

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Kedung Kandang	β0	-11.706	-23.026	-13.188	-26.137	-12.483	-24.969	-23.020
	β1	0.1085	0.2076	0.1105	0.2086	0.1082	0.2082	0.2076
	β2	0.4673	0.0964	0.5207	0.0997	0.4370	0.0960	0.0964
	β3	0.0068	0.9072	0.0066	1.0330	0.0069	0.8822	0.9068
	β4	0.0000	0.0064	-2.7381	0.0059	0.1129	0.0065	0.0064
	β5		0.0000		-4.3333		0.2113	
	RMSE	10.2767	10.0582	10.2731	10.0829	10.2416	10.0255	10.0578
	AIC	297.52	288.86	297.50	289.03	297.28	288.64	286.86
	SD	9.3482	9.2201	9.3455	9.2391	9.3154	9.1911	9.2198

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models.

Model 6 has equation as follow:

$$\ln(\mu_t) = -24.97 + 0.21\ln(\mu_{t-1}) + 0.10\ln(\mu_{t-2}) - 0.88T_t + 0.01H_t + 0.21\ln(Pop_t) + e_t$$

Sukun

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Sukun	β0	34.2654	28.8714	16.4765	0.1139	1.9447	2.0568	1.5723
	β1	0.2255	0.1587	0.2405	0.0014	0.0023	0.0016	0.1381
	β2	-0.8222	0.1988	-0.6818	0.0022	-0.0082	0.0020	0.2349
	β3	0.0099	-0.5582	0.0094	-0.0049	0.0001	-0.0055	-0.0987
	β4	-0.0001	0.0100	-92.0561	0.0001	-0.1448	0.0001	0.0084
	β5		-0.0001		-1.0931		-0.1597	
	RMSE	10.8517	10.7864	11.2138	10.9912	10.8682	10.8085	11.0770
	AIC	301.339	293.619	303.637	294.898	301.445	293.759	293.427
	SD	9.3934	9.4310	9.6087	9.4069	9.3993	9.4420	9.3594

According to RMSE, SD, and AIC calculation, Model 2 is deemed as the best model compare to other six models. Model 2 has equation as follow:

$$\ln(\mu_t) = 28.87 + 0.16\ \ln(\mu_{t-1}) + 0.20 \ln(\mu_{t-2}) - 0.56\ T_t + 0.01\ H_t - 0.0001\ Pop_t + e_t$$

Lowokwaru

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Lowok Waru	β0	2.1314	-6.2861	6.9657	0.8621	-41.4497	-60.4262	-7.3230
	β1	0.3324	0.2309	0.3183	0.2132	0.3331	0.2340	0.2029
	β2	-0.2696	0.2697	-0.3100	0.2569	-0.2939	0.2694	0.2659
	β3	0.0076	0.0045	0.0076	-0.0851	0.0077	-0.0165	0.2389
	β4	0.0000	0.0088	17.5198	0.0090	3.9460	0.0089	0.0078
	β5		0.0000		20.8700		4.8933	
	RMSE	9.8592	9.7011	10.1711	10.0425	9.7742	9.6223	10.1267
	AIC	294.625	286.408	296.805	288.760	294.019	285.853	287.328
	SD	8.0483	8.3015	8.3415	8.5221	8.0009	8.2823	8.4923

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models. Model 6 has equation as follow:

$$\ln(\mu_t) = 60.43 + 0.23 \ln(\mu_{t-1}) + 0.27 \ln(\mu_{t-2}) - 0.02 T_t + 0.01 H_t + 4.90 \ln(Pop_t) + e_t$$

Blimbing

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Blim-bing	β0	-19.1723	-24.869	-0.1183	-0.1985	-1.3689	-1.4999	-10.4211
	β1	0.1356	0.0969	0.0013	0.0010	0.0014	0.0010	0.1049
	β2	0.3607	0.1132	0.0047	0.0010	0.0036	0.0011	0.1197
	β3	0.0045	0.5590	0.0000	0.0078	0.0000	0.0056	0.4147
	β4	0.0001	0.0039	1.7768	0.0000	0.1060	0.0000	0.0044
	β5		0.0001		2.4424		0.1127	
	RMSE	10.2958	10.4360	10.1916	10.3572	10.2957	10.4357	10.3452
	AIC	297.65	291.37	296.946	290.858	297.657	291.371	288.779
	SD	9.1226	9.3032	9.0465	9.2739	9.1237	9.3039	9.1894

According to RMSE, SD, and AIC calculation, Model 3 is deemed as the best model compare to other six models.Model 3 has equation as follow:

$$\ln(\mu_t) = -0.12 + 0.0013 \ln(\mu_{t-1}) + 0.01 T_t + 0.00 H_t + 1.78 RatePop_t + e_t$$

Plot of Poisson Regression Model calculation for Malang city is illustrated in Figure B.1.

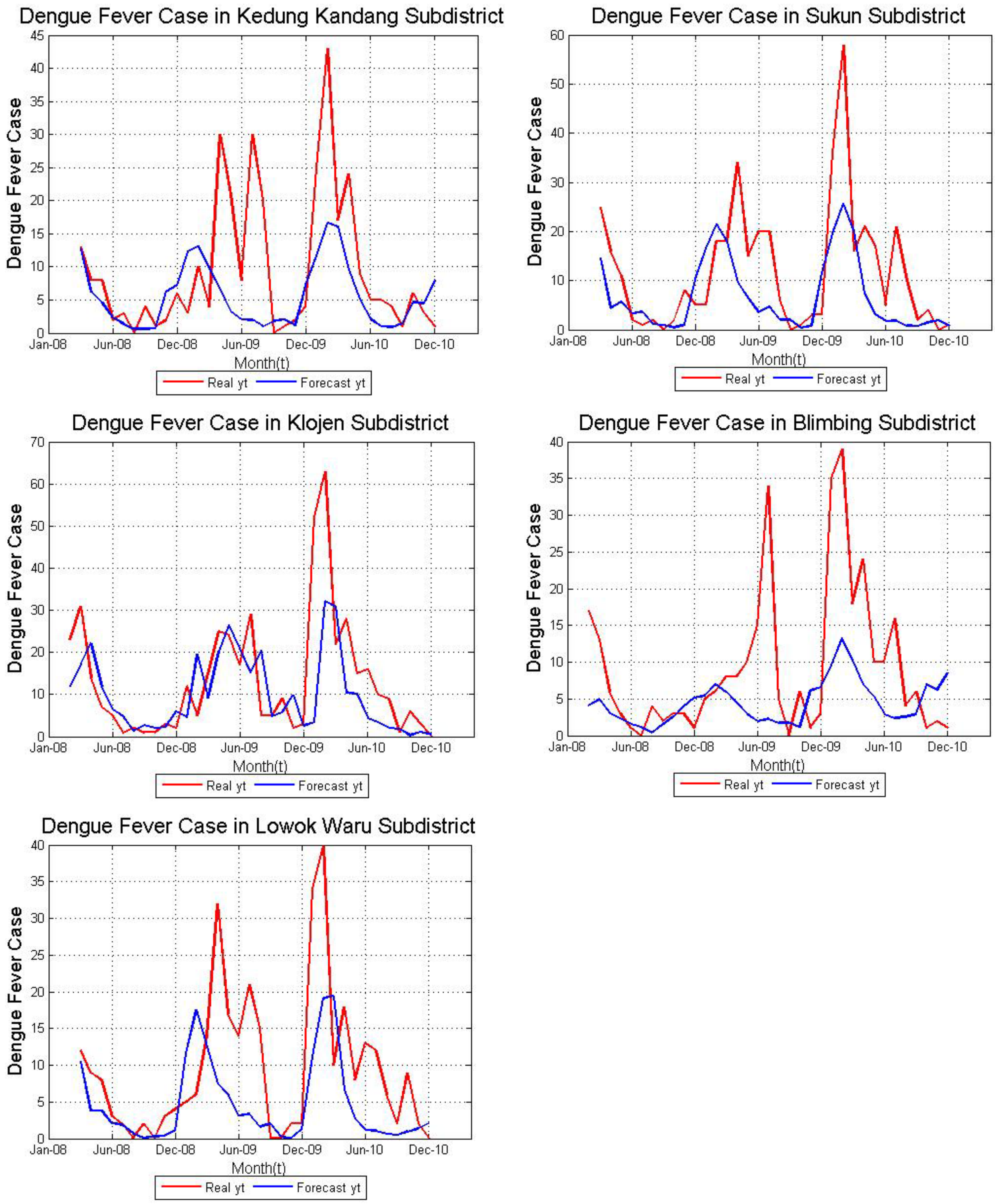


Figure B. 2 Plot of Poisson Regression Model Calculation in Malang City

B.2 Poisson Regression Calculation for Batu City

Poisson Regression Model was conducted for DHF case in 3 subdistrict in Batu city. Detail calculation is shown in Appendix B. For example, the result of calculation for Batu subdistrict is given in the Table B.3.

Table B. 3 : Poisson Regression Model Calculation of DHF Case Data for 2008-2010 in Batu Subdistrik, Batu City

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
β0	27.3812	17.0095	0.3883	0.2792	-30.4866	-47.8914	34.5859
β1	0.3956	0.1413	0.0040	0.0014	0.3940	0.1408	0.1893
β2	-1.3391	0.3163	-0.0134	0.0031	-1.3342	0.3110	0.3909
β3	0.0099	-0.9503	0.0001	-0.0088	0.0084	-0.9132	-1.4040
β4	0.0084	0.0077	-3.5605	0.0001	5.8102	0.0075	0.0096
β5		0.0001		-4.0827		6.4142	
RMSE	10.0721	8.4569	9.6163	8.4588	9.8256	8.4431	9.5028
AIC	296.1213	277.0749	292.8795	277.0906	294.3864	276.9640	283.0042
SD	9.7986	7.8718	9.3086	7.8970	9.5388	7.8749	8.5663

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models and these best model is illustrated in Figure A.2. Model 6 has equation as follow:

$$\ln(\mu_t) = 47.89 + 0.14\ln(\mu_{t-1}) + 0.31\ln(\mu_{t-2}) - 0.91\, T_t + 0.0075H_t + 6.41\ln\,(Pop_t) + e_t$$

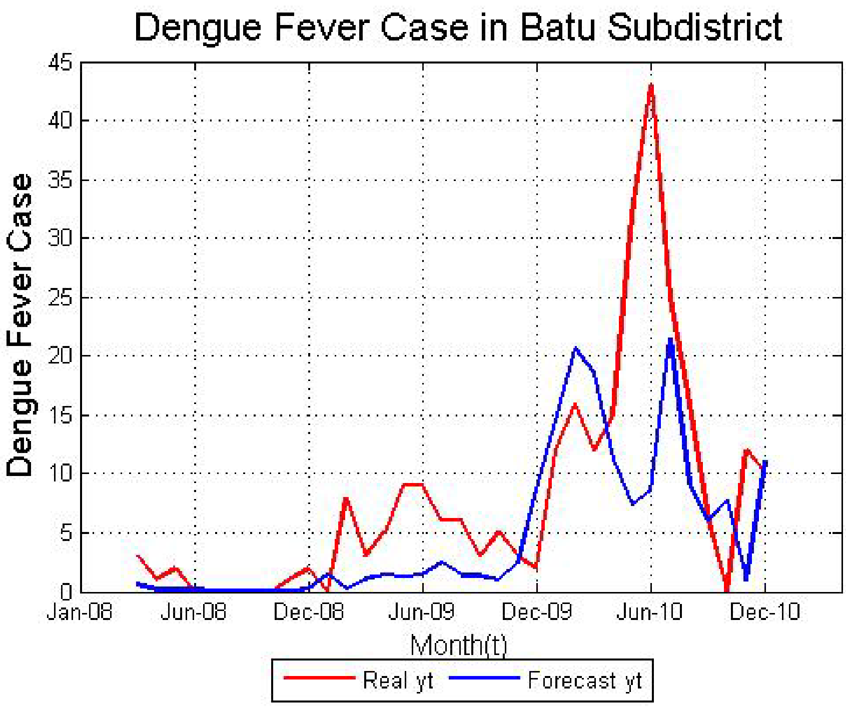


Figure B. 3 Poisson Regression Model Analysis for Batu Subdistrict, Batu City

Poisson regression model was calculated for DHF incidence in 3 subdistricts in Batu City. The calculation result and plot of them are described as follow.

Junrejo

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Junrejo	β0	46.5373	33.6451	45.0257	33.0013	50.9104	31.9770	33.5409
	β1	0.0226	0.1722	0.0233	0.1728	0.0230	0.1726	0.1723
	β2	-1.8459	0.0227	-1.8252	0.0233	-1.8337	0.0230	0.0227
	β3	0.0079	-1.3690	0.0079	-1.3359	0.0079	-1.3510	-1.3658
	β4	0.0000	0.0081	28.1698	0.0080	-0.4798	0.0081	0.0081
	β5		0.0000		-15.054		0.1083	
	RMSE	3.9477	4.0532	3.9518	4.0502	3.9501	4.0514	4.0528
	AIC	230.556	227.062	230.629	227.012	230.599	227.032	225.056
	SD	3.1723	3.3845	3.1766	3.3825	3.1748	3.3831	3.3842

According to RMSE, SD, and AIC calculation, Model 1 is deemed as the best model compare to other six models.

Model 1 has equation as follow:

$$\ln(\mu_t) = 46.54 + 0.02\ln(\mu_{t-1}) - 1.85\,T_t + 0.01\,H_t + 0.00\,Pop_t + e_t$$

Bumiaji

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Bumiaji	β0	60.3691	42.6006	0.8139	0.0671	-45.352	-90.113	71.3559
	β1	-0.0644	0.1439	-0.0006	0.0001	-0.0610	0.1454	0.2398
	β2	-2.8931	-0.1353	-0.0290	-0.0001	-2.8914	-0.1360	-0.0059
	β3	0.0079	-2.2884	0.0001	-0.0022	0.0080	-2.2562	-2.8789
	β4	0.0002	0.0063	-9.1588	0.0000	10.5380	0.0062	0.0092
	β5		0.0002		-1.1723		13.1148	
	RMSE	1.7619	1.7604	1.7644	1.7600	1.7626	1.7598	1.7993
	AIC	174.083	170.352	174.184	170.335	174.110	170.329	169.840
	SD	1.4854	1.4863	1.4858	1.4853	1.4851	1.4856	1.5096

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models.

Model 6 has equation as follow:

$$\ln(\mu_t) = -90.11 + 0.15\ln(\mu_{t-1}) - 0.14\ln(\mu_{t-2}) - 2.26\,T_t + 0.07H_t + 13.12\ln(Pop_t) + e_t$$

Plot of Poisson Regression Model calculation is illustrated in Figure B.2.

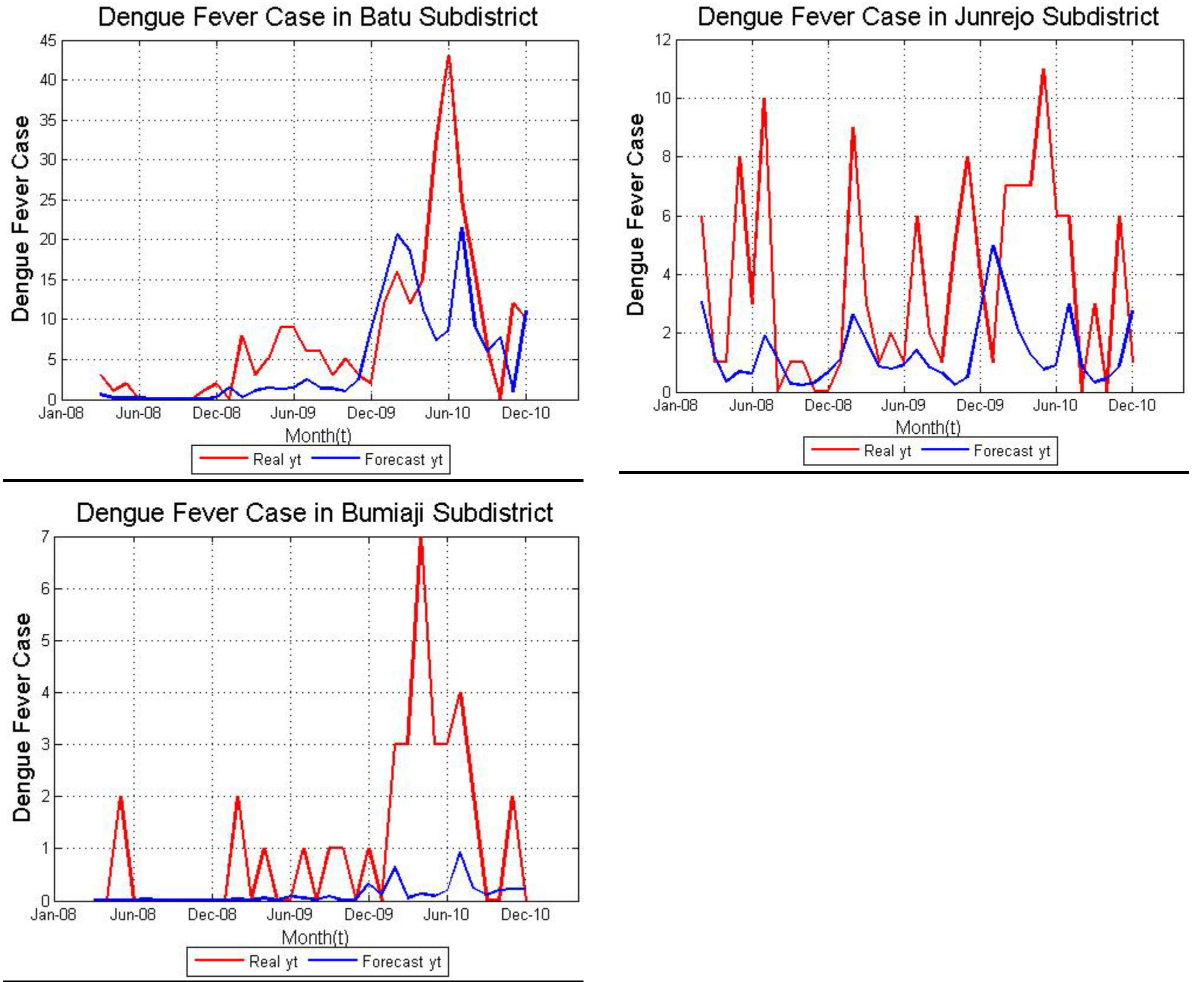


Figure B. 4 Plot of Poisson Regression Model Calculation in Batu City

B.3 Poisson Regression Calculation for Malang District

Poisson Regression Model was conducted for DHF case in 33 subdistrict in Malang district. Detail calculation is shown in Appendix C. For example, the result of calculation for Kepanjen subdistrict is given in the Table B.4.

Table B. 4 : Poisson Regression Model Calculation of DHF Case Data for 2008-2010 in Kepanjen Subdistrik, Malang District

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
β0	-9.9803	-20.5470	6.8484	-4.5785	-3.0113	-3.1064	-4.9790
β1	0.4189	0.1520	0.4430	0.1535	0.0042	0.0015	0.1536
β2	-0.8484	0.3464	-0.3979	0.3688	-0.0085	0.0035	0.3689
β3	0.0143	-0.4090	0.0124	0.3688	0.0001	-0.0042	0.0926
β4	0.0003	0.0137	15.9911	0.0116	0.2756	0.0001	0.0116
β5		0.0003		6.9566		0.2746	
RMSE	6.4963	6.2947	6.5607	6.3307	6.4965	6.2955	6.3300
AIC	265.4232	256.9962	266.1145	257.3837	265.4259	257.0045	255.3767
SD	6.3145	6.1398	6.3089	6.1059	6.3168	6.1425	6.1044

According to RMSE, SD, and AIC calculation, Model 2 is deemed as the best model compare to other six models and these best model is illustrated in Figure A.3. Model 2 has equation as follow:

$$\ln(\mu_t) = -20.55 + 0.15\ \ln(\mu_{t-1}) + 0.35\ln(\mu_{t-2}) - 0.41\,T_t + 0.01\,H_t - 0.0003\,Pop_t + e_t$$

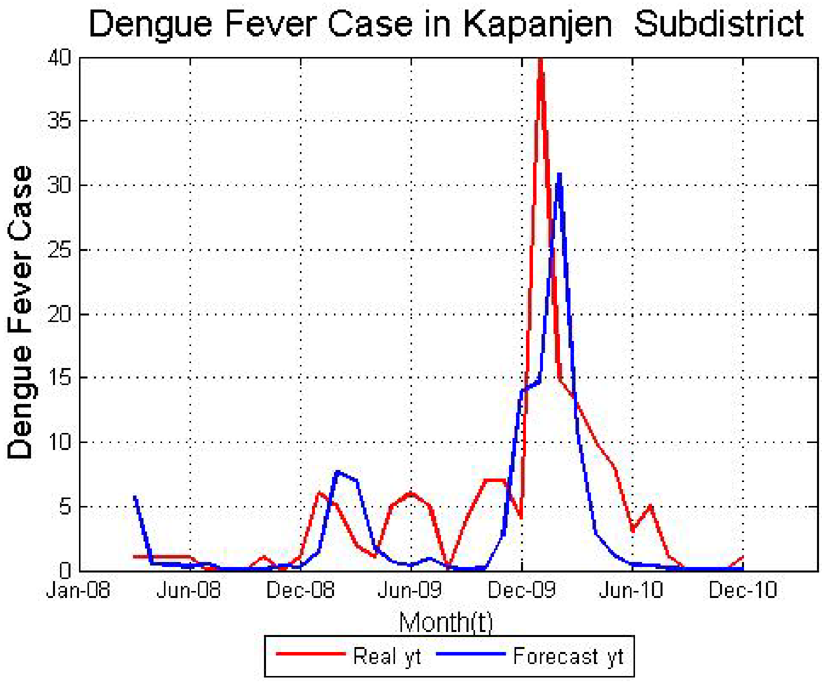


Figure B. 5 Poisson Regression Model Analysis for Kepanjen Subdistrict, Malang District

Poisson regression model was calculated for DHF incidence in 33 subdistricts in Malang District. The calculation result and plot of them are described as follow.

Tumpang

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Tumpang	β0	72.1777	1.4793	0.0928	0.1119	-2.0218	5.0510	1.0407
	β1	0.1163	0.0014	0.0001	0.0001	0.0012	0.0014	0.0012
	β2	-4.1187	0.0015	-0.0040	0.0002	-0.0411	0.0015	0.0014
	β3	0.0137	-0.0472	0.0000	-0.0046	0.0001	-0.0472	-0.0437
	β4	0.0003	0.0002	2.3339	0.0000	0.2674	0.0002	0.0002
	β5		0.0000		-1.6248		-0.3499	
	RMSE	5.2395	4.2733	5.2151	4.2732	5.2378	4.2737	4.3139
	AIC	250.3733	230.6591	250.0457	230.6576	250.3500	230.6643	229.3017
	SD	4.3605	3.6184	4.3457	3.6057	4.3593	3.6180	3.6247

According to RMSE, SD, and AIC calculation, Model 4 is deemed as the best model compare to other six models.

Model 4 has equation as follow:

$$\ln(\mu_t) = 0.11 + 0.0001\ln(\mu_{t-1}) + 0.0002\ln(\mu_{t-2}) - 0.01T_t + 0.00\,H_t - 1.62RatePop_t + e_t$$

Poncokusumo

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Poncokusumo	β0	48.4508	27.2650	-0.0244	-0.0332	8.4247	6.8681	-57.6725
	β1	-0.0920	0.0468	-0.0001	0.0000	-0.0009	0.0005	0.0847
	β2	0.9311	-0.0987	0.0009	-0.0001	0.0093	-0.0010	-0.0780
	β3	0.0055	1.2795	0.0000	0.0013	0.0001	0.0128	2.1766
	β4	-0.0008	0.0041	-3.2194	0.0000	-0.7619	0.0000	0.0007
	β5		-0.0007		-2.6601		-0.6330	
	RMSE	1.5045	1.5250	1.5031	1.5244	1.5046	1.5251	1.5346
	AIC	163.0313	160.5928	162.9641	160.5629	163.0331	160.5948	159.0165
	SD	1.2146	1.2340	1.2136	1.2331	1.2146	1.2340	1.2370

According to RMSE, SD, and AIC calculation, Model 3 is deemed as the best model compare to other six models.

Model 3 has equation as follow:

$$\ln(\mu_t) = -0.02 - 0.0001\ln(\mu_{t-1}) + 0.0009T_t + 0.00H_t - 3.22RatePop_t + e_t$$

Jabung

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Jabung	β0	50.7440	-24.2183	0.3360	0.0379	1.5711	-3.9623	8.3399
	β1	0.3152	0.4417	0.0031	0.0040	0.0032	0.0044	0.4070
	β2	-1.7643	0.2171	-0.0153	0.0019	-0.0177	0.0022	0.2032
	β3	0.0144	-0.6285	0.0001	-0.0031	0.0001	-0.0063	-0.4912
	β4	-0.0001	0.0143	-2.5830	0.0001	-0.1047	0.0001	0.0136
	β5		0.0005		-1.5946		0.3637	
	RMSE	1.5947	1.5965	1.5893	1.5833	1.5948	1.5967	1.5879
	AIC	167.1043	163.7079	166.8665	163.1415	167.1102	163.7166	161.3405
	SD	1.3577	1.3960	1.3556	1.3746	1.3578	1.3965	1.3786

According to RMSE, SD, and AIC calculation, Model 4 is deemed as the best model compare to other six models.
Model 4 has equation as follow:

$$\ln(\mu_t) = 0.04 + 0.004\ln(\mu_{t-1}) + 0.0019\ln(\mu_{t-2}) - 0.0031T_t + 0.0001\,H_t - 1.59RatePop_t + e_t$$

Pakis

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Pakis	β0	41.6979	25.4586	0.4618	0.2604	-56.1422	-28.8541	32.5336
	β1	-0.0303	0.3694	-0.0011	0.0028	-0.0401	0.3610	0.4199
	β2	-1.9958	-0.0090	-0.0192	-0.0010	-1.9729	-0.0161	0.0247
	β3	0.0065	-1.2150	0.0001	-0.0111	0.0064	-1.2074	-1.3388
	β4	0.0001	0.0068	1.9546	0.0001	8.8613	0.0067	0.0078
	β5		0.0000		1.7246		4.9125	
	RMSE	11.2020	8.1746	10.7891	8.8737	11.3765	8.2665	7.3003
	AIC	303.5638	274.7661	300.9347	280.3468	304.6457	275.5263	265.0744
	SD	10.7579	7.4170	10.5501	8.5346	10.9855	7.5556	6.2366

According to RMSE, SD, and AIC calculation, Model 7 is deemed as the best model compare to other six models.

Model 7 has equation as follow:

$$\ln(\mu_t) = 32.53 + 0.42\ln(\mu_{t-1}) + 0.02\ln(\mu_{t-2}) - 1.34T_t + 0.01H_t + e_t$$

Lawang

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Lawang	β0	36.3984	8.4756	0.0428	-0.2378	3.3538	2.7520	-6.1432
	β1	0.0352	0.2399	0.0001	0.0022	0.0004	0.0024	0.2706
	β2	-0.4722	0.0458	-0.0038	0.0004	-0.0048	0.0005	0.0769
	β3	0.0122	0.5269	0.0001	0.0075	0.0001	0.0052	0.0966
	β4	-0.0003	0.0102	-3.2808	0.0001	-0.2823	0.0001	0.0114
	β5		-0.0002		-3.3042		-0.2519	
	RMSE	3.4040	3.3750	3.3257	3.3166	3.4084	3.3799	3.2943
	AIC	220.182	214.610	218.555	213.424	220.274	214.708	210.965
	SD	3.0607	3.0447	2.9701	2.9755	3.0671	3.0515	2.8879

According to RMSE, SD, and AIC calculation, Model 7 is deemed as the best model compare to other six models.

Model 7 has equation as follow:

$$\ln(\mu_t) = -6.14 + 0.27\ln(\mu_{t-1}) + 0.08\ln(\mu_{t-2}) + 0.10\,T_t + 0.01H_t + e_t$$

Singosari

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Singosari	β0	84.6541	74.3408	80.1912	71.8534	1.1416	85.0512	73.6231
	β1	0.1523	0.1469	0.1513	0.1466	0.0015	0.1470	0.1473
	β2	-3.3026	0.1308	-3.2475	0.1293	-0.0331	0.1309	0.1314
	β3	0.0151	-2.9743	0.0149	-2.9246	0.0002	-2.9770	-2.9923
	β4	0.0000	0.0159	-55.6302	0.0158	-0.0270	0.0159	0.0160
	β5		0.0000		-33.4156		-0.9863	
	RMSE	3.6872	3.9200	3.7009	3.9265	3.6835	3.9196	3.9180
	AIC	225.7786	224.7898	226.0381	224.9037	225.7084	224.7837	222.7564
	SD	3.4597	3.6598	3.4819	3.6696	3.4552	3.6594	3.6579

According to RMSE, SD, and AIC calculation, Model 5 is deemed as the best model compare to other six models.

Model 5 has equation as follow:

$$\ln(\mu_t) = 1.14 + 0.0015\ln(\mu_{t-1}) - 0.03T_t + 0.0002H_t - 0.03\ln(Pop_t) + e_t$$

Plot of Poisson Regression Model calculation for Tumpang, Poncokusumo, Jabung, Pakis, Lawang, and Singosari Subdistrict is illustrated in Figure B.3.

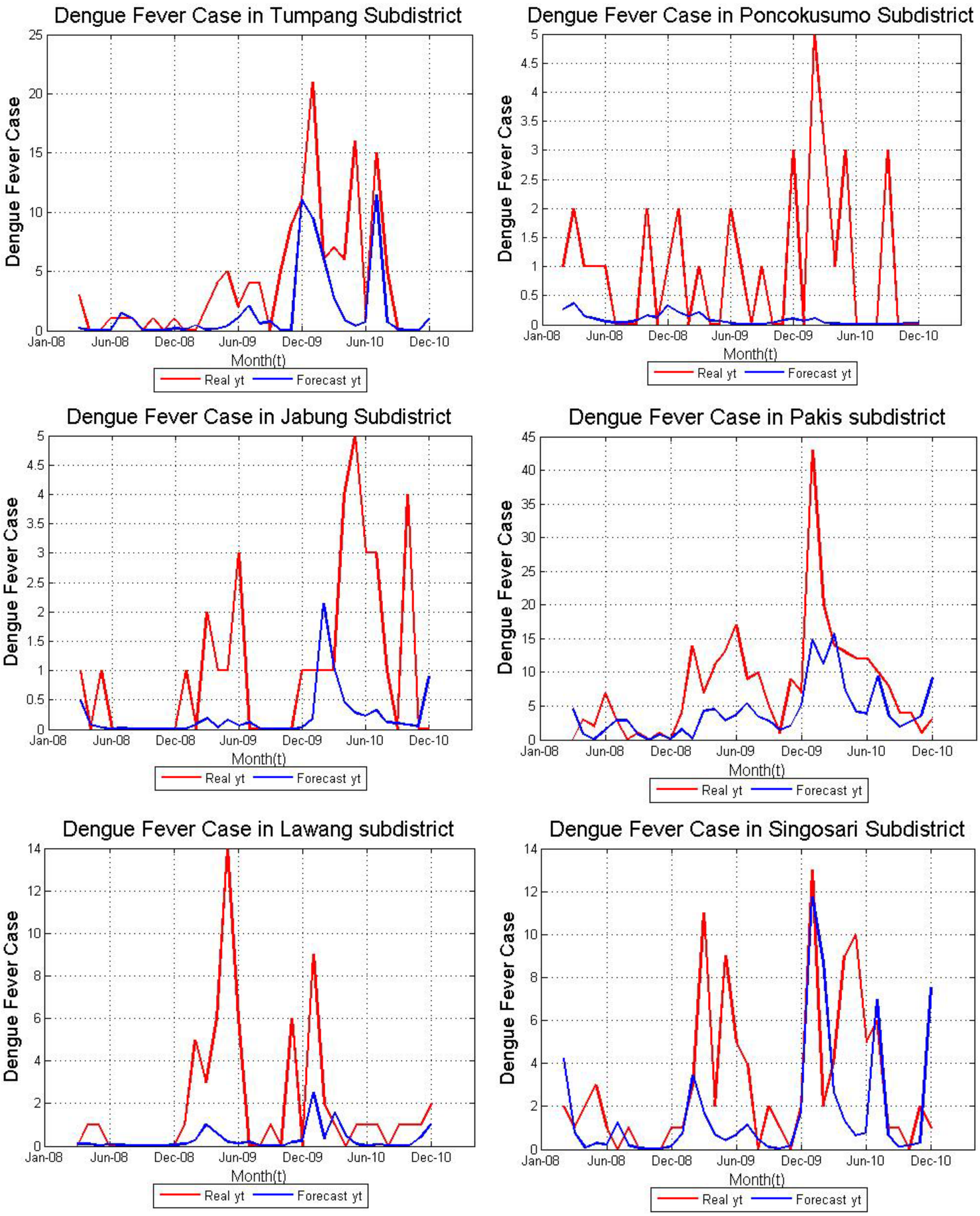


Figure B. 6 Plot of Poisson Regression Model calculation for Tumpang, Poncokusumo, Jabung, Pakis, Lawang, and Singosari Subdistrict, Malang District

Karangploso

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Karangploso	β0	37.0180	22.3459	0.3867	0.2565	-70.9096	-34.9566	25.7479
	β1	-0.1667	0.2721	-0.0030	0.0011	-0.1833	0.2541	0.3320
	β2	-1.8211	-0.0771	-0.0161	-0.0023	-1.7747	-0.0942	-0.0206
	β3	0.0011	-1.0583	0.0000	-0.0109	0.0009	-1.0675	-1.0278
	β4	0.0001	0.0010	2.4368	0.0000	10.2880	0.0008	0.0016
	β5		0.0001		2.2127		5.4896	
	RMSE	2.2193	2.0690	2.1847	2.0932	2.2361	2.0731	2.0536
	AIC	190.2409	181.3356	189.1409	182.1266	190.7687	181.4717	178.8302
	SD	1.8523	1.5943	1.9340	1.7883	1.9006	1.6191	1.5381

According to RMSE, SD, and AIC calculation, Model 7 is deemed as the best model compare to other six models. Model 7 has equation as follow:

$$\ln(\mu_t) = 25.75 + 0.33\ln(\mu_{t-1}) - 0.02\ln(\mu_{t-2}) - 1.03\,T_t + 0.0016\,H_t + e_t$$

Dau

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Dau	β0	-7.3131	-37.1367	-0.3374	-0.6399	2.2349	1.7157	-56.0095
	β1	0.5520	0.1893	0.0052	0.0016	0.0055	0.0019	0.1949
	β2	1.1882	0.5370	0.0129	0.0053	0.0119	0.0054	0.5435
	β3	0.0033	2.2851	0.0000	0.0249	0.0000	0.0228	2.1835
	β4	-0.0005	0.0007	-3.0403	0.0000	-0.2344	0.0000	0.0011
	β5		-0.0004		-4.3006		-0.2119	
	RMSE	4.2417	4.5210	4.2837	4.8060	4.2392	4.5204	4.4104
	AIC	235.5848	234.4906	236.2743	238.6478	235.5435	234.4805	230.8066
	SD	3.8670	4.2769	3.9473	4.6374	3.8643	4.2763	4.1693

According to RMSE, SD, and AIC calculation, Model 5 is deemed as the best model compare to other six models. Model 5 has equation as follow:

$$\ln(\mu_t) = 2.23 + 0.01\ln(\mu_{t-1}) + 0.01T_t + 0.00H_t - 0.23\ln(Pop_t) + e_t$$

Pujon

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Pujon	β0	50.6514	47.5299	-0.0349	-0.0545	5.6055	5.1638	1.8008
	β1	-0.0004	-0.2360	-0.0002	-0.0025	0.0000	-0.0024	-0.2422
	β2	-0.1881	0.0129	-0.0006	0.0000	-0.0019	0.0001	0.0248
	β3	-0.0055	-0.2704	-0.0001	-0.0003	-0.0001	-0.0027	-0.3014
	β4	-0.0008	-0.0061	-4.3689	-0.0001	-0.5064	-0.0001	-0.0060
	β5		-0.0007		-5.1368		-0.4657	
	RMSE	0.3762	0.3811	0.3760	0.3808	0.7624	0.3811	0.3809
	AIC	66.0096	66.2989	65.9746	66.2375	66.0095	66.2989	64.2702
	SD	0.3491	0.3528	0.3489	0.3526	0.3491	0.3528	0.3527

According to RMSE, SD, and AIC calculation, Model 3 is deemed as the best model compare to other six models. Model 3 has equation as follow:

$$\ln(\mu_t) = -0.04 - 0.0002\ln(\mu_{t-1}) - 0.0006T_t - 0.0001H_t - 4.37RatePop_t + e_t$$

Ngantang

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Ngantang	β0	-1.4227	-1.9213	0.0028	0.0048	-1.2297	-1.8550	-20.711
	β1	0.0031	-0.0034	0.0000	0.0000	0.0003	-0.0003	-0.1337
	β2	0.0110	0.0032	0.0001	0.0000	0.0011	0.0003	0.4877
	β3	0.0000	0.0068	0.0000	0.0001	0.0000	0.0007	0.6463
	β4	0.0000	0.0000	-7.3754	0.0000	0.1098	0.0000	0.0016
	β5		0.0000		-9.2976		0.1679	
	RMSE	0.6413	0.6356	0.6393	0.6382	0.6413	0.6356	0.6482
	AIC	103.343	101.081	103.121	101.352	103.343	101.084	100.419
	SD	0.5940	0.5893	0.5919	0.5908	0.5940	0.5893	0.5983

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models. Model 6 has equation as follow:

$$\ln(\mu_t) = -1.86 - 0.0003\ \ln(\mu_{t-1}) + 0.0003\ \ln(\mu_{t-2}) + 0.0007\ T_t + 0.00H_t + 0.17\ \ln\ (Pop_t) + e_t$$

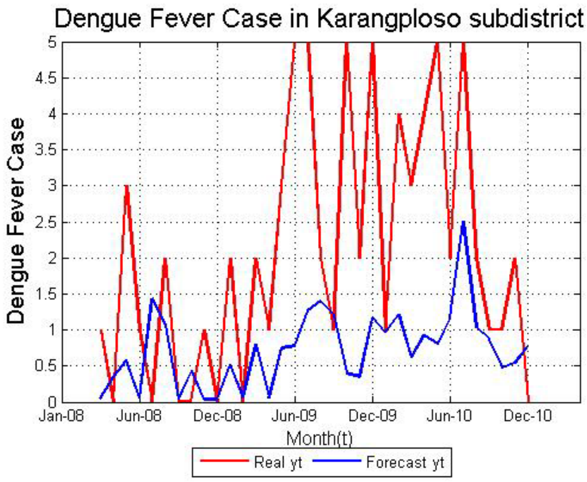
Kasembon

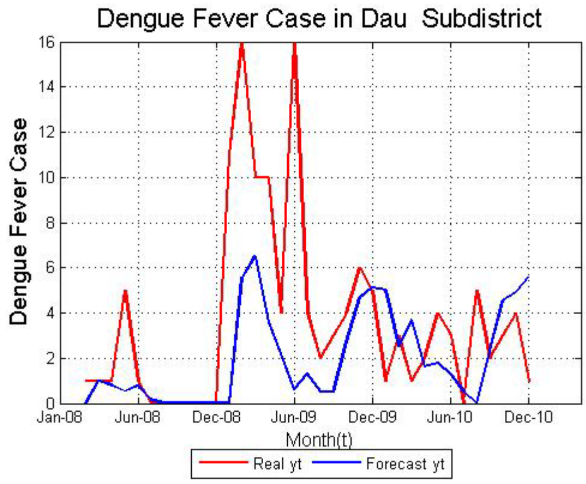
Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Kasembon	β0	9.4021	1.9362	0.2082	9.7918	-75.186	-70.003	9.0115
	β1	0.1845	-0.0284	0.0014	-0.0361	0.1844	-0.0285	-0.0281
	β2	-0.9282	-0.1321	-0.0103	-0.1357	-0.9283	-0.1321	-0.1303
	β3	0.0050	-0.6847	0.0001	-0.6959	0.0050	-0.6848	-0.6637
	β4	0.0003	0.0050	1.9644	0.0050	9.0322	0.0050	0.0049
	β5		0.0002		53.2132		7.6782	
	RMSE	0.2371	0.1707	0.2368	0.1707	0.2371	0.1706	0.1707
	AIC	33.6978	11.6628	33.5986	11.6648	33.6977	11.6625	9.6709
	SD	0.2305	0.1682	0.2301	0.1682	0.2305	0.1682	0.1682

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models. Model 6 has equation as follow:

$$\ln(\mu_t) = 70.00 - 0.03\ln(\mu_{t-1}) - 0.13\ln(\mu_{t-2}) - 0.68T_t + 0.01H_t + 7.68\ \ln\ (Pop_t) + e_t$$

Plot of Poisson Regression Model calculation for Karangploso, Dau, Pujon, Ngantang, Kasembon, and Kapanjen Subdistrict is illustrated in Figure B.4.





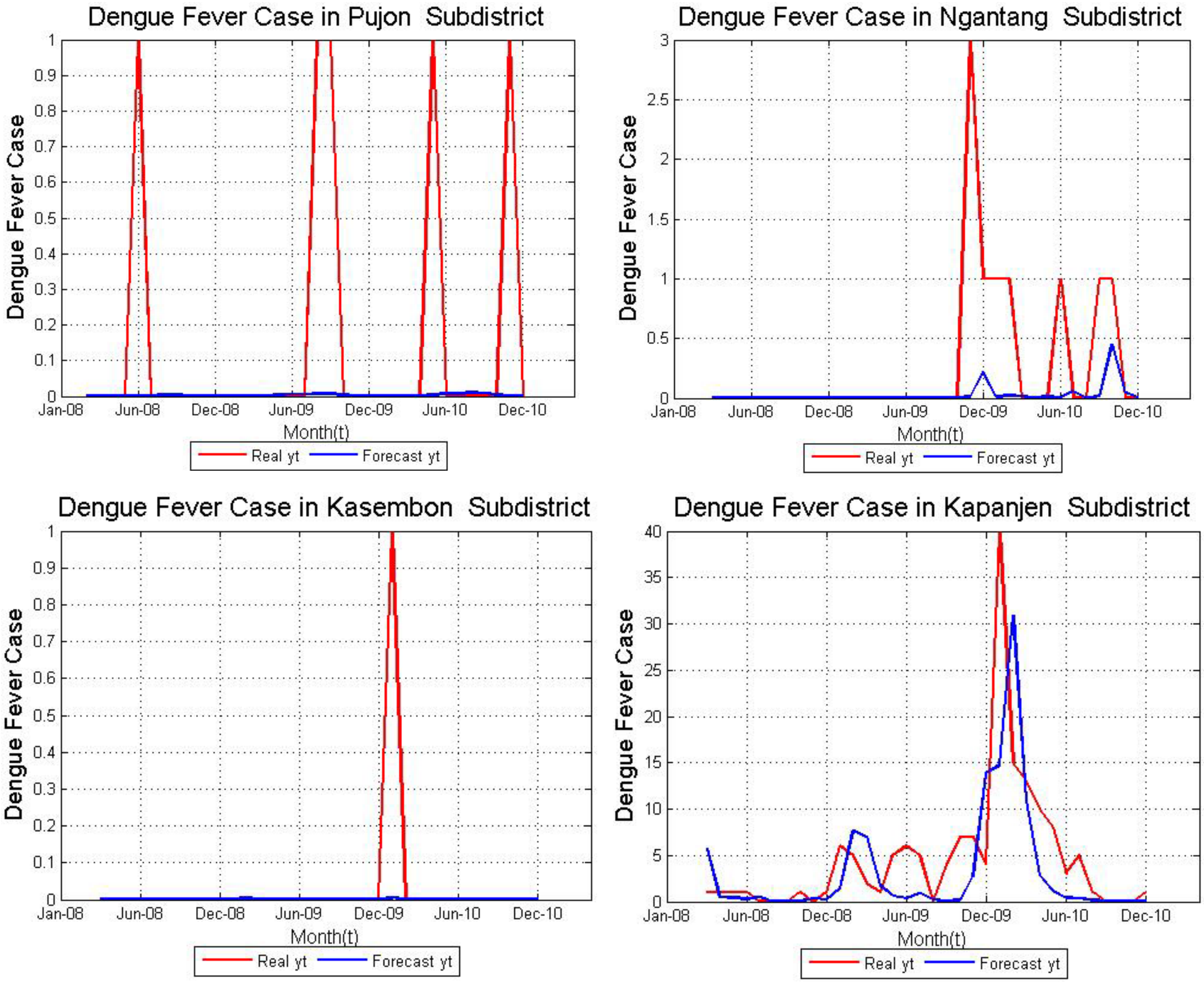


Figure B. 7 Plot of Poisson Regression Model calculation for Karangploso, Dau, Pujon, Ngantang, Kasembon, and Kapanjen Subdistrict, Malang District

Sumber Pucung

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Sumber Pucung	β0	41.2312	34.1551	-0.0326	-0.0933	3.6465	3.3243	- 25.5869
	β1	0.1321	0.0255	0.0021	0.0008	0.0014	0.0003	0.0946
	β2	-0.4743	0.1150	0.0021	0.0018	-0.0046	0.0012	0.2036
	β3	0.0053	-0.2764	0.0000	0.0032	0.0001	-0.0026	0.9713
	β4	-0.0006	0.0042	-2.9449	0.0000	-0.3285	0.0000	-0.0013
	β5		-0.0006		-2.2196		-0.3031	
	RMSE	2.7243	2.6310	2.7482	2.6550	2.7252	2.6325	2.6520
	AIC	204.592	197.677	205.202	198.294	204.615	197.716	196.217
	SD	2.2218	2.1688	2.2373	2.1840	2.2226	2.1701	2.1743

According to RMSE, SD, and AIC calculation, Model 2 is deemed as the best model compare to other six models. Model 2 has equation as follow:

$$\ln(\mu_t) = 34.16 + 0.03\ \ln(\mu_{t-1}) + 0.16 \ln(\mu_{t-2}) - 0.28\ T_t + 0.0042\ H_t - 0.0006\ Pop_t + e_t$$

Kromengan

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Krome-ngan	β0	56.3719	68.1734	29.1418	0.3830	1.8197	2.6102	28.0326
	β1	0.1491	0.1729	0.1435	0.0018	0.0015	0.0017	0.1620
	β2	-2.0057	0.0828	-1.4490	0.0010	-0.0198	0.0008	0.0874
	β3	0.0184	-2.1999	0.0162	-0.0178	0.0002	-0.0218	-1.3833
	β4	-0.0004	0.0200	14.7474	0.0002	-0.1327	0.0002	0.0165
	β5		-0.0005		-1.6999		-0.2026	
	RMSE	1.3307	1.3026	1.3497	1.3274	1.3323	1.3048	1.3380
	AIC	154.437	149.871	155.428	151.153	154.520	149.988	149.697
	SD	1.1073	1.0854	1.1237	1.1047	1.1086	1.0871	1.1130

According to RMSE, SD, and AIC calculation, Model 2 is deemed as the best model compare to other six models. Model 2 has equation as follow:

$$\ln(\mu_t) = 68.17 + 0.17\ \ln(\mu_{t-1}) + 0.08 \ln(\mu_{t-2}) - 2.20\ T_t + 0.02\ H_t - 0.0005\ Pop_t + e_t$$

Pakisaji

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Pakisaji	β0	46.9617	50.4426	64.1034	0.7321	-2.5173	-3.0378	66.6387
	β1	0.3314	0.2384	0.3201	0.0022	0.0033	0.0024	0.1962
	β2	-3.1489	0.2400	-2.6626	0.0025	-0.0316	0.0024	0.2376
	β3	0.0109	-3.5322	0.0091	-0.0304	0.0001	-0.0354	-2.7738
	β4	0.0004	0.0129	34.4117	0.0001	0.2899	0.0001	0.0098
	β5		0.0004		1.0108		0.3439	
	RMSE	4.3357	4.4472	4.7507	4.5904	4.3253	4.4523	4.6649
	AIC	237.1193	233.3715	243.5175	235.5264	236.9508	233.4496	234.6212
	SD	3.4287	3.9880	3.7586	3.8467	3.4241	4.0004	3.8810

Ngajum

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Ngajum	β0	31.3296	71.0979	0.1342	0.0276	1.7576	4.8324	17.8131
	β1	0.0380	-0.0970	0.0004	-0.0001	0.0004	-0.0010	-0.0935
	β2	-0.9511	0.0996	-0.0084	0.0001	-0.0094	0.0010	0.0972
	β3	0.0143	-1.4754	0.0001	-0.0014	0.0001	-0.0147	-1.0386
	β4	-0.0003	0.0168	-2.4915	0.0000	-0.1482	0.0002	0.0151
	β5		-0.0009		-2.2473		-0.4213	
	RMSE	0.8792	0.8758	0.8794	0.8778	0.8792	0.8759	0.8795
	AIC	125.4228	122.8820	125.4387	123.0365	125.4240	122.8885	121.1663
	SD	0.7891	0.7827	0.7893	0.7846	0.7891	0.7828	0.7863

According to RMSE, SD, and AIC calculation, Model 2 is deemed as the best model compare to other six models. Model 2 has equation as follow:

$$\ln(\mu_t) = 71.10 - 0.10\ \ln(\mu_{t-1}) + 0.10 \ln(\mu_{t-2}) - 1.48\ T_t + 0.02\ H_t - 0.00\ Pop_t + e_t$$

Wonosari

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Wonosari	β0	1.0555	1.0124	0.5176	0.4932	6.2169	5.9029	24.8487
	β1	-0.0011	-0.0005	-0.0009	-0.0004	-0.0011	-0.0005	-0.0142
	β2	-0.0237	-0.0010	-0.0227	-0.0009	-0.0236	-0.0010	-0.0524
	β3	0.0001	-0.0230	0.0001	-0.0218	0.0001	-0.0230	-1.2301
	β4	0.0000	0.0001	-9.8875	0.0001	-0.5318	0.0001	0.0077
	β5		0.0000		-9.0946		-0.5040	
	RMSE	1.2669	1.2858	1.2701	1.2880	1.2672	1.2860	1.2898
	AIC	150.998	148.991	151.174	149.108	151.014	148.999	147.201
	SD	1.1047	1.1261	1.1078	1.1273	1.1049	1.1262	1.1270

According to RMSE, SD, and AIC calculation, Model 1 is deemed as the best model compare to other six models. Model 1 has equation as follow:

$$\ln(\mu_t) = 1.06 - 0.0011 \ln(\mu_{t-1}) - 0.02\, T_t + 0.0001\, H_t + 0.00\, Pop_t + e_t$$

Wagir

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Wagir	β0	9.5555	5.8360	-0.1148	0.0077	90.5415	-20.700	7.4035
	β1	0.2037	0.0572	0.0013	0.0002	0.2043	0.0577	0.0555
	β2	-0.1581	0.2066	0.0031	0.0016	-0.1653	0.2070	0.2050
	β3	0.0086	-0.4407	0.0001	-0.0018	0.0086	-0.4457	-0.4242
	β4	-0.0001	0.0111	-4.8830	0.0001	-7.9644	0.0112	0.0111
	β5		0.0000		-2.9496		2.5493	
	RMSE	3.2182	3.0423	3.2392	3.1389	3.2169	3.0396	3.0507
	AIC	216.254	207.553	216.709	209.679	216.227	207.493	205.742
	SD	2.4922	2.3725	2.6265	2.5251	2.4904	2.3698	2.3815

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models. Model 6 has equation as follow:

$$\ln(\mu_t) = -20.70 + 0.06 \ln(\mu_{t-1}) + 0.21 \ln(\mu_{t-2}) - 0.45\, T_t + 0.01 H_t + 2.55 \ln(Pop_t) + e_t$$

Plot of Poisson Regression Model calculation for Sumber Pucung, Kromengan, Pakisaji, Ngajum, Wonosari and Wagir Subdistrict is illustrated in Figure B.5.

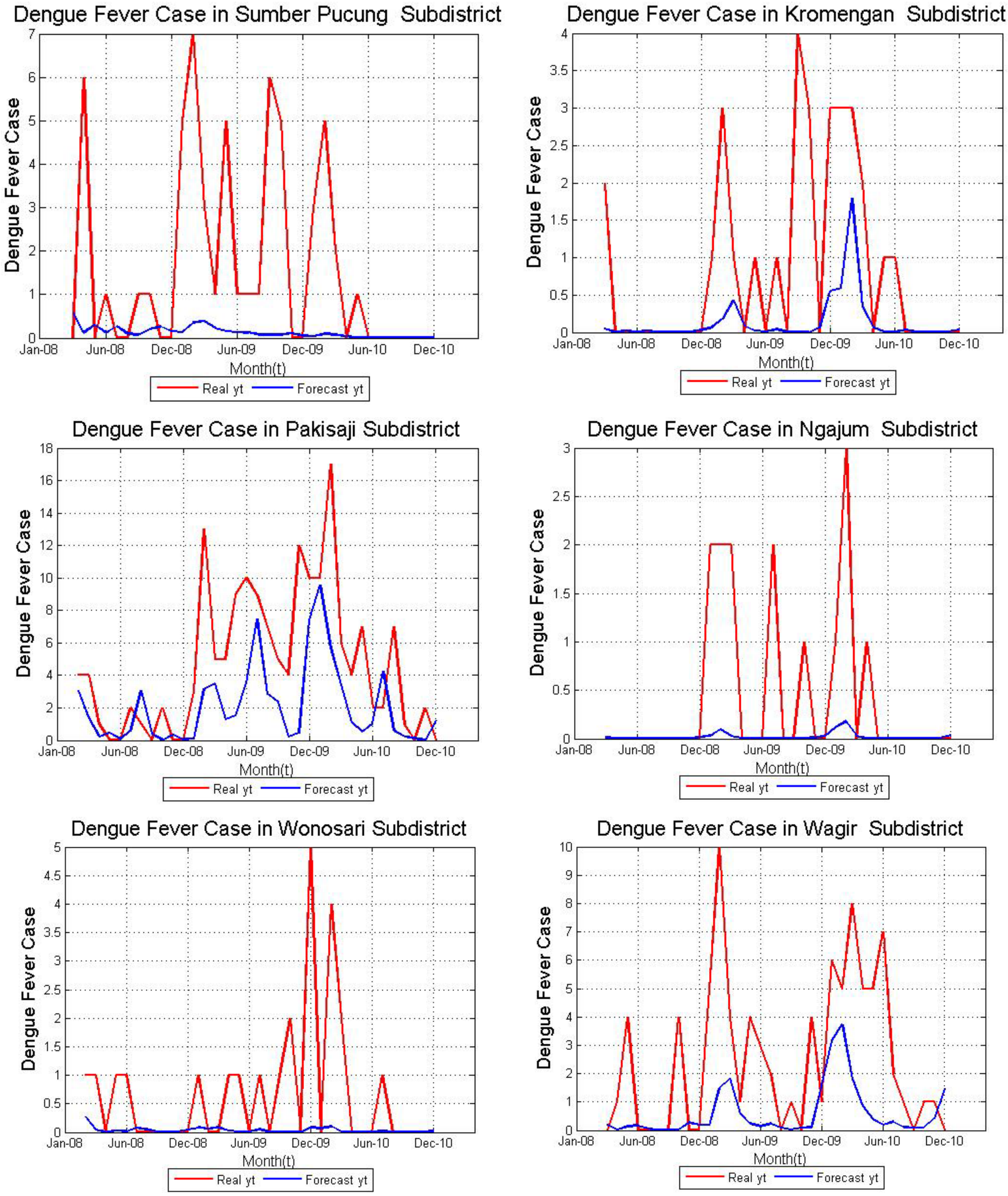


Figure B. 8 Plot of Poisson Regression Model calculation for Sumber Pucung, Kromengan, Pakisaji, Ngajum, Wonosari and Wagir Subdistrict, Malang District.

Pagak

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Pagak	β0	41.5651	41.2997	11.4828	7.7508	1.7978	1.8609	12.5662
	β1	0.4226	0.1114	0.4313	0.0910	0.0042	0.0011	0.0969
	β2	-1.3138	0.3616	-0.6557	0.3767	-0.0129	0.0036	0.3775
	β3	0.0142	-1.2700	0.0111	-0.4973	0.0001	-0.0124	-0.6936
	β4	-0.0003	0.0142	57.2263	0.0105	-0.1426	0.0001	0.0114
	β5		-0.0003		95.4407		-0.1493	
	RMSE	2.4144	2.4082	2.4957	2.5519	2.4212	2.4168	2.5268
	AIC	196.137	191.661	198.456	195.600	196.335	191.903	192.930
	SD	2.1080	2.1049	2.1840	2.2381	2.1143	2.1128	2.2140

According to RMSE, SD, and AIC calculation, Model 2 is deemed as the best model compare to other six models. Model 2 has equation as follow:

$$\ln(\mu_t) = 41.30 + 0.11\ \ln(\mu_{t-1}) + 0.36\ln(\mu_{t-2}) - 1.27\ T_t + 0.01\ H_t - 0.00\ Pop_t + e_t$$

Donomulyo

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Dono-mulyo	β0	27.2662	50.2385	0.2627	0.3688	-1.2623	59.7055	47.4401
	β1	0.1394	0.1815	0.0007	0.0015	0.0014	0.1806	0.1793
	β2	-1.8756	0.1503	-0.0133	0.0011	-0.0185	0.1489	0.1469
	β3	0.0148	-2.1481	0.0001	-0.0171	0.0001	-2.1309	-2.1069
	β4	0.0002	0.0152	6.5551	0.0001	0.1497	0.0151	0.0150
	β5		0.0000		3.0789		-1.0486	
	RMSE	2.6037	2.3665	2.6440	2.4172	2.6076	2.3679	2.3702
	AIC	201.422	190.470	202.497	191.912	201.527	190.512	188.577
	SD	2.2469	2.0661	2.3143	2.0807	2.2520	2.0648	2.0635

According to RMSE, SD, and AIC calculation, Model 2 is deemed as the best model compare to other six models. Model 2 has equation as follow:

$$\ln(\mu_t) = 50.24 + 0.18\ \ln(\mu_{t-1}) + 0.15\ln(\mu_{t-2}) - 2.15\ T_t + 0.02\ H_t - 0.00\ Pop_t + e_t$$

Kalipare

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Kalipare	β0	-4.0770	-7.2537	-0.1927	-0.2562	16.7702	-6.7997	-9.0787
	β1	0.5602	-0.0338	0.0056	-0.0003	0.5608	-0.0337	-0.0337
	β2	0.1612	0.5666	0.0067	0.0054	0.1874	0.5667	0.5667
	β3	0.0055	0.2113	0.0000	0.0091	0.0053	0.2429	0.2514
	β4	0.0000	0.0051	1.4543	0.0000	-2.2012	0.0049	0.0049
	β5		0.0000		2.3829		0.0049	
	RMSE	1.8260	1.8725	1.8248	1.8789	1.8270	1.8736	1.8739
	AIC	176.586	174.552	176.539	174.783	176.626	174.590	172.599
	SD	1.5980	1.6500	1.5977	1.6584	1.5989	1.6510	1.6512

According to RMSE, SD, and AIC calculation, Model 3 is deemed as the best model compare to other six models. Model 3 has equation as follow:

$$\ln(\mu_t) = -0.19 + 0.01\ln(\mu_{t-1}) + 0.01T_t + 0.00H_t + 1.45RatePop_t + e_t$$

Bantur

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Bantur	β0	96.6103	1.2872	0.0223	0.0334	8.1301	1.0860	-2.5035
	β1	0.5463	0.0012	0.0006	0.0001	0.0055	0.0001	0.1317
	β2	-1.2606	0.0042	-0.0010	0.0005	-0.0125	0.0004	0.4730
	β3	0.0110	-0.0165	0.0000	-0.0014	0.0001	-0.0016	0.0146
	β4	-0.0010	0.0001	-1.6356	0.0000	-0.7032	0.0000	0.0058
	β5		0.0000		-2.4699		-0.0939	
	RMSE	3.7435	3.5929	3.7780	3.6337	3.7453	3.5950	3.7392
	AIC	226.838	218.865	227.480	219.634	226.872	218.906	219.580
	SD	3.1794	3.0928	3.2002	3.1139	3.1807	3.0943	3.1825

According to RMSE, SD, and AIC calculation, Model 2 is deemed as the best model compare to other six models. Model 2 has equation as follow:

$$\ln(\mu_t) = 1.29 + 0.00\ \ln(\mu_{t-1}) + 0.00 \ln(\mu_{t-2}) - 0.02\ T_t + 0.00\ H_t - 0.00\ Pop_t + e_t$$

Gedangan

Subdistict	Parameter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Gedangan	β0	50.5993	42.7554	0.1319	4.0685	2.8872	2.4773	0.8083
	β1	0.2411	-0.0261	0.0027	-0.0122	0.0024	-0.0002	-0.0111
	β2	-1.3250	0.2420	-0.0073	0.2646	-0.0130	0.0024	0.2657
	β3	0.0118	-1.1213	0.0001	-0.3430	0.0001	-0.0109	-0.2042
	β4	-0.0005	0.0107	-1.7798	0.0070	-0.2427	0.0001	0.0064
	β5		-0.0004		-56.6351		-0.2094	
	RMSE	2.5056	2.5181	2.5146	2.5252	2.5067	2.5191	2.5249
	AIC	198.7350	194.6942	198.9849	194.8866	198.7636	194.7203	192.8769
	SD	2.2231	2.2520	2.2279	2.2559	2.2239	2.2528	2.2552

According to RMSE, SD, and AIC calculation, Model 1 is deemed as the best model compare to other six models. Model 1 has equation as follow:

$$\ln(\mu_t) = 50.60 + 0.24 \ln(\mu_{t-1}) - 1.33\ T_t + 0.01\ H_t - 0.0005\ Pop_t + e_t$$

Gondanglegi

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Gondang-legi	β0	-22.6347	-59.4715	-0.5955	-81.0325	3.1512	90.7742	-82.1541
	β1	-0.1674	0.2433	0.0014	0.2638	-0.0017	0.2443	0.2664
	β2	2.1800	-0.1967	0.0238	-0.1844	0.0219	-0.1961	-0.1832
	β3	0.0129	2.9897	0.0001	3.2746	0.0001	2.9999	3.3197
	β4	-0.0004	0.0092	-5.1170	0.0078	-0.3276	0.0091	0.0076
	β5		-0.0002		-48.378		-14.613	
	RMSE	2.8375	2.9248	2.6966	2.7610	2.8321	2.9187	2.7408
	AIC	207.442	204.876	203.876	200.957	207.308	204.733	198.457
	SD	2.7572	2.8931	2.5676	2.7100	2.7499	2.8863	2.6873

According to RMSE, SD, and AIC calculation, Model 3 is deemed as the best model compare to other six models. Model 3 has equation as follow:

$$\ln(\mu_t) = -0.60 + 0.0014 \ln(\mu_{t-1}) + 0.02T_t + 0.0001H_t - 5.12RatePop_t + e_t$$

Plot of Poisson Regression Model calculation for Pagak, Donomulyo, Kalipare, Bantur, Gedangan, and Gondanglegi Subdistrict is illustrated in Figure B.6.

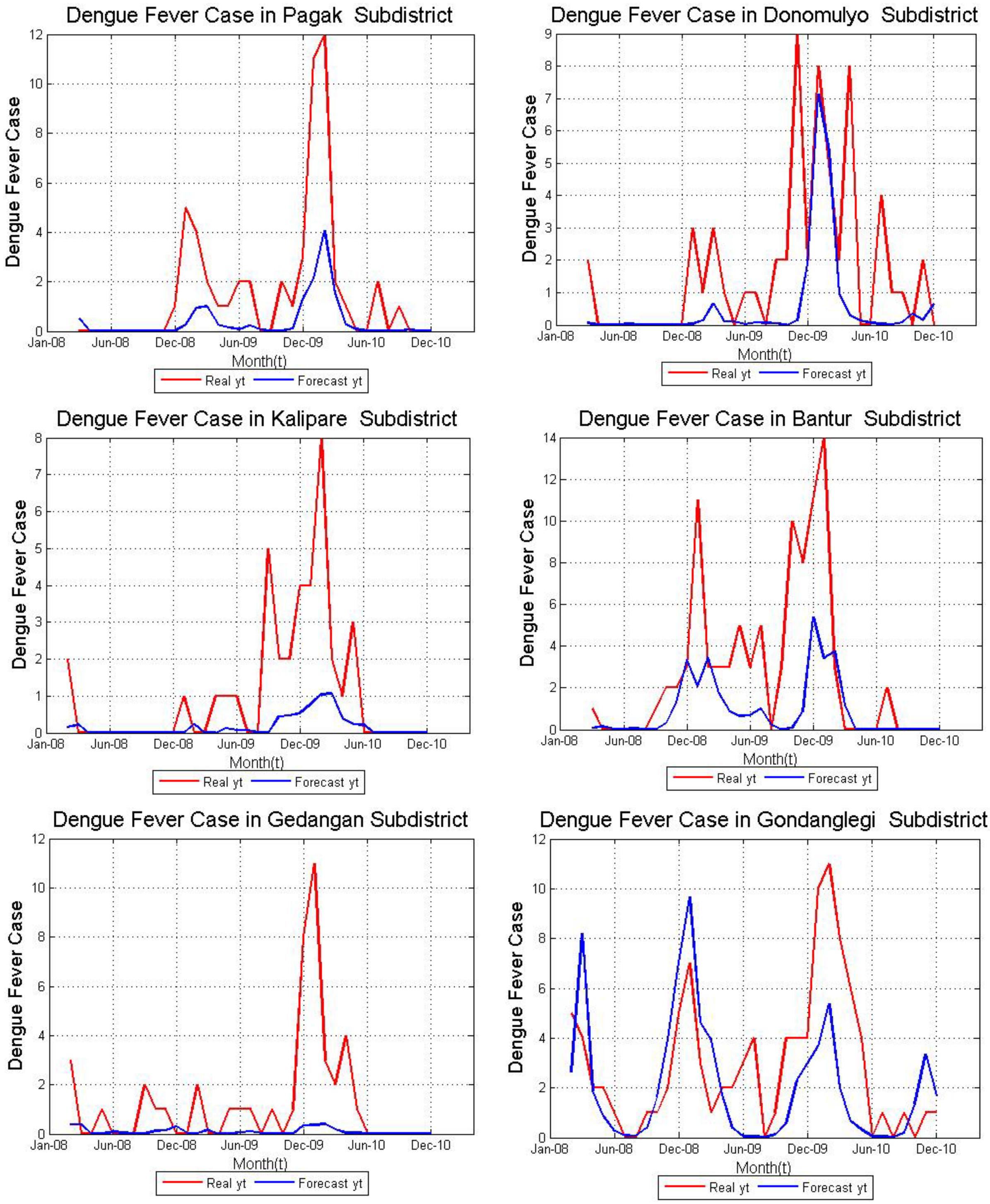


Figure B. 9 Plot of Poisson Regression Model calculation for Pagak, Donomulyo, Kalipare, Bantur, Gedangan, and Gondanglegi Subdistrict, Malang District

Bulu Lawang

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Bulu Lawang	β0	5.6105	-3.1106	0.1787	0.0109	-1.8532	-2.6067	29.4997
	β1	0.5010	0.0691	0.0048	0.0000	0.0050	0.0007	0.0946
	β2	-1.0988	0.4401	-0.0091	0.0004	-0.0109	0.0044	0.4500
	β3	0.0114	-1.0004	0.0001	-0.0006	0.0001	-0.0099	-1.3476
	β4	0.0003	0.0112	9.6842	0.0000	0.1880	0.0001	0.0127
	β5		0.0004		1.3857		0.2536	
	RMSE	4.5002	4.3366	4.5789	4.3523	4.5039	4.3389	4.2570
	AIC	239.725	231.659	240.939	231.903	239.783	231.693	228.399
	SD	4.0284	3.8945	4.1541	3.9394	4.0339	3.8978	3.7953

According to RMSE, SD, and AIC calculation, Model 7 is deemed as the best model compare to other six models. Model 7 has equation as follow:

$$\ln(\mu_t) = 29.50 + 0.10\ln(\mu_{t-1}) + 0.45\ln(\mu_{t-2}) - 1.35T_t + 0.01H_t + e_t$$

Wajak

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Wajak	β0	71.8406	69.5559	0.0123	0.0112	5.9942	5.6406	-1.0247
	β1	0.1932	-0.0713	0.0002	-0.0001	0.0019	-0.0007	-0.0735
	β2	-0.9125	0.1999	-0.0005	0.0002	-0.0090	0.0020	0.2382
	β3	0.0080	-0.9418	0.0000	-0.0005	0.0001	-0.0092	-0.0274
	β4	-0.0007	0.0073	-1.3142	0.0000	-0.5149	0.0001	0.0039
	β5		-0.0006		-1.0650		-0.4829	
	RMSE	3.6197	3.6750	3.6279	3.6805	3.6203	3.6755	3.6688
	AIC	224.484	220.401	224.642	220.504	224.495	220.411	218.287
	SD	2.8141	2.8626	2.7915	2.8414	2.8132	2.8618	2.8149

According to RMSE, SD, and AIC calculation, Model 1 is deemed as the best model compare to other six models. Model 1 has equation as follow:

$$\ln(\mu_t) = 71.84 + 0.19\ln(\mu_{t-1}) - 0.91\,T_t + 0.01\,H_t - 0.0007\,Pop_t + e_t$$

Tajinan

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Tajinan	β0	22.3132	9.3816	2.8324	-0.0866	2.5022	1.0329	-5.4559
	β1	0.3230	0.0763	0.3201	0.0008	0.0032	0.0008	0.0771
	β2	-0.4911	0.2918	-0.2691	0.0028	-0.0048	0.0029	0.2881
	β3	0.0117	-0.1069	0.0109	0.0020	0.0001	-0.0009	0.0795
	β4	-0.0003	0.0103	-11.385	0.0001	-0.1359	0.0001	0.0096
	β5		-0.0002		1.8763		-0.0969	
	RMSE	2.9794	3.0237	2.9694	3.0160	2.9793	3.0237	3.0208
	AIC	210.857	207.137	210.623	206.964	210.854	207.137	205.071
	SD	2.4821	2.5150	2.4638	2.5022	2.4815	2.5146	2.5082

According to RMSE, SD, and AIC calculation, Model 3 is deemed as the best model compare to other six models. Model 3 has equation as follow:

$$\ln(\mu_t) = 2.83 + 0.32\ln(\mu_{t-1}) - 0.27T_t + 0.01H_t - 11.39RatePop_t + e_t$$

Turen

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Turen	β0	-15.523	-22.799	0.0080	0.0048	-3.0245	-3.7017	17.9269
	β1	0.4693	-0.0597	0.0005	-0.0001	0.0047	-0.0006	-0.0118
	β2	-0.4804	0.4954	-0.0004	0.0005	-0.0048	0.0049	0.5166
	β3	0.0051	-0.4009	0.0000	-0.0003	0.0001	-0.0040	-0.7798
	β4	0.0002	0.0045	1.1945	0.0000	0.2696	0.0000	0.0063
	β5		0.0003		1.5084		0.3263	
	RMSE	24.1672	24.6516	24.0797	24.5676	24.1638	24.6492	24.5775
	AIC	357.386	349.825	357.132	349.593	357.377	349.818	347.620
	SD	23.6715	24.1336	23.6151	24.0800	23.6695	24.1326	24.0037

According to RMSE, SD, and AIC calculation, Model 3 is deemed as the best model compare to other six models. Model 3 has equation as follow:

$$\ln(\mu_t) = 0.01 + 0.0005\ln(\mu_{t-1}) - 0.0004T_t + 0.00H_t + 1.19RatePop_t + e_t$$

Dampit

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Dampit	β0	-2.2139	-4.3077	-0.5042	-0.0716	-2.2193	-4.4536	-51.592
	β1	0.0026	0.0034	0.0024	0.0003	0.0003	0.0003	0.2939
	β2	0.0145	0.0019	0.0213	0.0002	0.0014	0.0002	0.2012
	β3	0.0000	0.0236	0.0000	0.0031	0.0000	0.0024	2.1625
	β4	0.0000	0.0000	-8.0955	0.0000	0.1859	0.0000	-0.0018
	β5		0.0000		-1.0684		0.3743	
	RMSE	4.2380	4.0960	4.2446	4.1062	4.2380	4.0958	4.1655
	AIC	235.523	227.776	235.632	227.945	235.522	227.773	226.921
	SD	3.5123	3.5224	3.5167	3.4918	3.5123	3.5222	3.5608

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models. Model 6 has equation as follow:

$$\ln(\mu_t) = -4.45 + 0.0003\ln(\mu_{t-1}) + 0.0002\ \ln(\mu_{t-2}) + 0.0024T_t + 0.00H_t + 0.37\ln(Pop_t) + e_t$$

Sumbermanjing Wetan

Subdistict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Sumbermanjing Wetan	β0	-2.0778	-2.4469	0.1540	0.0221	-2.7620	-3.1635	19.6773
	β1	0.0027	-0.0006	0.0028	-0.0007	0.0003	-0.0001	-0.0519
	β2	-0.0177	0.0028	-0.0085	0.0029	-0.0018	0.0003	0.3061
	β3	0.0002	-0.0167	0.0001	-0.0027	0.0000	-0.0017	-1.0416
	β4	0.0000	0.0002	-3.1101	0.0001	0.2432	0.0000	0.0127
	β5		0.0000		-7.0730		0.2779	
	RMSE	1.8534	1.7431	1.9812	1.8648	1.8529	1.7426	1.8689
	AIC	177.6288	169.6802	182.2973	174.2717	177.6110	169.6619	172.4185
	SD	1.4782	1.4010	1.5990	1.5067	1.4777	1.4006	1.4965

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models. Model 6 has equation as follow:

$$\ln(\mu_t) = -3.16 - 0.0001\ln(\mu_{t-1}) + 0.0003\ln(\mu_{t-2}) - 0.0017T_t + 0.00H_t + 0.28\ln(Pop_t) + e_t$$

Plot of Poisson Regression Model calculation for Bulu Lawang, Wajak, Tajinan, Turen, Dampit and Sumbermanjing Wetan Subdistrict is illustrated in Figure B.7.

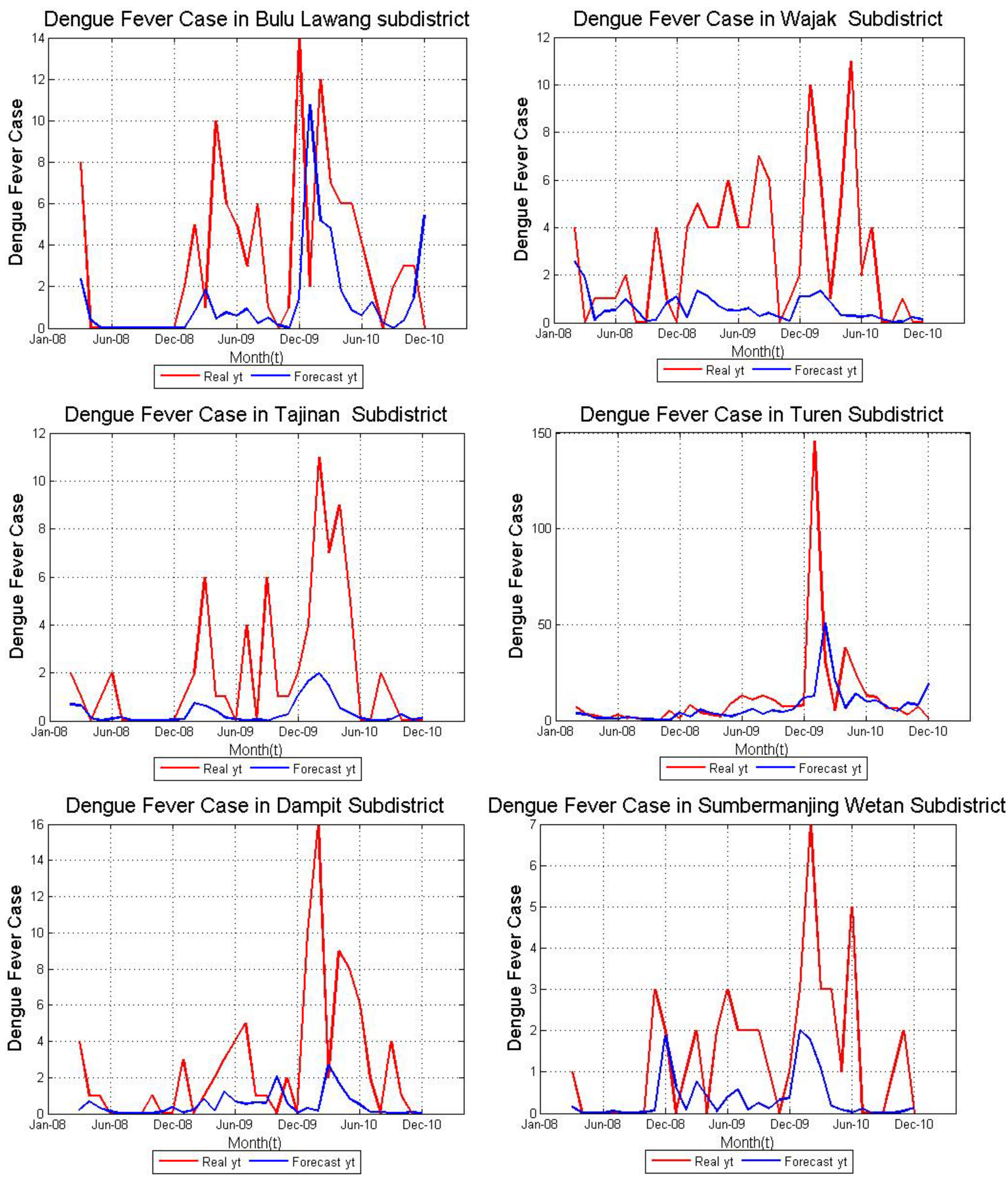


Figure B. 10 Plot of Poisson Regression Model calculation for Bulu Lawang, Wajak, Tajinan, Turen, Dampit and Sumbermanjing Wetan Subdistrict, Malang District

Ampel Gading

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Ampel Gading	β0	1.0884	1.7595	0.6514	0.1060	4.5349	8.8169	63.7570
	β1	0.0014	0.0037	0.0014	0.0004	0.0014	0.0037	0.2885
	β2	-0.0329	0.0013	-0.0290	0.0001	-0.0328	0.0013	0.1047
	β3	0.0001	-0.0461	0.0001	-0.0045	0.0001	-0.0461	-2.8491
	β4	0.0000	0.0002	-4.5217	0.0000	-0.3474	0.0002	0.0133
	β5		0.0000		-1.6659		-0.7097	
	RMSE	0.8094	0.8026	0.8100	0.8058	0.8094	0.8027	0.8166
	AIC	119.632	116.944	119.684	117.209	119.635	116.954	116.119
	SD	0.6828	0.6856	0.6825	0.6865	0.6828	0.6857	0.6876

According to RMSE, SD, and AIC calculation, Model 2 is deemed as the best model compare to other six models. Model 2 has equation as follow:

$$\ln(\mu_t) = 1.76 + 0.0037\ \ln(\mu_{t-1}) + 0.0013 \ln(\mu_{t-2}) - 0.05\ T_t + 0.0002\ H_t - 0.00\ Pop_t + e_t$$

Tirtoyudo

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Tirtoyudo	β0	17.3751	25.7302	0.0131	-0.2485	95.3849	2.8285	9.0012
	β1	0.1695	-0.1503	0.0015	-0.0022	0.1700	-0.0015	-0.1161
	β2	-0.4605	0.2085	-0.0014	0.0018	-0.4726	0.0021	0.2201
	β3	-0.0050	-0.0243	-0.0001	0.0101	-0.0050	-0.0004	-0.4612
	β4	-0.0001	-0.0099	-2.0948	-0.0002	-7.7667	-0.0001	-0.0074
	β5		-0.0004		-6.4658		-0.2551	
	RMSE	1.1222	1.1197	1.1190	1.0957	1.1223	1.1199	1.1226
	AIC	142.507	139.585	142.306	138.111	142.511	139.597	137.759
	SD	0.9004	0.9068	0.8980	0.8900	0.9005	0.9069	0.9086

According to RMSE, SD, and AIC calculation, Model 4 is deemed as the best model compare to other six models. Model 4 has equation as follow:

$$\ln(\mu_t) = -0.25 - 0.0022 \ln(\mu_{t-1}) + 0.0018 \ln(\mu_{t-2}) + 0.01T_t - 0.0002\ H_t - 6.47RatePop_t + e_t$$

Pagelaran

Sub-distict	Para-meter	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
Pagelaran	β0	-59.366	-69.247	0.1330	32.6527	-1.0366	-1.2523	31.1055
	β1	0.5436	0.4568	0.0049	0.4413	0.0005	0.0005	0.4348
	β2	-1.7302	0.2100	-0.0068	0.2389	-0.0017	0.0002	0.2363
	β3	0.0098	-2.1993	0.0001	-1.4840	0.0000	-0.0022	-1.4196
	β4	0.0016	0.0137	-5.8768	0.0105	0.0973	0.0000	0.0102
	β5		0.0019		72.1768		0.1179	
	RMSE	3.4881	2.5008	3.8276	2.9995	3.4861	2.4992	3.0397
	AIC	221.893	194.226	228.394	206.590	221.851	194.181	205.496
	SD	3.0491	2.2777	3.3814	2.6991	3.0470	2.2767	2.7329

According to RMSE, SD, and AIC calculation, Model 6 is deemed as the best model compare to other six models. Model 6 has equation as follow:

$$\ln(\mu_t) = -1.25 + 0.0005 \ln(\mu_{t-1}) + 0.0002 \ln(\mu_{t-2}) - 0.0022T_t + 0.00H_t + 0.12\ln(Pop_t) + e_t$$

Plot of Poisson Regression Model calculation for Ampel Gading, Tirtoyudo, and Pagelaran Subdistrict is illustrated in Figure B.8.

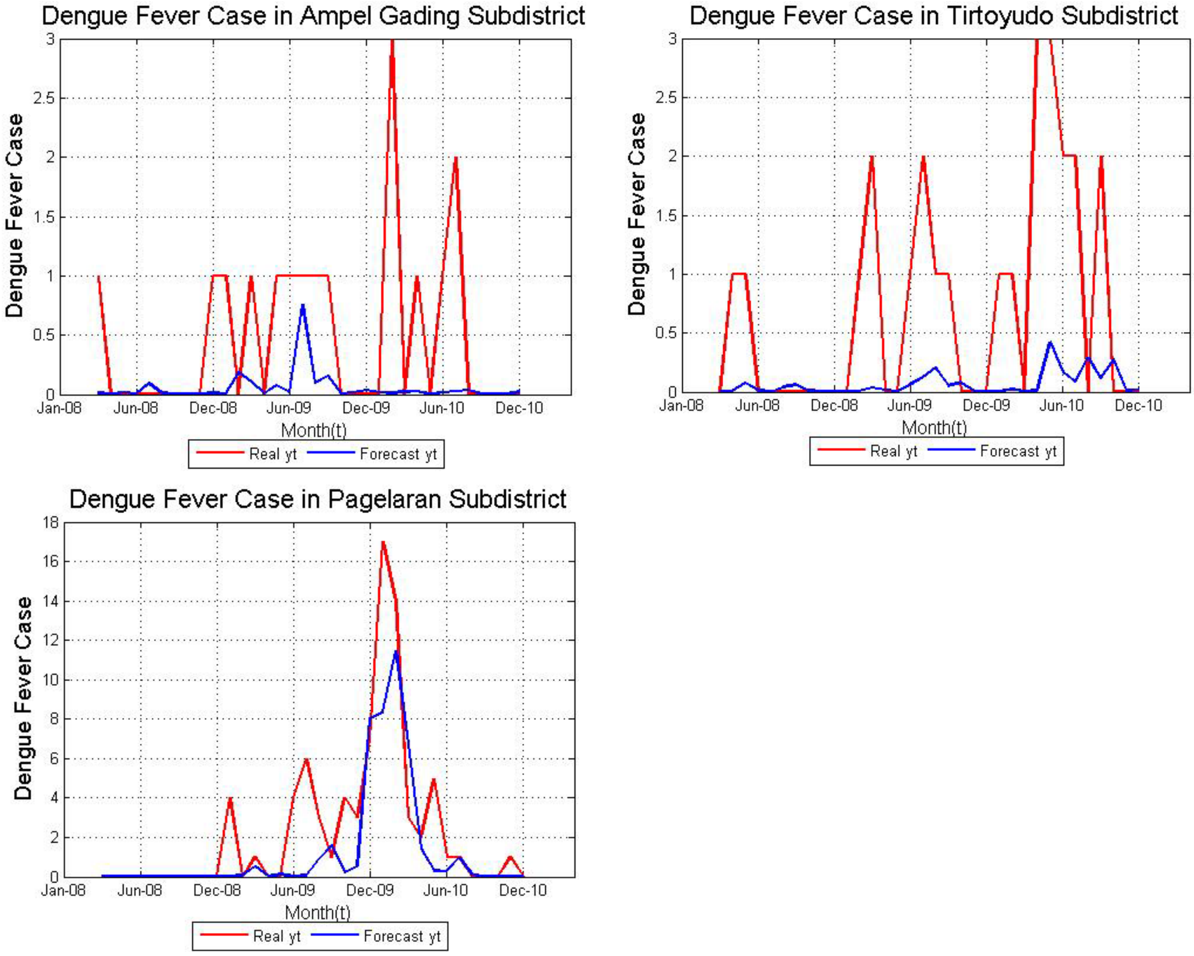


Figure B. 11 Plot of Poisson Regression Model calculation for Ampel Gading, Tirtoyudo, and Pagelaran Subdistrict, Malang District

APPENDIX C COMPARTEMEN MODEL ANALYSIS

C.1 Background

A compartment model provides a framework for the study of transport between different compartments of a system. In epidemiology, models of the behavior of an infectious disease in a large population of people consider each individual as being in a particular state. These states are often called compartments, and the corresponding models are called compartment models. DHF, malaria, and diarrhea are such infectious disease that can be analyzed by this compartment model. This study assume that a person can be in one of three states, e.g. susceptible (S), infectious (I) or recovered (R). Individuals move from the Susceptible state (S) to the Infectious state (I) by mixing or interacting with infectious individual/vectors. After exposure to microparasitic infection, individuals who recover (R) from a disease will enter a third state where they may immune to subsequent infection. Since these three compartments S (for susceptible), I (for infectious) and R (for recovered) are standard convention labels. Therefore, this model is also called the SIR model.

C.2 Previous Researches

Compartment model has been used widely in epidemiology study. For example, a compartment model was used to analyse dengue outbreaks in Salvador for 1995–1996 and 2002 (Yang *et al.* 2009). Compartment model also was used to analyze the dynamics of dengue for testing the vector control strategies (Esteva & Yang 2005; Ferreira *et al.* 2008; Yang & Ferreira 2008). Compartment model by using the next generation operator approach was used to compute the basic reproductive number, *R*0, associated with the disease-free equilibrium (Diekmann & Heesterbeek 2000; Van den Driessche & Watmough 2002). Compartment model to compute the basic reproductive number was also conducted for Brazil case (Favier *et al.* 2006; Pinho et al, 2010), Singapore case (Burattini *et al.* 2008) and city of Salvador case (Wallinga & Lipsitch, 2007).

C.3 Derivation of The Formulation

DHF, malaria, and diarrhea are such infectious disease that can be analyzed by the compartment model. We include the temperature and rainfall effect to this compartment model by assuming that in DHF and malaria case:

- The seasonal nature of transmission may reflect the influence of climate on the transmission cycle.
- Increases in temperature and precipitation can lead to increased mosquitos abundance by increasing their development rate, decreasing the length of reproductive cycles, stimulating egg-hatching, and providing sites for egg deposition.
- Higher temperature further abets transmission by shortening the incubation period of the virus in the mosquito
- Mosquito species are responsible for transmission and they are sensitive to temperature changes as immature stages in the aquatic environment and as adults.
- If water temperature rises, the larvae take a shorter time to mature and consequently there is a greater capacity to produce more offspring during the transmission period.

- In warmer climates, adult female mosquitoes digest blood faster and feed more frequently, thus increasing transmission intensity.
- Malaria parasites and viruses complete extrinsic incubation within the female mosquito in a shorter time as temperature rises, thereby increasing the proportion of infective vectors.
- Changing rainfall patterns can also have short and long term effects on vector habitats.
- Increased rainfall has the potential to increase the number and quality of breeding sites for mosquitoes and the density of vegetation, affecting the availability of resting sites.

In diarrhea case, we assume effect of rainfall and temperature are as follow:

- Climate change could greatly influence water resources and sanitation in situations where water supply is effectively reduced.
- Temperature and relative humidity directly influence the rate of replication of bacterial and protozoan pathogens and the survival of enteroviruses in the environment.

In compartment model approach, controlling dengue and malaria transmission is based on the control of the growth of the mosquito, temperature and rainfall. In diarrhea transmission, control factors are bacterium Escherichia coli growth, temperature and rainfall. The basic reproductive number, *R*0, as the most common measure of the strength of an epidemic is also used in calculation. The model developed here is based upon the one given in Jafaruddin and Sofyan (2011), where the mosquito population related to the winged female form of the mosquito.

C.3.1 Construction Model the Transmission Dynamics of the Dengue Virus with Precipitaion Effect

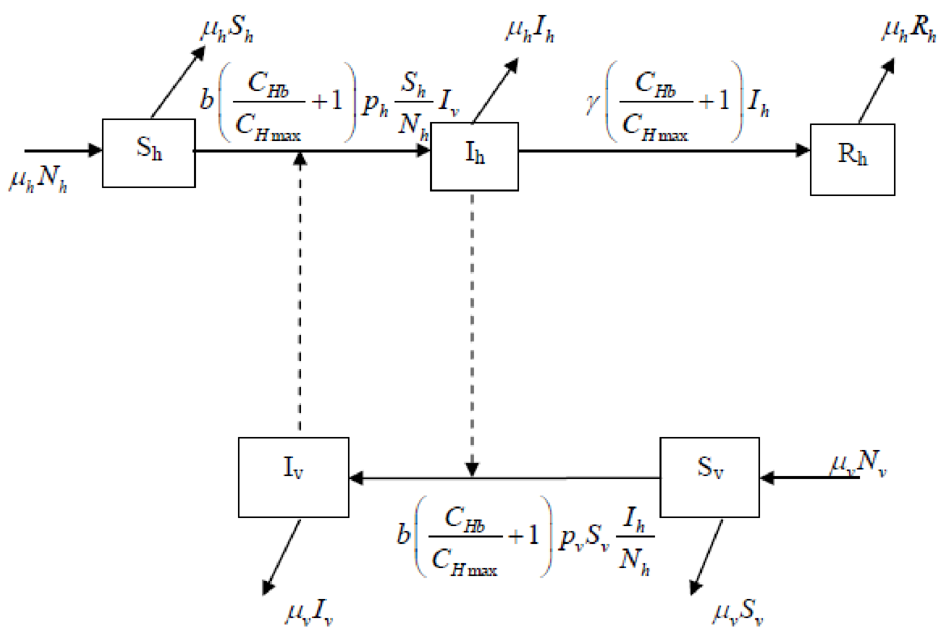


Figure C. 1 Schematic model for dengue virus transmission with precipitation effect
(Jafaruddin and Sofyan, 2011)

Model transmission of the dengue virus in human and mosquito:

$$
\begin{cases}
\dfrac{dS_h}{dt} = \mu_h N_h - b\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right) p_h \dfrac{S_h}{N_h} I_v - \mu_h S_h \\
\dfrac{dI_h}{dt} = b\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right) p_h \dfrac{S_h}{N_h} I_v - \left(\gamma\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right)+\mu_h\right) I_h \\
\dfrac{dR_h}{dt} = \gamma\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right) I_h - \mu_h R_h
\end{cases}
$$

$$
\begin{cases}
\dfrac{dS_v}{dt} = \mu_v N_v - b\left(\dfrac{C_b}{C_{\max}}+1\right) p_v S_v \dfrac{I_h}{N_h} - \mu_v S_v \\
\dfrac{dI_v}{dt} = b\left(\dfrac{C_b}{C_{\max}}+1\right) p_v S_v \dfrac{I_h}{N_h} - \mu_v I_v
\end{cases}
$$

Effective reproductive ratio :

$$
\Re(C_b) = \sqrt{\dfrac{\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right)^2 b^2 p_h p_v N_v}{\mu_v\left(\gamma\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right)+\mu_h\right) N_h}}
$$

Force of infection of dengue in human

$$
\Lambda_v = b\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right) p_h \dfrac{I_v}{N_h}
$$

Force of infection of dengue in vector

$$
\Lambda_v = b\left(\dfrac{C_{Hb}}{C_{H\max}}+1\right) p_h \dfrac{I_v}{N_h}
$$

C.3.2 Construction Model the Transmission Dynamics of the Dengue Virus with Temperature Effect

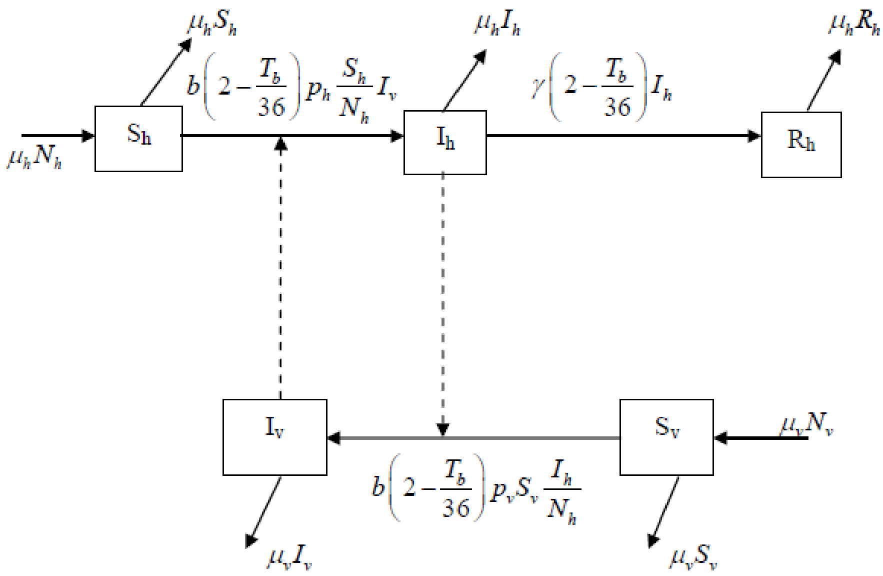


Figure C. 2 Schematic model for dengue virus transmission with temperature effect
(Jafaruddin and Sofyan, 2011)

Model transmission of the dengue virus in human and mosquito:

Model transmission of the dengue virus in human

$$\begin{cases} \dfrac{dS_h}{dt} = \mu_h N_h - b\left(2-\dfrac{T_b}{36}\right)p_h\dfrac{S_h}{N_h}I_v - \mu_h S_h \\ \dfrac{dI_h}{dt} = b\left(2-\dfrac{T_b}{36}\right)p_h\dfrac{S_h}{N_h}I_v - \left(\gamma\left(2-\dfrac{T_b}{36}\right)+\mu_h\right)I_h \\ \dfrac{dR_h}{dt} = \gamma\left(2-\dfrac{T_b}{36}\right)I_h - \mu_h R_h \end{cases}$$

Model transmission of the dengue virus in mosquito

$$\begin{cases} \dfrac{dS_v}{dt} = \mu_v N_v - b\left(2-\dfrac{T_b}{36}\right)p_v S_v\dfrac{I_h}{N_h} - \mu_v S_v \\ \dfrac{dI_v}{dt} = b\left(2-\dfrac{T_b}{36}\right)p_v S_v\dfrac{I_h}{N_h} - \mu_v I_v \end{cases}$$

Effective reproductive ratio :

$$\Re(T_b) = \sqrt{\frac{\left(2-\frac{T_b}{36}\right)^2 b^2 p_h p_v N_v}{\mu_v\left(\gamma\left(2-\frac{T_b}{36}\right)+\mu_h\right)N_h}}$$

Force of infection of dengue in vector

$$\Lambda_v = b\left(2-\frac{T_b}{36}\right)p_h\frac{I_v}{N_h}$$

Force of infection of dengue in human

$$\Lambda_h = b\left(2-\frac{T_b}{36}\right)p_v\frac{I_h}{N_h}$$

C.3.3 Construction Model the Transmission Dynamics of the Malaria Parasite with Precipitation Effect

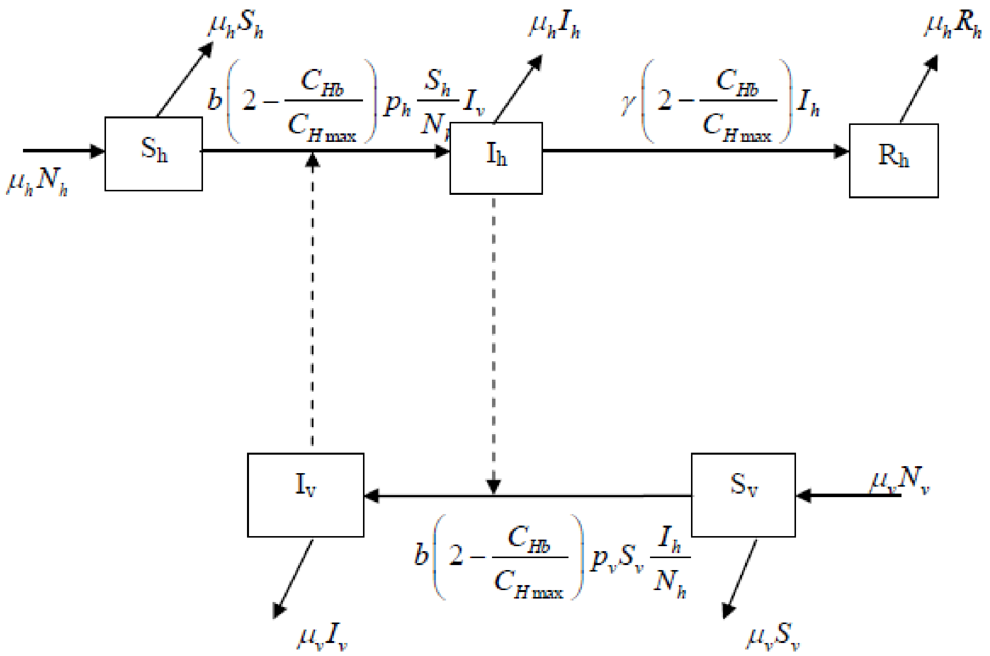


Figure C. 3 Schematic model for malaria virus transmission with precipitation effect
(Jafaruddin and Sofyan, 2011)

Model transmission of the dengue virus in human and mosquito:

$$\begin{cases} \dfrac{dS_h}{dt} = \mu_h N_h - b\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) p_h \dfrac{S_h}{N_h} I_v - \mu_h S_h \\ \dfrac{dI_h}{dt} = b\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) p_h \dfrac{S_h}{N_h} I_v - \left(\gamma\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) + \mu_h\right) I_h \\ \dfrac{dR_h}{dt} = \gamma\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) I_h - \mu_h R_h \end{cases}$$

$$\begin{cases} \dfrac{dS_v}{dt} = \mu_v N_v - b\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) p_v S_v \dfrac{I_h}{N_h} - \mu_v S_v \\ \dfrac{dI_v}{dt} = b\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) p_v S_v \dfrac{I_h}{N_h} - \mu_v I_v \end{cases}$$

Effective reproductive ratio :

$$\Re(T_b) = \sqrt{\dfrac{\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right)^2 b^2 p_h p_v N_v}{\mu_v \left(\gamma\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) + \mu_h\right) N_h}}$$

Force of infection of Malaria in vector

$$\Lambda_v = b\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) p_h \dfrac{I_v}{N_h}$$

Force of infection of Malaria in human

$$\Lambda_h = b\left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) p_v \dfrac{I_h}{N_h}$$

C.3.4 Construction Model the Transmission Dynamics of the Malaria Parasites with Temperature Effect

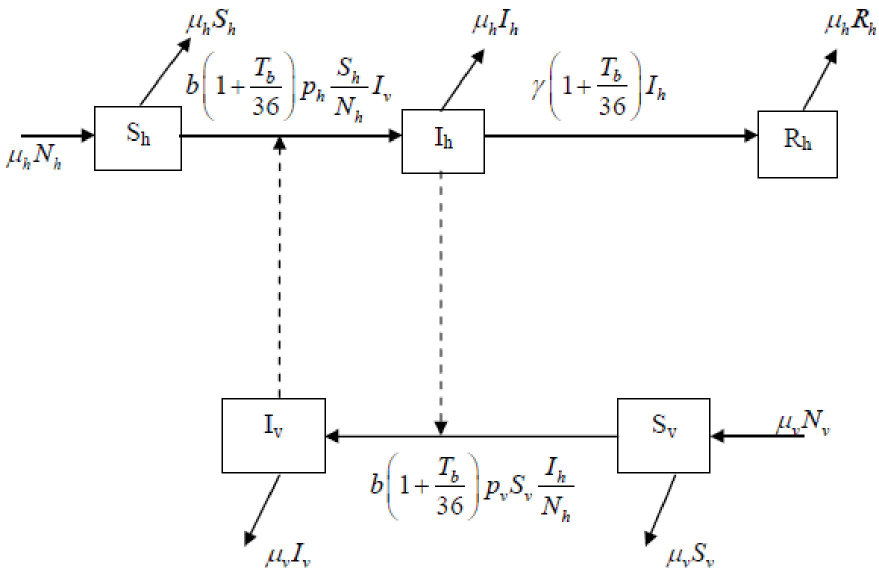


Figure C. 4 Schematic model for malaria parasite transmission with temperature effect

(Jafaruddin and Sofyan, 2011)

Model transmission of the Malaria parasite in human

$$\begin{cases} \frac{dS_h}{dt} = \mu_h N_h - b\left(1+\frac{T_b}{36}\right)p_h\frac{S_h}{N_h}I_v - \mu_h S_h \\ \frac{dI_h}{dt} = b\left(1+\frac{T_b}{36}\right)p_h\frac{S_h}{N_h}I_v - \left(\gamma\left(1+\frac{T_b}{36}\right)+\mu_h\right)I_h \\ \frac{dR_h}{dt} = \gamma\left(1+\frac{T_b}{36}\right)I_h - \mu_h R_h \end{cases}$$

Model transmission of the Malaria parasite in Mosquito

$$\begin{cases} \dfrac{dS_v}{dt} = \mu_v N_v - b\left(1+\dfrac{T_b}{36}\right) p_v S_v \dfrac{I_h}{N_h} - \mu_v S_v \\ \dfrac{dI_v}{dt} = b\left(1+\dfrac{T_b}{36}\right) p_v S_v \dfrac{I_h}{N_h} - \mu_v I_v \end{cases}$$

Effective reproductive ratio :

$$\Re(T_b) = \sqrt{\dfrac{\left(1+\dfrac{T_b}{36}\right)^2 b^2 p_h p_v N_v}{\mu_v \left(\gamma\left(1+\dfrac{T_b}{36}\right) + \mu_h\right) N_h}}$$

Force of infection of Malaria in vector

$$\Lambda_v = b\left(1+\dfrac{T_b}{36}\right) p_h \dfrac{I_v}{N_h}$$

Force of infection of Malaria in human

$$\Lambda_h = b\left(1+\dfrac{T_b}{36}\right) p_v \dfrac{I_h}{N_h}$$

C.3.5 Construction Model the Transmission Dynamics of the Diarrhea bacterium (E. Colli) with Precipitation Effect

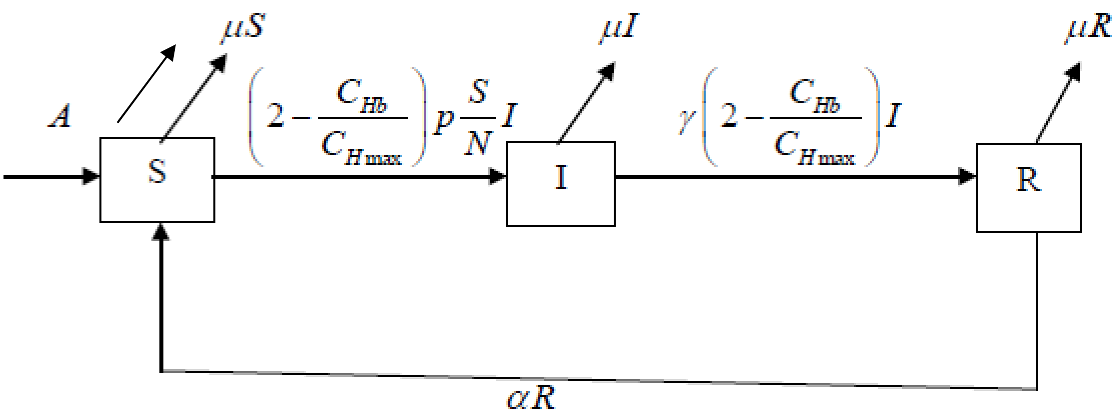


Figure C. 5 Schematic model for diarrhea (bacterium E. coli) transmission with precipitation effect (Jafaruddin and Sofyan, 2011)

Model transmission of the diarrhea (bacterium E. coli):

$$\begin{cases} \dfrac{dS}{dt} = A - \left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) p \dfrac{S}{N} I - \mu S + \alpha I \\ \dfrac{dI}{dt} = \left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) p \dfrac{S}{N} I - \gamma \left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) I - \mu I \\ \dfrac{dR}{dt} = \gamma \left(2 - \dfrac{C_{Hb}}{C_{H\max}}\right) I - \mu I - \alpha I \end{cases}$$

$$\Lambda = \left(2 - \frac{C_{Hb}}{C_{H\max}}\right) p \frac{I}{N}$$

C.3.6 Construction Model the Transmission Dynamics of the Diarrhea bacterium (E. Coli) with Temperature Effect

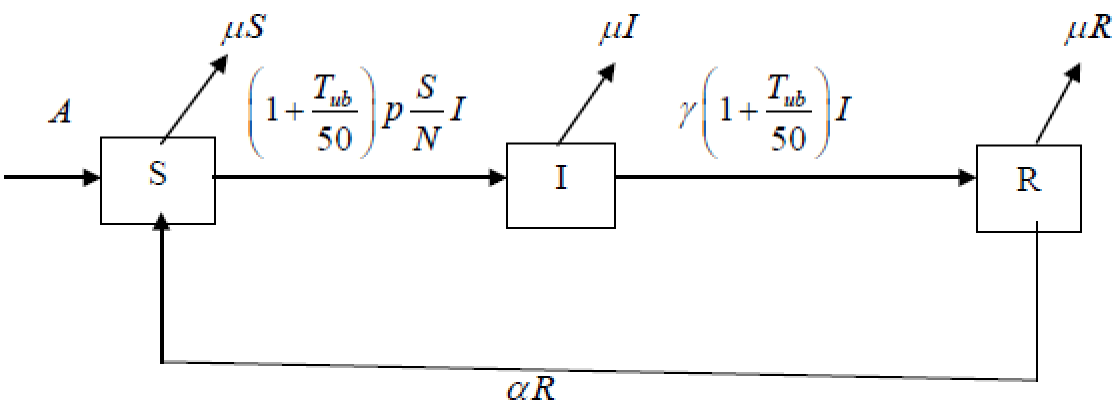


Figure C. 6 Schematic model for diarrhea (bacterium E. coli) transmission with temperature effect (Jafaruddin and Sofyan, 2011)

Model transmission of the diarrhea (bacterium E. coli):

$$\begin{cases} \dfrac{dS}{dt} = A - \left(1 + \dfrac{T_{ub}}{50}\right) p \dfrac{S}{N} I - \mu S + \alpha I \\ \dfrac{dI}{dt} = \left(1 + \dfrac{T_{ub}}{50}\right) p \dfrac{S}{N} I - \gamma \left(1 + \dfrac{T_{ub}}{50}\right) I - \mu I \\ \dfrac{dR}{dt} = \gamma \left(1 + \dfrac{T_{ub}}{50}\right) I - \mu I - \alpha I \end{cases}$$

$$\Lambda = \left(1 + \frac{T_{ub}}{50}\right) p \frac{I}{N}$$

C.4 Limitations of This Compartment Models

Theoretical models of dengue transmission dynamics based on mosquito biology support the importance of temperature and precipitation in determining transmission patterns, but empirical evidence has been lacking especially in Indonesia. On global scales, several studies have highlighted common climate characteristics of areas where transmission occurs. Meanwhile, longitudinal studies of empirical data have consistently shown that temperature and precipitation correlate with dengue transmission but have not demonstrated consistency with respect to their roles.

Moreover, all of the equations used to define compartment models discussed above represent Finite Difference equations. In a Finite Difference equation, the time step in this case is fixed one month and the value at the current time step is used to predict the value at the next time step. Computationally efficient, this approach is fast and lends itself to simple solutions. Unfortunately, it is also inaccurate. In reality, time is a continuous variable. Trying to predict the number of people that will be infectious one day from now based on the number infectious now will give a different answer than trying to predict the number of people infectious one hour from now, given the number infectious now, and repeating that calculation every hour. If the variables in the compartment model are changing slowly relative to the length of the fixed time step, then a finite difference algorithm will behave well. However, if the variables are changing rapidly, for instance, at the onset of an epidemic, finite difference algorithms can produce nonsensical results.

C.5 Additional Rerefences

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APPENDIX D ADAPTATION STRATEGY FORMULATION

D.1 Adaptation Strategy for DHF Risk

Many area in Greater Malang are endemic of Dengue hemorrhagic disease, but the endemicity is not homogenous. Sub-districts in Malang such as Poncokusumo, Lawang, Pujon, Ngantang, Ngajum, Wonosari and Donomulyo reported low prevalence of DHF for the last five years. This might be due to several factors such as sub-district with better housing and sanitation, less densely population, low mobility hence low transmission of infection, or better or safer water supply.

As shown in Chapter 6 about Risk Analysis, high risk areas need extra protection since their locations often becomes the mosquitoes breeding site. Moreover, during occasional outbreak (KLB) the emergency response relies on disease management and the recovery is pointed toward disease prevention by means of environmental engineering. Combination of two or more strategy had proven to give good results in decreasing DHF incidence. Areas with medium risk need to implement less strategy than higher risk areas. Preventive and long term strategy is more important in this area.

Table D. 1: Common Adaptation Strategy For DHF based on Level of Risk

Type of Adaptation	Very Low	Low	Moderate	High	Very High
Vector Control management	1. **Household level** of vector management (Abate, spray cans, mosquito coils, repellents etc.) 2. Routine yearly seasonal spraying 3. Community awareness program	1. **Household level** of vector management 2. Routine, twice yearly seasonal spraying 3. Routine mosquito quarterly surveillance (measurement of mosquito density index)	1. Mosquito source reduction 2. **Community level** of vector management 3.Increased Community participation	1. Mosquito source reduction 2. **Citywide level** of vector management (pesticide fogging program at high incidence and specific locations)	1. Mosquito source reduction **2. Citywide level** of vector management 3. Increased number of fogging
Environmental Improvement	1. Routine implementation of 3M Plus program 2. Improvement of housing condition Better water supply and covered water storage	1. Routine implementation of 3M Plus program 2. Meteorological surveillance (Rainfall, temperature)	Development of early warning method based on meteorogical surveillance	Legislative measures (enforcement of existing regulation on environment and health)	
Disease Agent Surveillance and control	**Non-Routine**, sentinel surveillance of DHF	**Routine** surveillance of DHF	**Increased Routine** surveillance of DHF	Vaccination on vulnerable population (still on trial)	Epidemic warning (KLB)
Human Infection Management	**Individual** patient treatment	1. Individual patient treatment 2. Identification of risk factors	1. **Hospital alert** preparedness 2. Increased access to emergency treatment	**Whole Hospital** emergency alert	1. **Citywide** hospital alert 2. Decrease in morbidity and mortality

Study also indicated the influence of climate change on the area triggers an increase and the abundance of Aedes mosquito. Increase of rainfall frequency provides abundance of breeding sites. Warmer temperature increases the gonotropic or mating habit of the mosquito. Based on those findings, strategy for adaptation of DHF in Greater Malang is divided into three main components (1) Short term, (2) Medium term, and (3) Long term (see Table D.2).

This strategy is based on the understanding that Dengue Hemorrhagic Fever is caused by transmission of dengue virus through mosquito borne or vector-borne route. Therefore, the adaptation strategy covers the breaking of transmission chain through elimination of etiologies and its vectors. The following strategy of adaptation for Greater Malang (see Table D.2) is based on the health and climate future projection and should be tailored to the different hazard, vulnerability and risk condition for each sub district of Greater Malang.

Table D. 2: Adaptation Strategy for Future DHF Risk

TYPE OF STRATEGY	SHORT TERM (2010-2020)	MEDIUM TERM (2020-2030)	LONG TERM (2030-2050)
Vector Control (based on seasonal climate change)	1. Mosquito source reduction 2. Routine seasonal spraying (3-4 times annually, especially targeting high risk subdistricts) 3. Additional/incidental spraying, during KLB (outbreak) 4. Extensive use of larvicides (e.g. temephos, IGR) 5. Personal use of anti mosquito measures (repellents, mosquito nets, spray cans, appropriate clothing)	1. Lesser routine spraying (2-3 times annually, based on the success of short-term program) 2. Less KLB is expected as program improved, therefore less incidental spraying 3. Continuation and maintenance of source reduction program	1. Development of inexpensive, less toxic and less resistant biological insecticides 2. Development of genetically modified sterile male mosquitoes
Environmental Improvement	1. Implementation of 3M Plus program 2. Extensive use of biological enemies, predators (bacillus, fungus, larvivorous fish) 3. Better housing with closed water storage and piped water	1. Develop 3M improved program 2. Law enforcement of local regulations (Perda) on environmental sanitation 3. Kampung improvement program 4. Review of building design to reduce potential breeding habitat	1. Construction of semi-urban housing development plan (Perumnas) to lessen the burden of crowding and slums in the city center.
Disease Agent Surveillance and control	1. Surveillance of dengue virus serology (alert warning for serious virus strain) 2. Further development of dengue vaccine	1. Develop rapid virus diagnostic 2. Human trial of pentavalent dengue vaccine	1. Mass field trial of dengue virus vaccine is expected 2. Development of antiviral antibiotics
Human Infection Management	1. Better case handling facilities 2. Better case reporting 3. Improve community awareness 4. Improve community	1. Better training of hospital personnel during emergency outbreak 2. To bring down	1. The long-term goal is to decrease incidence and mortality due to DHF infection by minimizing hazard,

TYPE OF STRATEGY	SHORT TERM (2010-2020)	MEDIUM TERM (2020-2030)	LONG TERM (2030-2050)
	education	the current incidence rate into halve by 2030	risk and vulnerability

Note:
KLB (=Kejadian Luar Biasa; disease outbreak)
3M (=Menguras, Menutup, Mengubur). A community program to regularly wash and clean water storages, to cover water storage with lid and to burry all rubbish which might collect water where mosquito breed.

D.2 Adaptation Strategy for Malaria Risk

Malaria cases have been reported from several sub district in Malang District. Climate changes in Greater Malang may influence the possible increase of malaria cases in the future except in Malang City and Batu City. The first factor is the predicted sea level rise, which increases the formation of marshy area, swamps and lagoons, an ideal place for Anopheles breeding, especially in the southern coast of Malang District. The second factor is the temperature rise, which shorten the gonotropic cycle of Anopheles, contributing to the rapid increase of mosquito population on the area.

Prevention strategy is very useful in areas with medium risk of malaria. It is proven that the combination of ITN and IRS could reduce the malaria occurrence. Areas with high risk of malaria have adequate community strength toward malaria, such as permanent housing, health facility provision, and location of house is far from the breeding site. Therefore, these areas need to combine the general prevention strategy toward malaria with the emergency response. The following strategy of adaptation for Greater Malang is based on the future projection and should be tailored to the different hazard, vulnerability and risk condition for each sub district of Greater Malang. If adaptation is based on the level of risk instead, then Table D.3 may become the general guidelines of adaptation.

Table D. 3: Common Adaptation Strategy For Malaria based on Level of Risk

Type of Adaptation	Very Low	Low	Moderate	High	Very High
Vector Control management	1. **Household level** of mosquito bites prevention (Abate, spray cans, mosquito coils, repellents etc.) 2. Routine annual seasonal spraying 3. Community malaria awareness program	1. **Household level** of vector management 2. Routine, twice yearly seasonal spraying 3. Routine mosquito quarterly surveillance (measurement of mosquito density index)	1. Mosquito source reduction 2. **Community level** of vector management 3. Increased Community participation	1. Mosquito source reduction 2. **Citywide level** of malaria vector management (pesticide fogging program at high incidence and specific locations)	1. Mosquito source reduction 2. **Citywide level** of malaria vector management
Environmental Improvement	1. **Coastal** Reclamation (drying of swamps and lagoons) 2. **Mangrove** re-forestation	1. Improvement of **housing** condition 2. Meteorological surveillance (Rainfall, temperature)	Development of **early warning** method based on meteorogical surveillance	**Legislative measures** (enforcement of existing regulation on environment and health)	
Disease Agent Surveillance and control	**Non-Routine**, sentinel surveillance of Malaria species	**Routine** surveillance of malaria	**Increased Routine** surveillance of malaria	**Vaccination** on vulnerable population (currently still on development)	Epidemic warning (KLB) of malaria

Type of Adaptation	Very Low	Low	Moderate	High	Very High
Human Infection Management	Availability and provision of **prophylactic anti malaria** tablets	1. Individual patient treatment 2. Identification of risk factors	1. **Hospital alert** preparedness 2. Increased access to emergency treatment	**Whole Hospital** emergency alert	1. **Citywide** hospital alert 2. Decrease in morbidity and mortality

Malaria is caused by transmission of plasmodium through vector-borne route. Therefore, the adaptation strategy covered the breaking of transmission chain through elimination of etiologies and its vectors. High-risk areas need extra protection since their locations are near the breeding site. Moreover, the short-term strategy relies on disease management and long term strategy is pointed toward disease prevention by means of environmental engineering. Table D.4 shows the adaptation strategies of malarial hazard in different area with various level of risk.

Table D. 4: Adaptation Strategy for Future Malaria Risk

TYPE OF STRATEGY	SHORT TERM (2010-2020)	MEDIUM TERM (2020-2030)	LONG TERM (2030-2050)
Vector Control (Designed for malaria endemic coastal and lowland areas)	1. Mosquito source reduction 2. Better implementation of WHO Roll Back Malaria Program 3. Routine indoor insecticidal spraying (1-2 times annually, targeting high risk subdistricts) 4. Additional/incidental spraying, during KLB 5. Extensive use of larvicides (e.g. temephos, IGR) 6. Personal use of anti mosquito measures (repellents, mosquito nets, spray cans, appropriate clothing)	1. Less routine spraying (2-3 times annually, based on the success of short-term program) 2. Less KLB is expected, therefore less incidental spraying 3. Maintenance of general source reduction program 4. Mass use of impregnated bednets	1. Development of inexpensive, less toxic and less resistant biological insecticides 2. Development of genetically modified sterile male mosquitoes
Environmental Improvement	1. Coastal reclamation program (swamps, lagoons, inundated areas) 2. Extensive reforestation/replanting of lost mangroves in coastal areas due to sea level rise 3. Better housing with installed mosquito screen doors and windows	1. Introduction of larvivorous fishes and other predators 2. Introduction of indigenous monkeys (bekantan) in forrested areas to attract zoophilic mosquitoes away from human	1. Development of more inland semi-urban housing plan (Perumnas) to move housing away from mosquito breeding areas.
Disease Agent surveillance	1. Routine surveillance of malaria parasites by field malariologists and entomologists	1. Develop rapid malaria diagnostic	1. Development of malaria vaccine 2. Development of non-resistant antimalaria drug
Human Infection Management	1. Better malaria case handling facilities	1. Better training of hospital personnel	1. The long-term goal is to decrease

TYPE OF STRATEGY	SHORT TERM (2010-2020)	MEDIUM TERM (2020-2030)	LONG TERM (2030-2050)
	2. Better malaria case reporting 3. Improve community awareness 4. Improve community education 5. Better availability of antimalarials	during malaria outbreak 2. Training of field malariologists	incidence and mortality caused by severe falciparum malaria

D.3 Adaptation Strategy for Diarrhea Risk

Diarrhea epidemic episodes in large city like Malang and Batu can be climate related or non-climate. Non climate episodes may occur for instance if city water pipe broke down and sewage system contaminate the broken pipe. Municipal clean water resources are priority issues in diarrhea problem. Water shortages are a serious problem in many sub districts around Malang Raya. During dry season, lack of save water supplies is an important factor in causing diarrheal disease. Good information on water resources in Malang Raya was available from PDAM and other sources but very sketchy. There have been no previous studies conducted in this area, which address and looking specifically at the relationship between climate variability and the incidence of diarrhea. Our finding indicate lack of safe water supply in many sub districts of Greater Malang plays an important role in diarrheal diseases especially during prolonged dry seasons.

Table D.5 shows the adaptation strategy of diarrheal hazard in different area with various level of risk. High risk of diarrhea is largely affected by the inadequate provision of health facility. Therefore, adaptation strategies in these areas are concentrated toward improvement of health infrastructure. Moreover, areas with high or medium risk of diarrhea should be concentrated toward behavioral change and long term prevention of diarrheal occurrence.

Based on the level of risk, adaptation may follow guidelines stated in Table D.5 below.

Table D. 5: Common Adaptation Strategy For Diarrhea based on Level of Risk

Type of Adaptation	Very Low	Low	Moderate	High	Very High
Management of extreme climate events (Flood, drought)	1. **Household level** of waterborne disease prevention 2. Boiling of household water	**Household level** water management	1. **Community level** of diseases manage-ment 3. Increased Community participation	1. **Citywide level** of diseases manage-ment	Better sanitation system in flood refugee camps
Environmental Improvement	1. **Prevention** of frequent flooding 2. Digging flood canals 3. Improvement of household sewer system	1. Improvement of **housing** condition against flood 2. Meteorological surveillance (Rainfall, temperature)	Development of **early warning** method based on meteorogical surveillance	**Legislative measures** (enforcement of existing regulation on environment and health)	
Waterborne disease Agent Surveillance and control	**Non-Routine**, sentinel surveillance of diarrhea agents	**Routine** surveillance of diarrhea agents	**Increased Routine** surveillance of diarrhea	**Vaccination** on vulnerable population	Epidemic warning (KLB)

Type of Adaptation	Very Low	Low	Moderate	High	Very High
			agents		
Human Infection Management	Soap and clean water hand washing training as prophylaxis against hand to mouth infection	1. Individual patient treatment 2. Identification of risk factors	1. **Hospital alert** preparedness 2. Increased access to emergency treatment	1. **Whole Hospital** emergency alert 2. availability of drugs and antibiotic against diarrhea	1. **Citywide** hospital alert 2. Decrease in morbidity and mortality

The following strategy of adaptation for Greater Malang on diarrhea is based on the future projection of increased rainfall in Greater Malang. Adaptation should be tailored to the different hazard, vulnerability and risk condition for each sub district of Greater Malang.
Diarrheal diseases are caused by transmission of pathogen microorganism through fecal oral route. Therefore, the adaptation strategy should be able to break the chain of transmission through elimination of etiologies and increasing the social immunity. High-risk areas need more comprehensive strategy in emergency response and prevention strategy, while low risk area need to be more concentrate in implementing the prevention strategy.

Table D. 6: Adaptation Strategy for Future Diarrhea Risk

TYPE OF STRATEGY	SHORT TERM (2010-2020)	MEDIUM TERM (2020-2030)	LONG TERM (2030-2050)
Management of Flood (Extreme climate events; prolonged flooding during rainy seasons)	1. Shelter camps for flood victims should be provided with good amount of clean water, good latrine facilities and good sewage system. 2. Isolated housing should be provided with facilities to sterilize drinking water	1. Development of drainage infrastructure in flood prone areas 2. Widening and deepening of existing drains and canals	1. Better community flood disaster preparedness 2. Improved coastal management against inundation and sea level rise 3. Waste water recycling and provision of bacteria-free source of household piped-water
Environmental Improvement	Water quality improvement: 1. Use of boiled water 2. Use of chlorinated water 3. Better latrines and sewage system 4. Availability of dug-well clean water	1. Adaptation of greywater usage 2. Law enforcement of local regulations (Perda) on environmental sanitation 3. Kampung(villages) improvement sanitation program 4. Extensive use of piped-water (PDAM); an increase of household piped-water in 2030	1. Better housing design against prolonged and more frequent flood in the future 2. Better housing development plan with piped water and separation of waste water
Disease Agent surveillance	1. Surveillance of gastrointestinal infection agents (E. coli, typhoid, cholera)	1. Develop rapid diarrheal diagnostic agents	1. Development of genetic or molecular screening model of diarrhea pathogen 2. Development of better vaccine

TYPE OF STRATEGY	SHORT TERM (2010-2020)	MEDIUM TERM (2020-2030)	LONG TERM (2030-2050)
			3. Development of antiviral/ antibiotics
Human Infection Management	1. Better case handling facilities 2. Better case reporting 3. Improve community awareness 4. Improve community education	1. Better training of hospital personnel during emergency diarrheal outbreak	1. The long-term goal is to decrease incidence and mortality caused by diarrhea

Note: PDAM (= Perusahaan Daerah Air Minum; Municipal Water Company)
Perda (= Peraturan Daerah; Municipal Regulations)